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on
Rural Affairs and Transport

"The management of the Murray-Darling Basin."

Barmah-Millewa Forest
Hydrologic Indicator Site.

A case study for effective and efficient environmental watering
and the role of the community.

Reference to:

(a) **the implications for** agriculture and food production and the **environment**;
(e) **the extent to which options for more efficient water use** can be found and the implications of more efficient water use, mining and gas extraction on the aquifer and its contribution to run off and water flow;
(h) means to achieve sustainable diversion limits in a way that recognises production efficiency;
(i) options for **all water savings** including use of alternative basins; and
(j) any other related matters [**community engagement**].

Prepared by
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Abstract.

This case study of the Barmah-Millewa Forest, one of 18 hydrologic indicator sites for a key environmental asset on the central River Murray floodplain, draws attention to data, not referred to in the MDBA's Guide to the Plan, which assists in describing the current water management issues at this icon site.

The uses of the Barmah-Millewa environmental water allocation (granted by the MDBC/MDBMC in 1993) are described together with a summary of the valuable lessons learnt. The vital role that community engagement plays in water planning and land and water management is also described.

It is concluded that the current bureaucratic arrangements are overly complex and counter-productive and must be streamlined in any new Plan for the Murray Darling Basin.

Recommendations are listed for meaningful community engagement and the potential for infrastructure for more effective and efficient watering of the floodplain.

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Introduction.

Barmah-Millewa Forest [B-MF], the largest contiguous area of river red gum forest and wetlands in the central Murray is the upstream icon site in the River Murray system. The Murray-Darling Basin Authority [MDBA] Guide to the Basin Plan identifies the forest as a **hydrologic indicator site** within the Murray Region[1] [Figure I.1, The B-MF meets all five of the MDBA's key environmental asset criteria [Appendix I].

The Barmah Forest and Millewa Group of forests were listed as RAMSAR wetlands in 1982 and 2003 respectively. The B-MF functions as a natural flood control reservoir in very wet years [Figure I.2 & I.3].

River Regulation and Irrigation Use

Three large reservoirs; Hume, Dartmouth and Lake Victoria [an off-river storage] and Yarrawonga diversion weir, associated with Lake Mulwala, facilitate extensive river regulation and diversions to service irrigated agriculture.

Progressively, increasing diversions for agriculture until an interim cap on surface water was applied in 1995 resulted in significantly altered frequency, season and duration of forest flooding to the detriment of the environment.

"Without Development" and Current River Flows

Between 1895 and 2000, **reduced natural flows** in the Central Murray, as a consequence of periodic drought, had, and would have had in the absence of river regulation from the mid 1930s, negligible effect on the long term vitality of the river red gum forests. There are 32 years when the forest was not "effectively" (this term will be defined in the following section) flooded. Significantly, there were only three occasions, widely spaced [1913/14 (2), 1940/41 (2) and 1976/77 (2)], where there were two consecutive years without effective flooding and one occasion of three consecutive years [1997/99 (3)].

Conversely **flows** [1895 – 2002] under current diversion limits i.e. *pre-river regulation [natural] flows adjusted to 1999 storages and system demands* [the latest figures available to us], would most likely have resulted in the majority of red gum stands dying from prolonged moisture stress. Modelled flows 1891 – 1999 [with 2000 – 2009 estimated] under 1999 demands show that there have been 82 years without an "effective" flood including long sequences of drought stress 1895/1905 (11), 1907/1915 (9), 1940/1950 (11), 1965/69 (5), 2001/2009 (9). This value judgement is based on research that identified large sections of red gum forest in the Murray Region, particularly downstream of Tocumwal, as reaching their threshold resilience/tipping point to accumulated drought stress over 2001/09[2] and regeneration, growth and flood dependence of Central Murray Riverain red gum forests[3].

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[1] The Murray Region includes the full 2,400km length of the River Murray from its source in the Snowy Mountains to its mouth in South Australia. Tributaries include the Mitta Mitta, Kiewa, Ovens, Goulburn, Broken, Campaspe, Loddon, Murrumbidgee and Darling Rivers. The physical geography is highly variable and zones include: the Headwaters, the Riverine Plains, the Mallee and the coastal lakes and estuary.

[2] Cunningham, SC, Read, J, Baker, PJ and MacNally, R (2007), *Quantitative assessment of stand condition and its relationships to physiological stress in stands of eucalyptus camaldulensis (Myrtaceae) in south-eastern Australia.* Australian Journal of Botany, Vol. 55, pp. 692-9.

[3] Dexter, B.D, and Poynter M.(2005)*, Water*, W*ood and Wildlife, Part I – Opportunities for the Riverain red gum forests of the central Murray.*

The Barmah Millewa Forest Environmental Water Allocation
Recognition of these problems led the Murray-Darling Basin Ministerial Council [MDBMC] in 1993 to approve an annual high security 100 GL environmental water allocation [EWA] for the Barmah [Vic] – Millewa [NSW] red gum forests. The forests were to be treated as a single entity for water management purposes. Subsequently, an additional general security 50 GL was made available under specified conditions. The then MDBC prepared storage and operating rules to manage the accumulation and release of the EWA as well as the interstate water accounting.

The EWA has been used on three occasions; 1998, 2000/01, 2005/06 and is currently [October 2010] being released from Hume Reservoir to augment (then) rapidly receding winter/spring flood flows mainly originating from the Kiewa and Ovens River catchments. The objective this time is to prolong forest and wetland flooding to induce a bird-breeding event.

Competing and conflicting demands for water and State's sovereign rights slowed progress in resolving complex issues over past several decades. The record drought, 2002 – 2009, which severely impacted on the social, economic and environmental well-being of Basin communities, brought to a head the need to specifically allocate significant quantities of water for the environment.

The impending Murray Darling Basin Plan is now to strike a balance between the environment and irrigation. Although some water purchases have already been made any increases in environmental and loss flows must come from irrigated agriculture entitlements and farm and system efficiencies.

There is broad consensus that a larger proportion of water must be provided to restore and sustain the MDB's environmental values.
Consensus will only be maintained if this is achieved in a socially and economically responsible way.

This places a heavy responsibility on environmental water managers to make the most effective and efficient use/re-use of EWAs. This should be reflected in icon site environmental management plans.

The objective of this case study is to consolidate data on:

- central Murray streamflow and flooding sequences in the Barmah-Millewa Forest over the longest period on record;
- streamflow parameters that govern forest and wetland flooding;
- policy and practice for water management including the granting and use of the Barmah-Millewa environmental water allocation;
- Community engagement

and

- summarize conclusions arising from the Case Study and make recommendations to the Murray-Darling Basin Authority for inclusion under the Barmah-Millewa Forest heading in the Draft Basin Plan.

Data selectively reviewed includes:

1. streamflow history of the central River Murray as measured at Tocumwal 1895 - 2009;

2. parameters for the "effective flooding" of the Barmah-Millewa Forest;

3. flood history of the Barmah-Millewa Forest 1895 – 2009;

4. forest and wetland flooding originating from River Murray streamflow at Tocumwal and use of the Barmah-Millewa environmental water allocation in 1998, 2000/01, 2005/06, and 2002 managed flows to assist passage of water past the Barmah Choke [Use of EWA in 2010 is not reported as it is still in progress] EWA ;

5. The History of the Barmah-Millewa Forum and the role of community engagement in environmental water planning and land and water management.

Figure I.1. Murray Region [From the Guide to the proposed Basin Plan – MDBA Oct 2010]

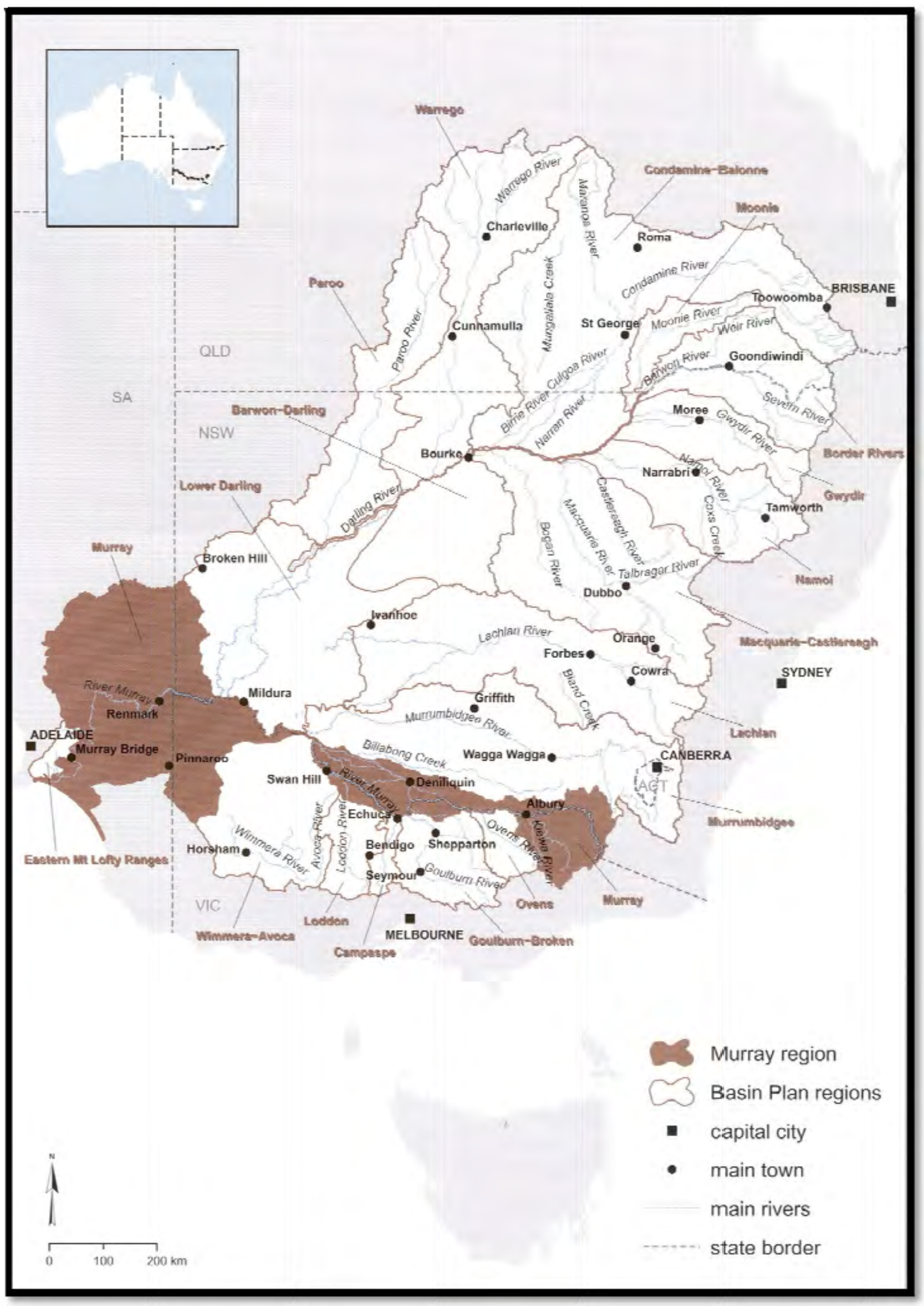


Figure I.2. Central Murray River Red Gum Forests and Irrigation Areas [Courtesy MDBC].

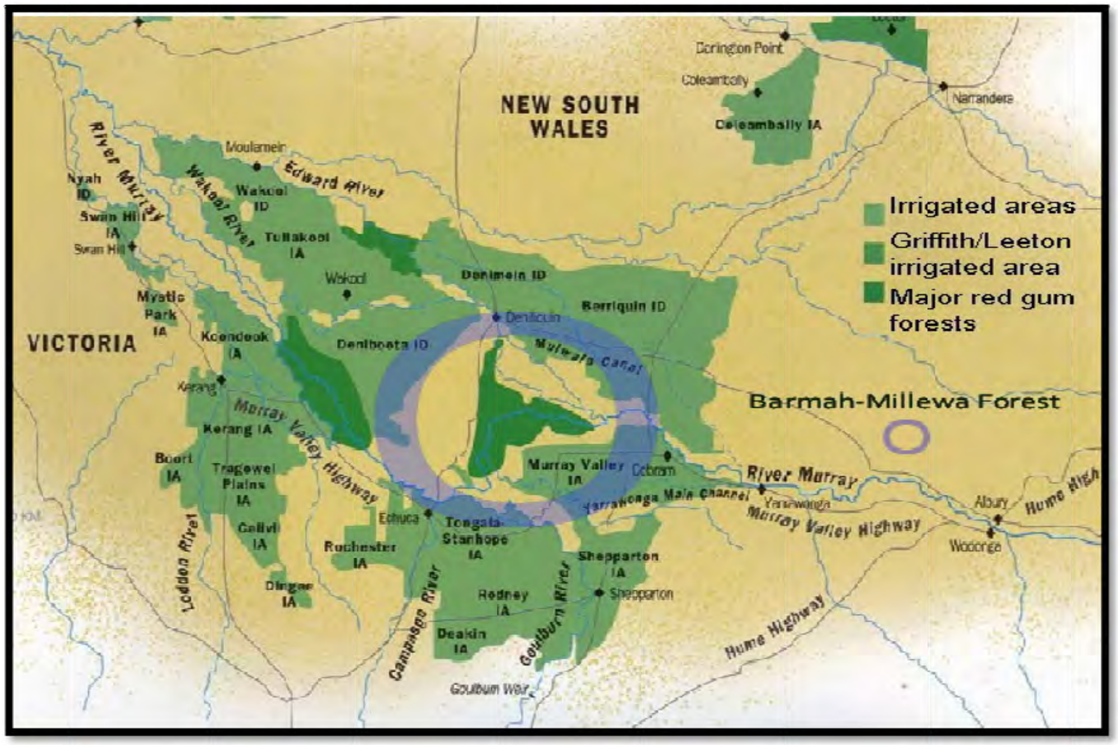
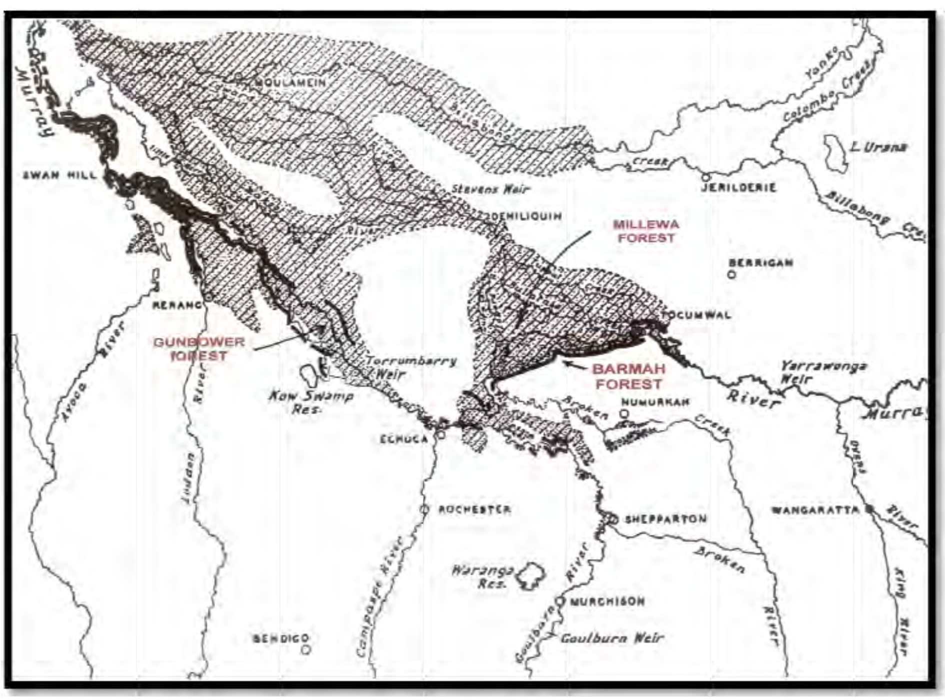


Figure I.3. Flooding in the Central River Murray. 1956 Flood [Courtesy RMC].



Section 1. Streamflow history of the central River Murray Tocumwal gauge 1895 – 2009.

The annual average recorded streamflow (over 115 years) is 5450 GL. This long term average is 46% of the "without development" outflow upstream of Wentworth but 87% of the outflow with current diversion limits (CDL).Decade or ten [10] year averages are shown in Table 1 below.

Table 1. Recorded Streamflow by Decades at Tocumwal[4]

10 year period	Annual Average by Decade (GL/a)	% of long term [115yr] average
1895/1904	4100	75
1905/1914	4900	90
1915/1924	7800	143
1925/1934	6050	111
1935/1944	4950	91
1945/1954	6050	111
1955/1964	6700	123
1965/1974	6050	111
1975/1984	4800	88
1985/1994	5750	105
1995/2004	4250	78
5 year period	5 year mean	
2005/2009	2650	48

The table shows that when considered in ten year cycles, stream flow averages have fallen below 80 % of the long term average in three decades, i.e. 1895-1904 [75%], 1995-2004 [78%] and (5years) 2005-2009 [48%].

Data on the flood history of the Barmah-Millewa Forest is presented in Section 3.

[4] For practical purposes flows downstream of Yarrawonga produce similar flood regimes in B-M Forest to those gauged at Tocumwal.

Section 2. Central River Murray streamflow parameters for "effective flooding" of the Barmah-Millewa Forest.

Background.
Since the 1970s there have been four published sets of "rules" or definitions describing, for circumstances and level of knowledge at the time, what was thought to be an "effective flood" for the river red gum forests.

In 1986 the River Murray Commission directed the Commission's Executive Engineer, R.I. Francis to prepare a detailed report on Water Management in the Millewa and Barmah Forests. The Commission at its 306th meeting on 9th February 1987 approved in principle this comprehensively researched document.

<u>Francis (1986), Chapter 4</u> – "Water Requirements of the Forests", traces the evolution of defining what is an "effective flood" and under clearly defined rules demonstrated the changes that had and were predicted to occur over a 94 year sequence of Tocumwal flows under natural and post-Dartmouth conditions. [These changes are set out in Appendix 2.1.]

Effective Flood Definitions
The first definition [1970] was specific to the Barmah Forest but given the inherent characteristics of the Millewa Group of river red gum forests, the evolving definitions were acknowledged to generally apply to both forests. There is however, an important distinction between the second [1986], third [1997] and fourth [2001] definitions.

Whereas the second definition applied to some 70% - 80% of the river red gum type together with associated grassy plains, billabongs, reed beds and wetlands, the third and fourth definitions, by virtue of the river regimes proposed to flood the forests, would at best only flood up to 50% of the whole forest thus excluding a substantial area of eco-systems that were regularly flooded under natural conditions.

The following is a brief summary of each definition.

1. In 1970 criteria for the flood requirements of the Barmah Forest were based on:
"Examination of stream flow data and intensive investigations into forest flooding during 1961-1966 indicated that a flow of about 24,500Ml/d (10,000cusecs, 13 feet) must be sustained at Tocumwal for four weeks to flood the Barmah forest. Floods capable of inundating the productive forest area 24,160ha (60,400 acres) regardless of depth and duration were considered to provide an adequate watering"[5 6 7].

2. In 1986 with the benefit of an additional 16 years of annual flood mapping in the Barmah Forest which also noted season and duration of flooding, and with several years research into the flora and fauna of the forest, the definition based on an average monthly flow of 24,500 Ml/day was modified, viz: "It does not necessarily guarantee the required depth and duration of flooding to satisfy all the requirements of the red gum ecosystem. However, provided that subsequent flows are in excess of 18,000 Ml/d for a similar period before the

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[5] Dexter, B.D. (1970), Regeneration of River Red Gum (E*ucalyptus camaldulensis*) DEHN. MSc (For) Thesis, The University of Melbourne.
[6] Dexter, B.D. (1978), Silviculture of the river red gum forests of the Central Murray Floodplain. R. Soc. Vic. Proc. 90: 175 – 191.
[7] River Murray Commission (1980) River Murray – Tocumwal to Echuca – River Regulation and Associated Forest Management Problems – Review Report, June 1980.

flood waters drain away and/or evaporate, the essential criteria for sustaining tree reproduction and growth and for waterbird habitat are met"[8] [9] [10].

These flows resulted in about 70% - 80% of the area of Barmah Forest being flooded. Under natural conditions frequency of occurrence was 8 years in every 10 for an average duration of 3.3 months. Similar conditions were observed in the Millewa Group of forests[11].

Depending on the level and duration of peaks and troughs in the hydrograph the highest elevated 20% of the forest, mainly small sections of SQII, SQIII red gum forest and box eucalypt ridges, is not usually flooded by these river flows. For these reasons the value judgment was made that river flows leading to some 70% - 80% of the forest area being flooded for a few months duration 8 years in every 10 years represented an "effective flood".

The modified definition of an "effective flood" was subsequently subject to quantitative research by the University of Melbourne (Bren, L.J., 1988)[12] [13] and in comprehensive reviews by Maunsell (1992)[14] , 1999[15] and 2000[16].

These reviews were in close agreement on the area of forest flooded (70-80%) by these flood regimes with the Maunsell Reports defining the flood requirements of specific flora and fauna with respect to season and duration.

Typical peak daily flow/average daily flow and equivalent monthly flow for the Murray River at Tocumwal leading to fully flooding major vegetation associations are given in Table 2.1 (extracted from Maunsell 1992). Note that full use was made of on-river regulators but in the absence of within-forest small-scale works to facilitate forest flood season, distribution and duration.

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8 Chesterfield, E.A., Loyn R.H., and M.A. Macfarlane (1984). Flora and Fauna of Barmah State Forest and Their Management. Research Branch Report No. 240. Forests Commission Victoria.

9 Dexter,[1] B.D., Rose [2] H.J. and N. Davies [3] (1986). River Regulation and Associated Forest Management Problems in the Murray River Red Gum Forest. Australian Forestry, Vol. 49 (1), 16-27.
   1. Von Mueller Institute, Dept. Conservation, Forests and Lands.
   2. Rural Water Commission of Victoria.
   3. Forestry Commission of New South Wales.

10 Francis, R.I. (1987). Water Management in the Millewa and Barmah Forests. Report to the 306th meeting of the River Murray Commission, February (1987).

11 Forestry Commission of N.S.W. (1985). Management Plan for Murray Management Area.

12 Bren, L.J. (1988). Flooding characteristics of a riparian red gum forest. Aust. For. 1988 51 (I) 57 – 62.

13 Bren, L.J. (1988). The Hydrology of the Barmah River Red Gum Forests – A collection of work undertaken 1984 – 1988 with collaboration from N.L. Gibbs and I.C. O'Neill. The University of Melbourne.

14 Maunsell Pty. Ltd. et al (1992). Barmah-Millewa Forests Water Management Plan – prepared for the Murray-Darling Basin Commission. January 1992.

15 Maunsell McIntyre Pty. Ltd. (1999). Barmah-Millewa Forests Water Management Plan – Business Plan Part I – prepared for the Barmah-Millewa Forum February 1999.

16 Murray-Darling Basin Commission (2000). Barmah-Millewa Forest Water Management Strategy.
Footnote: The BMFWMS was adopted by the Barmah-Millewa Forum in February 1999, passed through the NSW Murray REP2 statutory process in December 1999, approved by the Murray-Darling Basin Commission and endorsed by the Murray-Darling Basin Ministerial Council on 14th and 24th March 2000 respectively.

Table 2.1 Barmah Forest – Vegetation Associations and Flooding Flows.
Extract from Maunsell Report 1992 (Working Paper 6), Barmah-Millewa Forests Water Management Plan, Table 4.4, page 48.

Bren coding	Vegetation Association	% of Forest	Cum: %	Peak daily flow at Tocumwal/Average daily flow at Tocumwal (to flood all the association) Ml/d	Equivalent Monthly Flow (GL/m)	Grouped Association for BMFWMP
1.	Rushlands	1.8	1.8	9,750 / 7,830	235	Rushlands
2.	Moira grasses	5.2	7.0	10,870 / 8,400	252	Moira grass
11.	RG regeneration on plains	4.3	11.3	11,900 / 8,900	267	
3.	RG & moira grass	13.8	25.1	15,900 / 10,860	326	SQI
4.	RG & disturbed areas of wallaby grass	1.9	27.0	16,550 /11,160	335	
5.	RG terete culm sedge & grasses	21.7	48.7	26,110 / 15,900	477	SQII
6.	RG terete culm sedge	10.8	59.5	32,760 / 19,200	576	
7.	RG & spike rush	5.7	65.2	36,930 / 21,230	637	
8.	RG & warrego summer grasses	19.4	84.6	55,510 / 30 400	912	
9.	RG & wallaby grasses	2.0	86.6	57,900 / 31,600	948	SQIII
10.	RG & swamp wallaby grasses and brown-black wallaby grass	9.6	96.2	70,830 / 37,960	1,139	
12.	Yellow box & grey box	3.2	99.4			Box
13.	Black box	0.4	99.8			

3. In 1997 Victoria's Sharing The Murray Proposal[17] (VSMP) gave a definition of an "Effective Flood" as Murray river flows downstream of Yarrawonga/Tocumwal characterised by:

- 3 months at 500 GL (pulsed between 550 and 450 GL) and the fourth month at 400 GL between August and December.

OR

- 500 GL in October and November and 400 GL in December with some topping up in January of areas when birds are breeding.

The VSMP specifically targets areas inundated by medium-sized floods on the grounds that such areas are important habitat for birds, fish and frogs and large floods would be too difficult to reinstate. In the case of Barmah Forest it is stated that medium flows of 550 GL/month (measured at Yarrawonga) inundate the rush beds, billabongs and large areas of Moira grass plain and fringing redgum which water birds need for breeding. It was assumed that watering should occur in spring and preferably last for four months. It was also considered that the longest period without floods should be five years.

It is well documented in published papers and reviews, together with practical experience of local people and of 34 years of forest flood mapping in the Barmah Forest, that floods originating from "medium" (450-550 GL) river flows at Tocumwal will only cover some 35%-50%

[17] Murray Water Entitlement Committee (1997), *Sharing the Murray, Proposals for defining people's entitlements to Victoria's water from the Murray*, October 1997.

of the Barmah Forest depending on the level and duration of peaks and troughs in the hydrograph.

As comprehensively reported in the Barmah-Millewa Forest Water Management Plan – Business Plan Part I – Final Report Maunsell McIntyre (February 1999)[18], no one vegetation association is fully flooded for a 550GL/m flow in the Murray River downstream of Yarrawonga Weir. Substantial areas ranging from 36% to 85% of all vegetation associations, except the Giant Rush beds association, are usually deprived of water at this flow. Consequently, many environmental and forest flood requirements are not satisfied.

Extract from Maunsell McIntyre February 1999. Section 4.3.2 Page 121 of 183 Revision: G.
4.3.2 Victorian "Sharing the Murray" Rules.

The first comment will concern the selection of the Murray flow rates for the two artificial floods adopted for the Victorian work. Ignoring for the moment the duration of the floods, the first flood nominated was a "Bird breeding" flood of 500Gl/m to 550GL/m and the second a "Forest" flood of 650GL/m. The vegetation associations affected by these floods are set out in the following Table 4.3.1. The area (or proportion) of each association flooded has been taken from Bren et al (1988).

This paper used analysis of 500m grids of the Barmah Forest to produce "box and whisker" plots of flooded vegetation associations against flows to achieve "substantial flooding". The analysis covered each of Bren's 14 associations. Unfortunately, there is not any corresponding data for the Millewa Forest.

For the 550GL/m flood, no one association is completely flooded although Giant Rush beds at 90% is thought to be close. Most associations are about 50% flooded. For the 650GL/m flood, the flooded percentage is now almost 60%. For the important Site Quality II areas, the flooded percentages are only – 50% for the 550GL/m flood and 58% for the 650Gl/m flood.

[18] Maunsell McIntyre Pty. Ltd. (1999). Barmah-Millewa Forests Water Management Plan – Business Plan Part I – prepared for the Barmah-Millewa Forum February 1999.

Table 2.2 Flooded Areas in Barmah Forest by Vegetation Association for 550GL/m and 650GL/m floods. (Table 4.3.1[19])

Vegetation Association	***Percentage of Barmah Forest Area***	***No.***	***% of the Assoc. flooded at***	
			550GL/m	***650GL/m***
Giant rush beds	*1.8*	*1*	*(90)*	*(90)*
Moira Grass	*5.2*	*2*	*63*	*66*
Red Gum and Moira Grass	*13.8*	*3*	*57*	*62*
Red Gum Regeneration on the plains	*4.3*	*11*	*64*	*68*
Red Gum, terete culm sedge and grasses	*21.7*	*5*	*51*	*55*
Red Gum and terete culm sedge	*10.8*	*6*	*47*	*54*
Red Gum and common spike rush	*5.7*	*7*	*51*	*55*
Red Gum and warrego summer grass	*19.4*	*8*	*54*	*55*
Red Gum and wallaby grasses	*2.0*	*9*	*40*	*38*
Red Gum, swamp wallaby grasses and brown black wallaby grasses	*9.6*	*10*	*44*	*46*
Yellow box and grey box	*13.2*	*12*	*25*	*31*
Black Box	*0.4*	*13*	*(15)*	*(15)*
Disturbed sites with introductions	*1.9*	*4*	*31*	*32*
Open water	*1.8*			
Total Flooded Percentage for Forest			***51.4%***	***59.8%***

Further work by Maunsell's [October 2000] examined flooded area relations for the Barmah-Millewa Forest on behalf of the Barmah Millewa Forum[20]. Key tables and conclusions are given below. The full report is in Appendix 2.2.

Table 2.3.1 Barmah Millewa Forest: Flooded Area Percentages: October November 1988. Based upon Tocumwal Peak Flow.

Flow Criteria	Measured Percentage Flooded **Millewa Forest**	Measured Percentage Flooded **Barmah Forest**	Bren Predicted Barmah Percentages based upon **Tocumwal Peak Flow**
Peak flow at Tocumwal, October 1998, 70,000 Ml/d	80%	47%	93% or "as flooded as it gets"
Tocumwal peak flow, November 1998, 17,500 Ml/d	21%	25%	28%

[19] Maunsell McIntyre Pty. Ltd. (1999). Barmah-Millewa Forests Water Management Plan – Business Plan Part I – prepared for the Barmah-Millewa Forum February 1999.

[20] The Barmah-Millewa Forum was established in 1994 under Clause 14 provisions of the River Murray Waters Agreement with defined responsibilities and accountabilities. The role of the Barmah-Millewa Forum in providing advice on developing, implementing and monitoring environmental water management in the Barmah-Millewa Forest is described in Section 5.

Table 2.3.2 Barmah Millewa Forest: Flooded Area Percentages: October November 1988.
Based upon average flow for the month at Tocumwal.

Flow Criteria	Measured Percentage Flooded **Millewa Forest**	Measured Percentage Flooded **Barmah Forest**	Bren Predicted Barmah Percentages based upon **Average Daily Flow for Month**
Average daily flow at Tocumwal based on: October 580GL	80%	47%	56%
Average daily flow at Tocumwal based on: November 330GL	21%	25%	34%

The Barmah-Millewa Forest Water Management Plan does not provide estimates of flooded areas but does quote estimates of inflows into both forests. These estimates are compared with the 1991 Mike 11 results [Maunsell 1991] in Table 2.4 below.

Table 2.4 Barmah Millewa Forests: Inflows to Forests (Ml/d)

1991 Mike 11 results	River Murray at Tocumwal	Flow into Barmah Forest	Flow into Millewa Forest
	15,000 Ml/d	4,100 Ml/d	2,200 Ml/d
	25,000	11,400	3,500
	35,000	17,000	7,400

The two sets of Mike 11 results come from the post Mary Ada regulator numbers and locations.

Summary

1. There is a reliable and robust link between peak flows and monthly totals at Tocumwal. It would greatly limit ongoing confusion if peak flows at Tocumwal were always quoted as “Ml/d” and monthly totals as “GL/m”.
2. The quoted forest inflows in the Millewa Water Management Plan check reasonably closely with the 1991 Mike 11 results.
3. Both Bren relationships remain robust but should only be used as a broad indicator of the flooded area within the Barmah Forest.
4. Corresponding data needs to be gathered for Millewa Forest.
5. At the two nominated “Effective Floods” and provided the floods last for 30 days, the percentage forest flooded would be about 65% at 24,000 Ml/d for Barmah and a figure between 40% and 80% for Millewa.

4. In early 2001 the Murray Darling Basin Commission (MDBC) developed a set of operating rules for managing the 100GL Barmah Millewa Forest environmental water allocation (EWA) approved by the MDBMC in 1993. The “rules and triggers” to manage the EWA evolved from Victoria’s Sharing the Murray proposal and were agreed to by the MDBMC on 30 March 2001.

*"The operating rules are targeted to meet a number of **desired hydrological outcomes**. The key outcomes are to achieve on average three medium sized, long duration floods every 10 years and to ensure that there is no more than 5 years between these events."*

"The targeted floods run for 4 months between September and January, inundating around 50% of the forest."
"Recommended triggers for the use of the environmental allocation have also been established. The objective of the triggers is to achieve the required frequency, duration and seasonality of flooding to sustain the forest ecosystem in the long term."

"The rules have received broad consensus from the Victorian Murray Water Entitlement Committee (MWEC) and the NSW Murray Lower Darling Community Reference Committee (MLDCRC)".
*In 2005 the operating rules were slightly modified [Appendix 2.3] but for all practical purposes the key 2001 provisions for streamflow to meet **desired hydrological outcomes** remained intact. The rules will need to be revised to meet the requirement of the MDB Plan.*

Barmah-Millewa Forest Water Management Strategy[21].
The strategy was adopted by the Barmah-Millewa Forum[22] in February 1999, passed through the NSW Murray REP2 statutory process in December 1999, approved by the Murray-Darling Basin Commission and endorsed by the Murray-Darling Basin Ministerial Council on 14th and 24th March 2000 respectively.

This strategy reflects *"the aspirations of the community and government agencies for sustainable water management of the Barmah-Millewa Forest. Essentially it involves managing the forest/water environment in accord with complex ecological, economic, and social factors inside and outside the forest. Acceptable trade-offs have been derived following consultation with the community and agencies.*

The Strategy's focus on maintaining or enhancing the ecological health of the forest will be achieved by managing the water regime in a manner that recognises the forest as a single ecosystem; by recognising appropriate economic, environmental and social factors; and by adapting to advances in knowledge".

To achieve these aims the Strategy specifically provides for:
- *"managing the forest as a single ecosystem;*
- *optimising the use of river flows to enhance water management of the forest environment;*
- *facilitating effective water management by dividing the forest into areas that can be managed independently or semi-independently;*
- *providing, operating and maintaining water management works or structures required for economic and effective operation of the Strategy."*

The objectives and targets set out in the Barmah-Millewa Forest Water management strategy 2000 are listed in Appendix 2.4.
With these definitions as background, this case study will now review the position changes from 2005 to date.

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21 Murray-Darling Basin Commission (2000). Barmah-Millewa Forest Water Management Strategy.
Footnote: The BMFWMS was adopted by the Barmah-Millewa Forum in February 1999, passed through the NSW Murray REP2 statutory process in December 1999, approved by the Murray-Darling Basin Commission and endorsed by the Murray-Darling Basin Ministerial Council on 14th and 24th March 2000 respectively.

22 The Barmah-Millewa Forum evolved from the Community Reference Group set up to review the 1991 Barmah-Millewa water Management Plan and was established under clause 14 provisions of the River Murray Waters Agreement – see Section 5.

Changes between 2005 and 2010

1) <u>**Barmah-Millewa Icon site Environmental Management Plan – draft revision [in preparation] as at 13 August 2010.**</u> The following is drawn from the draft revision EMPlan.

The Plan updates progress since the previous plan [BM ASMP 2005] and outlines intended activities for the next five years.

Vegetation communities.

Under this plan vegetation communities present in the Barmah Millewa Forest [BMF] are grouped into five broad categories.

<u>Table 2.5 Barmah–Millewa Forest Vegetation Types by Area (based on analysis of data presented in DSE 2008 and GHD 2009).</u>

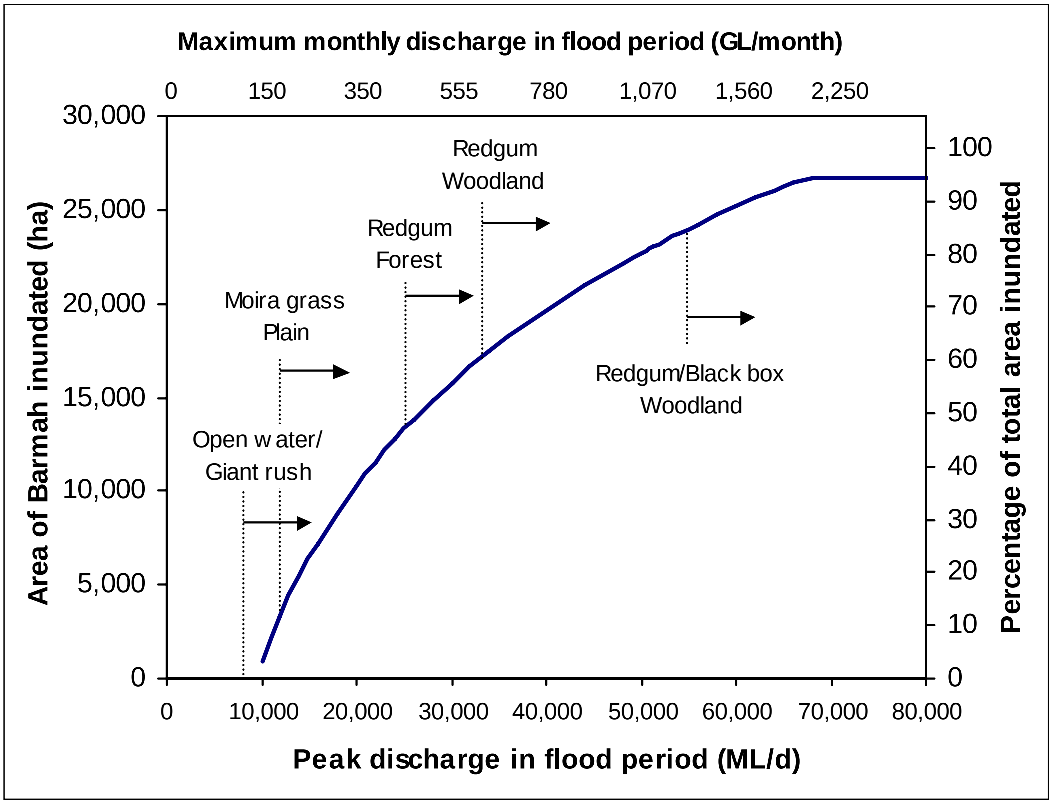
Vegetation Types	Barmah (ha)	Millewa (ha)	Total Area (ha)
Giant Rush	531	2,667*	3,198 (4.8%)
Moira Grass	1,535	774*	2,309 (3.5%)
River Red Gum Forest (with a flood dependant understorey)	16,617	26,181	42,798 (64.8%)
River Red Gum Woodland (with a flood tolerant understorey)	9,711	4,002	13,713 (20.8%)
River Red Gum/Black Box woodland	1,063	2,919	3,982 (6.0%)
Total	29,457	36,543	66,000

*Note: * Area of Giant Rush and Moira Grass in Millewa Forest not directly identified in GHD (2009). Areas shown are derived from area of wetland.*

Streamflow criteria for vegetation communities.

Figure 4, Section 3.2, in the draft plan indicates “commence to flow discharges” [quoted as flows at Tocumwal] of the main vegetation associations in the BMF icon site. “Effective flooding” [that is, with a minimum required depth of water] of these communities is said to occur at higher discharges.

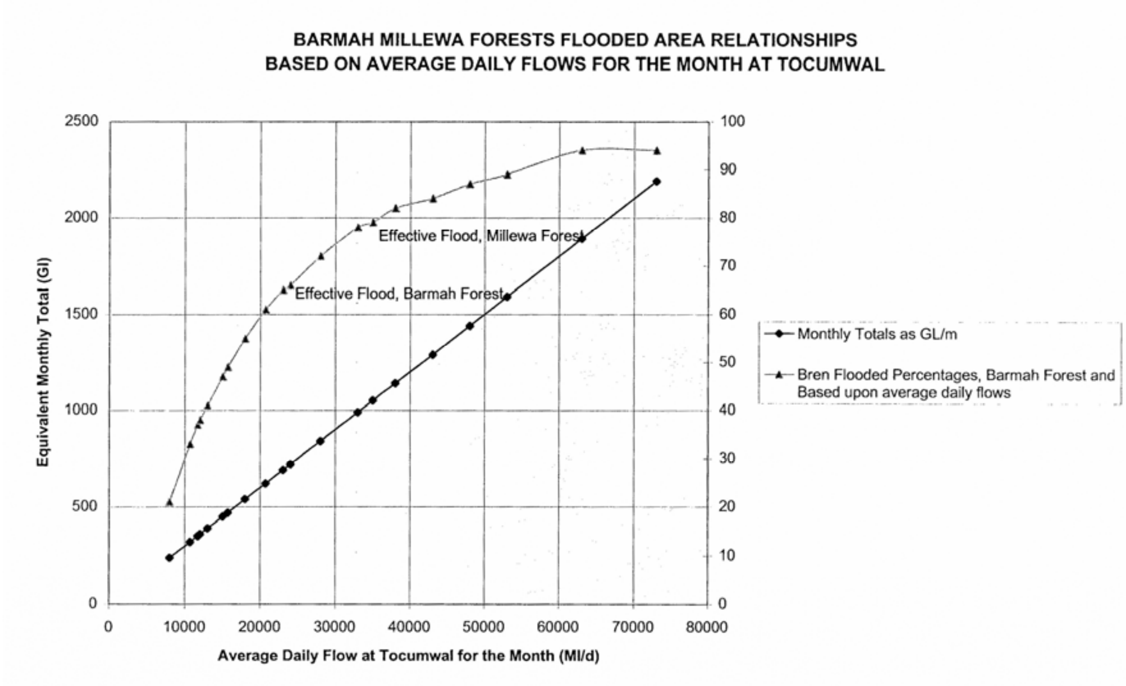
Figure 2.1 Area of Barmah Forest inundated as a function of River Murray flood peak and monthly peak discharge at Tocumwal (instantaneous peak discharge) and Yarrawonga (monthly total discharge). (Bren *et al*. (1987), Bren *et al*. (1988) and REG C (2003) as cited in DSE and GBCMA 2005). [Extract from draft Guide to Plan Figure 4.]

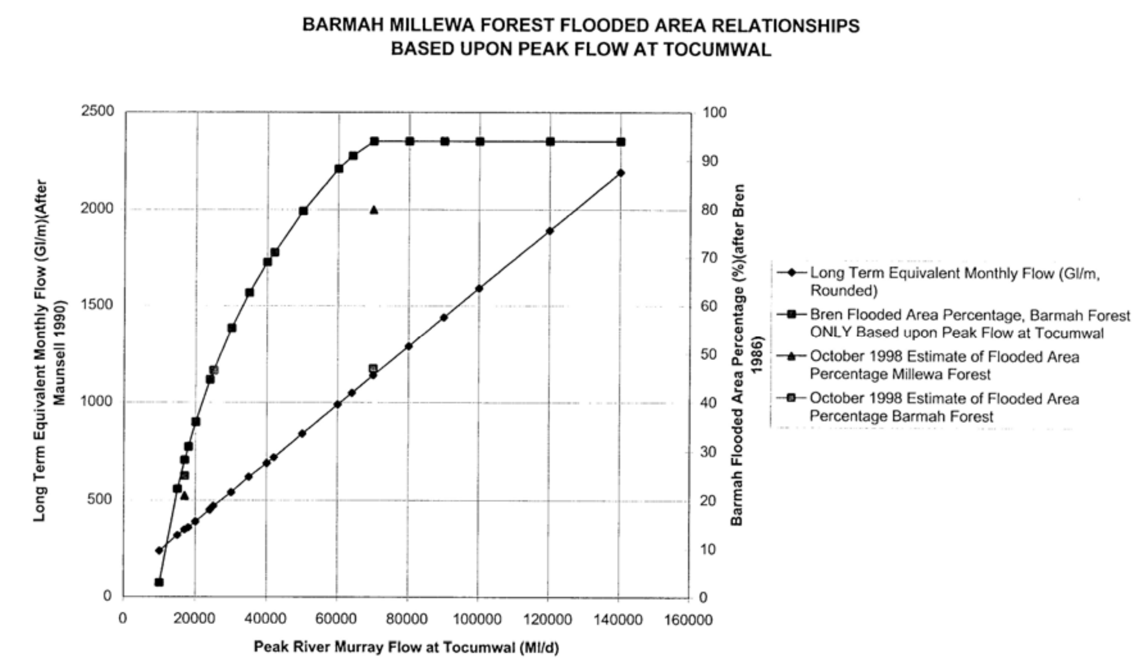


Such generalised figures must be treated with caution as they do not take into account the variability in monthly totals with various daily peak flows at Tocumwal.

Barmah Millewa Forest flooded area relationships, with appropriate caution, were described by Maunsell [2000][23] see Appendix 2.2 and Figures 2.2.1 & 2.2.2 below. These values are based on a more detailed understanding of the data informed by extensive field observations over several decades.

[23] Maunsell McIntyre Pty Ltd (2000), *Barmah Millewa Flooded Area Relationships.* Macleod, D.J. October 2000.





The draft plan identifies the "higher" parts of B-MF most in need of watering [following the 2001/09 drought] but channel capacity constraints [25,000 Ml] between Hume Reservoir and Yarrawonga prevent these areas being watered by managed flows. This is discussed further in Section 3.

At present only some "low" levels of BMF can be watered by Tocumwal streamflow around 15,000 – 18,000 ML/d]. The implications are discussed in detail in Section 6.

The draft Plan sets out the water management strategy [Barmah Forest] and watering sharing plan for NSW Murray [Millewa group of forests] and Lower Darling regulated rivers together with interim operating rules for managing the EWA.

Note: ***"... these operating rules designed to efficiently manage the water distribution [within the forest and wetlands] under conditions of varying irrigation demand and natural conditions in the flow patterns ...***
Since 1993 [inception of EWA] the operating rules have been mainly targeted to meet <u>desired hydrological outcomes</u> ... ***"to inundate around 50% of the forest, and ... to ensure that there is no more than 5 years between these events".***

Ecological objectives and associated hydrological conditions are summarized in Appendix G [of draft Plan] and reproduced below.

Appendix G of the Plan summarises ecological objective and associated hydrological conditions.

Appendix G Existing objectives from relevant documents

Asset Environmental Management Plan: Barmah Significant Ecological Asset – Draft 11 May 2005

OBJECTIVES &/OR TARGETS

General ecological objectives:

- protect the ecological character of the floodplain, as required under the Ramsar convention;
- enhance the ecological functions and diversity of the floodplain by re-instating a more natural flood regime;
- enhance breeding and recruitment of native floodplain fauna and germination and regeneration of native flora;
- provide suitable habitat conditions for native flora and fauna;
- ensure that all natural, flow related ecological functions can occur;
- protect and restore Moira Grass plains; and
- ensure breeding success of colonial waterbirds.

The overall ecological targets:

- provide successful recruitment of large colonies of colonial waterbirds at least 3 years in 10;
- increase the area and quality of Moira Grass plains;
- provide breeding opportunities for floodplain fish, frogs and tortoises;
- provide Winter-Spring floods to 50% of red gum forest; and
- provide Winter-Spring floods to a proportion of all Barmah-Millewa wetland communities.

More detailed ecological objectives and associated hydrological conditions are below:

Ecological objective	Associated hydrological conditions
• Reduce encroachment of Giant Rush and River Red Gum onto Moira Grass plains	Flow maintained <10,600 ML/day during Summer and Autumn (ie. prevent unseasonal flooding)
• Maintain health of sedges, Giant Rush and wetland communities; assist maintenance of majority of Moira Grass; maintain up to half of River Red Gum forest; provide events suitable for successful waterbird breeding ○ 55% of forest inundated	• 4-month flood of 400 - 550 GL/month for 4 months in 50% of years (equivalent to average daily flow of 13,135 ML/day to 18,330 ML/day) • Less than 5 years between these events
• Maintain health of majority of River Red Gum forest; maintain some River Red Gum woodland ○ 66% of forest inundated	760 GL/month (equivalent to average daily flow 25,300 ML/day) in 40% of years; any month Aug-Nov, duration 4 months
• Maintain up to one half of River Red Gum woodland communities ○ 75% of forest inundated	912 GL/month (equivalent to average daily flow 30,400 ML/day) in 30% of years; any month Aug-Nov, duration 1 – 4 months

Great care must be taken in interpreting this data and using it for modelling without reference to real time variability. The interim operating rules specify flood parameters in GL/month (which appears not to be Bren's "equivalent monthly flow in GL/m") while the ecological objectives recognise the GL/month flows but then wrongly express them as an equivalent to an average daily flow in Ml/d rather than Bren's "peak flow at Tocumwal in ML/d".

As demonstrated by Maunsell [2000] and in Barmah Forest flood mapping described in Section 3, the daily variability in the hydrograph can have a significant bearing on the area flooded and duration of flooding.

The MDBA "Assessing environmental water requirements Chapter 10 – Barmah–Millewa Forest"[24] recognises that these operating rules do not optimise efficient management nor effectively manage streamflow to achieve desired environmental outcomes.

2) MDBA Guide to the proposed Basin Plan, October 2010.

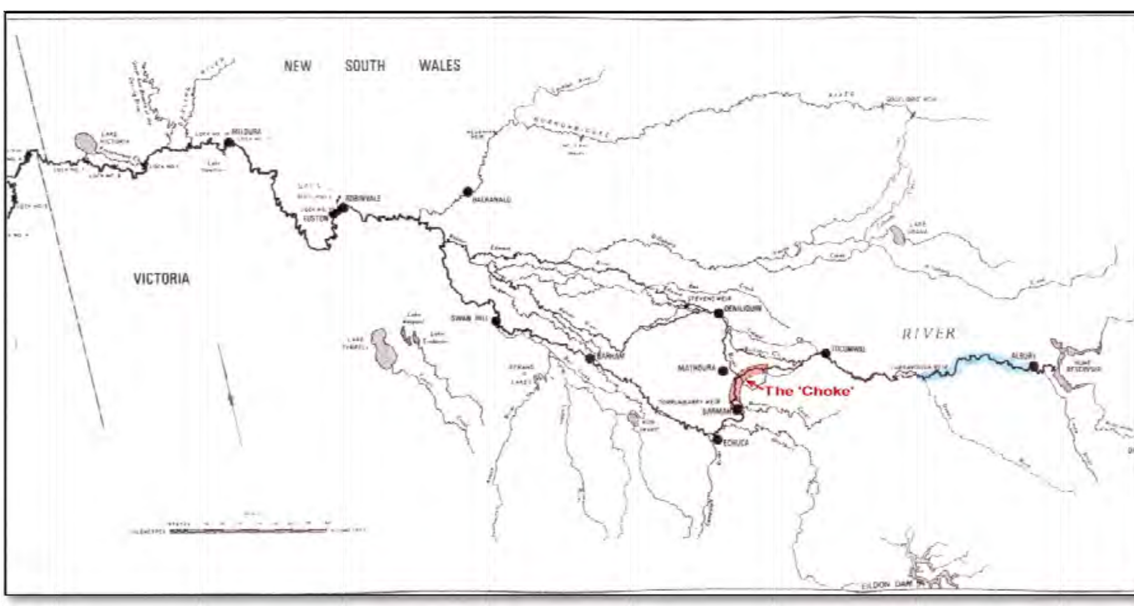
The following is extensively drawn from Assessing environmental water requirements Chapter 10 – Barmah–Millewa Forest July 2010 and from other reports as referenced.

Background to setting out hydrologic parameters for "effective" flooding of the forest & wetlands.

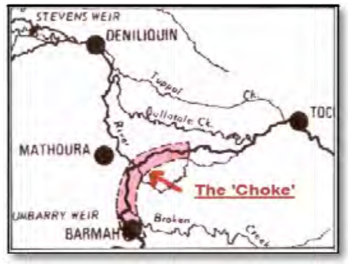
[i] Hydrology.

The River Murray and the Barmah Choke define the hydrology of Barmah–Millewa Forest.

Figure 2.3 Bankful channel capacity constraints affecting management of irrigation & environmental flows.



24 Murray Darling Basin Authority (2010) *Assessing environmental water requirements: Chapter 10 – Barmah–Millewa Forest*. July 2010.



- The 10,200 Ml/d channel capacity in the region of the Barmah Choke severely constrains river management options particularly from mid-December to late April.
- The problem will be exacerbated under recommendations to open up inter-district water entitlement trade (d/s of the Barmah Choke)
- Channel constraints now taking effect more often due to less water available to call from mid-Murray tributaries & changes in demand patterns
- Solving problems related to the Barmah Choke have been under investigation for over 30 years; so far without resolution.

Barmah–Millewa Forest is dissected by many ‘effluent’ streams, the largest of which are the Edward River and Gulpa Creek. Provided the regulator gates are open, key effluents start to flow* at various River Murray flows. For example, information provided by the Victorian Department of Sustainability and Environment suggest Gulf Creek begins to flow with Tocumwal flows above 3,500 ML/d*, Boals Creek at 6,000 ML/d and Smiths and Tullah creeks begin to flow once Tocumwal flows exceed 9,500 ML/d.

Wetlands are also flooded at different flow levels. Flows up to 15,000 ML/d inundate large areas of open wetlands and moira grass plains (Water Technology 2009b). Most red gum forest with flood-dependent understorey is flooded at flows of 25–35,000 ML/d, with higher flows up to and in excess of 60,000 ML/d needed to inundate red gum/black box woodland (Water Technology 2009b).

More than 50 water management structures are present throughout the Barmah–Millewa Forest and comprise two broad categories of regulators (MDBC 2006b). **Primary regulators** (discharge capacity generally >100 ML/d) occur in anabranch streams near their exit point from the River Murray, Edward River and Gulpa Creek. These structures maintain regulated flows within stream and permit river freshes and floods to pass into the forest. **Secondary and tertiary regulators** (discharge capacity generally <100 ML/d) are mostly situated in drainage features within the interior portions of the forest and include pipes, culverts and regulators, and earthen banks. These structures manipulate water distribution and depth within localised areas, and provide vehicle access. They are overtopped or outflanked during large floods. Regulators provide flexibility for use of the existing and any future environmental water allocations for Barmah–Millewa Forest (Victorian Department of Sustainability and Environment 2008).

Now almost lost in the mists of time, the primary purpose of secondary and tertiary regulators was to protect roads and access in the Barmah Forest. When primary regulators are open many of the secondary and tertiary regulators do not flow. There is the potential for a network of secondary and tertiary regulators specifically designed and integrated with the primary regulators to service water management areas within the forest to significantly improve the effectiveness and efficiency of forest flooding. This is discussed in Section 6.

[ii] Environmental objectives and targets.
Environmental objectives for the Barmah–Millewa Forests have been determined using the key environmental asset criteria. Targets to achieve these objectives have been specified for flood-dependent vegetation communities considered essential to support wetland processes and to provide crucial habitat for identified flora and fauna species. These are outlined in Table 10.3.

The criteria under which Barmah–Millewa Forest is considered to be a key environmental asset are broad and so are the objectives. However, a review of the Ramsar ecological character descriptions indicates that if Objective 1 is achieved, the requirements of Objectives 2 to 5 will also be met (i.e. conserving the ecological character will require water-dependent ecosystems to be protected and restored).

Rather than specify targets and water requirements for each component, targets and water requirements will be specified for a number of representative habitats and vegetation communities. Achieving these targets will meet the needs of the other components and objectives, except for those regarding colonial nesting waterbirds. Consequently, additional targets are set for colonial nesting waterbirds.

The Barmah Forest Ramsar site ecological character description (Victorian Department of Sustainability and Environment 2008) has predominantly been used in determining the targets for the Barmah–Millewa Forest indicator asset (Table 10.3). GHD (2009) does not set limits of acceptable change for vegetation communities. The interconnected hydrology between the two forests means that compliance with limits of acceptable change at Barmah Forest will deliver similar outcomes at Millewa Forest for red gum and black box and therefore drives targets for the entire Barmah–Millewa Forest indicator site.

The targets to achieve Objectives 1 – 5, said to be met if Objective 1 is achieved, determine the hydrologic parameters [streamflow D/S Yarrawonga/Tocumwal] that will achieve "effective" flooding of the B-MF.

Table 2.6 Objectives and targets [Table 10.3 in MDBA's "Assessing environmental water requirements: Chapter 10 – Barmah–Millewa Forest"]

Objectives	**Justification of targets**	**Target**
1 To conserve the Ramsar site consistent with its ecological character and to protect and restore ecosystems that support migratory birds listed under international agreements. (Criterion 1) 2 To protect and restore natural or near-natural, rare or unique water-dependent ecosystems (in their current state). (Criterion 2) 3 To protect and restore water-dependent ecosystems that provide vital habitat. (Criterion 3) 4 To protect and restore water-dependent ecosystems that support Commonwealth-, state- or territory-listed threatened species and communities. (Criterion 4) 5 To protect and restore water-dependent ecosystems that support or are capable of supporting significant biodiversity. (Criterion 5)	Victorian Department of Sustainability and Environment (2008) and GHD (2009) specify that any decrease in the current area of these wetland types would signal a change in ecological character.	Maintain 100% of the current extent of freshwater meadows or shallow freshwater marshes in good condition.
Objectives 1 to 5	A change in ecological character would be signalled by a decrease in the area mapped by Chesterfield et al. (1984) as being dominated by moira grass and accompanied encroachment of giant rush and regeneration of red gum (Victorian Department of Sustainability and Environment 2008).	Maintain 100% of the current extent of moira grass plains in good condition.
Objectives 1 to 5	Any loss or substantial decline in the current area or health of vegetation communities would signal a change in ecological character (Victorian Department of Sustainability and Environment 2008).	Maintain 100% of the current extent of red gum forest in good condition. Maintain 100% of the current extent of red gum woodland in good condition. Maintain 100% of the current extent of black box in good condition.
Objectives 1 to 5	Interim ecological objective under The Living Murray. Victorian Department of Sustainability and Environment (2008) specify that any reduction in the recorded frequency and abundance of bird breeding would signal a change in ecological character. GHD (2009) specify successful breeding of thousands of colonial waterbirds in at least three years in 10.	Provide conditions conducive to successful breeding of colonial nesting waterbirds.

[iii] Environmental water requirements.

10.4. Environmental water requirements

Hydrology has been identified as critical to the ecological character of Barmah–Millewa Forest... with variation in flood regime across the River Murray floodplain being the primary determinant of vegetation composition and structure (GHD 2009). Similarly, the Victorian Department of Sustainability and Environment (2008) identify hydrology as being critical to maintaining most of Barmah Forest's ecosystem services and, in order to maintain vegetation associations as they were in 1982. **The flood history of the forest 1895 – 1982 is described in Section 3.**

These associations were described by Chesterfield et al[25] (Jan 1984) following three years of field work between 1977 and 1980. The map describing vegetation, prominent birds and mammals is reproduced below.

At the time the flora of the Barmah Forest consisted of more than 550 species of which approximately 30 percent are introduced aliens.

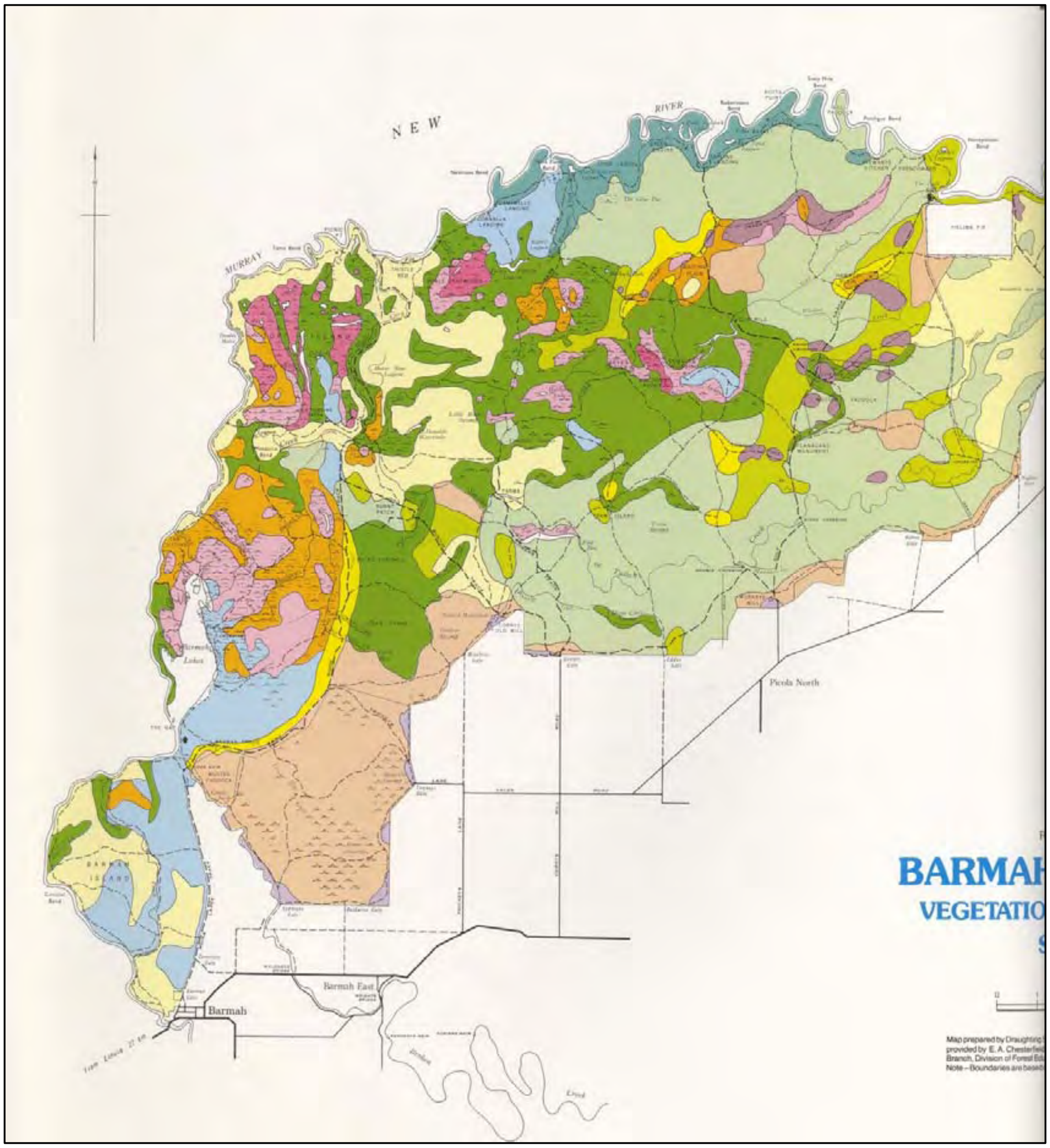
The majority of species are herbaceous with only about 40 species having tree or shrub habit. At least one third of the flora is associated with the box woodlands which occupy only 3.5 percent of the forest area.

Chesterfield et al (1984) identified and mapped five main vegetation categories on the composition and structure of the dominant species and a number of understory associations. Nine river red gum subsets are described under Open Forest and Woodland including red gum regeneration [colonisation] on plains. Earlier surveys from 1960 described 8 subsets in terms of RRG site quality based on mature tree height which were closely linked to flood regime. About 70 percent of the RRG type was in the Open Forest [51 – 80% crown cover] category.

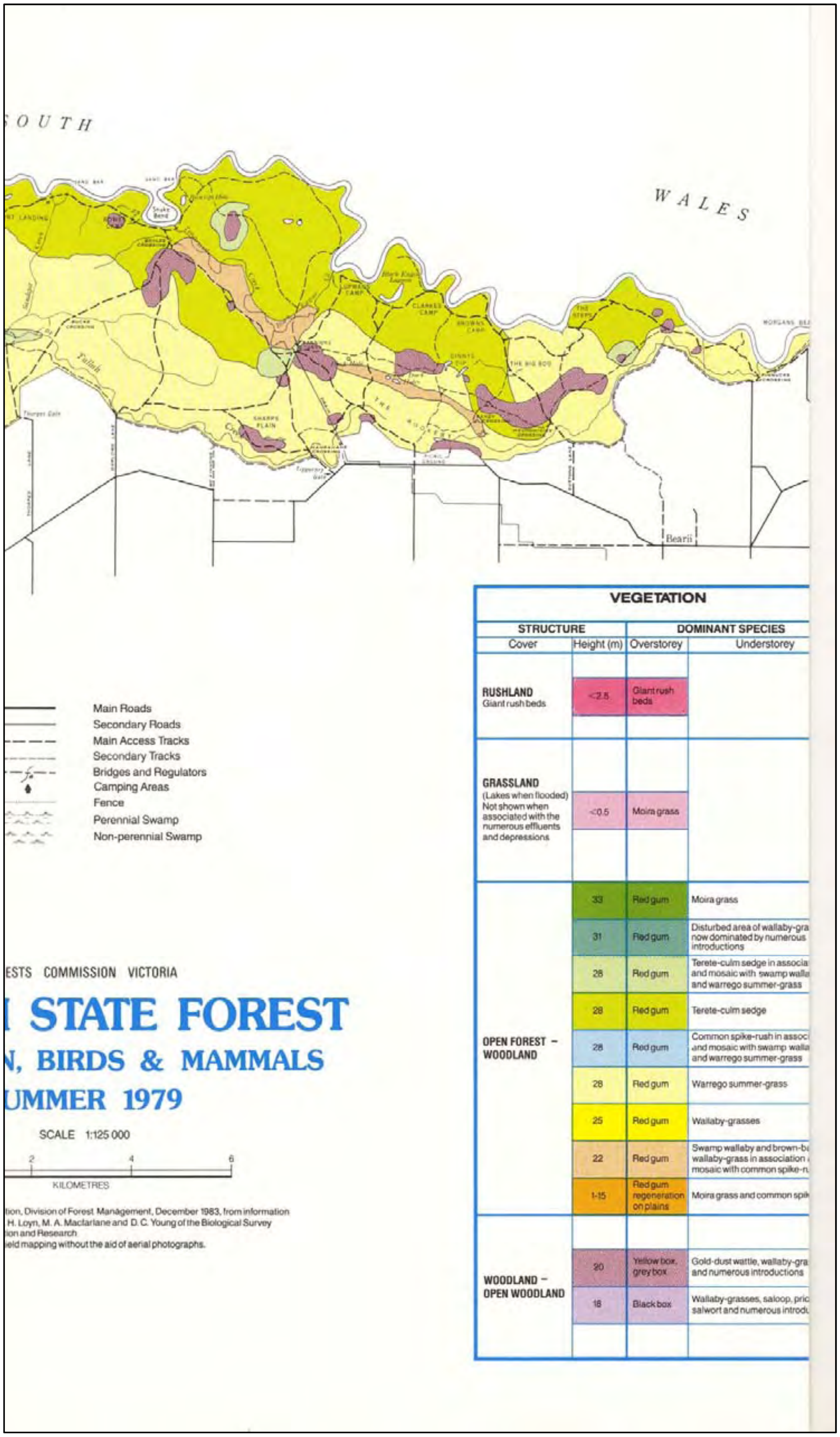
Table 2. 7 River Red Gum Site Quality – Barmah Forest.

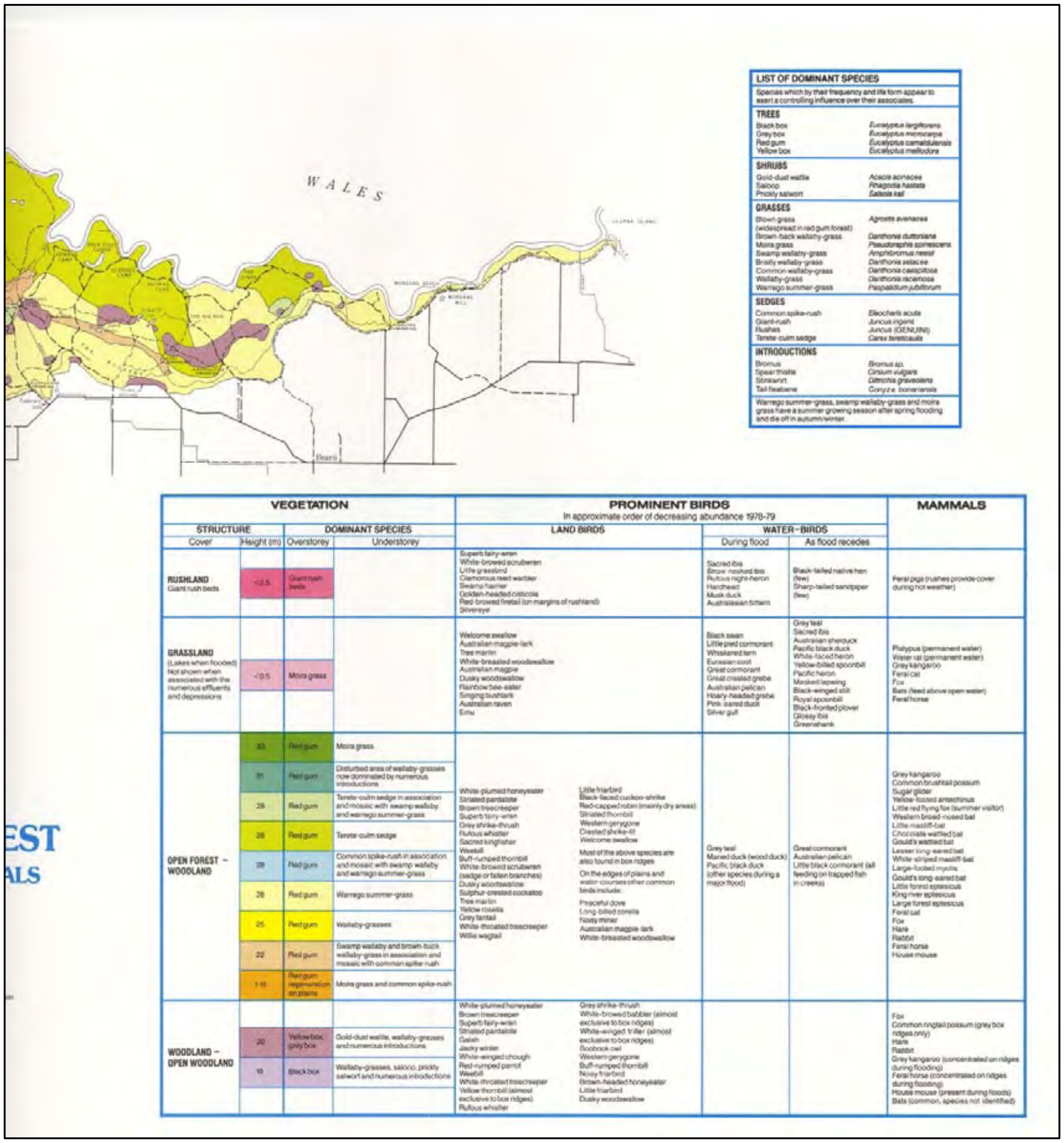
Site quality	Mature top height in metres	Area in hectares	% of total area	
SQ I	> 30.5	8,500	29	78
SQ II	> 21.3 - 30.5	14,500	49	
SQIII	< 21.3	2,500	8.5	
RRG area		25,500	86.5	
Total area forest		29,500		

25 Chesterfield, E. A., Loyn, R. H. and Macfarlane, M. A. 1984 Flora and fauna of Barmah State Forest and their management. For. Comm. Vic., Res. Branch Rep. 240, 73 pp. + App. (unpubl.).



Barmah State Forest. Vegetation, Birds & Mammals. Summer 1979.


OUTH
WALES
Bearii
Main Roads
Secondary Roads
Main Access Tracks
Secondary Tracks
Bridges and Regulators
Camping Areas
Fence
Perennial Swamp
Non-perennial Swamp
ESTS COMMISSION VICTORIA
STATE FOREST
N, BIRDS & MAMMALS
UMMER 1979
SCALE 1:125 000
2 4 6
KILOMETRES
tion, Division of Forest Management, December 1983, from information
H. Loyn, M. A. Maclarlane and D. C. Young of the Biological Survey
ion and Research
eld mapping without the aid of aerial photographs.
VEGETATION
STRUCTURE
DOMINANT SPECIES
Cover
Height (m)
Overstorey
Understorey
RUSHLAND Giant rush beds
<2.5 Giant rush beds
GRASSLAND (Lakes when flooded) Not shown when associated with the numerous effluents and depressions
<0.5 Moira grass
OPEN FOREST – WOODLAND
33 Red gum Moira grass
31 Red gum Disturbed area of wallaby-gra now dominated by numerous introductions
28 Red gum Terete-culm sedge in associa and mosaic with swamp walla and warrego summer-grass
28 Red gum Terete-culm sedge
28 Red gum Common spike-rush in assoc and mosaic with swamp walla and warrego summer-grass
28 Red gum Warrego summer-grass
25 Red gum Wallaby-grasses
22 Red gum Swamp wallaby and brown-b wallaby-grass in association mosaic with common spike-ru
1-15 Red gum regeneration on plains Moira grass and common spik
WOODLAND – OPEN WOODLAND
20 Yellow box, grey box Gold-dust wattle, wallaby-gra and numerous introductions
18 Black box Wallaby-grasses, saloop, pric salwort and numerous introdu

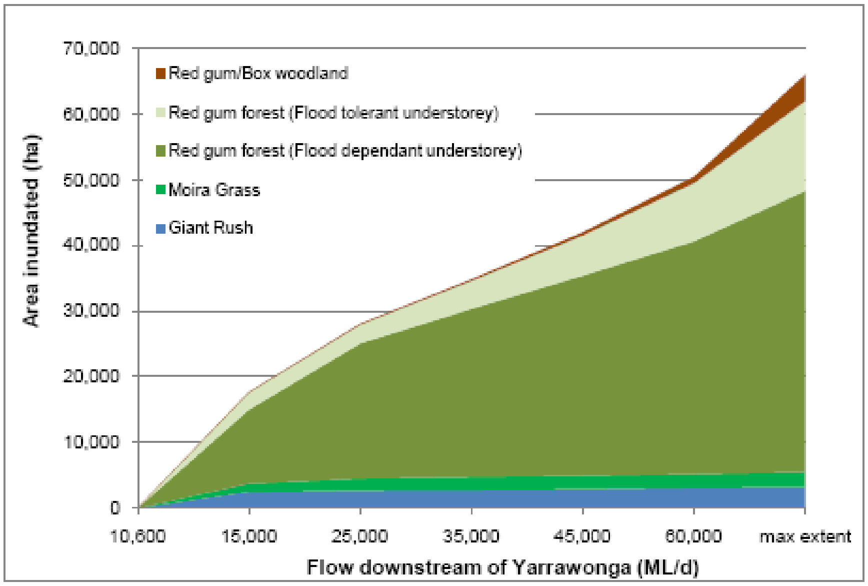


The MDBA's "Assessing environmental water requirements" states that an increase in both flooding frequency and duration, in the range of 15–60,000 ML/d, is likely to be necessary to maintain ecological character of Barmah Forest (Victorian Department of Sustainability and Environment 2008).

A number of documents were assessed to determine the flows required to achieve the specified targets. [It is claimed that] No single existing plan or document sets out these requirements completely. (Maunsell 1992 covers all associations but critics could suggest it was only for Barmah forest.)

Data presented in the Barmah–Millewa Forest hydrodynamic model report (Water Technology 2009b) has been assessed in parallel with the ecological character descriptions of the forests (Figure 10.2) (Victorian Department of Sustainability and Environment 2008; GHD 2009). This has been supported by on-ground inundation observations to estimate flows required to inundate selected vegetation communities.

Figure 2.4 Flows required to inundate selected vegetation communities within Barmah–Millewa Forest (MDBA analysis of data in Water Technology 2009b; Victorian Department of Sustainability and Environment 2008; GHD 2009. Figure 10.2.)



Environmental water requirements set out in Table 2.8 [Table 10.5 of their report] represents an amalgam of [some] information within existing literature and vegetation inundation hydrodynamic modelling data, checked against analysis of modelled without development and current arrangements flow data. Where a discrepancy exists between literature and inundation modelling and hydrology modelling, analysis of modelled without development flows has been used to guide determination of environmental water requirements, particularly to ensure the recommended flows are achievable and not greater than without development flows.

The implications of this are discussed in Sections 3 & 6.

The water needs of colonial nesting waterbirds within Barmah–Millewa Forest have been informed by analysis of the relationship between breeding attempts by colonial nesting birds at Barmah–Millewa and flow thresholds (Overton et al. 2009).

MDBA analysis of modelled without development flow data shows that flows of 15,000 ML/d for five months duration are regularly associated with higher flow peaks (> 30,000 ML/d) of shorter duration. These flow peaks are likely to be important for successful waterbird breeding by providing a shifting spatial and temporal mosaic of wetland inundation patterns (Overton et al. 2009) and the healthy and productive foraging and nesting habitat.

The MDBA Assessment noted that Table 10.5 should be read in its entirety to understand the environmental water requirements of Barmah–Millewa Forest. Multiple flow rules will contribute to achieving each target. Therefore, while particular flow thresholds and durations may have been specified for particular targets, these should be read in combination with other recommendations as part of a broader flow regime.

Hands on experience over many decades show that, in reality, it is not possible to apply this modelled data without extensive field verification when it is so far divorced from the actual dynamics/variability in streamflow and consequent forest and wetland flood regimes. [See discussion on Barmah-Millewa water requirements and Section 3.]

Table 2.8 Environmental water requirements for Barmah–Millewa Forest
Table 10.5 Assessing environmental water requirements: Chapter 10 – Barmah–Millewa Forest. July 2010.

Target	Event			Proportion of years event required to achieve target		Proportion of years event occurred under modelled—without development conditions	Proportion c years even occurred under modelled—current arrangemen conditions
	Flow required (measured at Yarrawonga)	Duration#	Timing	Low uncertainty	High uncertainty		
Maintain 100% of the current extent of freshwater meadows or shallow freshwater marshes in good condition.	12,500 ML/d	10 weeks total (with 7 day minimum)	June to November	80%	70%	87%	50%
Maintain 100% of the current extent of moira grass plains in good condition.	16,000 ML/d	14 weeks total (with 7 day minimum)		50%	40%	66%	30%
Maintain 100% of the current extent of red gum forest in good condition.	25,000 ML/d	6 weeks total (with 7 day minimum)		50%	40%	66%	29%
Maintain 100% of the current extent of red gum forest in good condition.	35,000 ML/d	1 month total (with 7 day minimum)	Preferably winter/spring but timing not constrained to reflect that high flows are dependent on occurrence of heavy rainfall and will be largely unregulated events	40%	33%	52%	26%
Maintain 100% of the current extent of red gum woodland in good condition.	50,000 ML/d	3 weeks total (with 7 day minimum)		30%	25%	39%	18%
Maintain 100% of the current extent of black box in good condition.	60,000 ML/d	2 weeks total (with 7 day minimum)		25%	20%	34%	14%
Provide conditions conducive to successful breeding of colonial nesting waterbirds.	15,000 ML/d	5 months total (with 7 day minimum)	June to December	30%	30%	44%	12%

Note#: Duration is expressed both as a total and minimum duration allowing multiple smaller flow events that met the minimum duration criteria to comprise a successful event. Minimum durations are therefore a subset of total duration and should not be read independently. MDBA analysis showed that if a minimum duration is not specified and individual events must meet the total duration criteria, this resulted in a significantly reduced proportion of years.

Discussion - River and Forest Water Regimes for Effective Flooding.
The extent to which current river flow regimes depart from natural flow regimes and consequent differences in frequency, season, and duration of forest flooding have been well documented. Likewise, the flood requirements and tolerance limits to flooding of key species/environments, including durations and frequencies have been broadly specified and reported.

There should be no dispute that large floods in the river are too difficult to re-instate without serious bank erosion, economic damage to floodplain farmers and unacceptable resource penalties to other water users.

The plan adopted by the MDBC from Victoria's Sharing the Murray (1997), wherein only up to 50% of the forest and wetlands would be flooded under storing the EWA [up to 5 years in Hume Reservoir] and specified Tocumwal streamflow, has been exposed as totally inadequate to conserve flood dependent flora and fauna. It does not meet RAMSAR requirements under which the forests and wetlands were originally listed.

The MDBA has foreshadowed substantially upgraded streamflow parameters for environmental water requirements ["effective" flooding] intended to secure comprehensive environmental outcomes.

Given RAMSAR considerations, it could perhaps be argued that colonial water birds should be given top priority from the EWA. Nonetheless, this one component of a complex and interrelated, flood-dependent ecosystem should not receive enhanced flooding conditions greater than that occurring under natural conditions to the detriment of other components of the ecosystem and human wellbeing, as has occurred.

Reid, M.A. and J. Brooks (1998)[26] describe the shortcomings of such a narrow approach in use of an environmental water allocation.

"Elsewhere in the basin, water allocations have followed the trend set in Kerang (Victoria) and have been used to support bird populations. Specifically, stored water is released to prolong inundation of wetlands where bird breeding events have been initiated in response to natural floods. Allocations have been used in this manner for the Macquarie Marshes (Wettin et al. 1994; DLWC 1997), Barmah-Millewa Forest (K. Ward pers. comm. 1997) and the Booligal wetlands (Wettin et al. 1994).

This ad hoc approach can be criticised because, in aiming to support only a small component of the wetland biota, no consideration is made of the full wetland ecosystem. As a consequence, the effect of allocations on the remaining biota may well be neutral or even negative (e.g. Ward 1991). Moreover, there is, as yet, no empirical evidence that increasing the number of young which fledge actually contributes to the maintenance of waterfowl populations in the long-term.

[26] Reid, M.A. and J. Brooks (1998). Measuring the effectiveness of environmental water allocation: recommendations for the implementation of monitoring programs for adaptive hydrological management of floodplain wetlands in the Murray-Darling Basin. Report on Murray-Darling Basin Commission Project R6050. Cooperative Research Centre for Freshwater ecology project C310.

Sid Cowling[27] (pers. comm. 2010) puts waterbird management in the Murray-Darling Basin in perspective.

"Australian waterbirds have evolved in and adapted to an unpredictable environment. Some species, such as some of the ducks, respond to the onset of shallow floods over previously dry land, such as the beds of swamps and lakes. Other ducks breed in the drying out phase of a flood. And colonial nesting birds, such as ibis, egrets and spoonbills, react to relatively stable water levels in mid-flood to provide nest sites over water which are relatively safe from predators. Timing of breeding seems to be related to the provision of optimal feeding conditions for the young. Some species are "dabblers", others are divers, some are filter-feeders, and some rely on the adults bringing in food from nearby floodplains, often up to 20 km and more from the nest sites.

In the vast Murray-Darling Basin it is rare that concurrently there are optimal waterbird breeding and feeding conditions in all the important sites in all four states. Australian waterbirds are not migratory as are those of Europe, Africa, Asia and the Americas. Rather they are nomadic, moving over eastern Australia, and sometimes the whole continent, utilising suitable breeding, feeding and resting environments wherever they might occur.

Nevertheless in nature it is not unusual for breeding attempts to fail. There are many instances of nesting attempts being overtaken by a second flood, or of wetlands drying out more quickly than the breeding cycle timetable. This should not be taken as an opportunity to adopt a "laiss'ez-faire" attitude to the allocation of water to the environment, especially for waterbirds. Rather it emphasises the need for management decisions to optimise the success of breeding at a site.

Such decisions need to recognize the inherent variability in flooding and will not necessarily meet the particular breeding requirements of the majority of species in any one year.

The allocation of scarce water resources needs to take advantage of the basic biology of Australian waterbirds. Rather than endeavouring to supply water to too many sites simultaneously, more effective management is to ensure that sufficient water is supplied to fewer sites to ensure breeding success of a range of species at that site – quality is more important than quantity.

Proper recognition also needs to be given to the role of irrigation areas – the supply system and irrigated farmland – in providing suitable habitat for some waterbirds. A key example is the habit of ibis species feeding on irrigated pasture, provided there are well watered wetlands within 20 km in which this colonial nester can breed.

Some 108 species of Australian birds have been identified as depending upon suitable water regimes in wetlands to complete their life cycle. There is a wealth of information on the breeding, feeding and general habitat requirements of Australian waterbirds, both in the Handbook of Australian, New Zealand and Antarctic Birds – a seven volume work published jointly by Oxford University Press and the Royal Australasian Ornithologists Union, and in the numerous publications by CSIRO, Australian universities and the state wildlife services. Sound management decisions can only be based on scientific research into the biology of the species in question. Otherwise there is the risk that the water allocated for the purpose may not achieve the desired result."

Water efficiency.

[27] Sid Cowling, - Fellow, Royal Australasian Ornithologists Union (RAOU)- formerly OIC, Wildlife Management and Assistant Director (Wildlife), Fisheries and Wildlife Department, Victoria; conducted research into breeding of colonial waterbirds; former Chairman, Research Committee, RAOU; sub-editor and co-editor of Handbook of Australian, New Zealand and Antarctic Birds (OUP).

To date, none of the specifications for effective flooding are explicitly concerned with watering the forest and wetlands efficiently.

Storage and river management are generally of a very high order as demonstrated under severe and prolonged drought conditions. However, apart from a few instances [Banrock Station is a good example] authorities have been slow to implement efficiencies in environmental watering although much fanfare has been given to some cosmetic and highly publicised environmental watering in recent years.

This is in stark contrast to efficiencies in on-farm irrigated agricultural practices progressively implemented since the 1960s. This is not to say that no more improvements need to be done.

Barmah Millewa Water Forest Requirements

Table 2.8 summarises the current MDBA thinking on Barmah Millewa water requirements. Despite the use of a large number of apparent recent references it bears a remarkable resemblance to figures produced by Leitch and Bren in response to questions raised by Maunsell in 1991. A new table (Table 2.9) combining Leitch's recommendations and Bren's flooding flows now follows. It allows flood flows, flood durations, flood regimes and flood frequencies to be readily depicted in the Guide's format.

A spreadsheet analysis (which can be provided if required) allowed flood volumes for the two cases to be compared. The results are summarised below.

Table 2.9. Barmah Millewa Forest: Summary & Comparison of Flood Volumes

Leitch & Bren 1980 - 1990		MDBA 2010		Estimate of Flood Volumes	
Bren Vegetation Associates & some fauna	**Leitch minimum Proportion of Years [%]**	**MDBA's Vegetation Associations**	**MDBA's proportion of Years associated with "no development" [%]**	**Leitch accumulated minimum total flood in GL**	**MDBA Accumulated ideal total flood in GL**
Rush lands	**75**	**Freshwater Meadows**	**87**	**1470**	**875**
Moira grass plains	**100**	**Moira grass plains**	**66**	**1596**	**1218**
Red Gum Forest SQ1	**70**	**Red Gum Forest 1**	**66**	**1737**	**1596**
Red Gum forest SQ2	**50 – 70***	**Red Gum Forest 2**	**52**	**2346**	**1876**
Red Gum Woodland SQ3	**30**	**Red Gum Woodland**	**39**	**2976**	**2191**
Black Box Forest	**0**	**Black Box forest**	**34**	**2976**	**2331**
Aquatic fauna generally	**20**				
Fishes	**35**				
Water birds	**70**				

✷ ≈80% of RRG SQ2 floods naturally in 7 out of 10 years.

To all intents and purposes, the flood flows and their desired annual frequencies for the listed associations are clearly similar. If in addition, the flows and durations from each source are added progressively to form an ideal and complete flood hydrograph, the total flood volumes are also close indicating that the same watering requirements are being described. Leitch suggests a flood volume of 2980 GL would flood all associations while the Guide’s figure is 2330GL. When the “proportion of required years” is incorporated into the analysis to produce an average annual allocation for the Forests, the totals become 1560GL/a for the Leitch and Bren analysis against an annual average 1770GL/a for the Guide. Both results are remarkably similar given that they were apparently prepared independently and invite the question, “why was not a greater reliance placed on the 1980 to 1990 work?”

In 1980 the River Murray Commission looked at a range of options to resolve river regulation and forest management problems in the Tocumwal-Echuca reach of the river. At the time there was not the imperative, now crystallised by excessive diversions and prolonged drought, to pursue a number of options that had the potential to more effectively and efficiently water the flood plain at low river levels downstream of Tocumwal.

In summary, although the MDBA has modelled a set of "effective" streamflow parameters that will satisfy environmental water requirements for the whole forest and wetlands, it has not been demonstrated that:

1. A man-made flooding strategy will be acceptable to riverbank farmers including increasing channel capacity above 25,000 Ml/d for managed flows between Hume Reservoir and Yarrawonga;
2. The loss of irrigation supplies is both equitable and acceptable;
3. The timing triggers for use of the release are meaningful in bird breeding terms;
4. The allocation between overall forest needs and some biological needs is acceptable ;
5. The modelled data adequately reflects the dynamics/variability in real time streamflow and actual forest and wetland flood regimes;
6. The modelling has field tested strategies that will significantly increase "efficient" use of EWAs that are operational friendly in implementation.
7. The models have been extensively verified in operational field trials testing the role of on-river regulators, separately and conjointly, in NSW and Victoria at low river flows.

Section 3. Flood History of the Barmah-Millewa Forest 1895 – 2009.

There is strong interdependence between the river and the floodplain forests. Reservoir management and river and weir regulation have a huge influence on downstream river and floodplain behaviour in all but years of high storage levels and substantially above average rain in the catchments when control options are minimal.

The floodplain which operates as a temporary natural flood control storage in peak flood years also influences downstream regimes when much of the water drains back into the river for re-use.

For these reasons it is important to consider each of the key floodplain forests and wetlands within a particular reach of the river in relation to its natural [pre-development] and current [actual flooding characteristics under current demands for domestic, industrial and irrigated agricultural requirements] flood regimes. Without this knowledge of the past it is impossible to interpret the present or to address the future.

River Murray streamflow downstream of Yarrawonga and Tocumwal [for practical purposes use either gauging station values] is strongly indicative of flooding within the B-MF. It is therefore surprising that neither gauging station appears in the MDBA's list of "hydrologic indicator sites. (See Figure 4.7, Technical Volume)
This submission therefore assumes that this is an oversight that will be corrected in the Draft Plan.

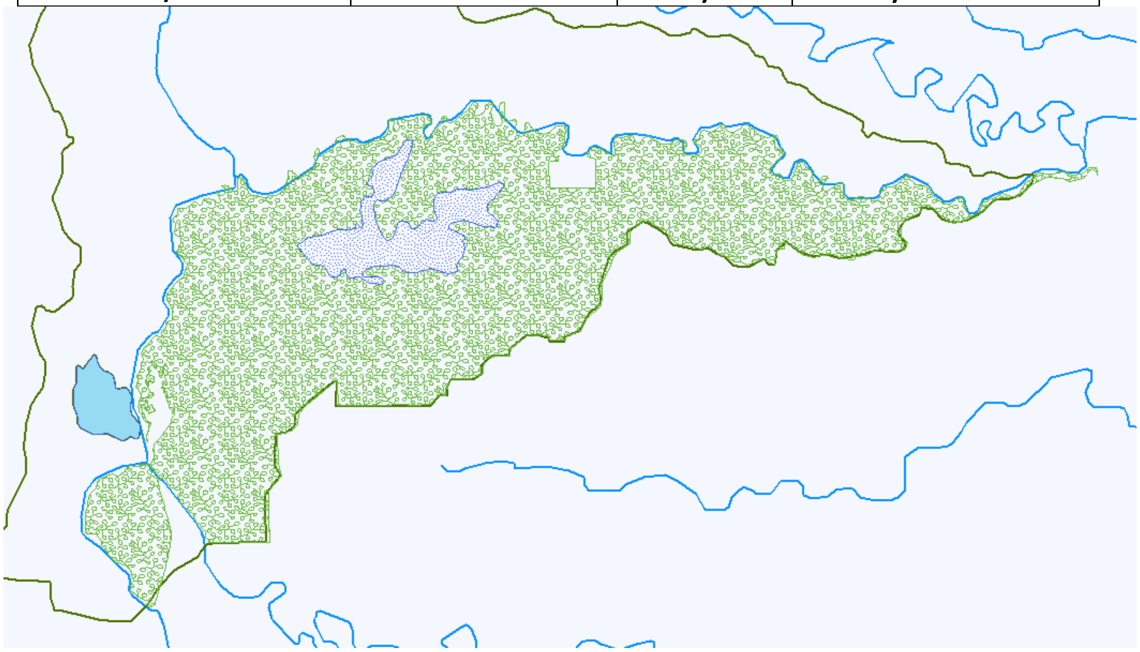
Streamflow history has been described in Section 1 and criteria leading to "effective flooding" of the B-MF in Section 2. Streamflow variability has a huge influence on duration and depth of floodplain flooding and area flooded. River Murray – average monthly flow, Ml/d May-December, Tocumwal gauge, 1895-2009 is given in Appendix 3.1.

This variability is illustrated in an annual series of real time flood maps[28] depicting area of Barmah Forest flooded 1965 – 1987. Extensive field surveys were matched against streamflows at Tocumwal. For example the daily hydrograph, Ml/d, is depicted on the 1965 and 1978 flood maps below.

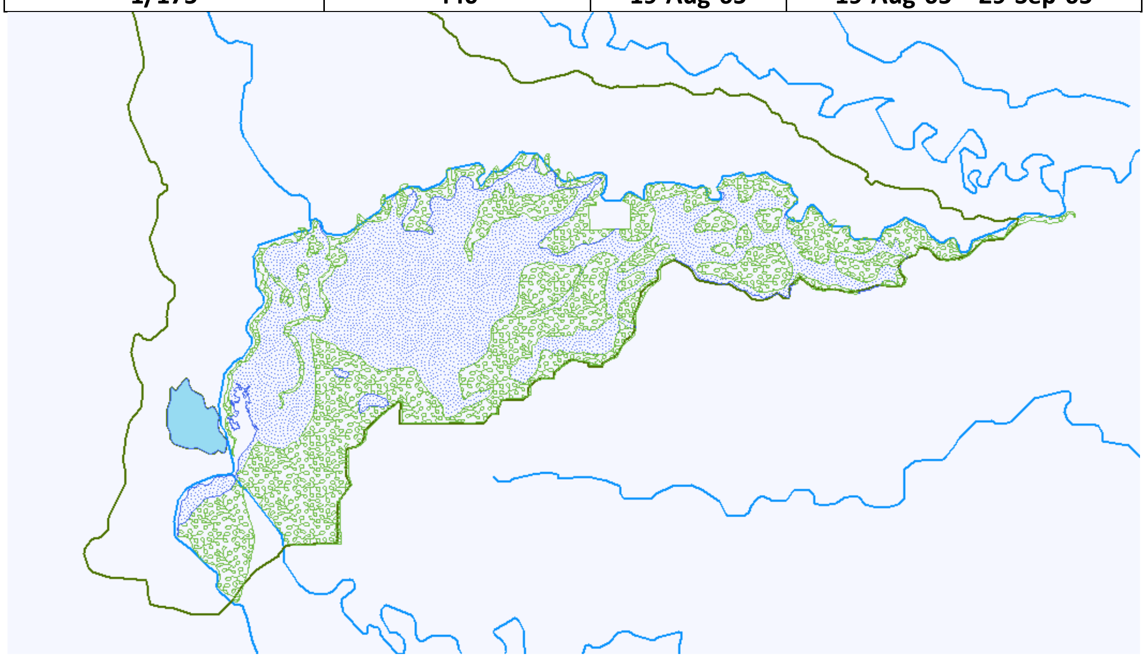
The entire map series is listed in Appendix 3.2 [similar maps are not available for the Millewa Forest] together with flood maps and daily hydrographs for 1966 [3 maps], 1972, 1974, 1976 and 1980.

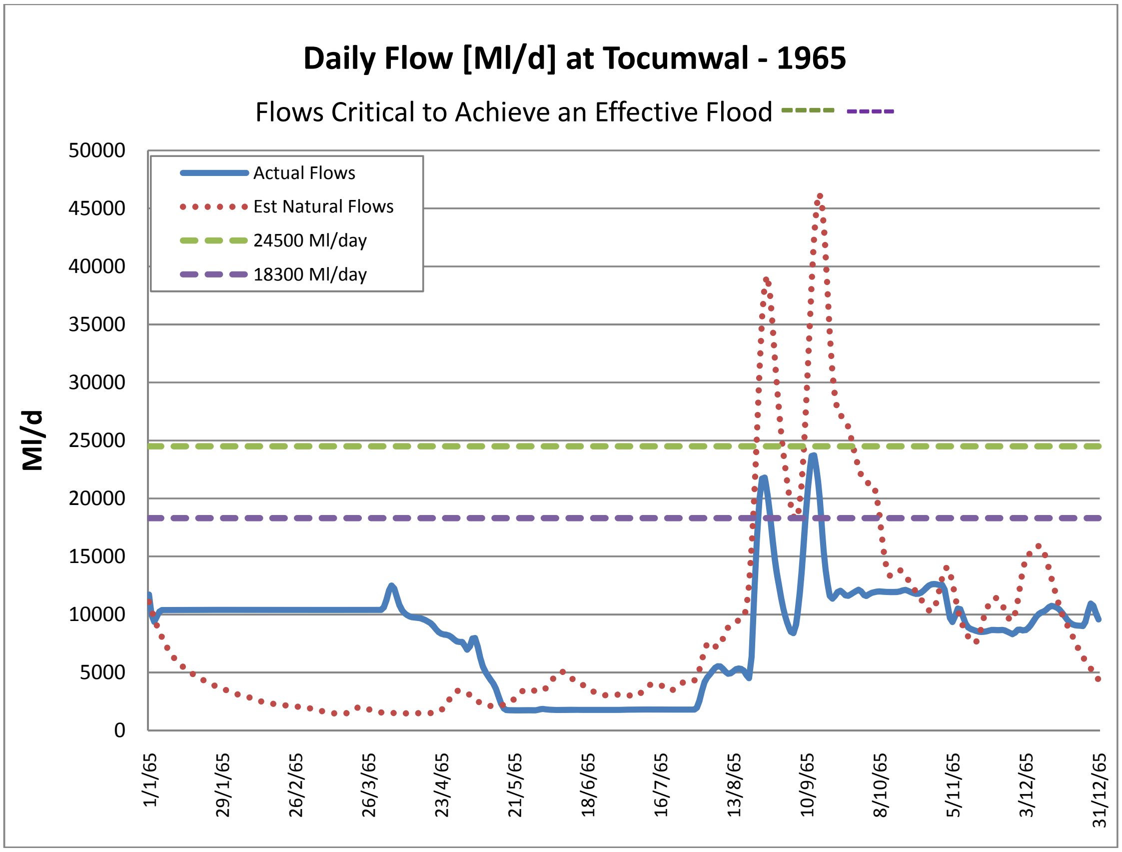
[28] Flood maps Dexter, B. D. (1970) and Forests Commission, Victoria and its successors [unpubl.]. This data was provided by DCNR (DSE) to the GBCMA and MDBC in 2001 as part of the work of the Barmah-Millewa Forum.

Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/216	777	May-65	May-65 – Jun-65



Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/175	440	19-Aug-65	19-Aug-65 – 29-Sep-65



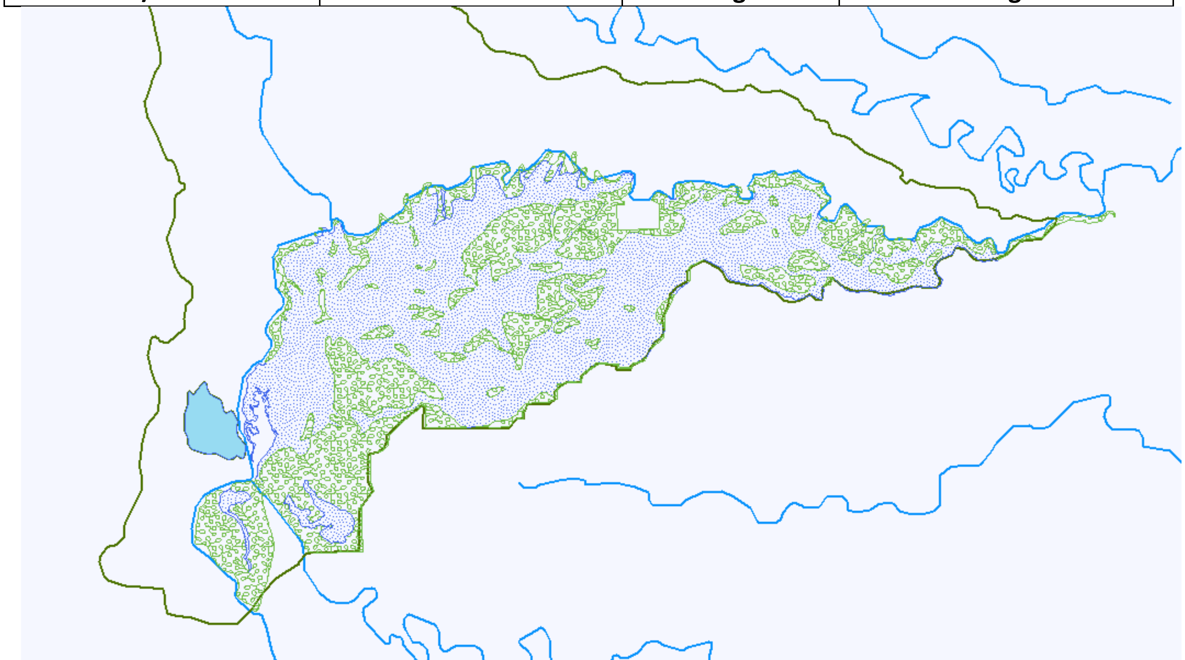


1965

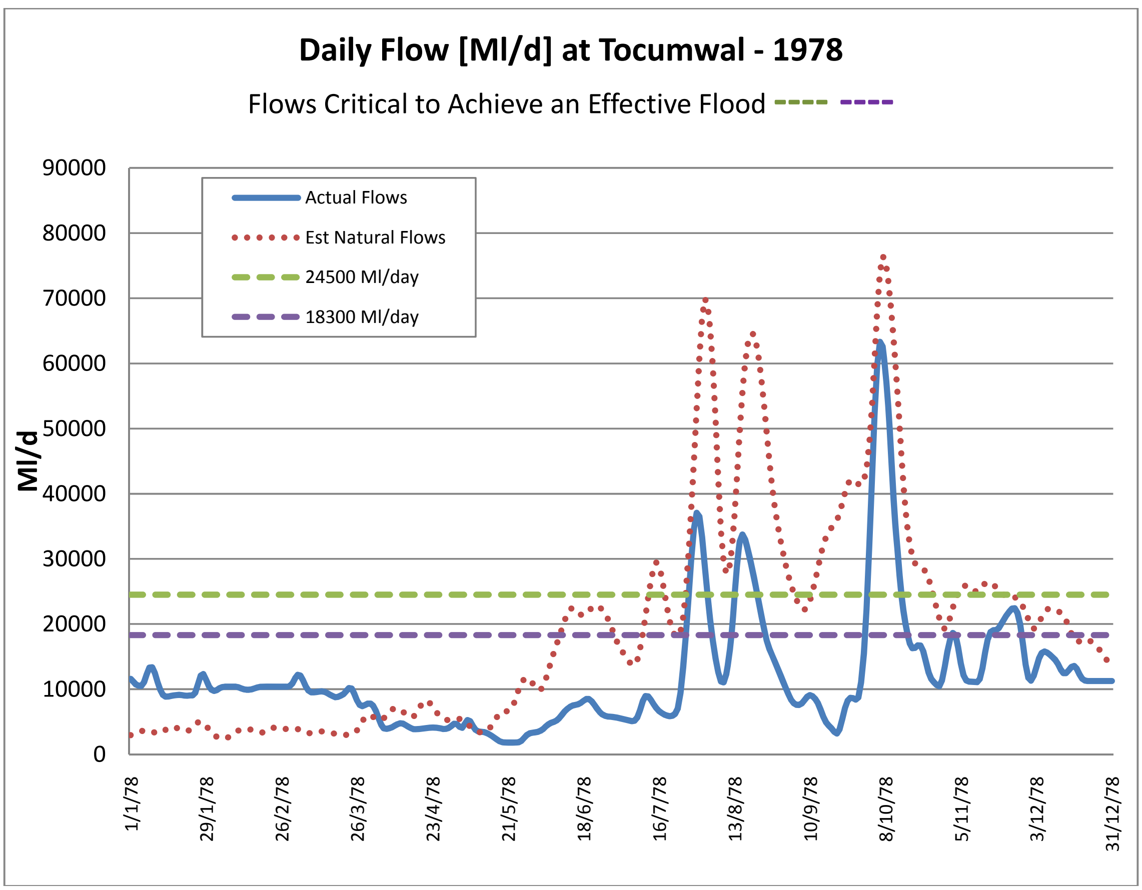
A typical year when storages captured flows in September and November. Pre-wetting of some forest runners and creeks in water management areas WMAs* G and F occurred when Yarrawonga Weir was drained for maintenance work in May/June. This flooded some 1600ha and facilitated initial ingress of the small flood peaks in August and September. Peak monthly flows in the Murray (originating from Ovens River) occurred in August, 5 consecutive days in excess of 18,000 Ml and again in September with 5 consecutive days in excess of 20,000 Ml/d. Although a small average monthly flow, these peak daily flows resulted in the spread of water over nearly half the total forest and wetlands (13,200 ha) but only a third of the river red gum forest. Significant wetlands were variously flooded for about 6 weeks. Some inter-connectivity between wetlands and river was maintained through the major creek systems and flood runners ultimately draining into the Barmah Lakes.

✷ The terms of reference for developing a Water Management Plan for the Barmah-Millewa forest devised by the MDBC in 1989 at the request of the MDB Ministerial Council contained a strong reference to water management areas. They were to represent subdivisions of the B-M forest based on habitat, current watering strategies [including new works and/or new procedures] that might allow deeper and more frequent watering of the forest habitat.

Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/194	773	4-Aug-78	4-Aug-78



Legend		Flooded		Not Flooded



1978

- In 1978 Barmah District forester Robert Paul reported:
- Gulf regulators (X2) being replaced by SR&WSC.
- Heavy rains in NE catchments in late July necessitated opening all regulators except Gulf (construction protected by coffer dams) 24 July 30,000 Ml/day+ below Yarrawonga.
- Flood pattern mapped from aerial & some ground survey in early August showing approximately 17,000 ha flooded (64%).

  Note: This area is inflated with flooding in Goose Swamp originating from the Broken Creek rather than the Murray. The % of forest actually flooded from the Murray flows are probably some 55 – 60%.

- River levels were affected for some 8 km upstream and downstream of Gulf with considerable overbank topping as far upstream as Tongalong Creek.
- Flooding was observed to be more extensive in the Tongalong/Sandspit Creeks area and Stewarts Kitchen/Red Tank area than expected for these flows d/s of Yarrawonga.
- Forest flooding was almost non-existent for some 4 – 5 kms down from Gulf regulator. Inspection revealed that no flood water breeched the coffer dams.
- Further heavy rain led to one Gulf regulator being opened on 17th August.
- Ultimately about 22,000 ha (83%) of Barmah Forest was flooded for 2 – 3 months.

Discussion.
Under the MDBA's Guide and related documents, much of the data on projected streamflow to identify environmental water requirements [EWR] of the B-MF hydrologic indicator site is based on modelling.

EWRs have been specified as daily targets and then aggregated into average monthly flows to predict inundation of major vegetation associations and [potential] bird breeding events.

These models do not adequately reflect the inherent variability in streamflow which has a significant effect on the duration of flooding and flooded area. The MDBA assessment states [*Assessing environmental water requirements: Chapter 10 – Barmah–Millewa Forest*. July 2010] duration of flooding is expressed both as a total and minimum duration allowing for multiple smaller flow events that meet minimum duration criteria to comprise a successful event.

This data cannot be applied in the real world without field verification as it is so far divorced from the actual dynamics/variability in streamflow and consequent forest and wetland flood regimes. It appears to take no account of the extensive reports based on field experience that encapsulates this variability – Section 2 refers.

To be of use to land and water managers Tocumwal streamflow and net (D/S Barmah and Deniliquin) volume of water] required to achieve biological outcomes in B-MF, and returns for re-use downstream, the modelling must be verified against real time data which shows the influence of variable streamflow.

Furthermore, for flows <20,000 Ml/d, field verification must fully explore the potential of individual and combinations of on-river regulator openings, separately and conjointly, in both NSW and Victoria for watering the Barmah and Millewa Forests and wetlands.

There are already rules in place for NSW and Victoria, alternately year to year, taking excess [to capacity of Barmah Choke] rain rejection flows in summer below ≈ 15,000 Ml/d. This allows low lying sections of wetland to dry out as part of the inherent wetting and drying cycle. There have been few serious attempts to do this in winter/spring at low flows to optimise flood regimes in various water management areas within the forests.

The background on forest and wetland flooding described in this section has been used by Dexter [1970], RMC [1980], Chesterfield et al [1984], Dexter et al [1986], Bren [1988], LCC [1986], Leitch [1999] and Maunsell [1992] [1999] [2000] and in the work of the Community Reference Group and its successor the Barmah Millewa Forum [1991 – 2005] but apparently ignored by the MDBA.

Recommendations for action are listed in Section 6.

Section 4. Lessons from the use of the Barmah-Millewa environmental water allocations in 1998, 2000/01, 2005/06 and 2002 managed flows to assist passage of water past the Barmah Choke.

Background – Operating rules for environmental water.
While the so-called water "buy-back" enjoys considerable publicity, little is ever said about how the water may be used. While some tiny "ad hoc" environmental allocations have been made during 2009, no management plan is controlling either the priority or its accounting. The Barmah-Millewa EWA experience has apparently been forgotten. The development of the EWA rules and the related trading and accounting still has important lessons. The following sections outline the history and the current rules.

Barmah-Millewa Environmental Water Allocation
The Barmah-Millewa Forest enjoyed a privileged position in environmental water allocation for many years. It was formalised in August 1993, 17 years ago, by the then Murray Darling Basin Ministerial Council (MDBMC) as is outlined in the following paragraphs. The reference to the Community Reference Group (CRG) is to a forerunner of the Barmah-Millewa Forum, the operation of which is described in Section 5. The Water Management Plan refers to the Maunsell report of July 1991 entitled:

> Maunsell (1992) *Barmah Millewa Forests, Water Management Plan, Final Report*, for the Murray Darling Basin Commission, January 1992.

Environmental Water Allocation by MDBMC, August 1993
At its meeting held on 19 August 1993, the MDBMC:

a) Approved in principle, as part of the Barmah-Millewa Water Management Plan, allocation of 100GL of water per year provided in equal shares by New South Wales and Victoria.

b) In recognition of strong representation from the community, directed the Commission to :
   - Refine management and funding arrangements for implementation of a forest Water Management Plan and appropriate administration arrangements, and
   - Seek community support and ownership for the Plan through the Community Reference Group (CRG).

c) Thanked the CRG for its significant contribution towards the development of a satisfactory forest Water Management Plan.

At the time, this was undoubtedly the most farsighted decision in favour of the environment taken in Australia. The strong encouragement offered to the members of the CRG was also noteworthy.

Surprisingly, the Council did not accept the CRG recommendations on partial flooding of the forest through small scale works, although in connection with water management areas they featured in the terms of reference [ToR], nor the Commission's recommended strategy to set up a Trust to manage the allocation and to trade any unused part to offset government funding.

The MDBC responded quickly as the report from its October 1993 meeting reveals.
Rules for EWA Use, MDBC October 1993

At its meeting on 22 October 1993, the MDBC agreed the first operating rules for the use of the Barmah-Millewa Forest Allocation (MDBC (October 1993).

The rules incorporated a number of features (underlined in the list below) that would become important for the operation of the future Barmah Millewa Forum.

a) For the water supply to the Barmah-Millewa environment
   I. <u>The Forest would be managed as a single unit using a single annual allocation.</u>
   II. <u>Use would be counted as upper states diversions.</u>
   III. <u>Use would be measured at Hume Dam through water ordering procedures.</u>
   IV. System modelling would be used to define property rights and treatment in the assessment procedures.
   V. Use of either rain rejection[29] or off-allocation water would not result in a debt.
   VI. <u>In any water year, use would be cancelled if Hume Reservoir subsequently spills.</u>
   VII. <u>The need for overdraws and underdraws would be tested using system modelling.</u>
   VIII. <u>Procedures for sales of water would be derived and tested using system modelling.</u>

b) <u>The CRG report and the Maunsell report be referred to the relevant state agencies to assist them in the formulation and implementation of a final water management strategy for the Forest.</u>

c) <u>Agency advice would be sought on cross border strategies for arrangements for the future management of the Forest including community involvement.</u>

d) <u>Community consultation would be deferred until advice was furnished as in (b) above.</u>

The use of the original Barmah-Millewa Environmental Water Allocation of 150GL (the original high security 100GL plus an additional general security 25GL provided later from each of the Upper States' environmental resources) (in 1998, 2000/01 and 2005/06) was controlled by a carefully considered set of storage and operational rules whose development following the MDBC decisions.

These rules allowed for sharing the EWA with other users in times of low environmental need and/or widespread seasonal drought. They dealt with river losses and accounting principles which facilitated paybacks to enhance environmental watering.

These rules should be re-visited and applied to other River Murray Icon Sites as the cooperative nature of their sharing between states, identifying key needs, allowing carryovers are likely to be the way of the future.

The rules and their field application during the first, second and third uses are described below.

<u>First Use of the Environmental Water Allocation (EWA), October 1998.</u>

The EWA had been created in 1993. Prompted by the Victorian "Sharing the Murray" report, the questions of loans of the EWA to irrigators, EWA accumulation in wet years and triggers for its use had been debated but not agreed between Victoria and New South Wales.

At the October 1998 meeting of the BMF's Advisory Committee (a sub-committee of the Forum responsible for annual operations) and led very strongly by the Chairman, it was agreed that the

[29] A comprehensive description of unseasonal flooding (rain rejection) can be found in Ladson, A.R. and Chong, J., 2005. *Unseasonal flooding of the Barmah-Millewa Forest.* Proceedings of the Royal Society of Victoria 117(1): 127-137. ISSN 0035-9211.

ecological triggers for EWA use had been met and there was both public and political pressure for a release to be made. Although water availability for NSW irrigators was low, the MDBC approved an initial allocation of 70 GL to add to the recession of an Ovens flood by maintaining a flow of about 16,000 Ml/d downstream of Yarrawonga until exhausted. During October, the water supply situation improved and the allocation was progressively increased to 100GL.

The Victorian approval for use of the EWA was guarded and subject to a number of operational and pilot study conditions (Maunsell 1999). The Forum agreed to closely observe the flood and its effect on the forests and their ecology. The Forum did not set any of the environmental objectives for this first trial use nor were they allowed to contribute to the release rules applied (including the matter of "pulsing" the Yarrawonga release), the matter of downstream credits and the question of the carryover of annual allocations.

The Forum's report on this first EWA use, discussed flooded areas (as observed in the field by Forum members and agency staff), forest health, bird counts, vegetation health, fish breeding, the use of GIS, the application of hydraulic models and other desktop reviews.

The detailed report on this first use of the EWA can be found in Maunsell McIntyre (1999)[30].
The key observations and conclusions from the event were:

- The Ovens flood of September 1998 peaked at 70,000 ML/d at Tocumwal and flooded 47% of the Barmah Forest and 80% of the Millewa Forest [Figure 4.1].
- Use of the EWA extended the tail of the high flow period from 14 to 35 days. The peak environmental release was 17,000 Ml/d [Figure 4.2] and the associated flooded area was only 25% for Barmah and 21% for Millewa Forests [Figure 4.2].
- Despite the short notice, the EWA release was well managed by River Murray Water.
- The trial allowed operating and accounting procedures to be refined.
- A well documented baseline is vital in judging the environmental benefits of the release.
- Bird numbers were thought to be low in the Forest before, during and after the release but high in the surrounding farmland. More research is needed to explain why.
- Although the Moira Grass did flower it was as much to do with the follow on November and January rains.
- Under existing infrastructure, far larger releases (probably 400 to 500GL) would be required to extend the flood period to December in order that say bird breeding events could be completed. To accumulate an EWA of this size, it would be necessary to forego annual releases and use rules such as those in the Victorian "Sharing the Murray" study to store the allocation for a number of years.
- At peak flows of 17,000 Ml/d only the lower levels of the forest are flooded. In the absence of within-forest water management such flows do not provide water to about 80% of red gum forest.

[30] Maunsell McIntyre (1999) Report on the Barmah-Millewa Flood of October 1998 – The First use of the Barmah-Millewa Forest (EWA) Allocation. August 1999. In Murray-Darling Basin Commission records of Barmah-Millewa Forum.

Figure 4.1 Flow Records for October 1998 Flood Event

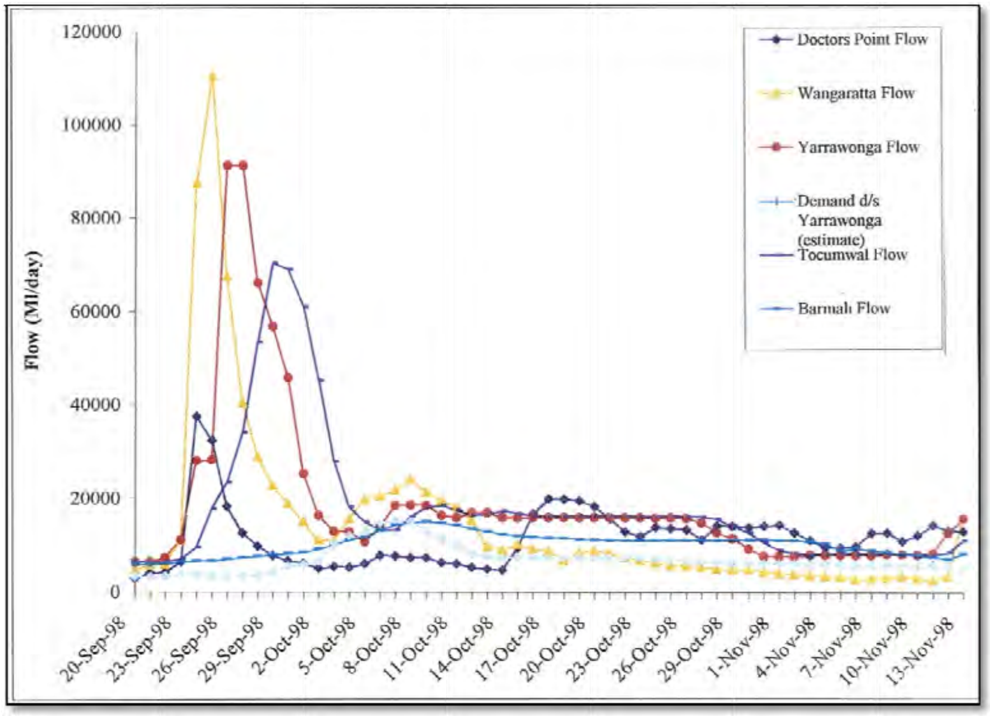
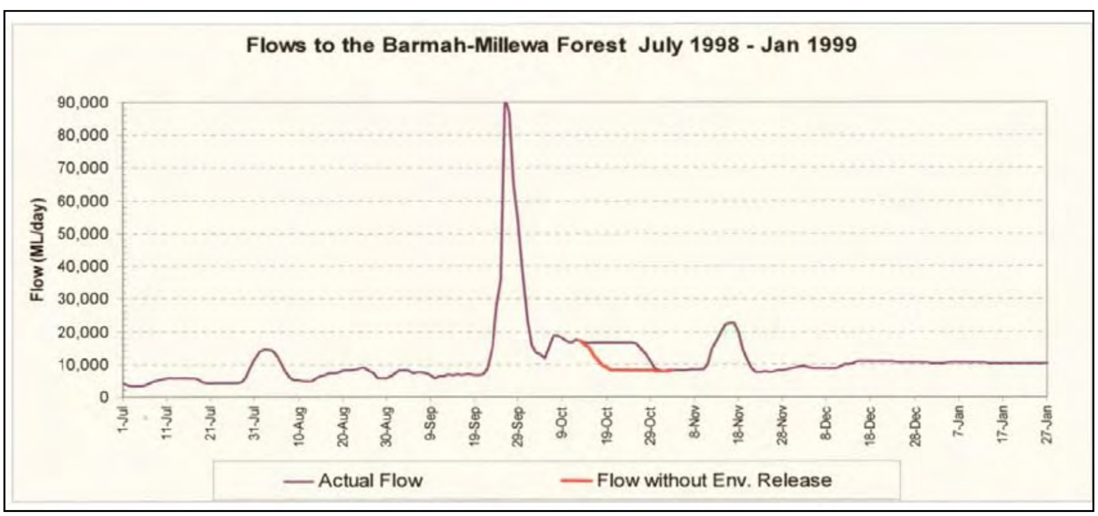


Figure 4.2 First use of the EWA, Spring/Summer 1998



The Barmah-Millewa Forum agreed to:

- Permanent forest transects for better vegetation comparisons.
- Development of the MIKE II Hydraulic Model for flows through the Forests.
- Further study and testing to:
  - better define trigger and operating rules
  - study carryover accounting
  - strike a better balance between forestry, ecological interests and irrigator needs, and
  - take the operating rules from a monthly to a daily timescale.

Second Use of the EWA, Spring/Summer 2000/2001

The Event in Brief
During the Spring and the early Summer of the year 2000 through to January 2001, the Barmah-Millewa Forest enjoyed two major floods and benefited from the second use of the Environmental Water Allocation (EWA). The first flood arose in late September from the Ovens River catchment and when added to Hume pre-releases produced a peak downstream of Yarrawonga of 68,000 ML/d. The second flood came in November from the Hume catchment and resulted in a Yarrawonga peak outflow of 88,000 ML/d. The EWA was used, acting on the advice of the land managers, to slow the recession of both floods. The most significant use took place in December and January when nearly 280 GL of the341 GL used in total was released. Because of borrowings and pay backs by NSW and with Victoria advancing next year's allocation, the resource available became about three times larger than the first EWA use in 1998.

Role of the Forum
Due largely to the rapid change in river flow conditions and the need for quick responses by the water authorities, the Forum was asked to endorse the use of the EWA only after the season had broken in late September 2000. Earlier meetings of the Forum had discussed the (then) low probability of a significant Hume spill. The agreed Annual Plan did however, describe the triggers to apply when setting flows for the spring months should the allocation be used.

The use of the EWA was predicated upon:

- The last "good floods" were in 1992 and 1993 while 1996 was seen as a lesser flood.
- The 1998 flood (when the EWA was first released) was not seen as a significant event.
- A "default release" in the fifth year to break the drought and allow recovery of the ecosystem was suggested.
- There had been a good initial biological response to earlier freshes in the 2000 season.
- There was a large accumulated EWA resource available. Further accumulation could be hindered by lack of storage space in Hume Reservoir.
- Industry could have difficulty in borrowing/paying back EWA accumulated loans.

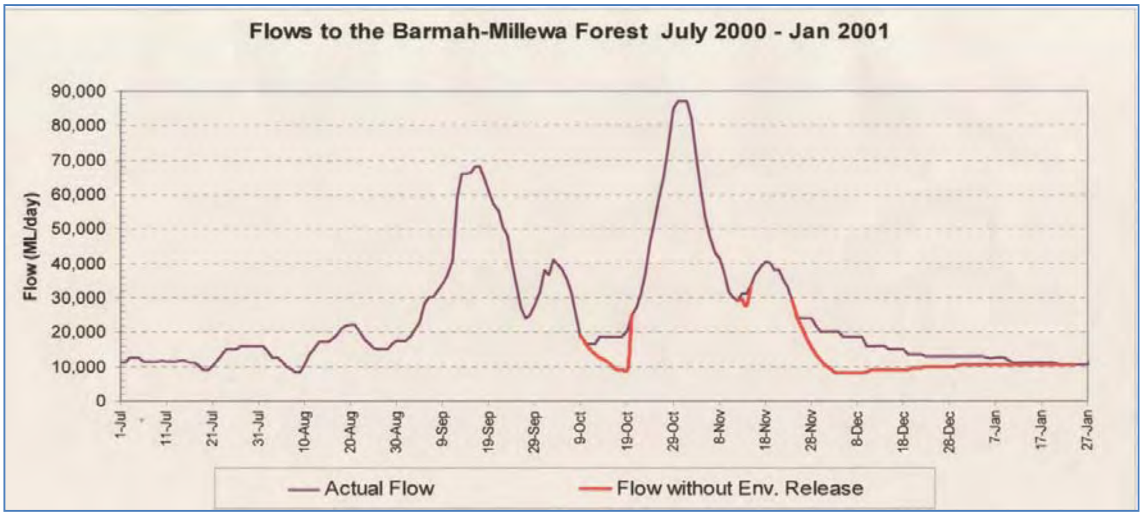
River Murray Water
River Murray Water handled the release of and the accounting for the EWA. The call upon the EWA was based upon the advice of the State Forest of New South Wales (SFNSW) and the Victorian Department of Natural Resources and the Environment (DNRE). The Murray Darling Basin Commission (MDBC) reported details of the release to a wide audience on a weekly basis.

EWA Account
The rules to determine the EWA account had not then been finally agreed and there was some doubt about a number of the entries. . The year 2000/2001 event provided some "food for thought" on the draft / interim rules. For example:

- There was an opportunity (although not taken) to cancel the initial use of the EWA when Hume spilled in November.
- When Victoria borrowed against next year's EWA allocation, the payback requirements have effectively forced the next use of the allocation to the year 2002/03.
- The recent NSW practice of lending the allocation in dry years with strict payback requirements has worked well. The loan cannot spill from Hume and it is thus stored in the most secure place.

River Flows
The EWA release volume needs to be kept in perspective. In total, the flow passing downstream of Yarrawonga from September 2000 to January 2001 inclusive was 4426 GL.

Figure 4.3 Second use of the EWA, Spring/Summer 2000/2001.



The hydrograph shows:

* Two significant flood flows in the Murray River d/s of Yarrawonga Weir;
* Flows peaked in September (68,000 Ml/d) and November (≈92,000 Ml/d), the first originating from the Ovens River catchment, the second from the Hume catchment.
* EWA total of 341,000 Ml worth some $ 409 M ($ 1,200/Ml) was part (7.7%) of the total flow (4,426 GL) passing d/s of Yarrawonga.

The EWA at 341 GL thus represents only 8% of this total. The streams which made the major contributions to this total were:

- Murray at Doctors Point
  (includes Hume releases and Kiewa flows) 4127 GL
- Ovens at Wangaratta 1410 GL
- Goulburn at McCoy's Bridge 862 GL.

Downstream of the Forests, 2478 GL were recorded passing Barmah and 1896 GL passed Deniliquin.

Claims against MDBC following Over-bank Flows
In order to meet coincident high irrigation demands at Yarrawonga and high EWA flows for the Forests, the Murray Darling Basin Commission authorised over-bank flows in the Hume to Yarrawonga reach for some days in late November and early December 2000.
River Murray Water also offered ex-gratia payments to a number of affected landowners.

Flooded Area
Given the scale of the floods, it is not surprising that both Forests recorded flooded areas "as flooded as it gets". The measured figures in November 2000 from aerial photography, field checks and calculated using the MDBC's GIS system were:

- Millewa Forest 33,642ha or 91%
- Barmah Forest 25,680ha or 85%.

The flooded areas were also measured again in January 2001 at the end of the EWA event. The figures were:

- Millewa Forest 3,431ha or 9%
- Barmah Forest 1,871ha or 6%.

For the first time in evaluating EWA coverage, sophisticated aerial photography was used to record the flooded areas. It was taken on 6 December 2000 using colour infra-red film from a height of 7650m.

Comparison with Past Floods

Given the long duration of the 2000/2001 flood and EWA release, comparisons with past floods have principally been done by comparing total flows over the five months. Based on the historic record, the 2000/2001 event was ranked 18 out of the 93 years of record at Tocumwal. This translates to a 20% probability of exceedance or a one year in five event.

Note, however, that the historic record covers a period (1909 to date) over which there was a significant change in the extent of river regulation including the construction of Hume and Dartmouth Reservoirs and Yarrawonga diversion weir.

Matching Flood Recessions

The managed recession from the November 2000 flood closely matched the November recessions recorded in 1924, 1934, 1955 and 1974 and therefore not a common event.

Colonial Water Birds

Colonial water birds bred successfully during the summer of 2000/2001 in the Barmah-Millewa Forest, more so than any time since the mid-1970s. This is especially interesting given that the forests only experienced a moderate sized flood to produce this good result. However, the forest and most of the wetlands had a good drying out period over several years that produced, when the forest was re-flooded, a well enhanced food chain. As well, the environmental flows down the River Murray and later down the Gulpa Creek allowed the wetlands to remain flooded for the duration of breeding and the forests did not experience a significant drop in water levels that has sometimes caused water bird colonies to abandon or to have very low rates of breeding success.

Bird Counts

The long term bird breeding record (33 years out of the past 100 years) developed by David Leslie[31] for his pioneering work on the links between bird breeding and river flows was used to rank the breeding success recorded in 2000/2001. For the Barmah-Millewa Forests, the important tallies were 10 species with more than 10 pairs breeding plus a further five species with less than 10 pairs breeding. When compared with the long term record, the combined total of 15 has only been equalled in 1939. The year 2000 observations thus represent a most exceptional event.

Frogs

The Forum included in this year's Annual Plan, a research project on frogs and appointed Ms Paula Ward to the task. Her reports during the flood and EWA event became wonderful reading and the monitoring results received high peer recognition.

[31] Leslie, DJ 2001, 'Effect of river management on colonially-nesting waterbirds in the Barmah-Millewa forest, south-eastern Australia', *Regulated Rivers: Research and Management*, vol.17, issue 1, pp.21-36.

Planned Forest Transects

The Forum has approved the commissioning of a “Forest Transect Study” and a detailed proposal is under discussion with Associate Professor Leon Bren from the Forestry School at Creswick. The original recommendation was included in the Business Plan Part 1 Study in 1998. The program will likely consist of a series of permanent forest transects in each Water Management Area to record on an annual or quarterly basis:

- Forest health, including stressed areas of forest.
- Understorey changes.
- Extent of recent flooding.
- Coverage by the EWA.

Conclusions

1. The year 2000 flood and EWA volume was a “one in five year” event in terms of the historic flood record. The forest was flooded for about 3.5 months and significant wetlands remained flooded with the aid of the managed flows for a further 1 – 1.5 months.
2. It produced water coverage for Millewa of 91% and Barmah 85% “as flooded as it gets” in both Forests. Flooded areas measured at the end of the EWA event were Millewa 9% and Barmah 6%.
3. When judged against “natural flows” the flood in the forest was late (peaking in November is rare) and at five months duration (including the EWA release), it was quite long.
4. The actual river operations and the release of the EWA marked a major change from the “Sharing the Murray minimum monthly flow” operations to a late season “slowing of the recession”.
5. The slow recession allowed important bird breeding events in Porter’s Plain to be completed.
6. The bird breeding successes could be ranked at least a one year in 10 event in terms of number of species.
7. It would probably rank at one year in 10 event for bird numbers as well.
8. More importantly, because the breeding event reached completion, a large population of birds is now available for future breeding events.
9. The EWA only represented about 8% of the total flow passing Yarrawonga but its timing gave it a far higher importance.
10. The monitoring programs in the forests were comprehensive and well run. In particular, there were worthwhile additions to the data banks for river hydrology, flooded areas, frogs, birds, tree and under-storey health, water quality, water levels and water temperatures.
11. The River Murray Water draft protocols for EWA use proved to be robust and worthy of the Forum’s review and later endorsement.
12. The recent adoption of water accounting rules covering storage and release of the EWA will help clarify accounting principles during the next EWA event.
13. An estimated 78% of the flow was available for re-use downstream.
14. With improved management, it is estimated that less than one third [100GL+] of the EWA would have kept wetlands flooded to meet bird breeding requirements.

Third Use of the EWA: Spring/Summer 2005/2006

2005 Operating Plan for the Barmah-Millewa Forest EWA[32] 10 October 2005
Purpose

1. *The Barmah-Millewa Forest Significant Ecological asset Coordinating Committee met by teleconference on 7 October 2005 and developed the following plan for the use in 2005 of the Barmah-Millewa Forest Environmental Water Allocation [BMF EWA]. This document outlines this plan in further detail to serve as a basis for agreement*

Background

2. *Previous loans from the BMF EWA have now been paid in full and the account currently contains 500 GL [NSW 275GL, Victoria 225 GL].*
3. *It has been 5 years since the Barmah-Millewa forest wetland system experienced a 3 month continuous flood exceeding 15,000 Ml/d. In contrast, four month medium floods at approximately 18,000 Ml/d [i.e. of a similar magnitude to the proposed release pattern] would have been experienced under pre-regulated conditions at least every second year.*
4. *Although some periods of higher flows have occurred since 2000, their duration has been shorter than 1 month and hence there have been limited ecological benefits.*
5. *A continuous low-level base flow, supported by occasional higher flushes from seasonal rainfall in upstream unregulated tributaries and possibly by a Hume Reservoir spill, will provide for considerably improved wetland health and functioning within the Forest.*
6. *The proposed flow release will contribute to satisfying the Living Murray First Step decision ecological objectives for the Barmah-Millewa Significant Ecological Asset.*

Ecological objectives

The 2005 EWA release was aimed at achieving multiple ecological objectives; including providing appropriate flood depth and duration to improve vegetation health, enhancing breeding opportunities and recruitment for native fish and frogs, improving wetland condition and sustaining any waterbird breeding events should they occur.

Unlike previous uses of environmental water at BM Forest, the planned use of the 2005 EWA did not initially include colonial waterbird breeding, as there was doubt that a flood of sufficient size would occur to trigger a waterbird breeding event[33].

The release of accumulated water (≈500 GL) extended the area and duration of flooding to about 55% of the Barmah-Millewa Forest for 2 to 3 months and, later, selected wetlands (9 to 15%) for a further 2 to 3 months. MDBC reported in December 2005 that:

- flooded sections of forest were showing signs of recovery from cumulative drought stress.
- some species of native fish including *Murray Cod* and significant numbers of waterbirds had started breeding and *Moira Grass* was flowering.

Of the estimated flows [Figure 4.4] passing through the forest and wetlands, 89 to 92% of the total flow measured downstream of Yarrawonga Weir was reused benefiting:

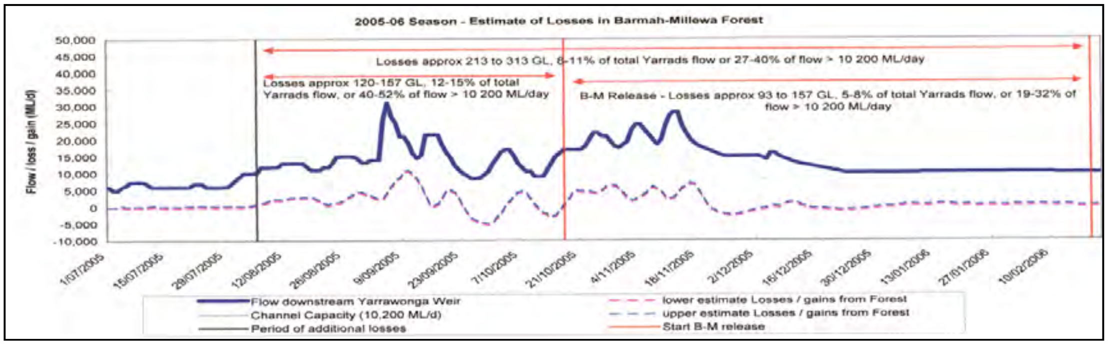
- the downstream River Murray Channel and Murray Mouth

[32] Ward, K. Powerpoint presentation on 2005 EWA usage: Effect of EWA release on Murray River flow downstream of Yarrawonga – 2005/2006

[33] Adaptive management of an environmental watering event to enhance native fish spawning and recruitment A. J. KING*, K. A. WARD†, P. O'CONNOR‡, D. GREEN§ , Z. TONKIN* AND J. MAHONEY*
*Freshwater Ecology, Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Vic., Australia
†Goulburn Broken Catchment Management Authority, Shepparton, Vic., Australia
‡Forest Management, Department of Sustainability and Environment, Tatura, Vic., Australia
§Murray-Darling Basin Commission, Canberra, ACT, Australia

- irrigated agriculture/horticulture
- drought stressed flood plain which had not been flooded for up to 9 years.

Figure 4.4 Third Use of the EWA 2005-06 Season – Estimate of losses in Barmah-Millewa Forest[34]. *Source MDBC.*

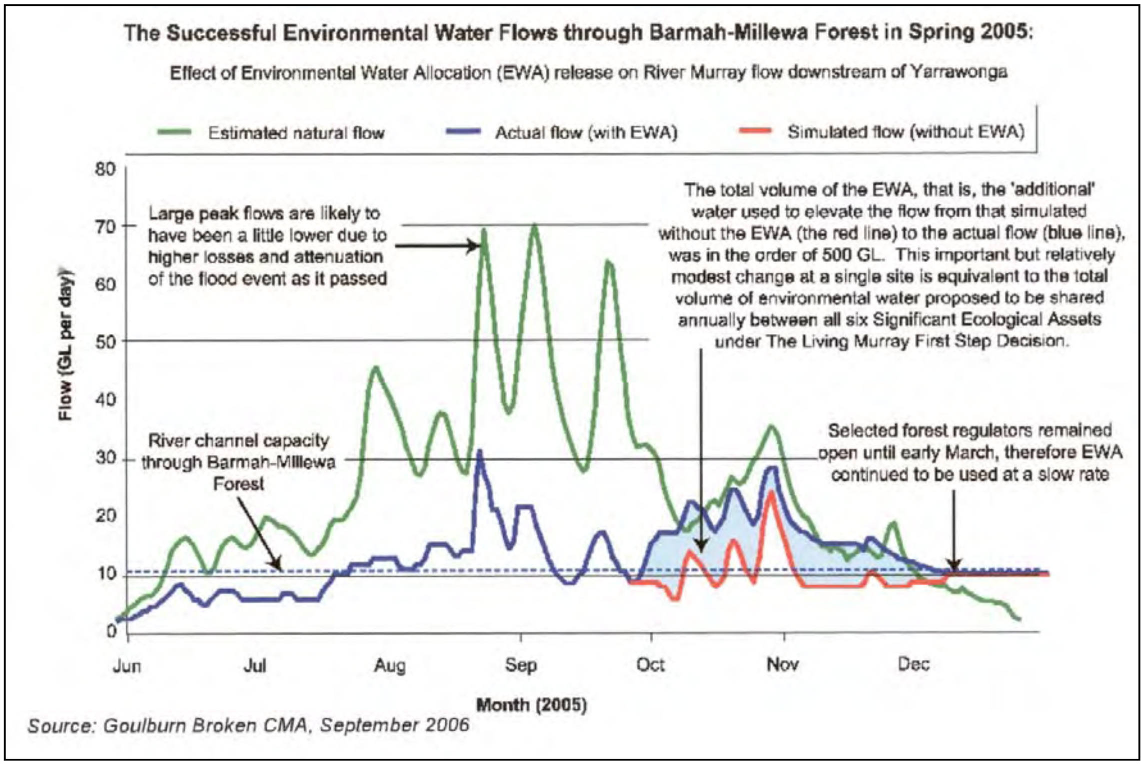


The hydrograph shows:

* Short term flow of 32,000 Ml/d in early September originating from inflows to the Murray from the Kiewa and Ovens Rivers;
* These flows produced an extended period of above channel capacity through the Barmah Choke and also through all on-river regulators which commenced watering the Barmah-Millewa Forest;
* From mid-October progressive release of the EWA from Hume Reservoir maintained flows d/s Yarrawonga >20,000 Ml/d through late October/early November with a peak to approx. 28,000 Ml/d in mid-November;
* Managed flows remained above the Barmah Choke capacity into February maintaining water in some wetlands where bird breeding had been artificially induced later than normal in the breeding cycle;
* From mid-October to mid-December some 480,000 Ml of EWA worth $576m [$1,200/Ml] was used to boost tributary flows to initiate and maintain ecological responses;
* Estimated "losses", August 2005 to mid-February 2006 (initial floodplain absorption, evapo-transpiration, accessions to groundwater, unaccounted) within the channel, forest and wetlands based on differences in flow rates upstream and downstream of the forest estimated in the range 8% - 11% [213 – 313 GL] of total flow d/s of Yarrawonga.

[34] The provision of data on modelled Murray River streamflow and loss estimates by Murray Darling Basin Commission was provided "without prejudice" to the interests of the Commission and River Murray Water. It is also acknowledged that neither the Murray Darling Basin Commission nor River Murray Water has any responsibility in terms of the accuracy, interpretation or use of the data.

Figure 4.5 The Successful Environmental Water Flows through Barmah-Millewa forest in Summer 2005.



Issues 2005

- Inspite of the large volume of the accumulated EWA at best only 55% of the forest and wetlands were flooded.
  - Timing of the EWA release in relation to tributary freshes disadvantaged forest coverage and many biological processes.
- Maintaining river flows above Barmah Choke capacity and very late closure of on-river regulators (Feb 2006) caused unseasonal flooding of low lying areas

Late inducement of bird breeding in some wetlands resulted in significant losses of eggs and newly hatched chicks due to high temperatures.

Photo: Max Moor

* A better environmental outcome would have been achieved with significantly less EWA if flows could have been effectively managed within the forest
* The whole concept of water "losses" needs evaluation. "Losses" were significant gains in forest health and for many flood dependent flora and fauna on up to 55% of the forest and wetlands (35 – 40% of red gums) and for all downstream stakeholders
* Allocation of specific EWAs to individual Living Murray icon sites needs re-evaluating given that:
    - Only a small proportion is utilized within the site: e.g., estimate "losses" mid-October 2005 to mid-February 2006 were in the range 5% - 8% (93 – 157 GL) of total flow d/s Yarrawonga
    - Operating rules, since inception, do not include credit for returns
* Improve accounting of re-use of significant returns (92 – 95%) to the system including quantifying benefits to downstream stakeholders.

SUMMARY: Experience with Use of Barmah-Millewa Forest EWA

- since approval in 1993 the EWA has been used 3 times [a fourth use October 2010 is in progress].

Use of EWA – 1998, 2000/01, 2005/06
Total Volume used ≈ 920 GL: Value - $ 1.1 b [@ $1,200/Ml].

Criteria for Use

* Identify operational issues
* Allow recovery (short term) of ecosystem following cumulative drought stress
* Capitalise on biological responses triggered by high surplus flows
* Extend duration of flooding originating from short term tributary inflows
* Trigger/sustain water bird breeding
* Industry can no longer afford to borrow/ pay back EWA accumulated loans
* Lack of storage space in Hume Reservoir

Key Outcomes

* One year's EWA alone floods only 10% of forest short term
* Extending flooding originating from high surplus flows meets requirements of most flood dependent flora and fauna over large sections of forest and wetlands, including significant bird breeding
* Attempts to flooding by taking advantage of short term tributary inflows with existing infrastructure does not meet requirements of most flood dependent flora and fauna and does not maintain flooding on the bulk of the river red gums
* 78% - 92% of total flow is estimated to drain back into the system and is available for downstream re-use.

Issues

* Current floodplain watering policy and practice, together with greatly reduced community consultation is preventing the trialling of measures that could make effective and efficient use of water and flood larger areas of forest to sustain flood dependent flora and fauna and improve productivity
* EWA not effective unless piggy backed onto managed and surplus flows
* Agricultural and environmental water allocations should be seen as complementary in order to optimise benefits for ALL stakeholders

* Current policy does not mimic natural flooding of this icon site and only gives short term relief from cumulative drought stress
* Current operating rules deny water to 50% + of the forest 65% – 70% of red gums
* Forest health severely affected for long periods
  - sections of forest reach threshold resilience/tipping point due to accumulated drought stress
  - huge reduction in vitality
* Better environmental outcomes can be achieved with much less of EWA – better water management within the forest
* Huge evaporation losses when EWA is used late in the season – high temperatures detrimental to unhatched eggs in nests and young water birds and also many other flora and fauna
* Improve accounting of significant returns and their re-use
* Quantify benefits to all downstream stakeholders.

Conclusions from the Use of the EWA

The 12 year (1993 to 2005) history of the Barmah Millewa Forest EWA shows that agreements on complex environmental water uses can be progressed through an agency/community structure [Described in Section 5].

The basic operating strategy of utilising the EWA to selectively supplement natural floods proved to be sound but, under existing infrastructure, only when added to large floods.

Producing long periods of high flow (as in 2005/2006) was both extravagant in water use and limited in forest flooding. This is an important constraint to be recognised as large quantities of environmental water are accumulated to the detriment of some biota and without any obvious plans for accounting, use and monitoring.

2002 managed flows to assist passage of water past the Barmah Choke.

Flood and vegetation mapping utilizing satellite imagery to determine the extent of surface flooding and of actively growing vegetation was undertaken during October – December 2002 by Abuzar and Ward[35] as a project of the Barmah-Millewa Forum.

Figure 4.6 shows extensive flooding as at 14 December 2002 predominantly in the Barmah Forest as a result of regulators being open during unusual and relatively steady-state flows of 13,000 – 15,000 Ml/d under drought conditions, Figure 4.7[36].

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[35] Abuzar, M. And Ward, K.A. [2003] Flood and vegetation mapping in the Barmah-Millewa Forest during October – December 2002 using remote sensing technology. Report prepared for the Barmah-Millewa Forum Project No. 2003.36. The State of Victoria, Department of Primary Industries. ISBN 1741064805.

[36] Abuzar, M. And Ward, K.A. [2003]

Figure 4.6 Flood Mapping in Barmah-Millewa Forests 14 December 2002[37]

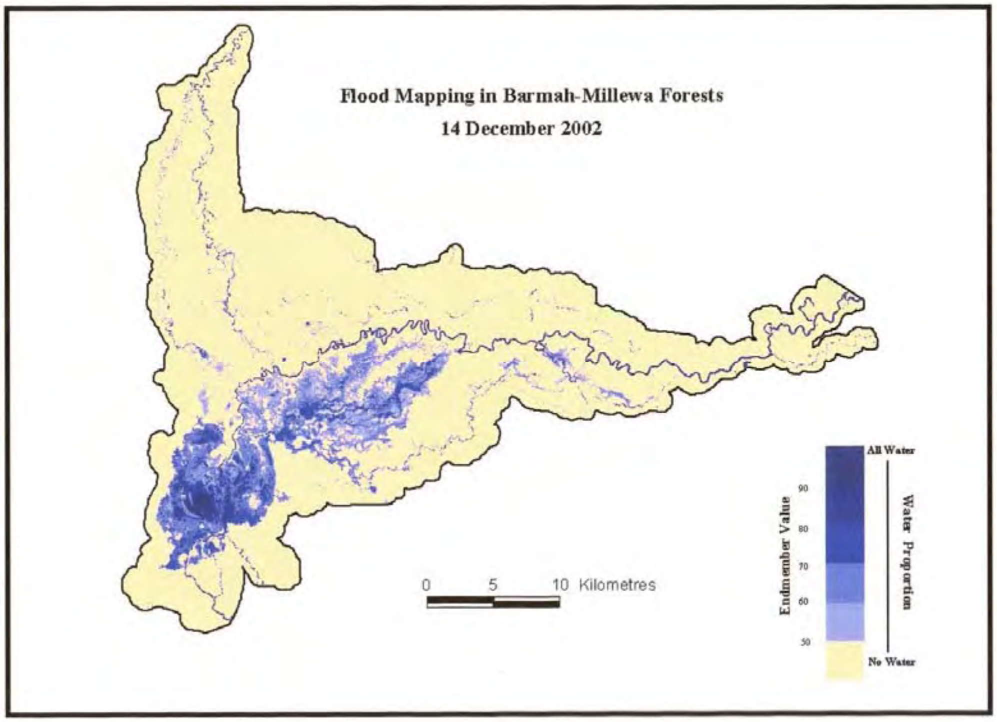
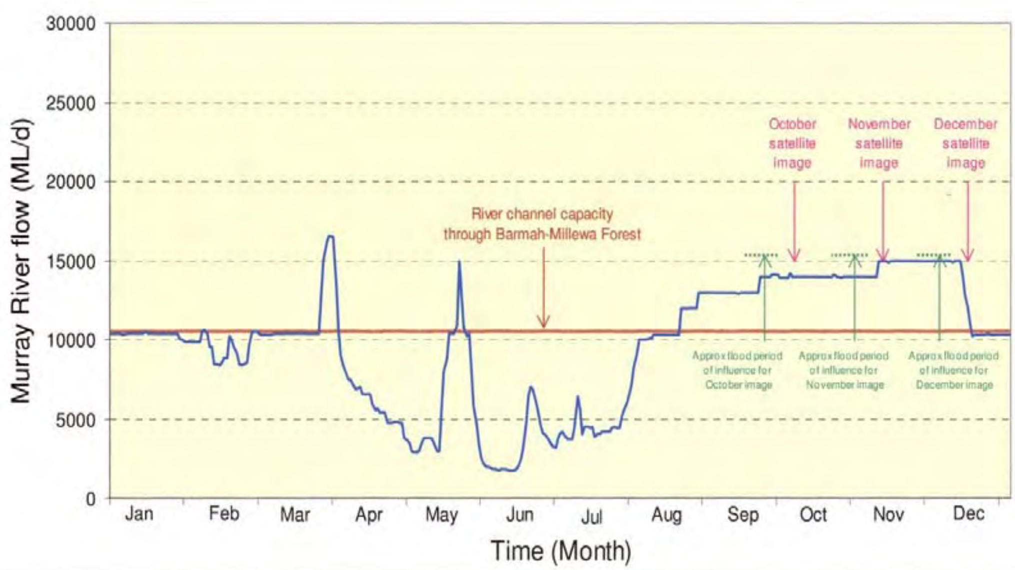


Figure 4.7 Murray River flow downstream of Yarrawonga - 2002[38]



Abuzar and Ward reported that vegetation response was closely correlated with surface flooding being mainly restricted to the river and low lying areas of Barmah Forest in October, compared with two months later in December when active growth was evident in the central region of the

[37] Abuzar, M. And Ward, K.A. [2003]
[38] Abuzar, M. And Ward, K.A. [2003]

Barmah Forest, (Figure 4.6). In addition, O'Connor and Ward [2003][39] reported on a bird breeding event arising from the regulated flows.

KEY POINTS.

- To meet downstream demands, River Murray Water (RMW) passed releases from Lake Hume to Lake Victoria from August to mid-December 2002 using the River Murray and the Gulf Creek system and thereby reducing any impact of the Barmah Choke.

- As had been practiced in earlier years, the Gulf Creek gates and other smaller Barmah Forest regulators were open during low to medium Yarrawonga flows of 13,000 to 15,000 Ml/d. Most of the Millewa Forest regulators were closed.

- Within this operation, just over 2200 Ml/d was diverted into Gulf Creek (and unknown but smaller flows through the other nearby Victorian regulators) to supplement the 10,200 Ml/d passing through the Barmah Choke at Picnic Point.

- Water "loss" estimates are available from RMW but were considered to be low and consistent with river losses in other sections.

- The exercise greatly assisted RMW's river management and helped meet Lake Victoria storage objectives during a drought period. In addition, and at no extra cost a long duration flood was produced in the lower reaches of the Gulf Water Management Area flooding both forest and wetlands and replenishing the lower lakes in the Barmah Forest.

- The existing stream water level recorders provided the necessary flow levels to allow calibration and verification of a hydraulic model of the Gulf Water Management Area

- The exercise highlights the environmental and operational benefits of utilizing existing infrastructure and provides further proof of the rewards available when such events are comprehensively monitored.

- There are a number of other creek systems in both the Barmah (e.g. Smiths Creek) and Millewa (e.g. Tuppal Creek) Forests that are worthy of investigation as carriers that could produce similar forest watering and environmental benefits. This is discussed in Section 6.

[39] O'Connor, P.G. and Ward, K.A. [2003] Waterbird monitoring in Barmah Forest, 2002 – 2003. Department of Sustainability and Environment, DPI. Tatura.

Section 5. The role and effectiveness of community engagement in environmental water planning and land and water management.

Background

The community was active with various authorities in the 1930s because of eroding effluent creeks letting water year round onto the floodplain and drowning thousands of hectares of forest and temporary wetlands. This led to the construction from 1939 [Gulf regulators] of a series of on river bank regulators to stabilize the eroding inlets of key effluent creeks. Threats to the security of flood levees on the private/public land interface were also of on-going concern. Community involvement was significantly stimulated in 1983 when the findings from a River Murray Commission study[40] into forest management and river regulation were released to the public through a community information program.

This involvement continued during Maunsell's 1990/91 *Barmah-Millewa Forest Water Management Plan* (Maunsell (1992))[41] when the response to local meetings, technical briefings and the wide distribution of an *Issues Paper*, encouraged the River Murray Commission to appoint an experienced facilitator and actively seek community involvement in developing a water management strategy (based on the above Plan) and then implementing its provisions.

The community response was both enthusiastic and responsible. Large public meetings (with representatives from over 70 organisations) and strong local leadership allowed formation of a Community Reference Group of nine community interests. By mutual agreement, these interests represented wood and non-wood based forest users, flood mitigation and catchment management, government water and land managers from both NSW and Victoria and private water scheme irrigators, Aboriginals, tourist operators and local government. This Community Reference Group (CRG) was then charged by the (then) Murray Darling Basin Commission to review the Water Management Plan.

The CRG's 1994 report endorsing the Plan was accepted by the Murray Darling Basin Ministerial Council in June 1994 with two exceptions; viz; selected "small-scale works and man-made flood enhancement.

The Barmah-Millewa Forum

The Forum was established according to the Clause 14 provisions of the River Murray Waters Agreement with an organisational structure reflecting the Community Reference Group and Agency membership, its own budget and terms of reference which left the Forum responsible to the Commission for:

- (Item 3.1) Provision of advice on annual operating plans prepared by the State agencies for the management of the forest to ensure that they are:
    - Coordinated between the States
    - Consistent with the Commission's Barmah-Millewa Water Management Strategy and State Agency Management Plans.
    - Effectively and efficiently using the 100GL/annum environmental water allocation granted in 1993.
- (Item 3.2) To monitor and report annually on implementation and effectiveness of the previous year's annual operating plan.

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40 River Murray Commission (1980) River Murray – *Tocumwal to Echuca* – River Regulation and Associated Forest *Management Problems* – Review Report, June 1980.

41 Maunsell Pty Ltd (1992), *Barmah-Millewa Forests, Water Management Plan*, Final Report, December, 1991. ISBN 1 875209 11 5

- (Item 3.3) Establishing appropriate mechanisms to provide information to the community and to facilitate community/agency input.
- (Item 3.4) Provision of advice on matters:
    - Relevant to water management of the Barmah-Millewa Forest.
    - Referred to it by the Commission.

The Forum was in its day highly regarded by at least the executive of the MDBC. They in fact sponsored the production of "*A Short History of Community Involvement in the Barmah-Millewa Forest on the River Murray"*[42] in 2005. It is available on request.

The history describes the organisational highlights and lowlights, the use of the generous MDBC budget for research works, monitoring tasks, promotional activities and administration. Since say 1983, the total expenditure from agency sources (largely MDBC) and, after making some arbitrary (but thought to be low) allowances for the value of the community inputs, is nearly $10 M. Since 1994, a rough distribution amongst Forum activities (based on initial budget allocations rather than expenditure) has been Research 35%, Monitoring 25%, Operations 0.5%, Promotions 2%, Works 30%, and Administration 12%. As many of the results of this program are now being applied to the other River Murray "icon sites", the investment can be seen to be not only sound but also good value for money.

The following narrative describes; Agency achievements and disappointments, community's achievements and disappointments and Forum highlights over 1994 – 2005.

Agency achievements and disappointments
From an agency perspective, the benefits of their involvement in the Forum included:

- When agencies were being downsized, community members often provided important background information and history. In other words, the Forum facilitated a better retention of "corporate history and knowledge".
- Considered reviews of their research projects and forest works from a wide community (and as a bonus, from an independent specialist with international recognition as well) perspective.
- Community members offer additional "eyes and ears" in the forests.
- The regular Forum meetings offered good opportunities for discussions with colleagues and peers from other state agencies as well as the MDBC.
- Better integration of state water management plans. The sharing of "rain rejection" flows, now practised on an alternating seasonal basis would be a good example.
- Ready access to additional works and research funds through the MDBC.

Agency disappointments would include:

- Notionally at least, there were additional approval steps in the use of the EWA.
- Occasionally, publicity on the use of the EWA within the forests must be shared with the Forum.
- All day Forum meetings represent an additional and sometimes unwanted, time demand. This concern was made worse by the number of community members. Perhaps the old Advisory Committee with half the community membership might have been a better model.
- Many of the community comments came from locals with a pre-occupation with perhaps outdated concepts.

[42] Donald Macleod and Barrie Dexter (September 2005*) Barmah- Millewa Forum, A Short History of Community Involvement in the Barmah-Millewa Forest on the River Murray- Community Perspective,* for the Barmah Millewa Forum, September 2005.ISBN 1921038527

- Although their continuing membership had been endorsed twice in recent years by their parent organisation, there still persisted an agency feeling that there was insufficient turnover among community members.
- Little recognition of the Australia wide "Green Revolution" and the need to involve other (and usually new) environmental groups in Forum discussions.

Community Achievements and disappointments

In 2005 and from the Community's perspective, the positive achievements of the Forum were thought to include:

- Further proof that well led and determined community pressure can soften bureaucratic inertia and overcome (in part) entrenched interstate "firewalls". That these frustrations were resolved only by addressing the issues directly to the members of the Ministerial Council is an important observation.
- Community members showed great willingness to consider the forests as a single entity. The regular school bus tours, senior citizen tours, youth Forums, flood mapping assistance always covered both Barmah and Millewa Forests.
- The major technical advances during the Forum era came from community members. The most important was the widespread application of laser altimetry to development digital elevation models not only of the forests but now of much of the near-by Murray Valley.
- The well documented "first and second uses of the EWA and the associated River Murray floods" may become key documents as uses for the increased environmental water allocation in the Murray are debated.
- Community members performed a necessary role in demanding financial and management accountability from the Commission and from agencies on Forum projects.
- Community members also encouraged investment in the Forum's long term monitoring programs (essential for planning future works and for judging ecological changes) as well as high quality annual reporting and annual water management planning.
- Community members led the way in promoting the Forum and its activities to local radio and TV and through the selective sponsorship of forest based events.
- The Forum has provided significant benefits to other icon sites particularly with the results from the Research and Works programs. For example, DEM, hydraulic modelling, low banks and flood monitoring are being applied (at least in part) at downstream icon sites.

The disappointments were:

- Following the President of the Murray Darling Basin Commission's (Dr Green) recommendation for community members to chair and thus lead the Forum's committees, with the exception of Stan Vale's promotion committee and Barrie Dexter's Research Committee, the performance of local community appointees was disappointing.
- The 1994 CRG report strongly endorsed the Maunsell recommendations for selected "small scale works" and man-made flood enhancement preferably when triggered by Ovens floods. While this strategy was also endorsed in 1992 by an ABARE study, the introduction of small scale works has been limited to the recent investigation by Maunsell of possible Low Banks on Gulf Creek. The State Agencies thus appear strongly opposed to intervening (with say engineering works) to spread water more widely through the forest. Strangely, other downstream management groups are applying the technique. As the State Agencies had set very limited watering objectives (only 50% of the forest), this reluctance could perhaps be justified as there is usually insufficient water available for the whole forest with existing infrastructure but more often, sufficient water for 50% of the Forest.
- Similarly, the CRG recommendation to investigate thoroughly the influence of discharges through individual regulators has not yet been attempted other than the recent use of Gulf

Creek to pass water around the Barmah Choke and the watering of Green Swamp and Red Tank.
- The winding–up of the Forum in August 2005.
- There was not sufficient turnover amongst community members particularly in the "green environmental "area. There was considerable debate on this issue tempered by a demonstrable concern that the Forum would be high-jacked by uncompromising radical green activists rather than practising conservationists who were already well represented on the CRG and Forum from both Agencies and community.
- As a group, they may not have developed a good understanding of agency issues and government pressures. For example, the same community members tended to bring up the same issues, meeting after meeting even though explanations had been offered by the agencies.
- The lack of engagement with the local aboriginal people. For much of the Forums existence the Yorta Yorta Native Title claim was being conducted in the High Court. MDBC respected the claim right from the outset, to the extent that when the Yorta Yorta chose not to be represented at the Forum and other community engagement activities, MDBC chose not to directly engage with other interested aboriginal groups in the region. NSW Department of Land and Water Conservation [DLWC] and MDBC facilitated the formation of Murray Lower Darling Rivers Indigenous Nations [MLDRIN] to bring in wider Aboriginal discussion but failed to develop communication between the wider community and aboriginal people on matters effecting Barmah-Millewa. The result was a moratorium on water efficiency works and measures for a period of about ten years, even though there was a budget and suitable projects approved.
- A general reluctance amongst the agencies to share research results and future plans and changes in a meaningful way. Examples would be:
    - There was never a Forum briefing on the MDBC's "Environmental Flows" program.
    - Technical papers prepared by agency based Forum members and observers for conservation and environmental journals were never described or reported to the Forum.
    - A near complete silence on agency funded works and research projects in the Forest.
    - Only after they were completed and released to the public did the Forum receive briefings on "The Living Murray" and "Sharing the Murray".

Forum highlights

The highlights resulting from this expenditure would probably be the Community Reference Group's (CRG) role in achieving MDBMC endorsement of the 1992 Water Management Plan, the Forum's role in the reporting of the environmental effects of the First and Second Use of the EWA, the successful introduction of Digital Elevation Modelling in the Forest; the funding of an integrated program of forest monitoring (covering hydrology, river levels, bird counts, frog programs, forest health and forest changes); encouraging a wide range of research applications (including such firsts as "Firestick Management of Moira Grass Plains", "Video Imagery of Tree Moisture Stress"); the adoption of a forest wide Water Management Strategy (unfortunately now largely ignored) and a Fish Management Strategy; the building of new forest regulators, raising roads and restoring banks; offering informed comment on forest management plans; winning Banksia Awards; developing successful local publicity programs (particularly for radio and TV and amongst local schools); running well documented meetings and producing sound Annual Operating Plans and Annual Reports.

The application of the Forum's work is well illustrated in a series of investigations carried out under the general heading of "MIKE II Hydraulic Model Gulf Water Management Area". These projects included:

1. Evaluation of air borne laser altimetry technology in the Barmah Forest.
2. Development of a Digital Elevation Model of the Gulf WMA. The Gulf WMA was selected for the DEM trial as a 1960's SRWSC "dumpy level and staff" survey existed to allow comparison to the air borne altimetry. The project proved to be wonderfully successful with tree top, understorey and ground levels being confirmed through a DEM of over 3,000,000 points.
3. The DEM and its close contours then became the basis for the first evaluation of low banks to enhance localised flooding. Maunsell [2003][43]
4. The fourth exercise was the development of a hydraulic model of the Gulf WMA which used flow data from the 2002 bypass operation.

This low bank project was a larger scale version of a series of small regulators introduced into the Millewa Forest in the 1970's. The operation of these regulators (which was not necessarily authorised at the time) utilised irrigation rejection flows to water areas of stressed trees. The engineering of the technique was modified in the Water Management Plan (Maunsell January 1992) to address water (particularly "Black Water", the lack of oxygen due to low through flow) quality issues. Joe Murphy[44] of Forestry Commission, NSW, Mathoura introduced the technique.

Low Bank Study Objectives
The object of the Study was to examine the benefits of "Low Banks" within the Gulf WMA to extend the flooded area from small floods and to minimise the use of water resources including the Barmah Millewa EWA.

Project Definition
The Gulf "Low Banks" extended the flooded areas by some thousands of hectares. The water supply was introduced to the WMA through the existing Gulf regulators. The increases in flooded area ranged from 1500ha for a bank 0.2m high to 4200 ha for a 2m bank.

To address environmental issues, a large downstream regulator allowed for both fish passage and through flows to minimise water quality effects and returns to the main stream. In 2003 dollars, the cost of all the banks at about $1000/ha flooded was then regarded as high.

Comparison with Natural Flooding Alternative
As well as developing a series of Low Bank works, the study compared their performance with the "natural flooding" alternative. In these "natural flooding" cases, it was assumed that sufficient water would be introduced through the Gulf Regulators to produce the same flooded area as the Low Bank work.

The Gulf WMA was always one of the better watered areas of the Barmah Forest. Both Bren and Dexter estimated the historic frequency of flooding was 7 years out of 10. Introducing the Low Bank works and /or the "natural flooding" option would allow the flooding frequency to be increased to 10 years out of 10. This increased frequency would produce benefits in terms of increased tree growth as well as allowing the forest to act as a more effective carbon sink.

The Low Bank analysis also investigated the likely value of "other environmental benefits", i.e. other than timber and greenhouse. This assumption was made that the water costs of achieving the same flooded area inferred one measure of environmental benefits.

[43] Maunsell Australia Pty Ltd (January 2003), *Mike 11 Hydraulic Model Gulf Water Management Area, Evaluation of Low Banks for Localised Flooding,* for the Barmah Millewa Forum, January 2003
[44] Murphy A.E. ("Joe") (1990) *Watering Millewa Forest,* page 247 in *The Murray,* editors Norman Mackay and David Eastburn (1990).

Evaluation of Unit Values

A number of relevant comparisons are set out in the following table.

Table 5.1. Comparison of low bank works and natural flooding.

Unit Value	Low Bank Works	Natural Flooding	Ratio Low Bank Works/Natural Flooding
Flood year water use (Ml/a)	18,602	58,032	0.32
Flood year water use per hectare (ML/ha/a)	10	31	0.32
Flood year cost/hectare ($/ha)	837	2,315	2.8
Non-flood year cost/hectare ($/ha)	79	0	Infinite

For non-flood years, the maintenance and capital costs for the Low Bank works continue but the Small Flood alternative does not incur any costs for these years.

The table summary clearly shows the Low Bank works offer superior performance in terms of lower water use and cost effectiveness.

Effect of water costs

As the table shows, the really dominant (at 70%) annual cost in the comparisons is water costs. They were deliberately included because each other water user on the Murray is required to pay not only for the licence to divert (the so-called current water "buy back") but also for the water actually diverted. The same principle has been applied to environmental uses. If water costs are excluded, the unit rates change significantly. The Low bank works costs become $100/ha/a and the Small Flood $24/ha/a.

Figure 5.1 Water proposal to AHD 96.4 Barmah-Millewa Forests Gulf Water Management Area

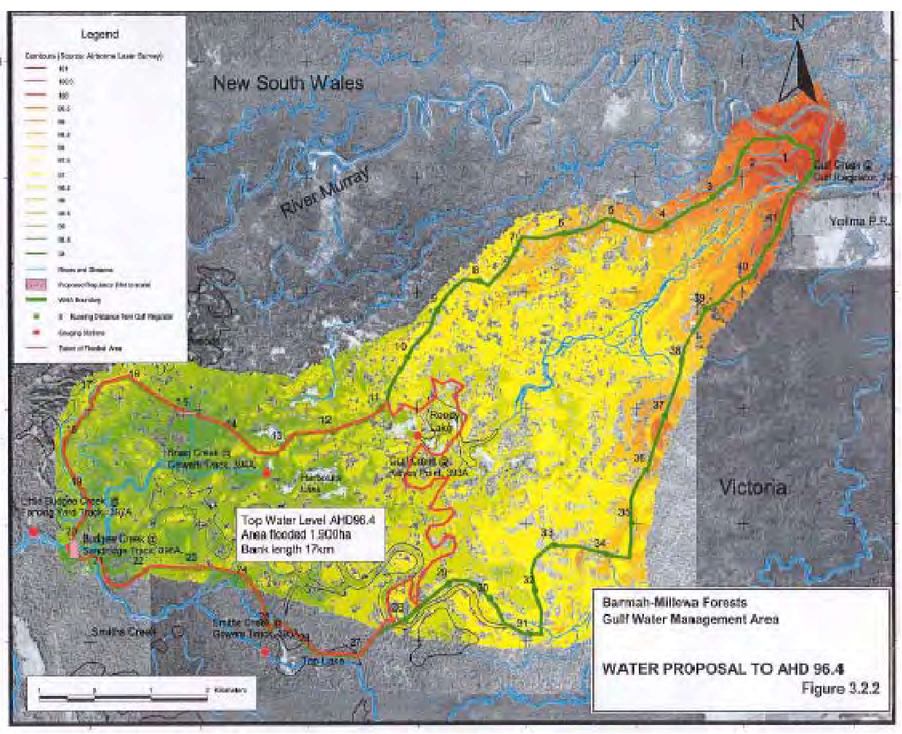


Table 5.2. Water Resources and Cost Comparison and Option Evaluation Preferred Low Bank TWL 96.4 and the Small flood alternative.

Feature		Low Banks Works		Small Floods	
	Unit		**Value**		**Value**
TWL low bank project	RL		96.4	Not applicable	
Flooded area within Gulf WMA	ha		1900		1900
Flooded period	months	2No 15 day shoulders plus 3 months	A,S,O&N		A,S,O&N
Small flood flow	ML/d			Taken as 1,600Ml/d through the Gulf regulators	
COSTS		**All costs in 2003 dollars**			
Capital cost	$1,000		1,874	Not applicable	0
Annual cost	$1,000	Taken as 8% of capital cost	149	Not applicable	0
Operating cost in flood year	$1,000	0.2 person year on a 2.7 multiplier	46	0.2 person year on a 2.7 multiplier	46
WATER USE					
Water to fill	ML/a	Flooded area volume	12,500	Assumed in the 16,000ML/d flow	
Evaporative loss	ML/a	0.47m/a	8,930	Covered in the 16,000ML/d	
Water quality through flow	ML/d	Assumed as 400ML/d	48,360	Covered in the 16,000ML/d	
Estimated returns to the Murray	ML	80% of through flow plus volume to fill	51,188	Assume 70% returns	135,408
Water cost	$1,000		1,395		4,352
FLOOD YEAR COSTS	$1,000	Total	**1,591**	Total	**4,398**

Application to other WMA's

In 2002, the Gulf WMA was the only area that could be analysed as the trial DEM was only available here. The position today is much improved as DEM's are available for not only the whole of the Barmah Millewa Forest but for all other Icon Sites. It is the availability of a DEM that has facilitated investigations for channel location in Koondrook and Perricoota as well as Chowilla.

The 2002 Gulf case is conclusive but had the Low Bank proposals been applied to other WMA's, the comparisons would be improved as:

- The Gulf WMA has a steep creek gradient and the flooded area is therefore lower for similar bank heights.
- As a WMA enjoying a high flood frequency (7 years out of 10), other less endowed WMA's would show a better performance in terms of overall environmental benefit.

As part of this MDBA inquiry, the next step should be to apply the technique to other WMAs in the Barmah-Millewa Forest. The Water Technologies model (2009b) could provide a suitable basis provided new low banks and roads can be incorporated. As for the Gulf case, comparisons could then be made of flooded areas and water use.

Advice could also be sought from environmental consultants on other ecosystem services and the likely EIS/approval process. These aspects were not studied in the Gulf example.

The full report *"Mike II Hydraulic Model – Gulf Water Management Area; Evaluation of Low Banks to Assist Forest Flooding". Barmah Millewa Forum. March 2003. Maunsell Australia Pty Ltd* is provided in Appendix 5.

Vale

The Forum suffered a quick and ignoble death in 2005 although not before the then Chairman of the Murray-Darling Basin Ministerial Council was advised of its contributions and ramifications of its clandestine and contrived demise.

Minister Peter McGauran's response recognised the Forum's contributions and foreshadowed the new approach to community engagement under the Living Murray process. The Minister also reflected in personal conversation it was a pity that he had not seen the report as his departmental briefing varied considerably from the advice he had received from the Acting Chairman of the Forum.

The Hon. Peter McGauran MP
Chairman, Murray-Darling Basin Ministerial Council
Minister for Agriculture, Fisheries and Forestry
Parliament House
CANBERRA ACT 2600.

Dear Minister McGauran,

MURRAY-DARLING BASIN MINISTERIAL COUNCIL MEETING 30TH SEPTEMBER 2005.
AGENDA ITEM – TERMINATION OF THE BARMAH-MILLEWA FORUM.

I write on behalf of community members of the Forum who have received advice from the President of the Murray-Darling Basin Commission that you have already endorsed their release from further Forum duties but that formal termination will be considered at Council's meeting in September.

Minister, this will be a momentous decision for Council with far reaching consequences because:

1. Council had the vision to experiment by setting up a cross-border "Committee" (The Forum) under Clause 14 of the MDB Agreement. Council wisely and deliberately reinforced this fundamental cross-border relationship with the proviso that the Barmah - Millewa Forests in Victoria and New South Wales were to be treated as a single entity for water management purposes. This was further reinforced in 1993 with the provision of a single environmental water allocation of 100 GL, each State contributing 50 GL.
2. The Forum has been one of the most successful committees set up by Council. Spawned from large public meetings, over 70 interested groups nominated 18 representatives who brought an in-depth knowledge on matters critical to the task, particularly of the forests, river, irrigation and natural history.
   The Forum is demonstrably the most effective example of community engagement across State borders with the best record of productive outcomes over a sustained period (1992 – 2005).
3. Total expenditure of some $10 m has generated substantive outcomes with many of the major technical advances coming from community members including:
   * Reporting on environmental effects of the only two uses (1998 & 2000/2001) of the EWA;
   * Successful introduction of digital elevation modelling of sections of the Barmah Forest paving the way for its application over 1.5 million hectares of the southern MDB; and
   * Integrated programs of forest monitoring (hydrology, bird counts, frog populations and forest health).

   It is no exaggeration to say this laid the foundation for applications to other Significant Ecological Assets.
4. A united cross-border community held individual state bureaucracies more accountable to work together to optimise scarce water resources although not without tension at times.
   Successive Chairmen of the MDBMC and Commonwealth Ministers for the Environment championed the community during particularly difficult times and Council has been consistently supportive.
5. Community members recognise the need for change having had a pervious major review. However, there is demonstrable concern that parochial state agencies are already seriously compromising effective within and cross-border community engagement consequent of the process various agencies are employing.

Enclosed is a copy of the executive summary of a review and short history of the Barmah Millewa Forum experience from a community view. Delays in the commission office have prevented the full document from being available to you at this date, and the late presentation of this summary.

On behalf of the community I ask that before Council considers terminating its own brainchild, one which it has strongly supported over a sustained period, Council is made fully aware of the Forum's documented experience. Particularly, the need for a model that will ensure effective cross-border community engagement and achieve what council originally conceived – treating the Barmah-Millewa Significant Ecological Asset as a single entity for water management purposes.
Yours faithfully,

Gordon Ball.
Acting Chairman
Barmah Millewa Forum

THE HON PETER McGAURAN MP
Minister for Agriculture, Fisheries and Forestry

Mr Gordon Ball
Melbergen
MAYRUNG
DENILIQUIN NSW 2710

18 October 2005

Dear Mr Ball

On behalf of the Murray-Darling Basin Ministerial Council I extend my sincere gratitude to past and present members of the Barmah-Millewa Forum for the advice the Forum has provided since 1994.

The Ministerial Council's 'First Step' decision for the Living Murray heralds a new era for the management of the Barmah-Millewa Forest. Community input will be an integral part of the development, implementation and monitoring of plans for the Barmah-Millewa Significant Ecological Asset.

On behalf of the Ministerial Council I thank Forum members for their considerable input in developing a cross-border approach to the management and watering of the forests.

Your efforts at Barmah-Millewa have paved the way for the approach adopted across all of the six Living Murray Significant Ecological Assets. We now look to build on this work across the whole of the river to achieve the Council's vision for the Living Murray of *'..a healthy River Murray system, sustaining communities and preserving unique values.'*

Our approach for the future is outlined in the Environmental Management Plan for the Barmah-Millewa asset, recently released by the Ministerial Council. I encourage you to remain actively involved and contribute your knowledge and experience to the Living Murray process.

Yours sincerely

The Hon. Peter McGauran MP
Chairman, Murray-Darling Basin Ministerial Council

27 OCT 2005

Parliament House Canberra ACT 2600 Telephone 02 6277 7520 Facsimile 02 6273 4120

Community engagement post 2005.

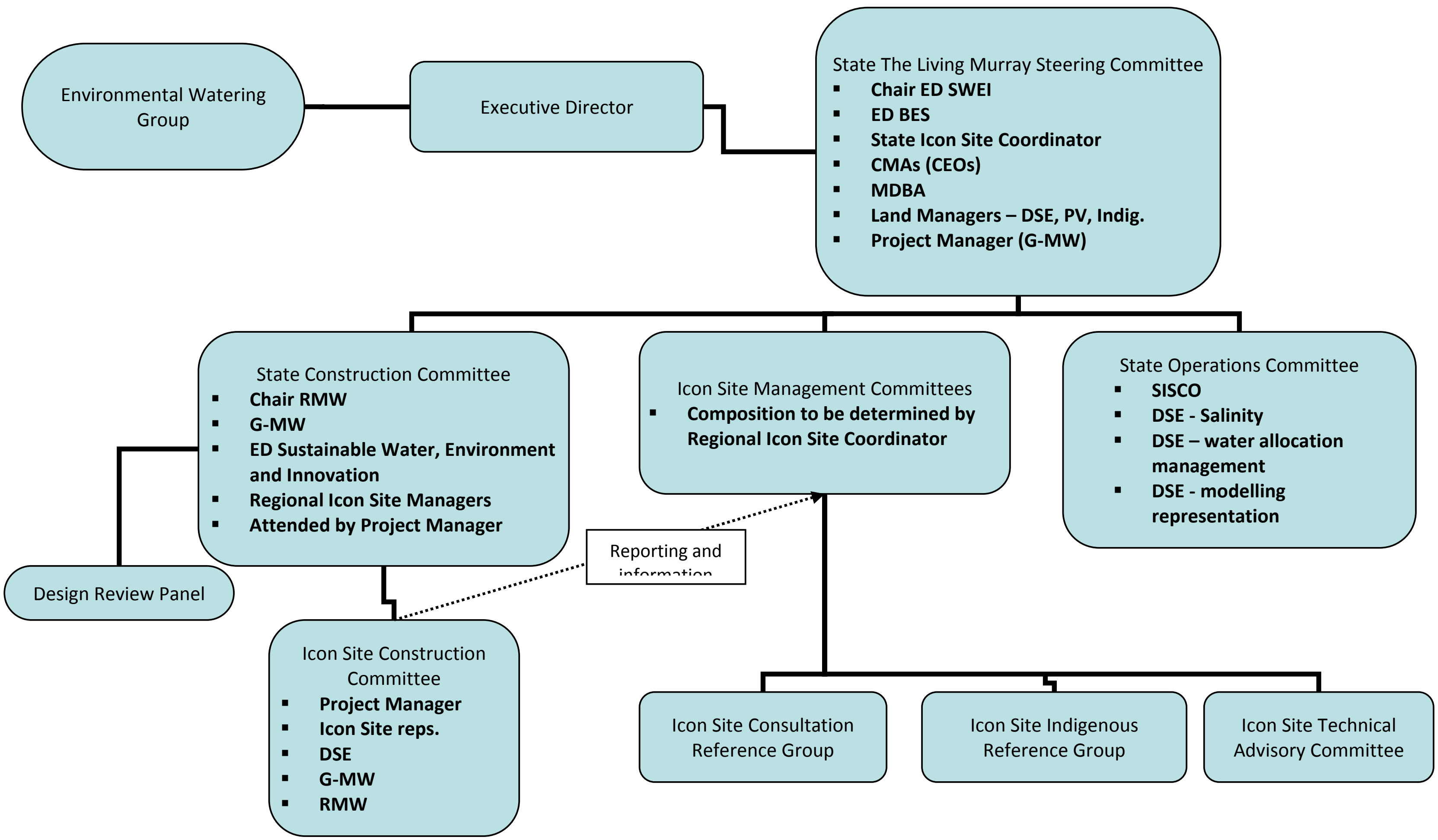
To compare where the community now fits into the grand scheme of environmental management planning post 2005 it is necessary to understand The Living Murray [TLM] project management structure for Victoria and New South Wales.

Within this structure the plethora of Agencies responsible for the management of land and water resources relevant to Barmah-Millewa Icon Site in Victoria and New South Wales is shown in Figure 5.2.

For further "enlightenment", the following is extracted from the Barmah-Millewa Forest Icon Site Environmental Management Plan 2006 - 2007[45].

[45] The Barmah-Millewa Forest Icon Site Environmental Management Plan 2006-2007
MDBC Publication No. 30/06 ISBN 1 921038 96 9

Figure 5.2 The Living Murray [TLM] project management structure – Victoria.

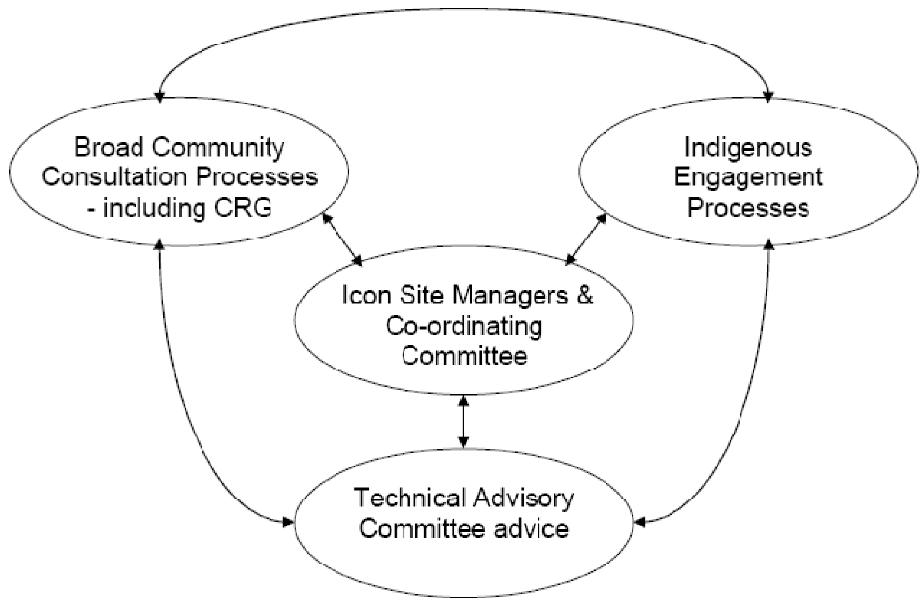


Cross-border water management arrangements

At the Barmah-Millewa Icon Site, state-nominated Icon Site managers will facilitate implementation of this Icon Site EMP under the Living Murray Business Plan through a cross-border **Co-ordinating Committee (CC)**, to which a **Technical Advisory Committee (TAC)** and **Consultation Reference Group (CRG)** will report.

The relationships of the above groups within broader engagement and consultation processes are shown in Figure 5.3 and descriptions of arrangements surrounding the groups are outlined below.

Figure 5.3. Cross-border Barmah-Millewa Icon Site groups and processes



NB. While The Living Murray provides a framework for water management within the Icon Site, overall management of each component remains the responsibility of the jurisdictions through their land management agencies (i.e. Department of Sustainability and Environment, Parks Victoria and Forests NSW).

Icon Site managers

Under The Living Murray, state-nominated Icon Site managers are responsible for the development and implementation of a co-ordinated Icon Site EMP designed to deliver recovered environmental water to the Icon Site in order to achieve ecological objectives set for the site. They are also responsible for carrying out consultation in a co-ordinated manner and ensuring Indigenous engagement is carried out in a manner that respects jurisdiction's legislation and other agreements and related processes.

The role of Lead Icon Site Manager, which will also be the Chairperson of the Co-ordinating Committee, will be alternated annually between the Icon Site managers. The Victorian Department of Sustainability and Environment will take the lead role in 2006.

Co-ordinating Committee

The main functions of the Barmah-Millewa Co-ordinating Committee include:

- development and implementation of a co-ordinated Icon Site EMP and co-ordinated consultation;
- formulation of Terms of Reference for the Technical Advisory Committee and CRG;

- review of the interim ecological objectives;
- determination of Project Officer activities; and
- providing assistance to the Icon Site managers in reporting requirements to the MDBC.

Membership of the Co-ordinating Committee will consist of representatives from the following organisations:

- Forests NSW (FNSW) – Icon Site Manager;
- NSW Department of Primary Industries;
- Department of Sustainability and Environment (DSE) – Icon Site Manager (Lead in 2006);
- Murray Catchment Management Authority (MCMA) – **CRG chair (2006) alternates annually with GBCMA**;
- Goulburn Broken Catchment Management Authority (GBCMA) – **provides alternate Chair of CRG (2007)**;
- Australian Government Department of the Environment and Heritage (DEH);
- Murray-Darling Basin Commission (MDBC); and
- Department of Infrastructure, Planning and Natural Resources (DNR).

In the long term, it is anticipated that the Co-ordinating Committee (CC) will meet twice each year.
Once in March, which will be the main meeting to review performance of the previous Annual Operating Plan (annual reporting) and to prepare for the upcoming Annual Operating Plan (annual planning); and in October, to provide opportunity for site inspections and discussions around the adaptive management of the environmental water allocations.

Technical Advisory Committee
The main function of the Barmah-Millewa Technical Advisory Committee is to provide technical advice to the CC with respect to the development and implementation of the co-ordinated Icon Site EMP, including advice to ensure appropriate monitoring activities are co-ordinated across the Icon Site.

Membership of the TAC will be based on skills and consist of representatives from the following organisations:

- FNSW;
- DSE;
- Parks Victoria;
- MCMA;
- GBCMA;
- DNR;
- Goulburn Murray Water (GMW);
- MDBC (including River Murray Water); and
- casual corresponding members, such as the NSW Department of Primary Industries (Fisheries), the Murray-Darling Freshwater Research Centre, the Arthur Rylah Institute and others, invited as required.

It is anticipated that the TAC will meet on an as-needs basis, with co-ordination and chairing the responsibility of the Icon Site Manager or their delegate.

Consultation Reference Group
As set out in paragraph 135 of the Living Murray Business Plan, Icon Site managers will establish an inclusive Consultation Reference Group at the Barmah-Millewa Icon Site.

The main functions of the CRG are:

- to provide community advice to the CC with respect to the development and implementation of the co-ordinated Icon Site EMP, and
- to provide advice on consultation with regional and local groups that have an interest in the management of the site.

Membership of the CRG has been determined based on being able to demonstrate the following attributes:

- spiritual, social, economic or environmental connection to the Barmah-Millewa Forest;
- involvement in community groups with an interest in the forest;
- experiences and/or skills in leadership, negotiation, community consultation and communication;

and

- knowledge or experience in water, wetland and/or forest management.

The Goulburn Broken CMA has recommended that Victorian membership be drawn from the Shepparton Irrigation Region Implementation Committee. In addition, the Murray CMA will select up to nine members (based either in Victoria and New South Wales) using an expression of interest process. Indigenous membership is yet to be determined; however consultation with Indigenous communities will occur.

The role of Chairperson of the CRG will be alternated annually between the relevant CMAs. Goulburn Broken CMA will provide the Chairperson in 2006.
It is anticipated that the CRG will meet on an as-needs basis.

Project Officer

A Barmah-Millewa Forest Project Officer is housed by, and reports to, the CMAs, however, their activities are directed by the Icon Site managers. The Project Officer is an ex-officio member of the CC, TAC and CRG and assists the Icon Site managers with planning and implementation of the coordinated Icon Site EMP.

Financial arrangements

The Murray-Darling Basin Commission will provide an annual budget to employ a Project Officer and to plan, implement and report on water management activities undertaken through TLM at the Barmah-Millewa Icon Site.
The Living Murray Environmental Works and Measures Program (EWMP) will be the funding source for works and measures specifically designed to achieve the ecological objectives at Barmah-Millewa (See Part A Section 6 for more information on EMWP activities at the Barmah-Millewa Icon Site).

Roles and Responsibilities for Operating the River Murray System

Operation of the River Murray system is directed by the Murray-Darling Basin Commission's operational arm, River Murray Water (RMW), according to the provisions of the Murray-Darling Basin Agreement and an evolving set of provisions agreed to by the Murray-Darling Basin Commission. This role has its origins with the establishment of the River Murray Commission in 1917.

RMW has responsibility for directing river operations, overseeing Icon Site management and modelling to support operational decisions and policy development. The River Murray system structures include:

- four major storages - Dartmouth and Hume Dams, Menindee Lakes (when under MDBC control) and Lake Victoria;
- Yarrawonga Weir;
- thirteen weirs and locks;
- five barrages located near the river mouth, forming Lakes Alexandrina and Albert; and
- a number of flow regulating structures (**such as Barmah-Millewa Forest regulators**).

With regard to the implementation of environmental management activities in this plan, RMW will:

- provide advice during the development of environmental flow rules and procedures to ensure their operational feasibility;
- provide the system wide context for environmental watering through the Annual Operating Plan for the entire River Murray system (this plan is continually updated to account for changing conditions as the year progresses);
- make operational decisions for River Murray System flow control works (large and small) and issue instructions to the relevant state operating authorities – to do this RMW coordinates River Murray system water management with that of the Snowy Scheme and state managed river systems;
- during 'real time' environmental events
- monitor river levels and flows
- provide forecast flow patterns
- provide advice on the availability of 'surplus' river flows
- issue instructions to flow control structures for the management of flows and river levels including regulator openings in coordination with advice from each Icon Site EMP
- keep operational water and environmental accounts
- oversee a program by state constructing authorities to construct, operate, maintain and renew assets (infrastructure works) on its Assets Register.

System operation is complex given the level of development for consumptive use, the long travel times, location and capacity of both assets and major diverters and channel capacity constraints across the length of the system.

The Water Liaison Committee is the forum through which the partner governments share in making day to day decisions regarding water delivery and water accounting.

Environmental Watering Group

The EWG has agreed to establish clearly defined roles and responsibilities for the management arrangements in this plan and other Icon Site EMPs. However, pending this review, and for specific flow events affecting operation of River Murray system works at specific locations, event management groups will continue to be convened by River Murray Water in co-operation with the River Murray Environmental Management Unit. These groups bring together key representatives of natural resource agencies, catchment management organisations, constructing authorities and community interest groups as necessary to ensure a coordinated response.

Community Engagement

Community engagement in the development, implementation and monitoring of plans, works and actions related to the application of water at the Barmah-Millewa Icon Site will be via two avenues.

The Consultation Reference Group (CRG) will provide community advice to the Coordinating Committee (CC) on ecological objectives, water management and complementary land management activities. The CC has sought advice from the key community leaders on the establishment and terms of reference and operating rules for this group. **For more information on the CRG refer to Consultation Reference Group above.**

In addition, upon advice from the CRG, the CC will facilitate targeted as well as broad community input with people and groups that have an interest in water management within the Icon Site.
A parallel process will be developed that encourages the engagement of Indigenous people in the project (see Section Indigenous Engagement below).

Community Engagement Strategy
Community leaders have provided advice on the principles and processes to be incorporated into a Community Engagement Strategy that will provide strategic direction as well as action plans for ensuring community engagement objectives and priorities are met. The CRG will be responsible for the refinement of the Community Engagement Strategy to ensure engagement mechanisms are appropriate to the target stakeholders and that risks to the overall engagement strategy are minimised.
The strategy will be constantly monitored and reviewed to accommodate community input.

Objectives
Community engagement for the Barmah-Millewa Icon Site will be focused around ensuring:
1. The community is ***informed*** of the context, history, proposed processes, constraints and opportunities for water management in the Barmah-Millewa Forest to enable them to engage actively in debate relating to the water management in the Barmah-Millewa Forest; and,
2. The community has opportunities for ***involvement*** and ***input*** in the development and implementation of the Icon Site EMP, including providing advice on desirable ecological objectives, watering requirements, works and monitoring to ensure community values and knowledge are considered in decision making and accommodated within the Icon Site EMP and actions.

Priorities
Upon discussing drafting of the second Icon Site EMP, the CC decided that there was insufficient time before the second draft is due to The Living Murray Board to allow meaningful consideration. It is intended to review the plan in the next 6 months following a community consultation and awareness program. Immediate attention will also focus on:
- scheduling the inaugural meeting of CRG (September 2006) [twelve months since the Barmah-Millewa Forum was disbanded];
- finalise a model for broad community engagement with community input (Finalise October
- 2006); and
- work with Indigenous communities to develop an agreed approach to engaging Indigenous peoples which respect jurisdiction's legislation and other agreements and related processes while providing an inclusive process (Finalise October 2006).

Indigenous engagement
Icon Site managers and CMAs will work with Indigenous communities to ensure Indigenous people are included in water planning and management at the Barmah-Millewa Icon Site.

Victoria
[Information sourced from DSE & GBCMA 2005]
In Victoria, the Yorta Yorta Cooperative Management Agreement between the Victorian Government and the Yorta Yorta Nations Aboriginal Corporation provides for the establishment

of the Yorta Yorta Joint Body, representing the Yorta Yorta people and the Government of Victoria, to provide advice to the Minister for Environment on the management of a range of designated lands, including the Barmah Forest.

This joint body is to ensure that there is adequate involvement of the Yorta Yorta people in any decisions as to land management and works programs in the forest, on the basis of 'informed consent' by the Yorta Yorta people.

Consultation with the Yorta Yorta people will require a process of presentation and discussion with a range of groups within the Yorta Yorta Nations Aboriginal Corporation, to ensure that all relevant family groups understand the proposals and have the opportunity to provide their views as part of the overall input by the Yorta Yorta people through the joint body.

The Yorta Yorta Cooperative Management Agreement was signed in June 2004. The appointment of Yorta Yorta Joint Body members was completed on 21 November 2005, consisting of five Yorta Yorta representatives and three Government representatives (two individuals from Victorian DSE and one from Parks Victoria). The group is now in operation.

New South Wales

In New South Wales, Indigenous consultation will be undertaken in an inclusive manner through the establishment of an appropriate Indigenous reference group. This process will allow for a broad range of interested parties to be consulted with, as well as allowing the NSW government to fulfil its statutory obligations to consult on land management activities with recognised Local Aboriginal Land Council/s (LALC). The Cummeragunja LALC is the LALC with jurisdiction over the Millewa group of forests.

MDBC TLM Indigenous Partnerships Project

The Living Murray Indigenous Partnerships Project Plan has been approved by The Living Murray Committee to help ensure Indigenous community knowledge, values and perspectives are taken into consideration in the Icon Site EMPs. The TLM Indigenous Partnerships Project provides the principles and outlines the approach for Indigenous engagement with respect to the TLM. A Memorandum of Understanding (MOU) between Murray Lower Darling Rivers Indigenous Nations (MLDRIN) and the MDBC was signed on 23 March 2006 in Albury. This MOU provides for engagement with Traditional Owners along the length of the River Murray and across state boundaries, while being inclusive of formal jurisdictional arrangements.

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Under the year on year alternate chairmanship of the CRG, NSW has generally honoured the new arrangements described above. However, there were occasions when the Goulburn Broken CMA has not turned up to a "cross-border" meeting and has not called a joint meeting when it had the responsibility to do so. At best, any cross-border community engagement has been tokenistic.

In summary, the process-driven bureaucratic arrangements since 2005 are nonsense. They are demonstrably a recipe for obscurantism used as a deliberate tactic to disallow, particularly at a local technical level, any meaningful community input on water and land management.

CONCLUSIONS.

The internal Authority deliberations that preceded the winding up of the Forum in 2005 are not publicly known.

What is known is that today:

- There is a lack of genuine cross-border consultation.
- Any effective community involvement is now vey restricted and, in practice, largely tokenistic under the current objectives of community engagement strategy.
- Recent major land use changes have brought in new land managers who are still developing expertise and are not directly responsible for water management.
- The TLM initiative had a Basin-wide Community Reference Group [CRG] that met on a regular basis, was well resourced and well attended. It brought together people with a good knowledge of Basin issues as well as local environment awareness.
  Although the TLM initiative had a community consultation process for Barmah-Millewa, it did not function effectively. This left the TLM CRG people relying on their own networks to provide the detail required to inform the CRG and MDBC of Barmah-Millewa issues.
  The CRG was disbanded when the MDBA was formed.

The Murray-Darling Basin Plan must set down clear and streamlined arrangements for the management of the Hydrologic Indicator Sites including planning, implementation, monitoring and accountability to the Authority. There must be fully inclusive participation with knowledgeable local community.

The Barmah-Millewa Forum model with its clear terms of reference which embrace all of the complex, convoluted, overlapping current arrangements is a proven standard for developing new effective and efficient arrangements.

The most critical points are governance, responsibility and accountability which must be enshrined in the Murray-Darling Basin Agreement as was the Forum under Clause 14 of the Agreement. Thus far the MDBA has chosen not to take this advice; neither in current practice nor in the Guide to the Plan.

This must be rectified in the Draft Plan.

Section 6. Summary, Conclusions & Recommendations.

In this last section, a series of conclusions are presented from the case study. Their arrangement matches the earlier case study sections. This is followed by a list of recommendations to the Murray-Darling Basin Authority on Barmah-Millewa Forest environmental water management issues to assist the Authority in preparing the Draft Murray-Darling Basin Plan.

Introduction.
The Guide reveals very little of the past scientific, hydrologic, water engineering and community involvement in the Barmah-Millewa Forest. This case study attempts to provide a balance by outlining:

* River Murray streamflow and flooding sequences in the Barmah-Millewa Forest;
* streamflow parameters that govern forest and wetland flooding; and by
* recommending policies and actions to improve the effectiveness and efficiency of flooding to conserve a wide range of flood dependent flora and fauna.

The first conclusions deal with River Murray streamflow record.

Section 1. Streamflow history of the central River Murray Tocumwal gauge 1895 – 2009.
Although both River Murray gauging stations at downstream Yarrawonga and Tocumwal feature prominently in the MDBA's assessment of environmental water requirements for the Barmah Millewa Forest, neither has been thought worthy of inclusion in the long list of hydrologic indicator sites. This is a major oversight in the Guide to the Plan which this case study will necessarily ignore. These gauging stations are fundamental to understanding and setting streamflow parameters for flooding the Barmah-Millewa Forest. The oversight will need to be corrected in the Draft Plan.

The 115 years of records provide not only a listing of historic flows but help form a basis of modelled flows for the now accepted conditions and important of "no development" and "1999 level of development" .

Sufficient work has been done to show that the two flow records are virtually identical and can be interchanged.

Tables in the case study show that when considered in ten year decades, historic average flows have dropped below 80% of average in only 1895-1904 [75%], 1995-2004 [78%] and (5years) 2005-2009 [48%].

Section 2. Central River Murray streamflow parameters for "effective flooding" of the Barmah-Millewa Forest.
Definitions of "effective flooding" attempt to link River Murray flood flows with impacts on vegetation associations. The most basic flooding parameter is the area flooded and this parameter has been related to river flows notably by Dexter and Bren. Unfortunately their work was in the Barmah Forest alone reflecting the strong influence of state boundaries and the different priorities being applied by state water and land managers. Never the less, as their geography and vegetation associations are similar Barmah conclusions can be readily transferred to Millewa.

Dealing first with flooded vegetations, the following table shows the relationship between the then recognized vegetation associations and the required flow at Tocumwal. The table lists both peak daily flows at Tocumwal and the equivalent monthly flow. This observed relationship is an important distinction that appears to have been lost in recent MDBA reporting.

Table 2.1. Barmah Forest – Vegetation Associations and Flooding Flows.

Extract from Maunsell Report 1992 (Working Paper 6), Barmah-Millewa Forests Water Management Plan, Table 4.4, page 48.

Bren coding	Vegetation Association	% of Forest	Cum: %	Peak daily flow at Tocumwal/Average daily flow at Tocumwal (to flood all the association) Ml/d	Equivalent Monthly Flow (GL/m)	Grouped Association for BMFWMP
1.	Rushlands	1.8	1.8	9,750 / 7,830	235	Rushlands
2.	Moira grasses	5.2	7.0	10,870 / 8,400	252	Moira grass
11.	RG regeneration on plains	4.3	11.3	11,900 / 8,900	267	
3.	RG & moira grass	13.8	25.1	15,900 / 10,860	326	SQI
4.	RG & disturbed areas of wallaby grass	1.9	27.0	16,550 /11,160	335	
5.	RG terete culm sedge & grasses	21.7	48.7	26,110 / 15,900	477	SQII
6.	RG terete culm sedge	10.8	59.5	32,760 / 19,200	576	
7.	RG & spike rush	5.7	65.2	36,930 / 21,230	637	
8.	RG & warrego summer grasses	19.4	84.6	55,510 / 30 400	912	
9.	RG & wallaby grasses	2.0	86.6	57,900 / 31,600	948	SQIII
10.	RG & swamp wallaby grasses and brown-black wallaby grass	9.6	96.2	70,830 / 37,960	1,139	
12.	Yellow box & grey box	3.2	99.4			Box
13.	Black box	0.4	99.8			

The table summarises the required river flow for complete flooding, the natural variability of seasonal streamflows has resulted in a number of definitions for first "adequate watering" and then "effective flooding" which take into account the duration of the flooding.

In time order, these definitions were:

1. A study of the **1960 to 1966** floods together with long term local knowledge suggested that a Tocumwal flow of 24,500ML/d for four weeks would (regardless of depth and duration) constitute an "adequate watering" of the productive forest area.
2. **By 1986** (with an extra 16 years of flood records plus research into the Forest's flora and fauna) the "adequate watering" definition was modified to add a further month of recession flows above 18,000ML/d. These flows then met the essential criteria for sustaining tree production and waterbird habitat. Such flows flooded 70 to 80% of Barmah Forest and under no development conditions, averaged eight years out of 10.
3. Although the highest 20% of the forest, mainly small sections of SQII, SQIII red gum woodland and box eucalypt ridges, is not usually flooded by these river flows a value judgment was made that river flows leading to some 70% - 80% of the forest area being flooded for a few months duration 8 years in every 10 years represented an "effective flood".

4. Although not part of the effective flood debate, the MDBCMC in June **1993** approved the allocation of 100GL per year for environmental purposes in the Barmah Millewa Forest. This was the most enlightened decision in favour of the environment ever taken in Australia. The rules controlling the use of the EWA and the history of its use are taken up below in these conclusions.
5. Returning to the question of an effective flood, after a decade of strong growth in irrigation demand and a consequent fall in flooding frequencies led the Victorian authorities in **1997** to introduce a reduced "effective flood". Their floods, which were to satisfy habitat areas for birds, fish and frogs consisted essentially of three months of 500GL/m and a fourth month at 400GL/m. Larger floods were considered too difficult to reinstate and the longest period without flooding was thought to be five years. Later analysis by the Barmah Millewa Forum showed that such floods only reached about 50 % of the forest and actually didn't completely flood any vegetation association. It was clearly a very limited scale of flooding.

Although the Victorian "Sharing the Murray" proposals were under discussion within the MDBC, almost independently, a <u>Barmah-Millewa Forest Water Management Strategy</u> was adopted by the Barmah-Millewa Form in February **1999**, achieved statutory approval through the NSW Murray REP2 process in December 1999, was approved by the Murray-Darling Basin Commission (MDBC) and endorsed by the Murray-Darling Basin Ministerial Council in March **2000.** The Strategy's objectives were broad ranging and required the MDBC to:

- *optimise the use of river flows to enhance water management of the forest environment;*
- *facilitate effective water management by dividing the forest into areas that can be managed independently or semi-independently;*
- *provide, operate and maintain water management works or structures required for economic and effective operation of the Strategy."*

Despite its high level of apparent endorsement and its carefully worded requirements, the Strategy proved to be a "damp squid" because it failed to: (1) provide guidance for the use of the Barmah Millewa Environmental Water Allocation (EWA) and (2) produce agreement on an "effective flood".

Given the Strategy was proving to be inadequate in these respects, in early 2001 the MDBC agreed to a set of operating rules for managing the 100GL EWA. The key outcomes were to achieve on average three medium sized, long duration floods (from September to January) every 10 years.

In 2005 the operating rules were slightly modified but for all practical purposes the key 2001 provisions for streamflow to meet desired hydrological outcomes remained intact. The first uses of the EWA were devoted to the completion of bird breeding events. These uses had strong advocates at the time and allowed spectacular photographs of new chicks to gather publicity. There was little or no serious attention given to such forest concerns as increasing the flooded area and so relieving accumulated drought stress on at least 50% of the forest.

This case study has used specialist advice to point out that any allocation of scarce water resources needs to take advantage of the basic biology of Australian waterbirds. Rather than endeavouring to supply water to too many sites simultaneously, more effective management is to ensure that sufficient water is supplied to fewer sites to ensure breeding success of a range of species at that site – quality is more important than quantity. Waterbirds are nomadic, moving over eastern Australia (and sometimes the whole continent) utilising suitable breeding, feeding and resting environments wherever they might occur.

Between 2005 and 2010, two Barmah-Millewa Icon site Environmental Management Plans have been prepared. The plans contain little reference to earlier activities and have concentrated on expressing key features (particularly vegetation associations) in their own terms. Today, the associations are grouped into five categories and required flood frequencies, flood volumes and durations are presented graphically and in terms of Tocumwal flows in both the Icon Site Plan and the Guide and its supporting volumes. Despite the absence of any old references the current vegetation areas and flooding requirements are almost identical to those credited to Leitch and Bren in the 1990's as the following table shows.

Table 2.9 Barmah-Millewa Forest: Summary & Conclusions

Bren Vegetation Associations	Leitch minimum Proportion of Years [%]	MDBA's Vegetation Associations	MDBA's proportion of Years associated with "no development" [%]	Leitch accumulated minimum total flood in GL	MDBA accumulated ideal total flood in GL
Rush lands	75	Freshwater Meadows	87	1470	875
Moira grass plains	100	Moira grass plains	66	1596	1218
Red Gum Forest SQ1	70	Red Gum Forest 1	66	1737	1596
Red Gum forest SQ2	50	Red Gum Forest 2	52	2346	1876
Red Gum Woodland SQ3	30	Red Gum Woodland	39	2976	2191
Black Box Forest	0	Black Box forest	34	2976	2331
Aquatic fauna generally	20				
Fishes	35				
Water birds	70				

The comparison shows that some vegetation associations (particularly the Red Gum Forest associations) have only been renamed and more importantly, that the required flood volumes is much the same. When the "proportion of required years" is incorporated into the analysis to produce an average annual allocation for the Forests, the average annual totals become 1560GL/a for Leitch and Bren against 1770GL/a for the Guide. Again very similar figures which asks the question, "why was not a greater reliance placed on the 1980/90 work?"

Supporters of the total Barmah-Millewa Forest environment (as opposed to preferencing a single issue) are encouraged that the Victorian (and MDBC) approach of "a 50% flooded forest is adequate" appears to have been abandoned. Furthermore, the recent DSE and the MDBA's Guide's environmental objectives and targets also mark a welcome change back toward the earlier (the year 2000) Barmah Millewa Forest Water Management Strategies. However, the dominance of the Ramsar needs and the unproven assumption that satisfying Ramsar will automatically save the forest requires more work.

As the current rate of accumulation of the Barmah Millewa EWA is at best 300GL/a there is a large gap in resources to be closed.

If it is assumed that about 60% of the average annual flood is returned to the mainstream after ponding in and draining from the Forest, it would represent a "use" of about 500GL/a

[approximately 10Ml/ha. With 18 Icon sites, it is not possible to provide this quantity everywhere so the question remains "how will priorities between Icon sites be determined?"
The last concern to be noted is that even if generous EWA allocations can be identified, their large scale application must be tied (as they generally are at present) to natural floods/surplus flows from either the Murray or Ovens catchments. It is not practical to send large floods (say above 25,000ML/d) to Barmah Millewa from Hume Reservoir.

Section 3. Flood History of the Barmah-Millewa Forest 1895 – 2009.

The flood history of the Barmah-Millewa Forest can be depicted through river flows and through flood maps. Flows provide the longest historic record while flooded area maps are available on the MDBC's GIS for the period 1964 to 1986 through to the three recent uses of the EWA since 1993 [The fourth (2010) use is not reported as it is still in progress] and for the 2002 event when managed flows were passed down Gulf Creek to bypass the Barmah Choke.

This case study has consolidated some unpublished (but held in Agency/Authority files) flood information in terms of River Murray daily flood hydrographs, gate operations within the Forest, flooded areas, vertiplan references to the maps and a commentary on the flood effects including published information on flood dependence of River Red Gum and the recovery of bird numbers.

The recent publication of reports describing the development of a hydrodynamic model of the Murray and flooding the Forests do not appear to have used any of this information nor do they have appeared to have conducted any field confirmation of flooded areas.

Section 4. Lessons from the use of the Barmah-Millewa environmental water allocations in 1998, 2000/01, 2005/06 and 2002 managed flows to assist passage of water past the Barmah Choke.

Flood events in mid 2010 have again shown that the most effective management tool is a large flood from either the Ovens or Murray Rivers. Given a large flood, the effective use of the stored EWA becomes easier, operators for any required gate changes can be arranged and ecologists and foresters to record forest responses can be mobilised.

The same staff have been organised in the past for Barmah Choke bypass events but there appears to be no available resources for such events as:

- The use of individual regulators to water selected Water Management Areas.
- The monitoring and recording of Forest transects.
- The funding and organisation of Forest research work.

While it may yet prove possible to plan individual watering events through the user of the new hydrodynamic model, even this work requires a "champion" as well as field staff to carry out the operation and monitor the results.

Both the Guide and at the MDBA's community gatherings much has been made of the need to use environmental water effectively and efficiently even to the extent of using engineering works. The Forum's "Low Bank Works" identify the potential in this regard but again it will require a "champion" to secure funds from historically reluctant state authorities.

While in the past, water and land managers have traditionally been reluctant to build large works in the Forest, this position is likely to become even more difficult given that national parks are now the land managers. Never the less, it is the only way to substantially mimic frequency, season, area and duration of pre-development flooding and use EWAs much more effectively and efficiently for the majority of flood dependent flora and fauna.

Section 5. The role and effectiveness of community engagement in environmental water planning and land and water management.

The Barmah Millewa Forum (BMF) and its predecessor the Community Reference Group (CRG) was a creation of the then MDBC under the vision of the MDBMC. It enjoyed strong support from MDBC Commissioners with a Deputy Commissioner as Chairmen and was provided with generous financial budgets.

The budgets were devoted to well developed programs in Research, Works, Monitoring, Publicity and Administration. With notional allowances for the input of community members a sum of over $10M was spent in the forests during its short life.

The Case Study text has described the achievements of the Forum from both an Agency and Community member's points of view. For Agency members it served as an additional source of funds, there was sound local advice on works, research projects and the Annual Operating Plans including the use of the EWA, interstate contacts were enhanced and additional local eyes and ears watched over forest assets. Community members led the technical advances particularly the introduction of LIDAR and facilitated local tourist tours for interested groups.

There were, of course, disappointments on both sides. Agency members were concerned at the long time of meetings, they were sometimes critical of the additional reviews of their work, the poor performance of some community members as sub-committee chairs and the lack of adequate turnover amongst community members particularly the slow introduction of "green representatives". Community members' biggest disappointment was obviously the winding up of the Forum but a determined lack of sharing of relevant of agency plans (particularly the Living Murray proposals) was also frustrating.

"A Short History of Community Involvement in the Barmah Millewa Forest on the River Murray", Barmah Millewa Forum, 2005, summarises the creation of the Forum, local support, the supportive review by the MDBC president and offers suggestions for future cross border community groups. Copies are still available on request.

Unfortunately, the Forum's considered advice has been largely ignored. The current management arrangements are charactertised by an impossible management structure, meeting attendance by the new authorities is spasmodic, state leadership is shared on an annual basis and lacks the consistent enthusiasm offered earlier to the Forum by the MDBC and community involvement (while notionally widespread) is tokenistic at best.

By contrast, the Barmah-Millewa Forum model with its clear terms of reference, strong leadership and support from the MDBC offered a new standard in effective and efficient community /authority arrangements.

An overall impression is that the visionary actions of the then MDBMC and MDBC have been frittered away since 2005 under a veil of bureaucratic process exacerbated by Agency turf wars and a marginalization of genuine community engagement.

Over the previous four decades forest and water management issues were refined, essential streamflow parameters for forest flooding confirmed and trials undertaken to improve operational practice, including identifying the need for better use of scarce water resources.

The reason for the significant strides 1990 – 2005 are clear. There was a "champion" with the vision, leadership and authority to set clear terms of reference, provide adequate funding, require diligent oversight of both agencies and the community and carry accountability back to the MDBC and to the MDBMC.

Similarly, new arrangements to be identified in the Draft Basin Plan must deal with governance, responsibility and accountability. All must be enshrined in the Murray-Darling Basin Agreement as was the Forum under Clause 14 of the Agreement. Thus far the MDBA has chosen not to take this advice; neither in current practice nor in the Guide to the Plan.

The potential for more effective and efficient use of scarce water resources has been identified.

The Authority's oft stated interest in engineering works to improve the efficiency of environmental water distribution may yet encourage a further review of Low Bank Works in the Barmah Millewa Forest. Preliminary studies (2003) show a three-fold advantage in water use over natural flooding at costs now seen as modest. Their use is now being adopted at other River Murray locations principally in South Australia.

Minister Burke is also on record (14 Sept 2010)[46]: *"I want to drive environmental efficiencies as hard as I can."* The Minister recognizes the need for a variety of measures that must involve infrastructure improvement. *"I am not only talking about irrigation. I want us to drive as hard as possible how smart we can be in management of our environmental assets."*

"Many of the wetlands along the Murray Darling Basin are not used to being constantly inundated with water. They don't need to be and nature never offered that to them. So with different engineering works, the possible uses of weirs and pumping mechanisms, I want to find out how we can deliver the environmental outcome with less water as well."

Does the Barmah-Millewa Forest have a new "champion"?

Recommendations.

Arising from this Case Study, a number of recommendations are made to the Murray Darling Basin Authority for inclusion under the Barmah Millewa Forest heading in the Draft Plan. It is recommended that:

1. Your researchers be encouraged to consider reference material on vegetation associations, water needs and flooding frequencies from the 1980's and 1990's.
2. An "effective flood" for the Barmah Millewa Forest should reach at least 80% of the forested area.
3. While the frequency of such floods in the future is unknown at this stage of Basin Plan development, targeting at least the Leitch minimum frequencies is encouraged.
4. The long term River Murray gauging stations at downstream Yarrawonga and/or Tocumwal be immediately added to the list of hydrologic indicator sites. Without them, water management in the Barmah Millewa Forest is impossible.

[46] The Hon Tony Burke MP, Minister for Sustainability, Environment, Water, Population and Communities. *Murray Darling Basin Plan.* Address to meeting of Councils within the Murray Darling Basin. 14 September 2010.

5. Research work to show that satisfying RAMSAR requirements under which the forests were originally listed will automatically satisfy other environmental needs in the Forest be urgently undertaken.
6. The Barmah Millewa EWA allocation, storage, release and trading rules be re-examined as a successful model when the Authority attempts to allocate environmental water between many competing sites.
7. The successful Barmah Millewa Forum model be re-considered as a cross border community/authority model.
8. This re-examination must include the provision of adequate funding particularly for research in the forest, monitoring of forest health and watering operations.
9. Inherent in recommendation 6 is the requirement that the Authority resumes its earlier dominant role in the water management of the Forest.
10. Modellers be encouraged to review the long series of detailed Barmah Forest flood maps (available in the MDBA's GIS system) for further model verification and later field testing.
11. Rather than blanket testing under steady (but unlikely) flood flows, the GBCMA model be used to investigate the watering of selected WMA's by the operation of individual regulators.
12. These investigations must then be field checked with staff from the new (but inexperienced water operations) land managers.
13. Further investigations be undertaken on the application of low bank works throughout the forest to effectively and efficiently water selected water management areas.

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Appendixes

APPENDIX I

The Barmah–Millewa Forest has been identified as a hydrologic indicator site in the Murray–Darling Basin by meeting all five of the MDBA's key environmental asset criteria (Table 10.1).

Table 10.1: MDBA key asset criteria met by the Barmah–Millewa Forest.

Criterion number	Description	Values
1	The asset is recognised in and/or is capable of supporting species listed in international agreements.	Barmah–Millewa Forest is formally recognised in, or is capable of supporting species listed in the Japan–Australia Migatory Bird Agreement (JAMBA), the China–Australia Migratory Bird Agreement (CAMBA) or the Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA). The site contains the Barmah Forest Ramsar site and includes part of the New South Wales Central Murray State Forests Ramsar site. For a full list of species listed under Commonwealth legislation that have been recorded in the Barmah–Millewa Forest refer to Appendix 10.
2	The asset is natural or near-natural, rare or unique.	Barmah–Millewa Forest supports the largest red gum forest in Australia (Victorian Department of Sustainability and Environment 2008; GHD 2009). As the largest floodplain listed as a Living Murray icon site, this asset is perhaps the largest and most intact floodplain system along the River Murray. The forests can be considered 'near natural', as they retain elements of pre-European aged trees and areas which are structurally equivalent to undisturbed forest, despite 150 years of timber harvesting (GHD 2009).The Barmah side of the forest supports the most extensive area of moira grass (*Pseudoraphis spinescens*) plains in Victoria with the grass dominating 5.2%, or 1,535 ha, of the Barmah Forest Ramsar site in 1979 (Victorian Department of Sustainability and Environment 2008). In addition, King et al. (2007) highlight that Barmah–Millewa Forest is a significant area for native fish conservation with the extensive wetland, creek and river habitats for fish now relatively rare in the region.
3	The asset provides vital habitat.	Because it floods at relatively low river flows, and therefore floods more frequently, Barmah–Millewa Forest provides drought refuge for waterbirds (Victorian Department of Sustainability and Environment 2008). About 54 waterbird species have been recorded breeding in the New South Wales Central Murray State Forests, including 25 colonial nesting species (GHD 2009).
4	The asset supports Commonwealth-, state- or territory-listed threatened species and/or ecological communities.	The Barmah–Millewa Forest meets this criterion because it supports species listed as threatened under Commonwealth or state legislation. For a full list of species that have been recorded refer to Appendix 10.
5	The asset supports or is capable of supporting significant biodiversity.	The Victorian flora information system and the Victorian Wildlife Atlas has recorded 381 indigenous flora species and 221 indigenous vertebrate species for the Barmah Forest site (Victorian Department of Sustainability and Environment 2008). Barmah Forest is listed under Ramsar criterion 5 because it regularly supports 1% of the population of Australian white ibis (*Threskionis molucca)* and straw-necked ibis (*Threskiornis spinicollis*) (Victorian Department of Sustainability and Environment 2008).

TABLE 1

COMPARISON OF NATURAL FLOWS AND POST-DARTMOUTH FLOWS.

94-year sequence of Tocumwal flows. Future conditions were also generated using the monthly simulated model.

	Number of months (out of 94 years) when flow at Tocumwal exceeded value shown. Tocumwal Flow (Average monthly).	
	18,000 ML/d	24,500 ML/d
Natural Flows #	367	277
Future Flows *	171	124
Difference	-196	-153
	Number of seasons (out of 94) when for a least one month in the period May to November the average monthly flow exceeded the rate shown.	
Natural Flows #	87	73
Future Flows *	55	35
Difference	-32	-38

Note:

- natural conditions estimated using monthly simulated model, 1891 to 1985.

* - future conditions estimated using monthly simulation model, 1891 to 1985.

The following tables show the effect of regulation of flows on periods between successive winter spring forest flooding (May to October) prior to the construction of Dartmouth Dam.

Source: Report to 306 meeting River Murray Commission, 9th February 1987 – Water Management in the Millewa Barmah Forests, R.I. Francis Executive Engineer. Chapter 4 – Water Requirements of the Forests, Table 4.2, page 4.20

TABLE 2

EFFECT OF REGULATION ON PERIODS BETWEEN SUCCESSIVE WINTER SPRING FOREST FLOODING (MAY TO NOVEMBER) - NATURAL AND POST-DARTMOUTH DAM CONDITIONS.

Period between successive forest floodings for flow shown – in years	Number of times between 1891 and 1985 when the period between successive winter spring forest flooding is as indicated			
	Tocumwal Flow – 30 D 18,000 ML/d – 540 GL		Tocumwal Flow – 30 D 24,500 ML/d – 735 GL	
	Natural	Post-Dartmouth	Natural	Post-Dartmouth
> 1	7	22	19	19
> 2	-	11	2	12
> 3	-	5	-	7
> 4	-	1	-	5
> 5	-	-	-	4
> 6	-	-	-	3
> 7	-	-	-	2
> 8	-	-	-	2
> 9	-	-	-	2
> 10	-	-	-	2

The following comments can be made about these results:

- **Over the past 50 years, since the construction of the Hume Dam, the frequency of flooding of the forest has been reduced significantly;**
- **Clearly future regulation of flows will result in a significant reduction in frequency of forest flooding compared to natural conditions.**

Source: **Report to 306 meeting River Murray Commission, 9th February 1987 – Water Management in the Millewa Barmah Forests, R.I. Francis Executive Engineer. Chapter 4 – Water Requirements of the Forests, Table 4.4 page 4.22.**

Table 3
Limits of Tolerance to Flooding of Species/Environments in Barmah Forest

Flood parameter 80% of forest flooded for at least one month	Rushlands	Moira grass plains	Red gum forest			Box forest	Aquatic Fauna general	Fishes	Water birds
			SQI	SQII	SQIII				
Frequency (% of years)									
- min tolerable	75	100	70	50	30	0	20	35	70
- max tolerable	100	100	100	100	100	50	100	100	100
- natural	100	100	90	70	45	10	100	90	100
- current	80	70	60	45	25	10	80	10	66
Duration (months)									
- min tolerable	2	2	1	1	0.5	0	3	2	2.5
- max tolerable	30	18	18	18	18	1	30	10	-
- natural av.	10	8	5	3	1.2	10.	8	3	10
- current av.	5	3	2	1.5	0.7	0.5	3	1.5	5
Timing									
- earliest to be effective	Anytime	August	June for regeneration *			Anytime	June	Sept	July
- latest to be effective	Anytime	December	November for regeneration *			Anytime	April	Feb	Feb
- ideal cycle of									
- wetting	May	September	August			August	August	October	July
- drying	June	January	December			September	March	March	January

* Occasional flooding at other times of year is unlikely to be determined to established trees and could well be beneficial.

Extract from Maunsell Report 1992 Barmah-Millewa Forests Water Management Plan, Table 4.2, page 44, modified from Leitch (1989).

Table 4
Flooding Durations and Frequencies.

	Lower CFF	Median CFF	Upper CFF	Min Months	Median Months	Max Months	Max Duration Without Drying (months)	* Max Interval Between Floods (months)
Rushlands	16	18.5	19	5	6	6	17	21
Moira grass	15.5	17.5	19	4	5	6	16	23
RG & moira grass	14	17	17.5	4	5	5	16	24
RG regeneration on plains	15	17.5	19	4	5	6	16	23
RG, terete culm sedge grasses	11.5	13.5	15.5	3	4	4	12	31
RG and terete culm sedge	10	13	15.5	2	4	4	12	32
RG and spike rush	11	13	15.5	3	4	4	12	32
RG and warrego summer grass	11	13	15.5	3	4	4	12	32
RG and wallaby grasses	6	8	12	1	2	3	6	42
RG, swamp wallaby grasses and brown-black wallaby grasses	8	8	12	2	2	3	6	42
Yellow box and Grey box	5	9	11	1	2	3	7	40
Black box	7	8	9	1	2	2	6	42
Disturbed sites with introductions	6	7	8	1	1	2	5	44

Notes:

CFF = Crude flood frequency or the number of floods in the 22 year period analysed. Shown are lower, median, and upper values. The 22 years are from 1966-88, corresponding to the DCE flood mapping.

Min months, Median months, Max months = These listings refer to the minium months of flooding, median months of flooding, and maximum months of flooding per annum, derived using data from Tocumwal from 1894 to 1985.

Maximum duration without drying = This figure, expressed as months, is an estimate of the longest period without a flood recession derived using data from Tocumwal from 1894 to 1985.

*** MAXIMUM DURATION BETWEEN FLOODS = THIS FIGURE EXPRESSED AS MONTHS, IS AN ESTIMATE (Bren 1990) OF THE LONGEST PERIOD BETWEEN SUCCESSIVE SITE FLOODINGS THAT THE VEGETATION WOULD BE EXPECTED TO ENDURE IN THE NATURAL STATE. AS SHOWN BY FRANCIS AND LATER REVIEWS SUCH EVENTS HAPPENED RARELY. IF SUCH EVENTS OCCURRED ON A REGULAR BASIS IT WOULD CAUSE IRREVERSIBLE DAMAGE TO THE ECOSYSTEM (Dexter 1999).**

Extract from Maunsell Report 1992, Barmah-Millewa Forests Water Management Plan, Table 4.3, page 45.
Source: Bren, L.J., pers. comm., July 1990.

Barmah Millewa Forum
Research, Evaluation and Monitoring Sub-Committee

BARMAH MILLEWA FORESTS
FLOODED AREA RELATIONSHIPS

INTRODUCTION
The best relationships linking flooded area with River Murray flow are those developed by Dr Leon Bren. They are based upon the River Murray at Tocumwal flow record and the Dexter flooded area maps and only apply to the Barmah Forest.

There are two such relationships. The first links flooded area with the peak flow at Tocumwal and a second relationship has been developed between flooded area and the average daily flow for the month. Each relationship is explained in the publication:

"The Hydrology of the Barmah River Red Gum Forest", A Collection of Work undertaken 1984 to 1988 by L.J. Bren with collaboration from N.L. Gibbs and I.C. O'Neill, The University of Melbourne, Forestry Section, Creswick.

In the attached table, these two relationships are set down in the following order:

1. Peak flow at Tocumwal (Ml/d), thence,
   - Flooded area percentage, Barmah Forest (after Bren 1986) and
   - Equivalent monthly flow in Gl/m. (after Maunsell 1991).
   - These relationships have been plotted on figure 1.

2. The average daily flow corresponding to the above monthly totals in Ml/d thence,
   - The flooded area percentage, Barmah Forest (after Bren, 1986)
   - The equivalent monthly total in Gl assuming a thirty-day month.
   - These relationships have been plotted in figure 2.

3. Using the definitions of "effective floods" from the "Water Management Plan for the Millewa Forest", SFNSW and DLWC, July 1996, the table and figure 2 then shows the two nominated floods as average daily flows, 24,000 Ml/d for at least 30 days for Barmah and 35,000 Ml/d for Millewa.

4. The 24,000 Ml/d flood for Barmah is also the Dexter "Effective Flood" (certainly for flooded area) as presented to the Forum in July 2000. The July presentation also commented that while the 24,000 Ml/d for 30 days does not necessarily guarantee the required depth and duration to satisfy all the requirements of the red gum ecosystem, provided the subsequent flows are greater than 18,000 Ml/d for a similar period before the flood waters can drain away and or evaporate, the essential criteria for sustaining tree reproduction and growth and for waterbird habitat are met. This additional requirement introduces the important concept of flood duration, which lies at the heart of the many of the present flow rules suggested for the use of the Barmah Millewa Allocation.

5. A final column shows the flooded area measurements from the October 1998 flood and the associated environmental release. They are compared with each of the Bren predictions in the two tables below.

Table 1: Barmah Millewa Forest: Flooded Area Percentages: October November 1998 Based upon Tocumwal Peak Flow

Flow Criteria	Measured Percentage Flooded **Millewa Forest**	Measured Percentage Flooded **Barmah Forest**	Bren Predicted Percentages based upon **Tocumwal Peak Flow**
Peak flow at Tocumwal, October 1998, 70,000 Ml/d	80%	47%	93% or "as flooded as it gets"
Tocumwal peak flow, November 1998,17,500 Ml/d	21%	25%	28%

Table 2: Barmah Millewa Forest: Flooded Area Percentages: October November 1998 Based upon average flow for the month at Tocumwal

Flow Criteria	Measured Percentage Flooded **Millewa Forest**	Measured Percentage Flooded **Barmah Forest**	Bren Predicted Percentages based upon Tocumwal **Average Daily Flow for Month**.
Average daily flow at Tocumwal based on: October 580Gl.	80%	47%	56%
Average daily flow at Tocumwal based on: November 330 Gl	21%	25%	34%

The Millewa Forest Water Management Plan also quotes estimates of inflows into both forests. These estimates are compared with recent Mike 11 results (Maunsell 1991) in Table 3 below.

Table 3: Barmah Millewa Forests: Inflows to Forests (Ml/d)

Flow Criteria	River Murray at Tocumwal	Flow into Barmah Forest	Flow into Millewa Forest
Water Management Plan estimates	24,000Ml/d	10,000 Ml/d	
	35,000		6,000Ml/d
Mike 11 results	15,000 Ml/d	4,100 Ml/d	2,200 Ml/d
	25,000	11,400	3,500
	35,000	17,000	7,400

The two sets of Mike 11 results come from the post Mary Ada regulator numbers and locations.

CONCLUSIONS

1. There is a reliable and robust link between peak flows and monthly totals at Tocumwal.
2. It would greatly limit ongoing confusion if peak flows at Tocumwal were always quoted as "Ml/d" and monthly totals as "Gl/m".
3. However, the long use of "daily Ml/d" as an average flow for the month may require its continued use.
4. The quoted forest inflows in the Millewa Water Management Plan check reasonably closely with the 1991 Mike 11 results.
5. Both Bren relationships remain robust but should only be used as a broad indicator of the flooded area within the Barmah Forest.
6. Corresponding data needs to be gathered for Millewa Forest.
7. At the two nominated "Effective Floods" and provided the floods last for 30 days, the percentage forest flooded would be about 65% at 24,000 Ml/d for Barmah and a figure between 40% and 80% for Millewa.

RECOMMENDATIONS

1. As the flow required to flood a significant area of each forest is quite different, it is recommended that no flooded area survey be undertaken for Tocumwal flows of less than 24,000 Ml/d and to start any such survey in the Barmah Forest. Should the flood reach 35,000 Ml/d, survey work in Millewa Forest could then start.

2. Anticipating higher floods later in the season could be a reason to delay fieldwork in order that the maximum extent of the flood be recorded.

3. Field surveys will always need to be undertaken, regardless of the flow, when the environmental allocation is being used.

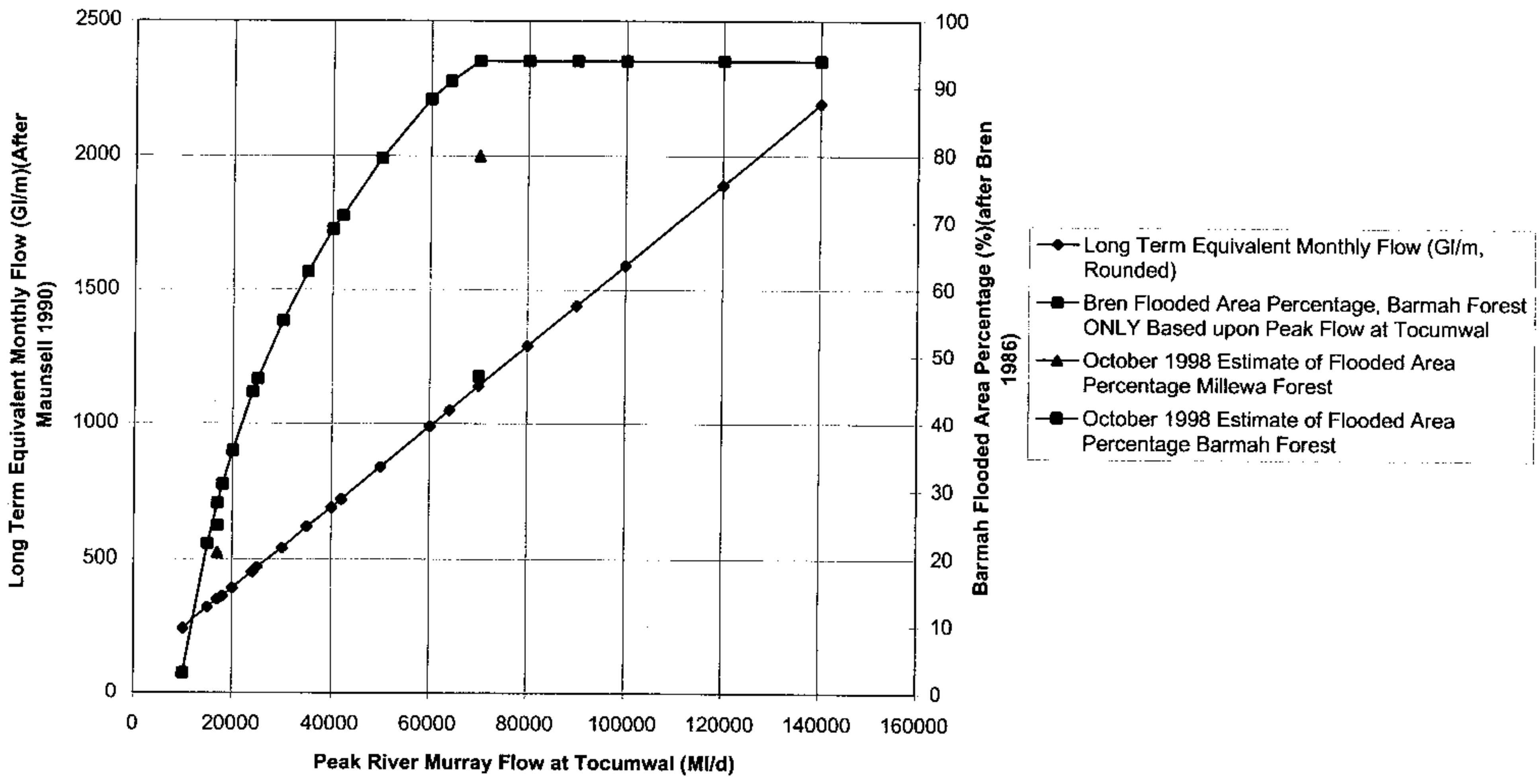
4. These lower flows may require the more selective use of forest regulators to distribute flows within both forests.

DJM
October 2000

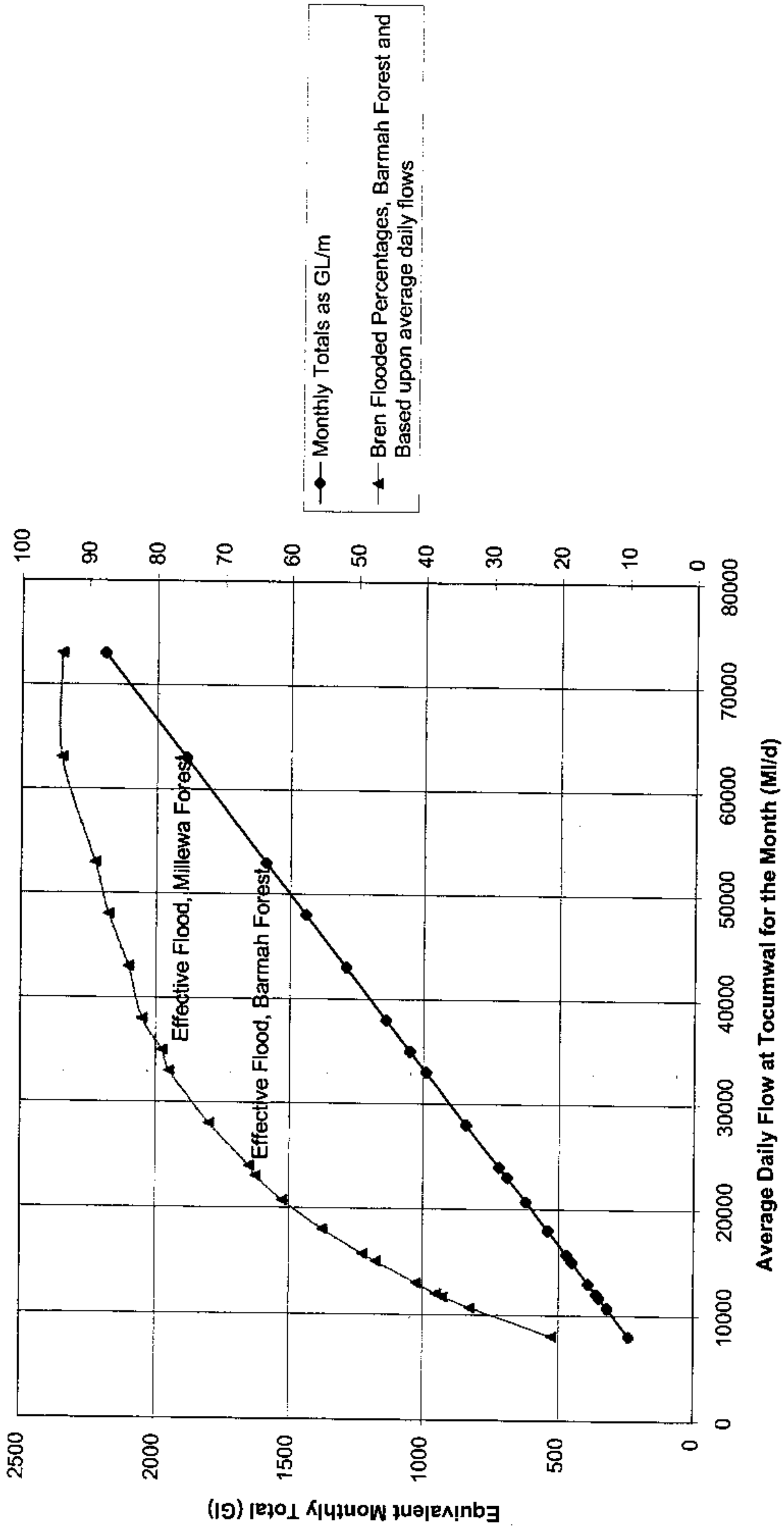
Barmah Millewa Forests
FLOODED AREA RELATIONSHIPS

Peak River Murray Flow at Tocumwal (Ml/d)	Bren Flooded Area Percentage, Barmah Forest Based upon Tocumwal Peak Flow in Ml/d	Long Term Equivalent Monthly Flow (Gl/m, Rounded)	Average daily flow corresponding to Long Term Equivalent Monthly Flow (Ml/d)	Bren Flooded Area Percentage for Barmah Forest based upon Average Daily Flow for the Month in Gl/d	Remarks	October 1998 Ovens Flood and First Environmental Release, GIS Measurements of Flooded Area Percentage	
	READ AGAINST TOCUMWAL PEAK FLOW ONLY	READ AGAINST TOCUMWAL PEAK FLOW ONLY	READ AGAINST EQUIVALENT MONTHLY TOTAL ONLY	READ AGAINST MONTHLY AVERAGE FLOW		BARMAH FOREST	MILLEWA FOREST
10,000	3	240	8,000	21			
15,000	22	320	10,700	33			
17000	28	350	11,700	37			
18,000	31	360	12,000	38		25	21
20,000	36	390	13,000	41			
24,000	45	450	15,000	47			
25,000	47	470	15,700	49			
30,000	55	540	18,000	55		47% shown first against monthly total	
35,000	63	620	20,700	61			
40,000	69	690	23,000	65			
42,000	71	720	24,000	66.5	"Effective" Barmah flood (WMP for MF, 1996) Dexter "Effective" Flood, as discussed by Forum July 2000, both 24,000Ml/d		
50,000	80	840	28,000	72			
60,000	88	990	33,000	77.7			
64,000	91	1,050	35,000	79.5	"Effective" Millewa flood, (WMP for MF, 1996), 35,000 Ml/d.		
70,000	94	1,140	38,000	81.7		47% shown next against Tocumwal peak	
80,000	94	1,290	43,000	84			80
90,000	94	1,440	48,000	87			
100,000	94	1,590	53,000	89			
120,000	94	1,890	63,000	94			
140000	94	2190	73000	94			

BARMAH MILLEWA FOREST FLOODED AREA RELATIONSHIPS BASED UPON PEAK FLOW AT TOCUMWAL



BARMAH MILLEWA FORESTS FLOODED AREA RELATIONSHIPS BASED ON AVERAGE DAILY FLOWS FOR THE MONTH AT TOCUMWAL



APPENDIX 2.3

Interim Operating Rules for the Barmah-Millewa Forest EWA

OBJECTIVES &/OR TARGETS

- a series of '**operating rules**' have been developed to improve the management of the Barmah-Millewa environmental allocation for the forest, to better meet the forest's needs.
- they have been designed to efficiently manage the water distribution under conditions of varying irrigation demand and natural conditions in the flow pattern.
- the operating rules are targeted to meet a number of desired hydrological outcomes. The key outcomes are:
  - to achieve on average three medium sized, long duration floods every 10 years and
  - to ensure that there is no more than 5 years between these events.
  - the target floods run for 4 months between September and January, inundating around 50% of the forest. This can be achieved, for example, when flows at Yarrawonga Weir exceed 500 GL/month during September, October and November, and exceed 400 GL/month in December.
- Recommended **triggers** for use of the environmental allocation have also been established. The objective of the triggers is:
  - to achieve the required frequency, duration and seasonality of flooding to sustain the forest ecosystem in the long term.

Releases for the Barmah-Millewa Forest will be made to top up the Yarrawonga flow using target flows similar to the following:

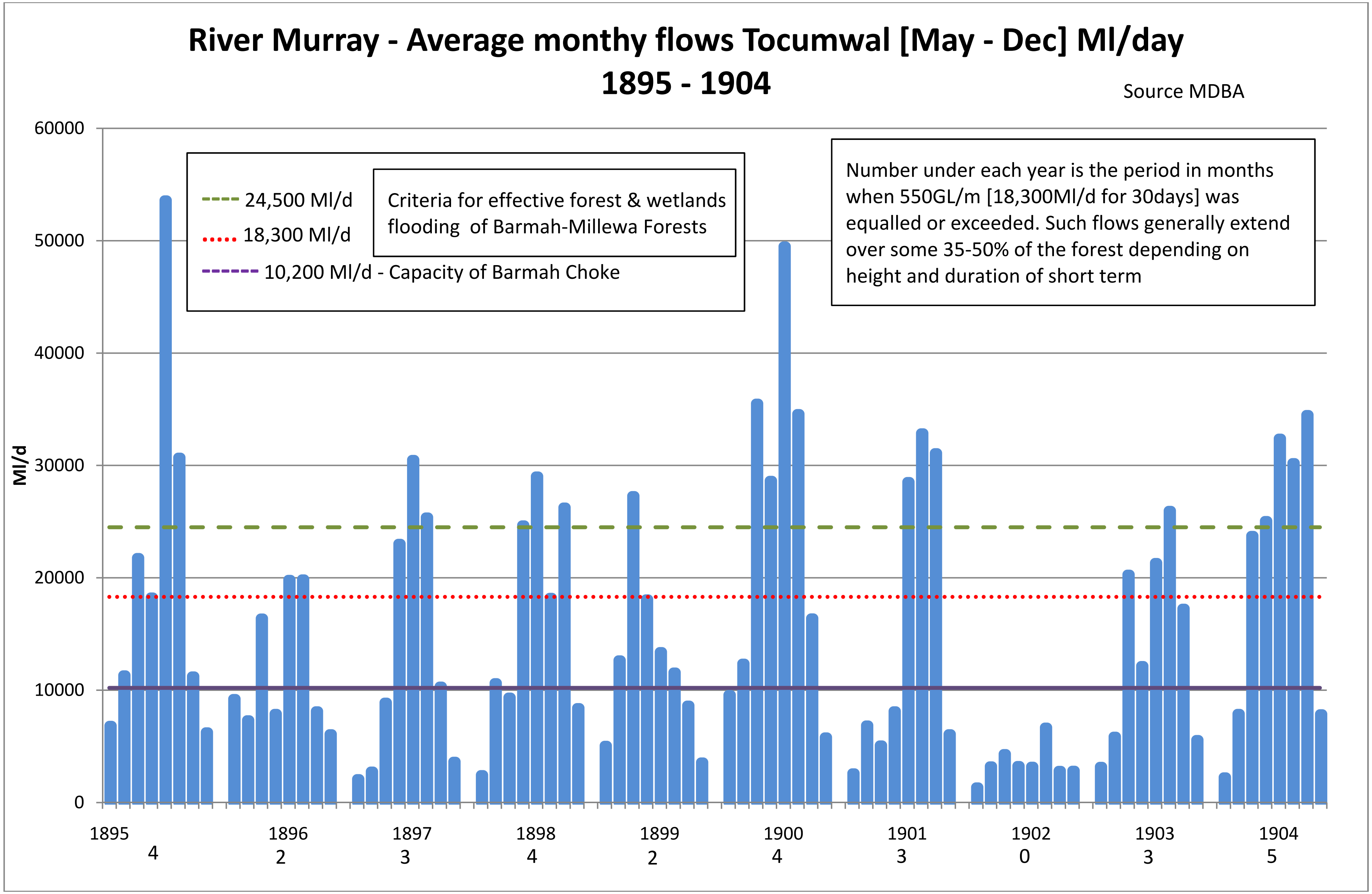
- if there is a flood ≥500 GL/m from September through to November, then maintain at 400 GL in December (if sufficient volume in the allocation);
- if there is a flood ≥500 GL in September or October and kitty is ≥400 GL (including overdraw), keep at 500 GL/m until November and 400 GL in December;
- if 4 years pass with no release, & no flood of ≥500 GL in September to November and 400 in December, try for 500 GL/m in October & November and 400 GL in December;
- if 3 years pass with no month from August to November with ≥660 GL, then if a release starts in October or November, the target flow increases to 660 GL at Yarrawonga.

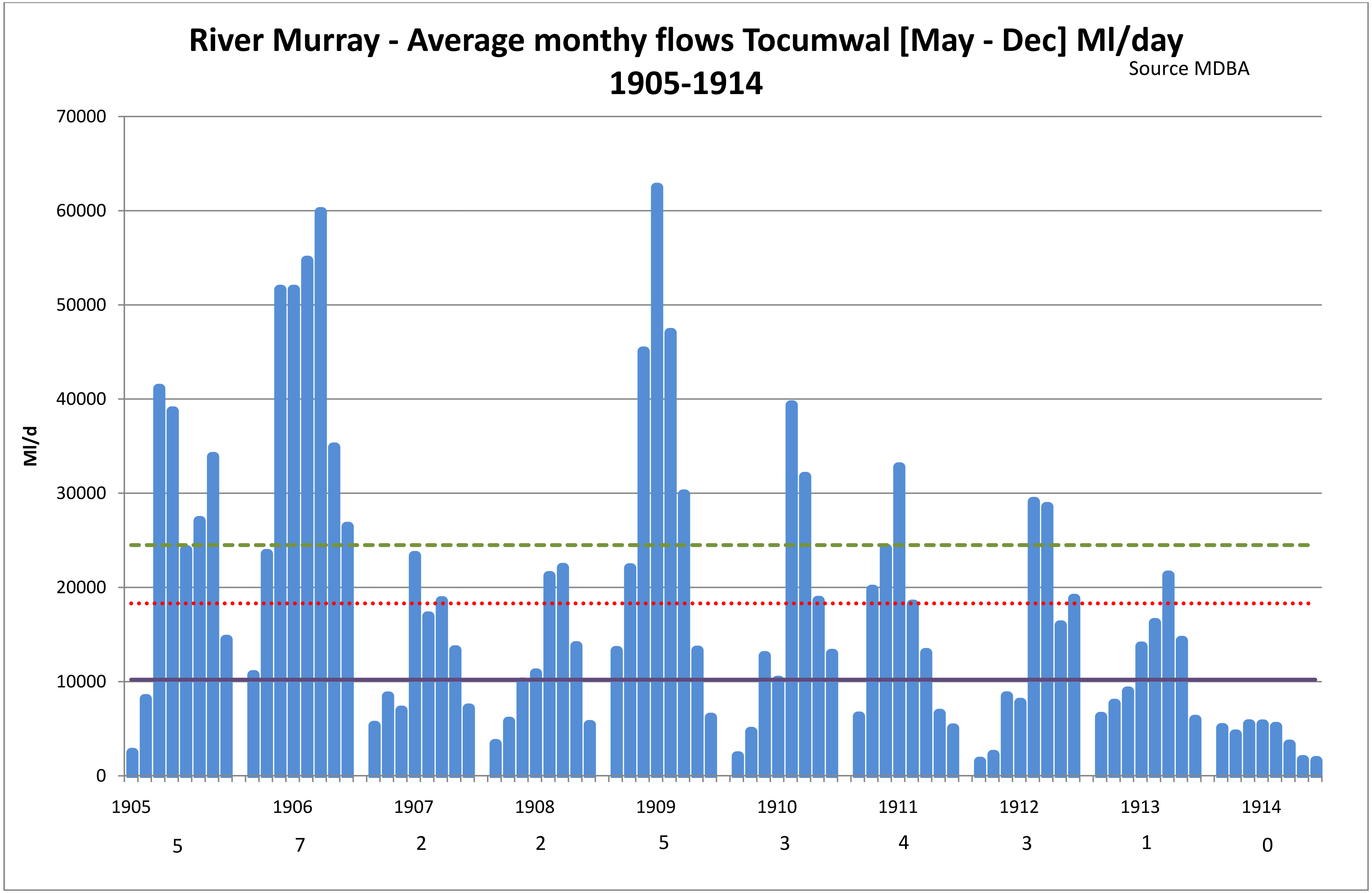
Source Barmah-Millewa Forest Icon Site Environmental Management Plan 2007 – 2010 Page 98.

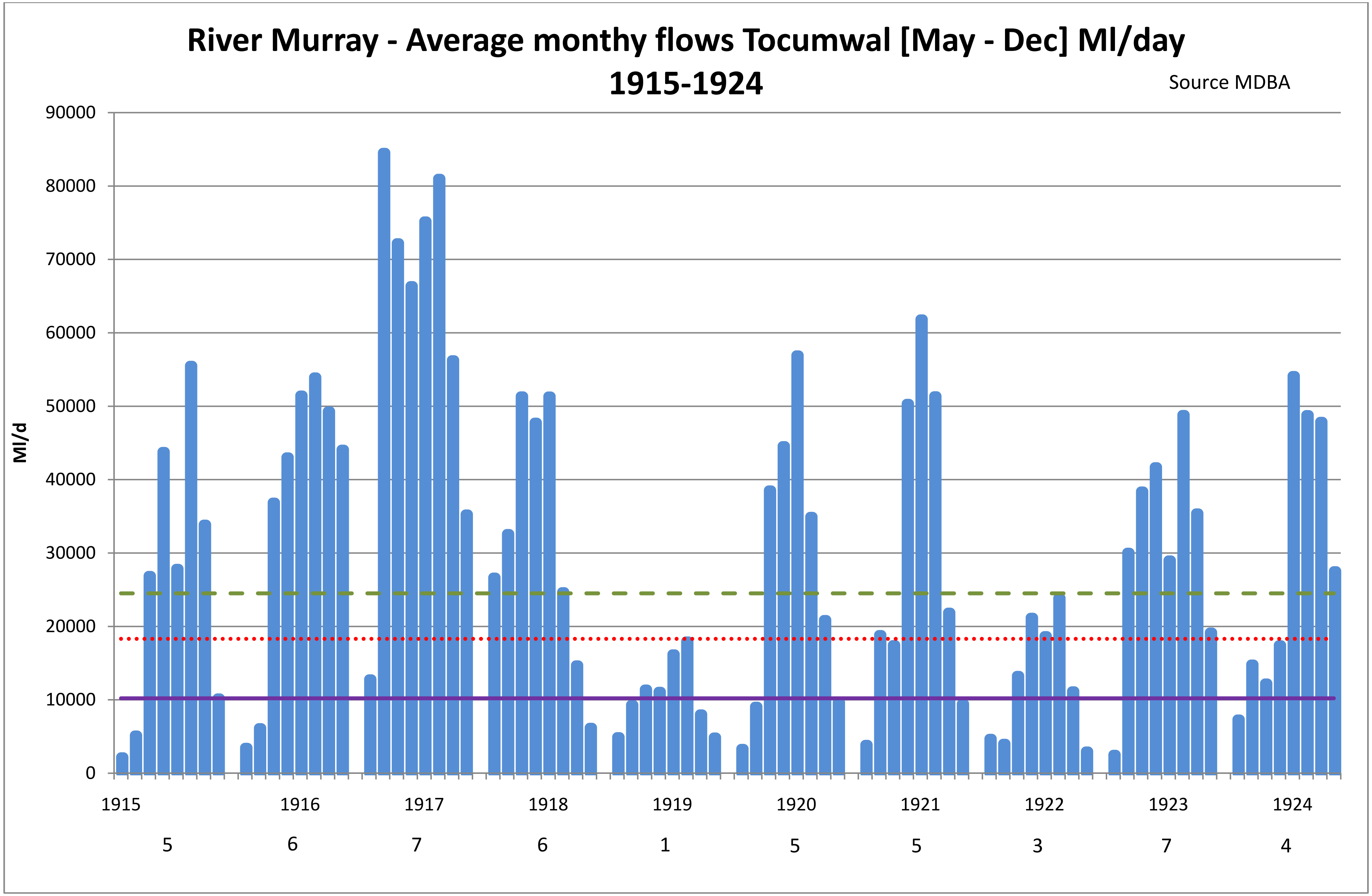
APPENDIX 2.4

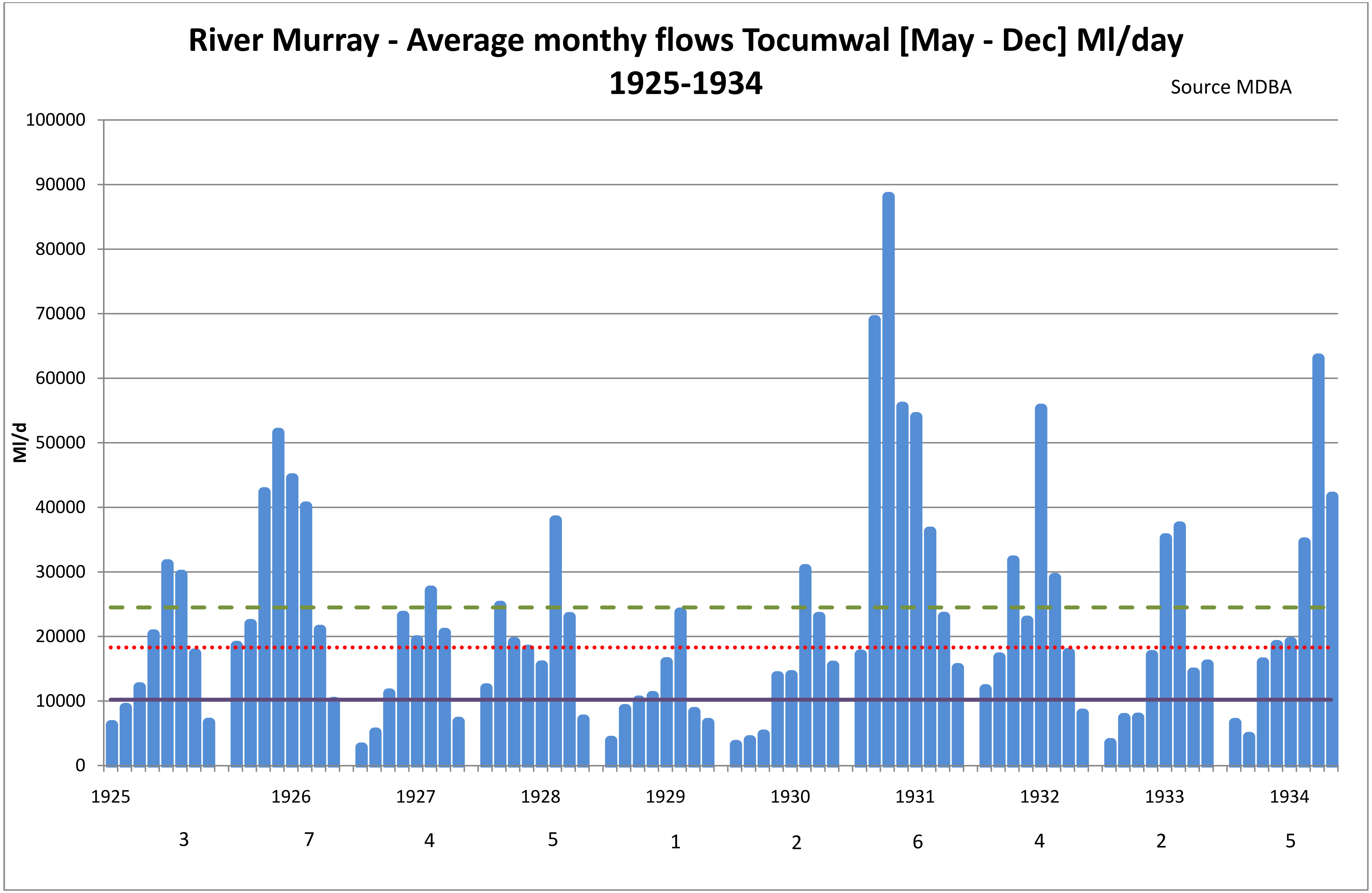
The Barmah-Millewa Forest Water Management Strategy
OBJECTIVES &/OR TARGETS ▪ to manage the Barmah-Millewa Forest as a single ecosystem for the purposes of water management ▪ to optimise use of river flows to enhance water management of the environment ▪ to facilitate effective water management by refining the division of forest into areas that can be managed independently or semi- independently ▪ to provide, operate and maintain water management works or structures required for economic and effective operation of the Water Management Strategy ▪ to record and evaluate information on the forest's history and past and on-going management practices, and apply that information to water management and to assessment of the Water Management Strategy's performance ▪ to monitor, record and evaluate scientific information required to manage water flow operations efficiently, and to use that information in assessing the Water Management Strategy's performance and in managing adaptively ▪ to monitor, record and evaluate socio-economic information to assist in managing water flow operations, and to use that information in assessing the Water Management Strategy's performance and in managing adaptively ▪ to increase knowledge of the needs of environmental watering regimes and of water management practices, and to apply that knowledge in assessing the Water Management Strategy's performance and in managing adaptively ▪ develop plans to implement the Water Management Strategy with maximum effectiveness

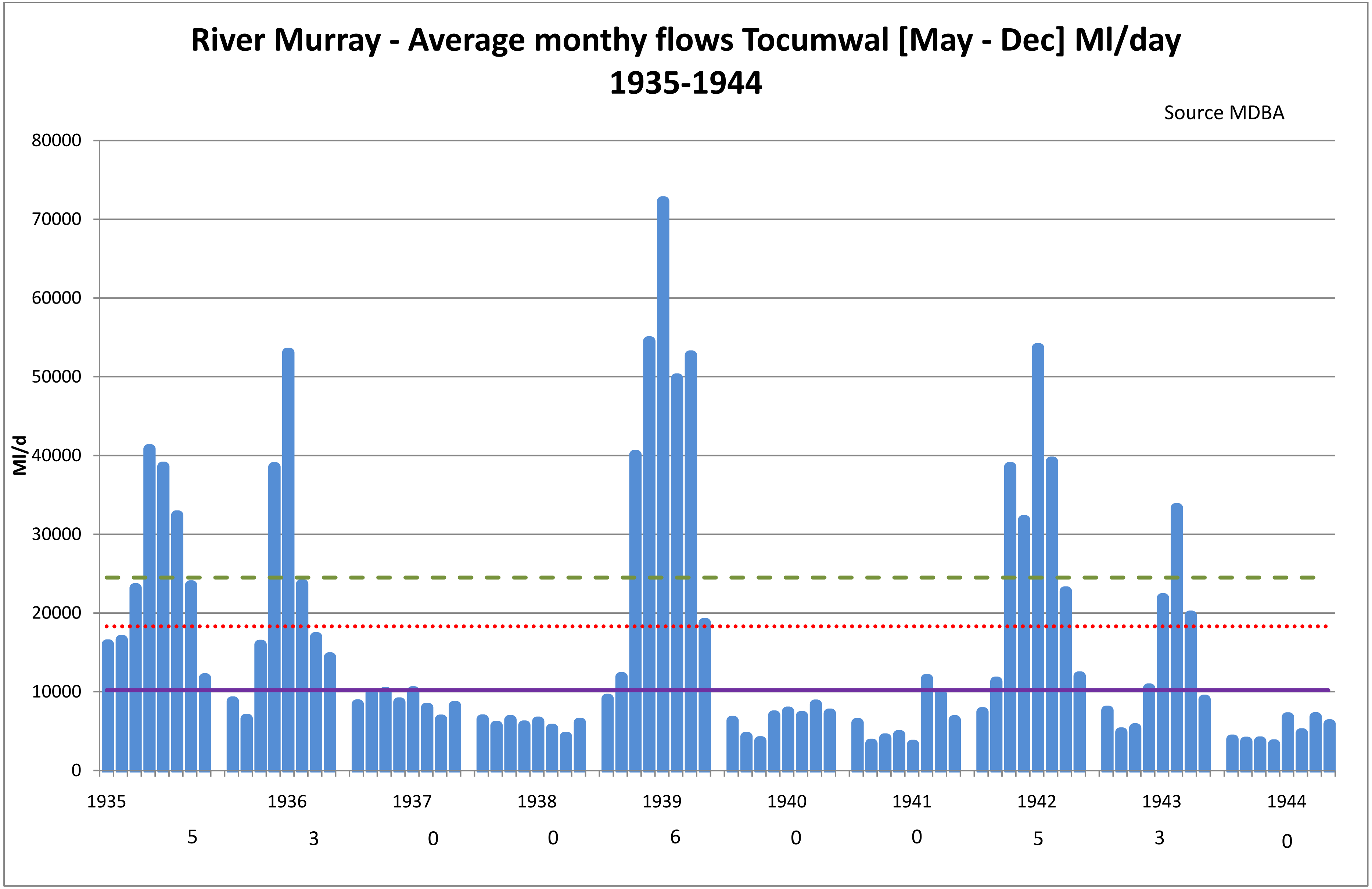
Source Barmah-Millewa Forest Icon Site Environmental Management Plan 2007 – 2010 Page 97.

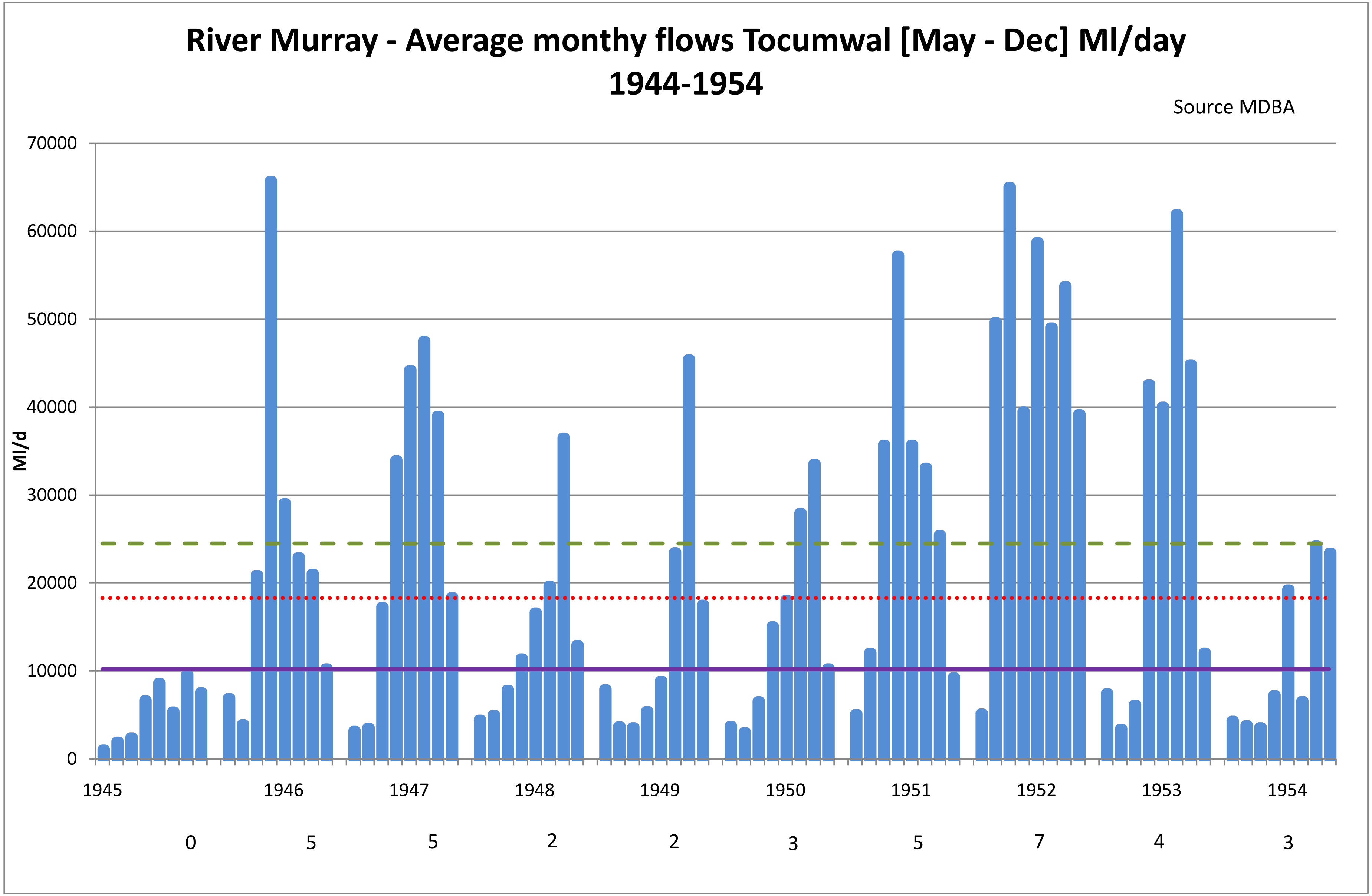

River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1895 - 1904
Source MDBA
24,500 Ml/d
18,300 Ml/d
10,200 Ml/d - Capacity of Barmah Choke
Criteria for effective forest & wetlands flooding of Barmah-Millewa Forests
Number under each year is the period in months when 550GL/m [18,300Ml/d for 30days] was equalled or exceeded. Such flows generally extend over some 35-50% of the forest depending on height and duration of short term
Ml/d
60000
50000
40000
30000
20000
10000
0
1895
4
1896
2
1897
3
1898
4
1899
2
1900
4
1901
3
1902
0
1903
3
1904
5

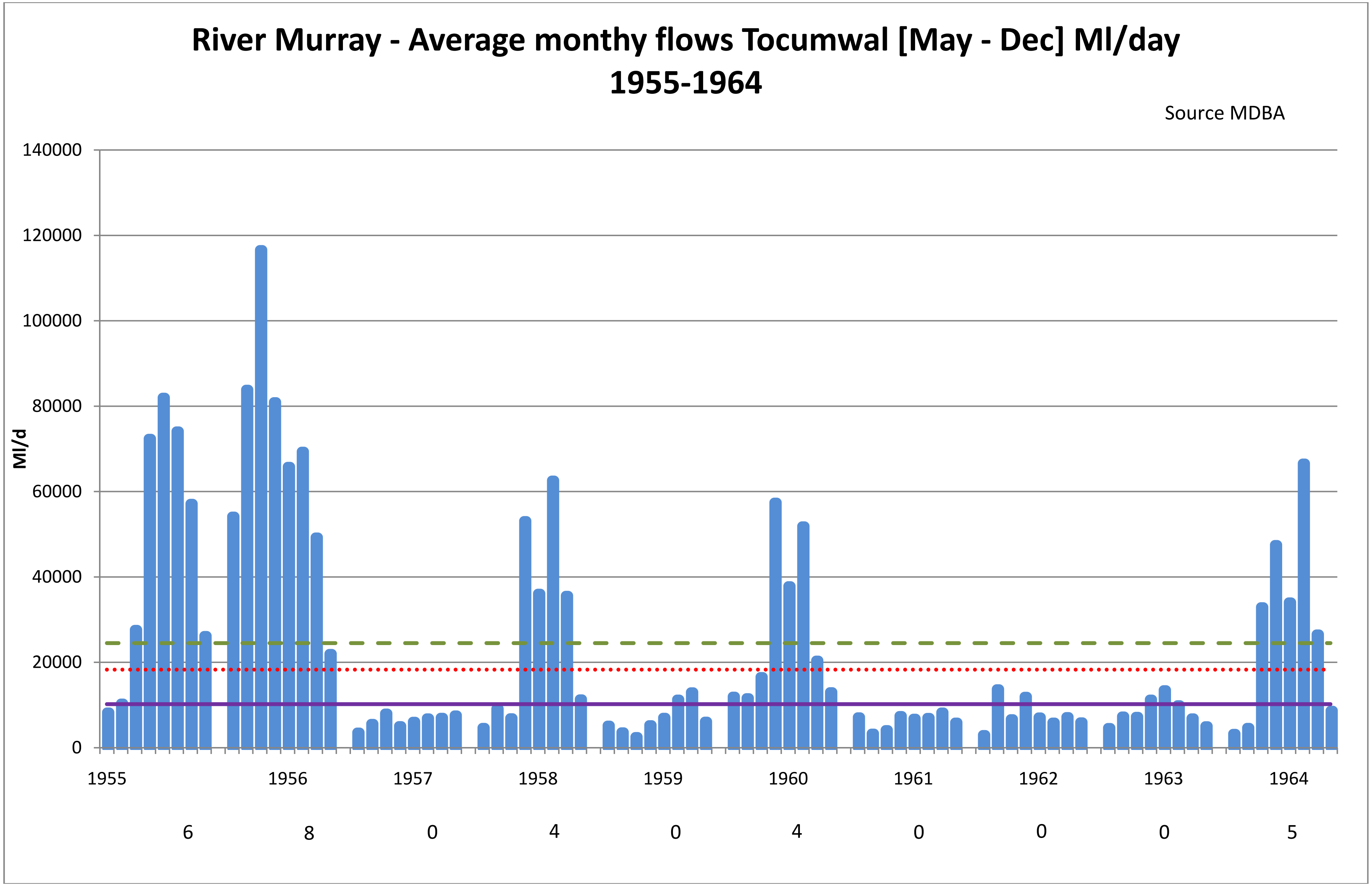

River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1905-1914
Source MDBA
70000
60000
50000
40000
30000
20000
10000
0
Ml/d
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
5
7
2
2
5
3
4
3
1
0

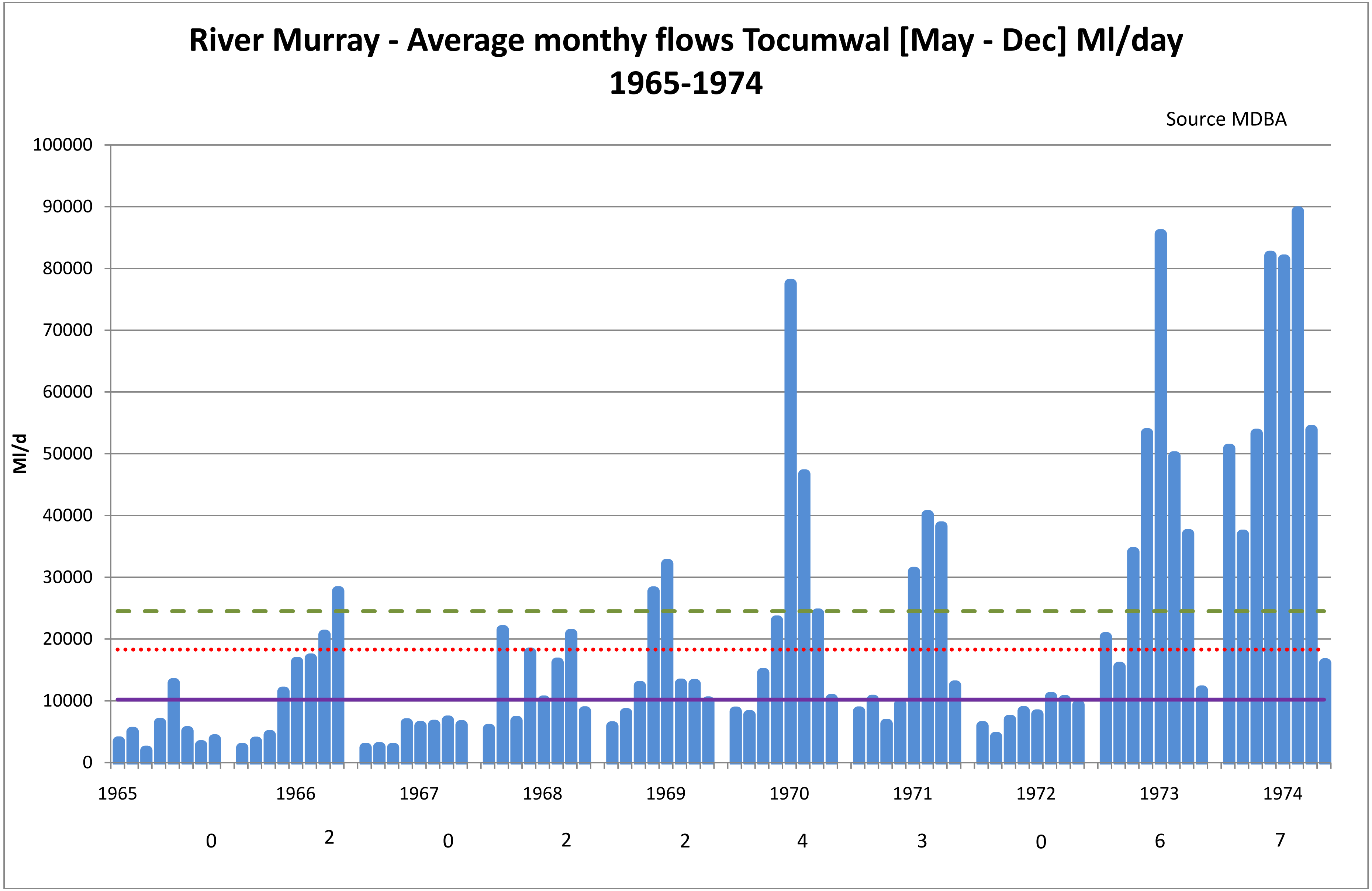

River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1915-1924
Source MDBA
Ml/d
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
5
6
7
6
1
5
5
3
7
4

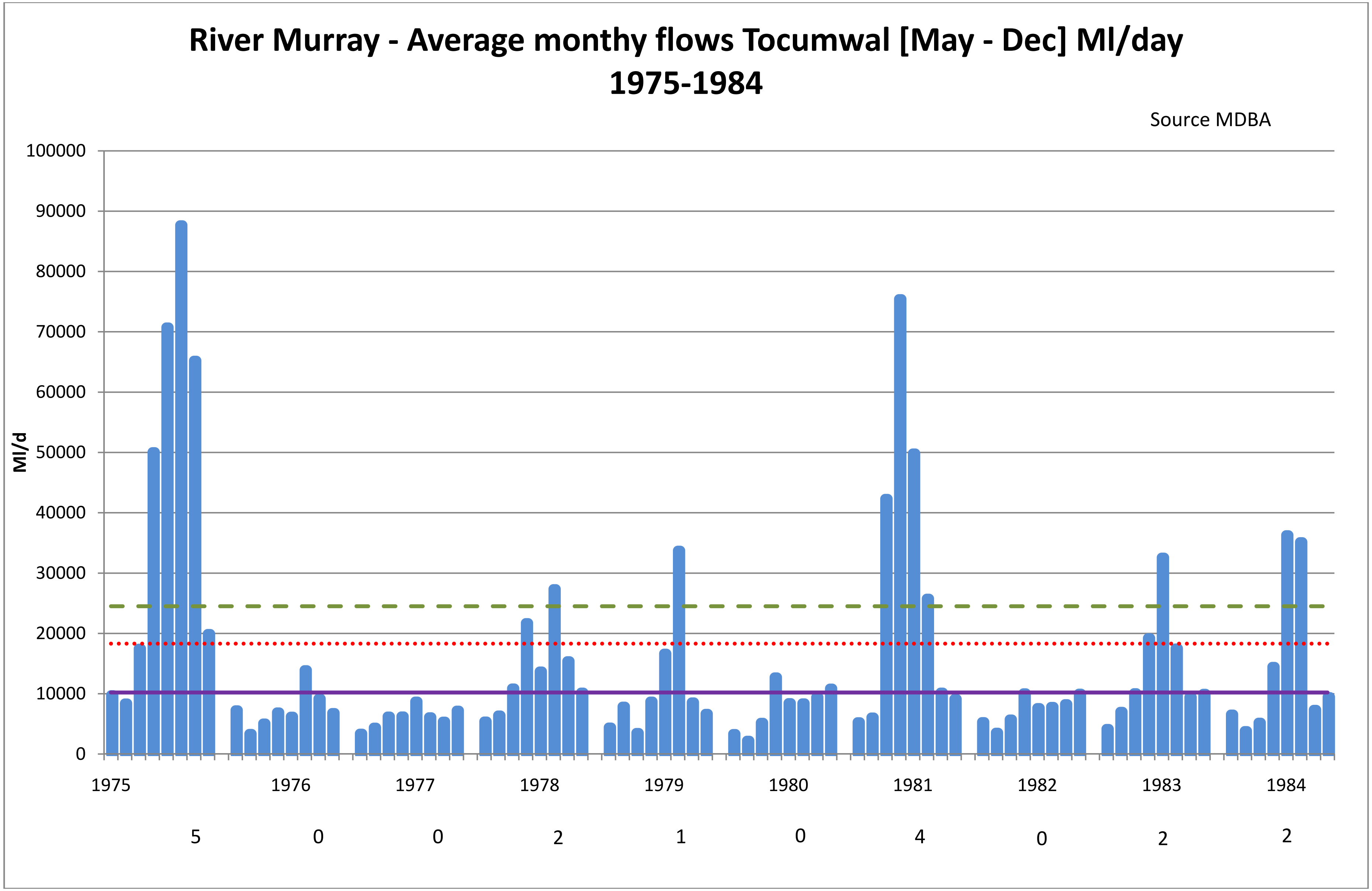

River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1925-1934
Source MDBA
Ml/d
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
3
7
4
5
1
2
6
4
2
5

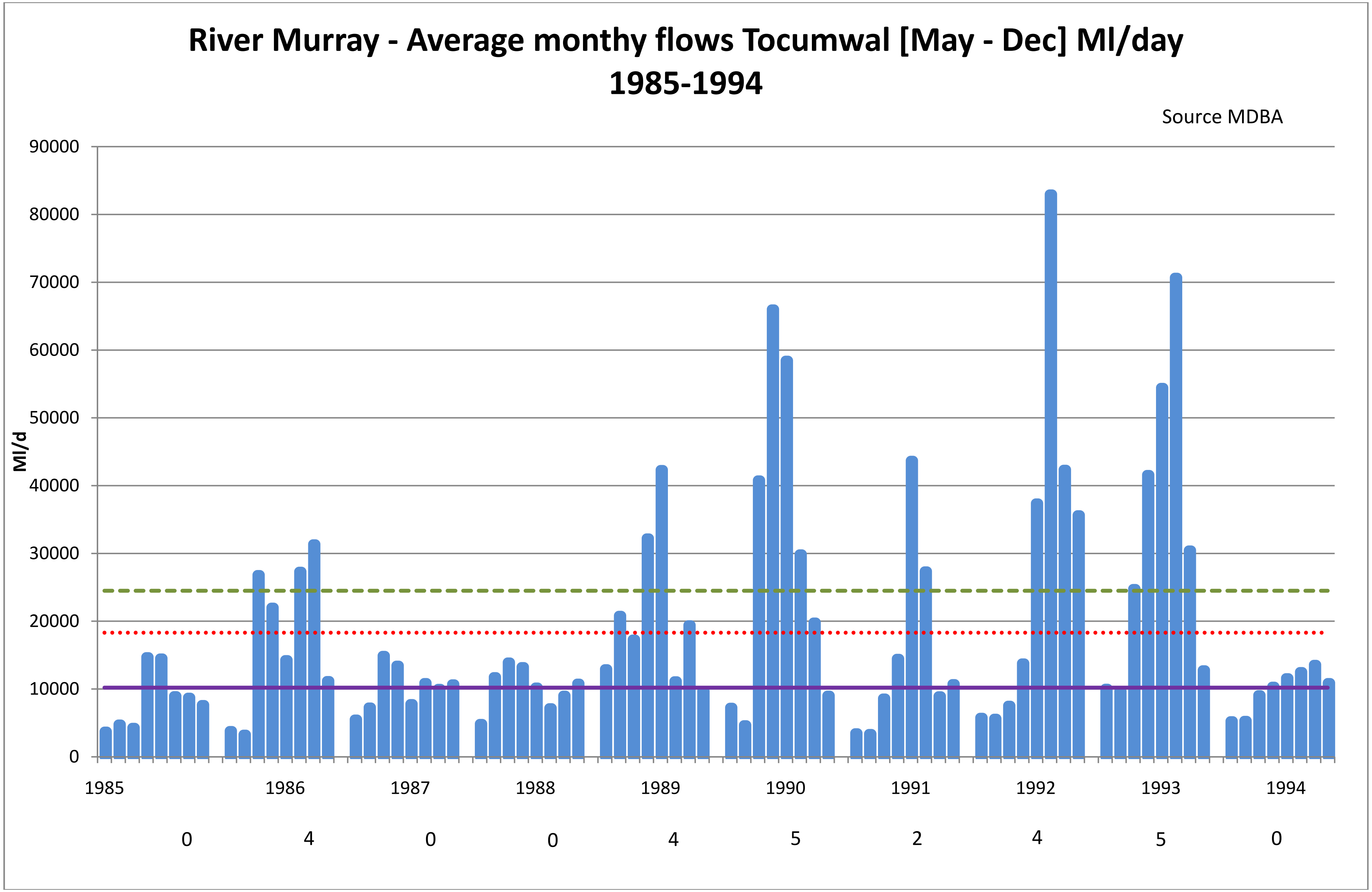

River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1935-1944
Source MDBA
Ml/d
80000
70000
60000
50000
40000
30000
20000
10000
0
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
5
3
0
0
6
0
0
5
3
0


River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1944-1954
Source MDBA
Ml/d
70000
60000
50000
40000
30000
20000
10000
0
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
0
5
5
2
2
3
5
7
4
3

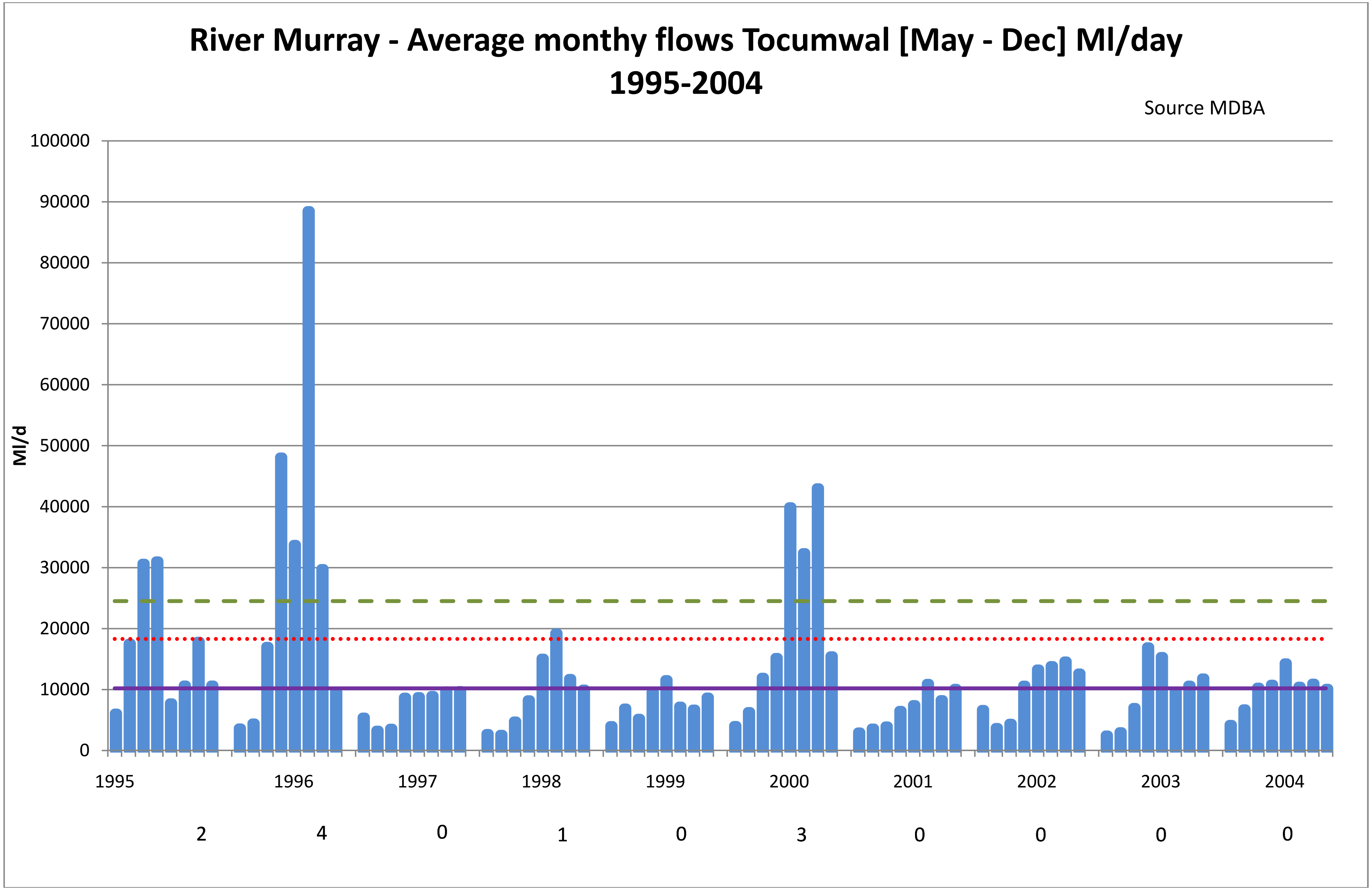

River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1955-1964
Source MDBA
Ml/d
140000
120000
100000
80000
60000
40000
20000
0
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
6
8
0
4
0
4
0
0
0
5

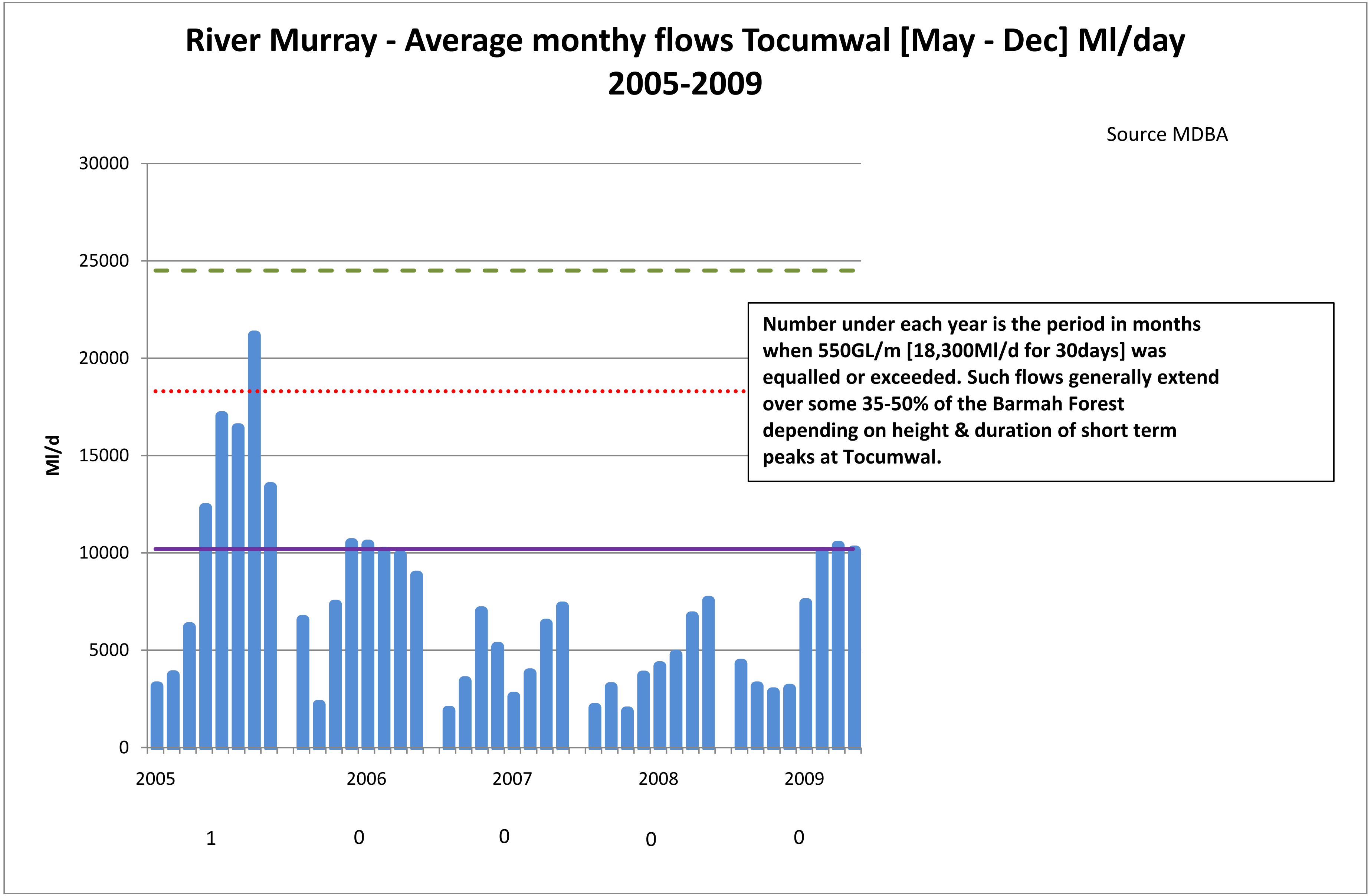

River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1965-1974
Source MDBA
Ml/d
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
0
2
0
2
2
4
3
0
6
7


River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1975-1984
Source MDBA
Ml/d
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
5
0
0
2
1
0
4
0
2
2



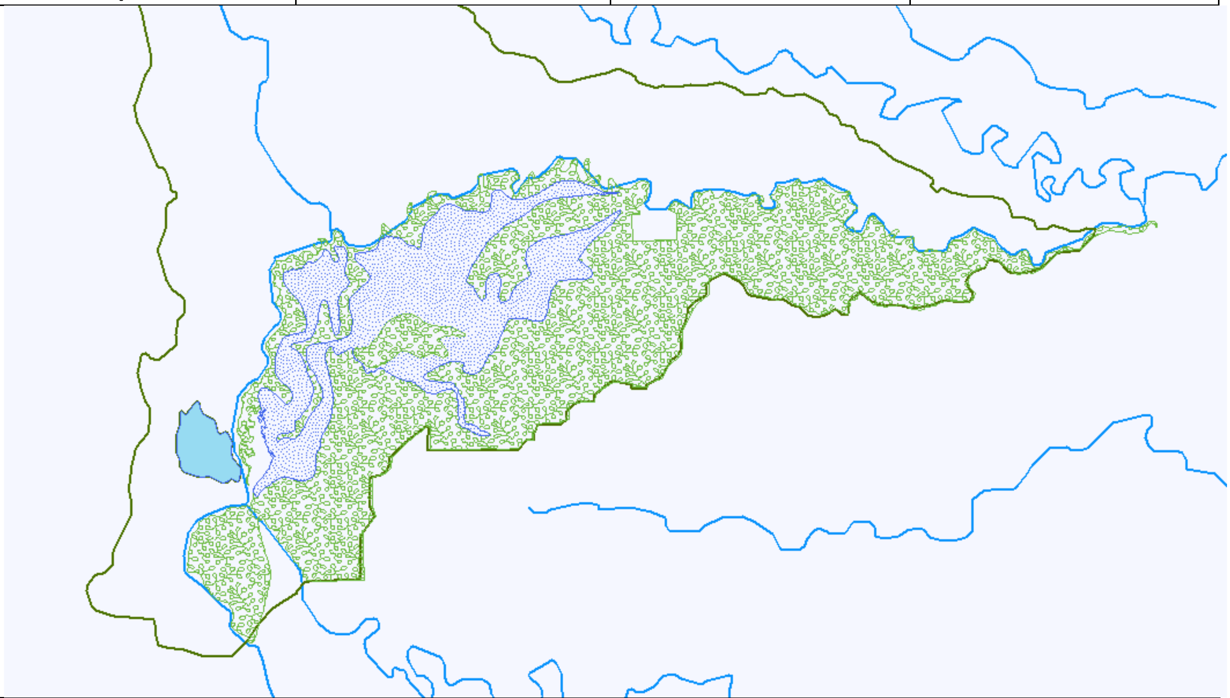
River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1985-1994
Source MDBA
Ml/d
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
0
4
0
0
4
5
2
4
5
0


River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
1995-2004
Source MDBA
Ml/d
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2
4
0
1
0
3
0
0
0
0


River Murray - Average monthy flows Tocumwal [May - Dec] Ml/day
2005-2009
Source MDBA
30000
25000
20000
15000
10000
5000
0
Ml/d
2005
2006
2007
2008
2009
1
0
0
0
0
Number under each year is the period in months when 550GL/m [18,300Ml/d for 30days] was equalled or exceeded. Such flows generally extend over some 35-50% of the Barmah Forest depending on height & duration of short term peaks at Tocumwal.

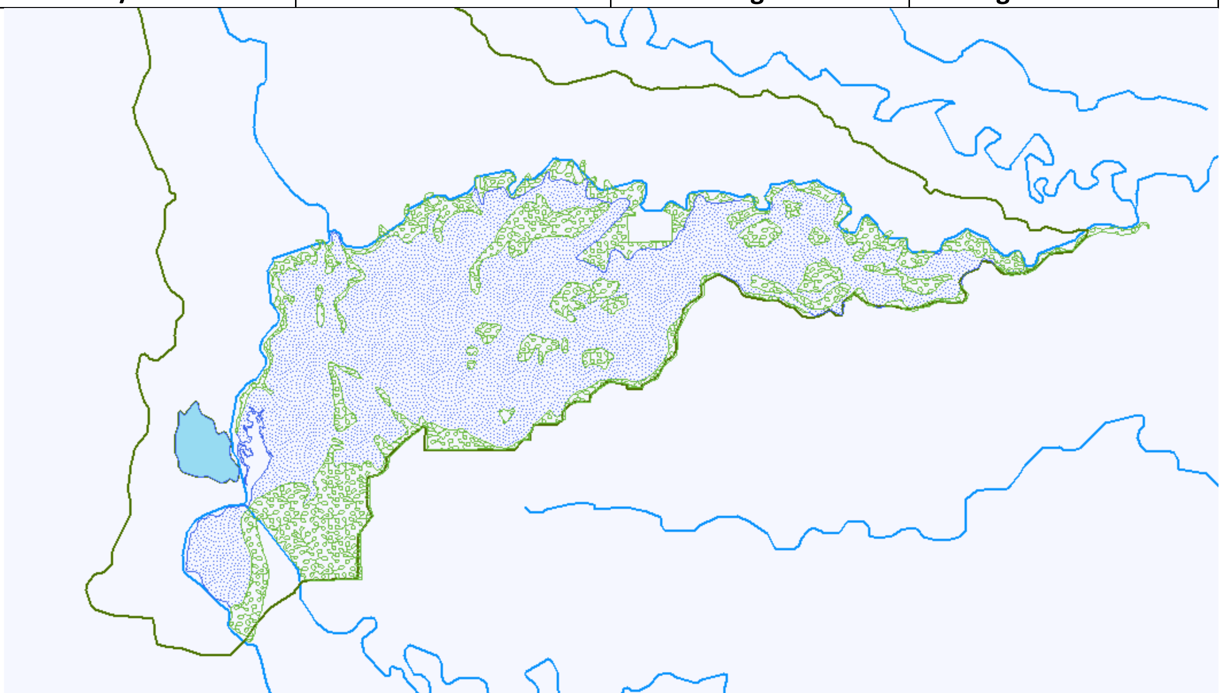
APPENDIX 3.2 **Index flood maps 1965-87, flood maps and daily hydrographs for 1966 [3 maps], 1972, 1974, 1976 and 1980 [similar maps are not available for the Millewa Forest].**

Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/215	761	Mar-66	Mar-66



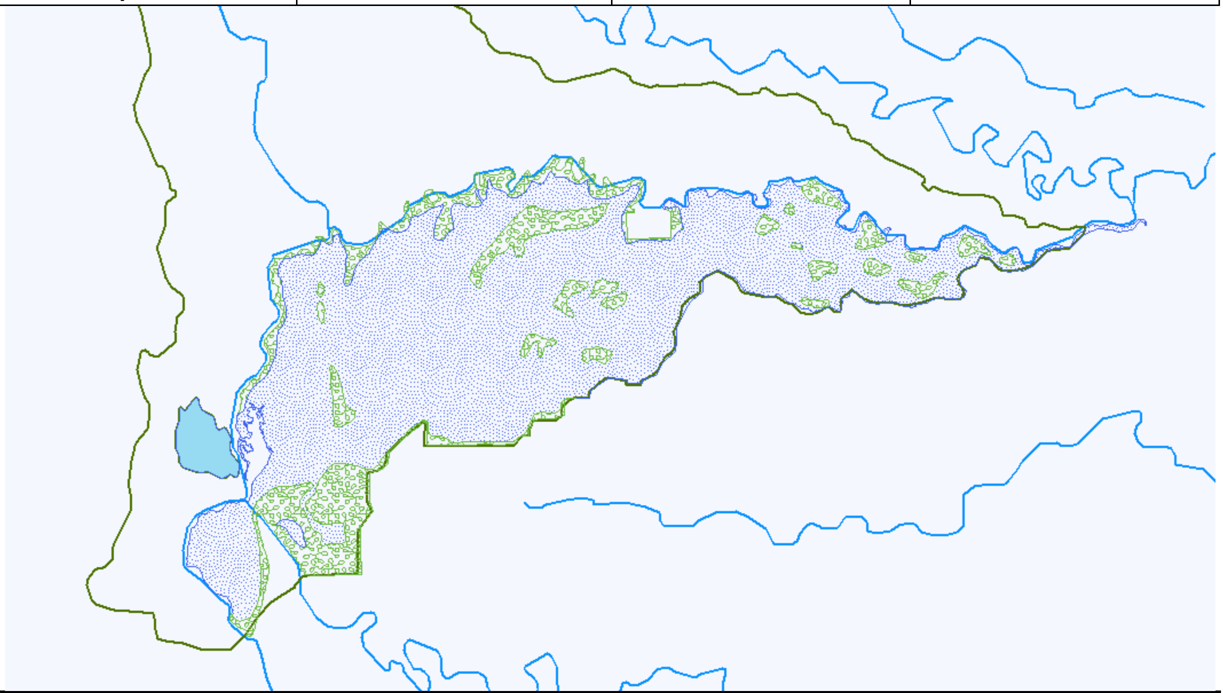
Legend		Flooded		Not Flooded

Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/214	762	Aug-66	Aug-66 – Nov-66

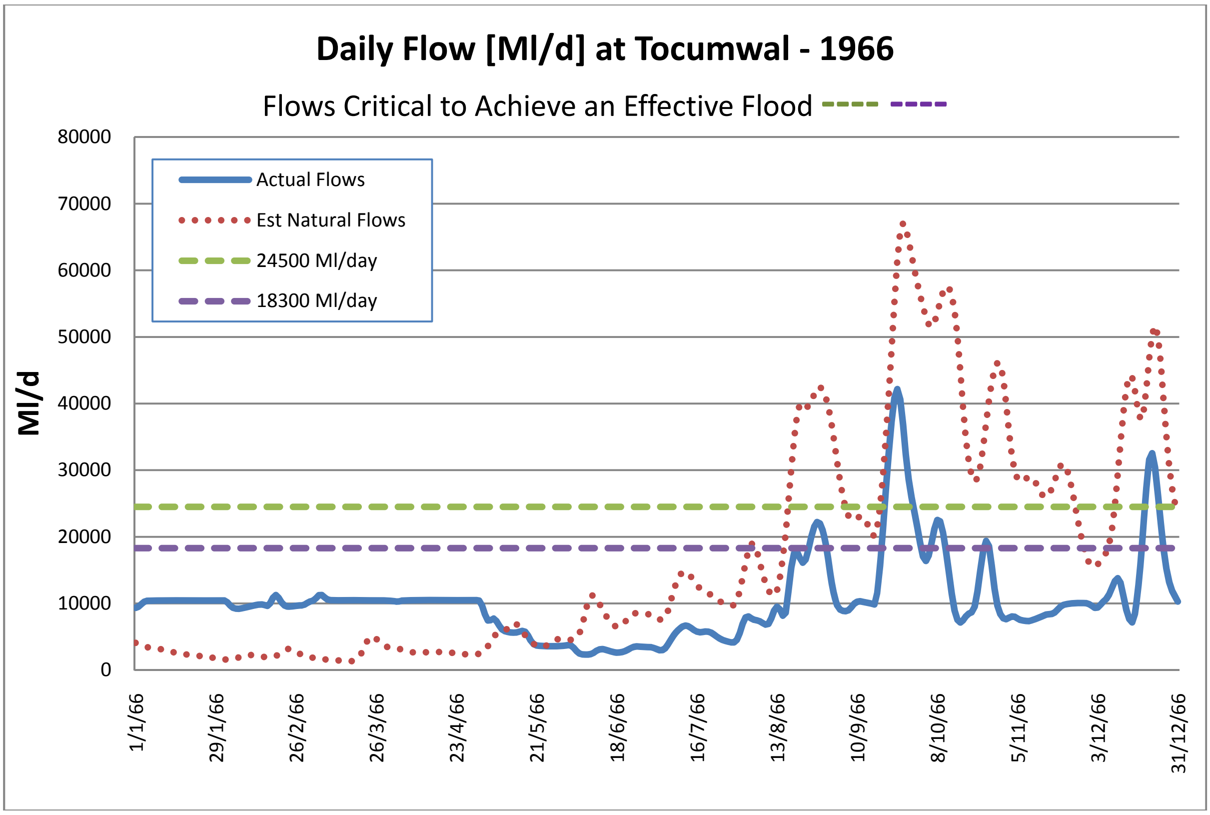


Legend		Flooded		Not Flooded

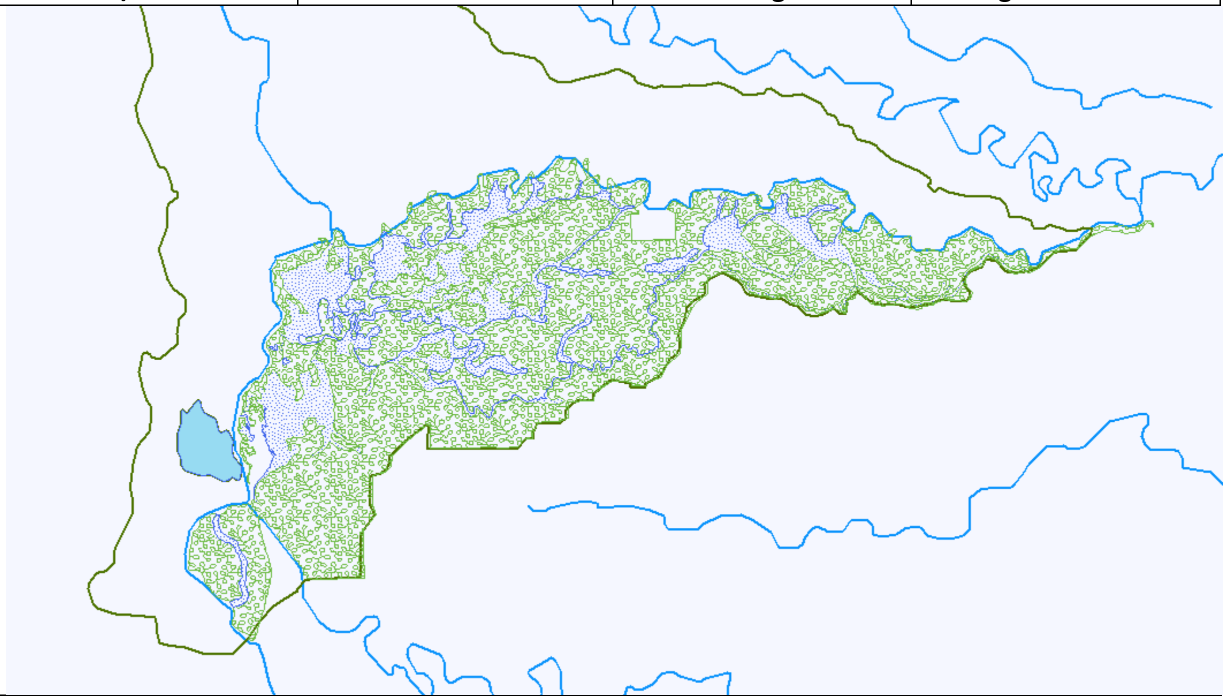
Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/213	763	Dec-66	Dec-66 – Jan-67



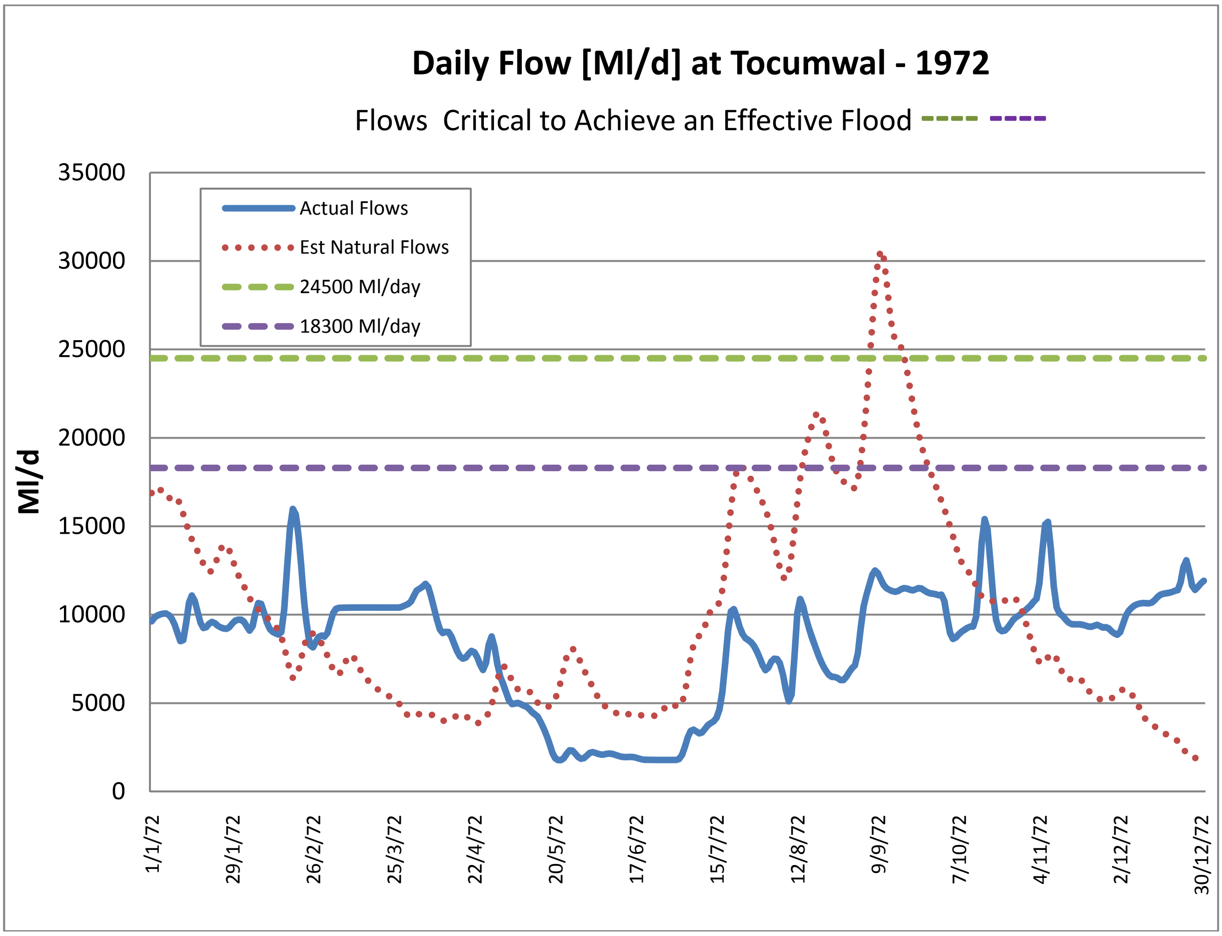
Legend		Flooded		Not Flooded



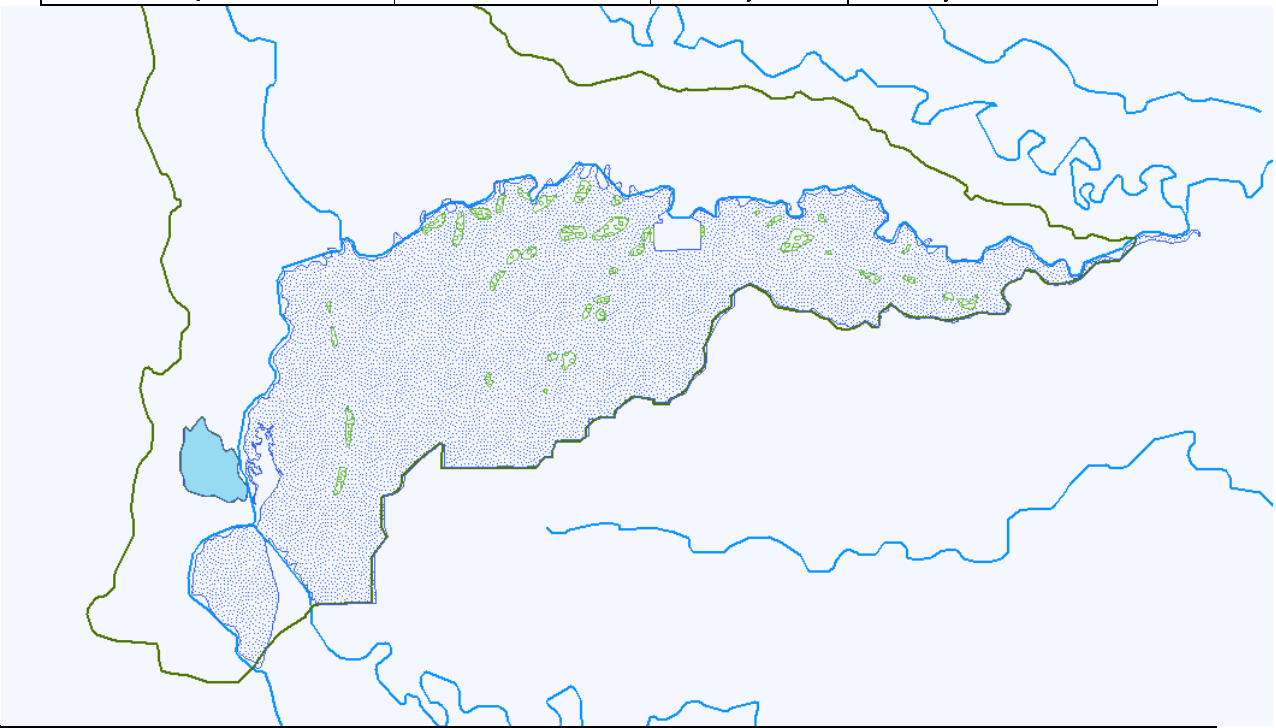
Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/206	443	10-Aug-72	10-Aug-72 – 10-Nov-72



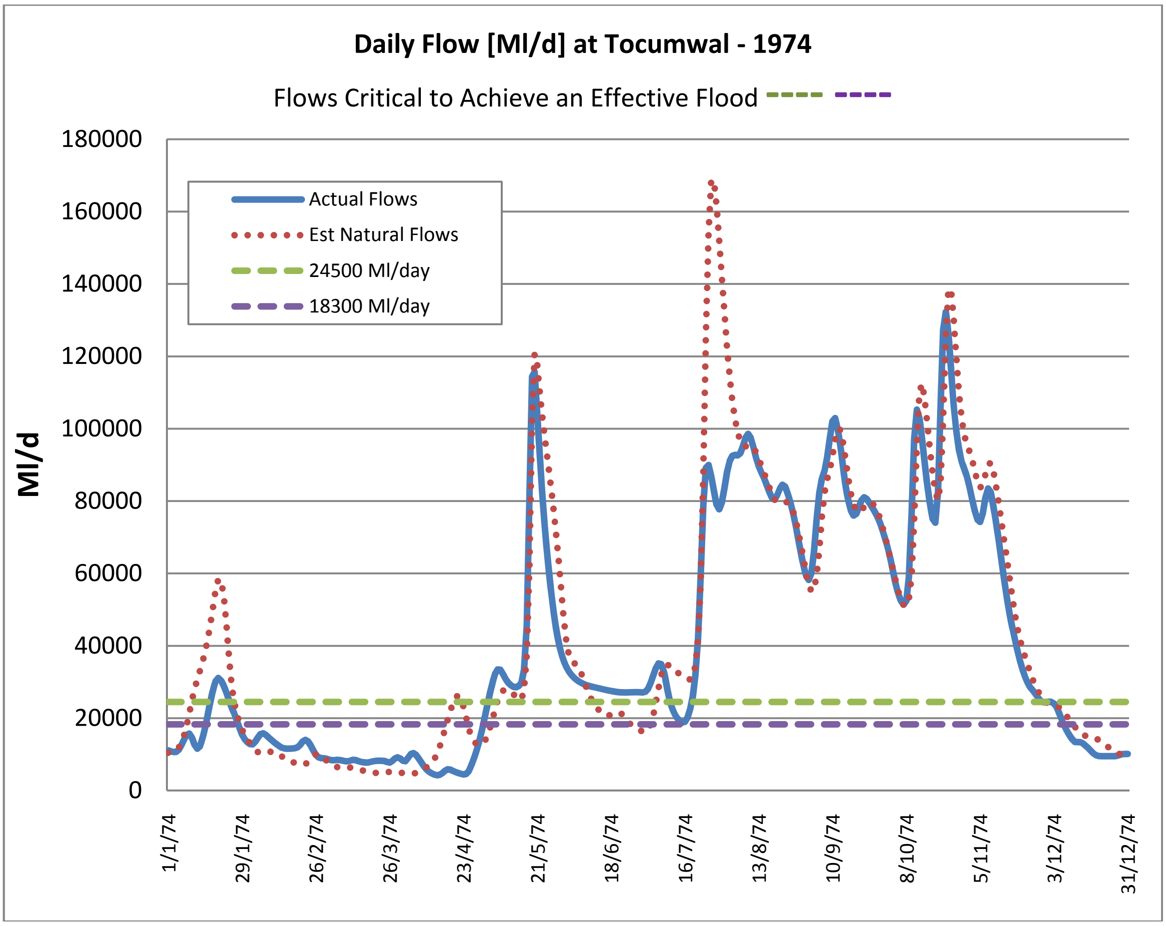
Legend		Flooded		Not Flooded



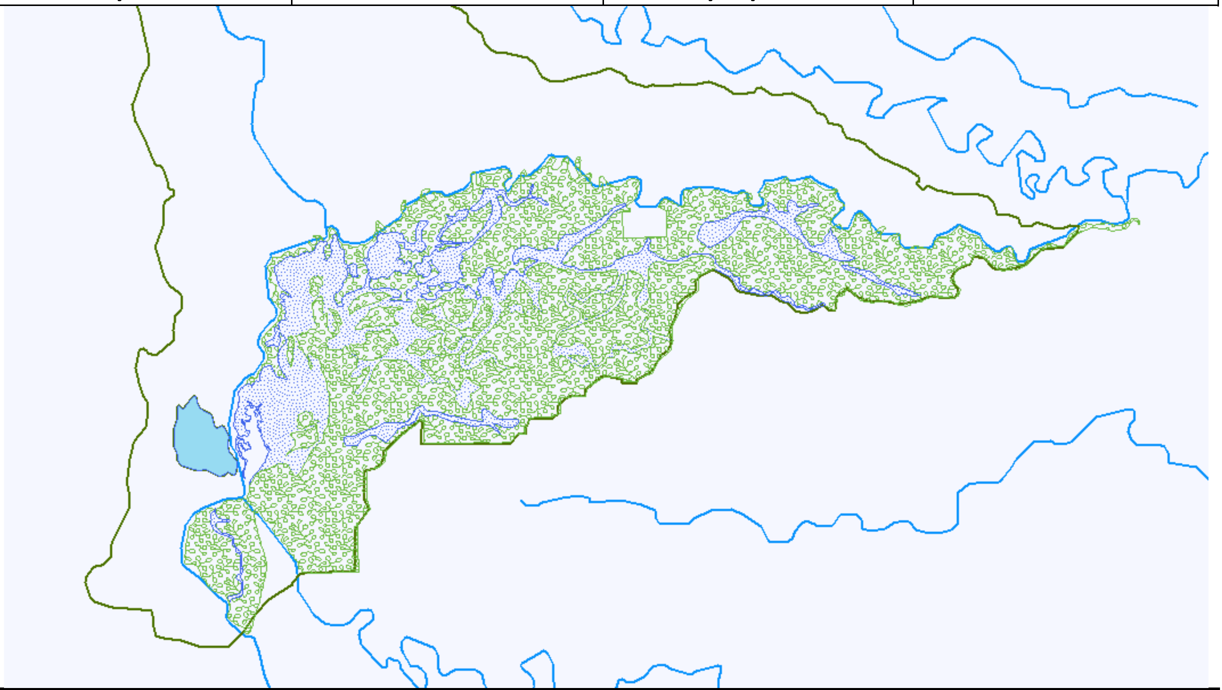
Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/200	769	May-74	May-74 – Dec-74



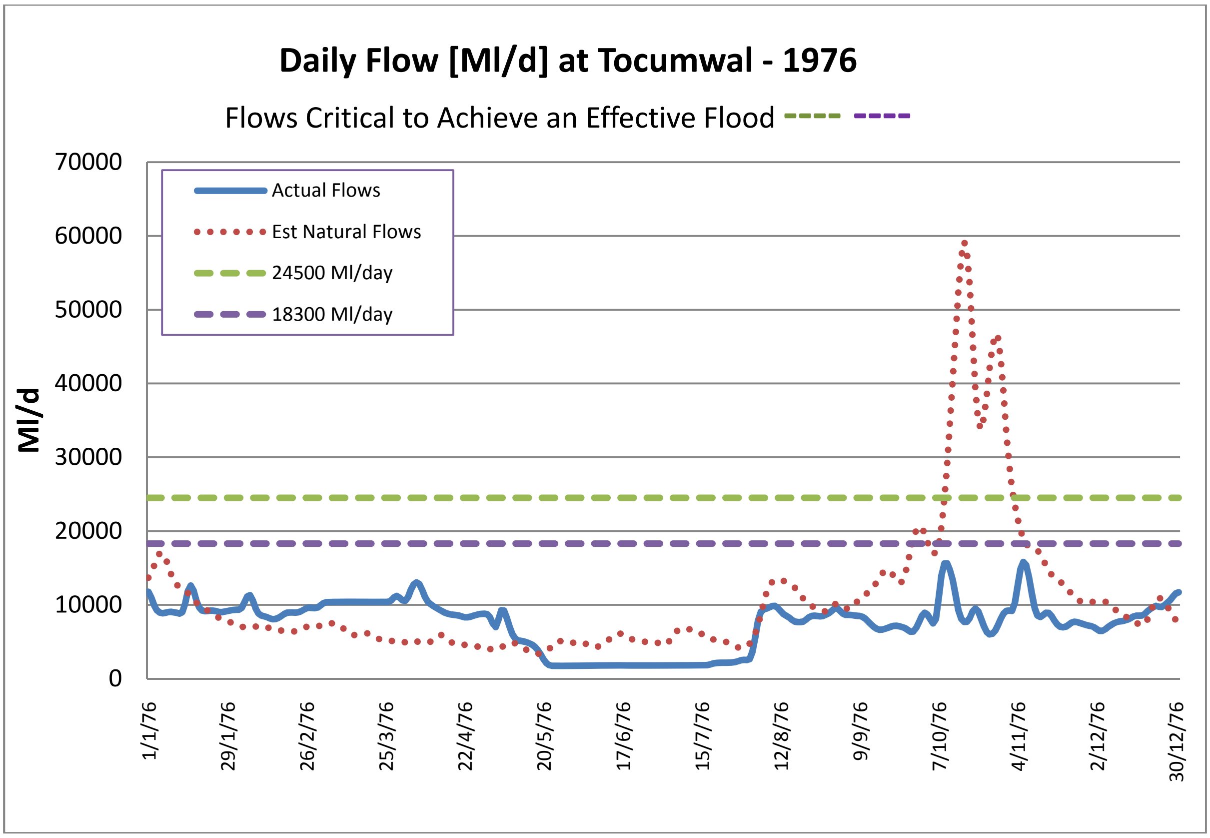
Legend		Flooded		Not Flooded



Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/198	771	1/12/1976	1976



Legend		Flooded		Not Flooded

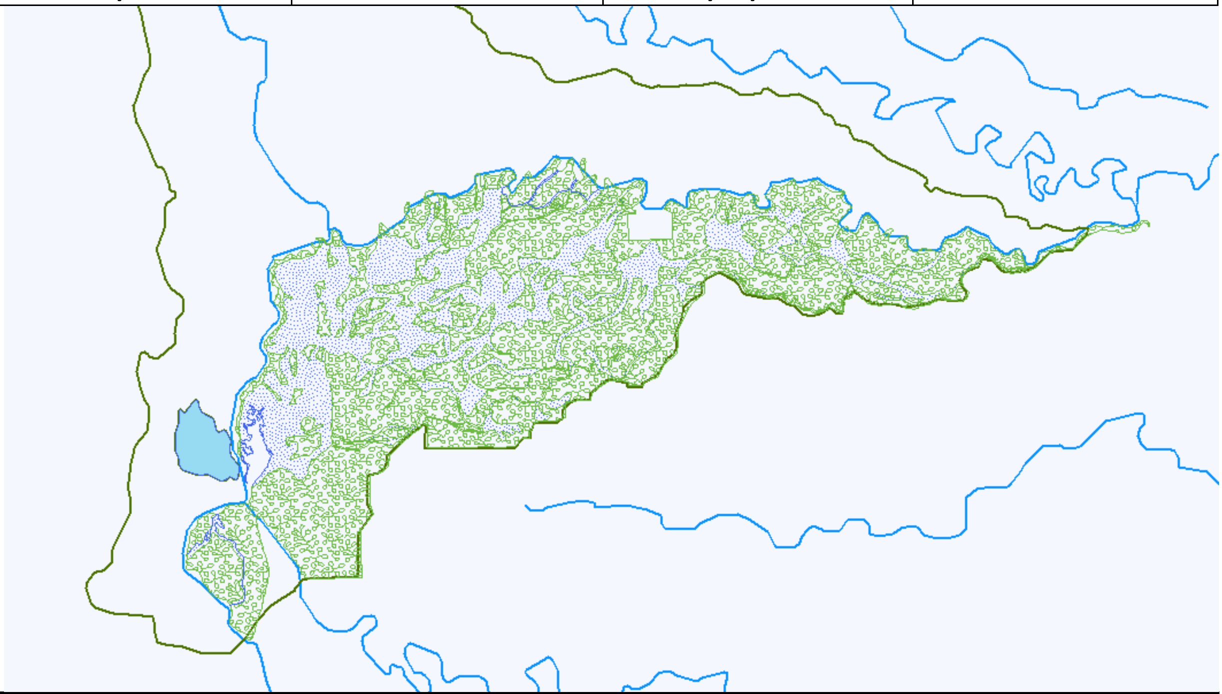


Approximately 8,000 ha, mainly moira grass plains, wetlands and red gum fringes, flooded for several weeks.
Regulators opened 8 October and closed 15 November.

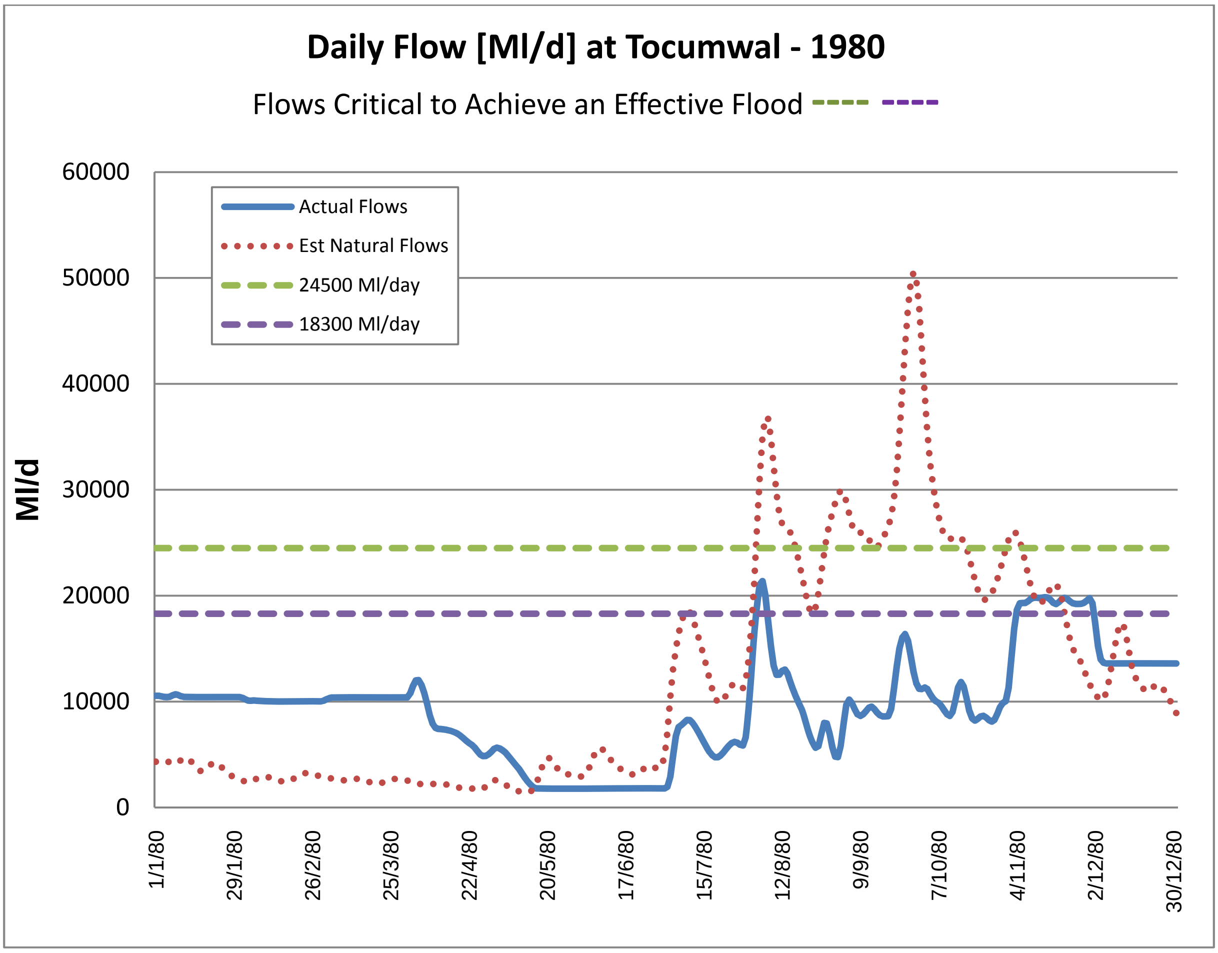
1976

Examination of monthly flow of the River Murray at Tocumwal, May to December, shows that October was the month of maximum average stream flow and that flows were relatively low 432 GL (mean 13,932 Ml/d) with substantial volumes being captured in Hume Reservoir. Records show that regulators were opened on 8th October and closed on 15th November with peak flows from 21st – 30th October totalling 209 GL (17,916 – 21,924 Ml/d) resulting in some 8,000 ha of moira grass plain, wetlands and some forest being flooded for several weeks.

Vertiplan No/map No.	Diapositive No.	Sort	Time of Flooding
1/186	753	1/12/1980	1980



Legend		Flooded		Not Flooded



1980

August 1980 was the month of maximum average flow, around 395 GL (12,740 Ml/day). Only two minor peaks occurred, viz: 4 – 6 August [20,457, 21,122, 19,283 Ml/day] and 22/23 September [17,376, 17,401 Ml/day]. All regulators were opened on 1 August and closed 9 September. Thereafter, selected regulators were opened and closed until all were closed on 23 December.

Approximately 9,000ha of plains, wetlands and red gum forest fringes were variously flooded in spring through to early summer in a pattern similar to 1976.

Comment. This highlights the desirability of examining daily flows rather than average monthly flows which masks the troughs and peaks leading to the coverage, fluctuations and longevity of the flood.
Given the regulator settings, key wetlands would have had water maintained for a few months although with fluctuating levels.
This again illustrates the role of regulators and potential for internal water management to effectively use very low river flows in winter/spring and early summer.
Again it would be important to know what NSW regulators were opened and closed and opportunities presented to improve flooding by active management of all regulators (NSW & Vic). Regrettably, this information is not available.

INDEX OF BARMAH FOREST FLOOD MAPS

Vertiplan No / Map No.	Diapostive No.	Sort	Time of Flooding			Scale
1/216	777	May-65	May-65	-	Jun-65	1:63,360
1/175	440	19-Aug-65	19-Aug-65	-	29-Sep-65	1:63,360
1/217	440	19-Aug-65	19-Aug-65	-	29-Sep-65	1:63,360
1/215	761	Mar-66	Mar-66			1:63,360
1/214	762	Aug-66	Aug-66	-	Nov-66	1:63,360
1/213	763	Dec-66	Dec-66	-	Jan-67	1:63,360
1/212	764	1/12/1967	1967			1:63,360
1/211	765	1/12/1968	1968			1:63,360
1/174	441	23-Jul-69	23-Jul-69	-	10-Oct-69	1:63,360
1/210	441	23-Jul-69	23-Jul-69	-	10-Oct-69	1:63,360
1/209	766	1/12/1970	1970			1:63,360
1/208	767	Jun-71	Jun-71			1:63,360
1/207	442 *	7-Jun-71	7-Jun-71	-	16-Dec-71	1:63,360
1/206	443	10-Aug-72	10-Aug-72	-	10-Nov-72	1:63,360
1/203	444	30-Apr-73	30-Apr-73	-	31-May-73	1:63,360
1/204	444	30-Apr-73	30-Apr-73	-	31-May-73	1:63,360
1/201	768	May-73	May-73			1:63,360
1/195	445	13-Jun-73	13-Jun-73	-	28-Nov-73	1:63,360
1/196	445	13-Jun-73	13-Jun-73	-	28-Nov-73	1:63,361
1/205	465	1/12/1973	1973			1:47,520
1/200	769	May-74	May-74	-	Dec-74	1:63,360
1/199	770	1/12/1975	1975			1:63,360
1/198	771	1/12/1976	1976			1:63,360
1/197	772	1/12/1977	1977			1:63,360
1/194	773	4-Aug-78	4-Aug-78			1:63,360
1/188	433	1-Jun-79	1-Jun-79			1:63,360
1/176	434	8/06/1979	08-Jun-79			1:63,360
1/192	434	8/06/1979	08-Jun-79			1:63,360
1/190	435	13/06/1979	13-Jun-79			1:63,360
1/171	436	19/06/1979	19-Jun-79			1:63,360
1/173	436	19/06/1979	19-Jun-79			1:63,360
1/191	446	19-Jun-79	19-Jun-79			1:63,360
1/178	437	22/06/1979	22-Jun-79			1:63,360
1/189	437	22/06/1979	22-Jun-79			1:63,360
1/187	448	29/08/1979	29-Aug-79	-	5-Nov-79	1:63,360
1/193	774	1/12/1979	1979			1:63,360
1/186	753	1/12/1980	1980			1:63,360
1/185	754	1/12/1981	1981			1:63,360
1/184	755	1/12/1982	1982			1:63,360
1/183	756	1/12/1983	1983			1:63,360
1/182	776	19/01/1984	19-Jan-84	-	25-Jan-84	1:63,360
1/181	775	May-84	May-84	-	Jun-84	1:63,360
-	757	1/12/1984	1984			1:63,360
1/180	758	1/12/1985	1985			1:63,360
1/179	Map Only	01-Dec-86	1986			1:63,360
1/177	Map Only	01-Dec-87	1987			1:75,000

Note: Diapositive 757 has no map printed.

* Map 442 not found on disc

Mike 11 Hydraulic Model - Gulf Water Management Area

prepared for

Barmah Millewa Forum

Evaluation of Banks for Localised Flooding

March 2003

Maunsell Australia Pty Ltd

COPY NO. [ ]

Barmah Millewa Forum

Mike 11 Hydraulic Model - Gulf Water Management Area

Evaluation of Low Banks to Assist Forest Flooding

MARCH 2003

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Our Reference: 20018600

Mike 11 Hydraulic Model - Gulf Water Management Area

Evaluation of Low Banks to Assist Forest Flooding

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	21/08/01	Draft Report	Donald Macleod	
B	30/08/01	Draft Report	Donald Macleod	
C	04/09/01	Draft Report	Donald Macleod	
D	09/01/02	Draft Report	Donald Macleod	
E	13/03/02	Draft for Barrie Dexter	Donald Macleod	
F	08/04/02	Draft for Forest Economists	Donald Macleod	
G	06/05/02	Revised all SQ forest economics	Donald Macleod	
H	31/07/02	Draft Report	Donald Macleod	
I			Donald Macleod	
J	10/01/02	Final Report		
K	13/03/03	Final Report	Donald Macleod	Donald Macleod

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Appendix A References

Appendix B Timber Production in Barmah Forest

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

Executive Summary

Executive Summary

Introduction

1. This Executive Summary and the following report has benefited from comments provided by members of the Research, Evaluation and Monitoring Committee in September 2002.

2. Following a presentation at the November 2002 Forum meeting, it was agreed that this Report will become, after Forum approval in early 2003, an input into the Murray Darling Basin Ministerial Council's "Living Murray" debate as a possible water use efficiency measure. It describes the expected engineering costs of typical low bank works within the Barmah-Millewa Forests as well the associated timber production and Greenhouse benefits.

3. At this time the report does not:
   - Provide an environment assessment to (NSW) REF standards.
   - Model any water quality effects .
   - Detail the required operational needs.
   - Prove the availability of the necessary engineering materials
   - Document the approval process required by Victorian and Commonwealth legislation.
   - Show that any enhanced timber production meets the environmental requirements of the Victorian Code of Forest Practice particularly those dealing with landscape, cultural and operational issues.

4. Later stages of this research project would address such issues.

Background

5. Support by the Forum for the development of a MIKE 11 hydraulic model of the Gulf Water Management Area (WMA) (in August 2000) followed the successful trial of air borne laser technology to create a Digital Elevation Model (DEM) of the area.

6. While calibration and verification of the MIKE 11 model still awaits small (or manageable) Murray floods, the opportunity has been taken to review the benefits and costs of creating low earthen banks (with the necessary regulators) to ensure regular flooding of selected areas within the Gulf WMA. This activity was originally proposed to follow the development of the MIKE 11 model but given the absence of floods for calibration, the low bank work has been advanced.

7. This report follows an earlier study by Maunsell in 1990 and field work in the Millewa Forest by Joe Murphy in the 1970's.

8. The objectives of the study (set by Maunsell as an expansion of Task 11 of the original brief) were to:
   - Seek practical means to use minor floods and freshes (plus a component of the EWA as required), for extensive watering of the forest.
   - Determine the increased timber production that might follow.
   - Review engineering and other costs particularly water costs.

Executive Summary

9. For the best of the practical means, compare costs and water use efficiency.

Strategies and Their Evaluation

10. Two strategies were followed to achieve these objectives for the Gulf WMA. The first was the use of low banks in the forest and the second the application of small man-made floods.

11. The low bank proposals consisted essentially of earthen banks (mainly constructed along existing roads) and water regulators (to ensure through flow (and thus maintain water quality, fish movement and interconnectivity with the Murray River) and also to control water levels and duration of flooding.

12. The “small flood” strategy developed relationships between the required flow in the River Murray, the operation of the Gulf and of other regulators in order to flood the same areas as the low bank projects. The key assumption to minimise Murray water use was to keep all other regulators closed during any such flood operation.

13. To contrast with both strategies a “Do Nothing” option was postulated. This option consisted of minor releases (100Ml/d) through the Gulf gates which was thought to flood about 3% of the Gulf WMA.

14. The strategies were evaluated beyond the “Do Nothing” case in terms of (1) cost effectiveness ($/hectare flooded) and (2) project benefits and costs.

Low Bank Works

15. Five banks were studied ranging from a Top Water Level (TWL) of 96.2 to 98.0. They were all based at the downstream end of the Gulf WMA. The flooded areas ranged from 1500 ha to 4200 ha or about 28% to 78% of the Gulf WMA. Figures in the following report shows the features of the low bank proposals as well as the DEM contours within the Gulf WMA and the location of existing gauging stations.

16. Helped by advice from Goulburn Murray Water, the low banks were costed at $1.4M for the low TWL 96.2 proposal to $7.6M for the TWL 98.0 scheme. These are serious construction costs for any Barmah-Millewa Forest works program. The cost items covered bulk earthworks, stripping and clearing, borrow pit and other rehabilitation works, road fixtures, (2) drop bar regulators, maintenance and operations.

17. The “cost effectiveness” of these banks ranged from $930/ha (for the lowest bank) to $1810/ha for the highest.

18. Given the high costs of these banks, an attempt was made during the study to optimise a low bank project. Two sites were selected in the middle of the WMA which appeared to show reduced bank lengths and reasonable flooded areas. The locations also required only one regulator. When analysed, the optimised sites showed mid range cost effectiveness at $1240 to $1340/ha flooded. The explanation appears to be that while

Executive Summary

bank lengths were optimised, the flooded areas were relatively reduced due to the increasing ground slope toward the Gulf regulator. On the related question that perhaps these “higher” areas might have a lower flood frequency, (and thus be capable of generating greater economic benefits), an estimate based on Professor Bren’s historic “Grid Square Analysis” showed no significant differences to the other Gulf project areas. Accordingly, the optimised low bank proposals were not considered further.

19. Water use for the low bank projects consisted of the water required to fill behind the low banks, evaporative losses for the months of August, September, October and November together with a 20% allowance for transmission losses associated with the through-flow water quality component.. The evaporative loss was taken as 0.47m each year. Of the through flow required to maintain water quality (taken as the “turn-over” of the ponded volume each month), 80% was assumed to be credited when returned to the Murray. The water required to initially fill the project area was also taken as a River Murray return credit.

Small Flood Projects

20. The flows assumed to flood the same Gulf WMA area as the low bank works were inferred from a set of gaugings taken in May 1984, the results from the 1990 River Murray MIKE 11 model and observations during the first and second uses of the EWA in 1998 and 2000.

21. The calculated Gulf regulator flows ranged from 1000ML/d for 28% flooded (corresponding to the TWL 96.2 project) to 3600ML/d for a flooded percentage of 78%, TWL 98.0). To match the low bank project, the inflows were assumed to run from August to November, a total of 120days.

22. Returns to the Murray of 70% of the inflow were assumed. This pattern of flows was assumed to balance evaporative losses and to provide adequate through-flow for water quality purposes. The total resource use ranged from about 45Gl for the small project to over 100Gl for the largest project. These estimated resources would represent a large portion of the annual 100 to 150GL EWA allocation.

23. When valued at $75/ML and capitalised to allow for three uses in each 10 years, this strategy produced resource costs of $9M to $29M, considerably greater than the low bank costs.

Environmental and Other Impacts

24. The low bank works could have environmental impacts including visual impact, perhaps transient water quality effects such as “Blackwater”, short term disruption during construction and some possible effects on fish passage. In addition, the effect of the low bank works on flood levels throughout the forest during the passage of high flood flows when the forest acts as a natural flood control reservoir needs to be a priority investigation when the MIKE 11 model is calibrated.

Executive Summary

25. The “Blackwater” effect (which received adverse publicity during the recession from the 2000 flood) will, for the low bank projects, depend upon the level of litter on the forest floor at the time of flooding. This in turn depends on additional litter fall induced by cumulative drought stress. With annual flooding, any impact should quickly decrease with time as was the case under natural flood conditions. Given the direct and precise control of the flooding operation, it would also be possible to provide extra flows during the December recession to maintain oxygen levels. This question should be a part of any subsequent EIS study.

Evaluation of Benefits

26. Benefit assessments have so far been limited to timber production increases and Greenhouse effects. Both of these are but one measure of the health and vitality of the river red gum trees in the ecosystem. The environmental benefits associated with bird and fish breeding, enhanced forest biodiversity and health, improved recreation opportunities and improved road access have not been considered at this time.

27. The low bank projects evaluated increased timber production and associated greenhouse benefits which could follow an improvement in flooding frequency from the present Gulf WMA frequency of about 7 years in 10 to a proposed 10 years out of 10.

28. Timber production values were based on data supplied by Timber Communities Australia. The data assumed increases in timber production (according to flooding regime) under three timber production scenarios. The first consisted of current timber stand and environmental prescriptions and current water management practice. Scenario 2 adopted timber production as the primary aim but allowed full cognisance of active water management, silviculture treatment and environmental prescriptions in accordance with the Code of Forest Practices and existing conservation areas. Scenario 3 assumed forest management was directed to maximising timber production.

29. Incremental timber production was then calculated for the case of an existing Gulf WMA frequency of 7 years out of 10 being encouraged to 10 years out of 10. The timber production increments were typically about 0.70m3/ha/a for saw logs and 0.50m3/ha/a for other products under all three scenarios.

30. The increased timber production was then valued as “Mill Door Values” as follows:

▪ Appearance timber	7% of the log	valued at	$1750/m3
▪ Structural timber	18%		$480
▪ Residual timber	14%		$260
▪ Firewood	28%		$55
▪ Mulch	33%		$5

31. The marginal cost of achieving these production increases (including felling and preparation, haulage, milling and kiln drying) was then deducted from the mill door values to produce total margins. For Scenario 1 the total margins were typically $28 to $35/ha/a.

Executive Summary

32. At a flooding frequency of 7 years out of 10, the Gulf WMA imposed some limitation on the benefits to be realised. For example, If the area being flooded had a present flooding frequency of only 5 years out of 10 (perhaps having fallen from say, 7 or 8 years out of 10), the total margins would more than double to become $57 to $78/ha/a.

33. The conservative evaluation of Greenhouse benefits used the same timber production scenarios and the same increases in flooding frequency. The resulting benefits amounted to about $2/ha/a or close to 7% of the timber production benefit.

34. Evaluation of timber and greenhouse benefits was done for each Scenario. Separate tables in the report then present the costs and benefits for each of the low bank works. Each table incorporated a separate analysis which assumed water costs (taken at $75/Ml) did not apply. Given water costs were generally equivalent to construction costs, this assumption was critical although it could be justified on the grounds of past history, lack of precedent, of ease of administration and environmental as the EWA, surplus flows and freshes do not attract payment.

Results

35. The best two low bank projects for each Scenario are almost always the two smallest projects with TWL's of 96.2 and 96.4. When water costs are excluded, benefit cost ratios are above 0.4. With water costs included the benefit cost ratio becomes 0.1.

36. The difference between timber production scenarios is not marked. For the TWL 96.4 project, the benefit cost ratio ranges from 0.56 for Scenario 2 to 0.46 for Scenario 3. This is to be expected on this WMA which considers increasing watering from 7 years in 10 to 10 years in 10.

37. As well as showing up in the benefit cost analysis, the two small projects were also the best when judged on a cost effectiveness ($cost per ha) basis. The TWL 96.4 project costs $980 per flooded hectare.

Preferred Project

38. If a preferred project had to be selected at this time it would probably be at the small end of the range. Those with a TWL between 96.2 and 96.5 appear to produce the highest benefits.

39. For the TWL 96.4 project, the following engineering features apply:
    - Bank length 17km
    - Bank width 10m
    - Clearing for roadway 24ha
    - Clearing for borrow pits 20ha
    - Maximum bank height about 2m
    - Average bank height about 1.2m

Executive Summary

- Regulator waterways — about 24m² and 12 m2
- Regulator capacities — about 2000ML/d and 1000 ML/d
- Bulk earthworks — 293,000m³
- Estimated cost — $1.9M

Water Resource and Cost Comparison

40. As a summary of the earlier benefit cost analyses, tables in section 8.5 present a water use efficiency and cost comparison between the above Preferred Project and its small flood alternative. The two tables cover first a year of water application and secondly, a non-watering year. The assumptions used in the comparisons are set out in each table and are generally as described earlier in this summary.

41. For a year when water is applied in the Gulf WMA, the low bank works (at $840/ha/a) show a significant cost advantage over the small flood strategy at $2320/ha/a. The water use comparison also favours the low bank project. Its water use in these years is estimated at 10Ml/ha/a compared to 31Ml/ha/a for the small flood alternative.

42. If however, water costs were to be excluded, the cost effectiveness position is reversed with the small flood option costing $24/ha/a against $100/ha/a for the low bank works.

43. The benefit cost ratios in the summary spreadsheets also reflect these conclusions with the low bank works (b/c = 0.11) showing double the return of the small flood strategy (b/c = 0.05) when water costs are included. With water costs excluded, the small flood strategy at a b/c figure greater than 5 shows as a preferred project over the low bank figure at 0.4.

44. Because of the capital cost of the low bank works, in any non-watering year (ie 7 years out of 10) when the timber production benefits remain the same, the low bank works still require a capital repayment of $150,000 against no costs at all for the small flood strategy.

Conclusions

45. The conclusions from this discussion paper include:
    - The air-borne laser DEM provides a suitable base for planning low bank and other engineering works in the forest.
    - The whole forest DEM should be analysed when available to seek “better” sites for possible low bank works.
    - The most cost effective projects and those with the highest benefits are at the small end of the scale.
    - Excluding water costs for the low bank works produces more readily justified projects but leaves the alternative small flood projects without a suitable cost base.
    - Comparisons between the Preferred Project and the small flood alternative match these economic conclusions and confirm that the water use advantages lie significantly with the small bank works.
    - The low bank works have serious capital requirements over any small flood option.

Executive Summary

- With water costs included, environmental benefits would need to cover about 90% of project costs. This would be a large but not impossible task.
- Timber production increases represent over 90% of the benefit stream.
- There are significantly greater benefits to be gained in water management areas involving increases in flood frequency to 10 years out of 10 from say 4-5 years in 10 rather than the 7-8 years in 10 tested here.
- When water costs are included, the low bank projects appear to offer benefit cost advantages over the small flood strategy.
- As illustrated by the short analysis of the two mid WMA projects, there may are also be greater benefits to be gained in those WMA's that are less steep than the Gulf WMA.
- River Red Gum forests further downstream say in South Australia may offer "flatter areas" more readily flooded with low banks.
- Finalisation of the MIKE 11 project will allow many of the assumptions in this discussion paper to be tested.

Follow on Actions

46. The conclusions from this study could be of interest to the "Living Murray" community consultation process and Forum support will be sought for the paper to be lodged with the Murray Darling Basin Commission.

Still Required

47. The Discussion Paper has been limited to providing indicative benefit costs of some low bank proposals to facilitate, at low river flows, mimicking (season frequency and duration) natural flooding characteristics and enhancing (annual) flooding in a section of the Barmah Millewa Forest.

48. There are significant environmental components which are widely recognised as difficult to value in dollar terms which have not been included in these benefit costs.

49. It is too early to provide detail on matters such as within forest operational requirements, specific actions to satisfy desired biological outcomes and on any EIS/Approval process.

50. What is required now is to consider the Paper's contribution, in the context of social, economic and environmental issues, to the environmental flows debate, including the important issues of water use efficiency and management.

1 Introduction

1 Introduction

To improve the understanding of Barmah-Millewa Forest hydraulics, the development of a MIKE 11 model of the Gulf Water Management Area (WMA) has been supported by the Barmah-Millewa Forum. This report deals with one of the promised aspects of the MIKE 11 proposal and reviews the use of low banks and other approaches to extend the area flooded by small floods, rain rejections and freshes during regulated flow periods and during use of the Environmental Water Allocation. These projects thus help to meet the watering requirements (frequency, season, duration) of flora and fauna by deliberately managing the EWA and small floods.

1.1 Barmah-Millewa Forests

The Barmah-Millewa Forests are the world's largest River Red Gum Forest. The forests support a unique range of wetland habitats including swamps, rush lands, lakes, streams, red gum and box forests. These habitats rely upon regular and extensive flooding at specific times and for adequate duration. Major consequences of the present level of River Murray water storage and regulation are the high summer irrigation flows and the associated reduction in spring floods. Regulators and levee banks have been constructed throughout the forest to help contain summer flows to the river. The Gulf Regulator is the largest of these regulators.

1.2 Barmah Millewa Forum

In June 1994, the Murray Darling Basin Ministerial Council approved the setting up, under the provisions of the Murray Darling Basin Agreement, of two advisory groups that have since become the "Barmah-Millewa Forum".

The vision of the Forum is:

- *To maintain and where possible, improve the ecological and productive sustainability of the Barmah-Millewa Forests*
- *To establish a planning and operational framework to better meet the flooding and drying requirements of the riparian forests and wetlands.*

The Forum has responded to its vision statement by developing the "Barmah-Millewa Forests Water Management Strategy". In April 2000, the Murray Darling Basin Commission finalised, with assistance from consultants, community representatives, forest and water authorities, a comprehensive strategy to help manage water planning and annual operations.

The links between the Water Management Strategy and the "Low Bank" project are discussed in the following section.

1.3 Barmah-Millewa Forests Water Management Strategy

The strategy is formally known as:

- Murray Darling Basin Commission, *The Barmah-Millewa Forest Water Management Strategy,* June 2000.

1 Introduction

The Strategy consists of nine (9) Objectives and a number of related and more detailed subordinate strategies. In the following table, the links between the "Low Bank" projects and the Objectives are summarised. The detailed wording of each Objective can be found in the above reference. The detailed description of the Low bank works follows in this report.

Links to the Barmah-Millewa Forest Water Management Strategy

Objective (Paraphrased)	Low Bank Link
(1) Single ecosystem	The Gulf Water Management Area (WMA) was selected as representative of the whole ecosystem
(2) Optimise use of river flows	The Low Banks can flood the Gulf WMA forest and wetlands from even regulated river flows, i.e. floods are not required.
(3) Independent management of selected areas of forest	The Low Bank works are studied within the Gulf WMA. The works are generally located along the WMA boundary.
(4) Provide water management structures	Low banks, roads and drop bar regulators are incorporated in the projects.
(5) Historical records	Not applicable to Low Bank works
(6) Monitoring scientific information	Only indirectly involved in the planning of the Low Bank works.
(7) Monitor social and economic information	The economic analysis of the Low Bank works relies on recent economic values of timber production and market prices, water costs and construction costs.
(8) Applying environmental knowledge to manage adaptively.	The planned Low Bank projects rely upon increasing flooding frequency, combating the threat of "Black Water" and encouraging fish movement
(9) Develop plans to implement the Strategy effectively.	As the works improve water use efficiencies, Water Management Strategy implementation is enhanced.

As can be seen from the table, the Low Bank proposals are well linked to seven (7) of the nine (9) Strategy Objectives.

1.4 MIKE 11 Model

MIKE 11 is software developed by the Danish Hydraulic Institute (DHI) capable of carrying out one-dimensional flow calculations in rivers and floodplains. A MIKE 11 model of the River Murray channel (and all the forest regulators) between Tuppal Creek and Barmah already exists. It is planned that in time, models of most WMA's could be combined with the main stream model thereby producing a comprehensive hydraulic model of the whole forest. The Gulf WMA is the first WMA to be tested.

1 Introduction

1.5 Digital Elevation Model of Gulf WMA

The Gulf WMA was selected by the Forum for the MIKE 11 modelling as it was earlier the first Digital Elevation Model (DEM) in the forest. The DEM was developed through air born laser altimeter technology. The Gulf WMA was selected for the first DEM trial as a 1960 SRWSC "dumpy and staff survey already existed for much of the WMA and was thus available to provide an independent check of the laser survey results. The trial DEM was completed in the year 2000 and checked remarkably well against the original SRWSC survey. The final DEM consisted of over three (3) million individual tree top, understorey and ground level points.. A report on the laser survey is available from the Forum as:

> Gang-Jun Liu, Rick Frisina and Adam Choma, "*Airborne Laser Scanning and High Precision Digital Elevation Modelling of the Barmah Forest, Pilot Study Report*", Land Information Group, Natural Resources and Environment, no date but thought to be about June 2001.

The DEM checked well against the original SRWSC survey.

The DEM (after testing and subsequent modification) has been used to provide contour information for low bank and flooding proposals.

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> Gang-Jun Liu, Rick Frisina and Adam Choma, "*Airborne Laser Scanning and High Precision Digital Elevation Modelling of the Barmah Forest, Pilot Study Report*", Land Information Group, Natural Resources and Environment, no date but thought to be about June 2001.

1 Introduction

The DEM (after testing and subsequent modification) has been used to provide contour information for low bank and flooding proposals.

1.8 Extensive / Intensive Management

In both 1998 and 2000/2001, the EWA (in conjunction with Murray floods) was successfully used to enhance bird breeding in the Millewa Forest. Forum reports on these uses of the EWA have been finalised as:

- Maunsell McIntyre, "Barmah Millewa Flood of October 1998 and the First Use of the Barmah-Millewa Forest Allocation", August 1999, for the Barmah-Millewa Forum.
- Maunsell McIntyre, "Barmah-Millewa Forest Flood of Spring 2000 and the Second Use of the Barmah-Millewa Forest Environmental Water Allocation, Spring and Summer 2000/2001", July 2001, for the Barmah-Millewa Forum.

By concentrating floods and the EWA in particular wetlands, the use of the EWA could be described as "Intensive". However, other parts of the Forest are then by definition, being neglected. While these intensive uses have been both successful and newsworthy, other members of the Forum and outside stakeholders have raised the question of alternative uses for the EWA. Resolving this question has been formalised as part of the Murray Darling Basin Commission's President's (Dr Roy Green) recent review of the Forum and terms of reference for a study to examine "Extensive versus Intensive" use of the EWA are under preparation for study in the 2002/2003 year. This suggestion had also been advanced previously by the immediate past Chairman of the Forum, David Harriss.

If targeting wetlands to encourage bird breeding is "Intensive", spreading water over large areas of the forest to say, encourage a wider range of biological outcomes including timber growth, could thus be regarded as "Extensive". Clearly, given the complexities of forest hydraulics, both approaches could produce benefits in the other area. The case for one approach or the other may therefore never be clear-cut.

This report will become one of the background papers for the "Extensive/Intensive" desk top study.

1.9 Joe Murphy Banks

Plans to spread rain rejection water in the forests had their genesis in the 1970's when Joe Murphy, then a State Forests of New South Wales Supervisor, used 'spare timber, free bulldozer hours' and out of hours work to create small earth banks and even smaller regulators to enable a large patchwork of areas of the Millewa Group of Forests to be watered and thus to relieve stressed forest. A description of the technique can be found in:

Murray Darling Basin Commission, *"The Murray",* 1990, Edited by Norm McKay and David Eastburn, Chapter 15, pages 245–248, *"Watering the Millewa Forest"*, Joe Murphy.

1 Introduction

The “small banks” were also favourably evaluated in the 1991 Water Management Plan by Maunsell and others. However, use of the Murphy banks was later criticised by environmental interests on the grounds of too many banks, the flooded areas were too small, water management operations could be costly, overtopping during floods could destroy the banks and “black water” (coloured water low in oxygen) would result because of inadequate through flow. These criticisms were largely overcome in the Water Management Plan (Maunsell 1991) by carefully engineering the banks, making the flooded areas bigger and by incorporating downstream regulators. A recent review of this 1991 analysis showed that the cost basis for the low bank works was probably far too low.

This report now attempts a further analysis in the light of even higher environmental expectations, environmental standards and even fewer operational staff.

2 Objectives

2 Objectives

2.1 Objectives for Extensive Use of the EWA

The objectives for this study were set by the Maunsell team as an expansion of the brief's task 11. They were:

1. To seek practical means to use minor floods, and freshes and/or the EWA for extensive watering of the forest. (This objective is consistent with the MDBC's Water Management Strategy).
2. To determine if increased timber production could arise from such approaches.
3. To review engineering and other costs.
4. To examine the benefits from any increased timber production.
5. To confirm the environmental acceptability of the preferred method.

2.2 Strategies

Two broad strategies were examined. The first was the use of "low banks" in the forest and the second the use of man-made floods without any banks.

2.2.1 Low Banks

A number of low bank projects (of varying heights) were developed (based on the DEM) to flood downstream areas of the Gulf WMA. The banks ranged in height up to 2m and were fed on an annual basis by water from rain rejections, freshes or the EWA.

2.2.2 Man-Made Floods

As the only real alternative to low banks, proposals using small man-made floods were developed to flood areas equivalent to the areas flooded by the low banks. Without the help of low banks, quite large Murray floods and high flows in the Gulf WMA were required.

2.3 "Do Nothing" Comparison

Both strategies were then compared with the "do nothing" scenario in terms of cost, benefits and environmental impacts. The "do nothing" scenario assumed only minor releases into the Gulf WMA.

3 Low Bank Proposals

3 Low Bank Proposals

3.1 Description

3.1.1 DEM

A Digital Elevation Model (DEM) provided by Natural Resources and Environment's (NRE) Land Information Group was utilised to produce a useable contour plan of the Gulf Water Management Area (WMA). The initial DEM data set provided very detailed information. However due to its large size it proved not to be practical for ready analysis and manipulation. The number of points in the data set was then reduced by 60%. The reduced data set, while still large, proved to be more manageable.

3.1.2 Survey Contours and Presentation

These resulting contours were overlain on aerial photographs for proofing and presentation purposes. Presentation options for the contours were evaluated, with a view to colour schemes that would provide a definable graduation between the contours. The colour scheme that was chosen was from red to green representing contours from high to low as is commonly used in atlas mapping. This adopted presentation is shown on Figure 3.1: *Contours and Features Plan*. The plan also shows the WMA boundary, the location of stream gauging stations and place names.

3.1.3 Location of Banks/WMA

The initial locations of the banks matched the downstream boundary of the Gulf Water Management Area (Gulf WMA).

This approach was then modified to have the low banks follow, as far as possible, any road network around the edge of the WMA. This minimised the vegetation clearance required. The majority of the proposal thus involves the raising of the existing roadways. However for part of the bank length, for example between chainages 10 km and 16km (see figure 3.1), there are no existing roads, resulting in additional earthworks and road works in this area.

A downstream regulator was required to both control water levels, maintain fish passage and pass flood flows. It was placed at the low spot near the Budgie Creek.

3.1.4 Chainage

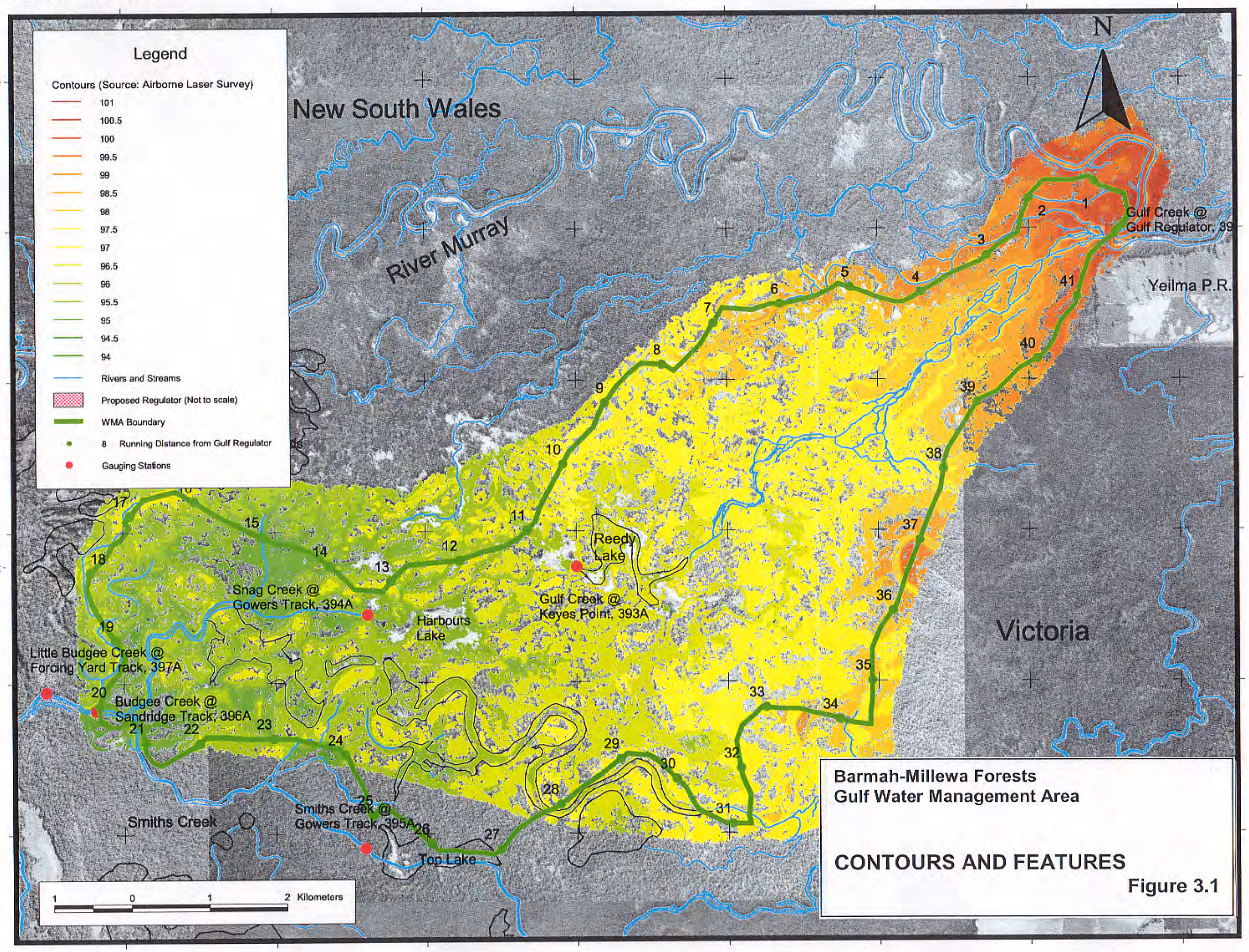
The banks have been designed to be overtopped thereby minimising major reconstruction/repair works after floods. Flat grassed side slopes of 1 to 5 both upstream and downstream have been adopted.

The chainages shown in Figure 3.1 were developed on the basis of having a starting point at the upstream end of the WMA. The chainage was then measured around the boundary in an anticlockwise direction. The chainage allows for the ready identification and location of the banks around the WMA.

At this time, the impact of the Low Bank works on larger Murray floods has not been determined. This task will become an important MIKE11 run once the hydraulic model is calibrated.

AMG 320000

AMG 6034000



Barmah-Millewa Forests
Gulf Water Management Area

CONTOURS AND FEATURES

Figure 3.1

3 Low Bank Proposals

3.1.5 Regulator

It is proposed to locate a regulator at the outflow point of the WMA on Budgie Creek The preliminary design for the regulator allows for a through velocity of about 1m/s to better cater for native fish movement.

In detail, the regulator design has been based on a flow of 2000 Ml/day through the Gulf WMA which corresponds to a Tocumwal flow of about 15,000 ML/d. To meet the 1 m/s velocity requirement, the regulator needs to be a 6 bay structure, with each bay nominally 2m wide by 2m high. Water levels and flows would be controlled with drop bars. A smaller regulator is also required on the northern side of the WMA to allow another natural inflow to enter the WMA. This flow could be up to 1000ML/d and the structure would be 2 to 3 bays of similar dimensions. At both locations, road bridges combined with the regulator will be provided. The bridges will be typically 8m wide to allow for passing movements on the bridge.

The Mike 11 modelling for the Gulf WMA will refine the design flow requirements of the regulator. In particular, there are a number of gauging stations both within the WMA (3) and downstream of the WMA (3) that may be utilised in the modelling and the design of the regulator.

Figure 3.2 shows the longitudinal profile around the boundary of the WMA, with the approximate locations of the proposed regulators indicated. It also shows typical cross sections of the regulators and the proposed banks.

3.2 Low Bank Alternatives

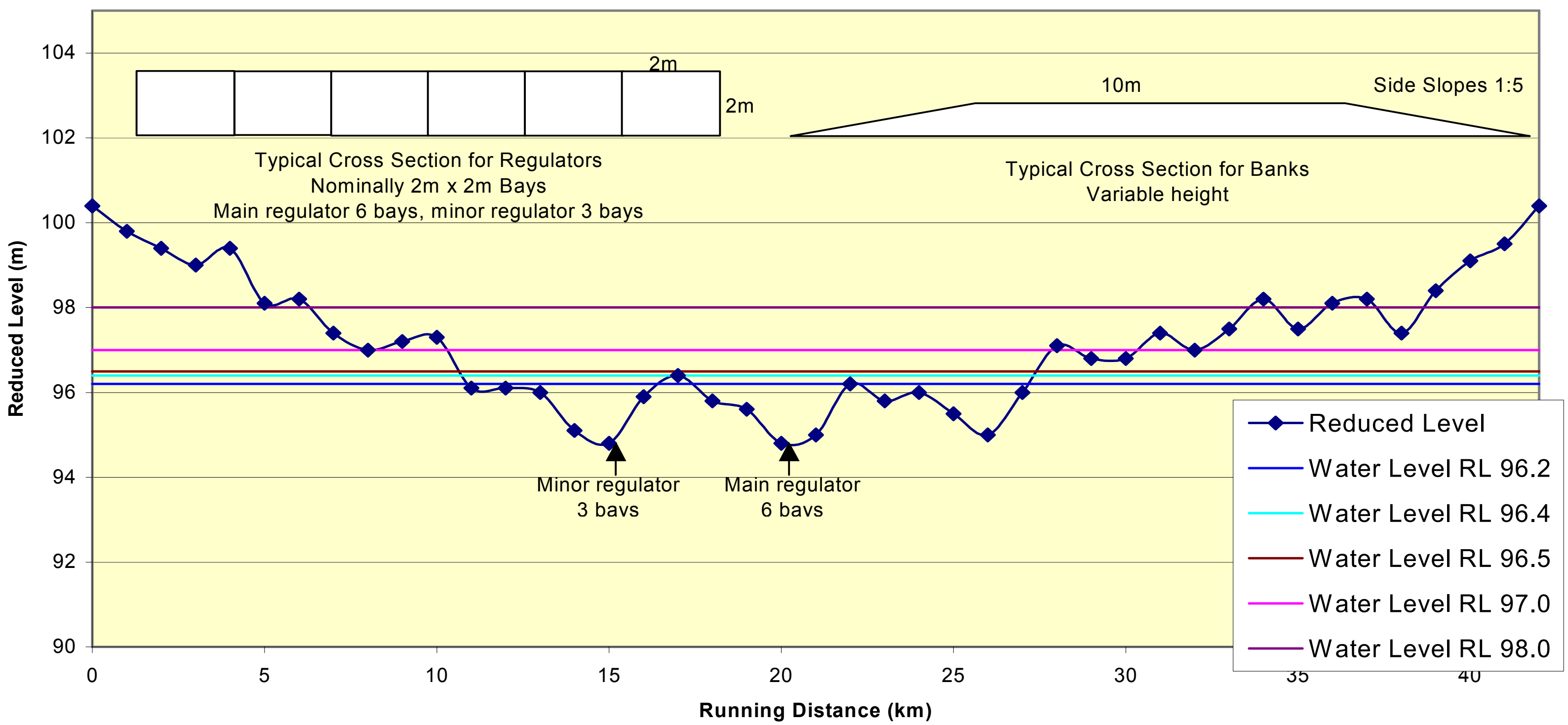
Initially, given the contour intervals provided by the airborne laser surveys, nominal bank heights providing notional water depths of 0.5m, 1m and 2m were selected for evaluation. In each case, the banks were designed to provide the notional water levels above much of the road around the downstream end of the WMA. Figure 3.2 provides an illustration.

In each case, freeboard (0.4m for the low banks and 0.5m for the high banks) was allowed above the effective water level, resulting in effective bank heights of 0.9m, 1.5m and 2.5m.

Upon a review of the range of the initial cost estimates, lower bank heights providing notional water depths of 0.2m and 0.4m were added to the analysis. Flooded areas were calculated using the ARCVIEW program. They ranged from 1500 ha for the lowest bank to 4200 ha for the highest. These flooded areas were thus far greater than the earlier “Joe Murphy banks”.

The range of proposals thus covered Top Water Levels (TWL) of 96.2 to 98.0. The top water levels and the top of bank elevations tested in this analysis are summarised in section 3.2.

Figure 3.2: Longitudinal Profile of Bank



3 Low Bank Proposals

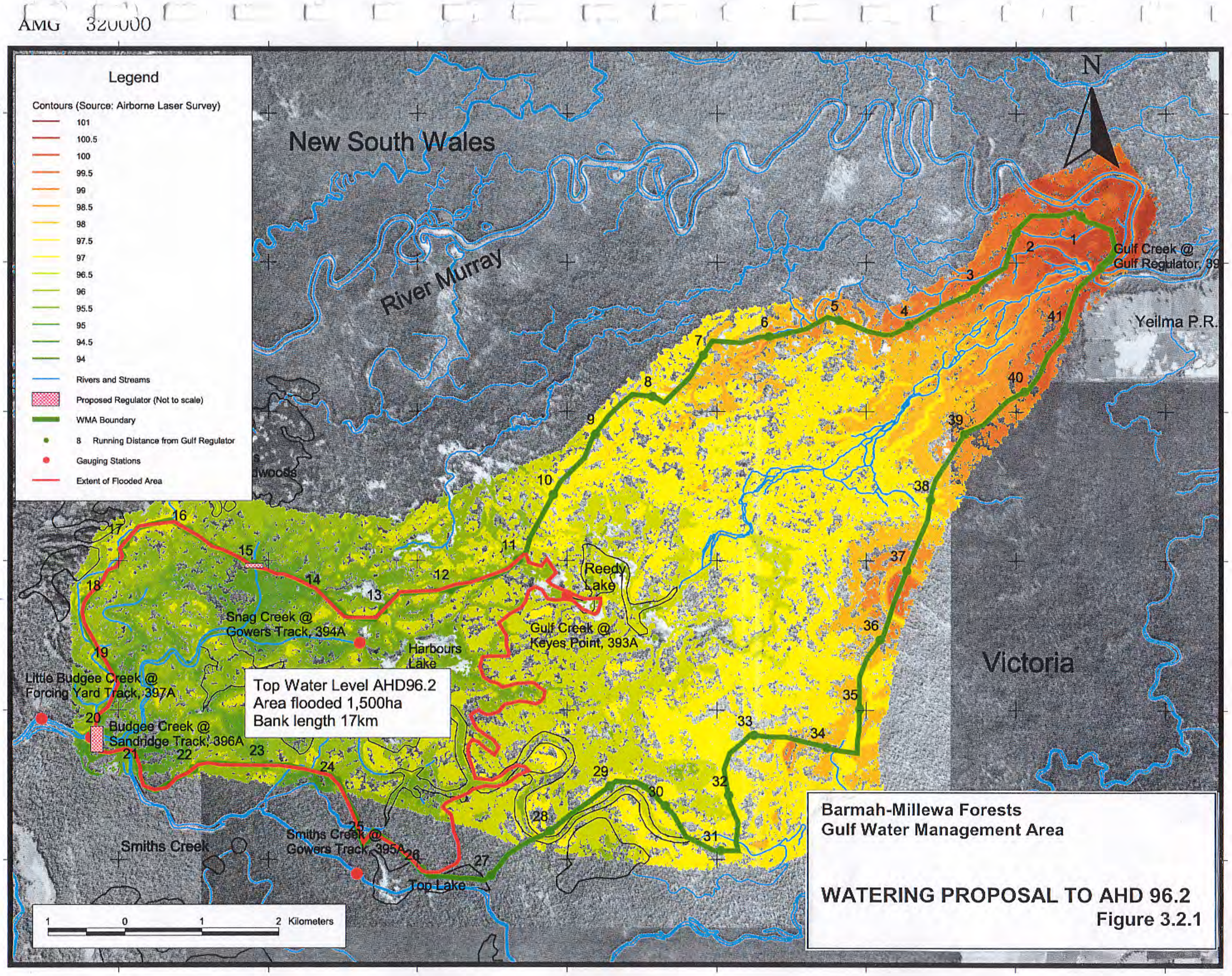
3.3 Low Bank Summary

The Low Bank alternatives can be summarised as shown in table 3.2.1 below:

Table 3.2.1 Low Bank Alternatives

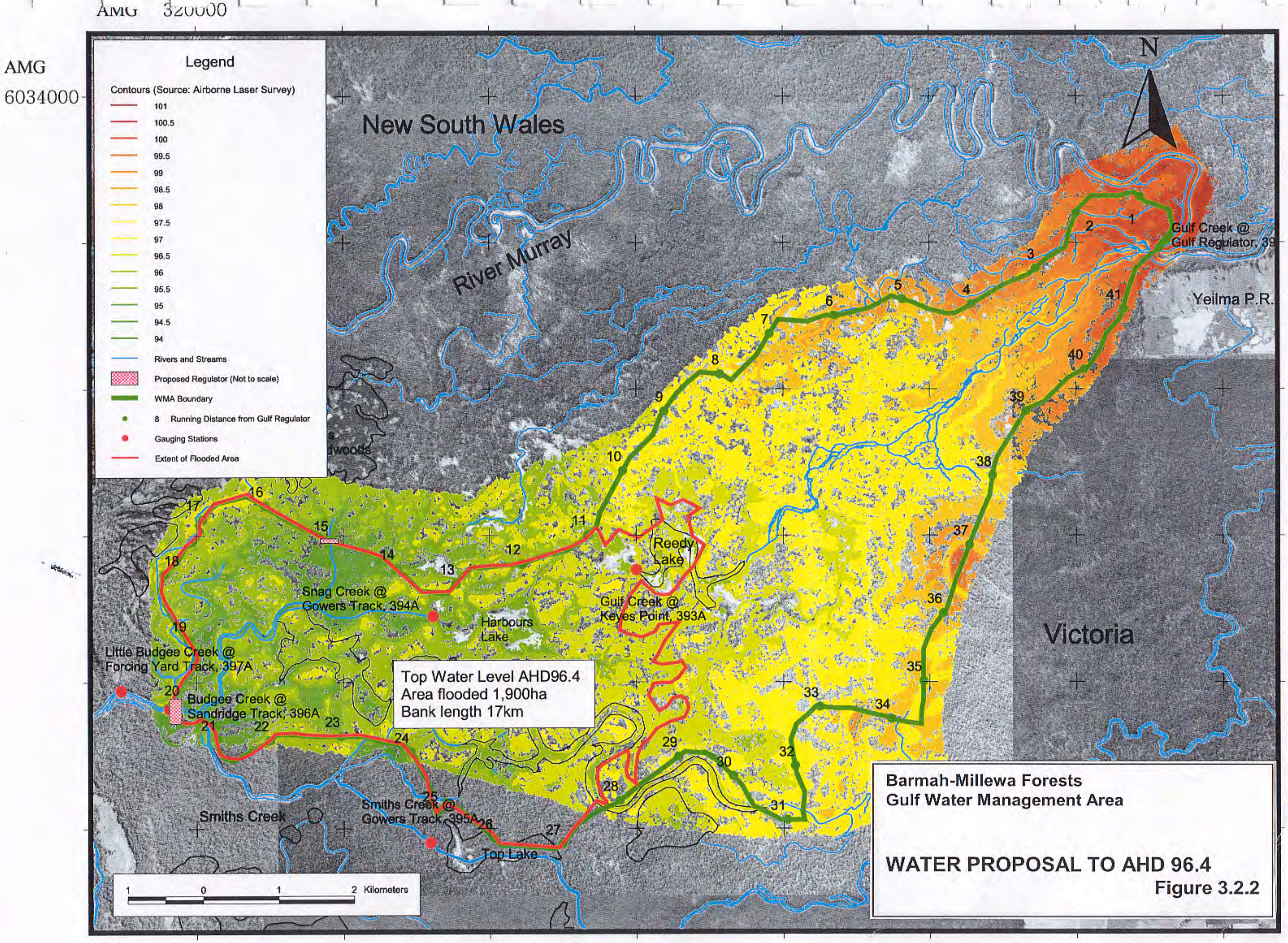
Low Bank Proposal *	Flooded Area (ha)
TWL 96.2	1,500
TWL 96.4	1,900
TWL 96.5	2,100
TWL 97.0	3,100
TWL 98.0	4,200

Drawings illustrating each of the low bank proposals now follow as figures 3.2.1 to 3.2.5. Each proposal is defined by Top Water Level, it is shown on the DEM contour base with the flooded area defined by a solid red line.



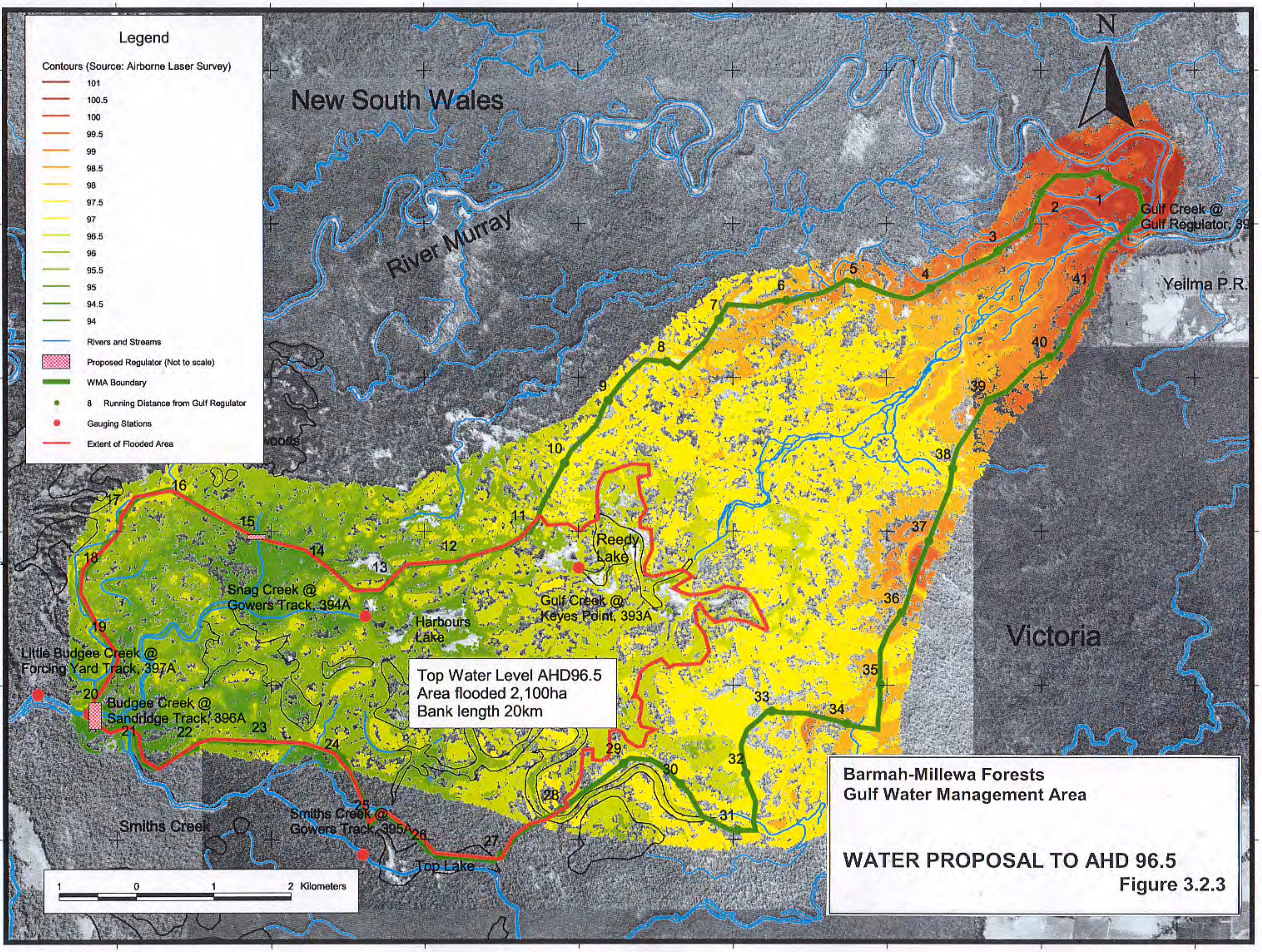
WATERING PROPOSAL TO AHD 96.2

Figure 3.2.1



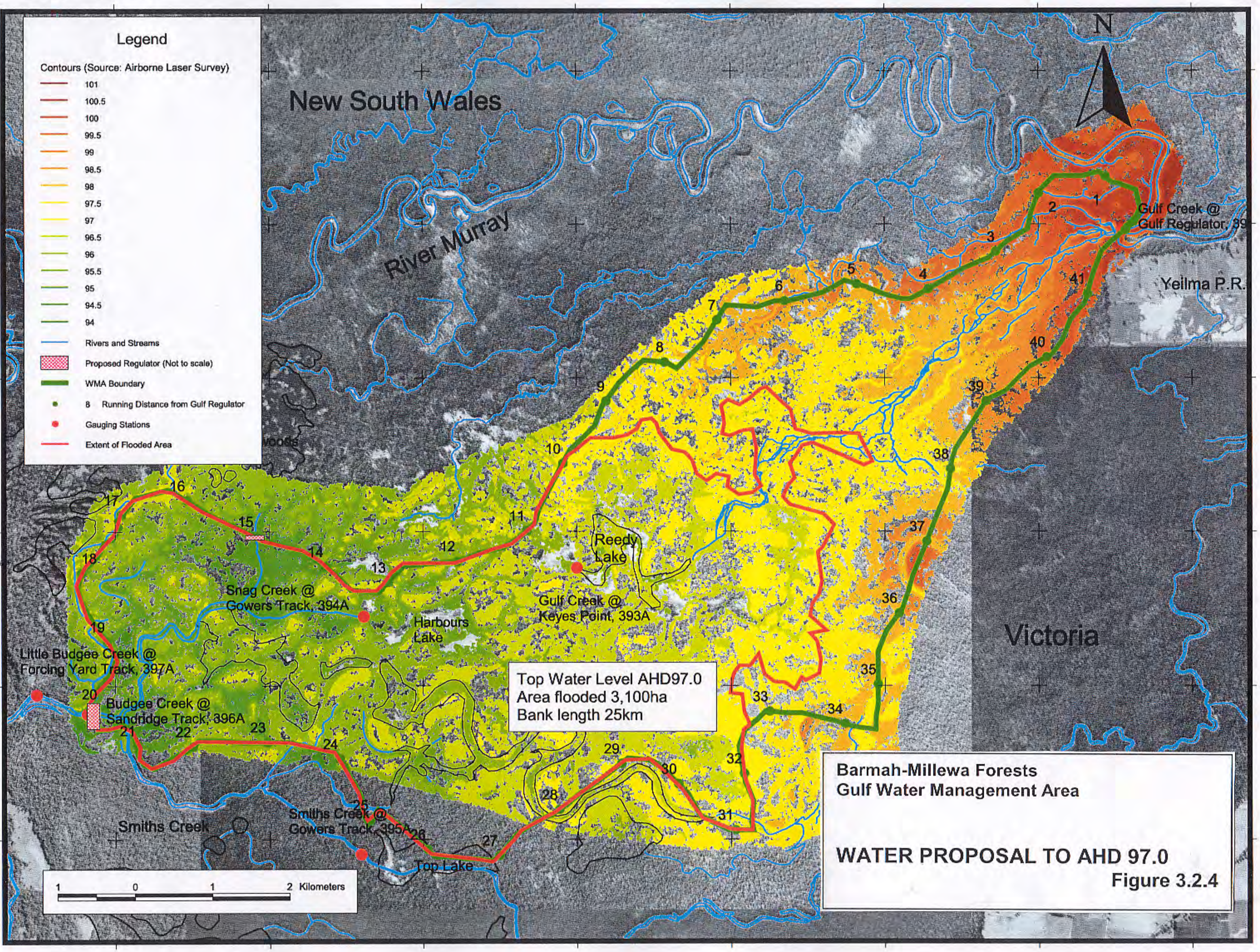
Barmah-Millewa Forests
Gulf Water Management Area

WATER PROPOSAL TO AHD 96.4
Figure 3.2.2



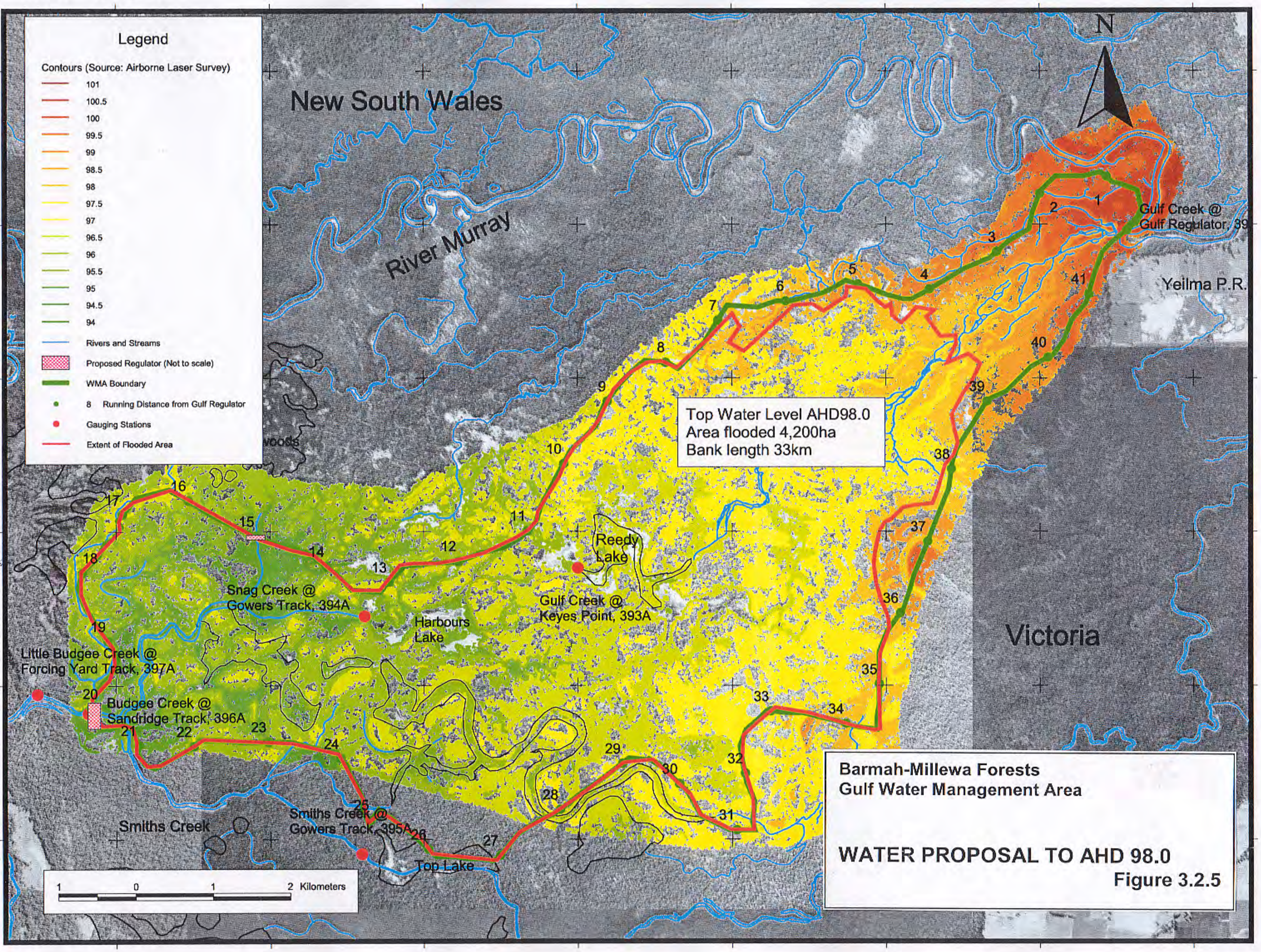
Barmah-Millewa Forests
Gulf Water Management Area

WATER PROPOSAL TO AHD 96.5
Figure 3.2.3



Barmah-Millewa Forests
Gulf Water Management Area

WATER PROPOSAL TO AHD 97.0
Figure 3.2.4



Barmah-Millewa Forests
Gulf Water Management Area

WATER PROPOSAL TO AHD 98.0

Figure 3.2.5

4 Flood Options

4 Flood Options

4.1 Introduction

Some benefits and costs (although not many environmental benefits) are relatively easy to measure as marketed inputs and outputs using observable prices. As a good example, the approach to be outlined in section 7.2 and 7.3 for the low bank works will use “mill door prices” to value the benefits of increased timber production. Project costs for the low bank works will also come from a set of well known and readily observable prices.

By contrast, measures to value “the environment” fall into two categories, “direct” and “indirect”. “Direct measures” often consist of considering a surrogate market where factors of production are bought and sold and where improvements to the environment can be observed. This is in essence the chapter 7 approach. A second direct approach uses “experimental techniques” which simulate a market where a respondent can express a hypothetical valuation of a real improvement. Contingent valuation (CV) techniques are an example of the experimental approach.

Indirect procedures for benefit estimation do not seek to measure directly revealed preferences. Instead they seek to produce a “dose response” relationship between resource use and some effect. In turn, some measure of preference is then applied.

For this study, the “dose response” relationship assumes that returning to near natural flooding frequencies for selected areas generates the total environmental benefit. As low banks represent an artificial or engineered approach to this issue, it leaves only small to medium man-made floods as an alternative.

Further explanation of these approaches can be found in:

Pearce and Turner, “*Economics of Natural Resources and the Environment*”, Chapter 10, Measuring Environmental Damage”, Harvester Wheatsheaf, 1990.

The application of small man-made floods in this study was based on producing the same flooded areas as the low bank works but through River Murray flows (and thus levels) and gate openings at the Gulf Regulators. As the only practical alternative to low banks, the cost of this option could be taken as a surrogate for all environmental benefits including wetland recovery and sustenance, bird breeding on wetlands, timber production, greenhouse and ecology recovery.

4.2 Assumed Relationship between Gulf Flooded Areas and River Murray Flows

In order to minimise the water resources required to flood parts of the Gulf WMA, the key issue to have the other regulators shut. This is a relatively unusual case. The River Murray gauging records show only the month of May 1984 as a period where River Murray levels were obtained while all forest regulators were shut.

4 Flood Options

It is possible to combine these May 1984 observations with flooded area observations from recent uses of the Environmental Water Allocation and from “Dexter Flood Maps” to produce a preliminary and of necessity, simple model of Gulf flooding. The assumptions lying behind this model are described in detail in section 6.2, “Flood Option Costs”.

When the MIKE 11 Gulf WMA hydraulic model is fully developed, it will be possible to test the section 6.2 assumptions.

4.3 Effective Floods and Water Use

For the man-made flood options, it will be assumed that flooding for the months of September, October and November is required together with “shoulder before and after” periods of 15 days each. Again this subject and the related water use assumptions are described in section 6.2.

4.4 “Do Nothing Option”

To complete the analysis of the man-made flood options, a “Do Nothing” case was postulated based on a token release through the Gulf regulator gates. The details of this case are also presented in section 6.2.

4.5 Summary of Proposals

The next table summarises the key elements of three options.

Table 4.5.1 Summary of Gulf WMA Proposals

Strategy Option	River Murray Water Source	Water Use	Flooded Area	Gulf Regulator	Flood Frequency	Option Benefits	Option Costs	Criteria
Low banks	Hume Reservoir through rain rejections, minor freshes and possibly EWA.	To balance the evaporation loss while holding the area behind the bank flooded for four months.	As created by the low bank options at the downstream end of the Gulf WMA. Ranges from 1900 ha to 4200 ha.	Regulator hydraulic capacity notionally limited to say 2000 Ml/d.	Operations to provide flooding in 10 years out of 10. This is an increase from 7 years out of 10.	Increased timber production over that associated with current flooding frequencies	Low bank construction Low bank maintenance Low bank operations Gulf gate operations Water costs Marginal timber production costs.	$/Flooded ha Timber benefits over the current flooding frequency case. Greenhouse benefits over the existing flooding case.
Man-made Floods	Hume Reservoir to provide small Murray floods or rain rejections and/or the EWA.	The water use over a four month period (and thus cost) will be the difference over the Murray "Do Nothing" hydrographs.	Natural flooded areas at the downstream end of the Gulf WMA only. Gulf flows set from the River Murray to best match the above low bank flooded areas.	Gates operated to create the required inflow. All other regulators to be closed to minimise water requirements.	As above, operations to provide flooding 10 years out of 10.	Total environmental benefits will be inferred from the cost of the water resources. Other inferred benefits will be estimated by deducting increased timber production	Water resource costs	Cost effectiveness measures particularly $/flooded ha over the "Do Nothing" case.

Strategy Option	River Murray Water Source	Water Use	Flooded Area	Gulf Regulator	Flood Frequency	Option Benefits	Option Costs	Criteria
"Do Nothing"	Small flows through the Gulf gates. Otherwise, rain rejections, minor freshes and possibly EWA.	To balance the evaporation loss while holding the small natural areas flooded for four months.	Small and limited to the immediate surrounds of the Gulf Creek and other waterways.	Inflow limited to say 100Ml/d.	As above, operations to provide flooding 10 years out of 10.	Total environmental benefits will be inferred from the cost of the water resources.	Water resource costs	Provides the base case flooded areas.

5 Low Bank Costs

5 Low Bank Costs

5.1 Introduction

The flooded areas for each of the alternative low bank options have been shown earlier on Figures 3.2.1 to 3.2.5, together with regulator locations and bank positions.

The following tables present a cost summary of each of the low bank proposals for the Gulf WMA. The tables cover proposals ranging from a TWL of 96.2 to a TWL of 98.0.

Phil Hoare of Goulburn Murray Water provided unit cost rates from similar projects undertaken in their region. The following components were utilised:

- Bulk earthworks ($3/m^3).
- Stripping and clearing (up to $8,000/ha + $100/tree) (the estimate allows for 60 trees per hectare, thereby covering the environmental prescriptions of avoiding “significant trees’).
- Drop bar regulator costs.
- (Limited) road furniture costs.
- Maintenance costs.
- Operational costs

The low bank data is presented as follows:

Table 5.2.1 contains indicative engineering quantities for each of the tested bank heights for:

- Bulk earthworks
- Stripping and clearing for roadworks and borrow pits.
- Road fixtures

Table 5.2.2 provides unit rates and the related cost estimates for each of these items.

Table 5 2.3 presents data on the flooded areas for the various bank heights, and the average cost per hectare flooded.

The total project costs range from $1.4M for the TWL 96.2 proposal to $7.6 M for the TWL 98.0 scheme with flooded areas of 1,500ha and 4,200ha respectively.

The cost of providing a crushed rock running surface on the top of the banks were also evaluated as a design option. This cost was found to be considerable and possibly even prohibitive, ranging from $1.3M for the TWL 96.2 proposal to $2.5M for the TWL 98.0 scheme making total project costs of $2.5M and $8.9M. Furthermore, it is not standard practice for logging roads in these state forests.

5 Low Bank Costs

The low bank costs have assumed that each project is “freestanding”. If low bank works were to be added to adjacent WMA’s, there would be common banks and roads and therefore some cost savings. For flooding adjacent WMA’s, it has been estimated that about 30% to 50% of the low bank length could be shared. If adopted. this could introduce cost savings for the Gulf projects of about 30% in the earthworks cost and thus about 20% in project costs.

Although these cost sharings are significant within the study’s estimates, it was decided that in this first analysis, the Gulf projects would stand on their own and thus no advantage from potential cost sharing was assumed. Presumably, later projects could benefit.

Given the high costs of these banks, an attempt was made during the study to optimise a low bank project. Two sites were selected in the middle of the WMA which appeared to show reduced bank lengths and reasonable flooded areas. The locations also required only one regulator. When analysed, the optimised sites showed mid range cost effectiveness at $1240 to $1340/ha flooded. The explanation appears to be that while bank lengths were optimised, the flooded areas were relatively reduced due to the increasing ground slope toward the Gulf regulator. On the related question that perhaps these “higher” areas might have a lower flood frequency, (and thus be capable of generating greater economic benefits), an estimate based on professor Bren’s historic “Grid Square Analysis” showed no significant differences to the other Gulf project areas. Accordingly, the optimised low bank proposals were not considered further.

5.2 Cost Estimates

Cost estimates for each of the low bank proposals now follow:

Table 5.2.1 Engineering Quantities

Element	Top Water Level RL 96.2	Top Water Level RL 96.4	Top Water Level RL 96.5	Top Water Level RL 97.0	Top Water Level RL 98.0
	Top of Bank RL 96.4	Top of Bank RL 96.7	Top of Bank RL 96.9	Top of Bank RL 97.5	Top of Bank RL 98.5
Bulk Earthworks (m^3)	196,300	293,000	368,000	696,000	1,511,250
Stripping and Clearing Roadworks (ha)	18.7	23.8	27.4	42.5	73.5
Stripping, Clearing and Restoration of Borrow pits (ha)	13.1	19.5	24.5	46.3	100.6
Road Fixtures (guide posts) (m)	17,000	17,000	20,000	25,000	33,000

Table 5.2.1 shows that all quantities increase as the bank height increases. The following Table 5.2.2 which introduces costs better identifies this proportionality.

Table 5.2.2 Engineering Cost Estimates

Element	**Rate**	**RL 96.4 at top of bank**	**RL 96.7 at top of bank**	**RL 96.9 at top of bank**	**RL 97.5 at top of bank**	**RL 98.5 at top of bank**
Bulk Earthworks	$3.00/cubic metre	$588,800	$879,000	$1,104,000	$2,089,000	$4,534,000
Stripping, Clearing and Restoration	$8,000/ha + $100/tree @ 60 trees/ha	$445,200	$605,200	$726,600	$1,243,200	$2,437,000
Road Fixtures	$600/kilometre	$10,000	$11,000	$12,000	$15,000	$20,000
Regulator 1 (Outflow)	$11,250/m Assume 6x2.0m bays with drop bars and 8m wide bridge	$140,000	$140,000	$140,000	$140,000	$140,000
Regulator 2 (Inflow)	$11,250/m Assume 3x2.0m bays with drop bars and 8m wide bridge	$68,000	$68,000	$68,000	$68,000	$68,000
Sub Total		$1,252,000	$1,703,200	$2,050,000	$3,555,000	$7,199,000
Environmental Impact Assessment, Detailed Design and Approvals	10% of estimated cost	$125,200	$170,300	$205,000	$355,500	$719,900
Total		**$1,377,200**	**$1,873,500**	**$2,255,000**	**$3,910,500**	**$7,918,900**

5 Low Bank Costs

5.3 Cost Effectiveness

Table 5.3.1 now draws together the above cost data and the flooded area estimates from section 4 to evaluate flooding cost effectiveness.

Table 5.3.1 Cost Effectiveness of the Low Bank Proposals

Low Bank Proposal *	Flooded Area (ha)	Total Cost	Cost per Hectare Flooded
TWL 96.2	1,500	$1,377,200	$920
TWL 96.4	1,900	$1,873,500	$990
TWL 96.5	2,100	$2,255,000	$1,070
TWL 97.0	3,100	$3,910,500	$1,260
TWL 98.0	4,200	$7,918,900	$1,890

In terms of cost per hectare flooded, the TWL 96.2 proposal represents the lowest unit cost ($920/ha) and would thus be the most cost effective of the above banks.

5.4 Water Applications

Table 5.4.1 lists the assumed water use for all the low bank projects. It consists of three components. The volume to initially fill the pond, the flow required to balance the estimated evaporative loss and the loss associated with the provision of a through-flow to help combat "Blackwater" and other water quality effects.

The through-flow was set to "turn-over" the ponded water each month and the expected river loss was taken as 20% of the through-flow, i.e 80% of the through-flow would be returned to the Murray. The initial fill volume would also be returned to the Murray as a credit. The evaporative loss figure represents typical evaporation totals for the months of August to November.

Table 5.4.1 Assumed Water Applications

Low Bank Model	Evaporative loss	Volume to fill	Assumed through-flow for water quality purposes	Assumed loss during through-flow
	(m)	(ML)	(ML/d)	(%)
TWL 96.2	0.47	9,100	280	20
TWL 96.4	0.47	12,500	400	20
TWL 96.5	0.47	14,500	460	20
TWL 97.0	0.47	27,500	880	20
TWL 98.0	0.47	64,000	2000	20

Although it would likely be surplus river flows following rain rejections, minor Murray floods and/or the Environmental Water Allocation that provided the flows to flood the Gulf areas, water costs were taken as the net total water use at a unit rate of $75/ML. Alternative evaluations without water costs were also undertaken.

5 Low Bank Costs

5.5 Flooding Characteristics

In 1998, Leon Bren prepared a paper entitled "Flooding Characteristics of a Riparian Red Gum Forest". The paper included a series of maps illustrating flooding characteristics of the Barmah forest, which were prepared on the basis of mapped flood events in the forest between 1963 and 1984.

One set of these maps were analysed for the Gulf WMA, to determine the benefits that the range of low banks could achieve. The selected characteristic was "percentage of years flooded" and the following table shows for the five low bank projects, the flooding frequency of those areas that could be taken to 10 years out of 10 frequency.

Table 5.5.1 Area Changes in Frequency of Flooding

Percentage of Years Flooded	Base Case	Top Water Level RL 96.2	Top Water Level RL 96.4	Top Water Level RL 96.5	Top Water Level RL 97.0	Top Water Level RL 98.0
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
0-12	0	0	0	0	0	0
12-24	53	53	53	53	53	53
24-36	146	146	146	146	146	-99
36-48	265	265	265	265	265	-138
48-60	384	384	-32	-53	-100	-268
60-72	1192	-218	-269	-290	-470	-897
72-84	2622	-1254	-1492	-1598	-2300	-2560
84-96	238	-28	-107	-159	-230	-238
96-100	0	1500	1900	2100	3100	4200
Total Area (ha)	4,900	4,900	4,900	4,900	4,900	4,900

As outlined in Chapter 3, the low bank works allow annual or "10 years out of 10" flooding to be achieved. As the "10 years out of 10" flooded area (shown in the table as "percentage of years flooded, 96% to 100%") is 0ha in the Base Case, the flooded area from each of the low bank works thus becomes the new "10 years out of 10" area. These values have been shaded yellow in table 5.5.1. Those lower frequency flooded areas above the solid black line are unaffected by the low bank works.

The table shows that most of the area able to be taken to "10 years out of 10" flooding comes from the high frequency group of more than "six to seven years out of 10". These changes are shown by the negative values in the table. This subject will be taken up again in Chapter 7 which discusses the benefits of more frequent flooding.

6 Flood Options and "Do Nothing" Costs

6 Flood Options and "Do Nothing" Costs

6.1 Introduction

The theoretical basis for the man-made flood option and the "Do Nothing" option were set out in section 4.2. In this section, resource costs are discussed for both options.

6.2 Flood Option Costs

When the Gulf MIKE 11 model is first calibrated and then verified, it will be possible to determine the area flooded within the Gulf WMA for a range of inflows through the Gulf regulator gates. These inflows can range up to quite high discharges as there are two Gulf regulator gates, both are large and high and they are located towards the upstream end of the Barmah-Millewa Forest.

While their capacity was analysed during the 1990 River Murray MIKE 11 model work, it was only for the specific case of all forest regulators also being open. To achieve watering in the Gulf WMA alone, the most likely operation would be to have all other regulators closed as this would require the lowest Murray flow. While this (and other similar) operations have been discussed at Forum meetings, nothing concrete has yet been done to either set up the necessary river model or to conduct the associated field trials. Thus, today (unfortunately) there are not any River Murray MIKE 11 runs corresponding to this case so it is not possible to accurately estimate the required River Murray flows.

What is known is the fact that for all Forest regulators open, the flows required downstream of Yarrawonga are considerable. For example, with 25,000ML/d leaving Yarrawonga, nearly 15,000ML/d is diverted through the Forest regulators. This diversion total includes 3,000Ml/d through the Gulf regulators.

For this Low Bank paper only, the following alternative model has been used to provide an initial estimate of the Murray water required to produce Gulf WMA flooding without any low banks. The model relies on:

1 River Murray levels recorded during a special gauging event at the Gulf regulator gates during May 1984 when all other forest regulators were shut. Working Paper 7 from the Maunsell 1990 "Water Management Plan" details this event).

2 The May 1984 period corresponded to a steady flow at Tocumwal of 15,800ML/d.

3 The levels recorded at the Gulf rose from RL99.25 to RL100.22 during the month.

4 According to the rating curve for the Gulf gates developed by Drew Bewsher during the 1990 Water Management Study, the hydraulic capacity at these levels ranges from 1,200ML/d to 3,200Ml/d.

5 For the existing MIKE 11 model of the River Murray between Tocumwal and Barmah, the capacity of the Gulf regulator when all other regulators are open rises from 1,900Ml/d at 15,000Ml/d at Tocumwal to 3,400ML/d at 35,000ML/d.

6 At these Tocumwal flows and with all regulators open, the percentage Barmah Forest flooded ranges (according to Bren's "monthly relationships") from 47% flooded to 80% flooded.

6 Flood Options and "Do Nothing" Costs

7 Taking the GIS and flow data recorded during the first (1998) and second (2000) uses of the EWA, it is possible to show that (for average monthly flows at Tocumwal for the maximum month in any flood sequence), the percentage of the Gulf WMA flooded is very close to the percentage of the Barmah Forest flooded.

8 This conclusion and the above assumptions then allows an (approximate) relationship to be set down linking inflows to the Gulf WMA and the required (low bank) flooded areas. The assumed relationship allows for small inflows (about 10%) from other parts of the Barmah Forest.

9 The water resource required allows for Gulf inflows for the months of September, October and November plus a fifteen day “shoulder period” both before and after, a total of 120 days. The assumed water use was arbitrarily taken as 30% of the Gulf inflow. . The water cost has been taken as $75/ML and the release has been assumed for an additional 3 years in every 10.

10 To complete the analysis, a “Do nothing” case was developed. The “Do Nothing” case has been defined as only token flows through the Gulf regulators (say 100ML/d) with the environmental benefits to come only from those areas that are flooded at this flow.

11 The area assumed to be flooded at this flow has been derived using the methodology set out in paragraph 8 above. At this time it is thought to be about 160ha (3% of the Gulf WMA) and to be consistent with the other project assumptions, this flow has been assumed to be required for 3 years in every 10, thereby ensuring flooding each and every year.

Table 6.2.1 now presents all the elements of this analysis. At the right hand end, the table deducts the “Do nothing” benefits and the “Scenario 3” timber and greenhouse benefits, from the environmental benefit estimate to infer “other environmental benefits”.

Table 6.2.1 Preliminary cost of Murray resources to produce annual flooding of the Gulf WMA.

Low bank TWL	Gulf WMA flooded area	Percentage flooded	Estimate of the required Gulf inflow	Allowance for other inflows to ensure flooding percentages	Murray resources required assuming 120 days and 70% returns	Value of used water each flood year @ $75	Capitalised value of resources @ 8% to allow flooding in an additional 3 years in every 10	Low Bank construction cost without water cost	Scenario 3 timber and greenhouse benefits	Inferred other environmental benefits after subtracting timber production and Greenhouse.	Inferred other environmental benefits over the "Do Nothing" case
	(ha)		(Ml/d)	(Ml/d)	(Gl)	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
"No flooding at all".	0	0.00%	0.0	0.0	0	0	0	0	0	0	0
96.2	1500	27.89%	1000.0	100.0	40	2,992	12,086	1,377	601	11,485	9,986
96.4	1900	35.33%	1400.0	200.0	58	4,352	17,580	1,874	764	16,816	15,317
96.5	2100	39.05%	1700.0	200.0	69	5,168	20,877	2,255	850	20,027	18,527
97.0	3100	57.64%	2700.0	300.0	109	8,161	32,963	3,911	1,268	31,695	30,195
98.0	4200	78.10%	3300.0	300.0	131	9,793	39,555	7,919	1,780	37,775	36,276
"Nearly as flooded as it gets".	4743	88.19%	3400.0	300.0	134	10,065	62,906	not applicable		62,906	61,406
"Do Nothing"	160	3.00%	100.0	10.0	4	299	1,209	not applicable	not applicable	1,209	0

6 Flood Options and "Do Nothing" Costs

Table 6.2.1 shows that 40Gl is required for an annual flooding corresponding to a Gulf flooded area of 1500ha. For a flooded area of 4200 ha, the annual water resource required becomes 130Gl. When valued at $75/Ml and for flooding in an extra three years in 10, the capital value (at 8% over 32 years) of the resources are nearly $12M for the 1500 ha area and $39M for the 4200 ha flooded area.

For the “Do nothing” case, 5Gl of Murray water is required for an annual flood and the equivalent capital sum is estimated at $1.2M.

7 Market and Other Benefits

7 Market and Other Benefits

7.1 Introduction

Three benefits are considered in this section. They are:

- The benefits from increased and sustained timber production following improved flooding frequencies after the development of the low bank works or the adoption of man-made floods.
- Associated with the first benefit, are greenhouse benefits from new timber providing an additional carbon sink.
- A indirect estimate of environmental benefits incorporating not only timber and greenhouse benefits but benefits associated with sustaining wetlands, improved bird breeding success and improved bio-diversity.

Each of these benefits are now discussed in turn.

7.2 Benefits from Increased Sustainable Timber Yields

7.2.1 Forest and Water Management Scenarios

The low bank works offer the possibility of near annual flooding of selected areas of the Gulf WMA. The incremental timber production from these selected areas has been based on the methodology used in the 1990 Water Management Plan (Maunsell 1990). The methodology relies on increased production from all Site Quality areas and follows an assumed increased frequency of flooding from say seven years in 10 today to ten years in 10. The Water Management Plan (Maunsell 1990) by contrast, used an approach that was limited to Site Quality II areas and increases in flooding frequency from say four to five years in 10 to say eight years in 10. For that case it was suggested that the incremental production could be between 1.0m^3/ha/a and 1.1 m^3/ha/a.

In order to deal effectively with this new case, advice was sought from Timber Communities Australia, State Forests New South Wales and Natural Resources and Environment, Victoria on the current knowledge of incremental production levels and current gross margins.

A range of values were offered. For this preliminary assessment, many of the values were incorporated as parts of the following scenarios as described in the following table 7.2.1.1. Four scenarios are described in terms of timber production, forest management, water management, stand structure, environmental prescriptions and gross margins. The scenarios attempt to recognise the impact of current water and forest management practices and the associated effects of environmental conservation zones as well as testing a number of operating methodologies.

Table 7.2.1.1 Increased and Sustainable Yield: Assessment Scenarios

Scenario	Timber Production	Forest Management	Water Management/ Forest Flooding	Stand Structure	Environmental Prescriptions	Gross Margins
Scenario 1	Severely constrained	Present	Present	Present	Present	TCA advice as summarised below in section 7.2.2.
Scenario 2	Silviculture treatment facilitating full stocking and subsequent progressive thinning over the rotation.	Recognises that significant areas are set aside for environmental conservation and that timber production is excluded in these areas.	Active water management according to Barmah Millewa Forests Water Management Strategy	Full cognisance	To meet Code of Forest Practice and thus ensure a high level of flora and fauna conservation	TCA advice as summarised below in section 7.2.2.
Scenario 3	Sustainable timber production now primary aim	No conservation areas set aside.	Forest flooding given priority.	Recognised	Lowest level of flora and fauna conservation.	TCA advice as summarised below in section 7.2.2.

7 Market and Other Benefits

7.2.2 Timber Production

The timber production values suggested by Barrie Dexter on behalf of Timber Communities Australia were the best researched and most comprehensive. They were adopted for almost all of the increased yield analyses and are shown in the following table 7.2.2.1. Scenarios 1, 2 and 3 as described in section 7.2.1 are called up in table 7.2.2.1 as current forest wide production rates. They have been weighted to allow for the relative proportions of SQI, SQII and SQIII timber stands in the Barmah Forest. A second table (7.2.2.2) then identifies higher timber production rates that could be expected if the quoted flooding frequencies were all increased to ten years in 10. A third table, 7.2.2.3, then shows incremental timber production rates for each scenario by subtracting the current rate from the ten years in 10 rate. For some cases, the incremental production values are greater than those used in 1990. The “saw log” title in the table generally matches the 1990 product description while the “other produce” descriptor covers product from residual timber, firewood and mulch.

Additional notes and a complete reference list can be found in Appendix B.

The production figures in Table 7.2.2 were based mainly on the values reported in:

Jacobs M.R. 1955, “Growth Habits of the Eucalypts”, Red Gum Forest section, Forestry and Timber Bureau, Department of the Interior.

Baur G.1983, “Notes on the Silviculture of Major NSW Forest Types, No 5 River Red Gum”, Forestry Commission of New South Wales.

Bacon P, Robertson A.P., Heagney G 1992, Proceedings of the Floodplain Wetlands Management Workshop, Albury NSW, October 1992, “The Responses of Floodplain Primary Production to Flood Frequency and Timing”

Bren L.T.2001, “Estimates of Loss of Growth Due to Habitat Tree Retention in Riparian River Red Gum Forests”, March 2001, Victorian Association of Forest Industries

Maunsell 1990, “Barmah Millewa Forests Water Management Plan, Murray Darling Basin Commission.

The highest incremental sawlog value of 2.35 m^3/ha/a corresponds to SQ I, SQII and SQIII areas being managed primarily for timber production (Scenario 3) and taken from a flooding frequency of two years in 10 to ten years in 10. Amongst the lowest applicable incremental sawlog value is 0.70 m^3/ha/a which covers the case of SQI, SQII and SQIII areas under present day water and forest management practices (Scenario 1) and currently flooded seven years out of 10 going to ten years in 10.

The SFNSW response by contrast referred to the benefit/cost analysis presented in the “Water Management Plan for the Millewa Forest”, 1996. That analysis assumed that the yield of premium grade saw logs from some WMA’s could be brought to the realistic upper limit of 0.55m^3/ha/a for SFNSW SQII forest.

Table 7.2.2.1 Year 2002 Timber Production for Various Forest and Water Management Strategies, Average for Whole of Barmah Forest: Unit m3/ha/a

Present flood frequency	Scenario 1 Current forest management, stand structure, environmental prescriptions		Scenario 2 Timber production as primary aim but full cognisance of active water management, siviculture treatment and environmental prescriptions and conservation areas		Scenario 3 Timber production as primary aim	
	Saw Logs	Other Products	Saw Logs	Other Products	Saw Logs	Other Products
	Production values in m3/ha/a					
10 years out of 10	1.48	1.10	2.12	1.57	2.50	1.85
7 to 8 years out of 10, all SQs	0.78	0.57	1.35	1.00	1.87	1.39
4 or 5 years out of 10, all SQs	0.22	0.16	0.43	0.32	0.75	0.56
2 years out of 10, all SQ's	Negligible to negative		0.04	0.02	0.15	0.11
Dependent on other seasonal factors						

Source: B.Dexter and Timber Communities Australia, February and April 2002

Table 7.2.2.2 Year 2002 Timber Production Following Low Bank Works and for Various Forest and Water Management Strategies

Present flood frequency	Planned flood frequency	Scenario 1 Current forest management, stand structure, environmental prescriptions		Scenario 2 Timber production as primary aim but full cognisance of active water management, siviculture treatment and environmental prescriptions and conservation areas		Scenario 3 Timber production as primary aim	
		Saw Logs	Other Products	Saw Logs	Other Products	Saw Logs	Other Products
10 years out of 10	10 years/10	1.48	1.10	2.12	1.57	2.50	1.85
7 to 8 years out of 10, all SQs	10 years/10	1.48	1.10	2.12	1.57	2.50	1.85
4 or 5 years out of 10, all SQs	10 years/10	1.48	1.10	2.12	1.57	2.50	1.85
2 years out of 10, all SQ's	10 years/10	1.48	1.10	2.12	1.57	2.50	1.85

Source: B.Dexter and Timber Communities Australia, February and April 2002

Table 7.2.2.3 Year 2002 Incremental Timber Production Following Low Bank Works and for Various Forest and Water Management Strategies

Present flood frequency	Planned flood frequency	Scenario 1 Current forest management, stand structure, environmental prescriptions		Scenario 2 Timber production as primary aim but full cognisance of active water management, siviculture treatment and environmental prescriptions and conservation areas		Scenario 3 Timber production as primary aim	
		Saw Logs	Other Products	Saw Logs	Other Products	Saw Logs	Other Products
10 years out of 10	10 years /10	0.00	0.00	0.00	0.00	0.00	0.00
7 to 8 years out of 10, all SQs	10 years /10	0.70	0.53	0.77	0.57	0.63	0.46
4 or 5 years out of 10, all SQs	10 years /10	1.26	0.94	1.69	1.25	1.75	1.29
2 years out of 10, all SQ's	10 years /10	1.48	1.10	2.08	1.55	2.35	1.74

Source: B.Dexter and Timber Communities Australia, February and April 2002

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7.2.3 Gross Margins

After seeking advice from a number of timber mills, Timber Communities Australia provided the following gross margin information (table 7.2.3.1) thought to be representative of the local industry in both Victoria and New South Wales.

The prices in the table are for a range of finished products at the "Mill Door". The products start with "Appearance timber" ($1750/m3) at the top end through to "Mulch" ($15/m3) at the low end. To calculate the applicable gross margins it is then necessary to subtract the marginal cost of the increased production. This aspect is taken up in the second table 7.2.3.2.

Table 7.2.3.1 Victorian "Mill Door" Red Gum Values

Product	Market	Product per m^3. (Percentage of log)	Value ($/$m^3$)	Mill Door Value ($/$m^3$ log equivalent)
Appearance	High grade products such as furniture	7	1750	$122.50
Structural	General market products including sleepers	18	480	$86.40
Residual	Typically garden timber	14	260	$36.40
Firewood		28	55	$15.40
Mulch		33	15	$5.00
Total				$265.70

Source: Timber Communities Australia

The next table outlines the estimates of marginal cost used in this analysis.

Table 7.2.3.2 Marginal Costs of the Increased Timber Production

Cost Element	Cost ($/m3)
Royalty, (including roading component and TPG levy).	$45.00
Felling and preparation	$7.50
Snig, load and haul to mill	$35.00
Milling	$105.00
Kiln drying (for the "Appearance timber" only).	$1200.00

Source: Timber Communities Australia

As this report concentrates on an economic analysis, the marginal costs have ignored the royalty payments as these are but transfer payments. The gross margin becomes the difference between the product value (at the various production levels) and the related marginal cost.

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The above timber values and costs and the incremental production figures from tables 7.2.2 3 were then combined to produce “Mill Door values” of the incremental production. The results are shown in the following tables 7.2.3.3 and 7.2.3.4. The first table covers the case of flooding frequency increases from seven years in 10 to 10 years in 10. The second deals with the four to five years in 10 to ten years in 10 for each project’s flooded area.

The tables show a range of Gross Margins. The lowest Gross Margin is for the “seven year” Scenario 3 case at \$28/m^3/ha/a. and the highest Gross Margin is for the “five year” Scenario 3 case at \$78/m^3/ha/a. The corresponding Gross Margins for the Scenario 2 cases are \$35/m^3/ha/a and \$76/m^3/ha/a and for Scenario 1, \$32/ha/a and \$57/ha/a.

Table 7.2.3.3 Mill door value of incremental timber production for flooding from 7 years in 10.

		2002 "Saw Logs"		2002 "Other Products"		Scenario 1		Scenario 2		Scenario 3	
						Saw Logs	Other Products	Saw Logs	Other Products	Saw Logs	Other Products
		Production (%)	Value ($/m3)	Production	Value ($/m3)						
Incremental timber production	m3/ha/a					0.70	0.53	0.77	0.57	0.63	0.46
						($/ha/a)	($/ha/a)	($/ha/a)	($/ha/a)	($/ha/a)	($/ha/a)
Appearance		7.00	$1,750.00			$85.75		$94.33		$77.18	
Structural		18.00	$480.00			$60.48		$66.53		$54.43	
Residual		14.00	$260.00	10.00	$260.00	$25.48	$13.78	$28.03	$14.82	$22.93	$11.96
Firewood		28.00	$55.00	70.00	$55.00	$10.78	$20.41	$11.86	$21.95	$9.70	$17.71
Mulch		33.00	$15.00	20.00	$15.00	$3.47	$1.59	$3.81	$1.71	$3.12	$1.38
Less marginal costs			$231.50		$53.00	-$162.05	-$28.09	-$178.26	-$30.21	-$145.85	-$24.38
						$23.91	$7.69	$26.30	$8.27	$21.51	$6.67
Total margin ($/ha/a)						$31.59		$34.56		$28.18	

Source: B.Dexter and Timber Communities Australia, February and April 2002

Table 7.2.3.4 Mill door value of incremental timber production for flooding from 5 years in 10.

Product	2002 "Saw Logs"		2002 "Other Products"		Scenario 1 Current stand structure, prescriptions and flooding.		Scenario 2 Production aim but with constraints		Scenario 3 Aim seriously at timber production	
	Production (%)	Value ($/m3)	Production	Value ($/m3)	Saw Logs	Other Products	Saw Logs	Other Products	Saw Logs	Other Products
Incremental timber production m3/ha/a					1.26	0.94	1.69	1.25	1.75	1.29
					($/ha/a)	($/ha/a)	($/ha/a)	($/ha/a)	($/ha/a)	($/ha/a)
Appearance	7.00	$1,750.00			$154.35		$207.03		$214.38	
Structural	18.00	$480.00			$108.86		$146.02		$151.20	
Residual	14.00	$260.00	10.00	$260.00	$45.86	$24.44	$61.52	$32.50	$63.70	$33.54
Firewood	28.00	$55.00	70.00	$55.00	$19.40	$36.19	$26.03	$48.13	$26.95	$49.67
Mulch	33.00	$15.00	20.00	$15.00	$6.24	$2.82	$8.37	$3.75	$8.66	$3.87
Less marginal costs		$231.50		$53.00	-$291.69	-$49.82	-$391.24	-$66.25	-$405.13	-$68.37
					$43.03	$13.63	$57.71	$18.13	$59.76	$18.71
Total margin ($/ha/a)					$56.66		$75.84		$78.47	

Source: B.Dexter and Timber Communities Australia, February and April 2002

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7.3 Greenhouse Benefits

As an important part of this low bank study, Barrie Dexter has reviewed the potential benefits associated with "forest management" as a carbon sink. Forest management is defined on page 2 of Appendix C. The complete paper is attached as Appendix C and a summary now follows:

7.3.1 Valuing Central Murray Floodplain Forests For Carbon Sequestration

Australia has strongly advocated mechanisms under the Kyoto Protocol that provide the maximum flexibility for industrialised countries to meet their commitments to regulate greenhouse gas emissions at least cost. These include crediting carbon sinks limited to reafforestation and reforestation since 1990.

Under the Kyoto Protocol, developed countries such as Australia are required to limit their greenhouse gas emissions to less than "the assigned amount plus or minus carbon sinks and Kyoto emissions".

With respect to the "carbon sinks" component it means that Australia can emit more than its assigned amount (which is 8% above its emissions in 1990) if it can simultaneously sequester the equivalent amount in sinks.

Whilst the major preoccupation particularly since 1997 has been on plantation-grown trees for timber production and potential carbon credits, it is proposed that valuing the enhanced carbon sequestration directly resulting from improved watering of the river red gum forests is a legitimate and tangible way of placing a $ environmental benefit (among others) on much improved forest and water management. These forests have been subject to human disturbance over many tens of thousands of years, initially by aboriginal people with the use of fire, since the 1860s by timber harvesting and 1930s by progressive and substantial depletion of natural flooding cycles.

Cost effective management activities that increase forest carbon sequestration are clearly in line with State and Commonwealth Government policies to offset Australia's relatively high per capita CO_2 emissions.

Only by continuing to grow a forest and removing the biomass in the form of wood or other product can the forest continue to play a role in carbon sequestration. The amount of carbon that can be sequestered depends on the rate of growth and tree species involved; highest rates are achieved by well managed, fast growing species on good soils in high rainfall areas.

Using the methods of Ryan (2001) and Fletcher (1999) it is possible to set down carbon production rates for the same forest production scenarios as used in the timber production chapter. These estimates are shown as averages for Barmah Forest and all Red Gum Site Qualities in table 7.3.1.below.

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Table 7.3.1 Carbon Production from Stem Volume Unit tonne/ha/a

		Carbon Production From Stem Volume T/Ha/Yr and Value @ $5/T/Ha/Yr.					
Flood Frequency		Scenario1		Scenario 2		Scenario 3	
		Tonne C	Value $	Tonne C	Value $	Tonne C	Value $
	10 years out of 10	0.91	4.55	1.29	6.45	1.52	7.61
	7-8 years out of 10	0.47	2.36	0.82	4.11	1.14	5.71
	4-5 years out of 10	0.13	0.66	0.25	1.26	0.46	2.29
	≤ 2 years out of 10	Negligible to negative		0.02	0.10	0.09	0.46

Source: Barrie Dexter and Appendix C

For the various Low Bank projects, these unit rates can now be used to assign values to the Greenhouse benefit. Table 7.3.2 provides details for each Scenario. The lowest rate is for the smallest pond (TWL 98.2) under Scenario 3 at $2850/a. For the largest pond, TWL 98.0, and Scenario 3 again, the value of the carbon storage becomes nearly $8,000/a. These benefits are about 7% of the timber production benefit and clearly are worth considering.

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Low Bank Model	Flooded area	Incremental Timber production: Scenario 1 Current forest management, stand structure, environmental prescriptions	Scenario 2 Timber production as primary aim but full cognisance of active water management, siviculture treatment and environmental prescriptions and conservation areas	Scenario 3 Timber production as primary aim
	(ha)	$/a	$/a	$/a
Top water level 96.2	1,500	3285	3510	2850
Top water level 96.4	1,900	4161	4446	3610
Top water level 96.5	2,100	4599	4914	3990
Top water level 97.0	3,100	6789	7254	5890
Top water level 98.0	4,200	9198	9828	7980

Source: Barrie Dexter and colleagues, June 2002

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7.4 Environmental Benefits

Earlier sections of this report suggested that the “other environmental benefits” could be inferred from the water cost of achieving the same flooded areas. Table 6.2.1 presented a preliminary analysis of the possible outcome. The right hand columns of that table then subtracted the value of the “Do Nothing” case and the Scenario 3 timber and greenhouse benefits to produce “inferred other environmental benefits”. The inferred benefits from section 6.2 are shown again in the next table 7.4.1.

Table 7.4.1 Inferred other environmental benefits

Equivalent Low Bank project	Flooded area	Inferred other environmental benefits after deducting timber and greenhouse benefits	Inferred other environmental benefits over the “Do Nothing” case
	(ha)	($1,000)	($1,000)
“Do nothing”	160	1,210	0
TWL 96.2	1,500	11,490	10,000
TWL 96.4	1,900	16,800	15,300
TWL 96.5	2,100	20,000	18,500
TWL 97.0	3,100	31,700	30,200
TWL 98.0	4,200	37,800	36,300

7.5 Royalty Benefits

In the Water Management Plan for the Millewa Forests (SFNSW and DLWC, 1996) the general case for low bank works was analysed. The analysis assumed that extra timber production came from Site Quality I and II areas and that the only benefits were the royalties earned by SFNSW. Timber production rates were drawn from the SFNSW compartment history records from 1947 to 1992 and applied to each of the Millewa Forest WMA’s. Premium saw log yield ranged from 0.17m^3/ha/a to 0.63 m^3/ha/a. Total yield ranged from 0.42m3/ha/a to 0.96 m^3/ha/a. These production rates are well below those advised by TCA as reference to section 5 will testify.

The analysis assumed that a target production level of 0.55m3/ha/a could be achieved everywhere in the Millewa Forest which typically left the incremental production at 0.1m^3/ha/a or less. Applying the (then) SFNSW Royalty rates as the revenue stream produced the general conclusion that once recurrent costs exceed about $5/ha/a, any watering project could not be justified on economic grounds.

The Low Bank works investigated in this report have unit costs of about $800/ha. If financed at say 10%, this represents about $80/ha/a, well beyond the SFNSW threshold figure.

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However, while acknowledging the basis of the SFNSW analysis, it has not been followed in this case because:

- Royalties are transfer payments and have nothing to do with the economic case.
- If serious Low Bank works are to be introduced, careful management of forest production and watering would be mandatory and thus yields could be expected to be higher, far higher than the forest wide averages quoted in the Water Management Plan.
- Even the TCA yield figures are orders removed from yields achieved in California when using trickle irrigation to encourage River Red Gum production.

Limiting revenues to royalties ignores the expanding appearance and structural timber markets.

8 Option Evaluation

8 Option Evaluation

8.1 Introduction

In this section on option evaluation, three different approaches are tested. They are:

- Benefit/cost analysis
- Proposal ranking
- Preferred project comparison
- Surrogate environmental benefits

8.2 Benefit Cost Analysis

In the following benefit cost analyses, project benefits come from:

- A once only value of the timber cleared to allow sympathetic bank and road construction and the development of local borrow pits.
- The capitalised value (at 8%) of annual incremental timber production from all Site Quality areas. These estimates allowed for the marginal costs associated with the increased timber production
- Greenhouse benefits
- Environmental and recreational benefits were not included.

Project costs were:

- The capitalised value (at 8%) of annual water costs including the water required to fill the pond, the losses associated with the through-flow and the balancing of evaporation losses..
- The estimated construction cost of the low bank works.

Operational costs were taken as $45,900 for each the three watering years in each ten years. In the spreadsheet they were capitalised at 8%.and added to a maintenance estimate taken as 2% of the capital cost. These allowances represent 16% of the capital cost and serve to emphasise that flooding operations are important and that staffing levels in the forests would need to reflect this input.

For the benefit cost analysis, the four cost and timber production cases from section 7 were analysed. In summary they were:

Table 8.2.1. Benefit Cost Analyses

Run	Section 7 Scenario	Water Costs	Royalties	TCA Gross Margins	Results in Table:
1	1	Yes	No	Yes	8.2.1
2	1A	No	No	Yes	8.2.1
3	2	Yes	No	Yes	8.2.2
4	2A	No	No	Yes	8.2.2
5	3	Yes	No	Yes	8.2.3
6	3A	No	No	Yes	8.2.3
	Summary of all Scenarios				8.2.4

8 Option Evaluation

All of the five flooded area proposals were tested in turn against these timber production and water cost cases. The results of each run are now summarised in tables 8.2.1 to 8.2.3.

Each table covers the results from one Scenario. In the tables, flooding frequencies increases from seven years in 10 are shaded green. Total benefits and total cost columns are shaded blue for all projects. Benefits without water costs are in the purple columns.

A final table 8.2.5 summarises each of the analyses in terms of net benefits and benefit/cost ratio. The two projects under each scenario with the highest benefit cost ratio are shaded yellow in the summary table.

For the economic analysis cases, the benefit stream was dominated by incremental timber production. On the cost side, water costs were typically more than twice construction and operation costs. The results are shown on pages that follow.

8 Option Evaluation

TABLE 8.2.1 YEAR 2002 BENEFITS AND COSTS

SCENARIO 1
PRESENT FOREST AND WATER MANAGEMENT AND ENVIRONMENTAL CONSTRAINTS

	Clearing			Timber Production					Benefits							Costs					Benefits without water costs		
Low Bank Option	Cleared area for low bank	Cleared area for borrow pits	Value of cleared timber @ $1150/ha	Flooded area, all SQs	Present flooding frequency	Annual timber return ($1000/a)	Capitalised timber value @ 8%	Capitalised greenhouse benefit	Total benefits	Water required to fill	Assumed throughflow to maintain water quality	Evaporative loss (0.47m) during through flow period	Transmission loss during throughflow period	Net water needs each flooding	Capitalised water cost ($1000) @ $75/ML for ten years in 10 flooding	Estimated construction cost	Estimated operations ($45.9k/a) and maintenance (2%)	Total cost including operations	Net benefits	Benefit/cost ratio	Total cost including operations but excluding water costs	Net benefits	Benefits/cost ratio without water costs
	(ha)	(ha)	$1,000	(ha)	yrs/10	$1000/a	$1,000	$1,000	$1,000	(ML)	(ML/d)	(ML)	(ML)	(ML)	$1,000	$1,000	$1,000	$1,000	$1,000		$1,000	$1,000	
Top water level 96.2	18.7	13.1	37	1,500	7	47	592	41	670	9,100	280	7,050	6,770	13,820	4,187	1,377	219	5,783	-5,112	0.12	1,596	-926	0.42
Top water level 96.4	23.8	19.5	50	1,900	7	60	750	52	852	12,500	400	8,930	9,672	18,602	5,635	1,874	229	7,738	-6,886	0.11	2,103	-1,250	0.41
Top water level 96.5	27.4	24.5	60	2,100	7	66	829	57	947	14,500	460	9,870	11,123	20,993	6,360	2,255	236	8,851	-7,904	0.11	2,491	-1,545	0.38
Top water level 97.0	42.5	46.3	102	3,100	7	98	1,224	85	1,411	27,500	880	14,570	21,278	35,848	10,860	3,911	269	15,040	-13,629	0.09	4,180	-2,769	0.34
Top water level 98.0	73.5	100.6	201	4,200	7	133	1,658	115	1,974	64,000	2,000	19,740	48,360	68,100	20,630	7,919	350	28,899	-26,924	0.07	8,269	-6,294	0.24

TABLE 8.2.2 YEAR 2002 BENEFITS AND COSTS

SCENARIO 2
TIMBER PRODUCTION TARGET BUT WITH LESSER MANAGEMENT CONSTRAINTS

	Clearing			Timber Production					Benefits	Water Costs								Costs			Benefits without water costs		
Low Bank Option	Cleared area for low bank	Cleared area for borrow pits	Value of cleared timber @ $1150/ha	Flooded area, all SQs	Present Flooding Frequency	Annual Timber Return ($1000/a)	Capitalised Timber Value @ 8%	Capitalised Greenhouse Benefit	Total Benefits	Water required to fill	Assumed throughflow to maintain water quality	Evaporative loss (0.47m) during through flow period	Transmission loss during throughflow period	Net water needs each flooding	Capitalised water cost ($1000) @ $75/ML for ten years in 10 flooding	Estimated construction cost	Estimated operations ($45.9k) and maintenance (0.2%)	Total cost including operations	Net benefits	Benefit/cost ratio	Total cost including operations but excluding water costs	Net benefits	Benefits/cost ratio without water costs
	(ha)	(ha)	$1,000	(ha)	yrs/10	($1000/a)	$1,000	$1,000	$1,000	(ML)	(ML/d)	(ML)	(ML)	(ML)	$1,000	$1,000	$1,000	$1,000	$1,000		$1,000	$1,000	
Top water level 96.2	18.7	13.1	37	1,500	7	52	648	44	729	9,100	280	7,050	6,770	13,820	4,187	1,377	219	5,783	-5054	0.13	1,596	-867	0.46
Top water level 96.4	23.8	19.5	50	1,900	7	66	821	56	926	12,500	400	8,930	9,672	18,602	5,635	1,874	229	7,738	-6812	0.12	2,103	-1,176	0.44
Top water level 96.5	27.4	24.5	60	2,100	7	73	907	61	1,029	14,500	460	9,870	11,123	20,993	6,360	2,255	236	8,851	-7822	0.12	2,491	-1,463	0.41
Top water level 97.0	42.5	46.3	102	3,100	7	107	1,339	91	1,532	27,500	880	14,570	21,278	35,848	10,860	3,911	269	15,040	-13508	0.10	4,180	-2,648	0.37
Top water level 98.0	73.5	100.6	201	4,200	7	145	1,814	123	2,138	64,000	2,000	19,740	48,360	68,100	20,630	7,919	350	28,899	-26761	0.07	8,269	-6,130	0.26

8 Option Evaluation

TABLE 8.2.3 YEAR 2002 BENEFITS AND COSTS

SCENARIO 3
SUSTAINABLE TIMBER PRODUCTION PRIMARY AIM, NO CONSTRAINTS

	Clearing			Timber Production					Benefits	Water Costs						Costs					Benefits without water costs		
Low Bank Option	Cleared area for low bank	Cleared area for borrow pits	Value of cleared timber @ $1150/ha	Flooded area, all SQs	Present Flooding Frequency	Annual Timber Return ($1000/a)	Capitalised Timber Value @ 8%	Capitalised Greenhouse Benefit	Total Benefits	Water required to fill	Assumed throughflow to maintain water quality	Evaporative loss (0.47m) during through flow period	Transmission loss during throughflow period	Net water needs each flooding	Capitalised water cost ($1000) @ $75/ML for ten years in 10 flooding	Estimated construction cost	Estimated operations ($45.9k) and maintenance (0.2%)	Total cost including operations	Net benefits	Benefit/cost ratio	Total cost including operations but excluding water costs	Net benefits without water costs	Benefits/cost ratio without water costs
	(ha)		$1,000	(ha)	yrs/10	$1,000	$1,000	$1,000	$1,000	(ha)			(m)	(ML)	$1,000	$1,000	$1,000	$1,000	$1,000		$1,000	$1,000	
Top water level 96.2	18.7	13.1	37	1,500	7	42	528	36	601	9,100	280	7,050	6,770	13,820	4,187	1,377	219	5,783	-5,182	0.10	1,596	-995	0.38
Top water level 96.4	23.8	19.5	50	1,900	7	54	669	45	764	12,500	400	8,930	9,672	18,602	5,635	1,874	229	7,738	-6,974	0.10	2,103	-1,338	0.36
Top water level 96.5	27.4	24.5	60	2,100	7	59	740	50	850	14,500	460	9,870	11,123	20,993	6,360	2,255	236	8,851	-8,001	0.10	2,491	-1,642	0.34
Top water level 97.0	42.5	46.3	102	3,100	7	87	1,092	74	1,268	27,500	880	14,570	21,278	35,848	10,860	3,911	269	15,040	-13,772	0.08	4,180	-2,912	0.30
Top water level 98.0	73.5	100.6	201	4,200	7	118	1,480	100	1,780	64,000	2,000	19,740	48,360	68,100	20,630	7,919	350	28,899	-27,118	0.06	8,269	-6,488	0.22

8 Option Evaluation

TABLE 8.2.4 YEAR 2002 BENEFIT COST SUMMARY

Low bank option	Scenario 1 Present forest and water management		Scenario 1A Present forest and water management but without water costs		Scenario 2 Timber production target but with reduced constraints		Scenario 2A Reduced constraints but without water costs		Scenario 3 Timber production main target		Scenario 3A Timber production main aim but without water costs	
	Net Benefits	Benefit Cost Ratio	Net Benefits	Benefit Cost Ratio	Net Benefits	Benefit Cost Ratio	Net Benefits	Benefit Cost Ratio	Net Benefits	Benefit Cost Ratio	Net Benefits	Benefit Cost Ratio
	($1,000.00)		($1,000.00)		($1,000.00)		($1,000.00)		($1,000.00)		($1,000.00)	
Top water level 96.2	-5,112	0.12	-926	0.42	-5054	0.13	-867	0.46	-5,182	0.10	-995	0.38
Top water level 96.4	-6,886	0.11	-1,250	0.41	-6812	0.12	-1176	0.44	-6,974	0.10	-1,338	0.36
Top water level 96.5	-7,904	0.11	-1,545	0.38	-7822	0.12	-1463	0.41	-8,001	0.10	-1,642	0.34
Top water level 97.0	-13,629	0.09	-2,769	0.34	-13508	0.10	-2648	0.37	-13,772	0.08	-2,912	0.30
Top water level 98.0	-26,924	0.07	-6,294	0.24	-26761	0.07	-6130	0.26	-27,118	0.06	-6,488	0.22

Highest two (or equal highest) benefit/cost ratios for each scenario and each analysis. (shaded)

8 Option Evaluation

8.3 Ranking of Proposals

As clearly illustrated in the Summary Table, (8.2.4), the two smallest projects (TWL 96.2 and TWL 96.4) (and sometimes the third smallest project) consistently show the highest benefit cost ratios. Typically, timber and greenhouse benefits represent about 50% of the construction (and operation) costs. If water costs are assigned to each proposal, the benefit stream then represents only between 10 to 13% of the total costs.

The two smallest pond proposals also showed (in section 5.3) the highest ranking when judged on a “cost effectiveness” basis.

Never-the-less, for what is essentially an environmental project, it is unusual to have 50% of the project’s cost covered by economic benefits. Furthermore, it should be recalled that Low Bank works in the Gulf WMA represent benefit streams at the lower end of the expected range. If the flooding frequency within the Gulf WMA was today only five years in 10, the timber benefits would increase by between 80% and nearly 300%. Under this assumption, Scenarios 2 and 3 without water costs, would then show net positive benefits. Even Scenario 1 is close to positive benefits under these assumptions.

8.4 Preferred Project Comparison

If a preferred low bank project was to be selected at this time it would likely look much like the TWL 96.4 project. This project has the following features:

- Bank length 17km
- Bank width 10m
- Clearing for roadway 24ha
- Clearing for borrow pits 20ha
- Maximum bank height about 2m
- Average bank height about 1.2m
- Regulator waterways about 24m^2 and 12 m2
- Regulator capacities about 2000ML/d and 1000 ML/d
- Bulk earthworks 293,000m^3
- Estimated cost $1.9M

As a comparison between this low bank project and its small flood equivalent the following two tables present a summary of water use and costs for a year of applied watering and a year of no extra watering. The tables describe both projects in terms of construction works, water use, operational costs and timber production benefits.

For a year when water is applied in the Gulf WMA, the low bank works (at $840/ha/a) show a significant cost advantage over the small flood strategy at $2320/ha/a. The water use comparison also favours the low bank project. Its water use in these years is estimated at 10Ml/ha/a compared to 31Ml/ha/a for the small flood alternative.

8 Option Evaluation

Table 8.4.1

Preferred Low Bank Project TWL 96.4 and Small Flood Option

WATER RESOURCE AND COST COMPARISON SUMMARY

WATERED YEAR

Feature	Unit	Low Bank Works		Small Floods	
PROJECT		**Basis**		**Basis**	
TWL Low Bank project	RL		96.40	Not applicable	
Flooded area within Gulf WMA	ha		1,900		1,900
Flooded period	m		A, S, O and N		A, S, O and N
Flooded period	d	2 No 15day shoulders plus three months	120.9	2 No 15day shoulders plus three months	120.9
Small flood flow	Ml			Taken as 1600 Ml/d	193,440
COSTS					
Capital cost	$		$1,874,000.00	Not applicable	$0.00
Annual cost (every year)	$/a	Taken as 8% of capital cost.	$149,920.00	Not applicable	$0.00
Operating cost, flood year	$/a	0.2 person year on a 2.7 multiplier	$45,900.00	0.2 person year on a 2.7 multiplier	$45,900.00
WATER USE					
Water to fill	Ml/a	Flooded area volume	12,500	Assume included within the 1600Ml/d	
Evaporative loss	Ml/a	0.47m/a	8,930	Covered within the 1600Ml/d	
Water quality through flow	Ml	Assumed 400Ml/d,to help control water quality	48,360	Covered within the 1600Ml/d	
Estimated return to Murray	Ml	80% of through flow plus volume to fill	51,188	Assume 70% return	135,408
Estimated total water use		Evaporative loss plus losses,20% of through flow.	18,602	Difference between inflow and outflow	58,032
Water cost	$	$75/Ml	$1,395,150.00		$4,352,400.00
TOTAL FLOOD YEAR COST	$	Includes water, interest and operation costs	$1,590,970.00	Includes water, interest and operation costs	$4,398,300.00
BENEFITS					
Annual timber production and Greenhouse benfits, "Scenario 2"	$/a	This benefit applies each and every year, not only those three "watered years" in 10.	$69,600.00	This benefit applies each and every year, not only those three "watered years" in 10.	$69,600.00
UNIT VALUES					
Annual benefit/cost (with water costs)			0.11		0.05
Annual benefit/cost (without water costs)			0.42		4.59
Annual flood year water use/ha	ML/ha/a		10		31
Water use as proportion of annual EWA	%		12%		39%
Flood year cost /ha (with water costs)	$/ha/a		$837		$2,315
Flood year cost /ha (without water costs)	$/ha/a		$103		$24
ENVIRONMENTAL					
Environmental impact		Visual, increased flood levels?, construction noise?			
Approvals		Works in a Ramsar area, constraints on forestry operations.		Constraints on forestry operations.	

Maunsell

8 Option Evaluation

Table 8.4.2

Preferred Low Bank Project TWL 96.4 and Small Flood Option

WATER RESOURCE AND COST COMPARISON SUMMARY

NON WATERED YEAR

Feature	Unit	Low Bank Works		Small Floods	
PROJECT		**Basis**		**Basis**	
TWL Low Bank project	RL		96.40	Not applicable	
Flooded area within Gulf WMA	ha		1,900		1,900
Flooded period	m				
Flooded period	d				
Small flood flow	Ml				0
COSTS					
Capital cost	$		$1,874,000.00	Not applicable	$0.00
Annual cost (every year)	$/a	Taken as 8% of capital cost.	$149,920.00	Not applicable	$0.00
Operating cost, flood year	$/a	Not applicable in a non-flood year		Not applicable in a non-flood year	$0.00
WATER USE					
Water to fill	Ml/a				
Evaporative loss	Ml/a				
Water quality through flow	Ml		0		
Estimated return to Murray	Ml		0		0
Estimated total water use			0		0
Water cost	$		$0.00		$0.00
TOTAL FLOOD YEAR COST	$	Includes water, interest and operation costs	$149,920.00	Includes water, interest and operation costs	$0.00
BENEFITS					
Annual timber production and Greenhouse benfits, "Scenario 2"	$/a	This benefit applies each and every year, not only those three "watered years" in 10.	$69,600.00	This benefit applies each and every year, not only those three "watered years" in 10.	$69,600.00
UNIT VALUES					
Annual non flood year benefit/cost			0.46	Not applicable, zero costs	Infinite
Annual benefit/cost (without water costs)			0.46	Not applicable, zero costs	Infinite
Annual non-flood year water use/ha	ML/ha/a		0		0
Water use as proportion of annual EWA	%		0%		0%
Non-flood year cost /ha (with water costs)	$/ha/a		$79		$0
Non-flood year cost /ha (without water costs)	$/ha/a		$79		$0
ENVIRONMENTAL					
Environmental impact		Visual, increased flood levels?, construction noise?			
Approvals		Works in a Ramsar area, constraints on forestry operations.		Constraints on forestry operations.	

8 Option Evaluation

If however, water costs were to be excluded, the cost effectiveness position is reversed with the small flood option costing $24/ha/a against $100/ha/a for the low bank works.

The benefit cost ratios in the summary spreadsheets also reflect these conclusions with the low bank works (b/c = 0.11) showing double the return of the small flood strategy (b/c = 0.05) when water costs are included. With water costs excluded, the small flood strategy at a b/c figure greater than 5 shows as a preferred project over the low bank figure at 0.4.

Because of the capital cost of the low bank works, in any non-watering year (ie 7 years out of 10) when the timber production benefits remain the same, the low bank works still require a capital repayment of $150,000 against no costs at all for the small flood strategy.

These conclusions are in line with those from the earlier economic comparison.

8.5 Environmental Benefits

Assuming that the cost of the Murray water can be used as a indirect indicator of “other environmental benefits”, the four projects equivalent to the tested Low Bank works infer high other environmental benefits. The analysis in section 6.2 and 6.3 shows surrogate benefits measured in tens of millions of dollars. Of the four tested Gulf WMA areas, the inferred benefits increase with flooded area but show a unit peak at 58% flooded of about $12,000/ha. The two smallest projects (equivalent to TWL 96.2 and 28% flooded and TWL 9.6.4 and 35% flooded) are at the low end of the unit results with $9,000/ha and $10,000/ha respectively.

It is widely recognised that valuing environmental benefits is difficult. Using the cost of Murray water as an indirect indication of environmental benefit allows comparison of the surrogate benefit with the value of other crops/products dependent on the same common denominator, water.

9 Preferred Proposal

9 Preferred Proposal

Based on cost effectiveness measures and benefit cost analyses, the most advantageous projects are at the small end of the range. The TWL projects 96.2 and 98.4 (and perhaps even the TWL 96.5 project) all cover about 50% of the project costs as timber and greenhouse benefits. If water costs are taken in account, the order of preference remains the same although only 10% of the project costs are now covered.

As was illustrated in section 8.4, the preferred low bank project shows better water use efficiency but only the expenditure of significant funds.

10 Conclusions

10 Conclusions

The following conclusions have been drawn from this study:

Air Borne Laser DEM

1 The air-borne laser DEM provides a suitable base for the planning of low bank and by inference, other engineering works in the Barmah-Millewa Forest.

2 However, more analysis needs to be done after data gathering to produce “user friendly” versions for likely uses such as new road location, the effect of additional regulators, possible low bank works, the documentation of forest floods and the classification of forest Site Qualities.

3 The DEM and its associated site quality data plus WMA flood history should be analysed to identify other WMA worthy of analysis. The Forum should assume this responsibility.

4 As DEM coverage is extended to other River Murray areas, analyses should be undertaken to check on the cost effectiveness of flooding other floodplain areas. As has been indicated throughout this report, the Gulf WMA, while appropriate for an initial analysis, may not be the most cost effective WMA in the Barmah-Millewa Forest. Furthermore because of the Gulf Creek’s relative steepness (there is a fall of over 8 metres from the Gulf regulator to Little Budgee Creek), other floodplain areas may be better suited to low bank works.

Project Evaluation

5 For this evaluation, selecting the most appropriate project depends upon the objective.

6 For a cost effectiveness measure based only on dollars per flooded hectare, the most cost effective design is the TWL 96.2 bank, at a cost of $930/ha flooded. The least effective design is the TWL 98.0 bank at a cost of $1,810/ha flooded.

7 The “inferred other environmental benefits” analysis suggest that the TWL 97.0 project may show the highest return for each hectare flooded. The two smallest projects (TWL 96.2 and TWL 96.4) produce the lowest per hectare returns. Caution is advocated in any attempt to make too much of either the analysis or the conclusion until the calibration and verification of the Mike 11 model is completed.

Benefit Cost Analysis

8 The benefit cost analysis was comprehensive and most thorough.

9 For the assumptions defined in the analysis, the benefit cost analysis suggested that:

10 Low bank projects that improve the flooding frequency in already well watered areas, will produce timber production benefits at the low end of the scale.

11 Ideally, low bank works should be developed in areas with lower flooding frequencies.

12 For any of the low bank projects and with water costs included, Scenario 2 produces the least negative net benefits. However, the differences between all three Scenarios is not large.

10 Conclusions

13 With water costs included, benefit cost ratios are typically about 0.1 for all three Scenarios. Again, Scenario 2 shows slightly better performance.

14 Water costs are typically more than 70% of total project costs so their exclusion improves the performance of all the low bank works.

15 Comparing the preferred low bank project (TWL 96.4) with its small flood alternative shows that the low bank project is more efficient in terms of water use and when water costs are included, more cost effective. If however, water costs are excluded, the small flood strategy shows better cost effectiveness.

16 Higher levels of cost effectiveness may be achieved if the terrain within the WMA is less steep and or if the cost of part of the low bank works can be shared with adjacent WMA's.

Follow on Actions

17 The conclusions from this study could be of interest to the "Living Murray" community consultation process and Forum support will be sought for the paper to be lodged with the Murray Darling Basin Commission.

Still Required

18 The Discussion Paper has been limited to providing indicative benefit costs of some low bank proposals to facilitate, at low river flows, mimicking (season frequency and duration) natural flooding characteristics and enhancing (annual) flooding in a section of the Barmah Millewa Forest.

19 There are significant environmental components which are widely recognised as difficult to value in dollar terms which have not been included in these benefit costs.

20 It is too early to provide detail on matters such as within forest operational requirements, specific actions to satisfy desired biological outcomes and on any EIS/Approval process.

21 What is required now is to consider the Paper's contribution, in the context of social, economic and environmental issues, to the environmental flows debate, including the important issues of water use efficiency and management,

11 Recommendations

11 Recommendations

1 The Low Bank conclusions were first presented to the Research, Monitoring and Evaluation Committee in September 2002 and after encouragement by the Committee, to the November 2002 Forum meeting.

2 The November 2002 Forum meeting asked that final copies of the full report be made available for a last review prior to a formal endorsement by the Forum expected now in February 2003.

3 Such an endorsement date would still meet the timetable of the “Living Murray” community consultation program

4 The conclusions should be further reviewed as part of the “Extensive vs Intensive” desk top study planned by the Forum.

5 Calibration and verification of the Mike 11 model proceed at the earliest opportunity using minor floods/river freshes, surplus flows/rain rejections supplemented from the EWA as required to facilitate project completion in 2002/2003.

6 Testing the benefit methodology in other WMA’s (particularly those with lower flooding frequencies) should be facilitated by the provision of the LIDAR project’s DEM and its associated site quality data.

Appendix A References

Appendix A References

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Appendix B Timber Production in Barmah Forest

Appendix B Timber Production in Barmah Forest

Timber Production M^3/Ha/Yr –

Average For Barmah Forest For All River Red Gum Site Qualities (1, 2, 3) Under Various Forest Management And Water Management Strategies.

B. D. Dexter May 2002.

Notes:

1. Present forest management for timber production under present stand structure, current environmental prescriptions, forest flooding and water management policy.

2. Forest management in zones specified for sustainable timber production as a primary aim and in full cognisance of:

   - Active water management in accord with the Murray-Darling Basin Commission's approved Water Management Strategy for the Barmah-Millewa Forest.
   - Silvicultural treatment facilitating full stocking and subsequent progressive selective thinning over the rotation.
   - Environmental prescriptions that meet the Code of Forest Practice and ensure a high level of flora and fauna conservation.
   - Forest management takes account of significant areas set aside where environmental conservation is the primary aim to the exclusion of timber production.

3. Forest management for sustainable timber production as the primary aim.

4. Annual Flooding.

5 & 6. Present flood frequency as a result of actual Murray River flows below Yarrawonga/Tocumwal 1955-2001.

7. Present/predicted flood frequencies on up to half of SQ II forest and most of SQ III forest as a consequence of MDBMC and NSW and Victoria State land and water management policy decisions. Values are for average timber production over all site qualities for each forest management scenario under present/predicted and managed flood frequencies.

Appendix B Timber Production in Barmah Forest

Supplementary Notes:

(i) Except in severe drought years annual flooding may occur on small sections of forest, wetlands and low-lying plains fed from major flood runners via on-river regulators. These areas flood at low river flows below Yarrawonga/Tocumwal (6, 500 – 1 5,000 Ml/day) and are the areas generally most prone to unseasonal flooding particularly as a result of rain rejections in summer and early autumn.

(ii) There are only very rare occasions when there are 3 consecutive years without a flood and few occasions, usually widely spaced, when there are 2 consecutive years without some flooding. Consequently, the forest, similar to natural/historic pre-regulation flooding (1895 – 1934) does not experience severe cumulative drought stress. This situation is reflected in forest productivity described by Jacobs, Baur and Bacon.

(iii) Cumulative drought stress results in a cessation of growth and recovery to pre-stressed levels takes place over several seasons.

It must also be borne in mind that flood duration, apart from 2-3 years each decade is often less (up to 2 months) then that under natural (pre-regulation) flooding conditions. (Refer to Forum paper and background notes on Definition of an Effective Flood).

The shorter duration of flooding, including season of flooding is considerably less than optimal for many biological processes including tree growth and overall vitality.

(iv) Tree vitality and growth is very significantly reduced under this level of flood frequency. Cumulative drought stress is much more evident particularly as the frequency of two or more consecutive years without a flood is a regular occurrence.

Biological activity, including tree growth is also more dependent on general seasonal conditions and duration of any flooding.

Appendix B Timber Production in Barmah Forest

Timber Production M^3/Ha/Yr
Average For Barmah Forest For All River Red Gum Site Qualities (1, 2, 3)
Under Various Forest And Water Management Strategies.

		Timber Production m^3/ha/yr Average for Whole Forest					
Flood Frequency		1		2		3	
		Saw Logs	Other Produce	Saw Logs	Other Produce	Saw Logs	Other Produce
4	10 years out of 10 Note (1)	1.48	1.10	2.12	1.57	2.50	1.85
5	7-8 years out of 10 Notes (1) (2)	0.78	0.57	1.35	1.00	1.87	1.39
6	4-5 years out of 10 Note (3)	0.22	0.16	0.43	0.32	0.75	0.56
7	≤ 2 years out of 10 Note (4)	Negligible to negative		0.04	0.02	0.15	0.11

Dependent on other seasonal factors

Data presented on River Red Gum Timber Production (m^3/ha/yr) was developed in cognisance of the following:

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Appendix B Timber Production in Barmah Forest

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Appendix C Valuing Central Murray River Forests for Carbon Sequestration

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

Discussion Paper
Valuing Central Murray River Floodplain Forests For Carbon Sequestration

Prepared for Timber Communities Australia.

Barrie D Dexter July 2002.

The views expressed in this paper are those of the author and do not necessarily reflect those of any individuals or organizations with whom the author is associated. The author has taken every care in the preparation of the discussion paper but reserves the right to correct any errors or omissions.

1 The Case For Including Sequestration Of Carbon In A Native River Red Gum (RRG) Forest As An Environmental Benefit

Australia has strongly advocated mechanisms and provisions under the Kyoto Protocol that provide the maximum flexibility for Annex 1 of the United Nations Framework Convention on Climate Change (industrialised countries and countries with economies in transition) parties to meet their commitments to regulate greenhouse gas emissions at least cost. These include crediting carbon sinks and allowing maximum use of the Kyoto Protocol flexibility mechanisms (1).

An important feature of the Kyoto Protocol is the definition of forestry activities as specified in article 3.3.

> *"The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments of each Party included in Annex 1."*

Under the Kyoto Protocol, developed countries such as Australia are required to limit their greenhouse gas emissions according to the following formula:

> *"Actual emissions must be less than or equal to the assigned amount +/- carbon sinks and Kyoto emissions."*

With respect to the "carbon sinks" component it means that Australia's target is to limit growth in greenhouse gas emissions to 8% above 1990 levels, on an average annual basis, by 2008-2012. Currently, allowable sink activities are confined to a limited number of forest related activities: - afforestation, reforestation and deforestation since 1990 and are referred to as "Kyoto Forests' (1) (2).

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

Definitions (3) relating to land use, land use change and forestry activities under Articles 3.3 and 3.4 of the Kyoto Protocol include:

(a) ***"Forest"*** *is a minimum area of land of 0.05 – 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 metres at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest;*

(b) ***"Afforestation"*** *is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or human-induced promotion of natural seed sources;*

(c) ***"Reforestation"*** *is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989;*

(d) ***"Deforestation"*** *is the direct human-induced conversion of forested land to non-forested land;*

(e) ***"Revegetation"*** *is a direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 hectares and does not meet the definitions of afforestation and reforestation;*

(f) ***"Forest management"*** *is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner."*

Australia has indicated in international negotiations that it does not intend to account for "forest management" in the first commitment period of the Protocol. This is because preliminary assessment of projected emissions and sequestration from forest management during the first commitment period highlighted the risk of Australia incurring net emissions. This is attributed to the biophysical characteristics of Australia's environment including climate variability, drought incidence and bushfire patterns. (Pers. comm. Mr Paul Ryan AGO).

The Australian Greenhouse Office (AGO) has described a very rough initial way for estimating the carbon sequestration potential in various parts of Australia by way off a map combined with outputs from the CAMFor model **(5)**. The applicability of the graph is heavily qualified under six points the last of which states:

> "(the graphs) *are not accurate enough to be used as a basis for making carbon sequestration claims about your plantings in most circumstances".*

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

> *"More accurate estimates of carbon sequestration specific to the site and species planted should be developed if you are planning to make any carbon sequestration claims for your planting and particularly if you are planning to harvest timber and/or sell carbon".*

In summary, the Kyoto Protocol identifies a limited range of carbon sink activities from which carbon sequestration could potentially be recognised within a national emissions trading system. It is clear that they will only include activities established in or after 1990, are human-induced and not accounted for under another Article. Techniques and processes to monitor and verify the amount of carbon actually sequestered from forest-related activities continue to develop as part of the National Carbon Accounting System. A decision on implementing a national emissions trading system incorporating carbon credits will only be made if Australia ratifies the Kyoto Protocol, Protocol commitments become legally binding and there is an established international emissions trading regime in place **(4) (5)**.

Notwithstanding the many issues to be resolved, nationally and internationally, there is already carbon trading occurring in Australia. In Victoria, the Forestry Rights Act of 1996 allows the ownership of trees to be separated from the land by means of a Forest Property Agreement, giving the tree owner security by protecting the rights to the trees even if the land changes ownership. An amendment in May 2001 recognises Carbon Sequestration Rights and enables ownership of these rights separately from the trees and the land. Greenhouse sink investors are therefore able to enter into a Forest Property Agreement to fund the establishment of environmental plantings without having to own or mange trees. However, such agreements can only be entered into on privately owned land **(6)**. State Forests of New South Wales also promotes plantation-grown trees for carbon credits and provides an advisory service to landholders including options covering renting land to SF NSW, establishing a planted forest for ultimate harvest and/or to address environmental issues such as salinity and biodiversity enhancement **(7)**. The AGO **(5)** provides a snapshot of 4 case studies, NSW [2], Vic [1] and WA [1], which include significant overseas investments – Japan's Cosmo Oil (WA) and Tokyo Electric Power Co (NSW). The AGO - among others, has warned that farmers who have received credits for sequestered carbon need to ensure that this carbon is not permanently re-released through activities such as harvesting without replanting.

The AGO also points out –

"It should be recognised however, that only a proportion of the existing sustained commercial forestry plantation and none of the existing native forest and woodland would be accountable under Article 3.3 of the Kyoto Protocol." **(1)**

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

A comprehensive paper *"Creating Markets for Ecosystems Services"* **(8)** by Greg Murtough, Barbara Aretino and Anna Matysek (2002) investigates how well environmental problems related to salinity, biodiversity and climate change can be addressed by creating markets for **ecosystem services**.
Ecosystems services are defined as: *"the functions performed by ecosystems that lead to desirable environmental outcomes. They include air and water purification, drought and flood mitigation, and the stabilisation of climate".*
The authors identify 8 key messages from their research and conclude that the environmental problem of climate change is the most suitable for market creation.

Key Messages

- *Ecosystem services are the functions performed by ecosystems that lead to desirable environmental outcomes, such as air and water purification, drought and flood mitigation, and climate stabilisation.*
- *Markets rarely exist for ecosystem services. Typically, those who supply ecosystem services are not rewarded for all the benefits they provide to others, and those who reduce ecosystem services do not bear all the costs they impose on others.*
- *Without markets, allowing parties to act in their own private interest can result in fewer ecosystem services than is optimal for society as a whole.*
- *In theory, governments can create a market for an ecosystem service by defining a new property right that is both linked to the ecosystem service and can be exchanged for reward. Two Australian examples are:*
  - *the introduction of tradeable emission permits to limit saline discharges into the Hunter River; and*
  - *state legislation separating title over the carbon sequestered in forest plantations from ownership of the timber.*
- *This approach to creating markets is more likely to be successful if the relevant property right has a number of characteristics, including:*
  - *ownership can be defined and enforced at reasonable cost; and*
  - *trades are not significantly hindered by high uncertainty; a lack of buyers and sellers; or a major imbalance in the information held by buyers and sellers.*
- *It appears that climate change is the environmental problem that is most suitable for market creation. The greatest difficulties are likely to arise in creating a single market for all aspects of biodiversity.*
- *A review of market creation schemes in Australia and the United States indicated that creating markets can, under the right conditions and with appropriate market design, be an efficient way to achieve certain environmental goals.*
- *However, policy makers need to pay particular attention to the issues of scientific uncertainty, market liquidity, and the role of supporting regulation.*

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

The introduction of carbon credits to assist in climate stabilisation is given further impetus in an article by Julie Macken (9).

"Economists and politicians have been slow to realise that a failure to put a price tag on the fundamentals of life – such as air, water and biodiversity – has produced unsustainable exploitation of these resources.

So, in an attempt to reverse this and make the use of scarce natural resources more expensive, the Natural Resources Management Ministerial Council will launch a $10 million program today (21 06 02) to investigate the use of market-based instruments (MBIs). The idea is to harness the discipline of the market to ration or discourage the use of natural resources and encourage their conservation.

MBIs cover a range of options, the most obvious being the introduction of carbon credits to fight global warming."

"The Minister for the Environment, David Kemp, does not regard MBIs as an environmental silver bullet, but he is keen to have their potential realised. "MBIs are not a quick fix, and many require legislative underpinning and support," he says. "Nevertheless, it is clear that MBIs have huge potential to achieve 'more from less'*, to drive innovation, place environmental considerations in the mainstream and give economic incentive for good natural resources management".*

"According to Chris Guest, assistant director-general in the Department of Land and Water Conservation and chair of the working group on MBIs that reports to the ministerial council, the process of getting the market into the environment is a two-step one.

"The first step is one of basic research. That is, how do you set up a market from an economic and scientific point of view? That's where these pilot schemes can provide some really good answers".

From an environmental perspective Australia benefits greatly from healthy native forest ecosystems but it is generally recognised that their $ environmental values are difficult to quantify compared with many other goods and services.

There is wide agreement that carbon sequestration by trees and a trade in carbon credits is a useful way of contributing to climate stabilisation. There is also strong agreement that biodiversity is extremely complex to define and value. For native forests these concepts are in the early stages of development. Complexity in flood plain forests is exemplified by the intended complementary, but in fact disparate actions of the Murray Darling Basin Ministerial Council (MDBMC) and the Natural Resources Management Ministerial Council (NRMMC). Each Council receives advice from the same Commonwealth and State bureaucracies and each has some commonality of State and Federal Ministers.

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

In March 2001(10) the MDBMC agreed to interim operating rules to be applied by River Murray Water, Victoria and New South Wales for managing the Barmah-Millewa (river red gum) Forest environmental water allocation approved by the MDBMC in 1993. Despite repeated community-based warnings to the MDBC, the advice given to and endorsed by MDBMC will perpetuate on-going and cumulative environmental degradation on at least 50 per cent of the forest and, on these areas, severely impact on social, economic and environmental values, including the effectiveness of the red gum forests as carbon sinks. This is because operating rules attempt to satisfy just a few elements of biodiversity, such as colonial water birds, rather than facilitating the investigation of promising water management options that would satisfy a wide range of environmental, social and economic values, including increasing the forest's potential to sequester carbon.

The Central Murray river red gum forests are well endowed with ecosystem services, leading to desirable environmental outcomes including: conservation of biodiversity, water purification, flood mitigation and climate stabilisation. The market related to climate stabilisation – carbon sequestration/trading carbon emissions is closely allied with one of the major economic values of the forests – timber production.

Murtough et al (8) identify three key issues facing policy makers in designing ecosystem service markets:

- Scientific uncertainty;
- Market liquidity;
- The role of regulation.

With respect to flood plain forests it is argued that such concerns are more easily resolved because the forests are:

- In public ownership under the stewardship of Government regulated management;
- Key ecosystem services with desirable environmental outcomes:
    - Conservation of biodiversity (of national/international significance);
    - Flood mitigation (major natural flood control reservoir serving Victoria, NSW and South Australia);
    - Climate stabilisation (the forests can continue to play a role in carbon sequestration with the sustainable removal of biomass in the form of wood products)

  are of regional and national benefit.
- Ecosystem processes particularly in matters of flood mitigation, natural flooding cycles/modified flooding cycles, growth habitats of river red gum and sustainable biomass removals (yield of wood products) in relation to forest and water management practices are relatively well understood.

In Australia, carbon sequestration/carbon trading, particularly since 1997, has been mainly targeted at plantation-grown trees on private land rather than any specified role for native forests. Well managed native forest where wood is sustainably removed and forests are effectively regenerated and tended throughout the rotation can also make a significant contribution towards climate stabilisation. This is achieved by the forest sequestering carbon in perpetuity rather than reaching a state of equilibrium whereby growth is balanced by decay. Management activities that increase forest carbon sequestration are clearly in line with State and Commonwealth government policies to offset Australia's relatively high per capita CO_2 emissions.

It is proposed that valuing the enhanced carbon sequestration directly resulting from improved watering of the river red gum forests is a legitimate and tangible way of placing a $ environmental benefit (among others) on much improved forest and water management.

2 Measuring Carbon Sequestered By Trees. (11)

"The quantity of carbon dioxide that can be sequestered into biomass depends on the type of forest, its rate of growth and the ultimate fate of the wood or other biomass harvested.
Natural forests tend to be in a state of equilibrium with growth being balanced by decay. This equilibrium may be disturbed, for example by fire, and this sudden loss of CO_2 tends to be followed by a period of growth and net sequestration until a steady state is again reached.

Forests which are to be locked up and not used for wood production will pass from a period of active growth when CO_2 is actively sequestered into the biomass, to a period when they mature and growth and decay are in balance. As trees die and the crowns of large trees become less dense, the amount of dead mass on the forest floor can increase substantially and the forest may be a net producer of CO_2. A new equilibrium is reached when net CO_2 production and sequestration are in balance.

Forests, which are regularly harvested, will continue to sequester carbon as long as growth continues. When a forest is thinned there will be a short period while the remaining trees occupy the available space and slash from harvesting breaks down. If a forest is clearfelled and replanted there will be a period while trees are being re-established when carbon sequestration may be low or even negative (eg when there is a lot of slash left on site which is breaking down).

ONLY BY CONTINUING TO GROW A FOREST AND REMOVING THE BIOMASS IN THE FORM OF WOOD OR OTHER PRODUCT CAN THE FOREST CONTINUE TO PLAY A ROLE IN CARBON SEQUESTRATION.

The amount of carbon that can be sequestered depends on the rate of growth and tree species involved; highest rates are achieved by well managed, fast growing species on good soils in high rainfall areas. The lowest rates of carbon sequestration are where rainfall is low, soils are poor, management is poor and slow growing species are used."

Whilst it can be argued that soil carbon and below ground biomass, plus non-harvestable components (leaves, branches etc.) could also be included – allowing an equivalent amount to stem biomass, there are still many issues to resolve concerning forest type, soil type and etc. For the sake of simplicity a conservative approach of limiting the parameter to easily measured stem volume is preferred (12).

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

There is general agreement on how to measure stem wood and convert the weight of the dry wood into the weight of carbon. Fletcher $_{(13)}$ outlines the process:
"The amount of carbon captured by trees is estimated from the volume of the trees, calculated from the heights and diameters.
The tree volume is then converted to tonnes of dry wood. The weight of dry wood is then divided into the weight of carbon and other elements such as hydrogen and oxygen.
For example, a fast-growing eucalypt plantation averaging a stem growth rate of 20 cubic metres of wood per hectare may yield 500kg of dry wood per cubic metre, that is 10 tonnes per hectare and contain 50 per cent carbon, that is 5 tonnes per hectare of carbon per year."

State Forests of NSW adopts a similar approach $_{(7)}$.

3 Carbon Content And Value.

Carbon sequestration is generally reported in either tonnes of carbon or tonnes of carbon dioxide $_{(5)}$. To convert tonnes of carbon to tonnes of CO_2, multiply the carbon figure by 3.67. Alternatively, to convert tonnes CO_2 to tonnes carbon divide the CO_2 figure by 3.67.

There are divergent views on the productive potential of forests and what carbon sequestration is worth. Well managed plantations have significantly higher growth rates than native forests and in either case the rates actually achieved depend on site potential and management practices.

Borough et al $_{(11)}$ indicate:

> *"The price likely to be paid for carbon credits could vary over time depending on either the legislative requirement to account for CO_2 produced or for a market advantage for a product which promotes the environmental value of its actions in CO_2 sequestations.*
>
> *Dobes (1996)* [as reported by Borough et al] *calculated the marginal cost in terms of \$/tonne CO_2 ranging from \$1.76 to \$5.18. This is equivalent to \$6.50 to \$19.20/tonne C. Indications from other sources suggest \$10/tonne is likely but \$20/tonne is not unreasonable.*

Ryan $_{(12)}$ urges a conservative approach, suggesting that readily acceptable figures for considering carbon credits could be based on:

- Limiting volume/weight to stem volume;
- Allowing carbon content of wood at 40% (Fletcher$_{(13)}$ Vic. Govt.$_{(6)}$ and NSWSF$_{(7)}$ use 50%);
- Valuing the stored carbon at \$5/tonne/ha/yr.

Ryan notes that some figures quoted to farmers have ranged up to \$40/tonne/ha/yr while others value CO_2 in the range \$10-\$50 per tonne – approximately \$2.50-\$13.50 per tonne of carbon.

4 Valuing Carbon Sequestration In Barmah Forest.

Background

- It is accepted from a national viewpoint that Australia's native forests are important for utilizing CO_2 emissions whether or not the parameters fit under the Kyoto Protocol.
- Under current water storage and cap rules the whole of the RRG type will, on average, receive full "natural flooding" 2 years in every 10. (Compare 7-8 years in every 10 under natural conditions).
- Under current State (Vic and NSW) and Commonwealth (MDBC, MDBMC) policy and interim operating rules at least 50% of the forest, the bulk of which will be RRG type, will not be flooded other than "natural" floods and the remainder (≤50%) will be flooded 3-4 times each decade with no non-flood period exceeding 5 years.
- The forest is subject to periodic selective fellings (thinnings over the rotation) with areas receiving final harvesting (Australian Group Selection) and regeneration/reforestation on a 130-year rotation. The forest is managed under scenarios 1, 2 or 3.

Carbon Production Tonne/Ha/Yr –
Average For Barmah Forest For All River Red Gum Site Qualities (1, 2, 3) Under Various Forest Management And Water Management Strategies

Notes:

1 Present forest management for timber production under present stand structure, current environmental prescriptions, forest flooding and water management policy.

2 Forest management in zones specified for sustainable timber production as a primary aim and in full cognisance of:
  - Active water management in accord with the Murray-Darling Basin Commission's approved Water Management Strategy for the Barmah-Millewa Forest.
  - Silvicultural treatment facilitating full stocking and subsequent progressive selective thinning over the rotation.
  - Environmental prescriptions that meet the Code of Forest Practice and ensure a high level of flora and fauna conservation.
  - Forest management takes account of significant areas set aside where environmental conservation is the primary aim to the exclusion of timber production.

3 Forest management for sustainable timber production as the primary aim.

4 Annual Flooding.

5 & 6. Present flood frequency as a result of actual Murray River flows below Yarrawonga/Tocumwal 1955-2001.

7 Present/predicted flood frequencies on up to half of SQ II forest and most of SQ III forest as a consequence of MDBMC and NSW and Victoria State land and water management policy decisions. Values are for average timber production over all site qualities for each forest management scenario under present/predicted and managed flood frequencies.

Rules For Calculating And Valuing Carbon.

- Based on harvesting stem volume only.
- $1m^3$ log weighs ≈ 1000kg.
- $1m^3$ dry wood weighs ≈ 700kg
- Dry wood contains ≈ 50% carbon.
- Stored carbon valued at $5/t/ha/yr.

Notes.

(i) Except in severe drought years annual flooding may occur on small sections of forest, wetlands and low-lying plains fed from major flood runners via on-river regulators. These areas flood at low river flows below Yarrawonga/Tocumwal (6, 500 – 1 5,000 Ml/day) and are the areas generally most prone to unseasonal flooding particularly as a result of rain rejections in summer and early autumn.

(ii) There are only very rare occasions when there are 3 consecutive years without a flood and few occasions, usually widely spaced, when there are 2 consecutive years without some flooding. Consequently, the forest, similar to natural/historic pre-regulation flooding (1895 – 1934) does not experience severe cumulative drought stress. This situation is reflected in forest productivity described by Jacobs, Baur and Bacon.

(iii) Cumulative drought stress results in a cessation of growth and recovery to pre-stressed levels takes place over several seasons.
It must also be borne in mind that flood duration, apart from 2-3 years each decade is often less (up to 2 months) then that under natural (pre-regulation) flooding conditions. (Refer to Forum paper and background notes on Definition of an Effective Flood).
The shorter duration of flooding, including season of flooding is considerably less than optimal for many biological processes including tree growth and overall forest vitality.

(iv) Tree vitality and growth is very significantly reduced under this level of flood frequency. Cumulative drought stress is much more evident particularly as the frequency of two or more consecutive years without a flood is a regular occurrence.
Biological activity, including tree growth is also more dependent on general seasonal conditions and duration of any flooding.

Appendix C Valuing Central Murray River Forests for Carbon Sequestration

Carbon Production From Stem Volume Tonne/Ha/Yr.
Average For Barmah Forest For All River Red Gum Site Qualities (1, 2, 3)
Under Various Forest And Water Management Strategies.

		Carbon Production From Stem Volume T/Ha/Yr And Value @ \$5/T/Ha/Yr. Average For Whole Forest.					
Flood Frequency		1		2		3	
		Tonne C	Value \$	Tonne C	Value \$	Tonne C	Value \$
4	10 years out of 10 Note (i)	0.91	4.55	1.29	6.45	1.52	7.61
5	7-8 years out of 10 Notes (i) (ii)	0.47	2.36	0.82	4.11	1.14	5.71
6	4-5 years out of 10 Note (iii)	0.13	0.66	0.25	1.26	0.46	2.29
7	≤ 2 years out of 10 Note (iv)	Negligible to negative		0.02	0.10	0.09	0.46
				Dependent on other seasonal factors			

Barrie D Dexter July 2002.

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