Wyaralong Dam: Century Scale Performance

Supplementary report to *Wyaralong Dam Issues and Alternatives*

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Summary

This report presents and discusses several models of the historical behaviour of the proposed Wyaralong Dam on the Teviot Brook, south east Queensland. The models are derived from calibrated historical catchment yield with historical rainfall and indicate the performance of the dam's storage over the past 120 year. With modest environmental flow allocation the proposed Wyaralong Dam would have failed to provide the expected prudent yield of 17,000ML/yr frequently during dry periods. Importantly the proposed dam would have failed every year from 2002 to 2006 to supply even half of the assumed prudent yield of 17,000ML/yr regardless of any environmental flow allocation. In the light of climate change, or even a return to a climate similar to the first half of the 20th Century, the performance of the Wyaralong Dam over the past five years should provide a sober warning that the project is destined to fail. The construction of a third dam in the Boonah Shire that will fail to provide adequate water efficiently or economically is not warranted. Alternatives to the proposed Wyaralong Dam must be considered.

Introduction

In July 2006, the Queensland Government announced its decision to construct a dam on the lower Teviot Brook, a tributary to the Logan River as part of its solution to the south east Queensland water crisis and future development in the area south of Brisbane. The Teviot Brook is situated in the most western catchment of the Logan River catchment with highly variable rainfall (Map 1). Median annual rainfall (which is a better indicator of rainfall that can be expected in most years) ranges from approximately 770mm at the site of the proposed dam up to 911mm in the upper catchment (median rainfall for the entire catchment is 836mm/yr). Due to the high variability in rainfall, the catchment yield is also highly variable. Observed catchment yields have ranged from as little as 301ML/yr to 237,344ML in extremely wet years. Median annual catchment yield is 31,821ML/yr.

There are many dams in south east Queensland that have been constructed over the past several decades as a consequence of political pressure to 'drought proof' the region and ensure adequate supplies of water for urban, industrial, agricultural use and even ground water recharge. Many of these dams are considered to be failures as they have consistently failed to provide adequate water for their purpose during the normal dry periods that are experienced in south east Queensland. Many of these dams are situated well away from the wetter coastal strip (the zone usually less than approximately 60km from the coast line, depending on topography). Examples of some of these 'failed' dams are listed in Table 1.

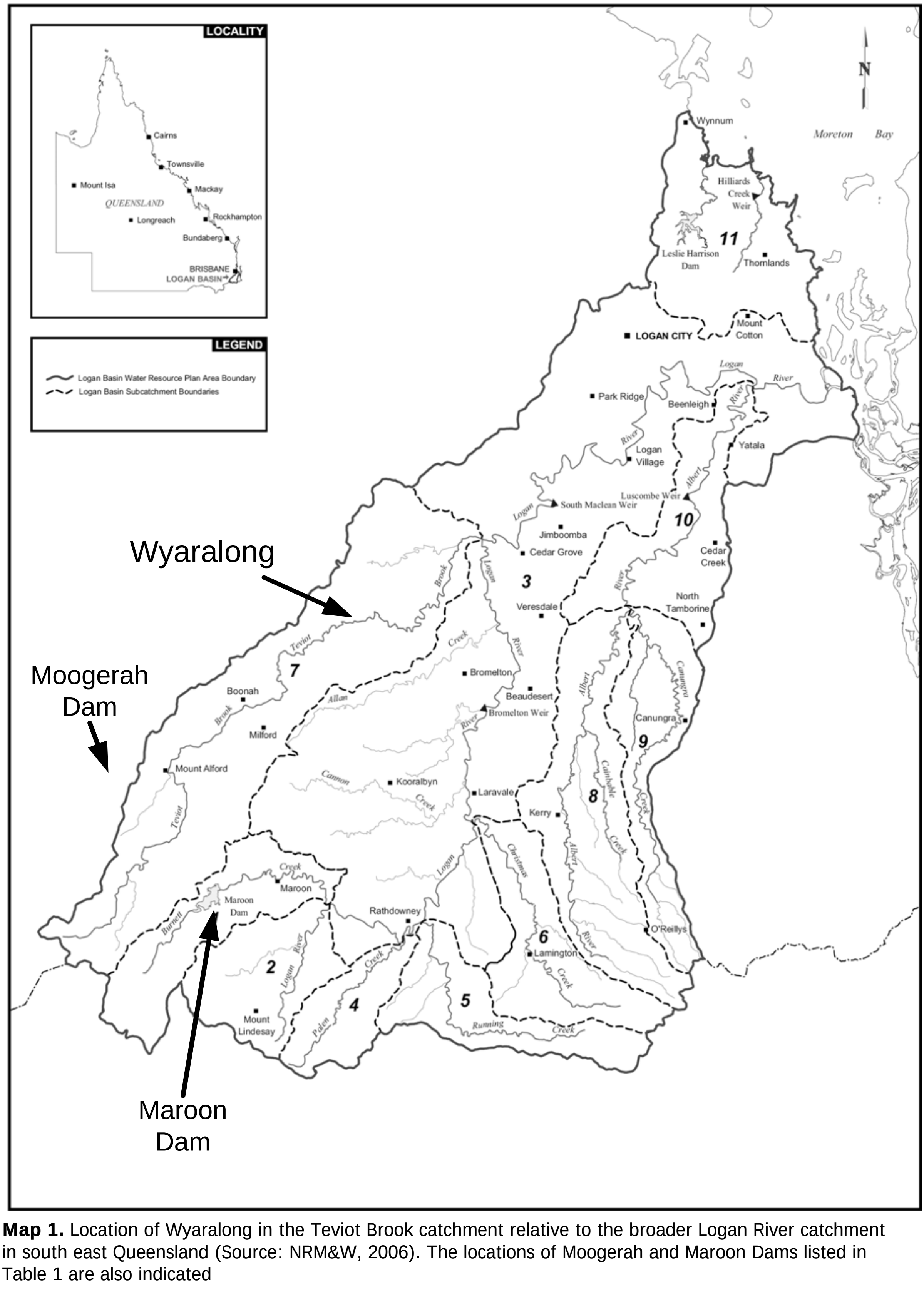
Table 1. Selected dams in south east Queensland and their storage capacity over the past 12 months

Dam	Primary purpose	Previous year dam storage (%)
Lake Clarendon	agriculture and ground water recharge	0
Bill Gunn Dam	urban and agriculture	<5
Moogerah	urban, agriculture, industry and recreation	5-10
Atkinson Dam	urban, agriculture, industry and recreation	0-5
Bjelke-Petersen Dam	agriculture and urban	3-20
Maroon Dam*	urban and agriculture	~20%

* NOTE: Maroon Dam has never been able to be filled beyond approximately half of its originally intended storage capacity due to a suspected geotechnical flaw. This flaw has never been fully investigated to determine if it can be feasibly corrected. If corrected the dam capacity would increase from 44,300ML to more than 80,000ML.

In a recent report it was shown that the proposed Wyaralong Dam on the Teviot Brook would have failed to provide the anticipated prudent yield 17,000ML/yr since 2002 (Witt and Witt, 2006). In addition other environmental, economic and social issues were raised highlighting the high level of risk associated with the proposed dam. These other issues are not revisited in this report. In essence the previous report clearly demonstrated that the dam will fail during periods of expected drought.

This supplementary report extends the analysis by modelling the proposed dam over the past 120 years using historical rainfall data in order to determine the reliability of a proposed dam on the Teviot Brook over a longer historical period.



Map 1. Location of Wyaralong in the Teviot Brook catchment relative to the broader Logan River catchment in south east Queensland (Source: NRM&W, 2006). The locations of Moogerah and Maroon Dams listed in Table 1 are also indicated

Methods

A set of models to assess the performance of a proposed Wyaralong Dam were developed by calibrating observed historical catchment yield with historical rainfall data. The range of models ranged from no allocation for environmental flows through very minor, and up to, reasonable allocations for that purpose. Observed catchment yield data are available from 1967 to 2005 from a point on the Teviot Brook near the location of the proposed construction. Total annual catchment yield from October to the end of September (of the following year) were used as these best represent the hydrological flow from the beginning of the 'wet' season and are consistent with Queensland Department of NRM data. Annual rainfall for the same period was calibrated with annual catchment yield for the 38 years of records and an appropriate curve fitted to the data that could then be used to predict catchment yield from rainfall. The period of observed data captures the range of expected catchment yield and rainfall variability as it covers the very wet 1970s and the recent drought. The fitted curve was then used to convert historical annual rainfall (1890 – 2005) into an estimate of catchment yield (Figures 1 and 2). It should be noted that the fitted curve does tend to overestimate catchment yield frequently at average (880mm/yr) and below average rainfall due to the 'outlier' year of 1996 which was relatively dry except for a significant flood event in May of that year. Variability in both the observed rainfall and catchment yield is high and this needs to be considered in the interpretation of the models produced later in the report. In summary, the modelled historical catchment yields are optimistic for years of average and below average rainfall which subsequently produces an optimistic model of dam storage behaviour.

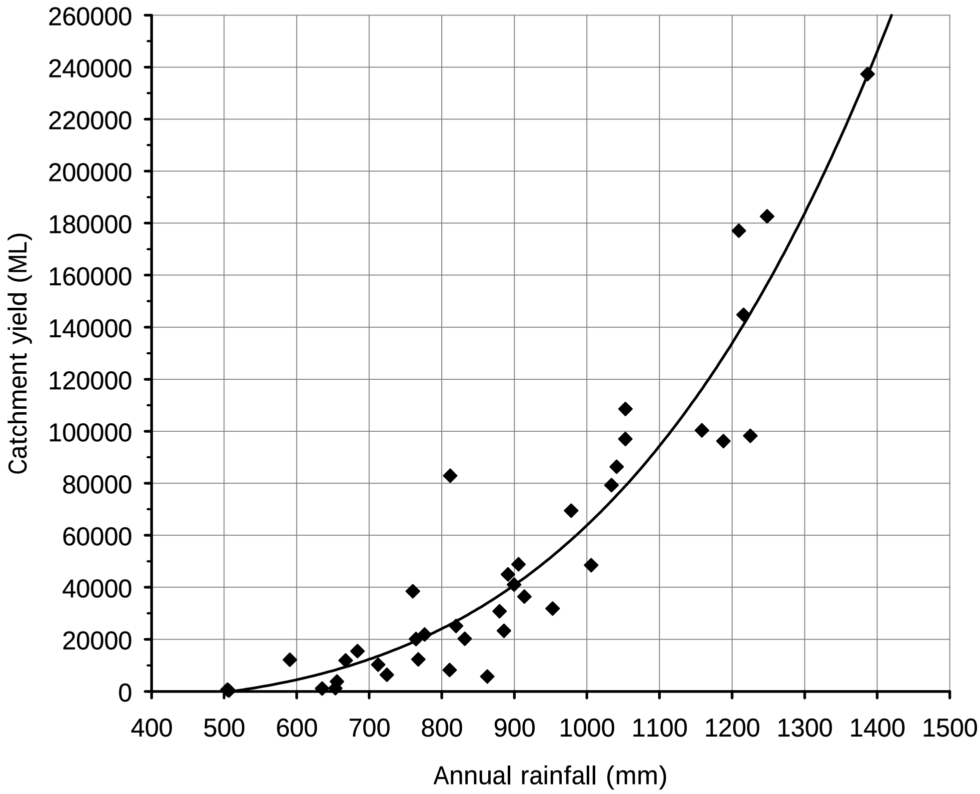


Figure 1. Calibration of historical annual rainfall (October-October) with historical observed catchment yield for the Teviot Brook.

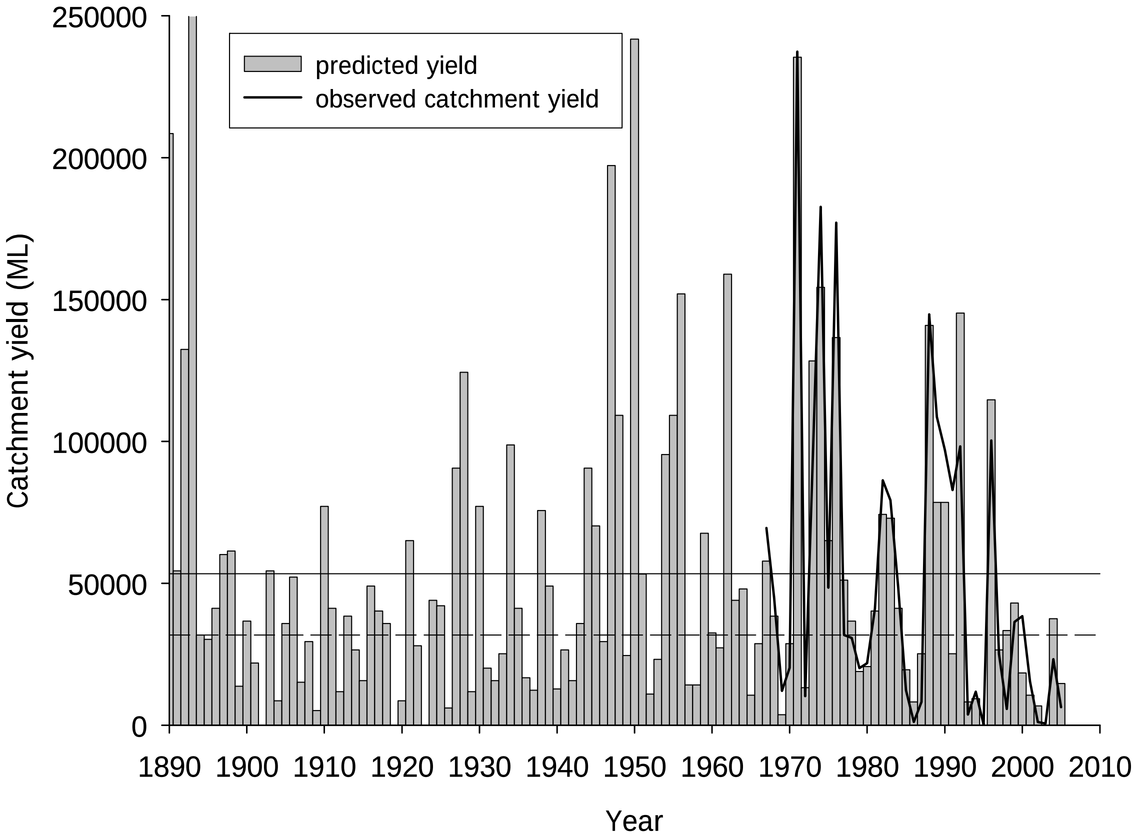


Figure 2. Modelled (predicted) historical catchment yield 1890 to 2005 (shaded vertical bars) in comparison to the observed catchment yield 1967 to 2005 (solid line). Average observed catchment yield is indicated by the horizontal solid line at 53,360ML and highlights the long period when catchment yield is well below this value. Long term median catchment yield is indicated by the dashed line at 31,821ML.

Estimates of historical catchment yield were then incorporated into a year by year model to determine the historical behaviour of the proposed Wyaralong Dam storage had it been in place. However, the model uses the observed catchment yield data for the period available (1967-2005). The storage level was assumed to operate at 63.6m above sea level. At this storage level the dam is expected to have a maximum storage capacity of 103,000ML. Several variables were used to calculate storage behaviour. These variables are described below.

Extraction

According to the Queensland Government 17,000ML is the prudent yield (a conservative estimate of annual extraction that will not lead to dam failure). In running the model, storage was not able to go below 1,000ML (dead storage). However, it is still frequently claimed by political leaders in Queensland that Wyaralong will provide 21,000ML/yr as they avoid discussing the function of Wyaralong Dam in isolation from the proposed Cedar Grove Weir on the Logan River. A model using this value of 21,000ML/yr has also been used as a scenario in this report.

Evaporation and percolation

Evaporation is a significant issue in dams and was calculated based on an annual average evaporation rate of 1.6m/yr for the area where the dam is to be located. At maximum storage capacity the dam would cover approximately 1,230ha leading to approximately 20,000ML/yr loss to evaporation alone. Evaporation rates at different storage levels were determined using the dam storage and ponded area curves provided by GHD (2006 p. 122). It needs to be stressed that 1.6m/yr is an average over the past 120 years and that there is a trend to increasing evaporation driven largely by increasing winter temperatures over recent decades. Since 2001 the evaporation rate has averaged 1.72m/yr. An extra 102mm of evaporation (over the 1.6m value used in the modelling for this study) sounds trivial but equates to an additional 1,300ML lost to evaporation at full storage each year.

No data are available to estimate percolation (seepage) from the dam. Two very conservative values of 1,500ML/yrs (approximately 4ML/day) at high storage levels, and 900ML/yr (approximately 2.5ML/day) at lower dam levels were assumed in the model.

Environmental flow

The allocation of environmental flow has not been determined for the proposed Wyaralong Dam. Methodologies to determine appropriate environmental flow to maintain downstream ecological and stream processes range from simplistic to very complex (Tharme, 2003; Gordon *et al.*, 2004). However, the determination of an appropriate flow is ultimately a judgement informed by technical and scientific data in combination with a balance between expert opinion on environmental requirements and human needs. Because an environmental flow regime has not yet been determined a range of scenarios have been developed to inform the models presented in this work. These scenarios range from no environmental flow allocation through to what could be considered minimum allocations for environmental purposes. No consideration of current down stream users has been incorporated into the models in this report. The scenarios where an allocation for the environment is provided from the proposed Wyaralong Dam range from a paltry 2,007ML/yr to a variable flow of 10% of each year's natural catchment yield up to an optimistic fixed annual allocation (from an environmental process point of view) of 20% (6,364ML/yr) of median catchment yield (median catchment yield is less than 32,000ML/year). An additional model of the often publicly cited prudent yield of 21,000ML/yr (Bligh, 2006) with the least environmental flow of 2007ML/yr was included as the fifth scenario.

Models were prepared in excel spreadsheets using the information described above to produce a year by year model of storage behaviour in the proposed Wyaralong Dam. The resulting data presented in the graphs that follow are the maximum storage available for each year. A threshold of 25,000ML is shown on the graphs and provides an indication of those years that the dam would have been unlikely to provide the 17,000ML/yr considered as prudent yield by the Queensland Government. If maximum storage for any year is below this threshold then it can be considered that due to combined effects of evaporation, seepage (percolation) and an environmental flow allocation (if applied) the prudent yield (extraction) of 17,000ML/yr cannot be achieved.

Results

The following graphed scenarios describe the outcome of five models of the proposed Wyaralong Dam.

Scenario 1: Historical Wyaralong Dam storage behaviour with no environmental flow allocation

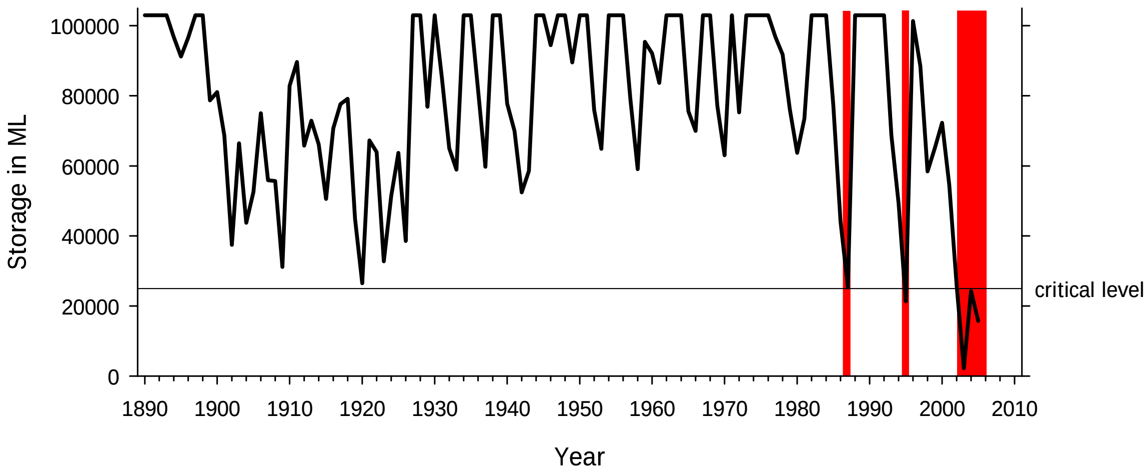


Figure 3. Scenario 1: A model of storage behaviour of the proposed Wyaralong Dam where no allocation at all is given to environmental flow 1890 to 2005. The red area (shaded) indicates years where the dam would have failed to provide the expected prudent yield of 17,000ML/yr. Note that observed catchment yield data are used in the model from 1967 to 2005 (this is the case for all modelled scenarios below).

Regardless of a zero allocation for environmental flow, or the needs of downstream users, the proposed Wyaralong Dam fails at least in 1995 and every year since 2002 to provide 17,000ML. For approximately 20 years (1898 to 1927) the dam never fills and the lack of any natural flow beyond the dam would have catastrophic effects on downstream riparian and aquatic ecosystems. As the modelled catchment yield tends to slightly overestimate catchment yield at average and below average annual rainfall it is likely that some years during the early 1900s and 1920s would also have failed even with no allocation for the environment. This scenario shows that there will be extended periods where the dam will not overflow to sustain environmental processes, and therefore, environmental flow allocations will be essential and that these need to be developed using the best available methods and expertise.

Scenario 2: Lowest allocation for environmental flow at 2,007ML/yr

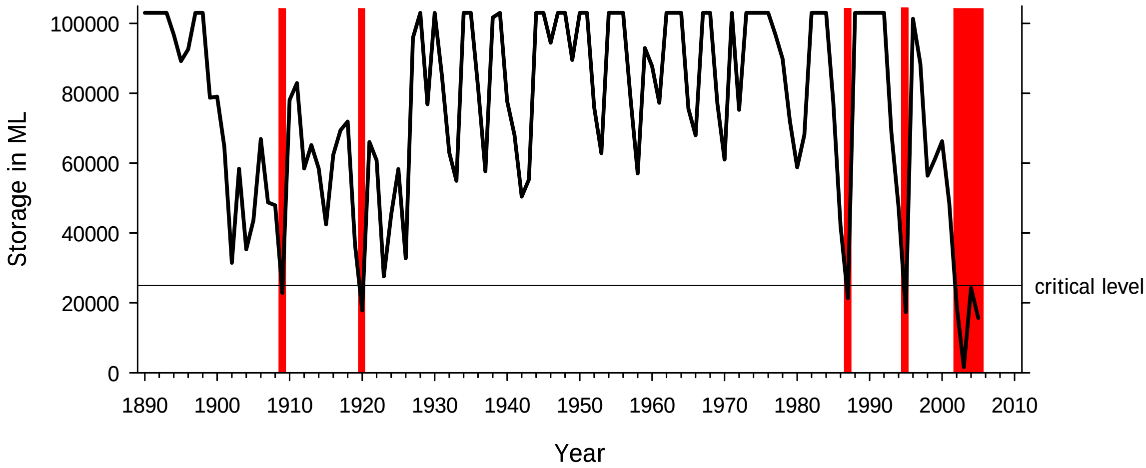


Figure 4. Scenario 2: Storage behaviour of the Wyaralong Dam with an insignificant environmental flow allocation that refects only the 'low flow' criteria outlined in the *Logan Basin draft water resource plan* (NRMW, 2006). This minimal environmental flow is 2,007ML/yr (approximately 5.5ML per day).

The extremely small environmental flow allocation in Scenario 2 is the equivalent of only 3.8% of average annual catchment yield. Such a low value would not maintain any ecological or stream flow processes and would not sustain the environment over extended periods such as that from 1898 to 1927 or from 1996 to 2006. In this scenario the dam fails to provide the expected yield a minimum of 8 years.
Note that no flow allocation is given in years where the dam fills and overflows naturally.

Scenario 3: Variable environmental flow at 10% of each year's actual catchment yield

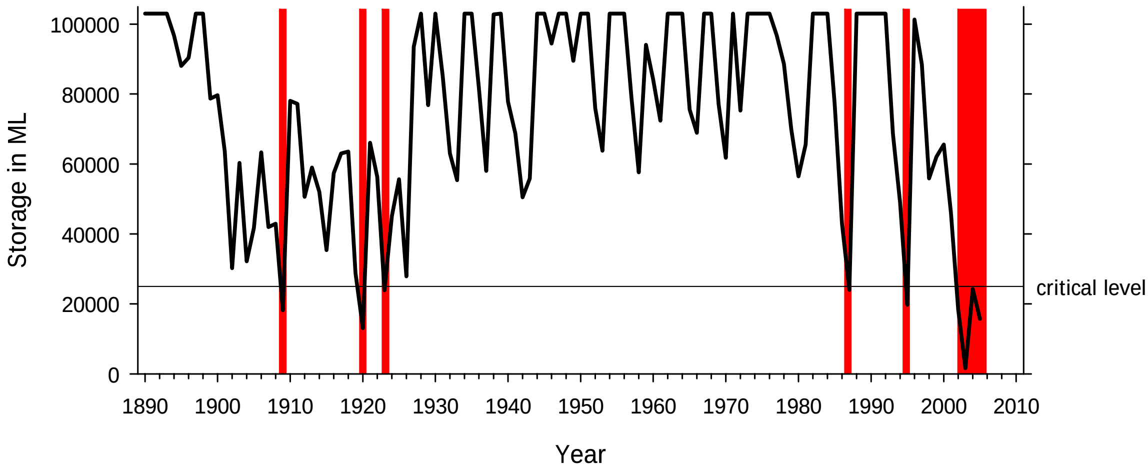


Figure 5. Scenario 3: Historical storage behaviour of Wyaralong Dam when a variable environmental flow of 10% of each year's catchment yield is extracted.

Under Scenario 3, which is approaching what can be considered an environmental flow allocation that would sustain environmental processes; the Wyaralong Dam becomes very unreliable. The dam would empty at least 9 years if 17,000ML was attempted to be extracted.

Scenario 4: Environmental flow fixed at one fifth (20%) of median catchment yield.

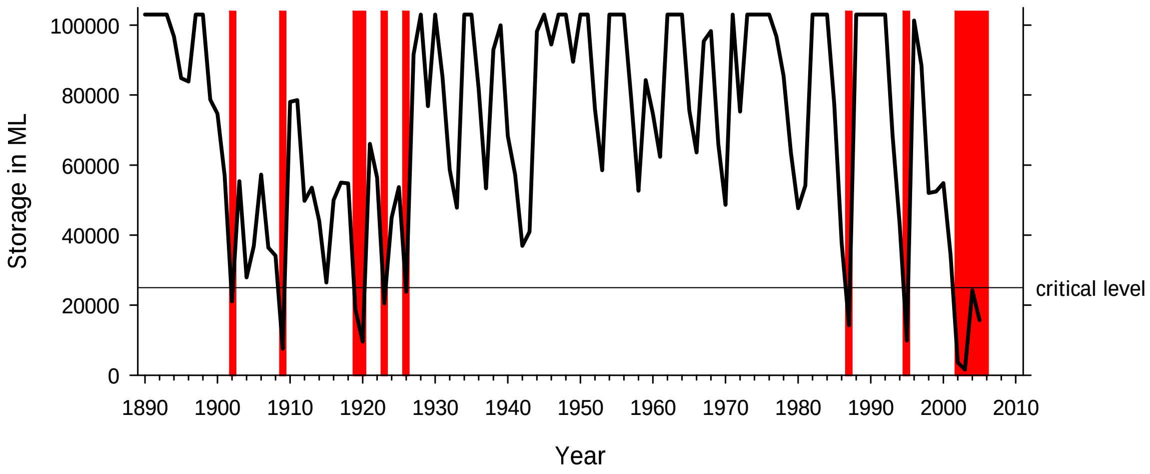


Figure 6. Scenario 4: Storage behaviour when environmental flow is fixed at 20% of the long term median catchment yield of slightly less than 32,000ML/yr (6,364ML/yr)

At an environmental flow allocation of 20% of the long term median catchment yield the proposed dam becomes a serious failure. Twenty percent of the median catchment yield translates to only 11.9% of the long term average annual catchment yield of 53,360ML/yr. Almost 12% of average catchment yield begins to match many recent recommendations for environmental flows to maintain natural ecological and stream flow processes. However, it falls far short of what is required for significant areas of biodiversity or conservation significance (e.g. Moreton Bay Marine Park) or areas requiring environmental restoration such as the Logan River Catchment which has recently received a very poor water quality and stream health report (Arthington and Pusey, 2003). Scenario 4 results in the dam failing 12% of years.

Scenario 5: 21,000 ML and 2,007ML/yr environmental flow (the lowest environmental flow allocation)

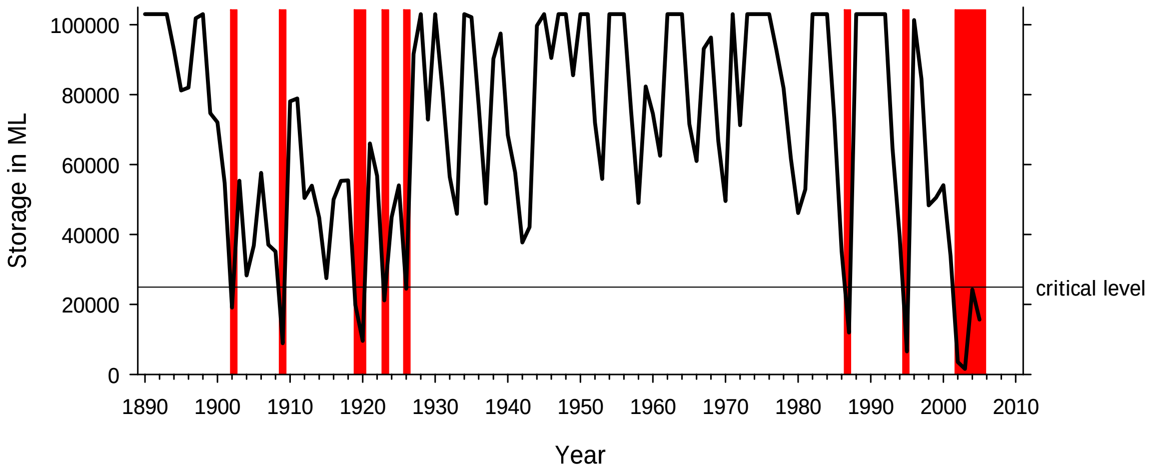


Figure 7. Scenario 5: Dam storage behaviour assuming the Queensland Government's assertion that Wyaralong Dam can safely provide 21,000ML/yr with the smallest environmental flow allocation of 2,007ML/yr.

The fifth and final scenario has only been added to illustrate clearly that the often cited yield of 21,000ML/yr for Wyaralong Dam by the Queensland Government is simply unable to be achieved. At this level of extraction the dam fails at least 12% of years.

Discussion

The Wyaralong dam fails to provide the expected yield frequently over the past five years regardless of any range of environmental flow allocation from zero (Figure 3) to a reasonable 20% of the long term median catchment yield (Figure 6). It has been demonstrated that many rivers in south east Queensland are ecologically stressed (in poor health) particularly the Logan River (South East Queensland Waterways, 2006). Environmental flow allocations will be essential for the Teviot Brook, Logan River and Moreton Bay should the proposed Wyaralong Dam be constructed. At this stage appropriate flow regimes have not been determined. However, the scenarios developed in this report span the range of possible low to moderate environmental flows that could be delivered.

Long periods of up to two decades can be expected with no natural flow beyond the dam wall due to the variable climate of the area. To illustrate the dramatic impact of a dam on the Teviot Brook, almost 900,000ML would have been blocked from the Logan River and Moreton Bay by the dam over the period 1898 to 1927 had it been in place. Between 1996 and 2005 this would have been approximately 161,000ML removed from the system. To ensure that the proposed dam does not have catastrophic environmental impacts on the immediate area below the dam wall (the lower Teviot Brook), the Logan River and Moreton Bay Marine Park environmental flow allocations will be essential. The dam is marginal without any allocation to the environment. With any environmental flow – which is essential – the dam is a disaster.

Unfortunately, if the dam is constructed the Queensland Government will be pressured to reduce environmental flow to ensure that the dam remains 'viable' for human water consumption during expected droughts. This has already been the precedent set for other dams in south east Queensland such as the near by Maroon and Moogerah Dams. Since 2001 the observed very low catchment flows in the Teviot Brook have been barely adequate to maintain any permanent natural water holes (pers. obs.). These past 5 years provide an indication of the type of flow that would be required as a minimum for the maintenance of ecological and hydrological processes in the lower Teviot Brook. The average catchment yield from 2001 to 2005 was only 11,000ML/yr (note: the total flow for these five years is only just over the long term catchment average yield for one year). 11,000ML/yr as an indicator of minimum required environmental flow is still almost double the highest environmental flow suggested in Scenario 4 (Figure 6) in this report.

The significant drought conditions since 2001 have often been linked to evidence of climate change by both the media and experts. If some of the predictions for climate change and its influence on south east Queensland (eg. Hughes, 2003) are accurate then, as a consequence of extended drought, lower runoff and increased evaporation due to higher temperatures, the proposed Wyaralong Dam will function even more poorly than the scenarios provided in this report.

Regardless of any predictions or potential impacts of climate change, should it eventuate, the climate of the first half of the 20th Century should provide a sober warning of the natural variability in rainfall and that extended decadal scale low rainfall is actually the norm. Unfortunately, it appears that many people and politicians in eastern Australia have developed an expectation that the very wet periods in the 1950s and 1970s are the normal climate pattern. This is also the period of major growth in south east Queensland and a rapid development of irrigation and other water uses across the entire east of Australia including the Murray Darling Basin. Water, during the past half a century has in effect been over allocated, not by deliberate design but simply because it was frequently available. Now that we are progressing into what can be considered similar climate conditions to the first half of the 20th Century our water resources are seriously over stretched. The response by many is simply to build more dams based on an optimistic hope that future rainfall will return to 'normal' (i.e. the 1950s and 1970s).

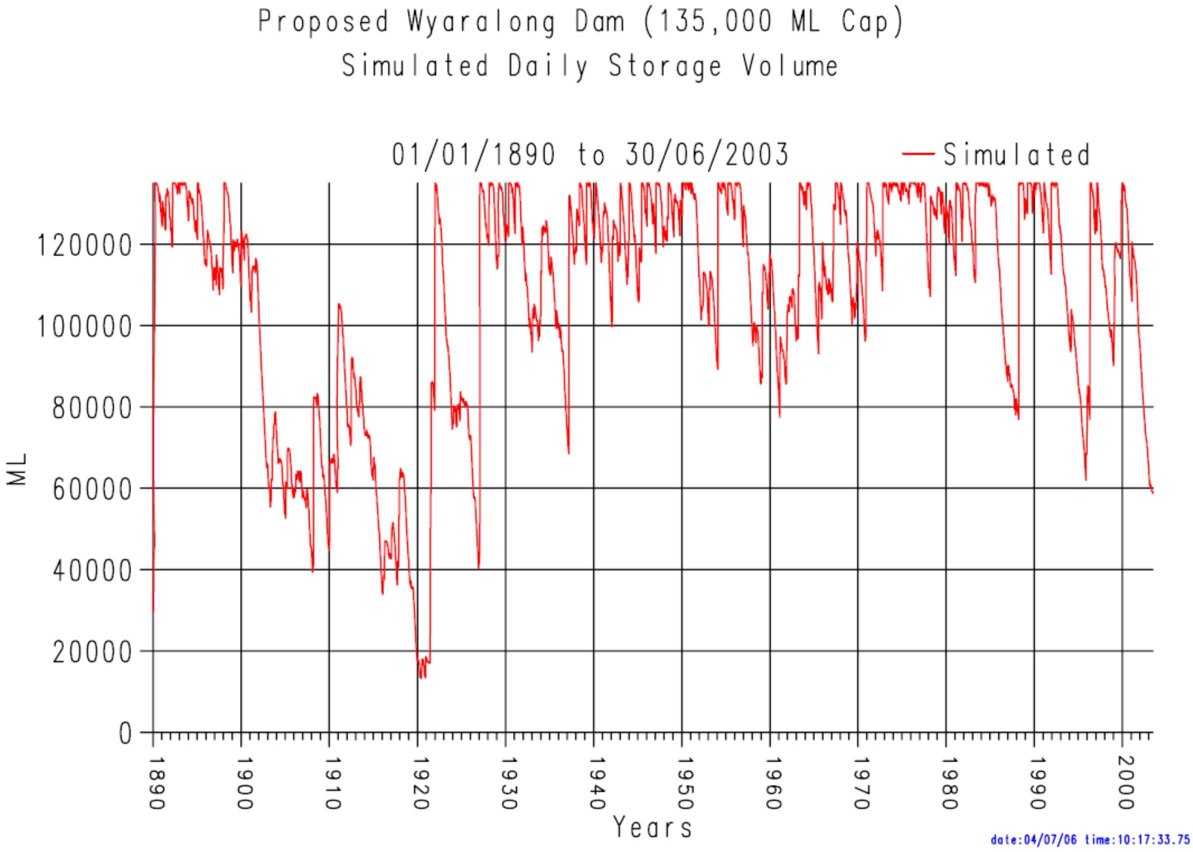


Figure 8. The storage behaviour model of Wyaralong Dam provided by the Queensland Government with no explanation of parameters or why the last few years of drought, when the dam would fail, were omitted (Queensland Government, 2006 p.65). The time when the graph was generated for inclusion in *Water for South East Queensland: A long term solution* was twenty minutes before the Premier announced that Wyaralong was selected over a dam site at Tilley's Bridge.

In the recent Queensland Government document *Water for South East Queensland: A long term solution* (Queensland Government, 2006) that was written in haste to justify the infrastructure decisions to solve south east Queensland water crisis; a model of historical Wyaralong Dam storage was included on page 65 (see Figure 8). This model, accompanied by just 169 words, provided no information on the behaviour of the dam or justification of how the decision was reached to proceed with its construction. The model provided (Figure 8) has no description of how it was derived. Neither was there any discussion on evaporation, extraction, environmental flow allocations or other assumptions. In general behaviour there are some similarities between the models derived in this study and that of the Queensland

Government. However, it appears to be an extremely optimistic model. Most importantly the model has deliberately excluded data during the recent drought when the dam would have failed. At no point has the modelling data and assumption behind it been made available for public or expert scrutiny.

Simply put; the Wyaralong dam will fail to adequately supply 17,000ML/yr to the expected 100,000 residences of the new growth corridor south of Brisbane during drought. It can be anticipated that as this drought continues or when the next big drought affects south east Queensland that these new residents (with no historical understanding of the variability of local climate) will demand that the State build yet more dams to ensure that they do not have to 'suffer' with water restrictions. These restrictions would be essential to ensure that complete failure of the Wyaralong Dam does not occur in future if it is built. The State Government will be pressured to ensure that its promised 21,000ML/yr (and on which future growth is dependant) are supplied for industrial and urban use. To make up for the poor performance of the Wyaralong Dam it can be anticipated that it will place increasing pressure on the proposed Cedar Grove Weir (on the Logan River) to make up the shortfall in available water. At the moment the Cedar Grove weir is intended to provide only 4,000ML/yr (making up the balance of 21,000ML).

To illustrate the inability of Wyaralong Dam to perform during drought the only way that the Government would have been able to prevent the failure of the dam since 2000 would have been to cease all environmental flow allocation and to reduce, on average, the extraction for human use down from 17,000ML/yr to a paltry 9,000ML/yr. The recent drought indicates clearly that the proposed Wyaralong Dam can actually barely supply half of its 'prudent yield' to avoid the dam running dry.

In our original report we indicated that the extremely high cost of construction of the dam (currently $500 million) made the dam one of the most expensive options available in south east Queensland at a cost of $23,810/ML/yr (five times the cost originally used as a criteria to select the dam site by the Queensland Government). Assuming that Cedar Grove is not over extracted to compensate for Wyaralong Dam's failure during extended dry period, then the cost to society of Wyaralong Dam and Cedar Grove combined as one unit increases significantly. The modelling data presented in this report indicate that if a fair allocation of water is permitted for the environment then a Wyaralong Dam can be expected to fail between 8 to 12 years out of every one hundred. These failed years are not evenly distributed and tend to occur in clusters around normal long term dry periods. With changing climate and even a return to dry conditions of the early 20th Century the proportion of failed years will increase. Averaged out over the past 120 years of modelling the 'prudent' yield for Wyaralong Dam falls well below 16,000ML/yr (i.e. the reduction in extraction during drought to ensure the dam does not empty reduces the average yield well below 17,000ML/yr).

From the modelling and scenarios in this report, and the fact that environmental flows must be adequate and guaranteed, it is clear that the proposed Wyaralong Dam is not a suitable location for an effective or economically efficient bulk water storage due to its naturally highly variable and unreliable rainfall. The construction of a third dam in the Boonah Shire that will fail to provide adequate water efficiently or economically is not warranted. Alternatives to the proposed Wyaralong Dam must be found and seriously considered.

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