Submission
No 389

INQUIRY INTO PROPOSAL TO RAISE THE WARRAGAMBA DAM WALL

Name: Dr Ian Fisher

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Submission – Warragamba Dam Raising Project – SSI-8441 – Ian Fisher – Potts Point

I object to the proposal because the EIS does not give adequate consideration to the impacts on drinking water quality, which the Secretary's Environmental Assessment Requirements say should not be adversely affected.

Drinking Water Quality in the EIS

The EIS for raising Warragamba Dam sets out the Secretary's Environmental Assessment Requirements. Their Performance Outcome 21: Water – Quality states that "the Project should not adversely affect drinking water quality" (Table 27-1). This requirement is presumably recognising that Lake Burragorang supplies about 80% of Greater Sydney's drinking water.

The Project's effects on water quality in the Lake, and hence raw water quality piped to Prospect, Orchard Hills and Warragamba water treatment plants (WTPs), are largely covered in Sections 27.2.5.2 and 27.2.5.3 of the EIS. This assessment does not adequately evaluate the possible multi-seasonal water quality effects following a large flood inflow into a deepened Lake Burragorang in different seasons. There is a detailed evaluation of this behaviour publicly available, based on the twenty years of data 1961-1980 (Ferris 1985), but this has been ignored in the EIS on the grounds that good water quality data is only available after 1985 (section 27.2.4). This 20-year period is particularly relevant as it contains several flood events larger than those in the post-1985 data.

Essentially, the greatest risk from deepening Lake Burragorang for even a few weeks at a critical time of year is the release of metals and nutrients from bottom sediments in the following winter and increased algal blooms (possibly toxic) over the summer after that. Ameliorating this risk would require substantial upgrades or additional treatment capacity at Prospect, Orchard Hills and Warragamba Water Treatment Plants (WTPs) to "not adversely affect drinking water quality" which is supplied to most of Sydney. It would also need upgraded disinfection facilities in the distribution system to maintain healthy microbiological quality until the treated water reaches the farthest consumers.

Raw water routed directly from Warragamba, enriched with phosphorus due to deepening Lake Burragorang, may cause increased algal growth sufficient to require additional removal processes at the three WTPs. Although raw water for Prospect WTP usually bypasses Prospect Reservoir, an alternative path through this reservoir is correctly shown in the EIS. Even if the increased algal growth in Burragorang does not create a major problem, this water from Warragamba may create one in Prospect Reservoir, as it is a much shallower lake. The quality of other inflows to Prospect Reservoir (from the Upper Nepean Reservoirs) would then also be adversely affected *en route* to the WTP, making treatment of all raw water more difficult at Prospect WTP. This issue has not even been raised in the EIS.

Section 27.5.2.3 describes the current dynamic methods available to assist ongoing decisions to select the withdrawal level that provides the best-quality raw water from Lake Burragorang. These methods can also be used as planning tools to evaluate the effects on water quality of major changes such as raising the dam wall.

The EIS states that this will not be done until pre-operation (p.27-56). Instead, these tools need to be applied to both Lake Burragorang and Prospect Reservoir at the EIS stage to determine the likelihood of the water quality impacts outlined above, so that the associated large cost of ameliorating them (hundreds of millions of dollars) is properly included in the overall risk assessment.

Section 27.5.3 lists the upstream (lake) water quality impacts and possible ways they could be ameliorated. "Adjusting treatment processes" is a mitigation suggested for all drinking water quality impacts, which does not recognise the complexity or very large cost of doing so. Another suggested mitigation measure of using alternative raw water supplies is unrealistic in that the same rainfall event producing a major flood would also adversely affect the quality in all available reservoirs. A much better estimate of the feasibility and costs is needed to determine how to ensure that drinking water quality will not be adversely affected.

These shortcomings of the EIS are discussed in more detail below.

Lake Burragorang water quality

Large, deep lakes and reservoirs undergo an annual cycle of "thermal stratification" due to seasonal variation in incoming solar radiation. In summer in Lake Burragorang, this results in warmer horizontal layers of water (strata) overlying cooler layers. This prevents transport of dissolved oxygen to the deeper layers, and to the bottom sediments in particular. In winter, these layers often break up so that the whole water body becomes vertically mixed, which replenishes oxygen throughout the water column, including the interface with the bottom sediments.

Historically, with its contents up to full supply level (FSL), Lake Burragorang is fully mixed for only about a month of the year. In some winters, it does not fully mix at all. Ferris (1986) determined that it fully mixed in only half of the years 1961-1980. Then the oxygen in the deeper waters and at the sediment interface may not be replenished sufficiently to prevent deoxygenation at the sediment interface over the following summer/autumn. Ferris (1986) showed numerous years of near-zero bottom dissolved oxygen at the wall site (3D or DWA2 in the EIS) and even anoxic levels at the Bend site 14km upstream. This causes abnormally high release of nutrients and metals (particularly iron and manganese) from the sediments, which are then mixed throughout the water body during the following winter.

The abnormally high concentration of nutrients (particularly phosphorus) produced in the surface waters fuels potentially toxic algal blooms in the summer after that. Ferris (1986) identified only three algal blooms over 1961-1980 and these were all of green algae. The occurrence of potentially toxic cyanobacteria blooms in more recent years is noted in the EIS, indicating that this is becoming an increasing risk.

This annual cycle is complicated by the volume and timing of inflow events. Outside winter, an inflow is generally cooler than the lake surface but warmer than the bottom water. So it inserts itself into a horizontal layer at the level of the same temperature in the stratified lake, usually along the thermocline (Figure 1, time 1). This interflow layer (IFL) expands upwards until the event finishes or the lake surface reaches FSL (Figure 1, time 2), after which the layer above it (the original epilimnion) flows over the spillway.

If Warragamba Dam is raised another 14m, the epilimnion is pushed further upwards into the FMZ by the expanding IFL until the event finishes or the lake surface reaches the new spillway (Figure1, time 3) and subsequently flows over it. Although initially well-oxygenated, the IFL is much more turbid than the original epilimnion and consequently contains substances and particles having high oxygen demand. Some of this material will settle below FSL in the several weeks between the start of filling and the end of emptying the FMZ. (Note this is much longer than just the emptying of the FMZ.) This will create a much greater oxygen demand than presently occurs with the same-sized interflow, as this additional material settles later to the bottom.

In winter, an inflow is generally cooler than the bottom lake water, so it forms an underflow layer (UFL), which pushes the entire pre-flood volume (PFV) upwards until the lake surface reaches the FSL (Figure 2, time 2), after which it flows over the current spillway. If the wall is raised, the upper part of the PFV is retained in the FMZ until the former's upper surface reaches the new spillway level (Figure 2, time 3). Further inflow causes the progressive spill of the entire PFV over the spillway. If the water supply outlet tower is not extended into the FMZ, then none of the cleaner PFV in the FMZ can be accessed. Eventually, if the event continues, the underflow fills the entire FMZ.

If the underflow event occurs in the short period that is critical for mixing, it is highly likely to prevent lake-wide mixing for that winter. This is only partly due to the disproportionately large extra volume (up to 50% of FSV) that would need to be mixed. The stratification will also be intensified because the large inflow in winter will be colder than the reservoir contents. The EIS acknowledged the occurrence of such underflows but is not clear on the implications for lake water quality.

Although a winter inflow is well-oxygenated, it will form a cold bottom layer with much higher oxygen demand than the pre-flood bottom layer due to the sediment it carries, increasing the likelihood of eventual deoxygenation of the sediment interface over the following summer stratification period. It will also pull the higher-quality shallower (PFV) water out of the reservoir during the drawdown following the flood, further decreasing the overall water quality in the reservoir. Ferris (1986) noted the effect of the HEPS outlet in sharpening the winter stratification by pulling water from above its depth, rather than from below. A similar sharpening will occur during the drawdown of the FMZ because it will be withdrawn through the wall at the current FSL. This will further inhibit mixing in the already short available period.

The largest inflow since Warragamba was built occurred in Nov 1961 and was about 50% greater than the volume of the proposed FMZ (Ferris 1986). Although it occurred in late spring, it was (unusually) still a cold underflow and resulted in complete bottom deoxygenation for the following six months and surface turbidity was still elevated after the natural destratification that occurred eight months later. Ferris (1986) also noted that underflows result in much higher turbidity than interflows, probably because the former entrain “fluffy mud” from the bottom.

The key questions for drinking water quality arising from this behaviour are:

- Is the additional oxygen demand brought into the FMZ by an inflow, and settling below the FSL during the weeks of the inflow event and following FMZ drawdown, exceed the additional oxygen supplied by that inflow?
- Is the sharpening of the stratification sufficient to decrease the likelihood of winter destratification and increase the risk of bottom anoxia, metals and nutrient releases?

These questions need to be answered with modelling studies of lake dynamics using the tools mentioned in the EIS (DYRESM, ELCOM and CAEDYM). They must be part of the EIS (not the design stage) so that they can show the extent to which raw water quality will be adversely affected. Only then (also at EIS stage) can a realistic assessment be made of the additional treatment capacity and new treatment processes required to prevent Sydney’s drinking water quality from being adversely affected. The EIS is entirely inadequate in this respect.

Prospect Reservoir

Even if the increased nutrient levels are insufficient to trigger algal blooms in Lake Burragorang, they may still be sufficient to trigger such blooms in Prospect Reservoir when the latter is being used as a holding reservoir for Burragorang water, rather than it flowing directly into Prospect WTP. Then water from the Upper Nepean storages would also become contaminated if it were also to be held in Prospect Reservoir.

Additional water treatment requirements

The treatment processes at Prospect and other WTPs listed above are already stretched to remove the elevated algal concentrations resulting from algal blooms that occur from time to time in Lake Burragorang (e.g., after the major 2020 bushfires and subsequent inflow). Table 27-8 of the EIS summarize their occurrence since 2006. Processes to remove the toxins that some of these algae are capable of producing do not currently exist.

Nor are the WTPs capable of removing any of the increase in natural organic matter (NOM) that potentially would result from the poorer-quality underflow being retained as a bottom layer, then mixed in the subsequent winter. Settling of highly turbid water from the FMZ during and after a major interflow event would also create an additional NOM load at the plants.

The increased NOM concentration would create extra demand on the disinfectants used in Sydney’s supply. This increase is over and above the rate of increase in NOM concentration already discernible from climate change, which has approximately doubled the NOM concentration (measured as dissolved organic carbon) in raw water from Burragorang in the two decades since the Prospect WTP was built. Its alleviation would require either additional NOM removal at Prospect, Warragamba and Orchard Hills WTPs or additional disinfectant dosing at these WTPs or at downstream locations in the distribution system (or both).

Algal blooms or higher turbidity/NOM can be handled to a limited extent during flood events and FMZ drawdown by slowing the water production rate. However, even this would require substantial extra filter-bed capacity to be built beforehand to ensure that the supply rate to consumers did not have to be restricted. It is more likely that both extra capacity and new removal processes would be needed to ensure that drinking water quality was not adversely affected in a major way during and after the large flood events of interest. Processes such as flocculation/sedimentation prior to filtration for algae and turbidity removal, enhanced coagulation for NOM removal, granulated activated carbon for algal toxin removal would all need consideration. These cannot be dismissed as "adjustments to existing treatment" as the EIS has done.

These substantial upgrades and/or additional capacity at Prospect, Orchard Hills and Warragamba WTPs, required to maintain a safe clean water supply to most of Sydney, have a probable capital cost of hundreds of millions of dollars. Substantially upgraded disinfection facilities may also be required in the distribution system to maintain appropriate microbiological quality, probably costing similar amounts in capital, but also requiring substantial increased operating costs.

Conclusion

The issues and costs detailed above surely warrant inclusion in any robust impact assessment of the raising of Warragamba Dam, before any decision is made to proceed.

References

Ferris, J. M. (1986). The influence of advection on water quality variation in a deep Australian impoundment. PhD thesis, University of Tasmania.

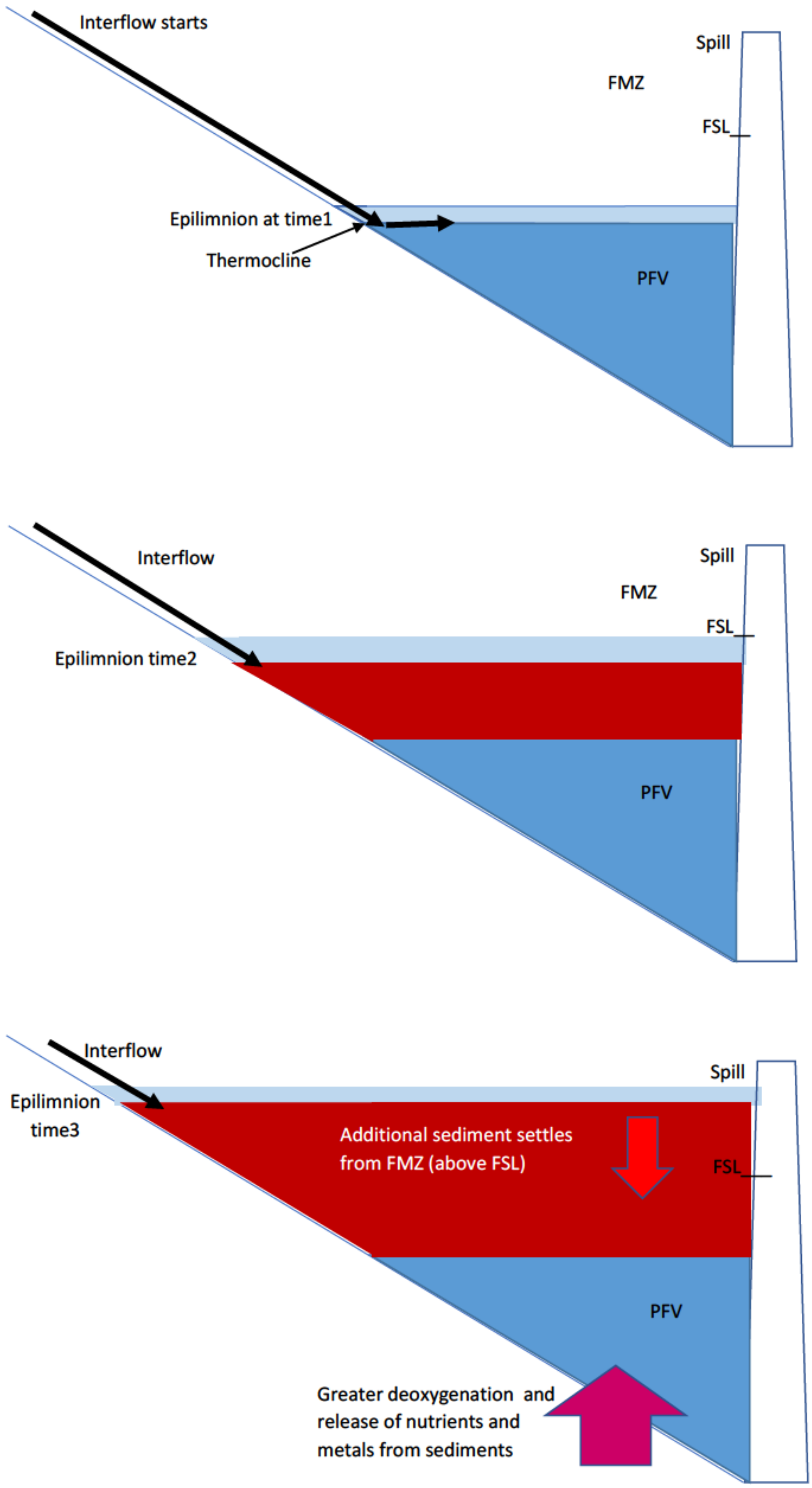

Figure 1 Evolution of an interflow event in Lake Burragorang after raising Warragamba Dam

Pre-inflow (stored) water shown blue, river inflow black, interflow layer brown

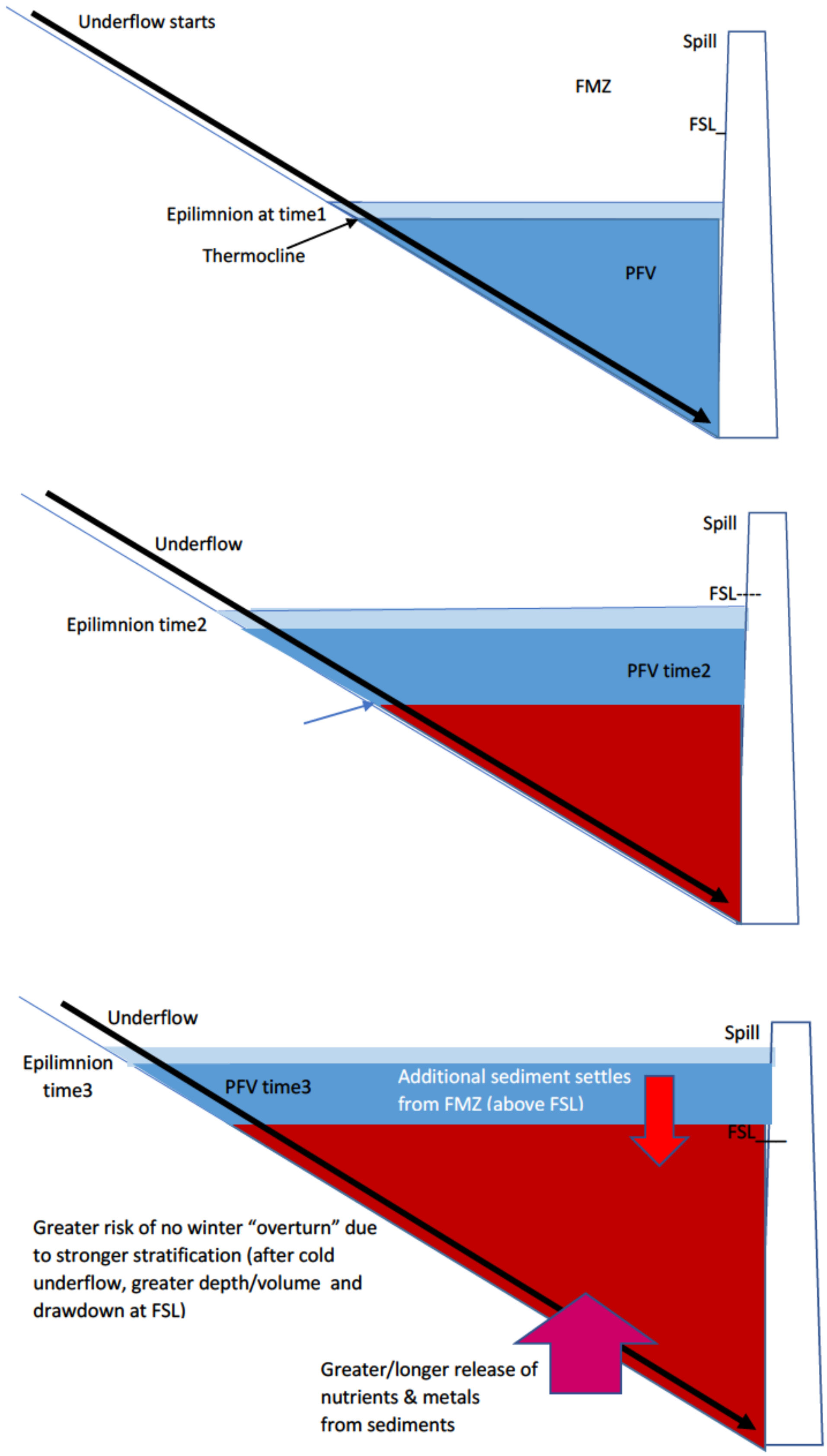

Figure 2 Evolution of an underflow event in Lake Burragorang after raising Warragamba Dam

Pre-inflow (stored) water shown blue, river inflow black, interflow layer brown

Author’s credentials

Dr Ian Fisher was formerly Principal Scientist for Drinking Water in Sydney Water Corporation over the decade before management of the dams and reservoirs supplying raw water to Sydney was transferred to the Sydney Catchment Authority. Prior to joining Sydney Water, he was a major contributor to, or leader of, several research projects concerned with physical and water-quality dynamics in Australian and international lakes, including the design and effects of artificial destratification.

He led the first application and validation of the DYRESM model in Sydney’s storages (Lake Nepean), including the destratification effects, in collaboration with the model’s originators at the Centre for Water Research, UWA (CWR). He also championed the development of CAEDYM, the CWR water quality model, and its application to Prospect Reservoir and Lake Burragorang, to examine issues surrounding the introduction of Prospect WTP.

Dr Fisher subsequently led the Distribution System Research Program of the national Cooperative Research Centre for Water Quality and Treatment. With colleagues, he developed new, accurate and efficient models that predict disinfectant and by-product concentrations in large distribution systems. These models enable system planners and operators to find cost-effective strategies that maintain adequate microbial quality while keeping by-products below regulated limits. This approach has been successfully applied to multiple-source systems from Perth to Gladstone. It has been extended to include the effect of additional removal of natural organic matter from any of these sources.