The Secretary
NSW Department of Planning, Industry and the Environment,
Sydney

Dear Sir,

I thank you for the opportunity to comment on the recently released EIS relating to the proposed raising of the Warragamba dam for flood mitigation purposes.

To provide some context to my submission I would like to advise that I was the Hydrology Manager for Sydney Water and the Sydney Catchment Authority (which were predecessor organisations of the Proponent) during the period 1986-2005. I was directly involved in many of the engineering aspects that led to the initial 5 metre raising of the dam in the nineties and also in the investigations relating to the (aborted) EIS for the flood mitigation dam proposed in the nineties. Subsequently I also served as Chief Technical Principal for SMEC (which has had a role in the current investigations) but I would like to emphasise that my following comments are based almost entirely on my experiences between 1986 and 2005.

My understanding of the proposal as presented in the EIS is that the existing dam is to be raised by 14 metres to provide temporary flood mitigation storage of about 1000 GL. Flood modelling studies are presented which demonstrate that this dam raising would provide significant flood mitigation benefits to the downstream communities.

It is recognised in engineering practice that there is a failure probability associated with any structure. Thus, the dam spillway has been designed to meet the flows generated in the Probable Maximum Flood but it is recognised that the structure could face (and possibly fail in) floods greater than the design event.

Observations of dam failure indicates that the main causes of dam failure are either inadequate spillway capacity to safely pass extreme floods or foundation failure. With the raising of the dam, my reading of the EIS suggest that the spillway capacity will not be reduced and hence the failure probability of the dam due to flooding will not be changed.

I am however unable to locate any mention in the EIS of the changes to the failure probability of the dam from foundation issues arising from the proposed raising of the dam.

In other words, my question is, **will the risk of dam failure have increased due to the raising of the dam**? Thus, despite providing flood mitigation to the downstream residents will the proposed construction subject them to a **higher risk** of total dam failure. On the same lines, will the risk of losing Sydney's main water storage (within a couple of days) be increased by this proposal, given that it takes about three years to build a desalination plant and nine months just to bring an existing plant into service.

During the Warragamba dam investigations of the eighties and nineties, the then Water Board were very fortunate to have had the services of the late J Barry J Cooke as expert adviser. Barry was at that time the world's leading expert on dams and had worked on over

a hundred dams in his time. Barry was highly concerned about the foundation conditions at the existing dam site and demanded an extensive system of post-tensioned anchors before he would even agree to the original five metre raising of the dam. He **clearly ruled out any further raising of the dam at this location** which was the reason that the previous EIS proposed structures which were some distance from the existing dam site.

One of the dam characteristics presented during those discussions was the concept of "dam power" or similar which was a function of the flow rate and the height of the dam. A comparison of world dams on this characteristic showed that Warragamba at the current spillway level of 116.72 was well above other dams worldwide. This might explain the enormous damage to the foundations and downstream of the dam following the 1961 flood event when blocks of rock as big as houses were gouged out of the foundations. Increasing the spillway height will increase the "dam power" even further up the scale. Whether the Proponent fully considered all the information collected during those investigations needs to be clarified in the EIS.

If the Proponents proposal is accepted, then the same dam foundation will be subject to significantly greater forces, particularly at the toe of the dam and must present a greater risk of failure. Just the additional dead weight associated with the proposal amounts to over 1.6 million tonnes. Then there is the dynamic loading that arises from the temporary stored waters. These dynamic loads will be active for long periods with the possibility of creep occurring in the underlying rock. **I would suggest that in consideration of the significance of this issue, that the EIS further describe the risk profile of the dam and the likelihood of failure from foundation problems and provide the reasoning behind the rejection of Barry Cooke's opinion**. I accept that the NSW Dam Safety Committee will provide an opinion on the safety of the structure but this dam is of such importance that in addition it is essential that any increased risk be recognised and disseminated to the wider public.

My other comments which follow are relatively less significant in comparison with the above issue and I have presented them from a fairly rapid review of a massive document.

Even a basic concept such as the Full Supply Level (FSL) as presented in the EIS needs to be clarified within the context of operational activities. The EIS document refers to the "existing" Full Supply Level as 116.72 and presumably bases all "Current" condition flood modelling on that level.

The Full Supply Level is generally defined as the level of the dam which is reached when all flood inflows are evacuated from the dam. Until sometime in the late eighties, the dam FSL was maintained at 116.72 through the operation of the Drum and Radial Gates. Following a series of flood events in the late eighties however, the then MD of the Water Board (Bob Wilson) issued an instruction that the **dam be drawn down to 116.22 metres** after any flood event. This drawdown was achieved through valves in the Warragamba pipeline and the HEPS system (when operational). That instruction has now been in place for **over thirty years** and I would argue that the **"Existing" FSL is actually 116.22** and not the assumed 116.72**.** The Proponent may have maintained the fiction of the FSL at 116.72 in order to be able to revert to that level when a flood mitigation solution had been implemented (as envisaged by Bob Wilson) but from the perspective of flood modelling, a bias is introduced into the analysis.

It is difficult to estimate whether the adoption of an incorrect FSL for "Existing Conditions" will have a significant impact on the higher flood levels but it will certainly affect the estimates for lower floods. It may also affect the estimates of flood levels upstream of the dam. Thus, the Executive Summary notes that as the November 1961 flood reached a level of 119.5m (2.8 m. above original FSL) the lower limit of the upstream impact area is 119.5m. It could however be argued that if the 1961 flood were to enter the dam today, due to the lower FSL, it will not reach 119.5m but some point lower than that (say 0.2 metres) and thus creating a larger upstream impact area.

The flood studies described in Chapter 5 refer to a number of models being applied to the flood studies including the one-dimensional flood model *Rubicon.* This model appears to have been extensively applied across the project. It could be noted that the Rubicon model represented the state of the art about forty years ago and had been superseded by far more accurate two (and even three-dimensional) models which have also been applied to a lesser extent. The Proponent should clearly explain the reasons for adopting such an antiquated approach to flood level modelling and comment on the effects of the loss of accuracy.

There are repeated references to the Monte Carlo approach to flood modelling and the Proponent presents it as a significant development in the flood modelling on this Proposal. There is also a comment in Chapter 5 that implies this approach has resulted in conservative estimates of the flood regime.

Irrespective of the recent adoption of this methodology for Australian Rainfall and Runoff by Engineers Australia, the Monte Carlo method has a long history of providing non-conservative results. One of the original proponents of this methodology (Emeritus Professor George Kuczera of Newcastle University) made the following recent comments in relation to the application of the Monte Carlo method "*The conclusions drawn thus far should rightfully shake the confidence of any user of ARR2016*[1]*. Even though ARR2016 represents the state-of-the-art, the reality is that, despite best efforts, we cannot estimate flood quantiles with much skill"*[2]*.*

"Given that JPA[3] *(Joint Probability Analysis) has a deeper scientific foundation than FFA (Flood Frequency Analysis, it is tempting to conclude JPA is intrinsically more accurate than FFA. However, an analysis of the sources of uncertainty affecting the design storm method, the most widely used JPA, presents evidence that suggests the contrary may be closer to the truth. Multiple sources of uncertainty in the rainfall distributions, in antecedent wetness and in rainfall-runoff parameters can combine to make JPA quantile estimates subject to very considerable uncertainty."*[4]

Given this understanding of the application of the Monte Carlo method, I think it is reasonable to expect the Proponent to explain the extent to which the Monte Carlo Method

[1] Australian Rainfall and Runoff published by Engineers Australia
[2] He was not directly referring to the Hawkesbury-Nepean studies in these comments.
[3] Monte Carlo Analysis in this particular instance
[4] These quotes have been extracted from a recent paper published in the Australian Journal of Water Resources.

has been applied in this EIS and the "**Adjustments**" if any that have been implemented to provide a "conservative" estimate of the flood risk downstream. It would also be reasonable for the Proponent to explain whether there is **an exaggeration of the flood risk** by these adjustments. For example, the 1961 flood (the largest recorded flood at Warragamba with records stretching to the twenties) has been reported as having an Annual Recurrence Interval (or Return Period) of around 40 years. It is simply not credible that the largest flood in a record of 100 years would have such a low ARI.

Review Processes

Throughout the document there are references to various local and international reviews of some aspects of the work presented here by the Proponent. The precise nature of these reviews however is not described to any significant extent.

The term "Review" can have various connotations ranging from a conceptual examination of one specific aspect of a sub-activity within any project activity to a detailed assessment and 'sign off' by an independent body of the major findings and designs at the Conceptual, Intermediate and Final phases. This detailed assessment is usually referred to as "Proof Engineering" and has been adopted by various authorities in Australia and overseas for major projects, particularly those with significant risk components.

The Proponents proposal is a major structural development with very large attendant risks to the downstream communities and the broader population of Sydney through the loss of water storage and flies against the prevailing wisdom developed during the last major works on the Warragamba Dam.

It should be noted that the dam engineering community in Australia (and this comment applies equally to the flood modelling community) is quite limited and in my opinion a comprehensive independent locally based review of these subject matters will be difficult to achieve. Furthermore, when the Proponent funds the review process, selects the reviewers and controls the flow of information to the reviewers, there is little opportunity for alternative viewpoints.

A truly accurate picture of the failure risks associated with the Proponent's proposal can only be achieved if the dam design (and the critical hydrologic factors) is Proof Engineered by a reputable international organisation or panel and this Proof Engineering process be managed (and perhaps funded) by an organisation with a vested interest in the security of the dam but is some distance from the Proponent, such as Sydney Water or the Department of Planning.