Independent Review Tillegra Dam: Project Justification

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INDEPENDENT REVIEW TILLEGRA DAM : PROJECT JUSTIFICATION

For: NSW DEPARTMENT OF PLANNING

November 2010

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1 BACKGROUND

The Hunter Water Corporation (HWC) currently serves a population of about 530,000 in the Lower Hunter with an annual supply of about 75 GL mainly through three major sources - Chichester Reservoir (20 GL), Grahamstown Reservoir (190 GL) and Tomago Sand beds (60 GL). These three sources contribute to 96% of Hunter region's supply. The remaining 4% of the supply is contributed by two smaller aquifer systems, Tomaree and Lemon Tree Passage sand beds. HWC have estimated the Yield of their current system as 67.5 GL/a and have proposed the construction of the Tillegra dam (450 GL) to cover this shortfall in supply as well as provide a buffer for future growth and possible climate change impacts.

HWC submitted the Tillegra Dam proposal for the approval of the NSW Department of Planning (DoP) under the NSW Environmental Planning and Assessment Act 1979. The Department commissioned SMEC to undertake a desk top review of this proposal.

The Department required SMEC to conduct a desktop review and specifically comment on:

- Whether appropriate inputs such as rainfall, inflows and projected water demand for the Hunter region have been used in modelling;
- Whether the level of drought security determined by HWC is justified;
- Whether an appropriate level of service has been adopted by HWC;
- Whether the supply yield used in modelling is justified;
- Whether the climate change predictions used in the modelling are justified;
- Whether the HWC water supply system requires augmentation now (based on the scale of Tillegra Dam) or whether other augmentation options would be more appropriate (or should be considered) at this point in time; and
- The veracity of the Proponent's justification for the dam based on the review of the relevant documentation.

It needs to be emphasised that the brief specified a desktop review of documentation and there has been no modelling or technical discussions authorized in this brief. It is also known that a project of this magnitude and interest has a substantial "history" and a large number of parties interacting with the proponent. There has also been a significant body of documentation developed on this project. It is not within SMEC's very limited scope to discuss this history, their relative points of view or the merits or demerits of their suggestions outside the very specific requirements of the brief and within the documents provided by the DoP.

2 REVIEW DOCUMENTS

The two key documents that provided the background information for the HWC proposal were accessed from the HWC website and are given below.

Reference 1: Why Tillegra Now? (HWC) July 2007;

Reference 2: H2 50 Plan (HWC) December 2008;

The DoP provided SMEC with access to the following documents associated with this proposal. It can be noted here that the scope of the review was limited to the relevant information available in these documents.

Reference 3: Hunter-Central Rivers CMA Response to EA November 2009;

Reference 4: Review of Yield Estimates (IPART/SKM) December 2008;

Reference 5: Environmental Assessment Submissions Report (HWC/Aurecon) March 2010;

Reference 6: Review of Tillegra Dam Project Justification (George Kuczera) March 2010;

Reference 7: Response to Hunter Water's Submission (ISF/UTS/WS) April 2010

Reference 8: Tillegra Dam Planning and Environmental Assessment (Aurecon), August 2009

Reference 9: An Independent Review of Supply-Demand Planning in the lower Hunter and the need for Tillegra Dam (ISF/UTS/WS), August 2009

Reference 10: Review of Demand Estimates (IPART/SKM) March 2009;

Reference 11: Tillegra Dam Submissions Report: Attachment A (NSW Office of Water) April 2010

HWC have developed a complex water resources model of the Hunter water supply system and this model is a critical tool for their planning strategy. None of the documents listed above provided detailed information on the workings of this model and an assessment of the outputs of the model.

A number of documents pertaining to the modelling undertaken by HWC are referred to in Chapter 10 of Reference 4. These documents[1] were not made available to SMEC in this desktop evaluation and were not considered as a part of the brief for this study.

[1] One reference document; *SKM, 2003, "Hunter Water – Water Resources Model review"* was later provided to SMEC as background information.

3 THE PROPOSAL

The broad proposal as presented in Ref 2 envisages construction of the 450 GL Tillegra dam to ensure supply security for the residents and industry of the HWC's area of operation. HWC have asserted that the Yield of the existing water supply system is 67.5 GL/a whereas the existing demand is in the order of 75 GL/a. This major imbalance is unsustainable and requires the provision of additional source/s in order that HWC can maintain its obligations to its customers and the regulators. After detailed consideration of a number of options, HWC propose construction of the Tillegra Dam which would increase the Yield of the supply system to 120 GL/a and enable HWC to accommodate an expected 160,000 new residents to the year 2031.

SMEC expects that there would have been a substantial body of modelling and planning subsequent to the publication of Reference 2 and some of the detail presented in that report may now be superseded. SMEC have however utilised the information presented in Ref. 2 in order to develop a comprehensive understanding of the proposal, but have not attempted to critically review that document. Nevertheless on examination of Ref. 2 in relation to the requirements of the brief, a number of issues of interest have arisen and comments on these issues are provided in the Appendix to this report.

4 YIELD METHODOLOGY

Assessment of the methodology adopted in the calculation of Yield for the HWC water supply system forms a central aspect of this review. As discussed previously, HWC claim to have had their modelling methodology endorsed by independent reviews[2]. A review of the HWC model and assessment of the reviews supporting the modelling was outside the brief of this study and SMEC are unable to provide further comment on this issue.

We have however examined the HWC methodology in some detail and our comments are shown below.

The Yield methodology as described in Refs 2, 4 and 5 comprises of three requirements:

i) *Restrictions should not occur more frequently than once every ten years;*

This is a common requirement to regulate the acceptable frequency of supply interruptions. This requirement ensures that the supplier whilst having sufficient sources for supply may not have sufficient capacity to prevent interruptions during the dry season. Typically a supply system based on a small storage on a large seasonal stream will have difficulty meeting this criterion.

SMEC accepts that this requirement is also fair and reasonable for a major supply authority.

ii) *Restrictions should not be applied more frequently than five percent of the months in the long term*;

This is a fairly common requirement imposed upon water suppliers to regulate the acceptable **duration** of supply interruptions. This requirement will ensure that the water supplier has sufficient sources of water in the system to ensure that supplies can be maintained across severe droughts. Typically if a supplier has a large dam on a smallish river he will have difficulty meeting this criterion.

SMEC accepts that this requirement is fair and reasonable for a major supply authority.

iii) Provide storage to meet four years supply below the drought trigger and sufficient storage above the drought trigger to satisfy demand during a 100 year drought.

This criterion has been developed from the WSAA Occasional Paper 14; “Framework for Urban Water Resource Planning” and is targeted at ensuring that even under the most extreme conditions; the supplier will be able to deliver an acceptable level of supply. Adoption of this criterion[3] has resulted in the Yield of the HWC system being reduced from 90 GL/a to 67.5 GL/a.

[2] The following documents are referred to in Ref 4
Kuczera, G, 2008, “Review of the method adopted by HWC for assessing yield”
Melbourne Water, 2008, “Review of the method adopted by HWC for assessing yield”
SKM, 2003, “Hunter Water – Water Resources Model review”

[3] An Australian Standard for water supply security does not exist due to the large number of factors such as risk averseness, supply sources, community attitudes etc. which have a bearing on the result. HWC have adopted the findings of WSAA Occasional Paper 14 as representing best practice in Australia.

Ref 4 has referred to this criterion being "conservative and unique" although further analysis in Ref 4 finds that the criterion is not under some circumstances as severe as application of criteria adopted by Sydney to target the likelihood of complete system failure. There is also a detailed critical examination of this criterion in Ref 9.

Conceptually the requirement for a minimum quantity of supply under all circumstances for Australian cities is very sound. The risk of failure of supply to a major industrial metropolis such as Newcastle is considered as being totally unacceptable. There have been recent nearly failures in supply to major cities in Spain and Japan and Ref. 6 mentions the near failure of the Brisbane water supply system. On each occasion it was realized after the event that the form and intensity of droughts are completely unpredictable and water supply system security should not be based on historical information alone.

Nevertheless underlying this criterion is a number of assumptions including;

- A minimum of seventy percent of demand is to be made available under even the most extreme drought;
- The inflows into the storages during a four year period will be a repetition of the lowest annual inflow repeated four times;
- The four years of low flow are preceded by a 100 year drought; and
- Drought contingency plan assumptions such as the 10% limit in Grahamstown Dam (Ref 11)

Following review of the documentation examined and acknowledging that Ref 4 has not rejected this requirement, we have however some difficulty in appreciating the basis of some of these assumptions. We are inclined to agree with Ref 9 that the basic assumptions and their application to the model require greater explanation[4].

The application of the third criterion to the HWC system requires a number of critical assumptions which are based on perceptions of community response to risk and drought management measures. SMEC is unable to form an opinion on the adequacy of this criterion without a detailed investigation of community perceptions and attitudes.

[4] The analysis assumes that at the end of a 100 year ARI drought event of unspecified duration; there should be sufficient water resources in storage to withstand four continuous years of the worst twelve month historic drought (whilst ensuring seventy percent of normal supply is maintained). This assumption appears quite conservative in comparison with the historic requirements of the Sydney system which envisaged only one year of demand in storage at the worst point of the observed historic drought (with more severe restrictions). In the HWC case we start with a drought event which is more extreme than the observed historic event and then impose a requirement for much greater reserves of water at the end of the event. HWC have estimated the likelihood of this sequence of events as 1 in ten million.

A second issue is whether these assumptions have been appropriately coded into the model structure; as discussed later SMEC would have preferred to have the model outputs examined by a "proofing" process with a second independent model rather than the "review" process adopted by HWC.

5 SPECIFIC RESPONSES

Further to the broad review of the Yield estimation, SMEC has responded to the specific issues raised by DoP in point form below

- *Whether appropriate inputs such as rainfall, inflows and projected water demand for the Hunter region have been used in the modelling*.

The HWC supply system model would require a large number of inputs such as rainfall, inflows, groundwater levels, evaporation, seasonal demand patterns, storage characteristics, operational criteria, environmental requirements, riparian requirements, seepage, initial dam levels, restriction policies, demand changes under restrictions, pumping systems and capacities, licence conditions, synthetic flow sequence etc. This information would have been collected over a long period of time and would be documented in the manuals covering the modelling process. Most of these inputs are critical to the understanding of the model and its outputs.

For example, even for a fairly straightforward variable such as evaporation, a number of queries could be raised such as;

- How has evaporation from the lakes been estimated?
- If pan factors were used, how were they developed?
- How was evaporation dealt with in the synthetic sequences?
- How was it dealt with in the historic data prior to pan measurement?
- Was there a relationship developed between inflows and evaporation i.e. lower warmer storages leading to higher evaporation?
- Was evaporation change considered in the climate change impacts?
- How were the submerged areas from construction of Tillegra Dam considered in the evaporation balance?

Without an understanding of the variables at this level of examination, it is not feasible to comment on their appropriateness.

Ref 4 discusses a few of the inputs, and refers to a number of documents (that were not available) to SMEC to justify the acceptance of the other inputs. Ref 4 discusses the synthetic flow sequence generation and the rainfall- runoff model in particular and finds those inputs as acceptable.

Ref 11 refers to the inflows entering the HWC supply system during the lowest inflow year and questions whether the assumptions made by HWC are accurate. It also refers to the storage characteristics of the Grahamstown Dam and recommends a bathymetric survey to better understand them.

There is no substantial information on any other model input in the documents reviewed although some of the background material indicated a significant review of the input data sets in 2003.

The HWC data sets were subject to detailed review in 2003 and the reviewers indicated broad satisfaction with the information presented. As the raw data sources were not available SMEC was not in a position to undertake any further review of the inputs.

- *Whether the level of drought security determined by the HWC is justified;*

There are a number of factors that affect the level of drought security of the HWC system. The Yield methodology covered in Section 4 is one factor whilst others include the restriction policy, the drought management plan, the modelling supporting these factors as well as the assumptions utilized. In Ref 6 Prof Kuczera appears to support the HWC position possibly based on information available to him (but not to SMEC) and rebuts the position advocated by ISF which questions some of the principles adopted by the HWC as well as the detail of some of their assumptions. HWC also claim substantial support for their position from independent reviews such as Ref 4 and other reviews not available to SMEC.

The comparison of HWC and Sydney Catchment Authority (SCA) performance criteria, as presented in the IPART review (Ref 4), does not appear to suggest that HWC criteria are overly conservative. In the existing case, the system yield based on HWC considerations (i.e. 67.5 GL/a) is lower than the system yield based on the SCA considerations (i.e. 81 GL/a) whereas with the proposed case with Tillegra Dam, both considerations (i.e. HWC- 120 GL/a, SCA- 123 GL/a) are quite comparable.

That may be explained along the following lines. The Robustness criterion for both systems is the same. The HWC Reliability criterion is more relaxed allowing restriction for 5% of time compared to SCA's 3%. The HWC storage-dependent drought security criterion generates a lower value of current system yield as the existing HWC storage is smaller. In contrast, in the "with Tillegra Dam" scenario with increased storage, the HWC yield prediction is still smaller but quite comparable and consistent. This implies that the Tillegra Dam will play a similar role to the Warragamba of the SCA system. Nevertheless, it is unusual for the provision of an additional 450 GL of storage in Tillegra to provide only an additional 52.5 GL/a of Yield, which gives the impression of Tillegra being a highly inefficient storage or other unexplained factors have reduced the Yield or some error in the modelling process.

Whilst SMEC remains unconvinced of some aspects of the process, we are of the view that there is a greater likelihood that HWC have justified the level of drought security adopted although the third criterion for Yield estimation may warrant further examination.

- *Whether an appropriate level of service has been adopted by HWC;*

The level of service criteria is covered in the discussion in Section 4. SMEC accepts the first two requirements as being standard industry practice.

The third requirement derived from Occasional Paper 14, can be considered as somewhat convoluted in presentation and appears to have raised a suspicion in the minds of ISF as having been developed after the fact. In SMEC's view the basic principles presented in Occasional Paper 14 are not unreasonable although the application of the principles by HWC is arguable. This point is also made in Ref 7.

SMEC is of the view that two of the three service level criteria adopted by HWC are standard industry practice and appropriate. SMEC requires more information before it can accept the third requirement as described by HWC.

- *Whether the supply yield used in the modelling is justified;*

As mentioned earlier, SMEC was not given access to the detailed documentation covering the model. This question has been interpreted as whether SMEC are confident of the modelling process and the yield derived from that process.

There is very little detail on the modelling and the assumptions that underpin it within the documents reviewed. There also appears to be some anomalies (see Appendix) in the few model outputs discussed in the text of Ref.2.

Validation of the model was discussed in Ref. 4 where HWC had compared observed storage values against modelled values and found a reasonable fit. It can be noted that a validation process of this nature does not necessarily prove that the model is accurate due to the inertia of the system and it is generally meaningless in the application of the model to situations outside the observed range. It would have been more advantageous to have developed a “proofing” process where an independent model of the system is created and model outputs for different cases are compared.

Refs 2, 4, 6, 10 and other “independents” appear to endorse the modelling process and SMEC is not in a position to comment on their endorsement. Furthermore a Yield of 67.5 GL/a for the current water supply system is not a particularly conservative estimate based on SMEC’s experiences in SE Australia.

The HWC estimate of Yield for the current system is not unreasonable for the catchment –storage system under consideration although qualified on the assumptions made in the Yield analysis which have not been subject to detailed review by SMEC.

- *Whether the climate change predictions used in the modelling are justified;*

Prediction of rainfall change due to climate change was carried using two approaches namely CSIRO and DECC (Department of Environment and Climate Change) and provided quite contrasting results. This by itself suggests that there is still a significant knowledge gap in the existing methodologies to fully understand this complex phenomenon. Both these institutions are capable of bringing state-of-art knowledge in their assessment. Nevertheless, it is recognized that the CSIRO is the apex research institution of Australia conducting such research studies.

As far as the use of most recent data on climate change is concerned, the current analyses by HWC are based on 2004 data. Mere use of an additional six years of data is not expected to significantly alter the current climate change predictions, and there has not been any breakthrough in climate change prediction methodology in the recent years.

It should be noted that our understanding of the modelling presented in the documents would indicate that climate change predictions were not used in the calculation of Yield.

Ref 2 discusses the issue of climate change impacts and observes that a ten percent reduction in rainfall would lead to a twenty five percent reduction in inflows. It has also commented that under this scenario the Yield of the System with Tillegra dam would reduce from 120 GL/a to 103 GL/a.

Ref 4 has a chapter on climate change considerations and observes that there are substantial differences between the CSIRO 2007 estimates for the Hunter Region and the figures produced by NSW Climate Change Action Plan 2008. These differences were attributed to different modelling methodologies. It concludes that the balance of probabilities does not point to a reduction in rainfall.

Ref 3 also refers to climate change assumptions and questions the methodology adopted by HWC.

Ref 6 re-iterates the point that the Yield estimation did not incorporate climate change scenarios.

Furthermore the CSIRO has recently published their work on the Rouse catchments to the north of Newcastle and it appears to indicate a greater likelihood of lower rainfall than higher rainfall.

We conclude that although HWC have considered only one of several possibilities relating to climate change impacts on their water supply system, the results of their investigations are unlikely to have been affected by this omission.

SMEC is not in a position to comment on climate change assumptions although it is understood that these climate change assumptions were only used for sensitivity analysis of Yield and were not adopted in the determination of Yield for both the current supply system and the supply system with Tillegra Dam.

- *Whether the HWC water supply system requires augmentation now (based on the scale of the Tillegra Dam) or whether augmentation options would be more appropriate (or should be considered) at this point in time;*

Based on the analyses above, the Yield of the current system appears to be substantially lower than the current demand. With the continued growth of the Hunter Region this difference will only become larger. It is in the nature of Australian hydrology that these imbalances can be carried for substantial periods without any apparent impact. Nevertheless this is not a sustainable position and it is important that HWC move towards a position of greater balance. Inflows into Australian rivers suffer a high degree of skewness with large floods sometimes followed by years of prolonged low flows. Consequently although HWC may appear to be enjoying a high level of water security at this point in time, there is a significant likelihood that it could enter a prolonged low flow situation at any time.

SMEC is of the opinion that if the HWC Yield analysis is accepted, augmentation of the system is required in the short term.

A number of options for augmentation and thus redressing the imbalance are discussed in Ref 2, 4, 5 and 10 whilst Ref 7 focuses on the use of demand management and other techniques to re-adjust the balance. Ref 6 provides a well considered approach to the issue of restoring balance and ensuring the integrity of the water supply system, with which we have no argument.

It needs to be re-emphasized that SMEC have not undertaken any examination of options for augmentation and have based their views entirely on the short term perusal of documents provided. A detailed assessment of options is provided in Refs 2 and it is not within SMEC’s scope to review that document.

Broadly speaking the above References consider five dam options, a desalination plant, a system for indirect potable re-use and rainwater tanks. They also consider emerging opportunities such as dam evaporation reduction, cloud seeding, stormwater harvesting, water grids etc. Two further options are suggested in Ref 11, the purchase of water allocation licenses from upstream users and access to supplies from the State Water Dams –Glenbawn and Glennies Creek. Neither option is canvassed or discussed by the HWC in the documentation reviewed.

Other options that could have been considered as either drought contingency or long term options are;

- Piping of water from Sydney's desalination plant during droughts;
- Transfers of water from the Clarence River;
- Development of small scale RO plants serving specific systems;
- Development of small scale groundwater systems

In our opinion it is unlikely that these options would have been totally ignored by HWC in their deliberations and are possibly not discussed due to space limitations in their report. Based on our experience the larger scale options above would suffer from fairly large operational costs due to pumping whereas the smaller scale systems can be difficult to manage as well as expensive for the quantities of water supplied.

The choice of Tillegra as the preferred dam option is set out in Refs 2,5 and 8. There are perhaps some considerations with the choice of Tillegra that have not been fully canvassed in the analyses shown but from an overall perspective it is clearly the preferred choice. We could note that although Tillegra provides a marginal Yield of only 52.5 GL/a (for a dam with 450 GL storage), this increase is clearly sufficient for the requirements of HWC in the medium to long term.

Based on the assumptions made for meeting the shortfall, the comparative assessment of options suggests Tillegra as the preferable option from a Yield and economic cost perspective.

- *The veracity of the Proponent's justification for the dam based on the review of the relevant documentation*

The proponent's justification for the dam appears to be based on the following factors;

- Population increases in the order of 6400 persons per annum: *SMEC accepts this as reasonable.*

- Various Australian cities facing drought restrictions during the recent past: *SMEC accepts this as reasonable.*

- Likelihood of climate change affecting Yield: *SMEC believes that this contention is arguable and not proven at this stage.*

- A new approach to Yield estimation based on Occasional Paper 14: *SMEC accepts this as reasonable.*

- An assumption that demand should not be reduced by more than seventy percent of average demand even during the most intense drought: *SMEC believes that this contention is arguable and not proven at this stage*

- An assumption that it would take four years to plan, design and construct a desalination plant: *SMEC accepts this as reasonable.*

- An assumption that the design inflow during this four year period would be the lowest 12 month inflow repeated four times: *SMEC believes that this contention is arguable and not proven at this stage.HWC advised that although the likelihood of such an event following a 100 year drought is in the order of 1:10 million their simulations suggest that during major droughts there is a fifty percent likelihood of this pattern of inflows.*

- The model developed by HWC is an accurate reflection of the physical system as evidenced by independent reviews: *SMEC would like to recommend that the model outputs be examined using a "proofing process" to confirm the accuracy of the model results.*

- The Yield of the current water supply system is 67.5 GL/a: *SMEC would prefer more evidence on the accuracy of the modelling as well as the assumptions; although we accept that this estimate is not over-conservative for SE Australia conditions.*

- The HWC water supply system is out of balance and requires augmentation: *This assumption is true if the Yield estimate is accurate.*

- HWC have implemented and are continuing to implement a substantial program of demand side measures to improve efficiency of water usage and thus minimise the need for augmentation: *SMEC is inclined to accept this contention although we recognize the concerns expressed by ISF.*

- HWC have implemented and are continuing to implement a program of loss management to minimise the need for augmentation: *SMEC is inclined to accept this contention although we recognize the concerns expressed by ISF*

- HWC have undertaken a detailed examination of all augmentation options: *SMEC is inclined to accept this contention based on the documents reviewed.*

- Tillegra Dam offers the best option for augmentation; *SMEC is inclined to accept this contention based on the documents reviewed*

6 SUMMARY

The DoP advised that there were two overarching issues to be considered in this review. Based on examination of the documentation provided and on SMEC's experience and understanding of water supply security issues;

1. Is there a shortfall in supply?
2. If so, has HWC selected the most appropriate option to redress this shortfall?

<u>A shortfall in supply</u>

A shortfall is the difference between demand and Yield. If a shortfall exists it could be redressed by a reduction in demand or an increase in the Yield.

A reduction in demand could be achieved by instituting a series of demand management measures for residential or industrial consumption. Demand could also be reduced by managing the leakage that is inherent in most water supply systems. Demand however increases with increasing population and may also change with lifestyle issues.

Within the scope of this review and notwithstanding the queries raised in Ref 7, it would appear that HWC have adequately addressed both leakage and demand management issues in Ref 2,

It should be noted that demand is generally measured at the bulk water meters and the demand (actual quantity of water supplied in any one year) is a material quantity. Yield on the other hand is an abstract quantity. It is determined in this case from a fairly complex mathematical model of the water supply system linked to a risk profile developed by HWC.

The mathematical model utilized for the HWC water supply system requires a number of variables and parameters. The review of the detail of these variables and parameters as well as of the modelling process is well outside the scope of this review. HWC have had their model reviewed and endorsed by independent bodies. Although SMEC have concerns on some of the detail presented in the reports reviewed, we are of the opinion that the model generally appears to reasonably represent the physical system under consideration.

The risk profile to be adopted is fundamentally a community based decision. In the past, some communities have accepted the risk that the drought of record would not be exceeded in the future. The Yield calculated by this method (also referred to as the Historic No Failure Yield) would be substantially greater than that determined using the process followed by HWC and based on that optimistic position under current conditions there would be no shortfall in supply.

If however we assume that the Hunter community is not willing to risk the failure of their water supply in the drought of record, we need to assume a lower level of risk than the recorded drought. The Water Supply Authorities of Australia (WSAA) methodology offers one process which has been reviewed by all major Australian water supply authorities and this has been followed by HWC. SMEC is unaware of the status and detail of the review processes within the other water supply authorities and their intentions towards adopting the process. Recent documentation released by South East Queensland Water (SEQW) would appear to suggest however that SEQW intend to follow a path similar to HWC.

Application of that methodology to the HWC system requires a number of assumptions that have been discussed in Section 4 of this report. Following one assumption, we have been advised by HWC that the likelihood of a 100 year drought followed by four consecutive years of the lowest flow on record is 1: 10 million. The accuracy of these figures can be questioned as they have been developed from a relatively short database but speaking broadly, this event is likely to be highly improbable. Nevertheless the consequences of this improbable event are near catastrophic and in the final analysis the risk that the community is desirous of accepting should determine the approach.

Following another HWC assumption, we were advised by HWC that if the maximum reduction in supply during droughts were to be increased from thirty percent to forty percent, the Yield estimate under current conditions would increase to 72 GL/a (from its current estimate of 67.5 GL/a). It can be noted that this estimate of Yield remains below the current demand of 75 GL/a.

Having noted that some of the technical detail in this analysis requires further explanation and clarification and that the modelling outputs have not been fully tested; we are however of the opinion that HWC appear to have adopted a "current best practice" approach to the determination of the risk profile.

Based on SMEC's experience and understanding of water supply security issues and on the review of the limited documentation provided, we are inclined to accept the HWC perspective and conclude that currently a shortfall of supply exists. We note however that all the assumptions underpinning the Yield analysis have not been completely accepted.

Appropriateness of option selected

Following from the above conclusion, the broad options for any source augmentation are;

- A new storage requiring
    - a large initial investment ;
    - a large footprint;
    - with low operating costs;
    - with recognisable environmental impacts;
    - affected by climatic factors; and
    - Resulting in a fairly large step increase in Yield.

- A new groundwater source requiring;
    - Possibly a smaller initial investment;
    - A smaller footprint;
    - A more limited capacity;
    - Higher operating costs;
    - Recognisable environmental impacts;
    - Affected by climatic factors; and
    - A smaller increase in Yield.
- A desalination plant
    - A large initial investment;
    - A smaller footprint;
    - Very high operating costs;
    - Possibly lesser environmental impacts;
    - Unaffected by climate factors; and
    - A larger stepped increase in Yield

- A wastewater recycling plant
  - A large initial investment;
  - Possibly a smaller footprint;
  - Very high operating costs;
  - Some environmental impacts;
  - Public perception issues;
  - Unaffected by climatic factors; and
  - Possibly a more controlled increase in Yield.

Dams and groundwater systems can be considered old technologies while the desalination plants and treated wastewater systems are the more modern approaches. Desalination plants in particular have been or are being constructed for all the major Australian cities and can provide a climate independent supply of water. Treated wastewater systems for public water supply have not as yet been proven in Australian or other industrial cities.

The current shortfall in supply is 7.5 GL/a and that is expected to increase with the increasing population being served by HWC. The HWC also anticipate a need to supply Central Coast Water as well as to provide a buffer against possible climate change impacts.

The most economic option for augmentation would be that option that just matches the shortfall in supply for the least cost and allows a capacity to match the demand as it increases. The nature of water supply infrastructure however requires a step wise increase in capacity to provide the best value for money.

The HWC have considered and costed a number of options in Refs 2 and Ref 5 and based on their analyses have preferred Tillegra dam on mostly economic grounds.

There are however a number of reasons advocated against the construction of Tillegra in Ref 5 and 9, particularly in environmental terms of damming a flowing river but also in terms of the Yield estimation underpinning it and the long term economic cost of this expensive asset. There is merit in some of the arguments postulated but on balance and within the scope of this Review; the arguments against Tillegra as the preferred option do not appear to be able to outweigh the information supporting the solution.

SMEC concludes that based on the information reviewed Tillegra Dam appears to be the preferred option for meeting the supply shortfall.

7 ADDENDUM

Subsequent to the issual of the Draft Final Report for this Project in June 2010, the NSW Department of Planning commissioned a further study relating to Tillegra Dam Hydrology.

An investigation of hydrological issues relating to the Tillegra Dam was undertaken by Bewsher Consulting P/L and a draft report issued on 24th August 2010 titled "Independent Review of Tillegra Dam Hydrology" (Bewsher Report). During the course of the studies associated with the Bewsher Report, Brendan Berghout of Hunter Water Corporation issued a report titled "Précis of Tillegra Dam EAR Hydrological Modelling" (SoMo Report) dated 12th July 2010.

Both reports delve in some considerable detail into some of the complexities associated with the hydrological and water resource modelling of the Tillegra Dam and the Hunter Water Supply System and are fairly substantial documents in their own right.

SMEC was advised by NSW Department of Planning that these two documents **did not form a part of the scope of the review conducted by SMEC.** Nevertheless the Department made inquiries of SMEC on specific aspects raised by these reports in September 2010 as outlined;

1. *Section 3.7 of the Bewsher Report provides simulated storage levels of Tillegra Dam and shows the dam will be more than 90% full for 90% of the time. Please comment on the need for the dam as over the 77 year historical period of record that the Bewsher Report has plotted, there are three events where there are drawdowns to about 70% full, otherwise the dam is almost 100% full for the remainder of the time. Please comment on the justification and size of the dam given this data.*
2. *As shown in the ISF report, with the addition of Tillegra Dam, HWC will almost never need to impose water restrictions (not even at the lowest level - refer to page 18 of the ISF report which refers to a table from a SKM report). The ISF report predicted that the probability of entering the lowest level of restrictions was around 1:1,250 at a demand of 85GL/year. Please provide a response to the reason and justification for the very low probability of entering water restrictions with the operation of the dam.*

In both queries the concept of "oversupply" is suggested. Oversupply implies that the Yield of the system is significantly greater than the demand for water and hence substantial capacity beyond the requirements of HWC has been created by this augmentation. It is not possible to definitively comment on the issue of oversupply without access to the HWC modelling programs; which is beyond the scope of this review. Instead SMEC has endeavoured to respond to the above queries based on their review of the specified documentation and their experience and understanding of water supply security issues.

1. The figure below is extracted from Section 3.7 of the Bewsher report and purports to show the simulated storage volumes in the proposed Tillegra Dam for the 77 year historical record with the "ultimate demand" of 120 GL/a. It shows that Tillegra dam is ninety percent full for ninety percent of the time and ninety five percent full for eighty five percent of the time. The Bewsher Report does not make any comment or draw any conclusions in Section 3.7 but in the immediately preceding Section 3.6 of the same report there is a reference to the availability of 'air space' to mitigate downstream flooding. It could be inferred that the intention of Section 3.7 of the Bewsher Report may have been the assessment of the availability of 'air space' for which a conservative approach is required.

   The query above however relates to the necessity of this storage and the size of the storage given that it appears to be full most of the time and is called upon on only three occasions.

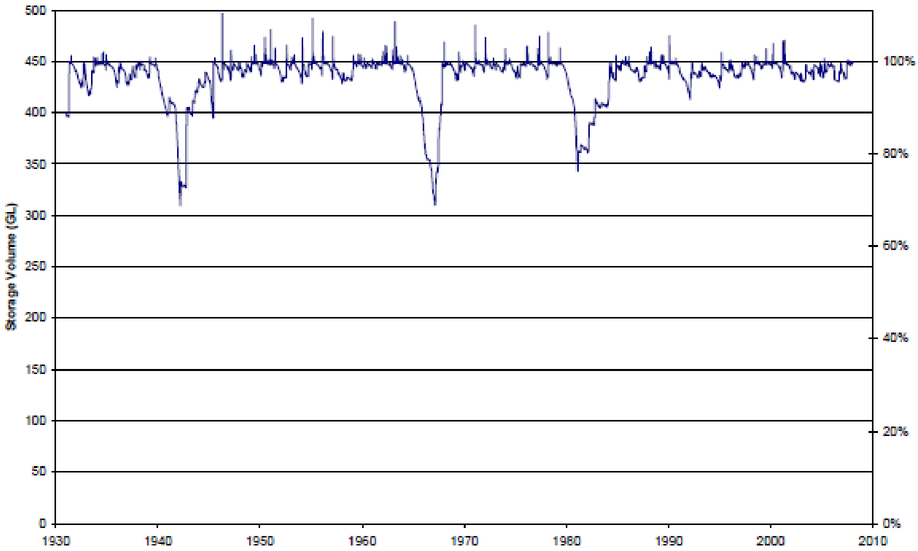

Figure 6: Simulated Tillegra Storage Volumes

The figure shows that under a repetition of the observed inflow record and with the demand at 120 GL/a, the dam will be required only during the droughts of 1942, 1967 and 1980. For the majority of the time that dam will be nearly full.

There are two points to be considered in relation to the above query. Firstly even under a repetition of current inflow conditions, with the higher demand the dam is drawn down to some significant extent on the three occasions. Without this dam (or other available source), the Hunter conurbation would suffer very severe water shortfalls in the three drought periods above. The system needs at least an additional 150 GL of storage just to survive a repetition of the observed historical inflow record. Secondly and more critically there is a need for substantial reserves to cope with droughts that are more intense than the previously observed droughts but which are equally likely within the observed inflows structure. In other words if the next drought on the Hunter is more severe than the observed droughts, there is a significant likelihood of complete system failure without Tillegra (or other available source).

Furthermore the detailed operation of Tillegra dam in the Hunter Water supply system determines to a significant extent, the usage of Tillegra dam. Detailed information on the future operation of the Hunter Water System was not available for review but it is possible that HWC intend to use Tillegra as a reserve storage. This is similar (in a fashion) to the role of Tallowa dam on the Shoalhaven River for the Sydney supply system. If that is indeed the case, Tillegra would be deliberately kept as full as possible for most of the time to ensure minimal interference with flow patterns (after reservoir filling) downstream of the dam. HWC would access its supplies from its currently available sources and only access Tillegra during major droughts.

In conclusion, it is our view that water supply systems dependant on the highly skewed patterns of surface inflows observed in South East Australia; need to be maintained at high levels of ‘fullness” to ensure that sufficient reserves of water are available to cope with droughts of greater intensity that those observed in the past. Consequently the behaviour pattern of Tillegra dam under historical conditions as shown in the above figure does not necessarily indicate an oversupply of water.

2. Section 3.4 of the ISF report quotes Table 10 and 11 of the SKM 1998 report to argue that construction of Tillegra dam would reduce the frequency of restrictions on the Hunter community to negligible levels which was seen as undesirable by ISF.This concern is discussed on Page 33 of the EASR (March 2010) where HWC argue that ISF have quoted a figure of 108 GL/a for the 2050 demand whereas the actual demand should be 120 GL/a. HWC have not however provided the restriction frequencies associated with the higher demand figure. HWC have also argued that due to their aggressive demand management programs, the efficiency of water usage in the Hunter has been substantially increased and the effectiveness of restrictions, consequently reduced.

   Tables 10 and 11 of the SKM 1998 report are presented below. They show that for demands of 85 GL/a the frequency of Level 1 restrictions will reduce from 1:21 years to 1: 1250 years with the construction of Tillegra Dam. Similarly the frequency of Level 1 restriction at a demand of 108 GL/a will reduce from 1:8 years to 1: 170 years.

Table 10: Probability of restrictions and low storage levels - Year 2025 demand of 85GL/yr.

Storage level	Without Tillegra	With Tillegra
60% (Restriction level 1)	0.047 (1 in 21)	0.0008 (1 in 1,250)
50% (Restriction level 2)	0.016 (1 in 63)	0.0001 (1 in 10,000)
40% (Restriction level 3)	0.004 (1 in 250)	<0.0001
30% (Restriction level 4)	0.001 (1 in 1,000)	<0.0001
20%	0.0001 (1 in 10,000)	<0.0001
10%	<0.0001	<0.0001
5%	<0.0001	<0.0001

Table 11: Probability of restrictions and low storage levels - Year 2050 demand of 108GL/yr.

Storage level	Without Tillegra	With Tillegra
60% (Restriction level 1)	0.13 (1 in 8 years)	0.0059 (1 in 170 years)
50% (Restriction level 2)	0.065 (1 in 15 years)	0.001 (1 in 1,000 years)
40% (Restriction level 3)	0.028 (1 in 36 years)	0.00014 (1 in 7,140 years)
30% (Restriction level 4)	0.011 (1 in 90 years)	<0.0001
20%	0.0025 (1 in 400 years)	<0.0001
10%	0.0003 (1 in 3,333 years)	<0.0001
5%	0.0001 (1 in 10,000 years)	<0.0001

A restriction policy is developed to ensure that available supplies are appropriately husbanded during a major drought event to enable the Water Supply Authority to meet its obligations during the course of that event. A restriction policy should however not be of such harshness that it affects the livelihoods of people affected by its imposition

The ultimate test is not with the restriction policy as such but with ability of the Authority to operate through major drought events without imposing undue hardships. In other words the requirement that water restrictions should not be imposed at a frequency greater than 1:20 years does not necessarily mean that the system is in deficient in some fashion, if restrictions are required only once in 100 years. Water restrictions are essentially interruptions to supply and the focus of the Authority should be on ensuring that these interruptions are minimised.

There is little information available on the manner in which HWC has determined its restriction policy. SMEC understands that the trigger levels for restrictions associated with the current storage system were applied to the augmented system on a proportional basis. The rationale behind adopting this policy was not available in the documentation reviewed by SMEC. Restriction Policy is essentially an operational tool and will depend on a number of factors which will vary with time. Without this information it is not possible to comment meaningfully on restriction policies adopted by HWC.

Augmentation of water supply systems is usually carried out in large steps and there will be periods of time where an excess of supply to demand will exist resulting in a relaxation of restriction requirements. Thus the likelihood of restrictions when the demand is 85 GL/a will be lower than when the demand is at the ultimate 120 GL/a. In theory if the augmentation could be carried out in small steps it may be possible to match the frequency of restrictions with the increase in supply but it will depend on the balance between the three Yield requirements in the modelling process.

It is not uncommon for one Yield requirement (Refer Section 4) to dominate the other requirements and in this case it is highly likely that ensuring the water supply system meets the third Yield requirement has resulted in a more relaxed assessment of the other two Yield requirements.

In conclusion it is SMEC's view that although the frequency of restrictions may reduce after the construction of Tillegra Dam, it does not necessarily indicate an oversupply as the reduction of the restriction frequency may be due to;

- **The stepped nature of the augmentation process; and/or**
- **Dominance of a single Yield requirement; and/or**
- **Changed operational policies.**

APPENDIX A: COMMENTS ON DOCUMENTATION AND TIMEFRAMES

Technical Comments on Reference 2

The comments provided are based on review of the documents within a fairly short time frame and without discussion with the authors. They are provided as a basis for clarification rather than an opinion.

The queries below were discussed with the HWC and their responses are presented in Appendix B.

1. Chapter 4: "During *drought years storages deplete faster due to higher water usage, higher evaporation from reservoirs and natural depletion of groundwater*".
   Were these increases incorporated into the modelling process, and if so on what basis were they constructed?

2. Chapter 5: "*The CSIRO study had rainfall decreasing by ten percent and evaporation increasing by eight percent*"
   Were both these factors included in the modelling process? The findings of the climate change analysis were not completely clear.

3. Chapter 5: "*The storage volumes fall twice as fast as in Sydney".*
   As the demand, existing storage volumes and drought inflows are generally in proportion, it is hard to appreciate the reasons for the greater rate of depletion. This needs to be explained.

4. Chapter 6: "The *maximum level of reduction in demand has been set at 70%*".
   This appears to be counter to the generally accepted view which postulates a substantially higher level of reduction for short periods during droughts. What differences to the Yield estimation would result from using 50 or 60 percent as the maximum reduction?

5. Chapter 6:"*The lowest 12 month inflow is concatenated to produce the four year drought inflow sequence*"
   It would be useful to estimate the likelihood of having a 100 year drought followed by a four year sequence of the lowest annual flow on record.

   On this issue, the NSW Office of Water (Ref 11) have advised SMEC that during the low flow period utilised by HWC there were substantial abstractions from irrigators in 1979-80 which are unlikely to occur again. HWC could check whether an adjustment to their data base is needed.

6. Chapter 6: "*The current trigger level is 70% and this will rise to 80% by 2012*"
   The calculations underpinning this ten percent rise are not clear. Over the period 2009-2012 one could expect an increase in demand of around 2.8 GL/a based on a population increase of 6,400 persons per annum. It needs to be explained as to why this change in demand requires a 10% (27 GL) of storage change to the trigger point.

7. Table 12.1: "*The yield of the desalination plant reduces from 32.5 to 24.5 GL/a under a rainfall reduction scenario*."
   The reason for this apparent reduction needs to be explained.

Comments on Reference 4

Table 10 in this document which is also referred to Ref 9 gives the likelihood of entering restrictions. Ref 5 refers to the assessment as inaccurate but does not provide any more accurate figures.

These estimates require clarification from HWC as it possibly demonstrates a serious weakness in the modelling structure.

Comments on time frames for development of infrastructure

Australia has so far completed two desalination plants, one is still under commissioning and two more are under construction. Details are given below. SMEC has been involved in the three most important desalination plants- Sydney, Melbourne and Adelaide.

List of Desalination Plant in Australia

Plant	Capacity (ML/d)	Upgradable Capacity (ML/d)	Notes
Gold Coast Qld	125	167	completed 2009
Perth Seawater WA	144	250	completed 2006
Kurnell NSW	250	500	completed 2010 (Commissioning)
Southern Seawater WA	50	100	Late 2011
Wonthaggi Vic	410	550	2011-2012
Port Stanvac SA	270		Late 2012

Australian experience in term of desalination construction technology is still relatively short. It took 30 months to complete the construction of Sydney desalination plant and it is currently under commissioning. That does not mean that all plants having a similar capacity will have a similar time requirement for construction. Depending on the geology of the site, construction technology, distribution system, operation and maintenance arrangement, scope for future modification etc, the time may vary considerably. Moreover, proper commissioning of the plant is invariably time-consuming and rarely trouble free.

There are several components in the planning, design and construction of any infrastructure that takes a similar amount of time irrespective of the size of the work. A billion-dollar contract invariably requires considerable time for the tendering process. There should always be adequate contingency while planning such important infrastructure where any delay in the completion of the work can be significant. With all these factors in consideration and considering the recommendation of the specific consultants, the 4-year timeframe for HWC desalination including tendering appears to be reasonable.

APPENDIX B: RESPONSES FROM HWC

Questions and Answers – SMEC and DoP review of "Project Justification" aspects of EAR

DoP 1

HWC to provide a corrected table of probabilities for entering each stage of water restriction, both with and without Tillegra Dam. The ISF (2009) "An Independent Review of Supply-Demand Planning in the Lower Hunter and the Need for Tillegra Dam" report includes these probabilities in Table 4.2, which was referenced from the SKM (2008) report. SMEC has advised that the HWC Submissions report states that these calculations have questionable accuracy (page 42 of HWC Submissions Report). We therefore request HWC to provide a correct table showing the probabilities for entering each stage of water restrictions with and without Tillegra Dam

A corrected table of probabilities is not required because the table in question provides the best estimates of the risk of reaching particular storage levels that is available. The problem is not that HWC has used an incorrect approach to estimate these risks, but that the low risks presented in the table have a high level of uncertainty. As a guide risks in the range 1 in 5 to 1 in 50 are reasonably accurate, and risks less than 1 in 100 are increasingly uncertain.

The fundamental reason for this uncertainty is the short length of available climate records. As with many Australian cities quality streamflow data is available since the 1930s in the Lower Hunter, and rainfall data is available from around 1900 onwards at a reasonable number of sites. While it is possible to estimate risks in the order of 1 in 1 year to 1 in 50 years with reasonable accurately from the historic data, it is impossible to estimate lower frequency events with accuracy.

This problem is exacerbated when attempting to characterise drought sequences. There are only 3 or 4 samples of severe drought in the Lower Hunter's 80 year historic streamflow record, so estimating the probability of severe droughts, especially droughts more severe than those recorded, is highly uncertain. It is further noted that the severity of two of the droughts, in terms of the lowest storage level that each would cause, has come down to one or two months of improved streamflow during the drought sequence, with dramatically more or less severity of outcome possible for just slight shifts in the weather patterns that occurred. It is HWC's opinion that risks assessed as being around 1 in 1,000 could be in error by up to an order of magnitude (i.e. the actual likelihood is probably in the range 1 in 100 to 1 in 10,000), and risks assessed as being around 1 in 10,000 even more so.

The stochastic data that has been used to estimate the low probability risks presented in the table is arguably of more benefit in terms of exploring the types of scenarios that can lead to severe water shortage than it is as a tool for assigning extreme low probability risks.

DoP 2

HWC to provide the probability of the 1 in 100 yr drought followed by 4 years of inflow data (from 1979-1980), which was used in formulating the response to the WSAA criteria used by HWC in determining yield calculations.

The estimated probability of experiencing a 1 in 100 year drought followed by 4 years of inflow data from the 1979 to 1980 drought is around 1 in 10,000,000.

In addition to the issues highlighted in the previous question relating to the uncertainty of this assessed risk, the acceptability or otherwise of this risk also needs to take into account the consequences associated with it. The consequence of complete exhaustion of water supplies is, in the words of Professor George Kuczera in his review, "a collapse of the social and economic fabric of the urban region". Not only would such an event be disastrous for the local population of over 500,000 people, but it would have a major impact on the state of NSW which relies heavily on both the economic prosperity and essential services that are derived from this region.

HWC has adopted the philosophy that it is unacceptable to entertain the risk of running out of water, and irrespective of the low chance, requires its system, in conjunction with a drought management plan, to be designed such that it cannot run out of water. The problem for HWC is that its existing system can deplete rapidly, and this leaves insufficient time to enact an effective drought management plan.

As reported in Section 3.4.2 of Ref 5, HWC has used stochastic modelling to investigate the types of streamflow events that lead to severe water shortage (in which storage can reach 10%), and it has found that when they occur, the median event is equally as severe as the 1979 to 1980 streamflow sequence repeating, with depletion rates for some events being considerably faster. The HWC drought management plan assumptions regarding climate during a drought are therefore considered to be entirely consistent with the types of events that could cause the region to run out of water.

Irrespective of the end risk of running out, HWC has a high probability of passing the point beyond which it cannot control that possible outcome. With high triggers, which are passed relatively often, one never knows whether or not to act because in all likelihood its not the real drought and in all likelihood the investment will be wasted. Indeed it is noted that HWC current storage levels are currently just under 75%, with the "4 year trigger" being around 70% for current demand.

It is also noted that prior to the current drought in Victoria, the estimated risk of storage levels falling as low as they have was considerably less than 1 in 10,000 (personal communication). There are strong parallels between Thomson Dam for Melbourne and the proposed Tillegra Dam for Newcastle in terms of both being large dams relative to average annual inflow, and both serving the purpose of providing the lead time to observe and react to an unprecedented streamflow sequence. The benefit of having the large capacity Thomson Dam in Melbourne's current drought response cannot be understated.

SMEC 1

Chapter 4: "During *drought years storages deplete faster due to higher water usage, higher evaporation from reservoirs and natural depletion of groundwater*". Were these increases incorporated into the modelling process, and if so on what basis were they constructed?

The HWC source model includes mass balance modules for Chichester Dam, Tillegra Dam (which is excluded for existing system analysis), the Williams River, Grahamstown Dam and Tomago Sandbeds. Each of these mass balance modules includes accounting for evaporation rates. The two modules in which evaporation (or evapotranspiration) has a significant impact on storage performance are the Grahamstown Dam module and the Tomago Sandbeds module. Both of these modules operate at a monthly timestep.

In the Grahamstown module in each month evaporation is derived from current dam surface area (which is a function of current dam storage), average pan evaporation for the month, rainfall for the month, a seasonal rainfall based evaporation reduction coefficient, and a seasonal pan coefficient. The coefficients for this model were derived through a parameter fitting process in conjunction with the derivation of catchment runoff generation coefficients, thus avoiding potential overlap of functionality between the runoff generation and evaporation functions. The rainfall based evaporation reduction coefficient effectively factors the average pan evaporation for the month up or down slightly depending on the month rainfall.

The Tomago module employs a lumped two-bucket model, each with conceptual saturated and unsaturated zone soil moisture stores. Again average month pan evaporation is an input, with the relationship between water level response, recharge, rainfall, ET, pumping, etc being driven by workings of the model. For a detailed explanation of both the Grahamstown Dam and Tomago modules and how they were calibrated, please refer to the attached document *Lessons learned from mass balance calculations for water supply reservoirs*.

On the demand side, "unrestricted" demand is calculated each month as a function of "average" demand for the month, and a function relating to streamflow and rainfall in the month. While the functionality is relatively crude, it does allow demand to be scaled up or down within the model as a function of how dry it has been. The unrestricted demand functionality is ignored when restrictions are imposed, and instead demand is modelled as a function of "average" demand and a reduction factor based on the restriction level that is in place.

In short, all three processes identified in the question are accounted for in the HWC modelling process, and each calculation method has a rational basis.

SMEC 2

Chapter 5: "*The CSIRO study had rainfall decreasing by ten percent and evaporation increasing by eight percent*"
Were both these factors included in the modelling process? The findings of the climate change analysis were not completely clear.

A climate change analysis was undertaken to test the sensitivity of estimated yield to downside risks associated with climate change to ensure that any supply solution was robust under a reasonably worst case climate change scenario. It was not used to justify the need for action. The modelling was relatively crude, with a 10% reduction in rainfall assumed. Evaporation increase scenarios were not tested at that time. The results are presented in Table 12.1 of the $H_2$50 Plan (Ref 2).

SMEC 3

Chapter 5: "*The storage volumes fall twice as fast as in Sydney*".
As the demand, existing storage volumes and drought inflows are generally in proportion, it is hard to appreciate the reasons for the greater rate of depletion. This needs to be explained.

The relativities between the Lower Hunter rate of depletion and Sydney rate of depletion (in percentage terms) are clearly evident in any comparison of historic data, and it is assumed that this question relates to why this is the case rather than whether or not it is the case.

The primary reason why the Hunter system depletes faster is the relativity between Hunter and Sydney uncontrolled "natural" loss rates – ie evaporation and evapotranspiration. While the demand to storage volume ratio is similar between the organisations, HWC has a much higher relative surface area of storage, especially when the areas of Tomago Sandbeds are taken into consideration. The average evaporation loss from Grahamstown Dam is around 30GL/yr, which is driven by a 27km^2 surface area (average depth is around 7m when full). The Tomago Sandbeds also lose a significant amount of water to evapotranspiration, especially when they are full. Tomago Sandbeds cover an area of around 100km^2, and the watertable is relatively shallow (generally less than 5m below ground surface), which means that the vegetation at Tomago has ready access to the groundwater, even during drought. When full, the average thickness of usable storage at Tomago is 3m, which is equivalent to a 0.6m deep storage over the 100km^2 area of aquifer once the porosity of the sand is taken into account.

Putting these evaporation rates in perspective, when the storages are full nearly as much water is lost each day (averaged over the year) to evaporation and ET as is supplied to the customers. Both ET and E drop as storage levels fall due to reduced dam surface area and reduced access to the groundwater at Tomago by plants and direct evaporation.

SMEC 4

Chapter 6: "The *maximum level of reduction in demand has been set at 70%*". This appears to be counter to the generally accepted view which postulates a substantially higher level of reduction for short periods during droughts. What differences to the Yield estimation would result from using 50 or 60 percent as the maximum reduction?

In broad terms the reason that restriction driven demand reduction is estimated to be less in the Hunter than in other cities is that under average conditions Hunter residents use a significantly smaller proportion of demand outdoors than is the case elsewhere. This means that Hunter consumption will drop less when restrictions are applied to outdoor use that would be the case in other cities.

The approach that HWC used to estimate demand reduction was to work up demand reduction potential for each demand category – residential, commercial, industrial, etc. Demand reduction in each category was then worked up from the type of end uses in that category. Residential demand reduction, for example, was worked up from an estimate of residential end uses and the likely response to the imposition of water use restrictions, with the results shown in the following table:

Table 1 Domestic end use requirements

End use	Normal (unrestricted) use rate	Maximum possible reduction	Estimated 'minimum requirement'
Outdoor	30 to 75L/person/day	100%	0L/person/day
Bath and shower	53L/person/day	33% (ie 7mins down to 4.5mins average shower length)	35L/person/day
Washing machine	42L/person/day	17% (5/6 washes)	35L/person/day
Toilet	30L/person/day	17% (5/6 flushes)	25L/person/day
Tap	30L/person/day	17%	25L/person/day
Other	5L/person/day	0%	5L/person/day
TOTAL	**190 to 235L/person/day (average of 210L/person/day)**	**40%**	**125L/person/day**

It should be noted that this analysis was undertaken around 5 years ago prior to the widespread adoption of water efficient washing machines, water efficient shower roses, and to a lesser extent, wider use of rainwater tanks.

In the non-residential sections it was estimated that demand could be reduced by around 20%, with industrial and commercial demand considered to be relatively inelastic. The following table provides the estimated demand reduction in the non-residential sectors:

Table 2 Non-domestic end use requirements

End use	Normal use rate in 2003	Maximum possible reduction	Estimated 'minimum requirement'
Water accounting errors (eg meter error)	5ML/day	30% (reduces in proportion with total supply)	3.5ML/day
Unmetered water use (eg mains flushing, main breaks, fire fighting)	3ML/day	30%	2ML/day
Unidentified losses (eg weeps and seeps)	20ML/day	30%	14ML/day
Industrial	30ML/day	10%	27.0ML/day
Commercial	10.5ML/day	5%	10.0ML/day
Hospices	8.5ML/day	0%	8.5ML/day
Parks, farms	5.5ML/day	80%	1.0ML/day
Clubs, hotels, motels	3.5ML/day	5%	3.5ML/day
Education	3.0ML/day	20%	2.5ML/day
HWC	2.0ML/day	50%	1.0ML/day
TOTAL	**91ML/day**	**20%**	**73.0ML/day**

HWC considers that a 50% to 60% reduction in demand in response to water use restrictions and advertising campaigns is not possible in this region, and therefore it would be unrealistic to calculate yield on this basis.

SMEC 5

Chapter 6:"*The lowest 12 month inflow is concatenated to produce the four year drought inflow sequence*"
It would be useful to estimate the likelihood of having a 100 year drought followed by a four year sequence of the lowest annual flow on record.

On this issue, the NSW Office of Water (Ref 11) have advised SMEC that during the low flow period utilised by HWC there were substantial abstractions from irrigators in 1979-80 which are unlikely to occur again. HWC could check whether an adjustment to their data base is needed.

Please refer to the answer to question **DoP 2** above regarding the likelihood question.

HWC has reviewed available river flow data for the 1979 to 1981 period. HWC has contacted NOW to check if they have additional information regarding irrigation water use and has been advised that this information does not exist except perhaps by inference from streamflow records. NOW advised that possibly irrigators may use less water under current water sharing rules compared with that used in 1979 to 1981 given that there is now a requirement that 6ML/day end of stream flow be maintained.

The new end of stream flow requirements is only one of a number of changes to river operation. The other major change since the early 1980s is that HWC is now required to make substantially higher releases from Chichester Dam than it was in 1979 to 1981. Historic releases from Chichester Dam averaged 0.6ML/day during the drought, but under today's operating rules would average around 13.1ML/day.

The question of whether irrigators would use more or less water today for the same sequence is therefore complex. It is arguable that in net terms 7ML/day more water would now be available, and depending on whether irrigation use was demand constrained or supply constrained in the previous drought they could potentially use more water.

Further confounding the matter was long periods of time with zero river flow and evidence of a river deficit forming at times. Indeed, it is noted that when freshes did occur there was at times substantial water loss between Chichester/Tillegra and Glen Martin before flow resumed.

Given all of these factors HWC considers that there is insufficient evidence for it to change the assumed historic inflow sequence nor its approach to modelling the combined influence of river losses and irrigation water use along the river.

SMEC 6

Chapter 6: "*The current trigger level is 70% and this will rise to 80% by 2012*"
The calculations underpinning this ten percent rise are not clear. Over the period 2009-2012 one could expect an increase in demand of around 2.8 GL/a based on a population increase of 6,400 persons per annum. It needs to be explained as to why this change in demand requires a 10% (27 GL) of storage change to the trigger point.

It would appear that the statement is in error. The following graph shows the relationship between the 48 month trigger and demand that should have been used to inform any such statement:

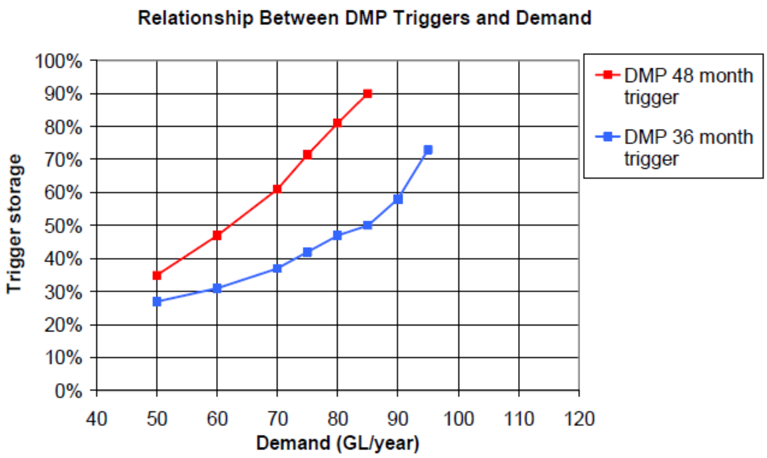

Figure 1 Re   ip between Demand and Lead Times in DMP

It can be seen from the above graph that demand would need to grow from 75 to 80GL/year for the 48 month trigger to be pushed up from 70% to 80%. Based on demand increase alone one might expect the trigger storage to be pushed up by a bit under 20GL once restrictions are taken into account (5GL/yr for 4 years). However, given that there are high loss rates when the storages are full, depletion rates are substantially faster than can be accounted for by usage alone, so when the trigger is pushed up, it needs to be pushed further than would initially seem necessary.

SMEC 7

Table 12.1: "*The yield of the desalination plant reduces from 32.5 to 24.5 GL/a under a rainfall reduction scenario.*"

The desalination plant that is considered in Table 12.1 is a 70ML/day plant, or 25.5GL/year. Under existing climate conditions such a plant is expected to increase system yield by around 32.5GL/year. The reason that the desalination plant has such a strong positive influence on yield relative to its nominal capacity is that there is a disproportionate improvement in system performance during the design drought due to having a constant source of 25.5GL/year while demand is heavily restricted.

The reason the yield increase drops to 24.5GL/year under the climate change scenario is not that the desalination plant produces less water, but that the existing system to which it is coupled produces less water. The 24.5GL/yr increase effectively represents the difference between current climate existing system yield and a reduced rainfall yield with the desalination plant.

SMEC Page 5

Nevertheless underlying this criterion is a number of assumptions including;

- A minimum of seventy percent of demand is to be made available under even the most extreme drought;
- The inflows into the storages during a four year period will be a repetition of the lowest annual inflow repeated four times;
- The four years of low flow are preceded by a 100 year drought; and
- Drought contingency plan assumptions such as the 10% limit in Grahamstown Dam (Ref 11)

Following review of the documentation examined and acknowledging that Ref 4 has not rejected this requirement, we have however some difficulty in appreciating the basis of some of these assumptions. We are inclined to agree with Ref 9 that the basic assumptions and their application to the model require greater explanation.

For an overview of the thinking behind the development of these requirements, it is recommended that SMEC refer to Appendix B in Ref 5, which is a copy of the AJWR paper titled *Incorporating drought management planning into the determination of yield*. The basic premise is that a city needs to be able to defend its water supply system against drought, and this cannot be done unless there is sufficient lead time to initiate drought response actions. While the posing of the criterion is new, the end result is not dissimilar to including a buffer storage in a yield calculation. In the HWC calculation the buffer storage has been set as the amount of water required to enact a drought contingency plan. Stochastic modelling by HWC shows that when the system runs out of water it generally runs out quickly. There is no such thing as an in-between drought – either the system continues to fall or it substantially recovers.

It is also noted that the SEQ Water Strategy has recently adopted a similar approach to defining yield, and they also include a 1 in 100 acceptability criteria for “triggering drought response infrastructure”. An important difference between the SEQ and HWC approaches is that SEQ has determined that desalination is a logical next augmentation, whereas HWC believes that Tillegra Dam is the preferred next augmentation. It is this difference that allows the SEQ strategy to assume that drought response infrastructure is triggered 3 years rather than 4 years prior to potentially running out of water with the assumption that the site acquisition and other pre-work required to bring the lead time for construction of a desalination plant down to around 3 years is already complete. Such preparatory work will not be "wasted" because it is the preferred next source.

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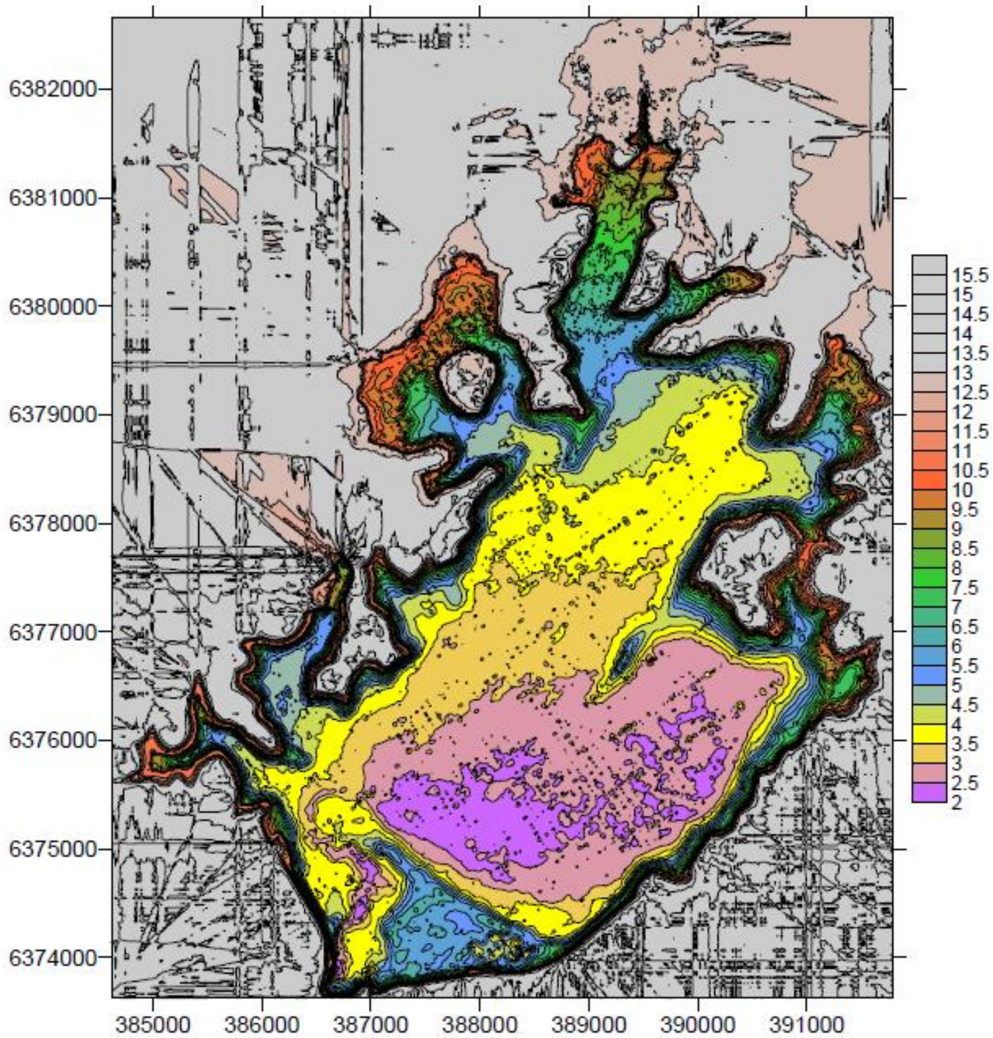
Ref 11 refers to the inflows entering the HWC supply system during the lowest inflow year and questions whether the assumptions made by HWC are accurate. It also refers to the storage characteristics of the Grahamstown Dam and recommends a bathymetric survey to better understand them.

A bathymetric survey of Grahamstown Dam was undertaken during 2009, though the data was not yet available at the time of modelling. As a result of the survey, the estimated total storage volume at Grahamstown Dam has been changed from 198,000ML to 192,350ML, dead storage from 8,000ML to 9,950ML, and live storage from 190,000ML to 182,400ML. In terms of live storage, the bathymetric survey has lead to a 4% reduction in available storage.

Grahamstown Dam Bathymetry - 2009 Survey (10m Kriging)



While theoretical storage is now better understood from a hydraulic perspective (ie how much water the pumps can access), HWC still has concerns regarding potential operational problems associated with operating the dam at extremely low levels. At dead storage levels, the water level in Grahamstown Dam is 3.91mAHD (constrained by pump intake), the surface area is 11.9km^2, the average depth is 0.84m, and the deepest depth is around 2m. Based on the combined potential problems of shallow water operation and supply zone constraints, HWC believes that in the absence of more compelling information it would not be prudent to assume supply can be maintained below 10% live storage.

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> Nevertheless, it is unusual for the provision of an additional 450 GL of storage in Tillegra to provide only an additional 52.5 GL/a of Yield, which gives the impression of Tillegra being a highly inefficient storage or other unexplained factors have reduced the Yield or some error in the modelling process.

The primary reason that the additional storage of 450GL provides a relatively modest increase in yield is that the dam is largely serving to correct an existing imbalance in storage capacity vs average streamflow for the pre-existing components of the HWC headworks system. In its own right the dam would be considered over-size. Like Thomson Dam in Victoria, Tillegra Dam will have the storage capacity to hold between 4 and 5 years of average annual inflow. It will work well in combination with the rest of the system only because in good years the other catchments can meet complete supply requirements and thus allow Tillegra to fill without the burden supplying water at the same time.

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> Others that may have been considered as either drought contingency or long term options but not reported are
>
> - Piping of water from Sydney's desalination plant during droughts;
> - Transfers of water from the Clarence River (a perennial favourite);
> - Development of small scale RO plants serving specific systems;
> - Development of small scale groundwater systems

It would be fair to say that while each option suggested by SMEC has some merit, there are also downside aspects that put them at a significant disadvantage compared with the options that were formally considered by HWC. The high cost of establishing a water grid is a major deterrent to long distance contingency plans. It is estimated that a link connecting Sydney to Newcastle would cost in the order of $2b, and it is understood that a feasibility study was undertaken by the then DEUS in around 2006.

The primary advantage of a piped drought contingency solution would be the potential for shorter construction lead times compared with a new desalination plant. It is questionable, however, whether or not a link could be established between Sydney and Newcastle (the closest source of sufficient capacity) with sufficient lead time savings to offset the fact that such a scheme would cost substantially more than construction of a desalination plant locally. Such a scheme would need to negotiate the outer urban areas of Sydney and cross the Hawkesbury River and associated rugged sandstone landscape.

With respect to the small scale solutions there are not enough sites for either small scale RO nor small scale groundwater to make a meaningful difference to Lower Hunter contingency planning. The HWC drought management strategy already makes significant use of local groundwater opportunities.

Additional Information for DoP/SMEC Tillegra Dam Environment Assessment Review Process

Brendan Berghout

25 May 2010

The following information with regard to HWC's Tillegra Dam proposal is provided in response to matters discussed at the meeting between DoP, SMEC and HWC held at DoP's Bridge Street, Sydney Office on 24 May 2010.

1. What would the impact on yield be if changes were made to the assumed "minimum supply requirement"? Specifically, how much would the yield change if it was assumed that the minimum supply requirement is 60% of average supply, rather than the current assumption of around 70%?

Answer

Assumed minimum acceptable fraction of average supply	Yield
70%	67.5GL/yr
60%	72GL/yr

Notes

a. Assumed restriction strategy in both cases is:
    i. 60%: Level 1 restrictions (fixed hose ban and limited days hand watering)
    ii. 50%: Level 2 restrictions (limited days hand watering)
    iii. 40%: Level 3 restrictions (outdoor use ban)
    iv. 30%: Level 4 restrictions ("minimum supply")

b. System model as per H_250 Plan, Why Tillegra Now? Paper, etc. Does not include any allowance for subsequent changes to HWC knowledge base. Revised Grahamstown bathymetry, for example, is not included.

Note that the 70% overall minimum supply requirement was based on a reduction to 60% for residential use and to 80% for non-residential as noted in the H_250 Plan. The reduction for the residential demand was based on an assumed minimum daily requirement of 125 litres per person per day. The non-residential demand reduction was based on nominal estimates for different classes of users.

As suggested we have also reviewed residential consumption for Ballarat. Based on the WSAA 2008/09 National Performance Report, Ballarat (Central Highlands Water) achieved the lowest annual average residential consumption rate per property of any water utility with over 20,000 connections in Australia. Under the severest level 4 water restrictions, residential demand fell to 125ML/property or 151 litres per person per day. It is not clear whether level 4 restrictions applied for the entire year, but it would be unreasonable to expect long term reductions below Hunter Water's assumed 125 litres per person per day. In other words, while we have modelled a greater reduction to answer the question posed, we do not believe that it would be prudent to assume such a reduction is possible.

2. Following up from the meeting, SMEC requested that HWC provide the tableau of yield outcomes for each combination of existing climate or reduced rainfall climate, and existing system or existing system plus a 70ML/day desalination plant.

Answer

HWC System Yields	Existing system	Existing system + 70ML/day desalination plant	Increase due to desalination
Existing climate	67.5GL/yr*	100GL/yr*	32.5GL/yr
Climate with 10% less rainfall	61GL/yr	92GL/yr*	31.0GL/yr

Notes

*Values as provided in the H_250 Plan.

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