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The many NSW Councils which have undertaken secure yield studies, thus enabling use of the study models for the analysis reported in the pilot study.

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Disclaimer: The information contained in this publication is based on knowledge and understanding at the time of writing (December 2013). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of the Department of Primary Industries or the user’s independent adviser.

NOW 13_11
Assuring future urban water security

Assessment and adaptation guidelines for NSW local water utilities
Foreword

Variable climatic patterns will affect rainfall in NSW and hence water availability and the security of some town water supplies.

These guidelines have been prepared by the NSW Office of Water to provide guidance to NSW local water utilities to help them assess and adapt to the impact of variable climatic patterns on the secure yield of their urban water supplies.

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Purpose

The Guidelines on Assuring Future Urban Water Security have been prepared by the NSW Office of Water to provide guidance to NSW local water utilities on assessing and adapting to the impact of variable climatic patterns on the secure yield of their urban water supplies. The guidelines will enable each utility to assess the future secure yield of its urban supplies and form the basis for planning its water supply headworks upgrade/augmentation where warranted for the impact of variable climatic patterns and population growth. An assessment of the future secure yield of each water supply needs to be undertaken in accordance with these guidelines and is an integral part of a utility’s Integrated Water Cycle Management (IWCM) Strategy.

Introduction

NSW local water utilities are responsible for managing their water supply systems. The recent decade long Millennium Drought resulted in a reduction of water availability in almost all water supplies across the state. While La Nina weather patterns since late 2010 have delivered above average rainfall, utilities must prepare for the return of drought conditions and reductions in water availability, which are expected to be exacerbated by the impact of variable climatic patterns.

Managing the impact of variable climatic patterns is a critical issue for NSW local water utilities with potentially severe consequences if not addressed properly. Lead times for developing new water sources are long and the capital costs involved are high, which could expose the utility to complete failure of its water supply system in worst case scenarios. Utilities therefore need to plan effectively to ensure they have appropriate water supply headworks capacity in order to avoid being forced to carry out costly emergency works. Each utility’s 30-year Integrated Water Cycle Management (IWCM) Strategy is required to determine the utility’s response to the risk posed by variable climatic patterns to its water supply as part of its long term planning process.

Although the Intergovernmental Panel on Climate Change (IPCC) has identified 40 possible greenhouse gas emissions scenarios, there is little difference in the temperature increase projected by these scenarios by the Year 2030 although they start to diverge markedly by mid century. Given that fact, the pilot study has adopted the medium emissions scenario A1B for water supply planning purposes which projects an average temperature rise of 0.9°C from 1990.

The IPCC has developed 15 global climate models (GCMs) which provide daily rainfall and evapotranspiration data suitable for planning purposes. Studies have not yet reached a consensus on which GCMs are likely to provide reliable future climate projections so planning is best carried out using a wide range of archived GCM simulations. The NSW Guidelines on Assuring Future Urban Water Security for use by the NSW local water utilities uses all the 15 GCMs with daily data.

Water Supply Security

Restriction-free urban water supplies at all times are generally neither affordable nor cost-effective so utilities generally need to allow for some level of water restrictions in dry periods in their water supply planning. The NSW Security of Supply methodology, known as the 5/10/20 design rule, was developed in the 1980s to assist local water utilities to effectively size their water supply headworks systems. It has in the main been used by local water utilities across NSW since that time. A study of the performance of water supply systems during the recent severe drought identified that the systems that were designed and operated in accordance with this 5/10/20 design rule performed well during the drought, thus confirming the robustness of this design rule.
The 5/10/20 design rule requires storages to be sized so as to ensure that full unrestricted demands can be supplied in wet, average and shorter dry periods but that moderate duration, frequency and severity of water restrictions will be required in extended drought periods. Under this design rule, the total time spent in drought restrictions should be no more that 5% of the time, restrictions should not need to be applied in more than 10% of years and when they are applied the water supply system should be able to provide 80% of the unrestricted dry year water demand (ie. 20% reduction in demand) through a repetition of the worst recorded drought commencing at the time restrictions are introduced. This methodology approximates the severity of a "1 in 1,000 year" drought.

Over the last 21 years there has been a 53% reduction in the average residential water use per property (Reference 1 on page 20). Accordingly, further average savings of 20% by introduction of water restrictions during droughts now involve a more significant impact on residents, business and local amenity. These guidelines have therefore adopted a ‘5/10/10’ design rule which requires water security planning on the basis of an average reduction of 10% in water usage during restrictions rather than the former 20%. Note that with significant draw downs of a utility’s storages in future droughts, the utility will need to implement progressively more stringent restrictions in accordance with the utility’s drought management plan¹.

Secure yield is defined as the highest annual water demand that can be supplied from a water supply headworks system whilst meeting the 5/10/10 design rule. The secure yield can be increased by providing larger storages, more water sources, increased transfer capacities or a combination of all three.

Water security is achieved if the secure yield of a water supply is at least equal to the unrestricted dry year annual demand.

Pilot Study

Recognising that the impact of variable climatic patterns was a risk that needed to be addressed by each NSW local water utility in its IWCM planning, the NSW Office of Water engaged NSW Public Works to conduct a pilot study to determine the potential impact of variable climatic patterns on 11 local water utility water supply systems in regional NSW. The key results are shown in Appendix D on page 14.

The pilot study, which used 0.9ºC global warming by ~ 2030, the 15 global climate models and the NSW Database of Future Climate Projections (Reference 2 on page 20) found that variable climatic patterns do pose a potential threat to local water utilities’ security of supply.

The pilot study found that future secure yield under the methodology proposed in these guidelines, is reduced by up to 9% for coastal utilities and by approximately 30% for inland water utilities in mid and southern NSW (Figure 3 on page 15).

¹ It is noted that the NSW Security of Supply methodology involves a design rule for the robust sizing of water supply headworks systems for long term planning purposes. It also enables evaluation and comparison of headworks options on a common basis. Refer also to ‘Managing a Water Supply During a Drought’ on page 18.
Methodology

The methodology in these guidelines enables local water utilities to estimate their future secure yield taking into account the expected impact of variable climatic patterns. It applies to all NSW local water utilities relying on a storage dam, weir, run-of-river or shallow bore supply.

NSW local water utilities with such water sources will need to assess the impact of variable climatic patterns on the future secure yield of their water supply headworks systems in accordance with these guidelines. As noted above, such secure yield assessments will form an integral part of the utility’s IWCM Strategy.

As the expected impact of variable climatic patterns on the future secure yield of inland systems relying on a storage dam, weir, run-of-river or shallow bore supply in mid and southern NSW is significant, local water utilities in these areas should move to assess their future secure yield in accordance with these guidelines as soon as practicable. Similarly, coastal utilities and inland utilities in northern NSW whose water supply headworks systems experienced stress in the recent drought and which have not undertaken significant augmentation works should now assess their future secure yield in accordance with these guidelines. Accordingly, the utilities listed in Appendix A should move to assess their future secure yield in accordance with these guidelines as soon as practicable.

The other utilities need not take any action on these guidelines until their IWCM strategy is due for revision.

It is important to note that a utility will normally need to carry out its future secure yield analysis in accordance with these guidelines before it proceeds to develop its IWCM strategy. Depending on the future secure yield results obtained, some of the utilities in Appendix A may find that further action on the utility’s IWCM strategy and water supply headworks can be deferred until the IWCM strategy is due for review.

Most NSW local water utilities with a surface water supply system have a system simulation model and a locally calibrated rainfall-runoff model with over 100 years of daily historical streamflow data, including observed data that has provided an estimate of the secure yield for the current water supply system based on the 5/10/10 design rule or the previous 5/10/20 design rule. Using the services of a specialist hydrologist (see page 5), the utility should extend the observed historical daily flow sequence to the analysis date and determine the secure yield of the existing headworks system based on the 5/10/10 design rule. The utility should then use the locally calibrated rainfall-runoff model to estimate daily streamflows for each GCM and for the historical data provided with the GCM data. It should then use the current system simulation model to determine the secure yield for each of the 15 GCMs, as well as for the above historical data on the basis of the 5/10/10 design rule.

Whilst the 15 GCMs represent a range of plausible climate futures for around the year 2030, there is some uncertainty which needs to be acknowledged when considering the full range of possible outcomes. Risk management dictates analysis with all 15 GCMs.

The NSW Office of Water therefore recommends that a utility should obtain the secure yield for all 15 GCMs under the 5/10/10 design rule for its preferred scenario in the IWCM strategy. It should also obtain the secure yield for the GCM with the lowest yield for a more severe restriction regime, a 10/15/25 design rule is suggested. The critical results are for:
(1) GCM with the median secure yield under the 5/10/10 design rule
(2) GCM with the lowest secure yield under the 5/10/10 design rule
(3) GCM with the lowest secure yield under the 10/15/25 design rule.

The NSW Office of Water recommends that a utility’s planning should take account of the results for all 15 GCMs on the following basis. This involves an adaptive management plan endorsed by the community to cope with the GCM with the lowest secure yield which considers:

- adopting a capital works program based on the GCM with the lowest secure yield under the 5/10/10 design rule if the additional capital cost above that incurred for the GCM with the median secure yield is affordable. A solution based on this rationale will satisfy the utility’s projected demand for 30 years or longer if the future climate and water security is better than projected by the lowest GCM.
- adopting a capital works program based on the GCM with the lowest secure yield under the 10/15/25 design rule if the additional capital cost above that incurred for the GCM with the median secure yield under the 5/10/10 design rule is acceptable. In a number of instances, the GCM with the lowest secure yield under the 10/15/25 design rule, albeit with relatively harsh water restrictions to cope with the reduced availability of water, provides a higher secure yield than the GCM with the median secure yield under the 5/10/10 design rule. In such circumstances, the GCM with the median secure yield should be adopted.
- adopting a capital works program based on the GCM with the median secure yield if the additional cost to move to the GCM with the lowest secure yield is not acceptable. A solution based on this rationale will satisfy the utility’s projected demand for 30 years or longer but will require more frequent and severe water restrictions if water security is worse than projected for the median GCM. However, the utility would then need to assess the impact of more severe drought water restrictions on the community and would also need to document how it would cope in the event of occurrence of a future drought of similar severity to those postulated by the lowest GCM.
- reassessing the timing of the required works as further research provides better information reducing some of the uncertainties which may enable some works to be deferred or advanced.

In summary, the NSW Office of Water recommends that utility planning for future water security should be on the following basis where practicable:

(a) Where affordable – the GCM with lowest secure yield under 5/10/10 design rule, otherwise,
(b) Lesser of: – GCM with median secure yield under 5/10/10 design rule; and
      – GCM with lowest secure yield under 10/15/25 design rule.

By comparing the results under (a) and (b) above with the result for the historical data provided with the GCM data, the adopted percentage change to the future secure yield can be determined, as shown in column (9) of Table 1 on page 14. The utility can then determine its best estimate of future secure yield by applying this percentage change to the utility’s secure yield using observed historical data, as shown in Item I of the worked example in Appendix E on page 16.

By considering the results of all 15 GCMs, the recommended approach to planning for water security is consistent with the views of Bates and Gleick (References 5 and 6 on page 20) that “there is a need to adopt an adaptive approach to water management that confronts uncertainty by considering a wider range of climate conditions than those captured by the historical record”.
It is important to note that the cost-effective staging of the construction of any capital works is an integral part of the IWCM strategy development process which requires careful consideration for each solution under the GCM with the median secure yield and the GCM with the lowest secure yield. Capital expenditure should be routinely deferred to the latest suitable date in order to minimize the economic cost and the impact on the typical residential bill. An advantage of staging is that it enables the utility to make use of the latest available information and climate research when determining future stages of its system.

The NSW Office of Water is aware that several utilities achieved a 35% reduction in usage during the 2001-2010 drought. However this required very severe water restrictions which had a substantial adverse impact on the local economy and social amenity. It is therefore recommended that a utility should not plan for a high severity of water restrictions unless it has demonstrable support from its community.

Accordingly, the NSW Office of Water suggests that an average 25% reduction in usage be the upper limit considered by a utility for planning purposes. The 25% severity for water restrictions under the GCM with the lowest secure yield is considered to be acceptable in view of the relative uncertainty associated with the occurrence of such a GCM. However, ultimately each utility in conjunction with its community must decide whether it wishes to plan on a lower or higher level of restrictions than those under the 10/15/25 design rule.

The above approach is considered to provide a reasonable balance between avoiding excessive capital expenditure by the utilities and avoiding very harsh future drought water restrictions. This approach minimises the risk of over capitalisation, through deferral of capital works until they are required and by the cost-effective staging of capital works.

Whilst a utility and its community would have flexibility in providing an appropriate level of future water supply security, a sufficient level of security must nevertheless be provided. If a utility and its community consider it to be cost-effective to provide a higher level of security than described above and are willing to pay for that security, no objection would be raised by the NSW Office of Water. However if a utility wishes to adopt a lower level of security, the NSW Office of Water would expect the utility to demonstrate community support, but would not accept extreme restrictions that did not at least meet minimum human needs (approximately 110 kL/a per house).

Section 60 Approval

A NSW local water utility carrying out a future secure yield analysis will need to select a suitable specialist hydrological consultant, obtain NSW Office of Water approval to the selected consultant (Appendix B), and then undertake the required future secure yield analysis for the utility’s existing water supply systems and for its key augmentation option and obtain Section 60 NSW Office of Water approval to its analysis. The utility may then carry out any further secure yield analyses required for other scenarios in its IWCM Strategy using the same methodology. The utility may also carry out additional analysis it considers to be warranted.

The above processes aim to provide assurance to the local water utility, its community and the NSW Government that the secure yield analyses carried out are robust and fit for purpose. The independent review by the NSW Office of Water as part of its Section 60 approval provides the necessary assurance that a utility’s analyses for determining future secure yields are soundly based in accordance with these guidelines.
Assumptions and Uncertainties

There are a number of assumptions and uncertainties involved in determining future water security, including:

- There is an intrinsic level of uncertainty in the projections due in part to a number of socio-economic assumptions with regard to the climate system and other natural and human related influences.

- Whilst the IPCC has developed 40 emissions scenarios there is little difference in the projections for ~2030 and the A1B medium emission scenario has been adopted for the pilot study.

- Global climate models (GCM’s) are generally attributed as having a large source of uncertainty. However, there is currently no consensus on which models perform best so the NSW methodology makes use of all the available 15 GCMs with daily data in order to represent a range of plausible climate futures. CSIRO recommends that “For now, the uncertainty and the range of future runoff in impact studies are probably best determined using future climate projections from a large range of archived GCM simulations.”

- Due to the coarse spatial resolution of GCM’s, downscaling is required to determine impacts at a regional or local scale. CSIRO has provided downscaled daily data using a perturbation approach as used for the Murray Darling Sustainable Yields project and recently adopted for use in Victoria. Concerns are sometimes raised that this ‘scaling method’ does not result in sufficient drought persistence for severe droughts. It is agreed that this is the case for the ‘number of rainfall days in any year’ and that fewer rainfall days may result in reduced streamflows and secure yields. However, the pilot study has shown that many GCMs have produced a smaller ‘number of streamflow days’, reduced streamflow volumes and reduced secure yields in comparison with the historical dataset. The concern on the impact of fewer rainfall days is somewhat accounted for in the 5/10/10 approach which considers a drought significantly longer than the historical drought. (Figure 1 and Figure 2 on page 11).

- Rainfall-runoff hydrological models often assume that calibrated parameters based on historical climate hold for changed climate conditions and that water use efficiency of vegetation will remain constant despite variable climatic patterns. Land use changes are also often ignored.

- Water sharing plans and environmental flow requirements have not been finalised in various locations. The utility should consult with the NSW Office of Water to identify appropriate water sharing rules for use in its system simulations.

- Uncertainty about population projections contributes to the uncertainty in urban water demand projections. Guidance on population growth is available in Department of Planning and Infrastructure regional population projections and guidance on estimating future water demand is available on the NSW Office of Water website (www.water.nsw.gov.au IWCM, Strategic Business Planning) and in Circulars LWU 11 and LWU15.

Using these Guidelines

These guidelines provide:

- A list of the utilities which now need to move to assess their future secure yield in accordance with these guidelines as soon as practicable (Appendix A),

- A consultant approval form setting out requirements for the specialist hydrological consultant for carrying out a utility’s future secure yield analysis (Appendix B),
• Technical details on the NSW Security of Supply methodology (Appendix C),
• The key results of the pilot study (Appendix D),
• A worked example to assist utilities in determining the future secure yield (Appendix E),
• Other considerations such as requirements for drought management plans and the need to use
  a locally calibrated daily rainfall-run off model to calculate daily streamflows for each GCM
  (Appendix F),
• References (Appendix G),
• A paper on the pilot study presented to the Institution of Engineers Australia’s *Practical
  Responses to Climate Change* National Conference (October 2010) (Appendix H).

Climate research is ongoing and dynamic and is being continually updated and improved. The South
Eastern Australia Climate Initiative (SEACI) has now published a synthesis of findings from Phase 2 of
its research (Reference 7 on page 20). SEACI Theme 2 of Phase 2 has recently provided the NSW
Office of Water with improved climate data projections for 1.0°C global warming. The SEACI Theme 2
projections\(^2\) use improved seasonal scaling factors derived from the period 2001-2100, rather than the
period 1896-2100 previously used for the SEACI Phase 1 projections. The SEACI Phase 1 projections
involve 0.9°C warming and were used in the pilot study and for the Murray Darling Sustainable Yields
project which provided the bulk of the data for Reference 2 on page 20. The *Guidelines on Assuring
Future Urban Water Security* require use of the SEACI Theme 2 data for 1.0°C warming for any new
urban water security studies as it is now the best available data set. This data is available from the
NSW Office of Water.

It is noted that a NSW and ACT Regional Climate Model (NARCLiM) is being developed which will
provide additional climate projections for NSW and ACT using advanced analytical techniques,
including dynamic and statistical downscaling of climate data. NARCLiM is developing a total of
12 projections on the basis of 4 global climate models and 3 regional climate models. This work is
expected to be completed in late 2014. The NSW Office of Water proposes to undertake a follow up
pilot study using the new NARCLiM data in order to assess its suitability for future urban water security
analysis.

As the science of climatic research is evolving rapidly these guidelines will be updated as required in
order to continue to make best use of the available insights and information.

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\(^2\) Note that comparison of a number of rainfall and future secure yield projections for the 1.0°C SEACI Theme 2
data set with those for the 0.9°C SEACI Phase 1 data set has indicated that the SEACI Theme 2 results were
significantly lower than those for SEACI Phase 1.
Utilities which Need To Assess their Secure Yield in Accordance with these Guidelines

The following utilities rely on a storage dam, weir, run-of-river or shallow bore supply and are located in inland mid and southern NSW.

Bathurst Regional Council  
Boorowa Council  
Cabonne Council  
Carrathool Shire Council  
Central Tablelands Water  
Cooma-Monaro Shire Council  
Fish River Water Supply  
Orange City Council  
Tumbarumba Shire Council  
Upper Lachlan Shire Council

The following utilities rely on a storage dam, weir, run-of-river or shallow bore supply and are located in inland northern NSW and coastal NSW. These utilities experienced significant stress in the recent severe drought and have not undertaken major augmentation works.

Bourke Shire Council  
Brewarrina Shire Council  
Central Darling Shire Council  
Cobar Shire Council/Cobar Water Board/Bogan Shire Council  
Essential Energy  
Glen Innes Severn Council  
Mid-Western Regional Council  
Narromine Shire Council  
Parkes Shire Council  
Rous County Council  
Tamworth Regional Council  
Tenterfield Shire Council  
Walgett Shire Council
# NSW SPECIALIST HYDROLOGICAL CONSULTANT³ APPROVAL FORM

## FOR FUTURE⁴ SECURE YIELD ANALYSIS

<table>
<thead>
<tr>
<th>Utility Name:</th>
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<tbody>
<tr>
<td>Utility’s Project Manager:</td>
<td>Name:</td>
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<td>Phone/Mobile:</td>
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<td>Email:</td>
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### Proposed Specialist Hydrological Consultant:

<table>
<thead>
<tr>
<th>Name:</th>
<th>Phone/Mobile:</th>
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<tbody>
<tr>
<td>Email:</td>
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- **Hydrology Team Leader:**
- **Hydrology Team Members:**
  - (Please attach brief resumes)

### Upper Limit Fee for Secure Yield Analysis of:

- **(a) Existing system and preferred future option**
- **(b) Other IWCM scenarios required**

### Does the proposed specialist Hydrological consultant have extensive experience in:

- Daily rainfall/runoff modelling (Yes/No)? Provide evidence.
- Simulation of storage behaviour to successfully determine the secure yield for urban water supplies (Yes/No)? Provide evidence.

### Does the proposed Hydrological consultant have adequate insurance coverage (Yes/No)?

### The following to be completed by NSW Office of Water

**Confirmation:** Specialist hydrological consultant has the necessary experience and the proposal involves analysis in accordance with pages 3 to 7, 11 and 19 of the Guidelines (Yes/No)?

- **Hydrological consultant approved by NSW Office of Water**
  - Name: |
  - Date: |

---

³ As urban secure yield analysis is a highly specialised area, it is essential that the consultant proposed by Council is a specialist with extensive experience in this area and has comprehensive understanding of the NSW Security of Supply methodology.

A copy of the proposal from the specialist Hydrological consultant must be provided with this form. The proposal must involve analysis in accordance with pages 3 to 7, 11 and 19 of the Guidelines on Assuring Future Urban Water Security.

⁴ Utility to nominate the approximate number of other IWCM scenarios to be analysed. For each scenario, a functional layout and the key components need to be identified by the utility.
The NSW Security of Supply Methodology

Restriction-free urban water supplies at all times are neither affordable nor cost-effective and an appropriate security of supply methodology is needed for sizing of water supply headworks systems.

The NSW Security of Supply methodology (References 8, 9 and 10 on page 20) was developed in the 1980s as a result of the lessons learnt from the severe 1978-83 drought in order to enable the regional NSW water utilities to size their water supply headworks systems on a sound, robust and cost-effective basis. Commonly referred to as the ‘5/10/20 design rule’, it has been replaced by the ‘5/10/10 design rule’ due to the 53% reduction in average annual residential water supplied per property since 1991 (Reference 1 on page 20). The design rule was designed to ensure that full demand can be met in wet, average and most dry years, with only water restrictions of moderate duration, frequency and severity required to ensure continuity of the water supply during extended drought periods as shown in Figures 1 and 2 on page 11. As it can cope with effectively a ‘1 in 1,000 year’ drought (Reference 3 on page 20), it is sufficiently robust to maintain continuity of supply in significantly more severe future droughts than have occurred in the last 120 years, albeit with a higher level of drought water restrictions.

**NSW Security of Supply methodology** - under the 5/10/10 design rule, water supply headworks systems are normally sized so that:

a) Time spent in restrictions does not exceed 5% of the time (5% duration – Figure 1) and

b) Restrictions should not need to be applied in more than 10% of years (10% frequency – Figure 1) and

c) The severity of restrictions does not exceed 10%. Systems must be able to meet 90% of the unrestricted dry year water demand (ie. 10% average reduction in consumption due to water restrictions) through simulation of the worst recorded drought (Figure 2), commencing at the time restrictions are introduced [ie. with a commencing storage volume equal to the restriction volume C in Figures 1 and 2].

This enables the utilities to operate their systems without restrictions until the volume of stored water approaches the restriction volume C which is typically about 65% of the storage capacity – refer to Figure 1). If at this trigger volume, the utility imposes drought water restrictions which reduce demand by an average of 10%, the system would be able to cope with a repeat of the worst recorded drought, commencing at that time, without emptying the storage, as shown in Figure 2.

‘Secure yield’ is defined as the highest annual water demand that can be supplied from a water supply headworks system while meeting the 5/10/10 design rule.

Water security is achieved if the secure yield of a water supply is at least equal to the unrestricted dry year annual demand.

The robustness of the NSW Security of Supply methodology has been demonstrated in Reference 3 on page 20, which showed that for the 10 NSW urban water supplies studied, the very severe 2001 to 2007 drought resulted in a reduction in the secure yield of up to 7% for 7 of the water supplies and a reduction of about 15% for the other 3 supplies.
Figure 1 Duration & Frequency of Restrictions

RESTRICTION VOLUME "C" IS THE VOLUME WHICH HAS FREQUENCY OF RESTRICTIONS < 10% OF YEARS AND DURATION OF RESTRICTIONS < 5% OF TIME. "S" IS THE FULL STORAGE CAPACITY (8,200 ML).

Figure 2 Severity of Restrictions

RESTRICTION VOLUME

Note:
Figure 2 shows the simulated storage behaviour for the worst drought identified in Figure 1 (approximately 5 years from January 1939 to December 1943) while supplying 90% of the unrestricted dry year demand, with a commencing storage volume equal to the restriction volume C (5,400 ML).
Box 1 – Why do we need both Figure 1 and Figure 2

**Figure 1** shows the results of simulating an example utility’s storage behavior for 120 years of observed historical daily streamflow, rainfall and evaporation data and shows that:

- Unrestricted water demand can be supplied for over 95% of the time and over 90% of years (i.e. whenever the storage volume is above the *restriction volume C*). In order to satisfy the 5/10/10 design rule, restrictions must be imposed whenever the volume of water in storage falls below the *restriction volume C*.
- A 10% reduction in demand is applied when the storage falls below *restriction volume C*
- The **worst historical drought** shown in Figure 1 is for approximately a *5-year* period from January 1939 to December 1943
- The minimum simulated usable storage volume is approximately 30% of the full storage capacity.

**Figure 2** shows the results of simulating storage behaviour for the worst drought identified in Figure 1 (5-year drought from January 1939 to December 1943) on the following basis:

- A 10% reduction to the unrestricted dry year water demand for the full 5-year drought as the storage volume is below the *Restriction volume C*
- The commencing storage volume for this simulation is the *restriction volume C* and the resulting minimum simulated usable storage volume is approximately 2% of the full storage capacity.

**Comment**

As noted on page 10, imposition of the requirements of the 5/10/10 design rule approximates the severity of a ‘1 in 1000 year’ drought and is necessary in order to enable a utility to manage its system in a drought of similar severity to the worst drought in the 120 year historical record, with only moderate drought water restrictions.

As the first year of the worst drought for this example utility is simulated in **both Figure 1 and Figure 2**, the water supply system must be able to **cope with effectively a 6-year drought**, rather than the 5-year worst historical drought in Figure 1.

It is important to note that the analytical process for the 5/10/10 design rule is iterative and that a solution is identified only when all the 3 requirements have been met.

Under the ‘5/10/10 design rule’, a water utility would be able to cope with a drought more severe than had occurred in the past 120 years with only moderate drought water restrictions. Restrictions would apply for no more than 5% of the time or 10% of years (Figure 1 on page 11). Severity of restrictions would be 10%, with 90% of the unrestricted dry year water demand supplied through a repetition of the worst recorded drought (Figure 2 on page 11). Similarly, only moderate drought water restrictions would be required to cope with the GCM with the median secure yield. Greater restrictions would be required to cope with the GCM with the lowest secure yield.

In its recent report on Australia’s Urban Water Sector (Reference 11 on page 20) the Productivity Commission has recommended increasing water security so that water restrictions are limited to emergencies and are of short duration. The NSW Office of Water considers that adoption of this
recommendation would not provide value for money for many utilities and recommends that NSW local water utilities and their communities should continue to aim to meet the above ‘5/10/10 design rule’. Utilities may wish to consider whether it is cost-effective for them to provide a higher level of security on a case-by-case basis.

Significant water restrictions during drought have social, environmental and economic impacts, including loss of amenity and adverse impacts on the local economy. Planning for a higher level of restrictions should therefore be avoided as far as possible. For example the Productivity Commission has estimated the welfare cost of water restrictions to Australian households in 2008 at about $900 million. In addition, the total welfare cost of Stage 4 water restrictions for the ACT was estimated at $290 million/a (Reference 11 on page 20).

Accordingly, as noted on page 4, the NSW Office of Water recommends that utility planning for future water security should be on the following basis where practicable:

(a) Where affordable – the GCM with lowest secure yield under the 5/10/10 design rule, otherwise,

(b) Lesser of: – GCM with median secure yield under the 5/10/10 design rule; and
– GCM with lowest secure yield under the 10/15/25 design rule.
Key Results of Pilot Study

The key results of the pilot study reported in References 12 and 13 on page 20 are shown in Table 1 below and Figure 3 on page 15. The final column of Table 1 and Figure 3 show the adopted % change in ~ 2030 Secure Yield for each utility in the pilot study.

In the worked example in Appendix E on page 16, the adopted % change in ~ 2030 Secure Yield is shown in Item G of Table 2.

Table 1: Comparison of Secure Yield Estimates (111 years of data from 1896 to 2006)

<table>
<thead>
<tr>
<th>Water Utility</th>
<th>Estimated Secure Yield (ML/a)</th>
<th>% Change in Secure Yield From Historical Data Set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Historical Data Set for 5/10/10 rule</td>
<td>Median of 15 Global Climate Models (GCMs) for 5/10/10 rule</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>1</td>
<td>21,500</td>
<td>20,000 [14]</td>
</tr>
<tr>
<td>2</td>
<td>3,400</td>
<td>3,500 [1]</td>
</tr>
<tr>
<td>3</td>
<td>12,400</td>
<td>12,200 [1]</td>
</tr>
<tr>
<td>4</td>
<td>7,700</td>
<td>7,200 [13]</td>
</tr>
<tr>
<td>5</td>
<td>5,200</td>
<td>4,900 [4]</td>
</tr>
<tr>
<td>6</td>
<td>495</td>
<td>450 [12]</td>
</tr>
<tr>
<td>7</td>
<td>4,850</td>
<td>4,150 [4]</td>
</tr>
<tr>
<td>8</td>
<td>3,600</td>
<td>3,600 [8]</td>
</tr>
</tbody>
</table>

Comment

Table 1 and Figure 3 show that for the 7 coastal utilities examined, the maximum reduction in secure yield at ~ 2030 was 9% (median reduction of 6%; range from a 3% increase to a 9% reduction).

However, Table 1 and Figure 3 show that for the 3 inland utilities examined in mid and southern NSW, the typical reduction in secure yield at ~ 2030 was almost 30%.

Each NSW local water utility will need to assess the impact of variable climatic patterns on the future secure yield of its water supply system in accordance with these guidelines. Such secure yield assessments will form an integral part of the utility’s IWCM Strategy (Reference 14 on page 20), which is a key element of the NSW Best-Practice Management of Water Supply and Sewerage Framework (Reference 15 on page 20).
Figure 3: Map of NSW showing adopted % change in ~Year 2030 Secure Yield for each utility in the pilot study

Note:
For Utility 9, the changes in secure yield for the existing small storage dam and for the proposed enlargement of the dam were -50% and -29% respectively.
A worked example to determine future secure yield

The following worked example in Table 2 below has been prepared to assist local water utilities in determining the future secure yield (based on 0.9ºC warming and the SEACI Phase 1 data). It is based on the results for Utility 5 in the pilot study (References 12 and 13 on page 20). The results shown are from Tables 7, 8 and B3 of Reference 12 on page 20.

**Table 2 – Determination of Best Estimate of Future Secure Yield**
*(based on Utility 5 in pilot study)*

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Data Set</th>
<th>Estimated Secure Yield (ML/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Historical Data from NSW Database based on 5/10/10 design rule</td>
<td>5,200 [Table 1 col 2 on page 14]</td>
</tr>
<tr>
<td>B</td>
<td>15 GCMs based on 5/10/10 design rule</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GCM1</td>
<td>5,400</td>
</tr>
<tr>
<td></td>
<td>GCM2</td>
<td>5,100</td>
</tr>
<tr>
<td></td>
<td>GCM3</td>
<td>4,800</td>
</tr>
<tr>
<td></td>
<td>GCM4</td>
<td>4,900 (median secure yield)</td>
</tr>
<tr>
<td></td>
<td>GCM5</td>
<td>4,900</td>
</tr>
<tr>
<td></td>
<td>GCM6</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>GCM7</td>
<td>4,900</td>
</tr>
<tr>
<td></td>
<td>GCM8</td>
<td>4,900</td>
</tr>
<tr>
<td></td>
<td>GCM9</td>
<td>4,500 (lowest secure yield)</td>
</tr>
<tr>
<td></td>
<td>GCM10</td>
<td>4,900</td>
</tr>
<tr>
<td></td>
<td>GCM11</td>
<td>5,300</td>
</tr>
<tr>
<td></td>
<td>GCM12</td>
<td>4,800</td>
</tr>
<tr>
<td></td>
<td>GCM13</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>GCM14</td>
<td>5,100</td>
</tr>
<tr>
<td></td>
<td>GCM15</td>
<td>5,000</td>
</tr>
<tr>
<td>C</td>
<td>Median of 15 GCMs [GCM 4] based on 5/10/10 design rule</td>
<td>4,900 [Table 1 col 3 on page 14]</td>
</tr>
<tr>
<td>D</td>
<td>Lowest GCM [GCM 9] based on 5/10/10 design rule</td>
<td>4,500 [Table 1 col 4 on page 14]</td>
</tr>
<tr>
<td>E</td>
<td>Lowest GCM [GCM 9] based on 10/15/25 design rule</td>
<td>4,800 [Table 1 col 5 on page 14]</td>
</tr>
<tr>
<td>F</td>
<td>Lesser of C and E</td>
<td>4,800</td>
</tr>
<tr>
<td>G</td>
<td>Adopted % Change in Secure Yield [F] versus [A] above</td>
<td>[(4,800 – 5,200)/5,200] x 100 = - 8%</td>
</tr>
<tr>
<td>H</td>
<td>Secure Yield using Observed Historical Data based on 5/10/10 design rule</td>
<td>5,420 [from Table B3 col 3 of Reference 12]</td>
</tr>
<tr>
<td>I</td>
<td>Best Estimate of Future Secure Yield [H] x [100% + G]</td>
<td>(5,420) x (100% - 8%) = 5,000 [also shown in Table B3 col 5 of Reference 12]</td>
</tr>
</tbody>
</table>

5 As noted on page 7, the SEACI Theme 2 data for 1.0ºC warming is now the best available data set and must be used for any new urban water security studies for regional NSW.
The secure yield using the observed historical data for Utility 5 on the basis of the 5/10/10 design rule is 5,420 ML/a (Item H of Table 2), which has been determined using estimated daily streamflow data for the period 1890 to 2007, and which includes ‘observed streamflows’ for the period 1992 to 2007. Each utility’s secure yield using observed historical data should include analysis of any available observed streamflows.

The historical secure yield from the NSW database at Reference 2 on page 20 is 5,200 ML/a (Item A of Table 2).

As noted on page 4, the future secure yield may be determined as either (2) below or the lesser of (1) and (3) below:

1. GCM with the median secure yield under the 5/10/10 design rule = 4,900 ML/a
2. GCM with the lowest secure yield under the 5/10/10 design rule = 4,500 ML/a
3. GCM with the lowest secure yield under the 10/15/25 design rule = 4,800 ML/a

On the basis of the 5/10/10 design rule, secure yield for the 15 GCMs for Utility 5 ranged from 4,500 to 5,400 ML/a (Item B of Table 2), with a median value of 4,900 ML/a (Item C of Table 2).

Under the 10/15/25 design rule, the secure yield for Utility 5 for the lowest GCM is 4,800 ML/a (Item E of Table 2). As this is less than the median secure yield of 4,900 ML/a, it is used to determine the future secure yield (0.9°C warming) in this example from the analysis of GCMs (Item F of Table 2).

The adopted percentage change in secure yield for Utility 5 is an 8% reduction (Item G of Table 2) in comparison with the historical secure yield from the NSW database (Item A of Table 2).

Therefore the Best Estimate of Future Secure Yield for Utility 5 is 5,000 ML/a (Item I of Table 2), which involves an 8% reduction to the secure yield of 5,420 ML/a for the observed historical data on the basis of the 5/10/10 design rule (Item H of Table 2).
Other considerations

Utilities relying on deep groundwater bores

Utilities relying on deep groundwater bores should consult with the NSW Office of Water on the impact of variable climatic patterns on their secure yield. Further information is available under the National Water Commission’s Raising National Water Standards Program, which is investigating the impact of variable climatic patterns on groundwater resources.

Utilities relying on a State Water Dam

Utilities relying on a State Water Dam cannot independently determine the impact of variable climatic patterns on their water supply security and should consult with the NSW Office of Water on their likely future water allocations.

In addition, such utilities may wish to examine the merits of purchasing additional water entitlements or constructing a local off-stream storage in order to increase their drought water security. In addition to increasing the utility’s water security, such a storage and entitlements may enable the utility to supply new industrial water demands.

Managing a Water Supply during a Drought

As noted in section 1.2 of Reference 3 on page 20, in managing a water supply during a drought (unlike at the investigation stage, where historical or estimated streamflows are known) the operating water utility needs to make decisions on whether to apply restrictions without knowledge of future inflows to its system. To make these decisions the utility may carry out probabilistic or stochastic analysis to estimate the likelihood of various inflow sequences and the future storage which would result with these inflows and various restriction policies. The utility therefore needs to consider trade-offs between the imposition of harsh restrictions which, in the future may be found not to have been necessary, and risking the failure of its water supply if insufficient restrictions are applied.

As noted on page 12, under the ‘5/10/10 design rule’, a water utility would be able to cope with a drought more severe than had occurred in the past 120 years and with the GCM with the median secure yield with only moderate drought water restrictions. As also noted, greater restrictions would be required to cope with the GCM with the lowest secure yield.

An example drought storage behaviour analysis which could be undertaken by a utility with a significant storage volume, as it operates its system through a moderate to severe drought is shown in Figure B2 in Appendix B of Reference 10 on page 20. Such drought storage behaviour analysis would inform the utility whether or not the adopted operating strategy in its drought management plan (see below) continues to be satisfactory. During future severe droughts, the utility could regularly undertake and update such drought storage behaviour analysis, which would enable the utility to estimate its minimum likely reserve storage volume for a number of low inflow sequences from the utility’s over 100 years of observed historical streamflow data (including the minimum drought inflow for the utility’s system). Similar drought storage behaviour analysis could also be undertaken for say the GCM with the median secure yield and for the GCM with the lowest secure yield.

Drought Management Plans

As noted in Appendix D of page 65 of Reference 4 on page 20, each utility needs to prepare and implement a drought management plan which includes a schedule of trigger points for the timely implementation of appropriate drought water restrictions. Town water supplies with significant storage, which have been sized using the 5/10/10 design rule and which have a sound drought management plan can be managed by the water utility so as to not fail in a future drought considerably more severe than the worst historical drought and the worst drought for the GCM with the lowest secure yield. Refer also to the drought storage behaviour analysis above.

Refer also to Footnote 1 on page 2
Local water utilities are reminded that the General Manager of each utility is responsible for the timely implementation of the strategies in its approved drought management plan, including:

- Implementation of supplementary water sources during a drought.
- Implementation of water restrictions during drought in accordance with the schedule of trigger points in the utility’s drought management plan in order to minimise the risk of failure of the water supply in times of drought.

Timely action on the above basis is a priority issue for each local water utility.

Additional Analyses

Providing it has undertaken the analysis set out in these guidelines, a utility may elect to carry out additional secure yield analyses it considers to be warranted. Such analysis may include stochastic data generation and analysis. The NSW Office of Water does not have a requirement for such additional analysis as it considers the requirements set out in these guidelines are sufficient to provide a sound, robust and cost-effective solution for a utility’s future secure yield.

With regard to utilities wishing to carry out annual stochastic analysis, utilities are advised that such analysis may be too coarse to provide meaningful results for many urban water supplies in regional NSW, where the duration of the worst drought is often less than 18 months. In addition, as such analyses effectively assume that streamflows occur uniformly during each year, they may be highly misleading by greatly overestimating the utility’s secure yield.

Daily Streamflow Data

Each utility needs to use its locally calibrated daily rainfall-runoff model, which was used to establish its over 100 years of historical daily streamflows for its systems, for calculating daily streamflows on the basis of the daily rainfall and potential evapotranspiration projections for the 15 GCMs and for the associated historical data.

The analysis carried out in the pilot study has demonstrated that use of generalised streamflow estimates is not appropriate for urban water security analysis. Utilities must therefore not use generalised streamflow data for their water security analysis as it is unsuitable for this purpose.
APPENDIX G

NSW Guidelines on Assuring Future Urban Water Security

References


Note:
An electronic copy of References 3, 8, 9 and 10 above is available from the NSW Office of Water on request (Haddie Man: 8281 7435, haddie.man@water.nsw.gov.au).
**NSW Response for Addressing the Impact of Climate Change on the Water Supply Security of Country Towns**

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   Sydney, NSW 2000
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**Abstract**

Under the NSW Government’s *Best-Practice Management of Water Supply and Sewerage Guidelines*, local water utilities in non-metropolitan NSW are required to prepare and implement a comprehensive 30-year integrated water cycle management (IWCM) strategy. The IWCM strategy is prepared for the utility’s water supply, sewerage and stormwater businesses, including the water supply headworks, and is effectively a 30-year rolling strategy, which must be reviewed and updated by each utility every 6 years.

For the past 25 years most urban water supply headworks in country NSW have been sized on a robust Security of Supply basis. This security of supply basis has been designed to cost-effectively provide sufficient dam storage capacity to allow the water utility to effectively manage its water supply in future droughts of greater severity than experienced over the past 100 or more years. ‘Secure Yield’ is the water demand that can be expected to be supplied with only moderate water restrictions during a significantly more severe drought than had been experienced historically. The required water restrictions must not be too severe, not too frequent, nor of excessive duration. Recent analysis for the severe 2001-2007 drought has confirmed the continuing robustness of the NSW Security of Supply basis.

To understand the potential impact of climate change on the security of urban water supplies, results are presented from a pilot study for 11 non-metropolitan NSW water supplies utilising 112 years of downscaled daily hydrometeorological data from 15 global climate models for climate change projections for the year 2030 using the A1B medium warming emissions scenario. This analysis enabled determination of the impact of climate change on the Year 2030 secure yield for each water supply.

Future 30-year IWCM strategies in NSW will need to include assessment of the secure yield of the utility’s water supply in accordance with the analysis reported for the pilot study. Implementation of these strategies, together with the required 6-yearly updates, will address future water security.

**Introduction**

The NSW Government is tackling the challenge of the impact of climate change on non-metropolitan urban water utilities in a multi-pronged approach through comprehensive best practice management requirements, as noted below.

The key element of the NSW response to climate change is that the utilities will be required to determine their urban water supply security along the lines of the analysis reported in this paper for the pilot study for 11 NSW water supplies. Reporting of such water supply security analysis will need to be documented in each utility’s 30-year IWCM strategy.
Background

The NSW Government's *Best-Practice Management of Water Supply and Sewerage Guidelines* (Dept Water and Energy, 2007) is the key driver for reform of planning and management and performance improvement in non-metropolitan NSW. 106 NSW local water utilities provide piped water supply and sewerage services to the 1.8 million people in NSW country towns (97.9% water supply coverage). The 19 requirements of the guidelines include:

- Annual performance monitoring by each utility;
- Current 20 year strategic business plan and financial plan;
- Regulation of water supply, sewerage and trade waste (including pay-for-use water pricing, full cost recovery, commercial sewer usage, trade waste and developer charges, trade waste approvals for all dischargers and a sound trade waste regulation policy by each utility);
- Demand management;
- Drought management; and
- Integrated Water Cycle Management (IWCM) - comprehensive 30 year strategy required for the utility’s water supply, including headworks, sewerage, and where cost-effective, stormwater businesses. A full range of scenarios must be evaluated on a rigorous triple bottom line (TBL) basis, with extensive community involvement. The IWCM Strategy is effectively a 30-year rolling strategy, which must be reviewed and updated by each utility every 6 years.

The non-metropolitan NSW utilities have annual revenue of $950 million and an asset base with a current replacement cost of almost $20 billion (NSW Office of Water, 2010 (1) : vii). Overall, the utilities had met 82% of the requirements of the *Best-Practice Management Guidelines* by June 2009. The Best-Practice Management Guidelines, the IWCM Guidelines, the 7 IWCM Information Sheets and the annual NSW Water Supply and Sewerage Performance Monitoring Reports and Benchmarking Reports are available on the NSW Office of Water website (www.water.nsw.gov.au).

NSW Security of Supply Basis

45 local water utilities have surface water supplies with storage dams in non-metropolitan NSW. Such utility storages have in the main been sized on the NSW Security of Supply basis since the mid–1980s (NSW Public Works, 1986; Samra & French, 1988 and Cloke, 1995).

The purpose of the NSW Security of Supply basis is to determine the cost-effective storage volume and transfer capacities required to enable each water utility to operate its system with only moderate water restrictions in the event of occurrence of droughts of similar severity to those in the historical record, generally back to at least 1895. The utility would also be able to cope with significantly more severe droughts albeit with more severe water restrictions. Effectively, each water supply system would be able to cope with approximately a ‘1 in 1000 year drought’ (Cloke & Samra, 2009 :13).

Under the NSW Security of Supply basis (commonly referred to as the ‘5/10/20 rule’), water supply headworks systems are normally sized so that:

a) Duration of restrictions does not exceed 5% of the time; and

b) Frequency of restrictions does not exceed 10% of years (ie. 1 year in 10 on average); and

c) Severity of restrictions does not exceed 20%. Systems must be able to meet 80% of the unrestricted water demand (ie. 20% average reduction in consumption due to water restrictions) through a repetition of the worst recorded drought, commencing with the storage drawn down to the level at which restrictions need to be imposed to satisfy a) and b) above.
This enables the utilities to operate their systems without restrictions until the volume of stored water approaches the trigger level determined by a) and b) above (typically about 50% to 60% of the storage capacity). If at this trigger level, the utility imposes drought water restrictions which reduce demand by 20%, the system would be able to cope with a repeat of the worst recorded drought, commencing at that time, without emptying the storage.

‘Secure yield’ is defined as the highest annual water demand that can be supplied from a water supply headworks system while meeting the above ‘5/10/20 rule’.

The robustness of the NSW Security of Supply basis has been demonstrated by Cloke & Samra (2009:7) who showed that for the 10 NSW urban water supplies studied, the very severe 2001 to 2007 drought resulted in a reduction in the secure yield of up to 7% for 7 of the water supplies and a reduction of about 15% for the other 3 supplies.

The first paragraph in footnote 2 below, which is a quote from page 3 of the 2008-09 NSW Water Supply and Sewerage Performance Monitoring Report shows that for the 15 years from 1986, the frequency of drought water restrictions by the non-metropolitan NSW water utilities was consistent with the implied target of no restrictions in 90% of years in b) above. Due to the prolonged severe drought commencing in 2001, there is a relatively low frequency of years with no restrictions of 75% for the 23 years from 1986.

The 2008-09 NSW Water Supply and Sewerage Benchmarking Report shows each utility’s drought water restrictions over each of the last 6 years (page 56).

The 2008-09 Performance Monitoring Report (page 8) also shows ‘there has been a 47% reduction in the volume of average annual residential water supplied per property in non-metropolitan NSW over the last 18 years (from 330 to 175kL per connected property)’. It is therefore considered that it will now be much more difficult to achieve a 20% reduction in consumption than it was 20 years ago as there has been a large reduction in outdoor water use. Accordingly, in February 2009 approval was provided by the NSW Office of Water for basing future planning in non-metropolitan NSW on being able to achieve an average of only a 10% reduction in consumption through a repetition of the worst drought commencing with the storage already drawn down to satisfy the restriction duration and frequency criteria in a) and b) on page 22. Thus the NSW ‘5/10/20 rule’ has been superseded by a ‘5/10/10 rule’.

Accordingly, a pilot study has been undertaken to examine the impacts climate changed hydrometeorological data has on water security for 11 surface water supplies and to develop a methodology suitable for application for this purpose by the other NSW water utilities.

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1 As noted above, this has been superseded by a ‘5/10/10 rule’ since February 2009.

2 ‘For the 15 years from 1986 to 2000/01, on average, the NSW utilities did not apply any drought water restrictions for 87% of the years, which include the severe 1993 to 1994 drought. This is consistent with the implied target of no restrictions in 90% of years in the NSW Security of Supply basis (commonly referred to as the ‘5/10/10 rule’).

For the 23 years from 1986 to 2008/09, on average, the NSW utilities did not apply any drought water restrictions for 75% of the years. However, this period includes both the above 1993 to 1994 drought and the very severe 2001 to 2008/09 drought.’
PILOT STUDY

A Climate Change Steering Group has been formed to oversee a climate change pilot study for 11 urban NSW water supplies and development of NSW guidelines for local water utilities on assessing the impact of climate change on the secure yield of their water supplies. The Steering Group members are:

- Peter McLoughlin (National Water Commission)
- Jai Vaze (NSW Office of Water/CSIRO)
- Peter Cloke (NSW Public Works - commissioned to carry out the pilot study)
- Sascha Moege (Local Government and Shires Associations)
- Wayne Franklin (NSW Water Directorate)
- Sam Samra, Mike Partlin, Peter Ledwos (NSW Office of Water)

As indicated above, the purpose of the pilot study was to provide insights on the impacts of climate change hydrometeorological data on the water security of the 11 water supplies in the pilot study and to then develop a suitable methodology and guidelines for application by the other NSW water utilities.

The pilot study (Samra & Cloke, 2010:10) involved undertaking hydrological and system modelling to determine the impact of climate change on secure yield. The pilot study incorporates the scientific logic of the CSIRO’s Murray Darling Basin Sustainable Yields Project (Chiew et al, 2008), which used daily historical data from 1895 to 2006 and applied the relevant global climate models (GCMs) to provide projected (~2030) climate changed data for each GCM for this period.

The pilot study uses daily values of rainfall and evapotranspiration from the NSW Office of Water’s 2008 data sets (Vaze et al, 2008) for 15 GCMs. These future climate change series for ~2030 were obtained by Vaze et al by scaling the historical 1895-2006 daily rainfall and evapotranspiration data using the methods detailed in Chiew et al., 2008.. These data sets involve extension of the CSIRO data for the Murray Darling basin to cover all of NSW and are based on the Year 2030 A1B warming scenario; a mid range emissions scenario.

The study essentially involved two modelling steps:

- Daily rainfall and evapotranspiration data were inputted into existing calibrated rainfall-runoff models to produce climate changed daily streamflows.
- The daily climate changed streamflows, rainfall and evapotranspiration were inputted into water supply system simulation models to determine climate changed secure yields.

The climate changed secure yields were compared with the secure yields for a repeat of the historical base data set.

Table 1 lists the 15 GCMs that were used to produce the data sets.

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3 This comprehensive data set provides projections of downscaled daily climate changed data for the Year 2030 for all of NSW. It is the best such data set available at present, and was therefore used for the pilot study. As noted on page 32 this data set now covers all of NSW, Victoria and the Murray Darling Basin, including Adelaide. As noted on page 33 improved and longer term projections of climate changed data are expected to be developed in the future and these should be applied by water utilities when they become available.

4 It is noted that there is little difference in the impacts of the various warming scenarios considered by the IPCC for the Year 2030. Such impacts diverge in longer term projections such as for the Year 2050 or 2070.

5 Use of a locally calibrated daily rainfall-runoff model for each water supply is essential. The analysis carried out in the pilot study demonstrated that use of generalised streamflow estimates available from the NSW Office of Water data sets is inappropriate for security of water supply analysis. In NSW, such a local daily rainfall-runoff model is routinely developed for any water supply secure yield study.

6 Similarly, a suitable system simulation model is routinely developed in NSW for any water supply secure yield study.
### Table 1: The 15 Global Climate Models

<table>
<thead>
<tr>
<th>Climate Data Series</th>
<th>GCM</th>
<th>Modelling Group</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CCCMA T47</td>
<td>Canadian Climate Centre</td>
<td>Canada</td>
</tr>
<tr>
<td>2</td>
<td>CCCMA T63</td>
<td>Canadian Climate Centre</td>
<td>Canada</td>
</tr>
<tr>
<td>3</td>
<td>CNRM</td>
<td>Meteo-France</td>
<td>France</td>
</tr>
<tr>
<td>4</td>
<td>CSIRO-MK3.0</td>
<td>CSIRO</td>
<td>Australia</td>
</tr>
<tr>
<td>5</td>
<td>GFDL 2.0</td>
<td>Geophysical Fluid Dynamics Lab</td>
<td>USA</td>
</tr>
<tr>
<td>6</td>
<td>GISS-AOM</td>
<td>NASA/Goddard Institute for Space Studies</td>
<td>USA</td>
</tr>
<tr>
<td>7</td>
<td>IAP</td>
<td>LASG/Institute of Atmospheric Physics</td>
<td>China</td>
</tr>
<tr>
<td>8</td>
<td>INMCM</td>
<td>Institute of Numerical Mathematics</td>
<td>Russia</td>
</tr>
<tr>
<td>9</td>
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<td>Institut Pierre Simon Laplace</td>
<td>France</td>
</tr>
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<td>10</td>
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<td>Centre for Climate Research</td>
<td>Japan</td>
</tr>
<tr>
<td>11</td>
<td>MIUB</td>
<td>Meteorological Institute of the University of Bonn, Germany</td>
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</tr>
<tr>
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<td></td>
<td>Meteorological Institute of KMA</td>
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<td>12</td>
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<td>Max Planck Institute for Meteorology, DKRZ</td>
<td>Japan</td>
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<tr>
<td>13</td>
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<td>14</td>
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<td>USA</td>
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<td>15</td>
<td>NCAR-PCMI</td>
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</tbody>
</table>

It is noted that to maintain relativity and ensure consistency in the pilot study, modelled streamflow data was used throughout. However in practice in determining ‘historical’ secure yield, best use is made of the observed data for each utility. Thus the historical estimates in Table 2 differ slightly from the current best estimates of secure yield, which include consideration of the observed data. Thus the Steering Group recommends applying the percentage change in secure yield in column (9) of Table 2 to the utility’s current best estimate of secure yield in order to obtain the climate changed secure yield estimate.

### Table 2: Comparison of Secure Yield Estimates

<table>
<thead>
<tr>
<th>Water Utility</th>
<th>Estimated Secure Yield (ML)</th>
<th>% Change in Secure Yield From Historical Data Set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Historical Data Set*</td>
<td>Median of 15 Global Climate Models (GCMs)</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>1</td>
<td>21,500</td>
<td>20,000 [14]</td>
</tr>
<tr>
<td>2</td>
<td>3,400</td>
<td>3,500 [1]</td>
</tr>
<tr>
<td>3</td>
<td>12,400</td>
<td>12,200 [1]</td>
</tr>
<tr>
<td>4</td>
<td>7,700</td>
<td>7,200 [13]</td>
</tr>
<tr>
<td>5</td>
<td>5,200</td>
<td>4,900 [4]</td>
</tr>
<tr>
<td>6</td>
<td>495</td>
<td>450 [12]</td>
</tr>
<tr>
<td>7</td>
<td>4,850</td>
<td>4,150 [4]</td>
</tr>
<tr>
<td>8</td>
<td>3,600</td>
<td>3,600 [8]</td>
</tr>
</tbody>
</table>
Figure 1 shows the general location of the 11 NSW water supply systems examined which covered a range of attributes: large, small, on-stream storage, off-stream storage, coastal, inland and multi-sources.

RESULTS OF THE PILOT STUDY

Climate Change

The projected impacts of climate change in ~2030 on the average annual rainfall, streamflow and evapotranspiration for each utility’s water supply, in comparison with the historical data sets are shown in Figures 2, 3 and 4 respectively. Note that there is a tendency towards drying in NSW.

Following determination of the average annual rainfall for each of the 15 GCMs for each utility, the GCM with the highest average annual rainfall is referred to as ‘Highest’ in Figure 2, expressed as a percentage change in comparison with the historical average annual rainfall. Similarly, the GCM with the lowest average annual rainfall for a utility is shown as ‘Lowest’ and the GCM with the median average annual rainfall from the 15 GCMs is shown as ‘Median’ in Figure 2.

Figure 2: % Change in the Average Annual Rainfall for the Global Climate Models (GCMs) shown compared with the result for the Historical Data Set

Figure 3: % Change in the Average Annual Streamflow for the Global Climate Models (GCMs) shown compared with the result for the Historical Data Set

Figure 4: % Change in the Average Annual Evapotranspiration for the Global Climate Models (GCMs) shown compared with the result for the Historical Data Set
Figure 2 shows that the changes in the average annual rainfall for the GCM median cases the changes range from no change (Utility 6) to a reduction of 3% (Utility 11) (median is a 2% reduction). For the GCM lowest cases, the change range is reductions of 5% (Utility 3) to 10% (Utility 9) (median is an 8% reduction). For the GCM highest cases, the change range is increases of 3% (Utility 11) to 7% (Utilities 1, 2, 6 and 7) (median is a 5% increase).

Figure 3 shows that the changes in the average annual streamflow for the GCM median cases the changes range from an increase of 13% to a reduction of 22% (median is a 7% reduction). For the GCM lowest cases, the change range is reductions of 5% to 34% (median is a 25% reduction). For the GCM highest cases, the change range is increases of 5% to 49% (median is an 18% increase).

Figure 4 shows that for the GCM median cases the change in the average annual evapotranspiration is a 2% increase in each case. For the GCM lowest cases, the change range is increases of nil to 2% (median is a 1% increase). For the GCM highest cases, the change range is increases of 3% to 4% (median is a 3% increase).

Secure Yield

The results of the pilot study with respect to secure yield are shown in Table 2. Columns (2), (3) and (4) show the secure yield for each of the 11 utilities in the pilot study for the historical data, the median of 15 GCMs and the lowest GCM on the basis of the ‘5/10/10 rule’.

Columns (6) and (7) show the changes in secure yield for the median of 15 GCMs and the lowest GCM in percentage terms. For the median GCM (column (6)) the change in secure yield varies from an increase of 3% (Utility 2) to a reduction of 25% (Utility 9). For the lowest GCM (column (7)) the change in secure yield varies from a 6% reduction (Utility 2) to a reduction of 54% (Utility 9).

As discussed in Samra & Cloke (2010 :5) the Steering Group considers that a balanced approach to determining the secure yield after climate change would be to adopt the lesser of:

a) secure yield for the median of 15 GCMs on the basis of the ‘5/10/10 rule’

b) secure yield for the GCM with the lowest secure yield on the basis of a ‘5/10/25 rule’; the 25% severity of restrictions under this rule amounts to being able to ‘survive’ occurrence of the lowest GCM, albeit with relatively harsh water restrictions to cope with the reduced availability of water.

Thus a utility’s core planning under a) above would be on the basis of the ‘5/10/10 rule’. However, under b) above, the utility would also need to ensure its system would be able to survive the lowest GCM under the severe restrictions involved in a ‘5/10/25 rule’.

Column (5) of Table 2 shows the secure yield of the lowest GCM on the basis of 25% severity of restrictions (ie. a ‘5/10/25 rule’). For comparison purposes, the percentage change in secure yield is shown in column (8).

The above approach is considered to provide a reasonable balance between avoiding excessive capital expenditure by the utilities and avoiding very harsh future drought water restrictions. The 25% severity for the GCM with the lowest secure yield is considered to be acceptable in view of the low probability of occurrence of such a GCM and is informed by the outcomes of at least 35% reduction in consumption achieved by several NSW utilities in the current drought, including Goulburn, Orange and the Central Coast (Samra & Cloke, 2010: 5).
The adopted change in the Year 2030 secure yield due to climate change for each utility is shown in column (9) of Table 2 and Figure 5. This is identical with the values shown in column (6), for 4 utilities (2, 3, 4 and 11). The adopted changes for the other 7 utilities are on the basis of 25% severity of restrictions for the lowest GCM, and are up to 25 percentage points lower than for the median GCM.

The 3 utilities with a reduction in the adopted secure yield of over 25% are inland utilities in mid and southern NSW. This finding is consistent with the Victorian expectation of increasing drought severities.

Storage behaviour diagrams for each utility are shown in Figures A1 to A12 in Appendix A on pages 35 and 36. These show the storage behaviour (expressed as % of full storage capacity) while delivering an annual demand\(^7\) equivalent to the secure yield determined for the historical data for a repeat of:

- the historical climate conditions and
- for a repeat of the climate changed conditions that produced the
  - highest,
  - median and
  - lowest climate changed secure yield for each utility.

Using the climate changed inflows, Figures A1 to A12 show that except for Utility 10 (Figure A11), the storages did not empty while supplying a demand equivalent to the historic secure yield for each utility. This includes the results in Figures A9 and A10 for Utility 9 which had the largest reduction in secure yield. It is important to note that the existing small storage capacity for Utility 9 results in a 50% reduction in secure yield (column 9 of Table 2). However after the proposed augmentation of the storage dam, there would be only a 29% reduction in the secure yield, which demonstrates that the impact of climate change is system dependent.

---

\(^7\) Unrestricted demand was supplied until the storage volume fell to the restriction volume for each utility (typically about 50% to 60% of full capacity). Thereafter 90% of the demand was supplied until there was a significant recovery in the storage volume, when the unrestricted demand was resumed. As it was necessary to use the first year of each dataset to initialise the daily rainfall-runoff models, each simulation was generally carried out with the remaining 111 years of daily hydroclimate data.
Figure 6 provides a graphical representation of the percentage change in secure yield for the GCM with the median secure yield, in comparison with the historical data set. These results are as shown in column (6) of Table 2 and range from an increase of 3% to a reduction of 25%.

Figure 7 also provides a graphical representation of this percentage change for the GCM with the lowest secure yield (from column (7) of Table 2) and that for the GCM with the highest secure yield, in comparison with the historical data set. As also noted above, the results for the GCM with the lowest secure yield range from a reduction of 6% to a reduction of 54% (column (7) of Table 2). The results for the GCM with the highest secure yield range from an increase of 22% to a reduction of 2%.

The GCMs which provided the median, lowest and highest changes in the average annual rainfall, streamflow and evapotranspiration⁸ (refer to Figures 2 to 4) are not necessarily those which resulted in the median, lowest and highest changes in secure yield (refer to Figure 7).

A report on the pilot study will be published on the NSW Office of Water website in 2010 in order to disseminate the results and findings of the study.

Tables 3 and 4 show the key characteristics of the 4 simulations shown for each utility in Figures A1 to A12, Table 3 provides a comparison of the resulting minimum storage volume for each simulation and indicates that the minimum storage volume for the historical data set ranges from 31% to 49% of the full storage capacity (column (3)). For the median of GCMs, the minimum storage volume ranges from 23% to 49%, with 3 utilities having a minimum storage volume of 23% to 25% of capacity (column (4)). However, for the lowest GCM, 4 utilities have a minimum storage of under 15% of capacity (Utilities 7, 9, 10 and 11), with the storage volume for the small Utility 10 emptying for a period of 6 months (column (5)). For the highest GCM, the minimum storage volume ranges from 32% to 51% of capacity (column (6)).

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⁸ Eg. for Utility 1, the median rainfall, streamflow, evapotranspiration and secure yield resulted from GCMs 5, 5, 9 and 14 respectively.
APPENDIX H

NSW Guidelines on Assuring Future Urban Water Security

Table 3: Comparison of Minimum Storage Volumes

<table>
<thead>
<tr>
<th>Water Utility</th>
<th>Storage Capacity (ML)</th>
<th>Minimum Storage Volume (%) while supplying the Historical Secure Yield</th>
<th>Historical Data Set</th>
<th>Median of 15 Global Climate Models (GCMs)</th>
<th>Lowest GCM</th>
<th>Highest GCM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>60%</td>
<td>40%</td>
<td>20%</td>
<td>60%</td>
<td>40%</td>
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<tr>
<td>1</td>
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<td>39</td>
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<td>3</td>
<td>4,500</td>
<td>43</td>
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<td>24</td>
<td>40</td>
<td>34</td>
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<tr>
<td>4</td>
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<td>7</td>
<td>22,500</td>
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<td>10</td>
<td>43</td>
<td>34</td>
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<td>23</td>
<td>10</td>
<td>43</td>
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</tr>
<tr>
<td>11</td>
<td>14,800</td>
<td>33</td>
<td>23</td>
<td>14</td>
<td>39</td>
<td>34</td>
</tr>
</tbody>
</table>

* Enlarged storage

In summary, Table 3 shows that for the median GCM, the minimum resulting storage volume for most of the utilities is a little lower than that for the historical data, indicating slightly more severe droughts than had been experienced historically. For the lowest GCM, all the minimum storage volumes are much lower than the historical data set. This indicates the occurrence of much more severe droughts, with 5 of the utilities experiencing a minimum storage volume of under 15% of full capacity, in comparison with the historical data set, where the minimum storage volume was 31% of full capacity.

For the 4 simulations for each utility discussed in Table 3 above, Table 4 provides a comparison of the percentage of time each storage is drawn down below 60%, 40% and 20% of full capacity. These draw downs indicate the relative vulnerability of each water supply to supply failure due to emptying of the storage. For the historical data set (column (2)) of Table 4 shows that the percentage of time the storage volume falls below 60% of full capacity exceeds 5% only for Utility 8, where restrictions are implemented at a storage capacity of 55% under the ‘5/10/10 rule’. Column (3) of Table 4 shows that for the median of GCMs, 2 utilities (Utilities 7 & 8) have storage volumes under 60% of capacity for more than 5% of the time. Only these 2 utilities have such storage volumes for more than 5% of the time for the lowest GCM, but the duration now extends to 16% to 18% of the time for this GCM (column (4)). For the highest GCM, the duration of such storage volumes does not exceed 2.5% of the time for any utility (column (5)).

Table 4: Comparison of Storage Drawdowns

<table>
<thead>
<tr>
<th>Water Utility</th>
<th>% of the time storage is drawn down below volumes shown while supplying the Historical Secure Yield</th>
<th>Historical Data Set</th>
<th>Median of 15 Global Climate Models (GCMs)</th>
<th>Lowest GCM</th>
<th>Highest GCM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>60%</td>
<td>40%</td>
<td>20%</td>
<td>60%</td>
</tr>
<tr>
<td>1</td>
<td>1.4 0.1 0.0</td>
<td>1.5 0.5 0.0</td>
<td>3.1 0.7 0.1</td>
<td>1.2 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3.7 0.8 0.0</td>
<td>2.8 0.7 0.0</td>
<td>5.0 0.8 0.0</td>
<td>1.1 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.7 0.0 0.0</td>
<td>0.8 0.0 0.0</td>
<td>1.3 0.1 0.0</td>
<td>0.5 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.5 0.0 0.0</td>
<td>2.1 0.0 0.0</td>
<td>2.9 0.0 0.0</td>
<td>1.6 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.2 0.0 0.0</td>
<td>1.1 0.2 0.0</td>
<td>2.1 0.3 0.0</td>
<td>0.7 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.4 0.2 0.0</td>
<td>1.1 0.2 0.0</td>
<td>2.3 0.4 0.0</td>
<td>0.7 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5.0 0.4 0.0</td>
<td>9.5 1.4 0.0</td>
<td>18 5.2 0.8</td>
<td>2.5 0.0 0.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>7.0 0.2 0.0</td>
<td>6.1 0.3 0.0</td>
<td>16 2.9 0.0</td>
<td>1.0 0.0 0.0</td>
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</tr>
<tr>
<td>9</td>
<td>1.4 0.2 0.0</td>
<td>1.7 0.6 0.0</td>
<td>2.5 0.8 0.2</td>
<td>0.8 0.1 0.0</td>
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<tr>
<td>10</td>
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<td>2.4 0.5 0.1</td>
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<td></td>
</tr>
<tr>
<td>11</td>
<td>2.0 0.5 0.0</td>
<td>2.7 0.8 0.0</td>
<td>4.3 1.4 0.7</td>
<td>1.5 0.4 0.0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1.5 0.3 0.0</td>
<td>3.4 0.7 0.0</td>
<td>4.9 1.3 0.4</td>
<td>1.6 0.1 0.0</td>
<td></td>
</tr>
</tbody>
</table>

* Enlarged storage
Table 4 also shows that for the historical data set (column (2)), the percentage of time the storage volume falls below 40% of full capacity, which could be expected in a severe drought, does not exceed 0.8% for all the utilities. Column (3) of Table 4 shows that for the median of GCMs, only Utility 7 has such storage volumes exceeding 0.8% of the time. However, for the lowest GCM only 7 utilities have such storage volumes not exceeding 0.8% of the time, with the other 4 utilities (Utilities 7, 8, 10 and 11) experiencing durations of 1.3% to 5.2% of the time (column (4)). For the highest GCM, the duration of such storage volumes does not exceed 0.4% of the time (column (5)).

In addition, Table 4 shows that for the historical data set (column (2)), the median of GCMs (column (3)) and the highest GCM (column (5)), the storage volume never falls below 20% of full capacity, which could be expected to occur only in an extreme drought. However, for the lowest GCM, 5 utilities (Utilities 1, 7, 9, 10 and 11) have a storage volume below 20% of capacity for at least 0.1% of the time (column (4)).

As previously noted, the Best-Practice Management Guidelines require each NSW water utility to prepare a comprehensive 30-year IWCM Strategy. The IWCM strategies will need to include assessment of the secure yield of the utility’s water supply on the basis of new NSW guidelines proposed for release in late 2010. The utilities will be able to soundly plan for the security of their water supply for climate change by developing and implementing their 30-year IWCM strategy on the basis of the climate changed secure yield determined along the lines of the pilot study for 11 NSW water supplies.

As noted on page 24, the pilot study has focused on climate change projections for the Year 2030 based on predictions for the A1B mid range warming emissions scenario. This is not only due to the availability of the daily database but because there is only a small difference in the climate change projections between different emissions scenarios for the year 2030. These differences will be magnified for longer-term projections, such as for the year 2050 or 2070.

DISCUSSION

The 1895-1902 Federation Drought

The severe 2001-2007 drought has been claimed as the worst drought since records began in Australia and has resulted in questioning of the reliability of several major water supplies in Australia. Fortunately NSW country town water supplies that had been planned on the basis of the NSW security of supply basis (ie. 5/10/20 rule) have been able to maintain the expected supply. It is hypothesised that this is because the 5/10/20 rule incorporates the very severe Federation drought of 1895-1902 and allows for maintaining a 20% restricted supply through in effect a ‘1 in 1000 year’ drought (Cloke & Samra, 2009 :13).

It is understood consideration of Perth’s and Melbourne’s water supply reliability was until recently based on flow records post the Federation drought, as shown in their plots of inflows (from 1911 for Perth and from 1913 for Melbourne) (Gill, 2008 and Rhodes et al, 2010). The plot of inflows to Perth’s water supply headworks has been repeatedly shown as an example of a shifting climate.

An equivalent plot of inflows for a Tablelands water utility in central NSW [catchment area 100 km²] is shown in Figure 8. With the inclusion of the Federation drought it suggests that the 2001-2007 drought was more likely to be due to climate variability rather than climate change and in terms of water supply headworks was not the worst drought on record.

If the Federation drought and pre 1915 droughts had not been incorporated in the water supply planning, secure yields for many NSW water supplies would have been determined to have been much higher and may have then been impacted by the 2001-2007 drought. For example for Utility 7,
post the Federation drought, the secure yield would have been determined as some 25% higher and post 1915, some 50% higher than the historical secure yield. This highlights the importance of including the Federation Drought in any security of supply simulation studies to avoid such over-estimation of secure yield.

Accordingly, it is considered that the robustness of the NSW security of supply basis, combined with analysis for climate change as developed in the pilot study, will continue to provide reliable and cost-effective water supply security for NSW country towns.

Reducing uncertainty in climate models

The overall summary of the Ozwater ‘10 Workshop on Climate Change Impacts on the Water Sector (Claydon, et al., 2010: 3) includes:

‘Reducing uncertainty in climate models is an active area of research – in particular coupled ocean-atmosphere general circulation models (GCMs). There have already been (published) steps made to provide this more refined (downscaled) output in Bureau of Meteorology and CSIRO climate projections, especially for drought. However, the core aspects of how best to apply these various models using sophisticated integrated modelling procedures remains an ongoing interesting research and operational issue.’

It is acknowledged that reducing uncertainty in climate models and how best to apply them is an area of ongoing research.

However, water supply planning and decision making requires assessment of the impact of climate change on water supply security. At present, the best available downscaled daily hydrometeorological data in Australia is for 15 GCMs along the lines developed by the Murray Darling Basin Sustainable Yields Project. Such data is now available for all of NSW and Victoria, as well as for all of the Murray Darling Basin, including Adelaide. It is therefore considered that the analysis carried out in this pilot study could be used to assess the Year 2030 climate change impacts for urban water utilities in the areas with such downscaled data which have surface water supplies with storage dams.
In addition, there are some major research activities such as the research in SEACI Theme 2 which focus on improving hydroclimate change projections for south-eastern Australia. They are specifically investigating

(i) GCM assessment and selection for hydrological application and
(ii) assessing the relative merits of different downscaling methods and relative uncertainties in various components in estimating climate change impact on runoff (GCM projections, downscaling methods and hydrological modelling) (Vaze J., 2010).

The above research includes consideration of dynamic downscaling, which has the potential to improve the projections of drought persistence for severe droughts.

Accordingly, as such better hydroclimate change data becomes available in the future, it should be applied in future planning. In this regard, where a utility has sufficient supply capacity to enable it to defer a major capital investment decision for additional surface water supplies for 5 or more years, it should do so, as the better hydroclimate change data likely to be available by that time would enable the utility to make a more robust investment decision.

CONCLUSIONS

1 A sound basis has been developed for non-municipal urban water utilities to assess the impact of climate change for the Year 2030 on the secure yield of their urban water supply. This is an adaptive management approach which enables utilities to carry out sound climate change planning and decision making immediately, using the existing 112 years of downscaled daily hydrometeorological data sets for 15 GCMs. As better hydroclimate change projections become available in the future, these will need to be applied in future planning by the utilities.

2 The results for the 11 utilities in the pilot study are shown in Figure 5 on page 28. These indicate that the main impacts on Year 2030 secure yield are:
   - no greater than a reduction of 9% for the 7 coastal and tablelands utilities
   - reductions of almost 30% for the 3 inland utilities in mid and southern NSW, after allowing for the proposed augmentation of the existing small storage capacity for Utility 9.

3 Future utility 30-year IWCM strategies in NSW will need to include assessment of the secure yield of the utility’s water supply in accordance with the analysis reported for the pilot study. Implementation of these strategies, together with the required 6-yearly updates, will address the future water security of these utilities.

Acknowledgments

Each member of the Climate Change Steering Group for their valuable strategic advice and inputs. Peter Ledwos, Ian Burton and Richard Cooke of the NSW Office of Water for their significant contributions to the pilot study.

Chee Chen and Dr Liz Chen of NSW Public Works Hydrology Group who carried out the detailed modelling required to produce the results provided in the pilot study.

The many NSW Councils which have engaged NSW Public Works over the years to carry out yield studies, thus enabling use of the study models for the analysis reported in the pilot study.

SEACI – South-East Australian Climate Initiative
References


*Climate data for hydrologic scenario modelling across the Murray-Darling Basin.* A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia.


APPENDIX A

Figure A1: Storage Behaviour Diagram for repeat of years 1895 to 2006 for different climate conditions for Utility 1

Figure A2: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 2

Figure A3: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 3

Figure A4: Storage Behaviour Diagram for repeat of years 1895 to 2006 for different climate conditions for Utility 4

Figure A5: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 5

Figure A6: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 6

Figure A7: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 7

Figure A8: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 8
Figure A9: Storage Behaviour Diagram for repeat of years 1898 to 2006 for different climate conditions for Utility 9 – Existing Storage

Figure A10: Storage Behaviour Diagram for repeat of years 1898 to 2006 for different climate conditions for Utility 9 – Enlarged Storage

Figure A11: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 10

Figure A12: Storage Behaviour Diagram for repeat of years 1895 to 2003 for different climate conditions for Utility 11