The Greater Sydney’s water supply system yield has been reviewed and updated following the release of 2017 Metropolitan Water Plan (“2017 MWP”).

**Greater Sydney’s water supply system yield is currently 570 GL/a**

WaterNSW supplies raw water for treatment and distribution by its Greater Sydney customers.

The Sydney Desalination Plant (SDP) supplies treated water directly into the potable water supply distribution system.

The water supply system supplying Greater Sydney is configured and operated by WaterNSW to optimise yield, taking into account all sources of water.

**BACKGROUND**

**What is yield?**

The yield of the water supply system is a calculated figure. It is the maximum amount of water that can be supplied annually in the long term, taking into account the constraints of the water supply system design criteria, and considering not just surface water but all sources of available water including desalinated water and drought triggered supply sources.

**Yield is the average annual demand for water that can be met sustainably over the long term.**

Yield is not static. It changes over time as inflows, infrastructure, demographics, the system design criteria and the operating rules for the system change.
Figure 1: Greater Sydney water supply system

Greater Sydney’s Water Supply System

[Diagram showing the Greater Sydney water supply system with labels for different water supplies and reservoirs, along with population figures and water flow directions.]

Legend:
- Water Filtration Plant
- Dam or Reservoir
- Pumping Station
- River Channel
- Pipeline / Canal
- Treated Water Pipeline
- Desalination Plant
- Hydroelectric Power Generation
- 2017 Population Figures
- Water flow direction

July 2017

WaterNSW Greater Sydney’s Water Supply System Yield
The surface water supply system

The WaterNSW water supply system for Greater Sydney is an integrated network of dams, pipelines, canals, tunnels and rivers that has been designed, and is operated, to optimise overall water supply outcomes. It includes:

- **the Warragamba system**: comprising Warragamba Dam and the pipelines that connect the dam to the Prospect Water Filtration Plant and Prospect Reservoir
- **the Shoalhaven system**: comprising Tallowa Dam, Fitzroy Falls and Wingecarribee reservoirs, pipelines, canals and pumping stations that supply local communities and Sydney via transfers either to the Warragamba system or the Upper Nepean system
- **the Upper Nepean system**: comprising Cataract, Cordeaux, Avon and Nepean dams, two diversion weirs and the Upper Canal that delivers water into Prospect Water Filtration Plant and/or Prospect Reservoir. This system supplies water to Sydney, the Illawarra, Macarthur and surrounding villages of Picton, Bargo and Thirlmere
- **the Prospect system**: comprising Prospect Reservoir and the Prospect Raw Water Pumping Station that delivers water into the Prospect Water Filtration Plant
- **the Woronora system**: comprising Woronora Dam, and supplies Sutherland and adjacent areas
- **the Blue Mountains system**: comprising the Cascades (x3), Greaves Creek and Medlow dams that supply the upper Blue Mountains. Water can also be transferred to the upper Blue Mountains from the Fish River Water Supply Scheme, which originates at Duckmaloi Weir.

All of the systems in the network contribute to WaterNSW’s capacity to supply water, and any changes to the system infrastructure, or the operating rules that apply in any part of the system, affect the overall calculated system yield.

**Sydney Desalination Plant**

When operating at full capacity, Sydney’s desalination plant at Kurnell can produce 91 gigalitres of water a year, enough to supply up to 17 percent of greater Sydney’s current (2017) potable water needs.

Water from the desalination plant can be distributed to approximately 1.5 million people across the Sydney CBD, inner west, eastern suburbs, southern Sydney and parts of the Sutherland shire.

The desalination plant was commissioned in January 2010. The plant will be brought into operation at full production capacity (250 ML/d) 8 months from when the total WaterNSW dam storage level is goes below 60 percent capacity and, once operational, will continue to do so until the total WaterNSW dam storage level reaches 70 percent (2017 MWP).

**Contingency Drought Measures**

The 2006 Metropolitan Water Plan (MWP) identified that if Sydney entered severe drought, several bore-fields could be built to tap into underground water sources (groundwater). Groundwater investigations were undertaken at Kangaloon and Wallacia/Leonay, but the
plan to use groundwater was shelved in 2008 as the dams recovered at the end of the drought. The 2010 MWP reaffirmed that a decision to extract groundwater would be made in the event that Sydney’s total dam storage falls to a level consistent with severe drought and with regard to seasonal weather outlooks and demand at the time.

2017 MWP does not include use of groundwater as a drought measure. However, it has identified a number of possible drought measures including temporary desalination plants.

**Water supply system design criteria**

The system design criteria used to determine the yield define the minimum ‘standards of service’, and are built into the model that estimates the likelihood of running out of water, or facing water restrictions.

The design criteria for Greater Sydney reflect the length and frequency of water restrictions that is regarded as ‘acceptable’, as well as ensuring that water supplies are not depleted. They are:

- **Security** - storages should not approach emptiness (defined as 5% of water in the storage) more often than 0.001% of the time, or one chance in 100,000 in any one month.
- **Robustness** – imposed water restrictions should not occur more often than once in every ten years on average. That is, restrictions should not be too frequent.
- **Reliability** – imposed water restrictions should not last longer than 3% of the time on average, or 3 months in 100 months.

The maximum volume of water that can be extracted from the water supply system when all three system design criteria are satisfied is the **system yield** - the average annual demand for water that can be sustainably met over the long term.

Estimates of yield are based on assumptions about the likelihood of severe droughts occurring, as well as the historic experience with the water supply system and its hydrology. Yield is a long-term construct, however, and periods of low inflows (droughts) may see the design criteria temporarily exceeded.

While relaxing the design criteria increases the system’s yield, it also increases the frequency or duration of water restrictions and/or increases the risk of water storages emptying. Whenever water restrictions are introduced, they too influence the system yield. For this reason, modelling work incorporates assumptions regarding the expected reductions in demand for water that can be achieved from the imposition of water restrictions.

**The regulatory context**

The 2012-2017 Operating Licence requires WaterNSW to report changes to the water supply system yield, the assumptions and inputs used to calculate yield, and the reasons for any changes to the yield or those assumptions and inputs.

Additionally, the Operating Licence requires WaterNSW to re-calculate and report any changes to its estimate of the yield when any of the following occur:

- the conclusion of any drought event;
• the commencement of any major modification or augmentation to the water supply infrastructure that would have a significant impact on the supply of water; and
• any material change to the operating rules of the water supply infrastructure, including any changes to the availability of desalinated water.

WATER SUPPLY PLANNING TOOLS

Use of Modelling in water supply planning

WaterNSW uses the Water Headworks Network (WATHNET5) software package to simulate the operation of the water supply system.

WATHNET5 draws on 108 years of inflow data (1909-2016), and then replicates these flows by stochastic modelling to provide 2000 synthetic inflow sequences each containing 108 years of inflows in order to estimate the system yield meeting the design criteria. The modelling incorporates all water sources: surface water data, and desalinated water. All water recycling initiatives are treated by the model as ‘negative demands’ on the water supply system; in other words, these volumes are subtracted from the estimated water use (or demand).

This modelling allows WaterNSW to plan the optimal use of the water supply system based on a wider range of scenarios than the historical data alone. For example, it allows WaterNSW to plan how to manage the water supply system during droughts that are more severe than any on historical record (the worst drought occurred in the period 1934-1942).

WaterNSW is also using this modelling capacity to participate in research that aims to assess the potential impacts of climate change on hydrology and system yield.

WATHNET5 also incorporates economic modelling capabilities. The software can optimise system parameters for a range of outcomes. WaterNSW developed MetroNet, a ‘lumped’ model based on WATHNET5, to improve computational efficiency for the screening and optimisation of alternative supply options and operating rules, identified as part of the metropolitan water planning process. The differences in the output between the MetroNet model and the detailed system model were compared and found to be minimal.

Yield calculation

The calculation of yield is based on the design criteria and the characteristics of the water supply system, and is based on 216,000 years (2000 replicates x 108 years) of synthetically generated inflows.

Analysing yield

Yield analysis can be used as a planning tool to help investigate a range of options for providing future water needs. For example, yield analysis can be used to assess the potential impacts of climate change or to investigate a range of possible management changes, including for example:

• implications of different desalination plant operating rules and staging;
• impacts of introducing environmental flows;
• short to medium term drought response measures;
WaterNSW reports to IPART any gap between system yield and the demand projected by Sydney Water, so that this can inform planning decisions being taken as part of the NSW Metropolitan Water Planning process, and enable actions to redress any imbalance between system yield and demand. System demand should not exceed system yield for too long, because eventually the system will run out of water or have water restrictions in place too often or for too long. The water supply network model provides the capability to investigate the performance of the system and to determine the best way to meet current and future needs, both in the long and short term.

Review of the water supply system modelling capability

Through the use of the WATHNET5 model, and in conjunction with industry experts, WaterNSW has developed a capability that enables assessment of water supply system performance (hydrologic and economic) under current and any future system configurations, in both the short and long term.

Its value is dependent on the WATHNET5 model itself and the underlying data used, both needing to be robust. For this reason, the Operating Licence requires a detailed independent review of the model during the term of each Licence. Historically, this review has suggested the need for additional research and development which has resulted in continuous improvements to the model's capability.

The model was independently reviewed by IPART in June 2003, and found to be an accurate representation of the supply system. The design criteria were also reviewed by IPART in July 2003. Fine tuning of the model was undertaken as an outcome of the review.

In 2010, the model was again comprehensively externally reviewed. The review tested the robustness of the model and confirmed the correctness of the model configuration and input data. The last independent review was carried out in 2016.

The assumptions of the model were subject to expert panel peer review.

An internal review of the capability of the model is also undertaken between independent expert reviews. This internal review identifies any corrections/modifications, and also allows for other incremental improvements to the model.

Improving modelling capabilities

The 2010 review suggested the incorporation of economic modelling capabilities into the modelling software in order to reduce reworking data through separate economic models. The economic modelling functionality was successfully applied to the optimisation of the Blue Mountains water supply system.

Examples of other modifications made to WATHNET5 in the past include:

- system optimisation (operating rules);
- asset reliability impacts;
- characterisation of floods and droughts;
- determination of dam depletion rates.
- Improved representation of environmental, riparian and Warragamba Hydro Electric Power Station (HEPS) flow releases.
- Incorporation of a number of extensions of hydrology data up to and including 2016 inflows.
- Replacement of the Shoalhaven and Woronora catchments inflows using hydrological (rainfall-runoff) modelling techniques.
- A number of modifications to the water restriction regime and the predicted demand reductions.
- Inclusion of deep water access at Warragamba and Nepean dams.
- Adjustment of water restrictions trigger levels for revised total storage volume (due to deep water access).
- Revised operating rules for Tallowa Dam.
- Inclusion of the desalination plant and its operating rules.
- Inclusion of groundwater aquifers and operating rules.
- Inclusion of updated reservoir capacity tables post bathymetric surveys.

More recent changes have included:

- Synthetic generation improvements to account for the limited period of hydrology.
- Improved representation of the behaviour of individual reservoirs.
- Emerging trends in demand in different parts of Sydney and the Illawarra.
- Revised assumptions about the likely savings from future water restrictions (as a consequence of the introduction of Water Wise rules).
- Emergency drought measures.
- Warragamba Dam environmental flow replacement facility at St Marys.
- Inclusion of releases for the North Richmond water filtration plant.
- Incorporation of releases from Warragamba Dam required under Greater.
- Metropolitan Water Sharing Plan (GMWSP) for the dilution of Wallacia Sewage Treatment plant effluent (5 ML/d) and for Sydney Water extractions at North Richmond (17 ML/d and 25 ML/d).
- Sydney Water has provided demand forecast in March 2015 incorporating new population forecast including an assessment of impact of water restrictions.
- The Hydro Electric Power Station (HEPS) at Warragamba Dam has now been handed over from Earring Energy. The storage above FSL -1.0 had been allocated for power generation. It cannot now be used, resulting in access to top meter (pending operational needs) for water supply purposes.
- 2017 MWP operating rules.
- Adjustment for Shoalhaven pumping to account for the impact of using monthly time step in the yield model (as recommended by 2016 independent review).

**UNCERTAINTIES THAT AFFECT YIELD**

Any action that delays the imposition of water restrictions, or enables the lifting of water restrictions, will have a POSITIVE effect on Reliability Yield (e.g. earlier pumping from the Shoalhaven System).

Any action which increases the rate of depletion of the dams, and brings on water restrictions sooner, will have a NEGATIVE effect on Reliability Yield (e.g. increased E-flows).
Any action which slows the rate of depletion of the dams in the latter stages of a drought will have a POSITIVE effect on Security Yield (e.g. supply from Stage 2 of the Sydney Desalination Plant).

Any action which accelerates the rate of depletion of the dams in the latter stages of a drought will have a NEGATIVE effect on Security Yield (e.g. less effective water restrictions).

Uncertainties include:
- population Growth,
- demand and demographics,
- efficacy of current drought response measures, and
- climate Change impacts.

Future decisions that could affect yield include:
- release of environmental flows from Warragamba Dam,
- changes to the Desalination Plant operating regime, and the timing of any augmentation, and
- flood Mitigation proposals which see an alteration to the FSL of Warragamba Dam.

The table below summarises the changes to Yield (Reliability and Security) over the past fifteen (17) years due to various initiatives.

### Changes to Yield Since 2000

**Situation in year 2000**: Yield = 600 GL/a (limited by reliability)

**Situation in year 2017**: Yield = 570 GL/a (limited by security)

![Changes to Yield from 2000 to 2017](chart_url)
**UPDATED YIELD**

The yield was last updated and reported in 2015 as 615 GL/a (Run 30), incorporating:
- Inclusion of hydrology 2010-2012.
- Inclusion of 8 month commissioning time for Sydney Desalination Plant to operate from deep shut down
- Reduced demand savings from restrictions
- Revised bathymetry for Warragamba and Woronora storage
- Release of storage allocation above FSL -1.0 for HEPS at Warragamba Dam

The incremental changes to the system yield estimated are shown below in Table 1, and expressed as a series of computer model “runs”. The resulting yield at any point in the table represents the estimated yield taking into account the cumulative effect of all the factors considered in that and previous model runs (see Table 2). Yield, comprised of both Reliability and Security criteria is shown in Table 1 below. The minimum of these values is considered as the yield complying with both criteria. Descriptions of each run are provided in Table 2.

**Table 1: Results of the latest yield simulations.**

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Change Description</th>
<th>Yield (GL/a)</th>
<th>Limiting criterion</th>
<th>Reliability Yield (GL/a)</th>
<th>Security Yield (GL/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 31</td>
<td>MWP 2017:</td>
<td>575</td>
<td>Security</td>
<td>590</td>
<td>575</td>
</tr>
<tr>
<td></td>
<td>- SDP Stage 1 supply trigger</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- SDP Stage 2 Plan/Construct Triggers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Removal of groundwater</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- inclusion of temporary desalination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 32</td>
<td>Inclusion of hydrology 2013-2016 and model refinements.</td>
<td>570</td>
<td>Security</td>
<td>600</td>
<td>570</td>
</tr>
</tbody>
</table>

**Current Sydney water supply system yield**

The supply system yield is now 570 GL/a, and which is limited by supply system security as illustrated in Run 32 of Table 1 above.
### Table 2 - Summary of Model Runs

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Description</th>
<th>Yield (GL/a)</th>
<th>Limiting criterion</th>
<th>Reliability Yield</th>
<th>Security Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td>System Model-2000</td>
<td>600</td>
<td>Reliability</td>
<td>600</td>
<td>650</td>
</tr>
<tr>
<td>Run 2</td>
<td>Improved representation of environmental, riparian and HEPS releases</td>
<td>590</td>
<td>Reliability</td>
<td>590</td>
<td>660</td>
</tr>
<tr>
<td>Run 3</td>
<td>Extension of hydrology for 1999-2004</td>
<td>565</td>
<td>Reliability</td>
<td>565</td>
<td>645</td>
</tr>
<tr>
<td>Run 3A</td>
<td>Extension for Shoalhaven by catchment HSPF model</td>
<td>565</td>
<td>Reliability</td>
<td>565</td>
<td>600</td>
</tr>
<tr>
<td>Run 4</td>
<td>Modification of water restriction regime</td>
<td>500</td>
<td>Security</td>
<td>570</td>
<td>500</td>
</tr>
<tr>
<td>Run 5</td>
<td>Implementation of deep water access at Warragamba and Nepean dams</td>
<td>540</td>
<td>Security</td>
<td>565</td>
<td>540</td>
</tr>
<tr>
<td>Run 6</td>
<td>Trigger levels for restrictions revised to total storage levels</td>
<td>532</td>
<td>Security</td>
<td>593</td>
<td>532</td>
</tr>
<tr>
<td>Run 7</td>
<td>Minimum operating level for Tallowa Dam raised from –5.2m to –3m below FSL</td>
<td>528</td>
<td>Security</td>
<td>585</td>
<td>528</td>
</tr>
<tr>
<td>Run 8</td>
<td>500ML/d Desalination Plant to commence production at 15% storage (until 30%)</td>
<td>585</td>
<td>Reliability</td>
<td>585</td>
<td>594</td>
</tr>
<tr>
<td>Run 9</td>
<td>2 borefields yielding 30GL/a of groundwater for 3 years commencing at 35% storage</td>
<td>585</td>
<td>Reliability</td>
<td>585</td>
<td>600</td>
</tr>
<tr>
<td>Run 10</td>
<td>Modification of restriction regime</td>
<td>565</td>
<td>Security</td>
<td>585</td>
<td>565</td>
</tr>
<tr>
<td>Run 11</td>
<td>3 borefields yielding 45GL/a of groundwater for 3 years commencing at 35% storage</td>
<td>570</td>
<td>Security</td>
<td>585</td>
<td>570</td>
</tr>
<tr>
<td>Run 12</td>
<td>Extension of hydrology for 2005-2008</td>
<td>550</td>
<td>Reliability</td>
<td>550</td>
<td>580</td>
</tr>
<tr>
<td>Run 13</td>
<td>Refinements of modelling dam depletion, and geographical distribution of demand</td>
<td>545</td>
<td>Reliability</td>
<td>545</td>
<td>565</td>
</tr>
<tr>
<td>Run 14</td>
<td>Commencement of environmental flow regime (80/20) from Tallowa Dam</td>
<td>525</td>
<td>Both</td>
<td>525</td>
<td>525</td>
</tr>
<tr>
<td>Run 15</td>
<td>New trigger for transfers from Shoalhaven to Sydney (pump mark 75% of total system storage to commence pumping and 80% to stop pumping)</td>
<td>535</td>
<td>Security</td>
<td>555</td>
<td>535</td>
</tr>
<tr>
<td>Run 16</td>
<td>Model &amp; hydrology updates, &amp; extension of hydrology to 2009. Revised drawdown rules &amp; inclusion of Prospect Reservoir, corrected evaporation, demand distribution.</td>
<td>520</td>
<td>Security</td>
<td>545</td>
<td>520</td>
</tr>
<tr>
<td>Run</td>
<td>Description</td>
<td>Security</td>
<td>Reliability</td>
<td>Reliability</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
<td>-------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Minimum operating level for Tallowa Dam raised from -3m to -1m below FSL (decrease of 14GL in available storage)</td>
<td>515</td>
<td>535</td>
<td>515</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Operating rules for desalination plant modified from 500ML/d when storage falls to 15%, and off at 30% to 250ML/day from when storage falls to 70% until storage reaches 80% (stage 1) or to 250ML/day from when storage falls to 20% until storage reaches 80% (stage 2)</td>
<td>585</td>
<td>595</td>
<td>585</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Environmental flow regime for metropolitan dams 80:20; release same as inflow when inflows are lower.</td>
<td>560</td>
<td>565</td>
<td>560</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Modification of water restrictions regime.</td>
<td>555</td>
<td>610</td>
<td>555</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Emergency drought measure 1 (Tallowa minimum operating level changed from -1m to -3m at 35% storage)</td>
<td>560</td>
<td>605</td>
<td>560</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Emergency drought measure 2 (halve environmental flow releases from dams when storage reaches 25%)</td>
<td>580</td>
<td>605</td>
<td>580</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Emergency drought measure 3 (voluntary water usage reduction to 22% at 25% storage)</td>
<td>605</td>
<td>605</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Warragamba environmental flow replacement (environmental and riparian flows replaced by Western Sydney recycling plant. 5ML/d released from Warragamba Dam to dilute Wallacia STP effluent releases)</td>
<td>620</td>
<td>620</td>
<td>645</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Releases for North Richmond Water Filtration Plant</td>
<td>610</td>
<td>610</td>
<td>640</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Inclusion of hydrology 2010-2012</td>
<td>620</td>
<td>620</td>
<td>660</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Inclusion of the 8 month delay in commencement of production of desalinated water from notification to operation.</td>
<td>600</td>
<td>600</td>
<td>660</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>New restriction savings based on Sydney Water demand forecast in March 2015</td>
<td>595</td>
<td>595</td>
<td>620</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Revised Bathymetry for Warragamba storage</td>
<td>605</td>
<td>605</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Release of HEPS storage allocation above FSL -1.0</td>
<td>615</td>
<td>615</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Metro Water Plan 2017 (SDP Stage 1 supply trigger, SDP Stage 2 Plan/Construct Triggers, Removal of groundwater, inclusion of temporary desalination)</td>
<td>575</td>
<td>590</td>
<td>575</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Inclusion of hydrology 2013-2016 and model refinements.</td>
<td>570</td>
<td>600</td>
<td>570</td>
<td></td>
</tr>
</tbody>
</table>
Explanation of each modelling run:

Run 1
Purpose
Undertaken to confirm the previous yield estimate. In 2000 the system yield was estimated at about 600 GL/a, based on the hydrology of the period 1909 to 1998.

Operating Rule
When the total operating volume of the storages falls below 60%, water is transferred from the Shoalhaven system. At 55% of total system storage, water restrictions are introduced to progressively reduce demand for water through 5 levels of restrictions (Level 5 restriction achieving 50% demand reduction).

Results
The system yield was confirmed, and the limiting criterion was the reliability criterion.

Run 2
Purpose
Undertaken to resolve model misrepresentations, and to incorporate improved representation of environmental, riparian and Hydro-electric Power Station (HEPS) releases.

Modification
The WATHNET model gave priority to water supply allocation over environmental flow releases during extreme droughts. This resulted in modelled environmental releases not meeting regulatory requirements specified in the Water Management Licence. Accurate representation of HEPS releases made the water supply system less vulnerable to emptying, hence the modest increase in security yield.

Results
The system yield was reduced by 10 GL/a, limited by the reliability criterion.

Run 3
Purpose
Undertaken to include hydrology for 1999-2004. Accuracy of estimates of dam inflows, losses and transfers has a significant impact on yield estimates.

Modification
Extension of the hydrological data by including the inflows from 1999 to 2004 resulted in a drop of about 6% on average annual flows.

Results
System yield was reduced by 25 GL/a, attributable to the current drought; again the yield was limited by reliability.

Run 3A

Purpose

Undertaken to incorporate stream flow records for Shoalhaven River system for a limited period of 1978-2004. A monthly regression model was previously used to extend the data for the period of 1909 to 1977.

Modification

A daily Hydrological Simulation Program-Fortran (HSPF) catchment model was developed for the Shoalhaven catchment to enable a more accurate estimation of inflows. This catchment model predicted annual average flows 20% less than the previous estimates. This result reasonably reflects the reduced rainfall during the first half of the 20th century.

Results

Revised Shoalhaven flows have a significant impact on the security of yield, due to its reduced contribution during droughts. System yield for security was reduced by 45 GL/a as a result of this revision. System yield remains limited by reliability criterion.

Run 4

Purpose

Undertaken to incorporate a modified water restriction regime which reduced five levels of restrictions to three. Water savings through mandatory water restrictions slow the rate of storage depletion during droughts and serve as an important guard against the dams emptying. When restrictions are less severe, system yield is reduced (and limited by security as shown by the results of this run).

Modification

Level 1 – at least 7% demand reduction, not more than 3% of the time
Level 2 – at least 12% demand reduction, not more than 1% of the time
Level 3 – at least 20% demand reduction, not more than 0.5% of the time
Level 4 – at least 30% demand reduction, not more than 0.3% of the time
Level 5 – at least 50% demand reduction, not more than 0.05% of the time

The above were modified to:

Level 1 introduced at 55% Total Storage: achieves a 7% reduction
Level 2 introduced at 45% Total Storage: achieves a 17% reduction
Level 3 introduced at 40% Total Storage: achieves a 19% reduction

Results

The adoption of the revised restrictions regime resulted in a 65 GL/a loss of security yield and 5 GL/a increase in reliability yield.
Run 5

Purpose
Incorporation of deep water storages as a result of projects at Warragamba and Nepean dams. For this run, triggers for pumping and restrictions are adjusted to the equivalent levels after deep storage is appended.

Modification
An extra 200 GL added to total storage volumes.

Pump mark and demand restriction levels revised for same depletion storage volumes. Deep storage is appended below to the current minimum operating level.

Based on percentages of new total storage volumes:
- Pump mark 63%
- Water restrictions:
  - Level 1 introduced at 59% Total Storage: achieves a 7% reduction
  - Level 2 introduced at 51% Total Storage: achieves a 17% reduction
  - Level 3 introduced at 45% Total Storage: achieves a 19% reduction

A minimum of 100 ML/d maintained in Upper Canal when deep water accessed.

Results
The 40 GL/a increase in yield is due to the availability of additional water during long droughts. There was a slight reduction in Reliability Yield due to the earlier onset of restrictions (this is corrected in Run 6).

Run 6

Purpose
Following commissioning of deep storage access at Warragamba and Nepean dams, the water restrictions regime was recalculated on the basis of new total storage volume. Triggers for restrictions remain at 55%, 45% and 40%, however application of these percentages to the larger storage capacity means that restrictions commence later in a drought.

Modification
Pump mark and demand restriction levels revised based on percentages of new total storage volumes:
- Pump mark 60%
- Level 1 introduced at 55% Total Storage: achieves a 7% reduction
- Level 2 introduced at 45% Total Storage: achieves a 17% reduction
- Level 3 introduced at 40% Total Storage: achieves a 19% reduction

Results
This run increased the reliability yield by 28 GL/a, but reduced security yield by 8 GL/a, because there was less opportunity to reduce demand for water through restrictions. System yield decreased by 8 GL/a.

**Run 7**

**Purpose**

The initial operating rules for the Shoalhaven Scheme allowed the transfer water from Tallowa Dam to supply Sydney whenever the level in the dam was higher than 5.2m below full storage level. In order to protect the Shoalhaven and Kangaroo rivers and to maintain levels in Tallowa Dam, operating limits for transfers were restricted to the top 3m from FSL.

**Modification**

The minimum operating level (MOL) for Tallowa Dam was raised from -5.2m below FSL to -3m below FSL.

**Results**

Reducing the amount of water that can be accessed from Tallowa Dam reduces the reliability yield by 8 GL/a and the security yield by 4 GL/a. System yield is reduced by 4 GL/a.

**Run 8**

**Purpose**

Initial planning to allow for the desalination plant for Sydney if the drought continued. The plant would produce 500 ML/d commencing when storage levels in the dams fell to 15% total operating capacity, and continue production until storages recovered to 30%.

**Modification**

500 ML/d desalination plant constructed
Desalination commences production at 15% of total storage
Desalination ceases production at 30% of total storage

**Results**

Availability of this additional supply source improved security yield by 66 GL/a as this supply is available during extreme drought and is not impacted by inflows. Reliability yield does not change as desalination does not commence until after all 3 levels of restrictions have been implemented. The significant increase in security yield means that the system yield, which has increased by 57 GL/a, is now limited by the reliability criterion.

**Run 9**

**Purpose**

Undertaken to incorporate access to groundwater resources.

**Modification**
Availability of groundwater at two bore-fields would enable an additional 30 GL/a to be accessed for a period of three years during drought, after which it is estimated that this groundwater source would naturally recharge within 7 years.

Results

As this supply source is not implemented until storages deplete to 35%, groundwater does not improve reliability, but increases security by an additional 6 GL/a.

Run 10

Purpose

Undertaken to incorporate revised demand modelling by Sydney Water. Experience during the drought suggested that estimates of demand reductions that could be achieved through restrictions should be lower.

Modification

Restrictions:
Level 1 introduced at 55% Total Storage: achieves a 7% reduction
Level 2 introduced at 45% Total Storage: achieves a 11% reduction
Level 3 introduced at 40% Total Storage: achieves a 12% reduction

Results

Reducing the estimated demand reduction does not affect the duration of restrictions, so reliability yield is not affected. Security yield is reduced by 35 GL/a as storages will approach emptiness more quickly if demand is not reduced significantly by water restrictions. System yield reduces by 20 GL/a, and security is now the limiting criterion.

Run 11

Purpose

Incorporating estimates of the flow that could be achieved from additional groundwater resources.

Modification

Availability of a third bore-field means that a total of 45 GL/a is available for 3 years during drought. Groundwater production will commence when storages deplete to 35% and continue for 3 years followed by a 7 year recharge period.

Results

The availability of this additional supply during severe drought improves system yield, and security yield, by 5 GL/a but does not affect reliability yield.

Run 12

Purpose
Undertaken to incorporate hydrological data for 2005 to 2008, resulting in a drop of about 3% on average annual flows.

Modification

Stream flow data extended from 2005-2008 using monthly flow estimates based on mass balance. HSPF model used to estimate flows to Woronora for period 1909-2004. The inflows for the period 2005 to 2008 included flow volumes that were less than the average inflow but were still high enough to increase or at least maintain the current level of storage. As a result, the generated inflows shifted more towards droughts of longer duration but of less severity. This resulted in a reduction in reliability due to an increase in the time the system is in drought but as the droughts were not quite as severe, the risk of running out of water was lessened thus the corresponding increase in system security. These changes show that the length of hydrology data set is inadequate to fully capture extreme drought conditions.

Results

System yield was reduced by 20 GL/a, and again limited by reliability. It was very interesting to note that the criteria determining the yield changed from security to reliability as a result of the incorporation of this data. Security increased by 10 GL/a, whereas Reliability decreased by 35 GL/a.

Run 13

Purpose

Undertaken to update WATHNET model drawdown rules - minor refinements of modelling dam depletion and geographical distribution of demand.

The operating rules are converted to drawdown charts and used by operational planning team on a day to day basis to select the supply storage. The drawdown chart is modified to include the new Nepean deep water pumping station. The nodal distribution of demand has also changed, increasing demand at critical sources and resulted in overall reduction of yield.

Modification

<table>
<thead>
<tr>
<th>New Distribution of Demand Zone</th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warragamba Township</td>
<td>0.3%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Orchard Hills and Blue Mountains</td>
<td>4.0%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Prospect</td>
<td>77.3%</td>
<td>79.5%</td>
</tr>
<tr>
<td>Helensburgh + Woronora</td>
<td>2.3%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Macarthur</td>
<td>6.0%</td>
<td>6.7%</td>
</tr>
<tr>
<td>Picton and Bargo</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Wingecarribee and Goulburn</td>
<td>0.7%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Illawara</td>
<td>8.8%</td>
<td>6.1%</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>100.0%</strong></td>
<td></td>
</tr>
</tbody>
</table>

Results

Refinements in modelling resulted in a decrease in system yield by 5 GL/a, and a reduction in security yield by 15 GL/a.
Run 14

Purpose

Undertaken to incorporate a modified environmental flow regime for Tallowa Dam. The regime was modified to mimic the inflow pattern: 20% of inflows released when inflows exceed the 80th percentile flow; release same as inflow when inflows are lower.

Modification

Tallowa environmental release changed from 2,736 ML/month (90 ML/day) or total inflow if inflow is less than 2,736 ML/month (90 ML/day) to 7,436 ML/month on average or total inflow if inflow is less than 7,436 ML/month on average + 20% of the difference between inflow and 7,436 ML/Month.

Results

The increase in environmental flows from Tallowa decreases system yield. The yield drops approximately 20 GL/a as a result of the introduction of an 80%ile transparent, 20%ile translucent flow release. The environmental releases for Tallowa Dam have a greater impact on system security than system reliability when the transfer pump mark is at 60%. At higher transfer pump marks the Shoalhaven System contributes mostly to reliability, as shown in Run 15.

Run 15

Purpose

Undertaken to incorporate a new trigger for commencing transfers from Shoalhaven to Sydney.

Modification

Revision of trigger for commencement of pumping from the Shoalhaven (new pump mark is 75% of total system storage to commence pumping and 80% of total system storage to stop pumping).

Results

When the pump mark is increased from 60% of total system storage to 75% of total system storage, it provides increased opportunity to transfer water from the Shoalhaven system to the Sydney system, helping to maintain the total storage. This reduces the frequency of the storage dropping below restriction triggers, resulting in a significant increase in reliability yield (30 GL/a) and some increase in both system yield and security yield (10 GL/a).

Run 16

Purpose

Incorporates improvements identified in 2009/2010 water supply system yield review.
Modification

Updates including:
- WATHNET model update and refinements including: revised drawdown rules; and Inclusion of Prospect Reservoir and inflow & evaporation losses from the reservoir);
- corrected evaporation;
- demand distribution based on Sydney Water Demand Projection of 20 May 2009, however the changes are minimal;
- inflow hydrology extended to 2009; and
- improvement to synthetic generation methodology.

Results

Some modifications had a positive impact on the yield, some had a negative impact, while others had no impact. For example, the evaporation correction had positive impact, incorporation of more uncertainty in synthetic generation had negative impact, whereas the introduction of Prospect Reservoir no impact on yield. Overall it resulted in a reduction in system yield of 15 GL/a.

Run 17

Purpose

Undertaken to incorporate new operating rules for transfers from Tallowa Dam.

Modification

Minimum operating level for Tallowa Dam moved from –3m to –1m. This results in a decrease of 14 GL in available storage for transfers to the Sydney system due to the changes from 22 GL at MOL -3m to 8 GL at MOL -1m.

Results

Reducing the volume of the pumping pool from Tallowa Dam from –3m to -1m results in a decrease in contribution from the Shoalhaven transfer scheme. The result is a decrease in the volume of water available for transfers, which has the effect of reducing the yield by 5 GL/a.

Run 18

Purpose

Revision of desalination plant operating rules.

Modification

Desalination plant operation modified from 500 ML/d on at 15%, off at 30% to Stage 1 – 250 ML/d at 70% storage until storage levels reach 80%. Stage 2 – 250 ML/d at 20% storage until storage levels reach 80%.
Results

Increasing the desalination triggers increases both reliability and security yields. System yield increases by 70 GL/a but is still security constrained.

Run 19

Purpose

Introduction of modified environmental flow regime from Metropolitan dams to mimic the inflow pattern.

Modification

80/20 Environmental flow release rules implemented at Nepean, Avon, Cordeaux, Cataract and Woronora dams. Under the new regime: if inflow is less than 80th percentile flow all inflow is released; if inflow is greater than 80th percentile flow then 80th percentile flow and 20% of the flow above 80th percentile flow is released.

Results

The increase in environmental flows released from the metropolitan storages results in a reduction in system yield by 25 GL/a with security yield still being the limiting criterion.

Run 20

Purpose

Undertaken to incorporate revised water restrictions regime.

Modification

Restrictions:

- Level 1 at 50% storage achieves a 10% reduction.
- Level 2 at 40% storage achieve an 11% reduction.

Results

Revised restriction regime increases reliability yield by 45 GL/a because the restrictions are introduced later in the drought. However, it reduces security yield by 5 GL/a because it increases the risk of the dams emptying. The system yield is reduced by 5 GL/a.

Run 21

Purpose

Incorporation of Emergency drought measure 1.

Modification

Tallowa Dam minimum operating level (MOL) lowered to -3 m at 35% storage.
Results

Accessing increased storage from Tallowa Dam during droughts increases the security yield by 5 GL/a. The system yield is increased by 5 GL/a.

Run 22
Purpose

Incorporation of Emergency drought measure 2.

Modification

Halve environmental flow releases from dams when storage reaches 25%.

Results

Halving environmental flow releases from all dams during severe droughts has a significant positive impact on security yield (+20 GL/a), and also on system yield. This is because it reduces the demand on the dams and therefore reduces the risk of dams emptying, providing more time for inflows to the dams. However there is no change in reliability yield as this measure comes late in the drought. The system is still security constrained.

Run 23
Purpose

Incorporation of Emergency drought measure 3.

Modification

Voluntary water usage reduction to 22% at 25% storage.

Results

Voluntary water usage reduction during a severe drought increases the security yield considerably by reducing the draw on the dams. However there is no change in reliability yield as this measure comes late in the drought. It is obviously very critical that the additional 11% reduction in demand (over and above Level 2 restrictions) is achieved, otherwise yield will remain somewhere between 580 and 600 GL/a. Assuming the 22% reduction in demand is achieved, the resulting system yield is increased by 25 GL/a, and the system becomes constrained by the reliability criterion.

Run 24
Purpose

Warragamba environmental flow replacement.

Modification

Warragamba environmental and riparian flows replaced by Western Sydney recycling plant.
Maximum of 5 ML/d released from Warragamba Dam to dilute Wallacia STP effluent releases.

Results

Reducing the current environmental and riparian flows from Warragamba Dam from 43.3 ML/d to 5 ML/d results in 15 GL/a increase in both security and reliability yields. The resulting system yield is increased by 15 GL/a, and remains limited by the reliability criterion.

Run 25

Purpose

Incorporate releases for North Richmond water filtration plant

Modification

Incorporate flow releases from Warragamba Dam to meet requirements of the Greater Metropolitan Water Sharing Plan under clause 35(1) and 35(2). The SCA is required to make the following daily releases from Warragamba Dam for supply to Nth Richmond WFP:

- 17 ML/d during 1 April to 31 October; and
- 25 ML/d during 1 November to 31 March.

Results

System yield is reduced by 10 GL/a, and remains constrained by reliability.

Run 26

Purpose

Inclusion of hydrology 2010-2012

Modification

The hydrological data of 1907-2009 was used previously in the model. This has been extended to include inflows for year 2010, 2011 and 2012. A new set of 2,000 synthetic hydrological sequences were generated and used in the model.

Results

System yield is increased by 10 GL/a, and is constrained by reliability. The inflow for year 2012 was 3,615 GL/a which is well above average inflow (2,629 GL/a). The supply system yield showed some recovery from the shock of millennium drought. The result also highlighted that 104 years' hydrological records is insufficient to capture the extreme variability observed.

Run 27

Purpose

Include an allowance for the start-up period from deep shutdown for the commencement of Sydney Desalination Plant (Stage 1) at 250 ML/d.
Modification

The MWP 2010 current supply configuration includes the availability of 250 ML/d capacity of Stage 1 desalination at 70% of total storage and Stage 2 capacity of 250 ML/d at 20% of total storage. An 8 month time period for start-up from deep shut down as per the IPART price determination has been modelled from the starting trigger of 70% of total storage.

Results

As a result of the 8 month delay, the long term average desalination production is reduced from 15.7 GL/a to 10.0 GL/a. This reduces yield by 20 GL/a, with reliability again constraining system yield.

Run 28

Purpose

New water restriction savings based on SWC demand forecast in March 2015.

Modification

SWC updated its forecasted demand for 5, 15 and 50 year time frames. The demand forecast also included an assessment of impact of water restrictions. The reduced demand due to restrictions is considered as demand savings. The previous yield evaluation in 2012 used demand savings of 10%, 11%, 22% respectively for restrictions of Level 1, Level 2 and Voluntary Targets. The restriction savings varied over time and also in scenarios.

The next 10 year average and reference case scenario for yield impact analysis will be used as it is being used for developing the 2017 MWP. The demand savings are modified as advised in the model to 3.7%, 7.8% and 13.7% for Level 1 and Level 2 and Voluntary Targets (Level 3) respectively.

Results

The 40 GL/a reduction in security yield is due to the reduction of demand savings under Voluntary Targets (Level 3). However, reliability yield is only reduced by 5 GL/a and remains the constraining factor.

Run 29

Purpose

Revised bathymetry for Warragamba and Woronora storages

Modification

Warragamba Dam storage volume increased by 37 GL and Woronora Dam storage volume reduced by 3 GL to reflect the results of the latest bathymetry survey.

Results

System yield is increased by 10 GL/a, and remains constrained by reliability.
Run 30

Purpose

The Hydro Electric Power Station (HEPS) at Warragamba Dam was handed over from Eraring Energy. The storage above FSL -1.0m had been allocated for power generation. Now it cannot be used, resulting in access to top metre (pending operational needs) for water supply purposes.

Modification

Release of HEPS storage allocation above FSL -1.0m for water supply.

Results

System yield is increased by 10 GL/a, and remains constrained by reliability.

Run 31

Purpose

In March 2017 NSW Government released the updated Metropolitan Water Plan 2017. The Plan outlines the new rules for the operation of Sydney’s bulk supply system.

Modification

a) Sydney Desalination Plant:

Stage 1: Desalination Plant 250 M L/d (DS1)

ON - when Total Storage is less than 60% (Note: eight month transition to start during which time the plant does not supply).

OFF – when Total Storage exceeds 70% (Note: will operate for at least a minimum of 12 months after starting irrespective of storage level).

Stage 2: Desalination Plant 250 ML/d (DS2)

Details for the Stage 2 Desalination Plant are provided in the Table below:

<table>
<thead>
<tr>
<th></th>
<th>Storage Trigger (%)</th>
<th>Duration (months)</th>
<th>Shelving Period (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Planning</td>
<td>50</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Detailed Planning</td>
<td>45</td>
<td>14</td>
<td>48</td>
</tr>
<tr>
<td>Construction</td>
<td>35</td>
<td>24</td>
<td>-</td>
</tr>
</tbody>
</table>

b) Removal of drought supply from groundwater and inclusion of drought supply from Temporary Desalination Plants (48 ML/d)

- Trigger for construction when Total Storage is less than 25%.
- 12 month implementation time for supplying at 50% of capacity.
- 24 months implementation time for supplying at 100% of capacity.
- ON when Total Storage is less than 40%.
- OFF when Total Storage is less than 85%.
Results

Security yield dropped by 55 GL/a and reliability yield dropped by 25 GL/a. System yield is decreased by 40 GL/a, and now constrained by security.

Run 32

Purpose

Inclusion of hydrology 2013-2016 and model refinements.

Modification

a) Model refinements include:
- Prospect evaporation and inflow were removed since they have no impact
- Fitzroy Falls deep storage was made available for evaporation (this was required to avoid the model crashing)
  - operating storage 10,000 ML
  - full storage 20,000 ML (23,500 ML)
- Fitzroy Falls e-flow modelled
  - FF inflow is 4.4 times Wilds Meadow Inflow
  - FF E-flow is 5/3 of Wilds Meadow Inflow
  - FF E-flow is 0.4 of FF inflow
- Avon deep storage was made available for evaporation (this was required to avoid the model crashing)
  - operating storage 146,700 ML
  - full storage 214,000 ML
- Adjustment for Shoalhaven pumping to account for impact of monthly time-step (as recommended by 2016 independent yield review)
  - Actual operation is daily; during an inflow event daily inflows can vary significantly (resulting in spill during some days in a month mainly due to very small operating storage at Tallowa). When monthly time step is considered, due to averaging, some inflow events may not spill and make more water available for pumping, resulting in more pumping in a monthly model compared to daily model.
  - In the graph below monthly Shoalhaven pumping volumes using daily and monthly time steps:
    - It can be seen that above 30,000 ML/month the monthly model overestimate the volume pumped compared to daily model. **Recommended to limit the monthly transfer capacity to a maximum of 30,000 ML (based on daily capacity monthly capacity = 1500*30.4=45,600 ML).**
Further the monthly transfer from daily model is about 10% less than the monthly transfer from the monthly model. **Recommended to apply a factor of 0.9 to in the monthly model for Shoalhaven pumping from Tallowa to Fitzroy Falls.**

b) **Historical inflow was extended from 2012 to 2016 and 2000 synthetic inflow replicates were generated using parameter uncertainty.**

**Results**

Security yield dropped by 5 GL/a, and reliability yield increased by 10 GL/a. System yield is decreased by 5 GL/a, and remains constrained by security.