WATER SERVICES ASSOCIATION
of Australia

Framework for Urban Water Resource Planning

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Foreword

This document provides a framework for urban water resource planning that is designed to assist water utilities to engage the community in water resource planning. The key elements of the framework are:

- An appreciation of the inherent trade-offs between the social, economic and environmental costs of supplying water versus not supplying water.
- An understanding of the importance of community input in setting level of service objectives and the need to express the level of service in terms that are easily interpreted by the community.
- A guide to the technical factors to consider when determining the current level of service or when undertaking a yield analysis.
- A discussion of the uncertainties inherent in a yield analysis.
- A preferred glossary of commonly used terms in water supply planning and recommendations to cease using confusing or misleading terms.
- A pro-forma for defining the current level of service and level of service objectives, which is an illustrative example of the type of information that can be used to engage the community.

This framework will help water utilities to communicate with stakeholders and the community in general and to reassure them that their water supplies are being managed to their expectations. This framework may evolve over time as new issues arise in the industry, as guided by each utility's experience in working with the community on these issues.

1. Acknowledgement

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The authors and WSAA also acknowledge the contribution of the project steering committee, which included WSAA members Gary Bickford of ACTEW-AGL, Brendan Berghout of Hunter Water, Bruce Rhodes of Melbourne Water, John Williams of SA Water, Peter Borrows of South-East Queensland Water, Amir Deen of Sydney Catchment Authority, Graeme Hughes of the West Australian Water Corporation, Shaun Cox of Gold Coast Water, and Ross Young of WSAA as Chair of the Steering Committee and Project Manager.

The Steering Committee provided valuable feedback on the contents of this document and engaged in healthy discussion on the long-term water supply planning issues facing water supply utilities.

Table of Contents

Table of Contents

Continued

2. Introduction

A safe and reliable water supply system is of utmost importance to the community. It is expected and understood that water utilities manage their water resources so that communities never run out of water. As a bare minimum, water utilities need to define what the minimum supply requirement is and then ensure that they always have enough water to meet it. Minimum supply volumes will vary depending on the community involved and the consequence of minimising supply. For example a small urban community may be prepared to cart water whereas a larger community such as a capital city cannot afford to do this.

Restrictions will be required from time to time in Australia because of the variability of rainfall, unless water supply systems are ‘gold plated’ through the construction of generous buffer supplies. Such buffers come at a high economic and environmental cost and are hard to justify when they may only be required once every 20 years. Some sectors of the community are however becoming dependent on a high level of reliability and are prepared to pay for it. This places additional stresses on the limited water resources but needs to be taken into consideration by water managers.

The current long drought across much of Australia and the potential effects of climate change have raised community awareness and concern about the reliability of their water supply systems. It is important that the urban water industry engages customers and stakeholders about how water supply systems work and the reliability of supply they can expect.

There is a culture in Australia that is quite accommodating when it comes to water restrictions, as most people understand the fickle nature of our climate. By the same token, people are less likely to accept regular or long duration harsh restrictions that may result in gardens dying or the lessening of the quality and amenity of urban life.

The issues facing water managers of the future may well be different to those which have been dealt with in the past. Uncertainty with factors such as the impacts of climate change and the way in which people use water will affect water resources planning. As urban communities become more affluent, there are expectations of higher levels of service from water supply systems. The opportunities to simply build additional dams to meet increasing demands are limited and alternative measures must be considered, such as demand management, desalination plants and the use of recycled water.

Consumers are also becoming more aware of the need to conserve water and where the implementation of restrictions in the past had a significant impact in demand reduction, hardening of customers to restrictions will mean that in the future less reductions in demand will be achieved.

A balance between what is desired, what is acceptable from an environmental perspective and what the community can afford needs to be found. Often the community will have to find a balance between a higher standard for the environment and a higher standard for itself.

Other issues facing water managers of the future relate to homeland security where it may be prudent to not rely on a single source of water for supply due to the threat of terrorist activity and potential water quality issues.

2. Introduction

Continued

The frequency, severity and duration of water restrictions that a community can expect is called the level of service. After a water utility has assessed its own risks, it is important that it works with the community to determine an appropriate level of service objective for a water supply system. This process inevitably involves tradeoffs between financial cost, environmental impact and the willingness of the community to accept restrictions on a periodic basis. Explaining these tradeoffs to the community has proven to be problematic in the past, not because the community does not understand them but more because the modelling used is complex and the terminology is technical in nature. Furthermore, levels of service are generally expressed in probabilities and probability theory is a concept that many people are not fully familiar with.

If the urban water industry has to communicate with decision makers and communities on the range of options they could potentially choose for determining a level of service, it is imperative that the industry can explain the concepts, the options and the tradeoffs in an easily understood manner.

This report aims to provide a framework to guide water utilities when working with their communities in planning for urban water resources. This report does not recommend a preferred or ideal level of reliability of supply (other than that communities should never run out of water) as this is a decision for regulators and utilities, taking into account community expectations, environmental, financial and other technical issues. The report outlines the elements that the water industry should take into account during the planning process, and the uncertainties involved in looking forward a number of decades when dealing with a complex system. Furthermore, the report provides a guide to terminology to be used and terminology to be avoided, as well as standard definitions so that the utilities speak the same language to their communities and stakeholders.

The adoption of the principles contained in this paper will also assist in making comparisons in the levels of service chosen in different areas around Australia.

The current drought and the recent imposition of restrictions has put fears into many that their community is going to run out of water. Such fear can often promote inappropriate and irrational decisions. It is important that the urban water industry is able to explain the concepts behind the reliability of supply calculations so that communities, key stakeholders and the urban water industry can work together to mutually agree on a level of service objective.

3. Level of Service Objectives

3.1 Long-term level of service objectives

Water utilities have a responsibility to supply water to the community, but at the same time they are running a business that must balance increasing demands for water due to population growth with the cost of supply and the willingness of the community to pay for that water. Costs include the financial, social and environmental cost of supply.

The primary objective of a water utility is to ensure that the community has a safe and reliable water supply system and to communicate this to consumers. This does not mean that there will never be restrictions, but it does mean that a community can expect to never run out of water. This primary objective consists of three main components, namely that:

- the supply system has the capacity to maintain an adequate level of supply over most periods in the long-term,
- when drought periods occur, a drought response plan provides short-term protection against running out of water through the implementation of water restrictions. Drought is defined by the Bureau of Meteorology as a serious (lowest 10% of records) or severe (lowest 5% of records) rainfall deficiency over a period of three months or more (Bureau of Meteorology, 2004), and
- in cases of extreme drought, a contingency or emergency plan exists that ensures that basic water needs for a community can be met for the duration of the emergency.

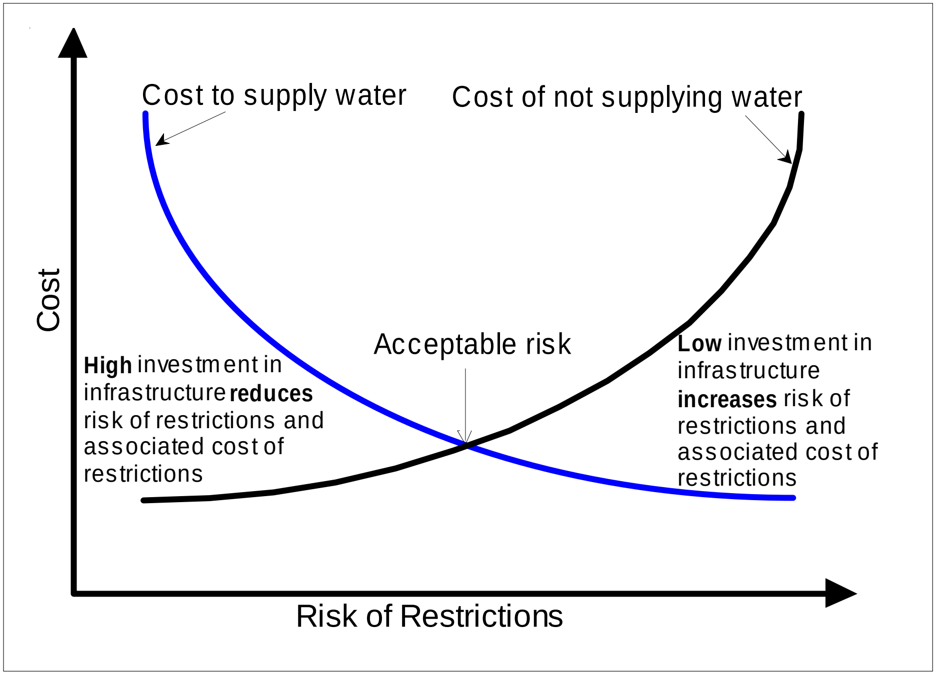
These high level objectives can be translated into specific objectives for a water supply system, known as level of service objectives. **The level of service objective is the desirable maximum frequency, duration and severity of water restrictions expected by the community** and is fundamental to the definition of water supply yield. The yield of a supply system is the average annual volume that can be supplied by a water supply system at the adopted level of service objective. **Yield is always assigned a probability of occurrence**, as defined by the level of service objective, and there will always be a probability that this yield cannot be provided.

Restriction policies must be simple to understand and clear to the community. Too many levels of restriction or too much detail will only serve to confuse the community and result in frustration for both consumers and the water utilities.

When defining level of service objectives, there is a trade-off between the cost of providing a given level of service and the cost of not providing that level of service, as illustrated in Figure 3-1. The cost of not providing a given level of service is the cost to the community associated with implementing and enduring drought response measures. Costs range from loss of aesthetics (eg fountains being turned off), inconvenience (eg not being able to water gardens during the day), loss of assets (eg lawns) and loss of income (eg reduction in tourist numbers or impacts on the home gardening industry). For large urban centres such as capital cities, the imposition of prolonged, severe restrictions that cause anxiety in the community that it may run out of water is untenable and must be avoided.

The frequency of water restrictions and emergency measures can be reduced but often only at increased financial, social and environmental cost of supply. The increased financial cost of supply arising from accessing new resources is passed on to the consumer, whereas the environmental and social costs are borne indirectly by the community. At some point, consumers will be unwilling to pay to achieve this level of service because they perceive the costs associated with restrictions to be less than the costs associated with reducing the frequency of those restrictions. The desirable level of service is where the cost of restrictions is acceptable to the community relative to the cost of supplying that water. Of course, it should be recognised that there are differing sectors of the community and these will have various interests and abilities to pay for water. The art in choosing an appropriate level of service objective is to fairly represent all sectors of the community having regard to long-term sustainability.

Figure 3-1 Trade-off for setting level of service objectives



3.2 Other level of service objectives

The ability to meet demands on a long-term annual or monthly basis does not necessarily guarantee that peak daily or peak hourly demands can be supplied. It is assumed that prudent planning incorporates upgrades of distribution mains and balancing storages and that these do not constrain the meeting of demand in local areas.

Level of service criteria for urban water supplies will also include water quality and pressure objectives that can affect reliability of supply. Poor water quality events that make water undesirable or unhealthy to consume will cause interruptions to water supply. Similarly, insufficient pressure to high elevation areas at times of peak demand can also result in consumer dissatisfaction. Meeting level of service objectives for supply is considered to be separate from the ability to meet level of service objectives for water quality and pressure, though implicitly performance in these other areas may impact on the ability of an organisation to meet demands. The drawing down of reservoirs during drought, for example, can cause water quality and pressure reduction problems before reservoirs drop to minimum operating levels. These factors should be incorporated into yield assessments to adjust minimum operating levels if these problems are observed in particular systems. Planning for water quality and pressure should therefore occur in conjunction with long-term water supply planning.

4. Framework for Methodology

This section of the report outlines a framework for assessing yield as part of long-term water resource planning.

4.1 Overall approach

The overall approach to yield assessment is as shown in Figure 4-1. The key aspects of this approach are:

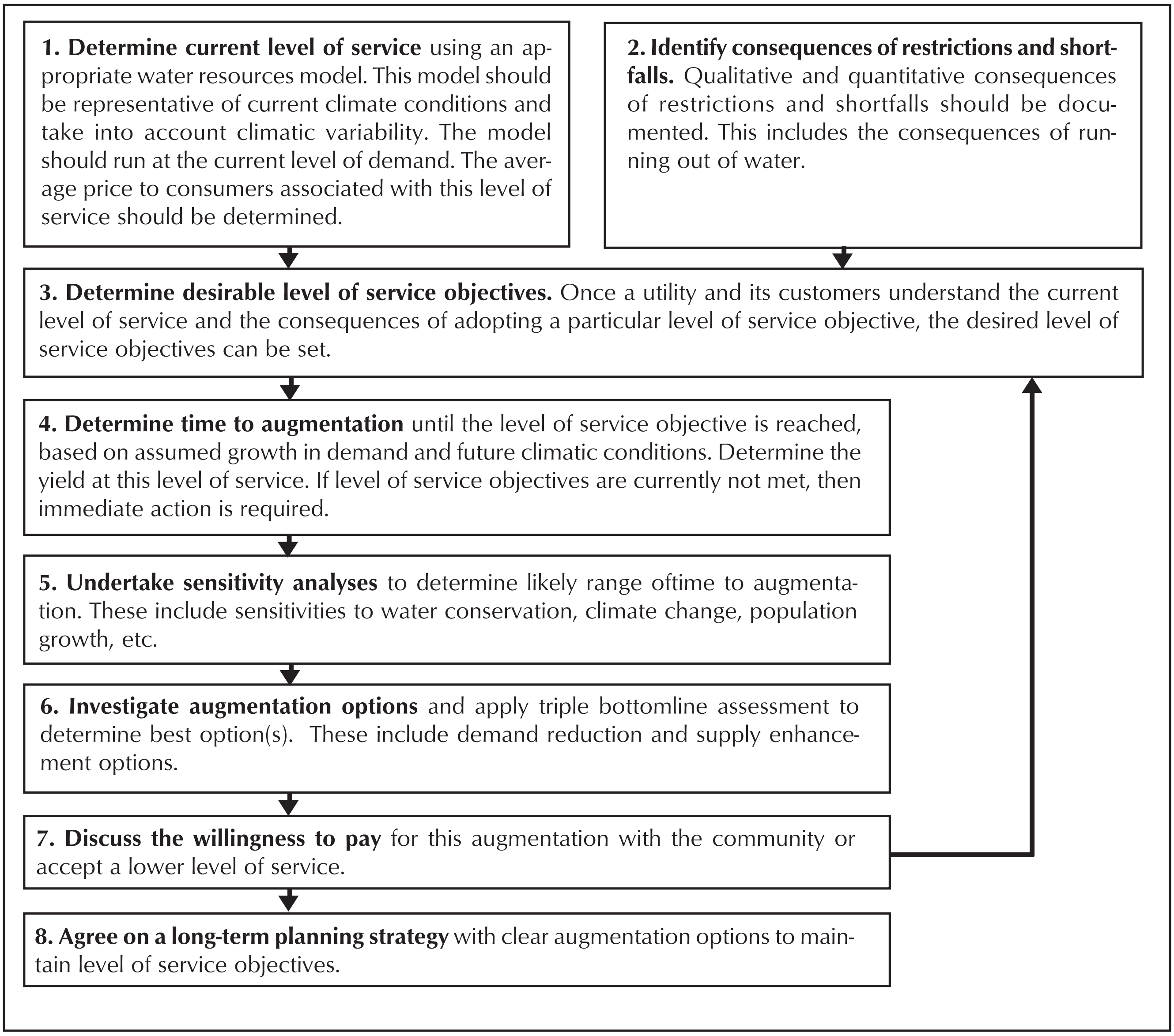
(i) that the community must be provided with an understanding of its current level of service,

(ii) that it understands in general terms the uncertainties and risk associated with that level of service, and

(iii) that it has the opportunity to amend its level of service objective if the social, economic and/or environmental cost of additional supply is considered unsatisfactory.

In this overall approach it is the responsibility of the water utility to select an appropriate water resource model, undertake relevant sensitivity analyses and adopt current best practices for triple bottom line reporting for modified or new supply options.

Figure 4-1 Overall approach for water supply planning



1. Determine current level of service using an appropriate water resources model. This model should be representative of current climate conditions and take into account climatic variability. The model should run at the current level of demand. The average price to consumers associated with this level of service should be determined.

2. Identify consequences of restrictions and shortfalls. Qualitative and quantitative consequences of restrictions and shortfalls should be documented. This includes the consequences of running out of water.

3. Determine desirable level of service objectives. Once a utility and its customers understand the current level of service and the consequences of adopting a particular level of service objective, the desired level of service objectives can be set.

4. Determine time to augmentation until the level of service objective is reached, based on assumed growth in demand and future climatic conditions. Determine the yield at this level of service. If level of service objectives are currently not met, then immediate action is required.

5. Undertake sensitivity analyses to determine likely range oftime to augmentation. These include sensitivities to water conservation, climate change, population growth, etc.

6. Investigate augmentation options and apply triple bottomline assessment to determine best option(s). These include demand reduction and supply enhancement options.

7. Discuss the willingness to pay for this augmentation with the community or accept a lower level of service.

8. Agree on a long-term planning strategy with clear augmentation options to maintain level of service objectives.

4.2 Setting level of service objectives

Level of service objectives should be established with input from the community. The objectives set should take into account the consequences of not supplying water and the ability to provide alternative sources of supply (eg small towns can often cart water from somewhere else at low cost). According to Samra (1989), level of service objectives should be framed from the customer's viewpoint, with the frequency, duration and severity of restrictions being what consumers most easily relate to. It was considered by Samra (1989) that expressing yield results as a percentage reliability is foreign to customer perceptions. Although most people now have some understanding of probability, many may still find the concept of reliability confusing. A pro-forma to help set level of service objectives is contained in Appendix A.

Community expectations will differ for different locations. In Canberra for instance, experiencing Stage 3 (of 5 stages) is considered unacceptable for some residents. Perth, Adelaide and Melbourne have introduced permanent water conservation measures, which represents a shift in community expectations. The actions restricted under each stage of restriction should be tailored to each community, because different communities will prefer different methods for achieving desired reductions in demand. For example, one community may value sports grounds more than public fountains, but another community may have an iconic public fountain with tourist value and may prefer to restrict the watering of sports grounds before turning the fountain off. A uniform national standard for each level of restriction is not appropriate because of these differences, but each water utility should be uniformly transparent about the users affected by each stage of restriction and the likely water savings that it will bring.

The risk associated with emergency measures and the ability to mitigate impacts should also be examined. Each water utility will have different level of service objectives commensurate with this risk. Gold Coast Water and South East Queensland Water, for instance, have opted to adopt very high level of service standards because it is extremely difficult to put in place emergency supply options for major urban centres within an appropriate timeframe. On the other hand Adelaide can purchase water from other water users at a reasonable cost if it is exposed to short-term supply shortfalls and the risk of catastrophic failure of its supply system is very low.

4.3 Developing an appropriate water resources model

The particular modelling approach selected may vary according to the risk associated with having a less accurate analysis. A guide for the type of model to be used is as follows:

- small towns (say less than 10,000 people) – use historical streamflow data with minimum 30 year period of analysis. More data should be used if available,
- large towns (say 10,000 to 100,000 people) – use historical streamflow data where available and supplement with synthesised data to produce a minimum 100 year period of analysis. This should be combined with a qualitative assessment of uncertainty, and
- cities (say greater than 100,000 people) – use both historical streamflow data with minimum 100 year period of analysis and stochastic data generation to help understand uncertainty and determine yield.

These minimum periods of assessment are required to reduce uncertainty in yield and reliability estimates, predominantly due to the uncertainty in climatic variability. It can be seen from Table 4-1 that to reduce the standard error of estimate of the mean annual flow to within 10%, at least 25 years will be required for streams of low variability ($C_V < 0.5$). A 100 year minimum period of assessment for large towns is considered appropriate given that this length of record is required to reduce the standard error of estimate of the mean annual flow to within 10% for highly variable streams (C_V=1.0) or within 5% for streams of low variability.

4. Framework for Methodology
Continued

Table 4-1 Minimum lengths of record (years) to estimate mean annual streamflow

Coefficient of variation, C_v	Minimum length of record for standard error $\leq \pm5\%$	Minimum length of record for standard error $\leq \pm10\%$
0.3	36	9
0.5	100	25
0.7	196	49
1.0	400	100

Source: T.McMahon, University of Melbourne, pers.comm. 12/1/2005 based on McMahon and Mein (1986)

Where historical streamflow data is not available for the lengths recommended, two principal techniques can be applied to synthesise streamflow data. These include the use of regressions with nearby streamflow gauges and/or calibrated rainfall-runoff models.

4.4 Whole of catchment modelling

The extent and level of detail in an urban water resource model must be sufficient to adequately represent the constraints on the resource. These include reductions in available resource due to other users, both upstream and downstream, or from groundwater. This includes the downstream requirements for water by the environment. Water quality can also be a constraint on available resources and needs to be dealt with as appropriate (refer Section 3.2 for further discussion).

4.5 Supply systems supplied from groundwater

Groundwater is not used as the sole source of supply for any of Australia's capital cities. In some cities, such as Perth, groundwater is a major component of total supply and in country towns, groundwater is often the only source of reticulated water supply. Groundwater yield is determined by long-term pump tests on individual bores and by regional assessments of the annual volume that can be extracted from an aquifer. The annual reliability of this yield is generally a function of previous drawdown and the aquifer characteristics. Nevertheless, restriction triggers can be set for extreme climatic events based on groundwater levels in a nearby observation bore, for instance. As demands increase due to population growth and the bore yield is approached, the cost of finding a new source of water, such as drilling a new groundwater bore, still needs to be assessed against accepting a lower level of service. This process is essentially the same in concept as for a surface water supply system.

4.6 Supply systems supplied from desalination

Desalination is currently proposed as a water supply option for Perth and potentially for other cities in the future. Desalination plants provide a very reliable source of water, albeit at an increased cost of production and with the associated need to dispose of the waste brine in an ecologically sensitive manner. In a yield analysis, water sourced from desalination plants can be defined by the capacity of the plant, provided that the source of water to be desalinated is inexhaustible, such as when using seawater.

4.7 Surface water supply options

Surface water supply options include the construction of new reservoirs, raising existing reservoirs or building new pipelines to transfer water from adjacent catchments. There are well established methods for accounting for these supply enhancements when calculating changes to water supply yield.

As available water becomes scarcer, surface water resources are becoming fully allocated in many parts of Australia. Water utilities are diversifying their water supply sources by using recycled water, third pipe systems, groundwater resources, desalination plants, stormwater and rainwater tanks.

4.8 Accounting for alternative water sources

Alternative water resources present an opportunity for supply enhancement but the methods for accounting for these in yield calculations are not well established. Alternative or non-traditional water sources include recycled water and rainwater tanks. Recycled water can involve a range of sources, including recycling water from a wastewater treatment plant or use of grey water for garden watering in an individual household. It can be speculated whether recycled water represents a reduction in demand, because the demand for water will reduce from existing supply sources, or whether it represents an increase in supply. The same dilemma exists for rainwater tanks, which fall outside of the reticulated water supply system. The decision about whether these water sources increase supply or reduce demand depends on where the boundary is placed around a water supply system. From a yield modelling perspective, it is recommended that all forms of alternative water sources should be considered as an increase in supply, because the demand for water, regardless of its source, remains unchanged. Only demand management measures, such as the installation of water efficient appliances, truly reduce demand. Accounting for alternative sources of supply in this way will help to communicate to the community that there is still a financial cost and potential environmental impact associated with supply from these options and will enable comparison of the amount of water sourced from existing and alternative supply sources. Private alternative water sources such as rainwater tanks could also potentially provide water to the supply system during extreme drought events.

Where the volume of this alternative water supply is small and distributed throughout the supply system (eg rainwater tanks), it may be more practicably feasible to model these as a reduction in demand. Care needs to be taken in assessing the reductions in demand from private water sources as data is difficult to obtain on how these systems are used, whether they are properly maintained and whether they still operate after home ownership change. This assessment needs to be made on a case by case basis.

Irrespective of the accounting method, it is essential for the purpose of calculating supply risks that all supplies and demands should be accounted for and that any climate dependency of these input and outputs is also taken into account. In an extreme drought, consumers may switch their source of supply from rainwater tanks to mains supply, for example. This will increase demand for water from the water utility during periods of scarce supply.

4.9 Stochastic versus historic data

Yield can be assessed using a historical sequence of inputs, a stochastically generated input sequence, or both. The use of historical data as input to a water resources model means that only one historical sequence is analysed. In the future, the sequence of wet and dry conditions could be different, resulting in a different estimated value of yield.

Stochastically generated inputs are a way of examining potential behaviour under different climatic sequences. It is important to note that stochastic data generation does not improve the estimate of yield, but rather it helps to understand the uncertainty surrounding an estimate of yield by providing insight into the distribution of estimates over a range of potential climatic sequences. Data sequences generated by stochastic modelling have the same statistical properties as the historic data but offer different sequencing so that the possibility of longer periods resulting in more severe dry spells can be modelled and understood.

Two approaches are available for generating stochastic data. All inputs (ie streamflow and climate) can be stochastically generated, or else only climatic inputs can be stochastically generated. If only climatic inputs are generated, then demands and inflows can be derived using climatically driven demand models and rainfall-runoff models. Both approaches are appropriate, however there are advantages and disadvantages with each approach. The main advantage of undertaking the stochastic data generation on streamflow is that:

- errors associated with rainfall-runoff modelling are not introduced because the stochastic data generation is undertaken directly on streamflow.

However, the advantages of undertaking the stochastic data generation on rainfall and evaporation, and then incorporating the stochastic data into a rainfall-runoff model are that:

- climate data is generally available for a longer time period than streamflow data and hence there is greater confidence about the statistical representativeness of the sample in the input data set; and
- climate and land-use change impacts on streamflows can be included in the analysis.

Stochastic data is usually best treated as replicates with the same length of record as the original reference time series. For example, the generation of 200 replicates from a 50 year input sequence is best analysed as 200 alternative realisations and not as a single 10,000 year sequence. Each of these realisations can be made independent by the random seeding of start conditions for each replicate.

In relation to interpreting system performance against the defined level of service criteria, it should be understood that using synthetic streamflow sequences does not provide an alternative “better” estimate compared to the estimate produced through analysing the historic sequence. The value of stochastic data is that it provides insight into:

- the likely impacts of potentially more extreme (than observed in the historic record) drought periods;
- the likely distribution of system performance measures and/or yield estimates given the uncertainty relating

to climatic variability; in this context, it allows confidence bands on performance measures and/or yield estimates to be estimated; and

- performance against measures that are more extreme than can be analysed using the available length of historic record.

Analysis of stochastically generated synthetic sequences should therefore be used to support, and provide context to, analysis of the historic sequence, rather than as a replacement.

4.10 Allowing for uncertainty

The various sources of uncertainty in water resources modelling are discussed in detail in Section 5. The use of stochastic data generation and sensitivity analyses can help to explain this uncertainty. Once the magnitude of this uncertainty is understood, appropriate allowance can be made for this uncertainty, for example through the use of contingency storages.

4.11 Average monthly versus climatically varying demands

The type of input demand sequence used in yield analysis depends upon the variability of observed volumes supplied. Urban demands exhibit a high seasonal variation and hence some form of seasonal variation in modelled demands is required. Annual variability of demands is generally less pronounced than seasonal variability, but consumers will consume more water in dry years than in wet years, for example because gardens require more water. Use of average monthly demands in urban centres with significant observed annual variability in volume supplied may lead to overestimation of yield.

4.12 Future Demands

Assessing yield generally requires demands to be increased until level of service objectives are no longer met. Yield estimates can be calculated through system simulation modelling assuming either:

- a constant level of average annual demand for each simulation sequence, with a single uniform increase over the whole period of simulation to represent each future demand scenario; or
- an increasing level of average annual demand, corresponding to the estimated population growth rate into the future.

Both methods are valid, but there are subtle differences that should be noted and understood. Assuming a constant level of average annual demand is, in general, more commonly used in yield assessments. This results in an estimate of yield that equates to the amount of water that can be supplied per year on average, whilst satisfying the level of service criteria, over the entire simulation period.

Simulation using an increasing level of demand (representing demand growth) over the simulation period is also used by some large urban water authorities in conjunction with the analysis of multiple simulation replicates. These replicates may be either recycled historic or synthetically generated inflow/climatic sequences. In these cases, yield is calculated based on assessing the level of service criteria (eg. frequency of restrictions, probability of reservoir levels dropping below a specified volume, etc.) for each simulation year across all replicates. This is in contrast to analysing the system's performance over the full sequence length in each simulation replicate as is typically done in the case where a constant level of demand is assumed.

Simulation using an increasing level of demand has the advantage of allowing one multiple replicate simulation run (as opposed to running multiple simulations) to be used to determine potential augmentation timing requirements. Augmentation timing is estimated using this approach by identifying the year in the simulation where the level of service criteria are no longer met, when assessed probabilistically across all replicates, due to growth in demand. The approach of using increased demands allows for the fact that the impact on reservoir levels would, in practice, be less during the years leading up to the time where the level of service criteria are no longer satisfied. This approach is particularly relevant in systems with several years of carryover storage.

On the other hand, a disadvantage of the increasing demand approach compared to the constant demand approach is that it does not explicitly include the potential impacts of successive years of drought conditions on the calculation of the level of service measures. That is, the previous year's demand will be lower than the current year, resulting in higher storage levels at the start of that particular year. It is therefore less appropriate for investigating criteria that relate to duration of impacts within a simulation sequence over a period longer than one year.

4.13 Hydraulically variable transfer capacities

The ability to supply water via pumps and pipelines can be diminished when the water level in storages reduces and there is less head to push water through the reticulation system. Models should account for the differences in infrastructure capacity, particularly the change in supply capacity at low reservoir volumes.

4.14 Adjustment of restriction rule curves

Yield analysis based on the frequency, duration and severity of restrictions is a function of the design of the restriction rule curves. Restriction rule curves should change as demands increase in order to maintain adequate protection against running out of water once restriction triggers are reached. The process for adjusting restriction rules for future levels of demand is time consuming and is rarely undertaken in yield analysis. (Note: Melbourne Water does not adjust restriction rule curves for its future resource planning, but has done so in the past for certain scenarios). It is expected that as the demand approaches the yield, adjustment of restriction rule curves will reduce the yield.

4.15 Counting restriction periods

When assessing annual reliability, the selection of the 12-month period over which the assessment is made can influence the value of reliability. The period of assessment should be selected such that periods of restriction occur only in one year. For example, in southern Australia, the water year for assessing reliability is July to June. Restrictions typically occur in summer and end by the end of June. If the assessment period is July to June and restrictions occurred from 1 December to 28 February, then this would be counted as one year of restrictions when determining annual reliability. However, if this same data were assessed on a calendar year, then the same restriction period would be counted in two years. In the community's mind, this would be one restriction period, not two and hence the use of a calendar year would be inappropriate for assessing annual reliability. The 12-month period for assessing annual reliability should reflect the community's perception of what is a single drought event. For multi-year droughts, careful consideration needs to be given to the way that restriction events are counted. If a restriction period extends from December 1999 to March 2001, then this can be construed as a two-year drought. On the other hand, Hunter Water, which use stochastic data would view this occurrence as a single event as they count events rather than individual years. Both methods are correct but the users should be aware of the assumptions made. A long drought (such as a multi year drought) would only be viewed as a single event if the Hunter Water model is adopted.

Reliability measures can be assessed on an event basis, with each separate restriction event counted as a single occurrence, even where it occurs over multiple years. The duration of restriction events could then be covered by a specific duration measure, such as the maximum desirable duration or the frequency of a given duration event.

4.16 Selection of an appropriate modelling time step

Water resource decisions in major urban centres are typically made on a monthly basis. The available supply is reviewed at the end of each month and compared against restriction triggers to determine whether to implement restrictions or not. Modelling on an annual time step is not appropriate because it does not adequately account for changes in seasonal behaviour. The use of a monthly time step can introduce some inaccuracies in yield modelling, particularly for run of river systems in highly variable streams. The greater the storage memory, the less likely that inaccuracies will be produced. The time step used in modelling needs to be fit for purpose. For example, it might be appropriate to use a combination of time steps in simulations, with daily timesteps used to model diversions from weirs and monthly time steps to model the behaviour of reservoirs.

4.17 Start storage conditions

When using a model to assess reliability of supply, the start storage conditions may influence the result. If it is assumed that a reservoir starts full, then there is less chance that restrictions will occur in the early part of the period of assessment than if it starts only part full. An assessment of seasonal storage conditions under historical conditions or a preliminary model run can be used to determine the probability that the storage will be at a given volume in a particular month of the year. A median start storage can be adopted, with the option of undertaking a sensitivity analysis for alternative start storage conditions, particularly where storage capacity is greater than the average annual inflow. Alternatively, simulations can start at the current level, which can be useful for short-term (say up to 2 years ahead) forecasting of storage volume. The longer the period of modelling and the smaller the storage relative to annual inflows, the less likely that start storage conditions will affect the reliability of supply.

4.18 Frequency of model updates

Models should be updated on a five yearly basis or as otherwise required to incorporate specific system changes.

Reservoir capacity can also change over time, particularly on rivers with high sediment loads. Reservoir capacity should initially be reviewed on a five yearly basis and then as frequently as required to detect changes in reservoir capacity due to siltation.

4.19 Regulatory Requirements

Urban water utilities do not make decisions in isolation and are subject to regulations governing the provision of essential services. These regulations can restrict the ability of a water utility to make decisions quickly and hence reinforce the need for sound planning and appropriate contingencies. Adherence to the above framework will encourage transparency in the approach taken and give reassurance to regulatory authorities that decisions are being made in accordance with best practice.

4.20 Minimum Supply Requirement

The minimum supply requirement for domestic customers could be calculated solely on the basis of sustenance of life and hygiene (eg 60L/person/day), the minimum supply rate that could be achieved by banning outdoor use and seeking community cooperation for indoor reduction but without needing to actually police in-house water use (eg 120 to130L/person/day), or maintenance of some outdoor amenity as well if the community is willing to pay for such a high level of guaranteed supply. The minimum supply requirement for non-residential use will depend on the level to which the organisation is willing or able to close down public, commercial and industrial users in a worst case. The net minimum supply requirement will also need to take into account water losses from the system that cannot be found and fixed or economically repaired.

5. Uncertainty in Yield Estimates

There is an inherent uncertainty in any water supply yield estimate. These uncertainties stem from data inaccuracies and the uncertain nature of consumer behaviour. Other uncertainties arise from short and long-term changes over time and include climate change, climate variability, bushfires, revegetation, change in consumer profile, consumer response to demand management and changes in water quality. Yield estimates should therefore contain a contingency to account for these uncertainties and should be regularly updated as more information is gathered or conditions change. A statement of these uncertainties relevant to a particular supply system should be included in documentation accompanying the yield estimate. Each of these uncertainties is discussed below.

5.1 Data inaccuracies

Yield estimates rely upon a variety of input data, principally streamflow, climate and demand data. All of these data sets have errors associated with their measurement.

- **Streamflows –** if recorded they contain hydrographic error, particularly at high flows due to errors in stage-discharge rating curves or in locations with poor control sections for monitoring streamflow. If streamflows are estimated by transposition or by rainfall-runoff modelling, then the error associated with the streamflow data estimation process will be introduced into the yield estimate. The errors associated with stochastic data generation are discussed in McMahon and Adeloye, 2004).
- **Rainfall –** typically accurate to record, but it varies spatially and may be unrepresentative if the recording station is remote from the location where the rainfall is being applied in a system model. If rainfall is estimated by transposition, then the error associated with the rainfall data generation process will be introduced into the yield estimate.
- **Evaporation** - potential evaporation is accurate to record, particularly when based on weather data, but is not easily linked to actual evaporation from an open water body. In the Climatic Atlas of Australia, the Bureau of Meteorology recommends that evaporation from major reservoirs should be the unknown term in any water balance. This is rarely practical and hence pan evaporation or Penman-Monteith evaporation is typically used. If pan evaporation data is used, an appropriate pan factor should be applied (Grayson et.al., 1996) and an allowance made for the introduction of bird guards, which have been estimated to decrease evaporation by around 7% after installation in the 1970s and 1980s.
- **Volumes supplied** - Metering errors are common in bulk meters for measuring supply and even modern magnetic meters can suffer from electromagnetic interference.
- **Losses –** Leakage and seepage are difficult to measure and they can impact on yield. Prudent estimates for these factors need to be taken into consideration when undertaking yield estimates.

All of these inherent inaccuracies mean that an estimate of yield is itself uncertain, even before taking account of other influencing factors. The elimination of systematic errors that cause a gross over or underestimation of input values should be avoided or corrected. Random errors are often unavoidable and will not adversely affect the estimate of yield, but will introduce uncertainty into the result.

5.2 Uncertainties in consumer behaviour

A city's water consumption is the sum of water consumption from all of its industries, municipalities and households. Each of these users makes decisions on a daily basis about how they will consume water. In general and for large population centres, the erratic behaviour of individuals will be smoothed and average behaviour can be reasonably well predicted.

There will be some uncertainties in consumer behaviour. These include, for example, planned major events (eg the Sydney Olympics, Melbourne Commonwealth Games) or unplanned major events such as bushfires. These events will place additional demands on the supply system that are not modelled and hence yield could be slightly over-estimated if these events correspond with dry climatic periods.

5.3 Maintenance and repairs

Changes to operation for maintenance and repairs can temporarily reduce available supply. An example of this is the remedial work on the dam wall at Lake Hume, which coincided with a drought period. Consumers may experience restrictions more frequently than modelled if maintenance and repair work results in loss of the full use of infrastructure. Temporary maintenance issues will not affect long term yield but may have an impact on the frequency of restrictions experienced over the short term.

The maintenance and repair program will affect system leakage. Losses will progressively increase over time until detected and repaired. The repair or replacement of leaky infrastructure will decrease losses and increase the volume of water available for supply. A certain infrastructure condition and losses associated with that condition will be an implicit assumption in estimates of system yield.

5.4 Minimum operating level

Yield can be overestimated if no allowance is made for storage below the minimum operating level. This volume of water can be inaccessible in practice because it is of poor water quality or because there is insufficient hydraulic gradient to drain the water. Examples have occurred where dead fish have blocked inlet screens at very low water levels or algal blooms have occurred at low water levels. Most reservoirs will have a volume of water below the minimum operating level and water resources modelling should allow for this.

5.5 The political environment

Periods of restriction have been imposed in the past that are the result of a political decision rather than a shortage of supply. This typically occurs because of political sensitivities about sharing the pain of drought. In the 1982/83 drought in southern Australia, a number of urban water utilities implemented restrictions because rural water users or other urban water users were already placed on restrictions. Introduction of restrictions for political reasons will change the community's experience of drought and its perception of the water utility's ability to manage water resources. Placing restrictions based on a political decision (rather than as triggered by restriction rule curves) will reduce the average annual delivery of water over the period of record and increase the duration of restrictions.

5.6 Climate variability

High variability is a natural function of Australia's climate. The climatic variability experienced over the period during which yield has been calculated is not necessarily representative of future climatic variability. A drought worse than that on record can always occur. This was evident in the 1998-2003 climatic sequence observed over much of Australia, which was a more prolonged dry spell than other periods on record. Yield has decreased as a result of the inclusion of this more recent drought data. Future droughts can always be more frequent and/or more severe than those experienced to date. As additional data is collected, yield estimates may change over time.

5.7 Population growth

Population growth in Australia's major urban centres is typically in the order of 0-5% per year. If more people are served from the same supply system, then demand for water will increase.

Historical population trends can be discerned from Australian Bureau of Statistics census data. Historical population trends do not necessarily reflect future growth rates. Local councils and State Government departments produce population projections for 20-50 year horizons. These projections can be used to plan for growth in residential demand for water. These projections are inherently uncertain and are subject to regular revision, typically as new census data becomes available. Projected increases in the number of dwellings should also be evaluated, particularly with the trend towards more single person households and an ageing population. Yield estimates should be updated as frequently as needed to keep pace with population and household growth projections.

Major industrial growth is not directly related to population growth and will require specific advice from local town planners and existing major industrial customers about their future water needs.

Major industrial water use, particularly in regional centres, can be a significant component of total water use. Major industrial growth is often sporadic and difficult to predict in the long-term.

5.8 Change in consumer profile

The proportion of each type of consumer in a city can affect seasonal consumption patterns and the degree of restrictable demand. The relocation of major water consuming industries to a city can reduce yield by altering seasonal consumption patterns and patterns of restrictable demand. The type of dwelling can also influence demand, with less water per capita typically being used in high density apartments relative to free-standing houses with their own private garden.

5.9 Consumer response to demand management

Demand management has encouraged consumers to voluntarily reduce some water practices that would normally be restricted during periods of water restriction. This means that water restrictions will have a reduced effect when they are introduced (sometimes referred to as "demand hardening"). The prevalence towards subdivision and apartment dwelling has reduced garden watering, which is the main component of restrictable demand.

5.10 Changes in water quality

Improvements in water quality can result in increased consumption. This is not generally an issue for major cities, where water quality is fairly standardised and of good quality.

5.11 Climate change

Climate change can potentially lead to changes in streamflow, whereby historical streamflows are not representative of current long-term average climatic conditions. This has occurred in Perth, for instance, where a dramatic reduction in both rainfall and streamflows has been observed over the last few decades and hence only recent streamflow data is utilised in yield analysis. The large persistent reductions in streamflow in Perth have not yet been observed to the same extent in other capital cities around Australia.

Climate change modelling by CSIRO indicates the potential for changes to yield associated with changes in climatic conditions. The CSIRO climate models predict a change in air temperature, which is linked to a subsequent change in rainfall and evaporation. The actual effect of climate change is specific to each region of Australia. In some regions, predicted increases in summer rainfall due to climate change will result in an increase in yield. In south-east Australia, anticipated reductions in streamflow are typically in the order of 5-10% by the year 2030 relative to 1990 conditions, with anticipated increases in demand of around 2-5%, but wider variability is possible (eg Wang et.al. (1999), CSIRO (2001)). Both changes in supply and demand should be taken into account in a climate change analysis. Any reduction in streamflow will decrease yield, while an increase in demand will decrease the level of service.

Despite the resolution of climate models improving, it is still difficult to determine whether an observed short term reduction in streamflow is due to climate change or due to natural climatic variability. This is primarily due to the inherent uncertainty in climate change models. The first test should be to determine whether recent climatic conditions have been observed over the historic period of record. If a drought equal to or worse than the current drought has occurred within the historical record, then it can readily be argued that the current drought is part of natural climatic variability and no adjustment of the historical record is warranted. If the current drought is worse than any previously observed drought, then additional tests can be carried out to assess whether climate change has occurred. These can include comparison of mean flow conditions over different periods and statistical trend analyses. In each case, the observed change in flow should be checked against the range of streamflow changes estimated from climate change scenarios.

There is currently no objective test to determine whether greenhouse gas induced climate change has occurred and hence any decision to adjust historical streamflow data due to climate change will be the result of considered interpretation and judgement on risk. If historical streamflow data is not adjusted, then yield assessments under climate change scenarios should still be examined as part of sensitivity testing.

Premature adjustments to models to take account of potential climate change impacts that do not come to fruition could prove costly to the community as resources will be allocated to projects to improve reliability of supply that are not required to maintain existing service standards.

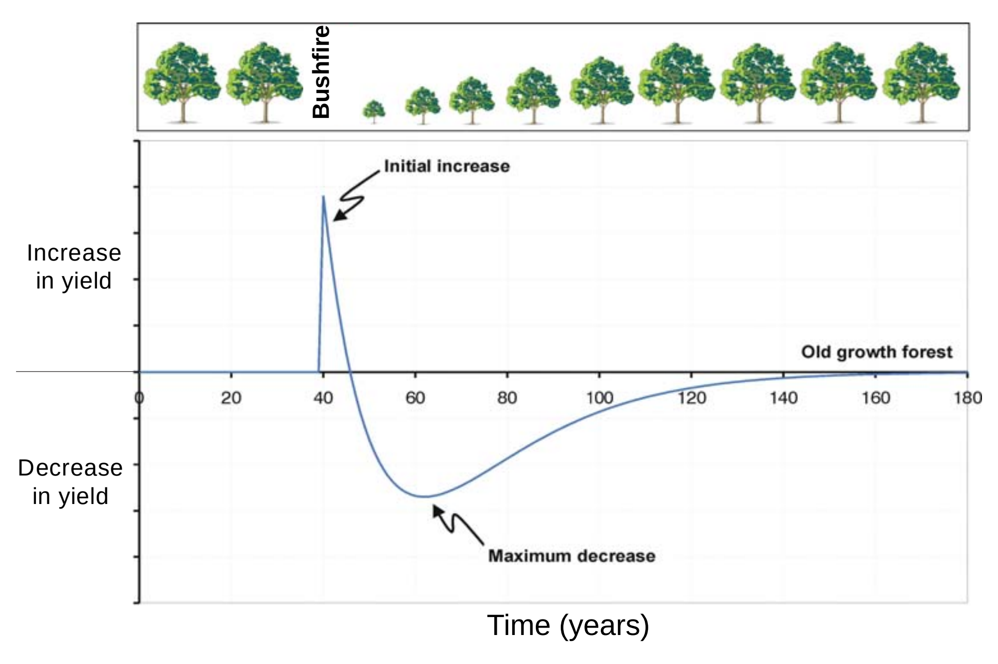
5.12 Bushfires

Fire-induced changes are capable of exerting major effects on the hydrology of forest areas, with consequent short- to long-term impacts on water yield. There is a large body of research that has investigated the impact of wildfire on water yields from forested catchments. Immediately after fire there will be an increase in runoff from the burnt catchment. If tree death does not occur, recovery of the leaf area (and hence evapotranspiration) occurs in 3 to 5 years. By this time the understorey is also usually re-established and once the canopy stabilises the water balance reverts to its pre-fire behaviour and hence yields return to their pre-fire values. However, where the forest tree species are killed by fire, recovery of leaf area takes a different course. Natural regeneration of the forest occurs, and the result is that the regrowth can develop total leaf areas much larger than in the original mature forest. This can occur at age 5-25 years. The denser canopies in regrowth intercept more rainfall and transpire more water than from the unburnt forest. There is significantly less "left-over rainfall" to appear as streamflow, so water yield from regrowth forest catchments is less than from mature forests. This process is shown in Figure 5-1. The long term yield reduction resulting from bushfire will depend upon the characteristics of the fire and the forests (i.e. the type of tree) but could be approximately 2 to 4 ML per hectare of forest burnt for Mountain Ash (adapted from Nandakumar and Mein, 1993).

5. Uncertainty in Yield Estimates

Continued

Figure 5-1 Notional Impacts of Bushfire on Catchment Yield



The probability of bushfire occurring in the future is difficult to ascertain and depends upon the proportion of the catchment already burnt in recent bushfires, antecedent moisture conditions and other random factors such as lightning strikes and deliberately lit fires. Actew-AGL has incorporated the probability of future bushfires and subsequent changes to yield into its scenario modelling by drawing on the work by Kulik (1990), which links bushfire risk to hydrologic conditions.

5.13 Logging and revegetation

Logging and revegetation of large areas of land can cause changes to hydrology similar to those experienced after bushfire. Large-scale revegetation can occur from activities associated with logging or for restoration of native forest in cleared areas. Planting of forests can have a major impact on groundwater resources and in some States (eg South Australia), groundwater licences are needed for approval to plant forests.

5.14 Catchment farm dams

Catchment farm dams can be a significant user of water upstream of water supply reservoirs or offtakes. Neal et.al. (2002) illustrated that catchment farm dams can reduce downstream flows by an amount in the order of one megalitre for every megalitre of farm dam. Increases in farm dam volume in water supply catchments will therefore reduce yield to urban water utilities. Water utilities should actively monitor and model the hydrologic impact of catchment farm dams where they form a significant proportion of the total storage in the water supply catchment and incorporate these impacts into yield assessments.

5.15 Pressures on groundwater resources

Links between groundwater and surface water are being increasingly better understood. Reductions in groundwater level can reduce baseflow discharge to streams. This baseflow discharge is important for retaining inflows during periods of no rainfall.

5.16 Quantifying Uncertainty

Uncertainty in model results is generally expressed as a qualitative statement of the type and potential impact of a given model input. Uncertainty can be expressed quantitatively in some circumstances using statistical analysis or by using bootstrapping techniques such as Monte Carlo analysis. In either case, a quantitative understanding of the uncertainty associated with each input is required, along with criteria for expressing uncertainty, such as 95th percentile confidence limits. Where uncertainty is quantitatively assessed, this should be incorporated into reporting on the level of service. For example, at the current level of service, the maximum duration of restrictions could be expressed as 12 months $\underline{+}$1 month at the 95th percentile confidence level. Quantifying and isolating the cause of uncertainty can be used as a guide to direct future investment to reduce uncertainty.

5.17 Adherence to Operating Rules

Caution is required when running models for which operating rules have been optimised in a theoretical sense. 'Real life' operation will generally be sub-optimal for a range of reasons, many of which are covered elsewhere in this section. Systems rarely perform better than designed. Some operating assumptions will be inherently robust (eg the flow rate over a concrete spillway will follow set rules), while others may be prone to reliability issues (eg weeds clogging screens, biofouling of reverse osmosis membranes, unexpected poor source water quality, power supply interruptions). The reliability of critical components should be assessed and reliability factors appropriately distributed.

6. Risk Management of Uncertainty

There are myriad potential uncertainties that can affect long-term water supply planning, as discussed in the previous section of this document. Dealing with these uncertainties in a meaningful way can be difficult and water authorities in the past have tended to either dismiss risk altogether or undertake extensive scenario modelling exercises that can generate more information than value. Risk management has already been incorporated into high risk areas of water supply operation such as asset management and dam safety and provide useful conceptual models for long-term planning.

Approaches to risk management range from a qualitative understanding of potential risks, to a sensitivity analysis through to a full quantitative assessment of risk such as a Monte Carlo analysis, which assigns a probability of occurrence to all potential scenarios to produce a probability distribution of potential outcomes. The most appropriate approach will depend upon the degree to which these risks can be quantified and the perceived risk associated with not quantifying uncertainties.

For long-term water resources planning, risks can be readily managed by regular review of the long-term plan and by setting contingency measures. Contingency measures include investigating actions prior to their implementation being required so that they are ready to implement if conditions change rapidly. Most risks associated with long-term water resources planning occur slowly, ie over several years or decades, so that the long-term plan can be adapted as those conditions actually change. A review frequency for long-term plans of around 5 years, which includes a review of likely future conditions based on historical information gathered since the last update, is considered suitable to manage most long-term water supply planning risks.

The prioritisation of future demand reduction and supply enhancement options can change under some future scenarios according to the likelihood of those scenarios occurring. If, for example, the worst case climate change scenario were to occur, then the incremental yield associated with additional surface water resources may decrease dramatically, which may significantly affect their viability. Under these changed circumstances in this example, water recycling options may gain a higher priority than would otherwise be the case.

A diversity of supply enhancement and demand reduction options may in itself serve to reduce risk relative to relying on a single option. In the context of homeland security issues, diversity of supply sources may reduce the vulnerability of supply, however there have been no recent instances of this occurring in Australia.

7. Terminology

7.1 Recommended terms

The following glossary of terms is put forward to encourage the use of a common language for communicating water supply planning and management activities and outcomes. These definitions are partly adapted from McMahon and Mein (1986), Rhodes (1993) and DSE (2004).

Buffer storage – See contingency storage.

Carryover storage – The volume of water stored at the end of one year that is carried over to the next.

Contingency storage – The volume of water reserved in a storage to take account of unprecedented climatic fluctuations and growth in demand. This storage provides a "buffer" or contingency if actual drought conditions are more severe than design drought conditions. The size of the contingency storage depends on the consequence of a community running out of water and the additional cost associated with reserving this volume.

Drought – A period of abnormally dry weather, expressed by the Bureau of Meteorology as a serious or severe rainfall deficiency for a period of three months or more. A serious rainfall deficiency is where rainfall lies above the lowest 5% of recorded rainfall but below the lowest 10% of recorded rainfall for the period in question. A severe rainfall deficiency is where rainfall lies below the lowest 5% of recorded rainfall for the period in question. Drought declaration is the responsibility of State Governments, which must consider other factors apart from rainfall, most notably the impact of the rainfall deficiency on the community. (Adapted from Bureau of Meteorology, 2004).

Estimated data – Synthetic data produced using available information to replicate historic data sequences. Includes data produced by regression analysis, rainfall-runoff models, transposition, extrapolation and other infilling.

Full supply level – This is the level at which the reservoir starts to spill and corresponds to the level of the spillway. For a gated spillway, this level will depend upon the operation of the spillway, but the full supply level would most likely be the top of the gate. Water can be temporarily surcharged above the full supply level in flood events, but will return to the full supply level after the flood event has passed.

Full supply volume – This is the volume that corresponds to the full supply level.

Groundwater yield – See yield.

Headworks – Dams, weirs and associated works used for the harvest and supply of water.

Infilled data – Short estimated sequences of data to replace missing recorded data.

Level of service – The frequency, duration and severity of water restrictions that would be experienced by the community on average over the long-term. Level of service should be measured in a manner consistent with the level of service objective.

Level of service objective – The desirable maximum frequency, duration and severity of water restrictions expected by the community. The frequency of restrictions should be expressed as an average recurrence interval (eg Stage 1 restrictions not more frequent than 1 in 10 years). The duration of restrictions should be expressed as a maximum number of consecutive months at a particular stage or stages of restriction (eg Stage 4 restrictions not to last longer than 6 months). The severity (or stage) of water restrictions is expressed in the above two measures for different stages of restrictions.

Minimum operating level – This is the level below which water cannot be used to supply customers, either because there is insufficient hydraulic gradient or because of poor water quality. Water below the minimum operating level can sometimes be accessed as part of a drought response action using temporary supply measures, such as installing a floating inlet pump on a gravity outlet supply. Storages should not drop below the minimum operating level unless it is part of an emergency procedure.

Minimum supply requirement - The minimum supply rate that would be met in a worst case scenario following the imposition of the maximum possible socially acceptable restriction regime.

Minimum operating volume – This is the storage volume corresponding to the minimum operating level.

Reliability of supply – The term used to indicate the proportion of time that a supply system is able to meet demand. Reliability is often expressed as the probability that restrictions of any given severity will not be imposed in a given year or month. Reliability is almost never equal to 100%. When presenting results to the community, reliability should be presented in a language consistent with level of service objectives and in a manner that the community can understand (eg as an average recurrence interval of restrictions; see SKM (2003) for further discussion).

7. Terminology
Continued

Replicate – a stochastically generated length of record with the same statistical characteristics as a base data set. See "stochastic data" for further information.

Restriction rule curves – a set of curves that define when to impose each stage of water restriction for a given month of the year. These curves are generally expressed as a volume of total system storage, but in systems with minimal storage, can also be based on streamflow.

Risk – the chance of injury or loss. In relation to water supply, the risk of injury or loss relates to the possibility of consumers not being provided with a supply of the required quality and quantity at the time the water is required.

Stochastic data – Stochastically generated time series data that has the statistical characteristics as the historical record for the data in question. The main advantage is to allow the examination of the effect of alternative sequences of flow on their design parameters.

Yield – The average annual volume that can be supplied by a water supply system subject to an adopted set of operational rules and a typical demand pattern without violating a given level of service standard. It is implied that this yield can be sustainably harvested. Yield is always associated with a probability of occurrence, as defined by the level of service objective.

7.2 Terms not recommended

The following terms are considered to be outdated or misleading and are not recommended for further use in long-term water supply planning:

Dead storage – This term should be replaced with the terms minimum operating volume and minimum operating level.

Drought proofing – The adoption of supply enhancement measures to reduce the risk of a supply shortfall to a negligible risk has been referred to as "drought proofing" a water supply system. This effectively makes it immune to drought based on historical records. Recent experience during the post 1997/98 extended drought in south-east Australia illustrated that droughts can always be worse than those on the historical record and that systems considered as being "drought proof" can run short of water. In order to recognise the probabilistic nature of water supply planning, the term "drought proofing" should be avoided.

Safe yield, firm yield, developed yield, theoretical yield, divertable yield, catchment yield – These terms have been superseded and should no longer be used in preference for the overarching term "yield". Yield is based on risk analysis and is never entirely "safe". The term safe yield is therefore misleading and should not be used. The term catchment yield is simply the streamflow and should be referred to as such. The term system yield is in common currency and is a suitable alternative to simply using yield when referring to the yield of a water supply system.

Security of supply – The term security of supply has historically been interchangeable with reliability of supply. It is recommended that the term reliability of supply should be used in preference to security of supply in order to avoid confusion in the community with homeland security issues.

Sustainable yield – Sustainable yield was a definition of yield required during the transition towards incorporating environmental flow requirements into the yield analysis. Given that all yield analyses should incorporate environmental water requirements, the term sustainable to describe the yield is a tautology. This is in line with community expectations of current best practice for water resources management. Environmental sustainability should be determined with reference to ecological values and threats to those values, including water requirements for maintaining healthy and diverse riverine, floodplain, wetland, estuarine and coastal environments. Particular issues include maintenance of a flow regime that mimics natural conditions, releases that prevent thermal pollution from fixed reservoir outlets, sufficient flow volumes to maintain downstream water quality and the maintenance of groundwater dependent ecosystems.

8. Conclusions

This document provides a framework for urban water resource planning that is designed to assist water utilities to engage the community in water resource planning. The key elements of the framework are:

- An appreciation of the inherent trade-offs between the social, economic and environmental costs of supplying water versus not supplying water.
- An understanding of the importance of community input in setting level of service objectives and the need to express the level of service in terms that are easily interpreted by the community.
- A guide to the technical factors to consider when determining the current level of service or when undertaking a yield analysis.
- A discussion of the uncertainties inherent in a yield analysis.
- A preferred glossary of commonly used terms in water supply planning and recommendations to cease using confusing or misleading terms.
- A pro-forma for defining the current level of service and level of service objectives, which is an illustrative example of the type of information that can be used to engage the community.

This framework will help water utilities to communicate with stakeholders and the community in general and to reassure them that their water supplies are being managed to their expectations. This framework may evolve over time as new issues arise in the industry, as guided by each utility's experience in working with the community on these issues.

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Appendix A
Pro-forma for Defining Level of Service

This pro-forma provides guidance on communicating the current level of service to the community and for setting a desirable level of service.

Defining Level of Service Objectives

Managing water resources is a complicated and challenging task. Australia has an extremely variable climate and this adds to the complexity as we are never sure what extreme climate condition or drought might lie ahead. It is often stated that drought in Australia is an abnormality whereas in actual fact drought is a very real part of the Australian hydrology. Planning to manage water resources into the future involves making decisions on how much water to store and when to make a start on resource augmentation. It is also important to understand the consequence of not being able to fully meet demand, or even worse, running out of water.

Water restrictions are used in the water industry to make scarce resources last through climate extremes. Contrary to many people's understanding, restrictions are supposed to happen periodically as they help manage a scarce resource through a drought and defer unnecessary community expenditure on over sized infrastructure that would rarely be drawn upon. Restrictions are perceived differently by the varying communities around Australia. In some areas where they are frequent (and in some cases even permanent) they are accepted as a way of life. In other areas where restrictions are less frequent, they can be perceived as undesirable and cause community concern.

The level of service provided by a water supply system is defined by the frequency, severity and duration of restrictions experienced by the community on average over the long-term. The level of service objective is the desirable maximum frequency, duration and severity of water restrictions expected by the community. A level of service objective is used by water managers to help understand when a water supply system can no longer supply demand in line with community expectation. There is no formula or prescriptive solution to setting a level of service objective. It simply comes down to trading off between what a community is prepared to accept in terms of the frequency, severity and duration of restrictions and what they are prepared to pay to avoid them. Once a level of service objective is adopted by a community, water managers can then monitor system performance to ascertain when the next augmentation is due. In other words when the frequency, severity and duration of restrictions is likely to exceed the standard set as acceptable to the community, it is time to undertake the next steps to shore up the supply or undertake conservation measures.

The impact of restrictions on the community can be assessed in three areas *viz:*

- financial loss – or a direct cost to a consumer due to drought (eg garden replanting etc);
- personal inconvenience – only being allowed to water by hand or with buckets at prescribed times; and
- community amenities – damage to parks, public gardens and sporting grounds due to lack of water.

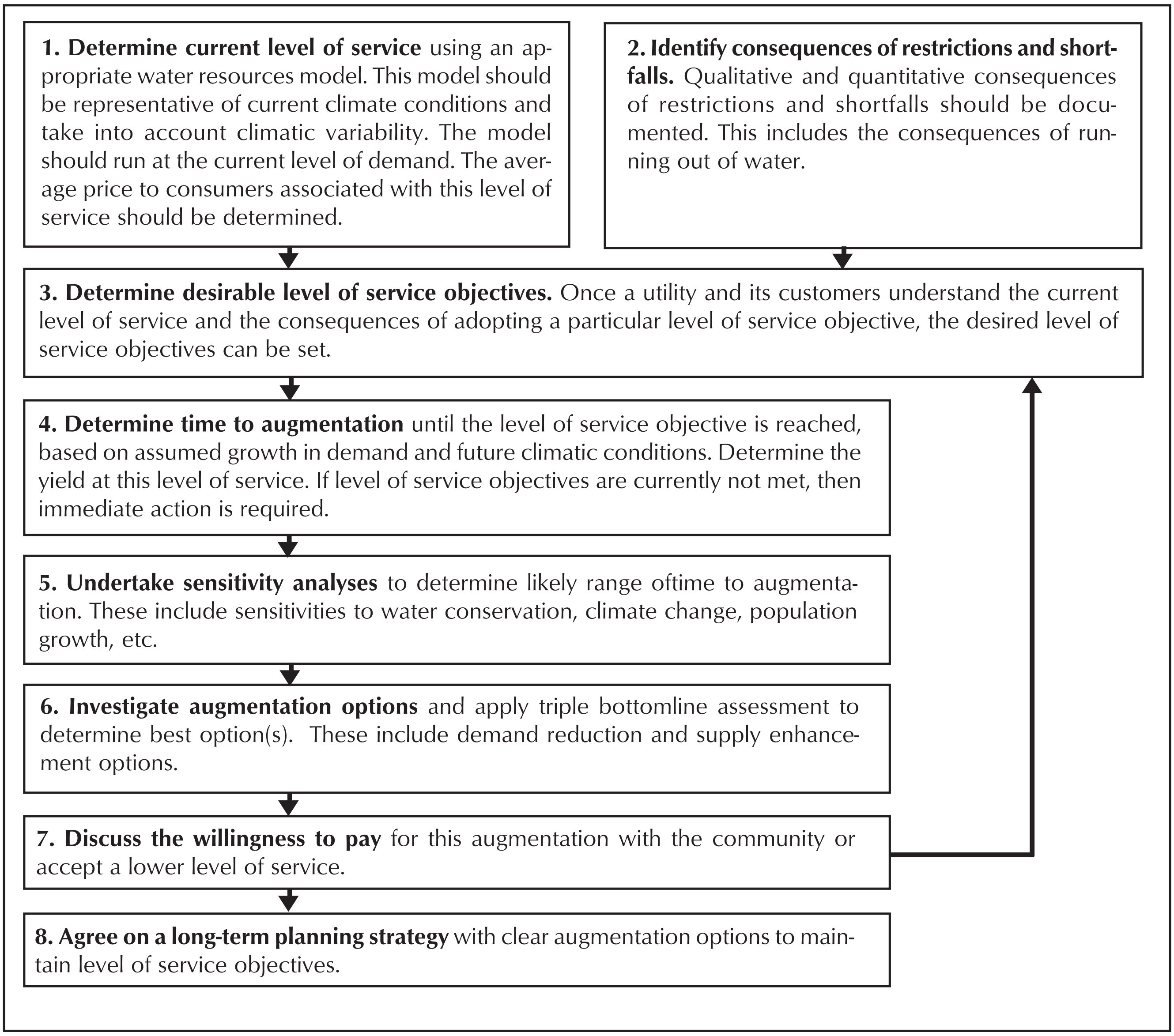
The acceptance of a level of service objective depends on how communities perceive these losses. The frequency, severity and duration of restrictions is an important issue in setting a level of service objective. For instance, is a community likely to be more accepting of more frequent less, severe restrictions rather than less frequent, more severe restrictions? Other communities (such as Canberra for example) are less likely to accept stage 3 (of 5) restrictions at all. Most communities will accept short term restrictions in some form (as long as they are not too frequent), but prolonged restrictions (over several years) can have a negative impact on the community perception of water utilities.

Once a level of service objective is set, it does not necessarily hold for all time. Community attitudes will change, particularly as there is ever increasing awareness of the need to conserve water. New augmentation schemes will often require additional extraction from already stressed streams and groundwater aquifers. Communities may tend towards greater conservation measures and increased tolerance of restrictions if these actions can be deferred. It is therefore imperative that water utilities, together with the community, should regularly review level of service objectives. In this way, the right decisions on augmentation timing can be made.

Appendix A - Pro-forma for Defining Level of Service

Continued

Figure 1 – Overall process for water supply planning



1. Determine current level of service using an appropriate water resources model. This model should be representative of current climate conditions and take into account climatic variability. The model should run at the current level of demand. The average price to consumers associated with this level of service should be determined.

2. Identify consequences of restrictions and shortfalls. Qualitative and quantitative consequences of restrictions and shortfalls should be documented. This includes the consequences of running out of water.

3. Determine desirable level of service objectives. Once a utility and its customers understand the current level of service and the consequences of adopting a particular level of service objective, the desired level of service objectives can be set.

4. Determine time to augmentation until the level of service objective is reached, based on assumed growth in demand and future climatic conditions. Determine the yield at this level of service. If level of service objectives are currently not met, then immediate action is required.

5. Undertake sensitivity analyses to determine likely range oftime to augmentation. These include sensitivities to water conservation, climate change, population growth, etc.

6. Investigate augmentation options and apply triple bottomline assessment to determine best option(s). These include demand reduction and supply enhancement options.

7. Discuss the willingness to pay for this augmentation with the community or accept a lower level of service.

8. Agree on a long-term planning strategy with clear augmentation options to maintain level of service objectives.

Key elements of each stage of restriction

An understanding of the consequences of each stage of restriction is required for the community to make decisions about the desirability of avoiding those restrictions. Table 1 shows a summary of each stage of restriction. For specific details, refer to the water restriction by-law. Exemptions are granted in some cases.

Table 1 – Activities affected in each stage of restriction (example only)

Activity	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**
Private lawn watering	🕒	🚫	🚫	🚫
Private garden watering	🕒	🕒✋	🕒✋	🚫
Municipal lawn watering	🕒	🕒	🚫	🚫
Municipal garden watering	🕒	🕒	🕒✋	🕒✋
Filling of new lakes or ponds	🚫	🚫	🚫	🚫
Topping up of existing lakes or ponds	✋	✋	✋	🚫
Operation of fountains	✋	🚫	🚫	🚫
Filling of new pools or spas (>500 litres)	🚫	🚫	🚫	🚫
Topping up of existing pools or spas	✋	✋	✋	✋
Filling or topping up wading pools (<500 litres)			🚫	🚫
Use of water toys	✋	🚫	🚫	🚫
Filling or topping up farm dams (excludes stock and domestic water supply or water for fire fighting)	🚫	🚫	🚫	🚫
Sports ground watering	🕒✋	🕒✋	🚫	🚫
Watering plants in plant nurseries	🕒✋	🕒✋	🕒✋	🚫
Filling mobile water tankers	✋	✋	✋	✋
Commercial vehicle washing	✋	✋	✋	✋
Private vehicle washing				
Cleaning food transport vehicles	✋	✋	✋	✋
Washing paved areas	🚫	🚫	🚫	🚫
Washing windows, building facades and rooves	✋	✋	✋	✋
Use of water for construction purposes	✋	✋	✋	✋
Cooling of poultry sheds	🕒✋	🕒✋	🕒✋	🕒✋

🕒 = restriction on time of day of activity

✋ = restriction on the manner in which the activity is carried out

🚫 = activity not permitted

Appendix A - Pro-forma for Defining Level of Service
Continued

Current level of service

The current level of service is specified in terms of the frequency, duration and severity of restrictions. The current level of service should always be specified before presenting any future possible levels of service in order to provide a reference point for comparison.

- **Scenario name:** *Current level of service*
- **Annual frequency of restrictions – See Table 2**
- **Maximum duration of any restrictions** (no. of months): *eg 8 months*
- **Maximum duration of severe restrictions** (no. of months at a particular stage(s) of restriction during the worst drought event): eg. *1 month at Stage 3 and 1 month at Stage 4.*
- **Most severe stage of restriction reached**: eg. *Stage 4*
- **Current average price of water** ($/kL): eg *$1.00/kL*

Assumptions

- **Level of demand** (year of development): *eg Year 2004 demands*
- **Current average annual demand for water** (volume/yr): eg *580 GL/yr*
- **Period of assessment:** *(eg 30 years of historic data or 1000 years of stochastically generated data)*
- **Environmental flow conditions:** *(eg reference scenario from environmental flow report)*

Current time to augmentation

The time to augmentation is the time available from the present time until level of service objectives are no longer met with the assumed water supply infrastructure. Estimating the time to augmentation requires assumptions to be made about future growth and climate conditions. This provides a reference point against which to assess other water supply augmentation options, including changes to the desirable level of service.

- **Assumed climatic conditions:** *eg current climate or 2030 average case climate change*
- **Assumed change in per capita demand per year** (% change in current average annual per capita demand per year): eg. *same as current or 0.3% reduction per year*
- **Assumed population growth** (% of current population per year): eg *1.5% per year*
- **Assumed average annual change in demand** (% of current demand per year): eg *5% growth in demand per year. This measure should incorporate changes in dwelling type and household formation.*
- **Average annual volume supplied when level of service is no longer met** (volume/yr): eg *680 GL/yr*
- **Number of years until level of service is no longer met by the existing water supply system** (no. of years): *eg. 10 years or level of service not currently met*
- **Assumed environmental flow conditions:** *(eg reference scenario from environmental flow report)*
- **Assumed changes to restriction triggers over time:** (eg. *lift stage 1,2, 3 and 4 restrictions by 2% per 5 years)*

Appendix A - Pro-forma for Defining Level of Service

Continued

Possible future levels of service

The level of service in the future may change because of changes to water supply operation, water supply infrastructure, changes in demand for water, changes in climate conditions or land use changes such as logging or bushfires that affect the amount of water available for use. The average price of water may increase if more water supply infrastructure is required, which in turn will influence the level of service objectives. The future level of service should be specified in the same terms as the current level of service to enable comparison against current conditions.

- **Scenario name:** *eg Adoption of new environmental flow recommendations*
- **Annual frequency of restrictions**

Table 2: Annual Frequency of Restrictions

Stage of restriction	Annual frequency (no. of years per 100 years)	
	Current Level of Service	***Possible Future Level of Service***
One	*10*	*20*
Two	*8*	*12*
Three	*4*	*4*
Four	*3*	*3*

- **Maximum duration of any restrictions** (no. of months): *eg 10 months*
- **Maximum duration of severe restrictions** (no. of months at a particular stage(s) of restriction during the worst drought event): *eg. 1 month at Stage 3 and 1 month at Stage 4.*
- **Most severe stage of restriction reached**: *eg. Stage 4*
- **Average price of water** ($/kL): eg *$1.00/kL*

Assumptions

- **Level of demand** (year of development): eg *Year 2004 demands*
- **Average annual demand for water** (volume/yr): eg. *580 GL/yr*
- **Period of assessment:** *eg 30 years of historic data or 1000 years of stochastically generated data*
- **Assumed climatic conditions:** eg. *current climate, year 2030 climate change*
- **Assumed per capita demand reduction relative to current year** (% of current average annual per capita demand): eg *5% or same as current*
- **Differences from current operation:** eg. *increased environmental flow release, change in timing of pumping, etc*
- **Differences from current infrastructure:** *eg additional 300 ML storage, increased pump capacity or no change from current system infrastructure*
- **Environmental flow conditions:** *(eg reference scenario from environmental flow report)*
- **Assumed changes to restriction triggers over time:** (eg. *lift stage 1,2, 3 and 4 restrictions by 2% per 5 years)*

Appendix A - Pro-forma for Defining Level of Service

Continued

Time to augmentation for future scenarios

Future scenarios may result in a change in the time available until the next required augmentation. The time to augmentation is the time available from the present time until level of service objectives are no longer met with the assumed water supply infrastructure. Estimating the time to augmentation requires assumptions to be made about future growth and climate conditions.

- **Scenario name:** eg *Adoption of new environmental flow recommendations*
- **Assumed climatic conditions:** *eg current climate or 2030 average case climate change*
- **Assumed change in per capita demand per year** (% change in current average annual per capita demand per year): *eg. same as current or 0.3% reduction per year*
- **Assumed population growth** (% of current population per year): *eg 1.5% per year*
- **Assumed average annual change in demand** (% of current demand per year): *eg 5% growth in demand per year. This measure should incorporate changes in dwelling type. State whether demands are increasing over time in modelling scenario.*
- **Number of years until level of service is no longer met by the existing water supply system** (no. of years): *eg. 10 years or level of service not met*
- **Assumed environmental flow conditions:** *(eg reference scenario from environmental flow report)*

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