RISKY DECISIONS CREATING BETTER INFRASTRUCTURE OUTCOMES

J. Preston & D. Alexander (Beca HunterH2O, Newcastle, Australia)

ABSTRACT

When projected future growth is pushing hard up against system capacity, how do you justify moving away from long held water storage requirements? How do you defend a treatment plant upgrade to a questioning regulator when a warming climate is wreaking havoc with water quality?

These are just two examples of situations where risk-based processes were used to support infrastructure decisions in a logical, structured and repeatable manner. In collaboration with water utility staff, major capital upgrades have been deferred or rescoped and defensible justification for decisions recorded for stakeholder scrutiny.

When defining a problem, a risk-based approach encourages consideration of four elements – the event itself, the ways in which it could occur, the consequences if it does and the likelihood of those impacts being felt. Recognising the wealth of knowledge that resides within a water utility, operational experiences and system performance are explored to identify known and reasonably foreseeable disruptive events. Building on this information, failure scenarios are jointly developed and the outcomes modelled to replicate the system and customer impacts. Risk ratings are agreed and the results compared to service level requirements or risk appetite expectations, with any gaps clearly identified.

These gap identification outcomes vary between utilities. The desire to take or avoid risk is influenced by the utility's capacity, operational resilience, stakeholder requirements and community expectations. Breaking a situation down into its components and comparing these to the agreed risk targets enables deliberate and objective decision making, thus avoiding blanket risk aversion or unsubstantiated risk taking.

Understanding the drivers to a risk event paves the way to identifying what levers can be pulled when crafting a solution and closing the identified gap. Capital investment isn't always the best answer; changes to network operation practices or strengthened contingency planning could achieve the desired future state with a fraction of the cost outlay. The value of this risk-based approach will be demonstrated in case studies that resulted in:

- The deferral of a $10M reservoir based on the customer impacts experienced from 32 failure scenarios

- A 50% reduction in size of a clear water reservoir after examining network supply interruption risk levels
- Justified support for a treatment plant upgrade to provide capacity to treat the impacts of bushfire and algal contamination risks via a process that took current and future risk into account.

Adopting a risk-based approach not only provides a structured methodology for addressing a specific issue, but it also establishes a level playing field that enables equitable comparison across a range of diverse infrastructure challenges. Collaboration with water utility staff builds robust understanding of the drivers for change, establishes clear links between operational management and future planning decisions, and provides objective and defensible justification for investment decision outcomes.

Embracing risk aware processes in the formation of the new water entities under the Three Waters Reform Programme also provides a unique opportunity to embed a positive risk culture from the outset – it simply becomes the way you work.

KEYWORDS

Risk, Decision, Model, Infrastructure

PRESENTER PROFILE

Jo Preston is a Senior Risk Advisor with 16 years' experience integrating risk awareness into business processes. Jo has supported organisations to develop enterprise risk frameworks, craft risk appetite statements, identify key opportunities and disruptors and critically examine strategic investment decisions.

Daniel Alexander is a highly skilled civil engineer with a 20-year background in all facets of water/wastewater system master planning and modelling. Daniel has extensive experience in hydraulic modelling, including population projections, model compilation and system analysis.

INTRODUCTION

Historically, when considering major investments in water system infrastructure, decisions have been informed by industry design standards. In Australia these legacy standards took a highly prescriptive approach to design requirements and embedded considerable conservatism into planning decisions. This was due in part to uncertainty in data sources and calculation methods for determining system capacities. As technology has improved, the accessibility of data to inform the planning process has been vastly enhanced. The introduction of computational modelling, and the ability to accurately represent complex networks, enables a reduction in the level of conservatism in line with increased confidence in predicted network performance.

Much of the design guidance across Australia is now informed by publications such as the Water Services Association of Australia's (WSAA) Water Supply Guidelines. Regional variations have been incorporated to bridge the gap from legacy design guidelines. It is worth noting that whilst health-based requirements are generally regulated by state health departments, there is no equivalent state department responsible for regulation of water supply continuity in Australia. With this absence, it rests upon the individual water utility to determine appropriate levels of service that are considered tolerable to the communities they serve. The prudent approach is to follow, where physically possible and economically responsible, the current water design standards to ensure that community expectations are met, including when comparing levels of service on a wider regional scale. In the New Zealand context, Water New Zealand are currently developing National Engineering Design Standards, which were, in their "strawman" format, based on the Australian WSAA guidelines, and have been undergoing development to incorporate aspects of some 40 regional New Zealand design guidelines.

A significant change in the WSAA design standards when compared to their legacy counterparts is the advocacy for a risk-based approach when considering the planning and design of major assets. Whilst there is still some prescriptive design guidance, the risk-based approach enables water utilities to look at site-specific risks that may impact the provision of safe, reliable water supply. The sizing of assets is then based on a true assessment of the likelihood and consequence of specific supply interruption events that may occur to actual assets within the water supply network. This approach can lead to significant cost savings by empowering water utilities to demonstrate their ability to respond to events without resulting in supply interruption to the community. It can also assist with justification of additional capacity requirements in cases where response times are extended due to staffing or remoteness. A further benefit is that the risk assessment process often uncovers peripheral issues within a network that may fall outside of risk appetite target areas, but need to be addressed to ensure a safe, reliable water supply.

WHAT DOES RISK-BASED THINKING LOOK LIKE?

Using the framework and principles provided by ISO 31000:2018, the international standard for risk management, we consider the elements shown in Figure 1:

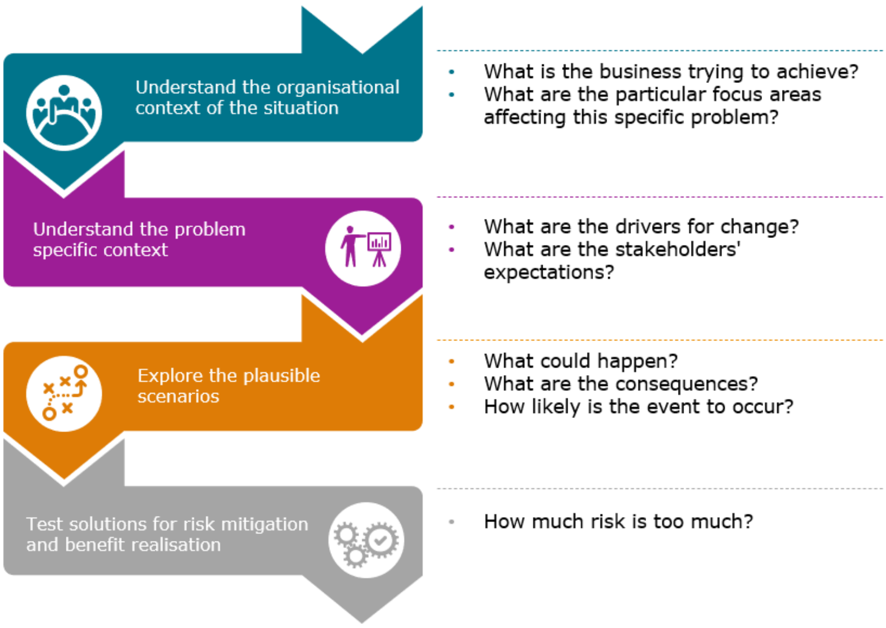


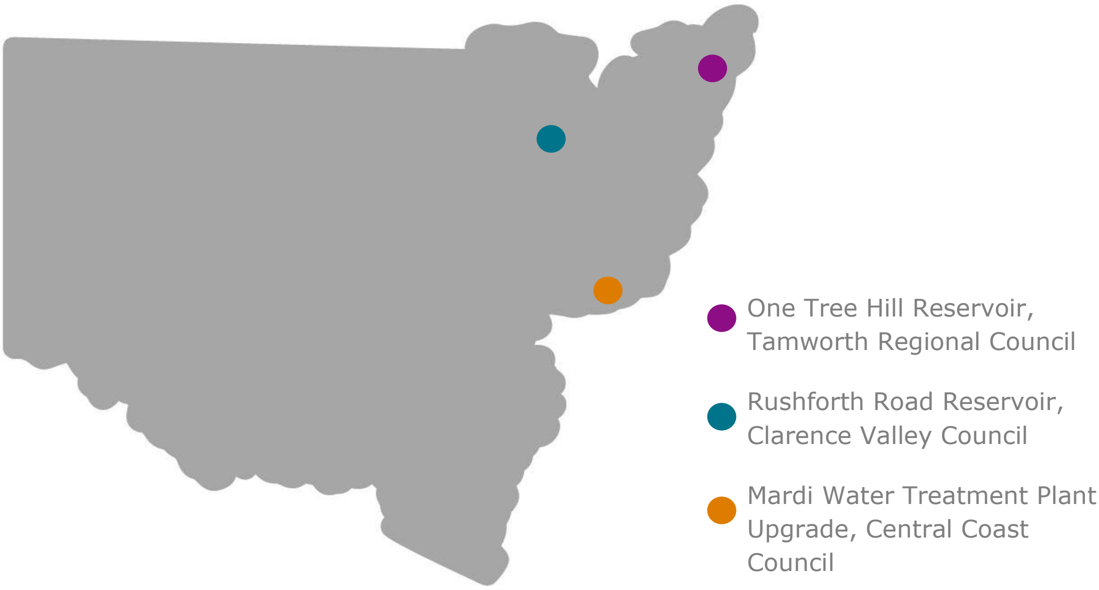
Figure 1: Applying Risk-Based Thinking

When applied to a water supply context, this translates to:

Establish the Scope & Objective	Be clear on the part of the network to be examined and the interdependencies between zones. Confirm the strategic or business outcomes being sought, particularly in relation to customer expectations and agreed levels of service.
Determine the Operating Environment	Identify key customers and stakeholders and their needs now and into the future. Examine recent experiences, the operational response and how that impacted the customer.
Identify Sources of Risk	These are the network assets that can fail, resulting in an interruption to normal network operations. Develop logical groupings based on the network components.
Identify Risk Events	Consider the actual failures that could occur. Be specific, if there are multiple events that could cause failure, note each event for assessment. Grouping by key failure mode can be useful both for stimulating event identification and later data analysis.
Determine Consequences	The aim is to maintain supply continuity, so events that don't lead to a customer interruption (even if they require major operator intervention) could be rated as an 'insignificant' consequence. Consideration should be given to separately recognising the cumulative impacts on workforce if too many 'insignificant' events are deemed acceptable.
Assess Likelihood	How likely are the consequences to be experienced because of the event? Higher consequences for the same event are often less likely, and there may be 'cascading' events that result in a more significant consequence, albeit at a lower likelihood. If the consequence is unknown, undertake hydraulic modelling to determine the impacts, then revisit the assessment.
What is your Appetite?	Just because a risk event could occur doesn't mean it exceeds risk appetite. In the absence of suitable corporate level risk appetite statements, examine known previous events and use the outcomes and resultant business attitude to them to determine where the appetite level is for different consequence events.

CASE STUDY APPLICATIONS

By maintaining alignment with the principles of risk-based thinking, the actual process can be adapted to the specific challenge being faced. Following are three such applications, with all having material impacts on the final infrastructure investment decision.



CASE STUDY 1 – ONE TREE HILL RESERVOIR, TAMWORTH NSW

Outcome = deferral of $10M reservoir based on customer impacts experienced from 32 failure scenarios

One Tree Hill Reservoir
(Credit: The Northern Daily Leader)

One Tree Hill/Murroon water network zone

<u>Background</u>

Tamworth Regional Council is situated in the New England area of New South Wales and has a population of approximately 64,000, with forecast growth to 80,000 by 2041. In 2017 the Tamworth Water Strategy was prepared and assumed that 2 peak days of storage was required for all water reservoirs. Based on this standard, the strategy recommended additional storage in the One Tree Hill/Murroon reservoir zone within the 2017-2021 growth horizon. It was further recommended that construction of any additional reservoir be subject to a risk and feasibility analysis prior to progressing to the design phase, examining potential modes of failure and operational response durations to determine if an alternate storage duration was suitable.

When examining network performance and reserve reservoir storage capacity, WSAA recommends undertaking a risk analysis to identify causes of potential supply disruptions, the likelihood of these failures and expected response durations. The outcomes from such an analysis are then used to inform the requirements for infrastructure or operational modifications to ensure that the risks of supply continuity are consistent with customer expectations.

Methodology

To understand the current network performance, hydraulic modelling outcomes were reviewed including total demand by zone under existing and ultimate scenarios, and a comparison of reservoir capacity and supply by water supply zone. The design criteria adopted to assess existing network performance was in accordance with WSAA codes, which suggest, as a starting point for capacity assessment, "useable reservoir capacity" equal to 8-24 hours of peak day demand, plus "reserve storage capacity" of 1/3 peak day demand, to be compared to current reservoir volumes.

It was noted that on the information provided and modelled there was in excess of the required "useable reservoir capacity" available under peak day demands. The focus was therefore on identifying and quantifying those reasonably foreseeable failure modes which could affect availability of source water into the reservoirs and subsequently affect the continuity of customer supply.

A workshop with Council examined the situation using the approach noted in

Figure *1*.

- To capture and reflect operational experiences, recent network interruptions were examined including the activation of contingency plans and other responses, and the subsequent impacts felt by customers. These discussions built a picture of the business and system capacity to respond to unplanned events. Critical customers within the network were identified, along with industrial customers and any known change plans (e.g., business expansion or relocation) that had the potential to affect future demand.

- The network was then segmented into its key components and potential failure modes agreed. These are shown in Table 1 and Table 2.

Table 1: Network Components

Network Components
Treatment plant
Pump station
Pipeline
Control system
Valves
Reservoir
Telemetry
Raw water supply

Table 2: Failure Modes

Failure Modes
Power loss
Mechanical
Water quality
Natural disaster
External/ malicious
Malfunction/ automation/ condition

- Given a risk-based approach was to be adopted, tools for assigning consequence and likelihood were required. A customised set of descriptors was developed which reflected the specific context of the situation and these then formed the basis of a risk matrix, which was also calibrated to reflect Council's position on risk.

  With regards to the consequence descriptors used, two areas of impact were addressed – the <u>source</u> interruption duration and the <u>customer</u> interruption duration. Both were used in a deliberate way during the assessment process to understand how each failure event could unfold.

- Scenario analysis was conducted and identified 32 reasonably foreseeable failure scenarios which could affect availability of source into the One Tree Hill reservoirs. The extent of the interruption to the source was determined (adopting a 'most reasonable worst case' approach), and then after taking current contingency actions and operational responses into account, the impact on the customer was assessed.

  Those scenarios with a potential customer interruption duration >12 hours were further analysed for likelihood of occurrence and overall risk rating. There were nine scenarios that underwent this analysis, indicating that >70% of unplanned disruptions could be adequately addressed by applying existing practices.

In general, the nine scenarios reflected catastrophic consequence/low likelihood events.

- The agreed aim was to reduce the customer interruption duration to less than 12 hours, reflecting the risk appetite of Council. A range of mitigation options were tested against that objective, in particular the effect of additional storage.

Outcomes

15 options other than increased storage were recommended, and it was concluded that:

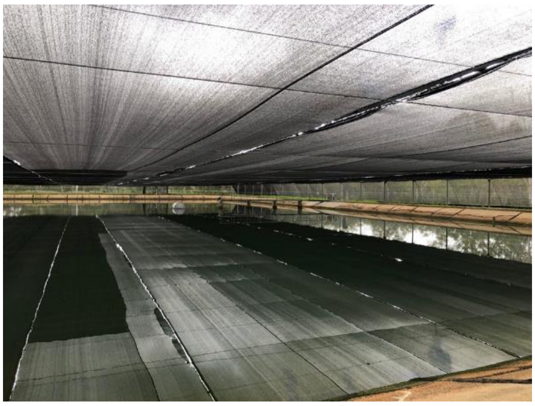
- There is no immediate justification for additional reservoir storage at One Tree Hill, and **reservoir construction may be deferred by 5-15 years**, pending growth in demands within the network and operational/technological advances.

- Additional data is required to determine when risk appetites will be exceeded, triggering a reservoir capacity upgrade. This can be achieved by quantifying the currently unknown impacts of reasonably foreseeable failures, such that restoration time and thus storage volume requirements are more clearly defined. This storage volume requirement can then be utilised in future strategy revisions to inform storage upgrade timing.

- Whilst increasing reservoir storage would provide additional repair time in the event of an unplanned disruption, it was shown to have no direct impact on customer interruption durations. There are numerous other tasks/projects that may be undertaken to better quantify or mitigate these risks.

CASE STUDY 2 – RUSHFORTH ROAD RESERVOIR, CLARENCE VALLEY COUNCIL NSW

Outcome = 50% reduction in size of a clear water reservoir after examining network supply interruption risk levels



Rushforth Road Reservoir – interior roof (Credit: Beca HunterH2O)

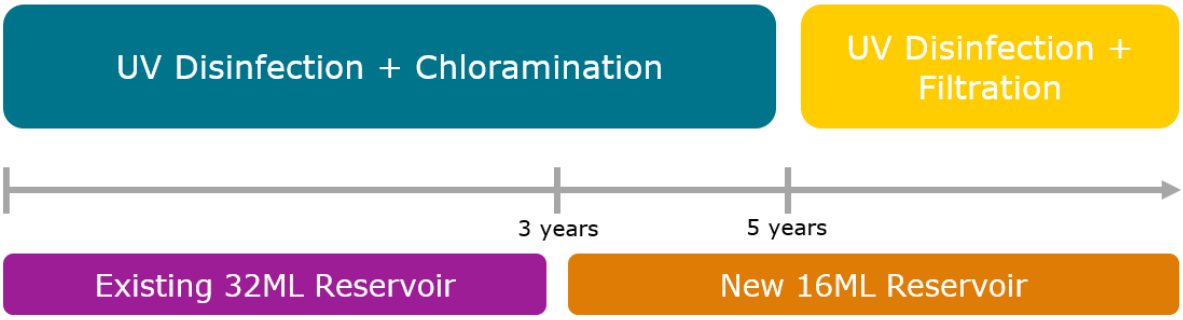
Rushforth Road Reservoir – exterior (Credit: Beca HunterH2O)

Background

Clarence Valley Council is situated in the Northern Rivers area of New South Wales and has a population of approximately 54,500, with forecast growth to 64,000 by 2041. In 2021 master planning for the Rushforth Road WTP site considered the need to replace the existing 32ML clear water basin with treated water storage tanks. Determination of an appropriate storage volume was required to bridge the gap between decommissioning of the existing basin and commissioning of the new WTP.

Supply continuity risks associated with staged improvements to water treatment needed to be identified, with the baseline design assumption shown in Figure 2:

Figure 2: Rushforth Road WTP Upgrade Design Assumptions



Distribution network optimisation was specifically excluded from the scope, with the assessment process focusing on source risks leading into the reservoir that could subsequently affect the continuity of customer supply.

Methodology

Adopting a similar process to that used in Case Study 1, current demand levels in relation to available storage were examined. Recent unplanned events affecting reservoir storage levels were identified, together with future demand changes (which indicated a potential 150% increase in current demand).

Thirty-three reasonably foreseeable failure scenarios were developed which could affect availability of source into the Rushforth Road treated water reservoir. Fourteen of these scenarios had 'most reasonable worst case' customer interruption durations greater than 6 hours, which was determined as being outside Council's risk appetite level.

An enhancement to the assessment process was introduced which allowed the failure scenario effects on storage levels to be tested 'live' in a workshop environment. This was enabled by a bespoke water balance model – Reservoir Impact Storage Calculator (RISC) – which incorporates many features of a reticulated network. This spreadsheet-based tool simplifies the representation of reservoir performance for ease of discussion and analysis.

Functionality of the RISC tool includes:

- Composite diurnal consumption patterns
- Adjustable:
  - Demand
  - Production
  - Reservoir volume
- Plot multiple failure scenarios to test diurnal impacts
- Modify source interruption start time and duration
- Represent actual reservoir controls, including complex level-based flow pacing

The tool enables rapid processing of different source interruption scenarios and can immediately show the impacts of modified network storage volumes, permitting many scenarios to be assessed real-time within the risk workshop. An example output is shown in Figure 3.

Figure 3: RISC Example Output

Mitigation options were grouped into three categories:

- Introduction of a water filtration plant
- Change in reservoir storage
- Reducing response durations (automated valves, SCADA control)
- Modification of current control philosophies

Using the RISC tool as an enabler of discussion, a range of scenarios were tested against the effects of each option.

Outcomes

Articulating a risk appetite in terms of customer supply interruption duration allowed the risk assessment to focus on those scenarios of highest importance to Council. Of the 14 scenarios falling into this category, 11 were determined to extend beyond 24 hours (well in excess of the 6-hour target) and the RISC tool clearly demonstrated that this exceeded total system capacity. Events of this magnitude cannot be effectively mitigated by storage alone and addressing the underlying cause of the failure event is the recommended risk management approach. In the case of the Rushforth Road reservoir, the introduction of filtration at the WTP provides a targeted response to the majority of the identified risks.

When implemented in conjunction with the other operational control recommendations, the planned storage volume (16ML) is sufficient to address and control the identified failure scenarios – **an increase in storage is not required**. Projected customer supply interruption durations were assessed as negligible after implementation of the recommended actions as shown in Table 3.

Table 3: Rushforth Road Water Reservoir Projected Risks

Risk Rating	Risk Event	Projected interruption duration
Extreme	Turbidity	No interruption
High	Algae	No interruption
High	Source contamination	TBD – subject to water quality risk assessment & ALARP actions
High	Bushfire	No interruption
High	Erroneous data	No interruption
High	Outlet failure	No interruption
High	Biofilm (low velocity)	No interruption
High	Tunnel collapse	No interruption
High	Valve seizure	No interruption
High	Loss of UV	No interruption
High	2ML reservoir failure	No interruption
Moderate	Earthquake	No interruption
Moderate	100ML reservoir failure	No interruption
Low	Filter failure	No interruption

CASE STUDY 3 – MARDI WATER TREATMENT PLANT UPGRADE, CENTRAL COAST COUNCIL NSW

Outcome = justified support for a treatment plant upgrade to address impacts of bushfire and algal contamination by identifying current and future risk levels

Background

Mardi Water Treatment Plant (aerial)
(Credit: Beca HunterH2O)

Central Coast Council were facing a number of challenges within their drinking water system, including:

- Difficulty meeting revised water quality targets with the current raw water envelope
- Significant and variable amounts of disinfection by-products (THM's) in the filtered water from Mardi WTP
- Rapid chlorine decay in the reticulation network
- Repeated blue green algae events in Mardi Dam, with five significant occurrences since 2015
- Increasing likelihood of Peak Demands coinciding with agreed transfer arrangements with a neighbouring utility.

An upgrade of Mardi WTP was planned to address these issues and the preliminary design proposed a DAF process with 160ML/day treated water production capacity. Council's Regulator confirmed a justified need for investment and supported the DAF process, however they challenged the efficiency of the upgrade capacity and proposed a lower capacity with 20% reduction in capital investment.

Council then needed to determine an appropriate capacity upgrade and consider any available efficiency gains (e.g., via staging).

Methodology

Prior to undertaking a scenario-based risk assessment, consideration was given to determining Council's risk appetite. These discussions centered on the ability to maintain continuity of drinking water supply to the community and examined the linkages between WTP capacity, reservoir capacity and service continuity. Network storage levels were agreed to be an indicator of acceptable levels of service and attention turned to selecting a level that was within risk appetite.

With a design horizon of 2050 and anticipated population growth from 350,000 to 470,000 over that period, the hours of storage available under forecast average day and peak day demand were calculated across the network. Progressively decreasing storage volumes were tested for tolerability, with a minimum of 80ML of water distributed between major reservoirs being the final agreed level. A major reservoir was defined as having a "full" capacity exceeding 8 ML. The 80 ML of network storage was then effectively being kept in reserve to maintain supply continuity in the event of a local supply interruption. As shown in Table 4, this provides between 11-17 hours of continued supply to address any localised failures affecting the provision of drinking water. This level was further tested against the pressure reduction consequences to customers of reduced storage, shown in Table 5, with the outcomes determined as being within tolerance.

Table 4: Storage Hours Available

PDD:	**131**	**ML/d**					
ADD:	82	ML/d					
Percentage full	100%	76%	67%	57%	48%	**38%**	10%
Volume (ML)	209.6	160	140	120	100	**80**	20.96
Hours of PDD storage at Specified Volume		*25*	*22*	*18*	*14*	***11***	4.83
Hours of ADD storage at Specified Volume		*41*	*35*	*29*	*23*	***17***	7.73

Table 5: Zone Pressure Reduction

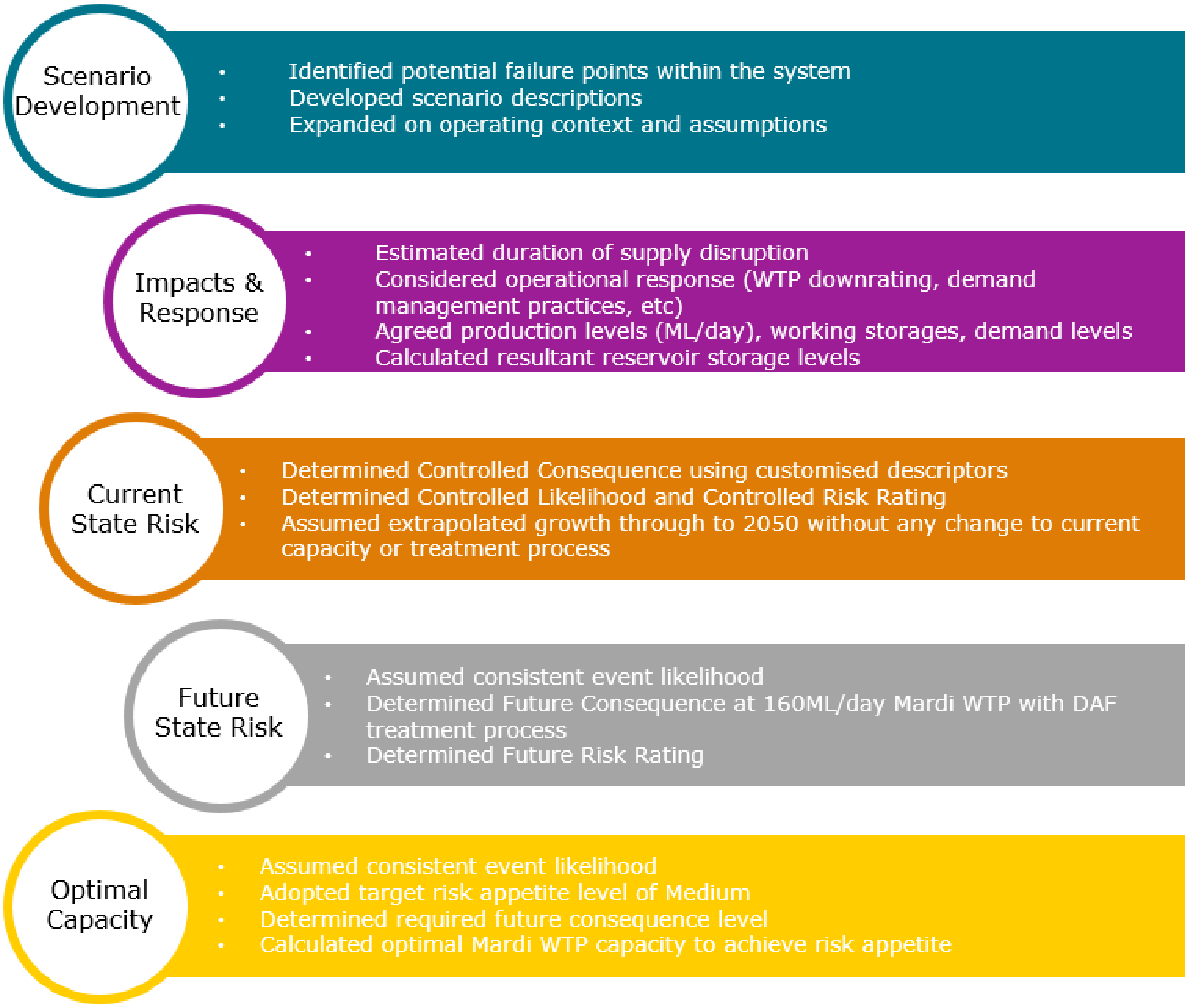
			Reduction in zone pressure for different total volumes (m)				
	100% Volume	% full	76%	67%	57%	48%	**38%**
	(ML)	Depth	160	140	120	100	**80**
Tuggerah 2 Reservoir	40	10.07	2.4	3.3	4.3	5.3	6.2
Wyrrabalong Reservoir	21	7.75	1.8	2.6	3.3	4.1	4.8
Kanwal Reservoir	21	12.69	3.0	4.2	5.4	6.6	7.8
Kanangra Reservoir	13.6	3.01	0.7	1.0	1.3	1.6	1.9
Tuggerah 1 Reservoir	13.6	5.95	1.4	2.0	2.5	3.1	3.7
Copacabana Reservoir	12.9	8.76	2.1	2.9	3.7	4.6	5.4
Niagara Park Reservoir	12.9	8.81	2.1	2.9	3.8	4.6	5.4
Terrigal Reservoir	10.5	14.71	3.5	4.9	6.3	7.7	9.1
Kincumber Reservoir	10.4	6.58	1.6	2.2	2.8	3.4	4.1
Bateau Bay Reservoir	9.1	15.4	3.6	5.1	6.6	8.1	9.5

Kanwal 2 Reservoir	9.1	8.86	2.1	2.9	3.8	4.6	5.5
Springfield Reservoir	9.1	4.8	1.1	1.6	2.1	2.5	3.0
Green Point Reservoir	9.1	11.7	2.8	3.9	5.0	6.1	7.2
Wamberal Reservoir	9.1	2.99	0.7	1.0	1.3	1.6	1.8
Kanwal 1 Reservoir	8.2	9.47	2.2	3.1	4.0	5.0	5.9
TOTAL VOLUME	**209.6**						

Council's risk consequence descriptors were updated to align with this agreed acceptable reservoir level and a target risk appetite rating of Medium determined for use in the risk assessment. This maintained consistency with the business level risk appetite for Organisational Performance, whilst allowing for targeted specificity in relation to the WTP upgrade.

Using the scenario analysis approach shown in Figure 4, potential failure points were identified across raw water sources, the treatment process and distribution network. 45 scenarios were developed, with 11 of these agreed to represent the 'most reasonable worst case' outcomes and taken through to further analysis.

Figure 4: Risk Assessment Process – Mardi WTP Upgrade



Three risk variations were assessed:

- The Current State: Continued operation of the existing WTP's through to 2050 in their current state without any upgrades undertaken.
- Upgrade Option 1: Mardi WTP with the preliminary design including a DAF process and 160 ML/day treated water production capacity.
- Upgrade Option 2: Mardi WTP with the preliminary design including a DAF process and with a treated water production capacity that would be required to provide an acceptable level of risk for each event scenario considered.

Each of the 11 failure scenarios was assessed against the three risk variations. The RISC tool was key in determining the optimal capacity of the WTP in each of the scenarios. Event duration, demand levels, production flowrates and working reservoir volumes were adjusted to reflect the specifics of the failure event and an appropriate WTP capacity determined that would meet the risk appetite for service continuity.

<u>Outcomes</u>

Key outcomes from the assessment included:

- Supply disruption as a result of the scenarios varied in length from 3 days to one month assuming peak demand levels.
- The current risk levels prior to the upgrade of Mardi WTP ranged from Medium to Extreme, supporting the need for investment at Mardi WTP.
- A capacity upgrade of Mardi WTP to 160ML/day would maintain full network storage during all assessed events.
- Future risk levels under this upgrade were determined as Low for Organisational Performance across all events, against a risk appetite of Medium. This level of upgrade would reduce the need for additional, proactive operational management during the assessed scenarios, as supply could be maintained with little or no impact on the community.
- Aligning more closely with the risk appetite target level (i.e., moving from Low to Medium) sees a shift in required capacity that varies across the scenarios from 100 ML/day to 150 ML/day.
- To adequately address all scenarios and meet risk appetite, **an optimal capacity for Mardi WTP of 150 ML/day** would be required.

There are however uncertainties to be recognised when considering these outcomes:

- Population growth projections were available only to 2036, which meant that outcomes from 2036-2050 required extrapolation to meet the planning horizon
- Direct climate change impacts could materially affect underlying assumptions by way of:
    - Increased storm frequency and severity
    - Changes in blue-green algae outbreaks and toxin levels
    - Prolonged drought periods
    - Increased bushfire intensity and longer bushfire periods

- Population migration in response to altered in-land living environments could see the Central Coast community increase beyond projections (sea change adopters). Alternatively, sea level rise and coastal erosion could entice inhabitants away from the area and result in a slowing of long-term population growth.

Whilst the risk assessment process was aimed at determining an optimal WTP capacity, it also highlighted the benefits of developing targeted operational management and contingency management actions.

Examples included development of pressure management procedures, individual reservoir level management processes, emergency management and business resilience protocols.

Adaptive planning was also considered a valuable approach given the uncertainties in population growth and peak day demand behaviour. Monitoring of agreed triggers would then enable reassessment of the optimal capacity requirement, further supporting a staged upgrade process.

CONCLUSIONS

Integrating risk-based thinking into infrastructure decision making has a range of benefits:

- It provides a structured and repeatable process that can be applied to a variety of major investment situations.
- Using the principles of ISO 31000:2018, problems can be broken down into causes, events, consequences and likelihoods and their alignment with overall objectives clarified.
- Recognition is given to a range of inputs, including operational experiences and system modelling. In this way it merges the qualitative and quantitative so that all voices are heard.
- By using tools that reflect the organisational context, outcomes can be compared with other, potentially disparate, situations.
- Incorporating risk appetite into the process strengthens alignment with strategic objectives and operationalises the risk-taking goalposts.

There are generally three questions that risk-based thinking can assist answer:

What could happen?

Why should we care?

What can we do about it?

Using failure scenario analysis enables the break down and understanding of how an undesirable event could impact the organisation and disrupt it from achieving its objectives.

Using tools that are reflective of an enterprise approach to rate the level of risk exposure enables comparability of issues and aids in the inevitable trade-offs that occur when operating infrastructure heavy businesses.

Establishing risk appetite statements provides clear guidelines and boundaries for risk taking decisions. They can materially help avoid blanket risk aversion by specifying those areas that require tight control and those where risk tolerance is higher. These statements need to be reflective of the operating environment of the organisation and take a range of factors into account. As a result, they can materially vary even between organisations providing similar services, as illustrated by the risk appetites of the three case studies.

Well-crafted appetite statements send clear signals to the business on the expected risk-taking behaviours and empower decision makers to move forward with confidence. Target outcomes are clarified and investment options can be tested against these to ensure prudent and efficient use of sparse capital.

Risk-based processes can be established at any time and provide value, but optimal outcomes are obtained when they are embedded into foundational frameworks. In this way they become part of the language of the business, a recognised way of working that continually evolves to keep pace with changing strategic goals and operational environments.

Incorporating risk-based planning into design guidelines will facilitate the flexibility required when attempting to consolidate a large number of regional guidelines, as is the case with New Zealand's current National Engineering Design Standards development.

And finally, risk-based thinking is a mindset, not a single process. It reflects a set of principles and is adaptable to a range of applications. It brings objectivity, consistency and comparability to decision-making, building organisational confidence and strengthening relationships with key stakeholders.

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