MODELLING THE RISKS AND RESILIENCE OF WATER SUPPLIES USING GOLDSIM

James Blyth (Jacobs New Zealand Ltd)

ABSTRACT

New Zealand is facing increasing pressures on our water supplies, from both population growth and abstraction for agricultural and industrial development. The general public is widely aware of water related issues and sustainable use of our water resources is not only a goal for many people, but is requirement under the National Policy Statement for Freshwater Management (NPSFM).

Holistic modelling of water supplies using software such as GoldSim can provide a more detailed understanding of the risks and uncertainties that a site, town or city may face under a range of scenarios, such as extreme droughts or random infrastructure failures during peak demand periods. These modelling approaches of the whole system can help site managers and councils plan into the future, catering for greater demand by optimizing their system with a targeted focus on the areas that pose the biggest risk or have the best cost/benefit relationship for improving resilience.

KEYWORDS

Water Supply, National Policy Statement for Freshwater Management (NPSFM), Risk, Resilience, Planning, Reliability, GoldSim.

1 INTRODUCTION

New Zealand is facing increasing pressure on our water resources, from decades of landuse intensification, increasing population and a changing climate. This is coupled with a greater public awareness of the threats to water (both surface and groundwater) and knowledge on how these can impact communities culturally, financially, socially and physically (e.g. bacterial outbreaks).

The National Policy Statement for Freshwater Management (NPSFM 2017 amended) sets out objectives and policies to assist councils in managing water in an integrated and sustainable way. This requires direct consideration and recognition at a regional policy level of Te Mana o te Wai – the holistic and integrated well-being of a freshwater body. The focus of this paper is on water quantity, although the NPSFM also encompasses water quality.

Regional councils are required to set objectives and policies around water allocation and sustainable water use. This has to consider efficient allocation of water takes, and where areas are over allocated, target dates must be set to phase out this over allocation. This central government led policy feeds directly into operational requirements for district councils, where water supply consented abstractions, discharges and infrastructure will be considered with closer scrutiny at renewal, repair and replacement phases.

Holistic 'whole of package' water modelling can help provide a greater understanding of the uncertainties and risks within the system, which may include climate variability, environmental flow restrictions, mechanical failures, extreme events and seasonal demand fluctuations. Rather than solely focusing on localized issues and design based modelling (i.e. network modelling), a holistic approach at a higher level can help managers of the water supply schemes identify key choke points under a range of scenarios.

This paper summarizes a typical water supply modelling approach in GoldSim, and how the outputs can be used to help in long term infrastructure planning and lead to increased sustainability of our water resources.

2 WATER SUPPLY RISK-BASED MODELLING

2.1 GOLDSIM AND MONTE CARLO ASSESSMENTS

GoldSim is a modelling software which can be used for a range of applications, from water modelling to financial accounting. The critical advantage of GoldSim is that uncertainty can be incorporated into modelling inputs through the use of probability distributions and statistical parameters (e.g. standard deviations), which are then run through a Monte Carlo analysis.

The Monte Carlo analysis runs numerous iterations of a model (perhaps a 5-year period on a daily timestep, run 50 times), with random sampling of the probability distributions occurring at each timestep. These model runs and random sampling of the probability distributions subsequently incorporate a range of possible outcomes, such as variations in climate records or fluctuations in daily water demand.

All simulations propagate through into the results, and can be viewed individually or compiled as a percentile distribution. This allows a user to understand the risk and reliability of various components of their system as a likelihood of exceedance (e.g. 5% chance of the 10,000 m^3 water reservoir running dry).

Water balances can be undertaken as a high level site or city-wide assessment at daily timesteps which provide a good overview of the system, key risk areas and areas for improvement. Alternatively, localized investigations can be undertaken for specific infrastructure (such as storage ponds and pumps), where the model can be run at timesteps down to seconds.

2.2 WATER BALANCE MODELLING APPROACH

2.2.1 DATA COLLECTION

A comprehensive data collection process would be undertaken as required in any modelling project. This would include all recorded flow rates, as built drawings, resource consent information, water demands and leakage assumptions.

Greater data abundance and resolution helps refine modelling assumptions; however, risk and uncertainty can be estimated for all data inputs, and where little information is known, this can be factored into modelling to provide an understanding of the flow on effects throughout the system.

2.2.2 CONCEPTUALIZATION

Conceptualization of the system is important to understand all the factors that may impact the water supply assessment. It is also a useful approach to highlight data gaps and uncertainties that can be incorporated into the modelling (see Section 2.2.5). Components that may be incorporated during this phase include;

- Site infrastructure and layout (e.g. dams, pumps, reservoirs) and water distribution/connection at a high level
- Key areas of water supply/abstraction (and discharge if required)
- Water demand at different locations (which may vary daily and seasonally)
- Leakage and loss areas (and estimations of rates)
- Where population growth may occur and at what rates

See Figure 1 for an example of a conceptual diagram.

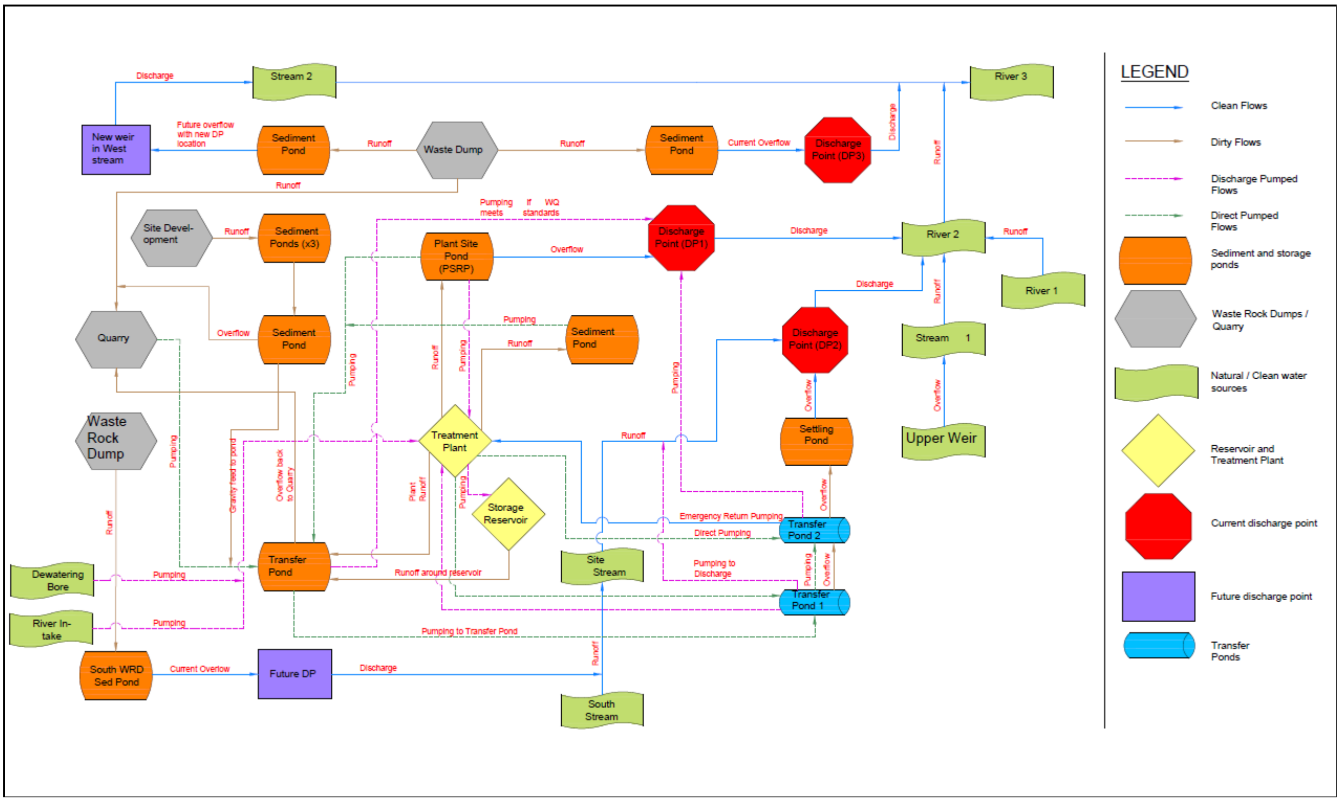


Figure 1: Conceptual site water balance diagram

2.2.3 BASELINE MODEL AND SCENARIO CONSIDERATION

Following the conceptualization of the system to be investigated, thought needs to be given to the objectives of the modelling. These objectives will need to consider how accurate the baseline model representing the current state will need to be, and if data exists to calibrate this model.

In some situations, there is little data to calibrate a baseline model. However, a simple model may still be built that represents the system to the best available operational knowledge, with uncertainty factored into the inputs. Approaching modelling this way is still beneficial as it identifies where improvements can be made.

Following the development of the baseline model, scenarios need to be considered. This could be used to assess the resilience of the system in the face of particular events (e.g. a groundwater pump failing during a period of peak water demand, or a 1% AEP drought occurring with a seasonal influx of tourists).

2.2.4 NUMERICAL MODELLING

Development of a numerical model in GoldSim will be based off the system conceptualization (see Section 2.2.2) and will be built to meet the objectives of the baseline model and scenarios that are to be evaluated. The model can incorporate components such as;

a. Calibrated rainfall runoff models for stream flow and bore yields based on sustainable pumping rates.

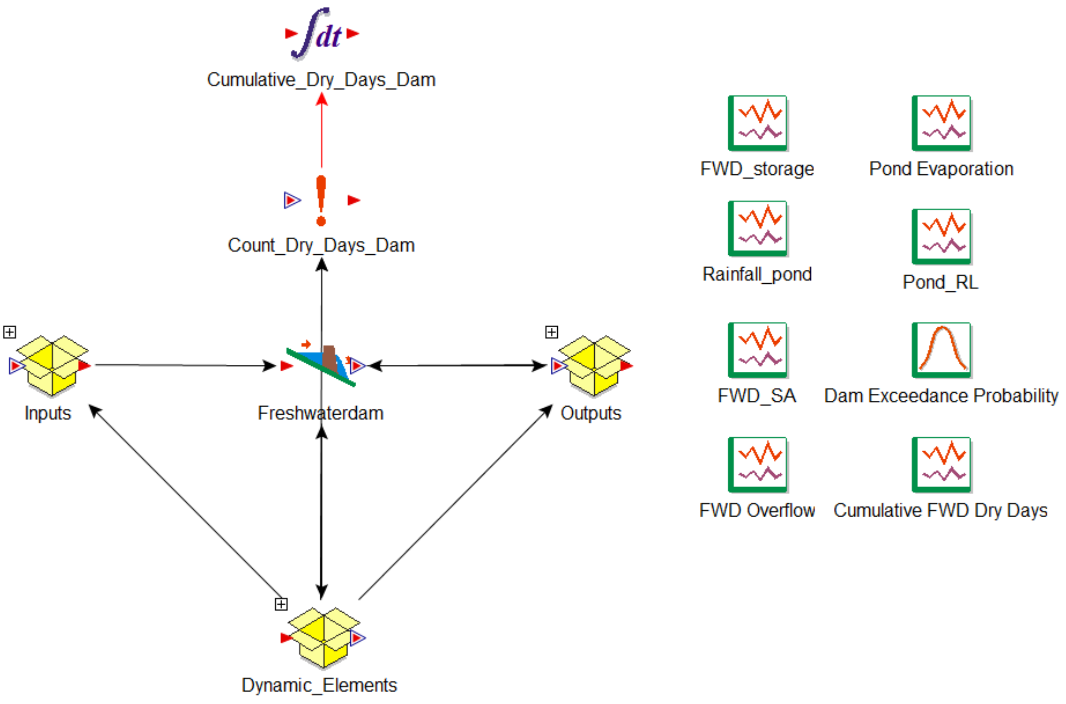
b. Long-term climate series and climate change (e.g. synthetic weather generators).

c. Water supply consents (including abstraction rates and restrictions as operational rules).

d. Water demand, which may vary across a site or town, and be linked to different sources of supply (and storages).

e. Relevant infrastructure and their associated 'controls', which may be based on as built drawings (dam stage storage curves), pumping abstraction rates, water demands, storage tank volumes, network (pipe) losses (even as a simplistic % loss per day).

An example of some of the coding in a water supply numerical model can be found in Figure 2 and 3.



\ *Figure 2: 'Container' within GoldSim showing subfolders and coding elements for a freshwater dam*

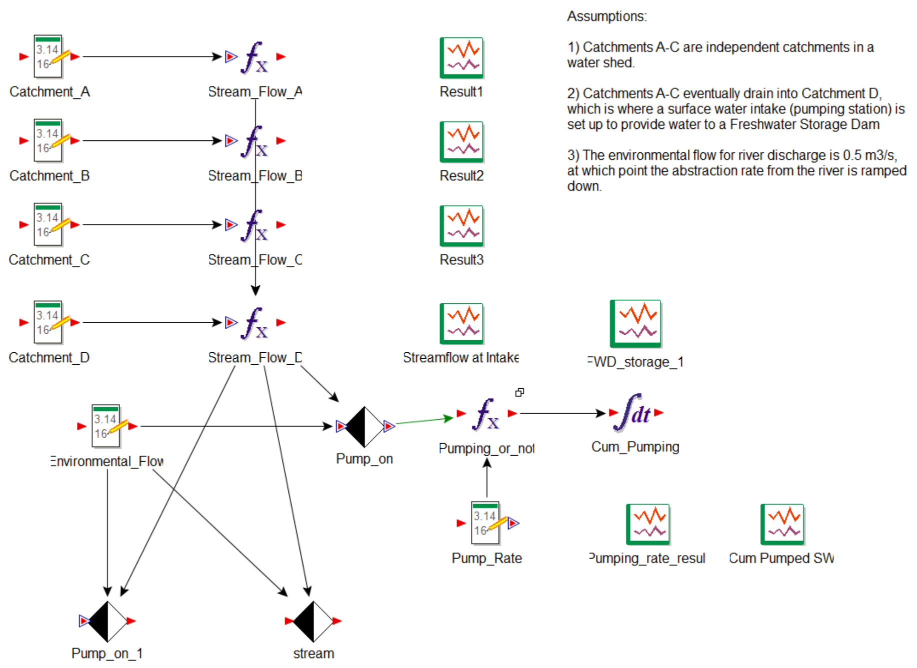


Figure 3: Additional coding for a surface water consented abstraction within a GoldSim 'container'

2.2.5 INCORPORATION OF UNCERTAINTY

Following the development of the numerical model and an understanding of the data limitations, uncertainty can be incorporated into GoldSim through the use of numerous probability distributions. For example, this uncertainty may be based on an assumed risk of a pump failure (e.g. 0.005% chance of occurring on a given day), or variability in daily demand (ranging from 130 to 250 L/pp/d).

An example of incorporating uncertainty into a modelling input has been provided in Figure 4 using a normal distribution.

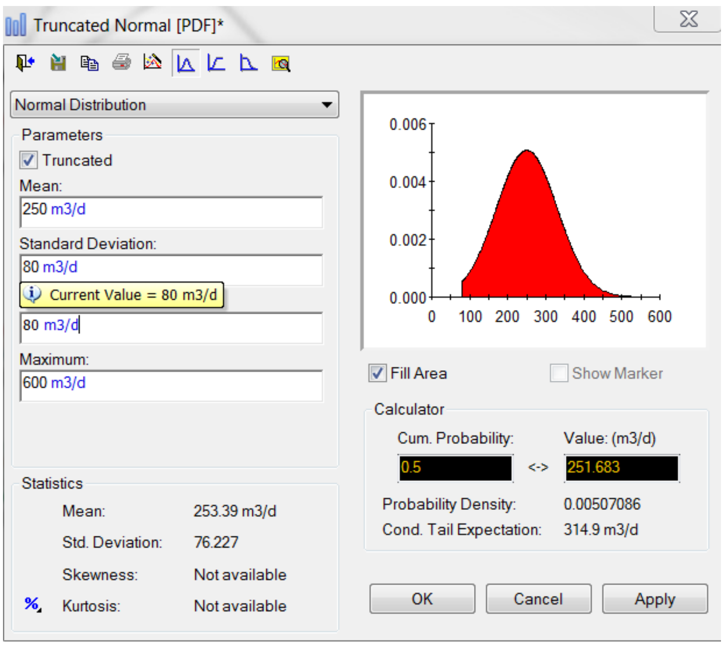


Figure 4: Applying a stochastic element (normal probability distribution) to a water demand input parameter, based on estimates of variability. The demand is resampled randomly from within the probability distribution at a chosen interval (i.e. daily).

2.2.6 MODELLING SIMULATIONS

Following development of the numerical model, simulations can be run as discrete events (e.g. fixed historical periods or wettest and driest years), or Monte Carlo (nested simulations run hundreds of times encompassing all possible outcomes).

2.2.7 RESULTS REVIEW AND COMPILATIONS

GoldSim provides result outputs for every component modelled in the system, both graphically and tabular. Subsequently, the large amount of available outputs requires a wide review to identify key risk areas of the system that may require improvement.

A useful way to evaluate the results is in terms of reliability and percentiles; for example, 'there is a 5% chance of the water supply dam running dry over a 30-year simulation, with the current consent requirements, infrastructure and water demands'. Re-running this scenario with modifications to the system could result in a reduction in risk, for example. 'reducing network losses from 25%/d to 15%/d would reduce the risk of the water supply dam running dry to 1.5%'. An example of some of the results outputs, which incorporate all uncertainty and variations in climate and demand, are presented in Figures 5 and 6.

By following the approach outlined above, industry site managers or councils can better understand their water supply systems and the risks they may face, which may lead to a variation in their long term strategies (and plans), including how consents are applied for and where infrastructure (and rates) should be best spent to increase sustainability.

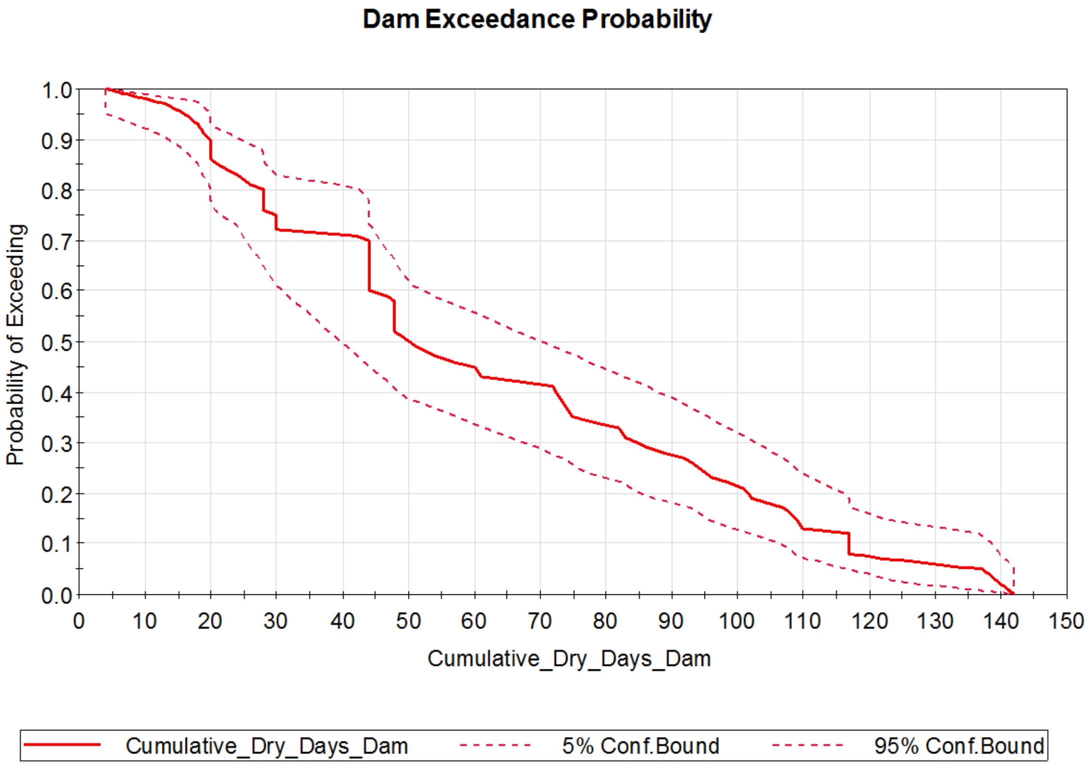


Figure 5: Reliability of a freshwater dam from a daily Monte Carlo simulation run 50 times for a 5-year period

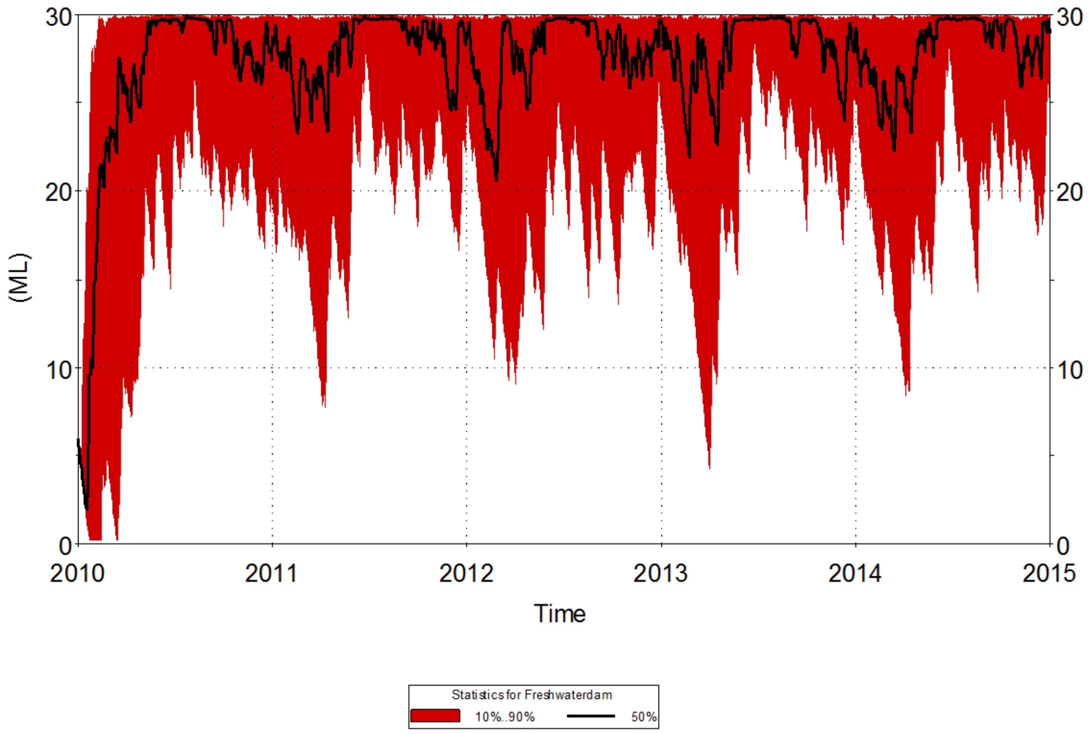


Figure 6: Volume of a freshwater dam from a daily Monte Carlo simulation run 50 times for a 5-year period (this is a revised run of Figure 5, with the dam volume increased by 15 ML).

3 APPLICATIONS FOR DISTRICT AND REGIONAL PLANNING

3.1 RESILIENCE IN WATER SUPPLY

A GoldSim model will help improve resilience of the site, town or city and provide an end user with:

- a better understanding of the system and key areas of risk (e.g. reservoir capacity or leakages)
- areas for improvement in data inputs (due to higher uncertainty)
- where critical areas of the system can be improved to reduce the risk of failure under certain scenarios (e.g. droughts)
- cost benefit assessments based on a variety of mitigations that could be implemented to improve the system performance

3.2 CONSENT RENEWALS AND AEE'S

Water supply modelling can incorporate operational consent conditions, such as abstraction and discharge consents. In doing so, evaluation of the system performance can determine:

- If the current consents are meeting the requirements for the site or town, and if this would be suitable under climate change and extreme events
- Whether improvements can be made to the infrastructure that would allow future consents to be more sustainable (e.g. reducing the abstraction rate by 20% due to network capacity improvements or resolving leakage issues)

3.3 WATER MANAGEMENT PLANS

Many regional councils are requiring water management plans for potable water takes, particularly when the consents are up for renewal. Greater consideration is now required of the sustainability of the abstraction (and available allocation) for water use, and the Assessment of Environmental Effects (AEE) is required to show how the abstraction is sustainable and will not lead to detrimental effects on the environment, while also meeting future demands.

The process of building a water supply model and conceptualizing the system can then be directly incorporated into a water management plan, with the model providing a much greater understanding of how the system can be improved and if it can meet population increases and seasonal demands. This will increase the likelihood of a more seamless consent renewal process and possibly result in a longer consent duration.

Alternatively, if the water management plan or AEE does not show sustainable water use in the face of aging infrastructure and population growth, a granted consent may have a shorter duration, requiring more frequent renewals and subsequently increased cost to rate payers.

3.4 LONG TERM PLANS

Allocation of funding in long term plans can be refined based on the outputs from a water supply model. The model provides an overview of the system and helps identify areas that need further data collection or even immediate infrastructure improvement.

This can be based on priority and risk, where a cost benefit analysis can be completed to determine whether an infrequent extreme event can be factored into the system's design, or where small improvements on regular events and current infrastructure could be more beneficial to the community.

This opens the door for more detailed investigations (e.g. network modelling) where required, and can provide enough information for cost estimates.

4 CONCLUSIONS

Conceptualizing and modelling of a water supply system through the process described in this paper provides end users with a better understanding of issues that may face the community and the assets they manage. This will help with water strategy plans and in the long term can lead to cost savings for rate payers, as it provides focus on the critical issues that need to be addressed through rapid scenario assessments.

This will help improve resilience through longer term and more sustainable water consents, targeted infrastructure/asset improvements and a greater appreciation of the risk and reliability of the water supply system.