RESURRECTING ROSS CREEK - AN INNOVATIVE SECURITY OF SUPPLY STRATEGY FOR DUNEDIN

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ABSTRACT

In Dunedin, on 9 December 1867 the private Water Works Company commissioned the Ross Creek Reservoir. This was New Zealand's inaugural major urban water supply, fuelling the rapid expansion of the City during the Otago gold rush and today is New Zealand's oldest surviving large dam.

The city was soon on the search for new catchments and expanded to take water from the remote Deep Creek and Deep Stream catchments. These pipelines weave for over 60km through 'tiger country' and cross the Taieri River together on a 1936 steel arch pipe bridge spanning 70m in a steep sided gorge before reaching the City. Today these systems are still the only means to supply Dunedin's high levels, accounting for at least 40% of the City's daily water demand.

With the Deep Creek Pipeline showing advanced signs of deterioration a 'lifelines' study was initiated for the replacement of these $110m assets. A long term, risk based strategy was required for determining the optimum timing; alignment; and configuration for renewal of the pipelines.

Learn about this award winning project where the surprisingly affordable risk mitigation for this 'critical' infrastructure was right on our doorstep and how Dunedin City Council aim to realise potential savings of up to $11.2m on existing LTP budgets and significantly reduce risk by augmenting existing systems and resurrecting New Zealand's first major urban water supply.

KEYWORDS

Security of Supply, Lifelines, Raw Water, Renewals, Dam Safety, Risk Mitigation, Strategy

1 INTRODUCTION

In Dunedin, on 9 December 1867 the private Water Works Company commissioned the Ross Creek reservoir. This was New Zealand's inaugural major urban water supply, fuelling the rapid expansion of the City during the Otago gold rush and, is today New Zealand's oldest surviving large dam.

The water demands of the booming city soon called for further development of the supply and so began Dunedin's penchant for expansive raw water infrastructure. A 29km water race was constructed from the Silverstream catchment to the City, officially opening in 1881. This source was later to be combined with a supply from the Taieri Bores, pumping water from the Taieri Plains to the City via an 18.5km pipeline.

Without the necessary elevation to supply water to the higher hill suburbs of Dunedin, the city was soon on the search for new catchments. The gravitational advantage was gained as Dunedin's supply system expanded again in 1936; this time to take water from the remote Deep Creek catchment. The steel pipeline weaves its way from the intake at 670m above sea level through 'tiger country' for 62km before reaching the City (see Figure 1).

By 1977 the Deep Creek supply was accompanied on its journey by a pipeline from the adjacent Deep Stream catchment. This 58km pipeline of concrete construction was delivered on a 'shoestring' budget and consequently has always proved challenging to operate.

Figure 1 – Deep Creel Pipeline in 'Tiger Country'

Today, the original Deep Creek and Deep Stream systems are still the only means by which Dunedin's high levels can be supplied, accounting for at least 40% of the City's daily water demand. Both pipes follow similar alignments; through extensive areas of land instability and crossing the Taieri River together on a 1936 steel arch pipe bridge spanning 70m in a steep sided gorge (see Figure 2). Pipe pressures at the crossing point are in the region of 350m of head.

These catchments have additional strategic value in that they feed by gravity into the highest parts of the City, eliminating pumping costs.

It is no revelation then that the Deep Creek and Deep Stream system as a whole; and in particular the Taieri River Pipe Bridge have long been recognised as key 'security of supply' risk areas. Indeed, these pipelines are regarded as 'lifelines' in the Dunedin context due to their criticality to high levels water supply. For context, a catastrophic failure at this point is likely to have a

downtime measured in months, whereas raw water supplies at the City's modest reservoirs, built predominantly for improving water quality, is measured in days. *Figure 2 – The Taieri River Pipe Bridge*

With the Deep Creek pipeline showing advanced signs of deterioration a 'lifelines' study was initiated for the replacement of these $110m assets. A long term, risk based strategy was required for determining the optimum timing; alignment; and configuration for renewal of the pipelines and an alternate crossing point of the Taieri River to mitigate the single biggest risk. It was recognised that the present configuration; the result of progressive development is not necessarily the most suitable for the future.

This paper outlines the journey to developing this innovative and surprisingly affordable risk-based strategy for the security of this critical infrastructure, realising potential savings of up to $11.2m on existing LTP budgets by augmenting existing systems and resurrecting New Zealand's first major urban water supply, the iconic Ross Creek Reservoir.

The Strategy is particularly successful because it did not require full information about the pipelines; hazards; or alternative options up front and is staged and able to adapt to future changes in demand or risk appetite.

2 BACKGROUND

2.1 THE 3 WATERS STRATEGIC DIRECTION STATEMENT

The Three Waters Strategic Direction Statement (2010–2060) outlines the guiding principles, priorities and planning assumptions that underpin decisions regarding water, stormwater and wastewater infrastructure and service delivery in Dunedin for the next 50 years.

Seven key strategic priorities have been integrated into business processes and decision making frameworks, so that the day to day operations and decision making become aligned to the strategic direction.

The key priority statement 'we will meet the water needs of the City for the next 50 years from existing sources' is of particular prominence to the Security of Supply Strategy detailed in this paper as it determined a deal-breaker criterion on which options could be considered feasible.

The 3 Waters Strategy Project was run in parallel to the development of the Strategic Direction Statement. The Project enabled the DCC to obtain a detailed understanding of the technical constraints and current capability of its three-waters networks and facilitated improvements in data quality. The development of decision support tools, including hydraulic network models were also a key output of the project and played a vital role in the development of the Security of Supply Strategy described in this paper.

2.2 THE STAGE IS SET FOR STRATEGY

The Security of Supply Strategy as we know it today began its life under a different guise.

In an attempt to mitigate the risks presented by the Taieri River Pipe Bridge conveying the City's most critical water supply infrastructure work commenced in earnest in 2009 on 'The Taieri River Bridge Bypass Project' with MWH as the principal consultants. The project proposed to create a subterranean crossing of the Taieri River approximately 1.5km upstream of the existing bridge and included the construction of the 4.3km of detour pipeline to reach the new crossing point.

The project evolved in 2010 to become the High Levels Raw Water Supply Lifelines Risk Mitigation Project. At this point the scope was expanded to include consideration of other risks present along the alignment of these critical raw water supply pipelines (such as landslides/landcreep, rockfall, earthquake and extended wet ground conditions) in addition to those immediately at the site of the crossing.

In summary, this initial project presented options for a subterranean crossing of the Taieri River to provide an alternative crossing point for the Deep Creek and Deep Stream pipelines. This second crossing point, coupled with 'local risk treatments' and a 'reticulation side' mitigation option would provide adequate mitigation against failure of the Deep Creek/Deep Stream pipelines either through failure of the existing Taieri River Pipe Bridge or through some other local failure mode such as rockfall or landslide. Drought risk was not considered in the scope of this project.

MWH provided a sound methodology that combined a quadruple bottom line analysis, conventional risk assessment techniques, and their in-house project appraisal methodology. One particularly clear point was that the strategy should focus on risk of interruption to supply. This was a key requirement as it took the emphasis away from traditional considerations of pipe condition, or even specific risks to the pipelines.

Some of the key elements to the methodology were:

- A clear 'Definition of Success' - specifying the quality and quantity of water able to be delivered to Dunedin's high levels in the event of a disaster event was paramount to the ability to test of potential solutions.

- Boundary Conditions - limiting the scope of the study kept control. For example, the 3 Waters Strategic Direction Statement stipulated 'meeting the water needs of the City for the next 50 years from existing sources'.

- Risk Analysis - desktop analysis of the pipelines at kilometre intervals with Geographic Information System (GIS) mapping for easy visualisation (see Figure 3).

- Base Case Assessment – testing alternative options in an interactive workshop against a pre-scored base case enabled competitive, appropriately weighted criteria assessment and ranking of options.

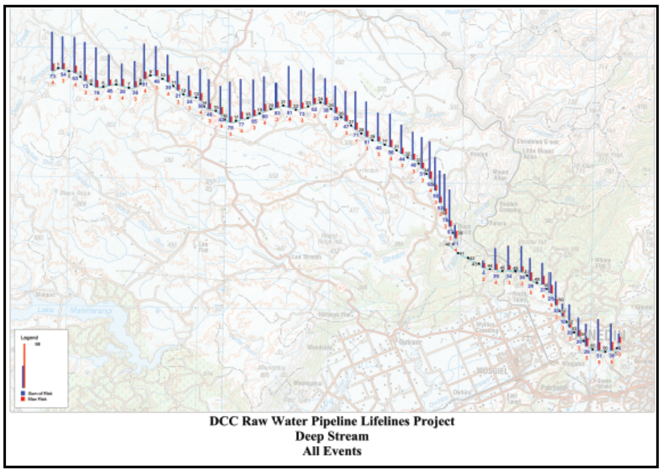

Figure 3 – Pipeline Risk Profile plotted in GIS

A testament to the rigor of this methodology was acceptance of the notion to renew the Deep Creek and Deep Stream pipelines as single pipe in the future, a concept which contributed considerable and enduring savings to the eventual strategy.

Initially there was a strong feeling among key stakeholders that the option of combining the two supply pipelines, each of approximately 60km in length was a poor option. Intuitively, it was felt that this would be putting all the eggs into one basket.

The definition of success identified a suite of measures that would act together to mitigate risk. Furthermore, since geography and hydraulics demanded that the two supply pipes largely follow the same route, at locations of specific risk the major hazard, for example landslip would likely affect both pipelines simultaneously, meaning twin pipes did not necessarily provide twice the level of risk mitigation.

The High Levels Raw Water Supply Lifelines Risk Mitigation Project established solid principles and a sound methodology through the skills and experience of the MWH led team. The project established a clear definition of success and the tools to achieve it. However, in 2011 the cost estimate for constructing the subterranean Taieri River crossing and detour pipeline, a key part of original project scope was revised from approximately $6m to at least $12.7m following considerably unfavourable geotechnical investigations.

This was a considerable setback for the project and it was ruled in a report to the Dunedin City Council Executive Management Team in May 2011 that capital investment in a subterranean bypass could not be justified until a more comprehensive, independent risk assessment of the Taieri River Pipe Bridge was completed. With the future of the project now in question Council staff determined it was time to take a fresh look at the problem.

3 AFRESH LOOK

3.1 (ANOTHER) PROBLEM DEFINITION

At the same time Dunedin City Council's Dam Safety monitoring programme had indicated that the Ross Creek Reservoir Dam and associated infrastructure, having been retired for nearly 20 years, was nearing the end of its life. The dam embankment was considered unsafe and an emergency irrigation system was established accompanied by a carefully managed lowering of the reservoir. Significant capital investment would be required in order to either entirely decommission or rehabilitate and stabilise the historic structure.

Subsequently a project was initiated to determine whether the Ross Creek Reservoir could serve any future purpose in the proposed 'reticulation side' mitigation option necessary to complement the subterranean crossing of the Taieri River in the now quiescent High Levels Raw Water Supply Lifelines Risk Mitigation Project.

Early in the investigations in was determined that the scope should be expanded to explore all alternative means of high levels raw water supply risk mitigation as it had become apparent that a satisfactory level of risk mitigation could potentially be obtained through augmentation of the existing and/or retired metropolitan raw water supplies at a lower cost than construction of a subterranean crossing of the Taieri River.

The scope of the investigation therefore was to answer two closely linked questions:

1. What is the optimum combination of supply options to maintain security of raw water supply for metropolitan Dunedin during a disaster event or drought at a minimum cost to the ratepayer?

2. Based on the above, is it advisable to retain Ross Creek Reservoir for security of raw water supply?

The strategy resulting from this work, as presented in this paper, builds on the methodology established in the High Levels Raw Water Supply Lifelines Risk Mitigation Project to protect the raw water supply to the City's water treatment plants (WTPs) in either a disaster event or drought scenario. A key feature of the strategy is the elimination of the single point dependency for the high levels, and therefore the need to mitigate those risks.

A disaster event for the purposes of this strategy was deemed to be a catastrophic failure of a raw water pipeline through mechanism such as earthquake; landslides/landcreep; rockfall; or third party collision and would be likely to result in downtime of the high levels systems measured in months.

A drought event for the purposes of this strategy was deemed to be a 30 day consecutive period of low flow relative to each of the water catchments. In the Dunedin context this is representative of a severe drought.

3.2 EXISTING SYSTEMS

The first step in addressing the expanded scope of the investigation was to examine the raw water supply systems that were currently available to the City.

The existing raw water supply systems capable of supplying the high levels of Dunedin are those of Deep Creek and Deep Stream (see Figure 4). The 1930's 300mm steel pipeline of the Deep Creek system travels 62km to the Mt Grand WTP. The catchment and hydraulic grade line is the higher of the two systems with a capacity of approximately 8,000m^3/day. The 1970's 850/700mm concrete pipeline of the Deep Stream system travels 58km to the Mt Grand WTP and has a system capacity of approximately 38,000m^3/day.

These combined systems provide water for approximately 19,000 residential connections and 1,500 commercial connections, representing approximately 40% of average daily demand. However, these systems feed the City via gravity they are often the most cost effective supply Dunedin's low levels also, at times providing for the entire metropolitan demand.

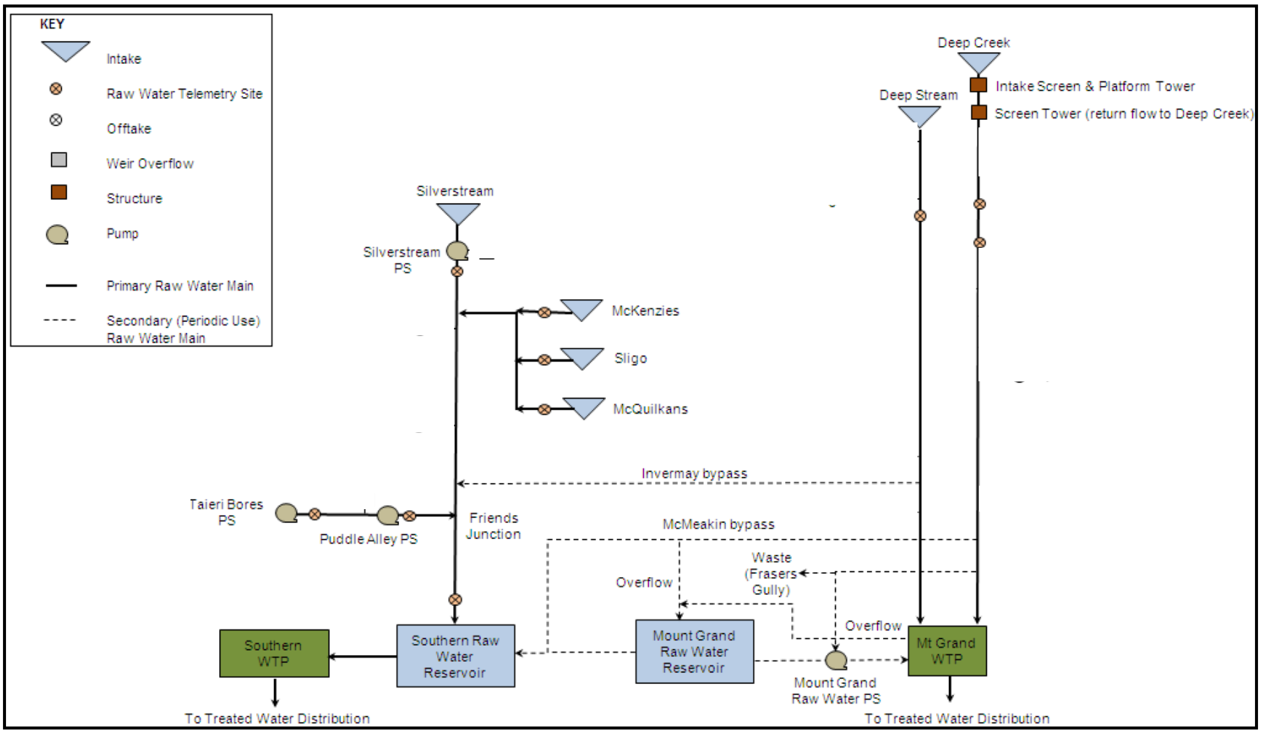

Figure 4 – Schematic of Existing Systems

The existing raw water supply systems capable of supplying only the low levels are the Silverstream system and the Taieri Bores system (see Figure 4). The Silverstream system dates back to an 1881 open water race. It now consists of predominantly 600mm late 1960's asbestos cement pipe and the small and steep catchment is well known as a 'feast or famine' system with variable water quality. Despite water takes consents for up to 34,000m^3/day, pre-existing hydraulic restrictions prevent the full consented flow from being obtained.

The Taieri Bores system was constructed in the 1950's and is capable of pumping the consented volume of 33,000m^3/day to the Southern WTP. The Taieri Bores and Silverstream flows share a single pipeline for the last 5km to Southern WTP which is limited to approximately 33,000m^3/day by pipe hydraulics.

The low levels metropolitan system currently provides water for approximately 26,000 residential connections and 2,000 commercial connections, representing approximately 60% of Dunedin's average daily demand.

3.3 IDLE SYSTEMS

The Ross Creek Reservoir, unused in almost 20 years has a useable storage volume of approximately 130,000m^3 and consented takes for 13,200m^3/day. The system's existing network infrastructure is predominantly out of commission but the associated buildings and pipe alignments are suitable for re-use.

Sullivan's Dam was constructed at the headwaters of the Leith in 1916 as an extension to the Ross Creek System. Also unused in almost two decades the reservoir has a useable storage volume of approximately 106,000m^3 and consented takes for a further 11,900m^3/day.

These systems are represented by a schematic in Figure 5.

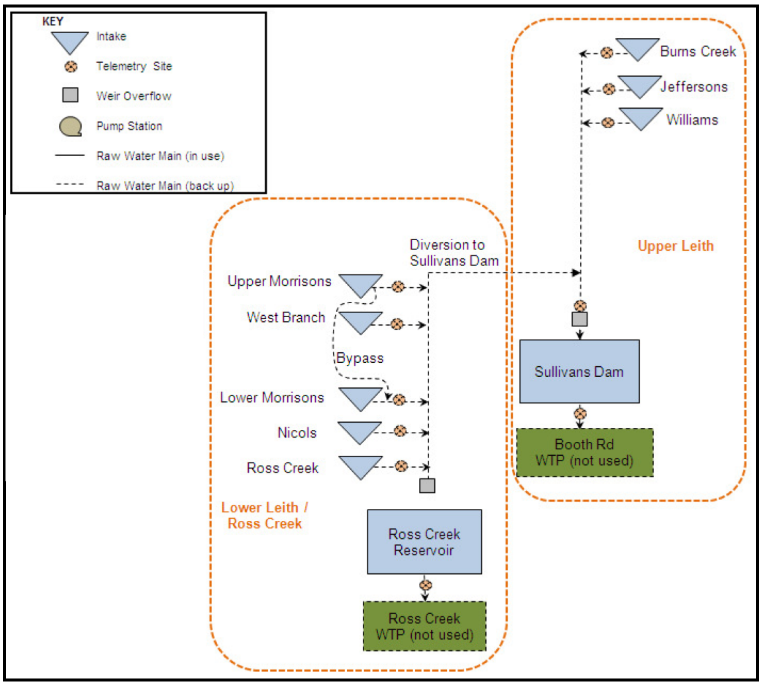

Figure 5 – Schematic of Idle systems

A geographic overview of all existing and 'idle' systems is depicted in Figure 6. The remoteness of the Deep Creek and Deep Stream pipelines in comparison to the proximity of the idle systems can be clearly seem here.

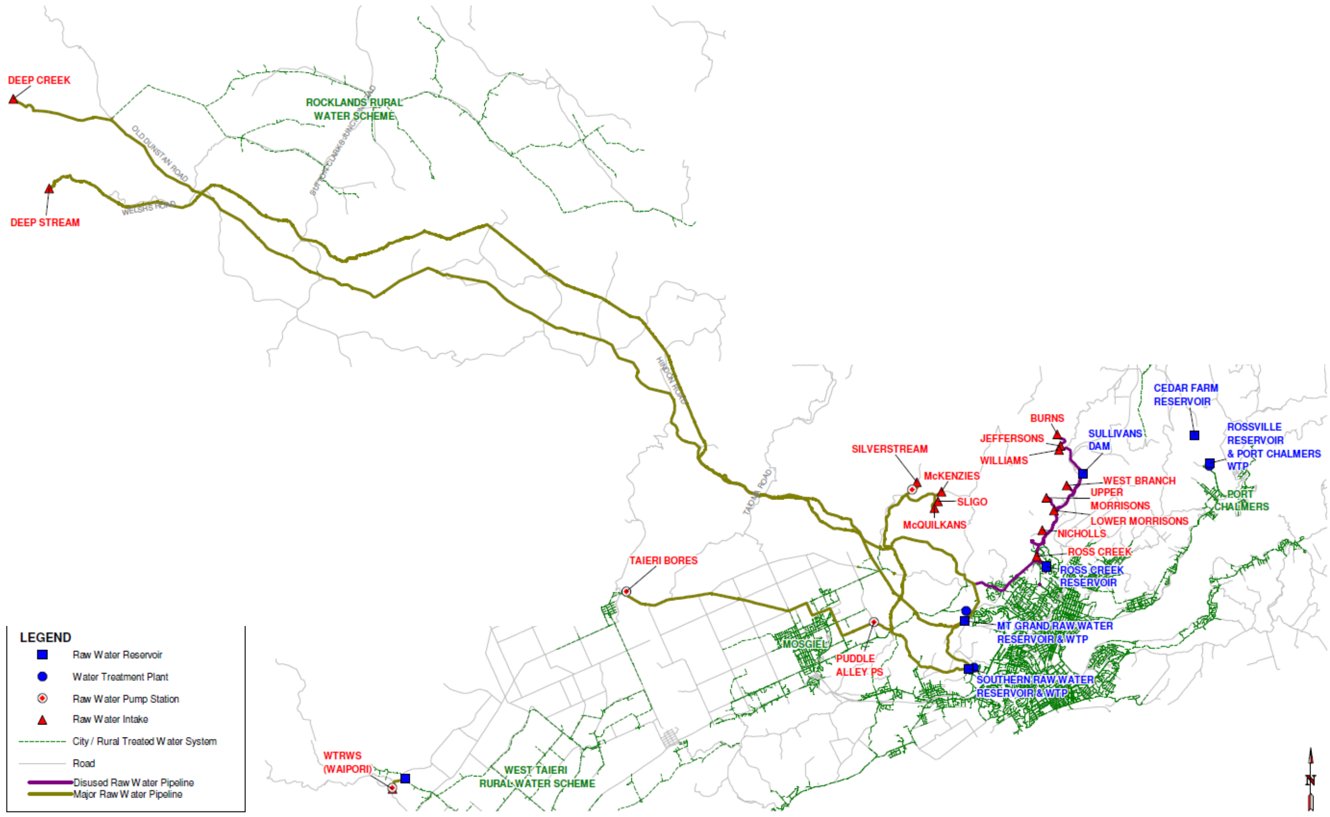

Figure 6 – System Overview Schematic

3.4 RISK SCENARIOS

A number of supply failure scenarios were defined by which to assess the viability of potential supply options:

Scenario 1. No disaster event
Scenario 2. A failure of the Deep Creek supply pipeline/intake
Scenario 3. A failure of both Deep Creek and Deep Stream pipelines/intakes
Scenario 4. A failure of all four raw water pipelines supplying Southern and Mt Grand WTPs

Scenario 1 was used solely for a 'status quo' comparison.

Scenario 2 was used to show the relative significance of the Deep Stream system compared to the Deep Creek system.

Scenario 3 considered the single greatest risk and presumes failure of the Taieri River Pipe Bridge or approaches.

Scenario 4 involves the loss of the Deep Creek, Deep Stream, Taieri Bores, and Silverstream and is considered extremely unlikely. The primary purpose of testing this scenario was to show the additional flows and storage that could potentially be provided by the 'idle' systems. This was not used as a deal breaker criterion or given significant weight when choosing a preferred strategy. However, in the unlikely event that this scenario did occur (for example following a catastrophic earthquake) the local reticulation and any additional supply pipelines are also likely to be damaged. The Ross Creek/Sullivan's systems could potentially provide some advantage over existing raw water pipelines as geographically they allow for easier repair access.

It was determined that the mitigation provided by each option against each disaster event should be assessed using both a mean flow scenario and a drought scenario, with the number of days of water supply available to the city calculated for each scenario. The coincidence of a drought event and one of the above disaster scenarios is used to present a worst case scenario.

The number of days of water supply available was assessed based on both present and future projected demand; and uses current climate change impact data to assess any likely effects on source availability. This analysis gives an indication of whether options are viable in the longer term.

4 ANALYSIS OF OPTIONS

4.1 OPTIONS IDENTIFICATION

Initially every conceivable augmentation of existing water supplies was examined, regardless of the intuitive credibility. These options had to focus on the use of existing water sources only to ensure alignment with the Three Waters Strategic Direction Statement.

These included both raw water and treated water options, using either augmentations of existing infrastructure or the creation of new infrastructure. The do nothing option and the subterranean Taieri River Crossing option were also analysed for completeness.

The potential need for a new large raw water reservoir had also been the subject of much discussion within Dunedin City Council for some time and there has been considerable research into the feasibility of such infrastructure. Subsequently, due to the prohibitive cost and lack of suitable location for such infrastructure downstream of the Taieri Bridge, this option was discounted from consideration at the initial assessment stage.

4.2 OPTIONS ASSESSMENT

A rough order costing exercise established that approximately $2m capital expenditure would have been required at Ross Creek Reservoir regardless of the security of supply option(s) chosen as costs were similar to strengthen the embankment; partially infill and stabilise the reservoir; or entirely demolish and fill the site.

Subsequently, the costs for the Ross Creek Reservoir were treated as 'sunk costs' in the security of supply assessment and not included in option costs. Any option(s) selected, including the Taieri Crossing options would therefore be subject to a cost of approximately $2m for the Ross Creek Reservoir works in addition to the capital cost of the option.

Each security of supply option was assessed to determine the flow and number of day's supply that it would be capable of providing under each failure scenario.

The four well-beings (the economic well-being of residents, health and social well-being of residents, cultural and environmental well-being of Dunedin) would be directly and severely affected by reduction or elimination of water supply. The assessment of each option's effect individually on the four well-beings was therefore not considered separately; instead the loss of supply itself was considered the key driver in the security of supply assessment.

The effects of installing physical infrastructure were considered secondary, and are similar for most options. All new pipelines could be constructed on existing/historic pipe alignments and therefore should present minimal environmental disturbance. Options which had a pumping component were represented in the Net Present Value (NPV) assessment by the operational cost.

The number of day's supply was therefore used as a proxy for risk mitigation and has been compared with the NPV; capital costs; and operational costs to determine the level of risk mitigation provided for each level of investment. An example of the results for a current demand scenario is shown in Table 1.

		Current Demand (2011) 44,100 m³/day		
Risk Scenario	Environmental Conditions	Days of Water Supply Available for Dunedin Low Levels	Days of Water Supply Available for Dunedin High Levels	Flow Deficit for Metro Dunedin after Storage Runs Out assuming supply at full demand ('000 m³/day)
No disaster event	Mean flow	Infinite	Infinite	none
	30 Day Drought	Infinite	Infinite	none
Loss of Deep Creek	Mean flow	Infinite	Infinite	none
	30 Day Drought	Infinite	Infinite	none
Loss of Deep Creek and Deep Stream	Mean flow	47 days	47 days	- 11.1
	30 Day Drought	30 days	30 days	- 17.1
Loss of Taieri Bores Silverstream and DC/DS	Mean flow	12 days	12 days	- 44.1
	30 Day Drought	12 days	12 days	- 44.1

Table 1 – Example of scoring an option against Scenarios

The estimated rough order of cost associated with each shortlisted option and the number of day's water supply each was presented for each risk scenario during both mean flow and drought conditions using average day peak week (ADPW) demand (see Table 1). It is important to note that because an ADPW demand was used in this assessment; the number of day's water supply presented in this report effectively represents a 'worst case' for each scenario. Both present day demand and projected future demand was calculated to ensure long term viability of any selected options.

To model a drought event a 30 day low flow scenario was used; this is representative of a severe event in the Dunedin context. For this synthetic drought it was assumed that low flow conditions existed from the point of supply failure and endured for 30 days. After 30 consecutive days of low flow conditions mean flow assumptions were resumed. This approach enabled the onset and conclusion of such an event to be representatively modelled with relative simplicity.

These calculations were also carried out for current and future mean daily demand, to model the effects of administering water restrictions during peak periods; and for current and future restricted demand to model the effects of administering permanent water restrictions. For the restricted demand scenario a 10% reduction in water use was applied to mean demand figures.

Whilst the reduced demand scenarios presented greater apparent resilience to each risk scenario they also represented a reduced level of service to the ratepayer through a restricted water supply. The reduced demand scenarios also eliminated any redundancy or contingency from each option. For these reasons recommendations are based on the use of ADPW demand. Options were not considered further if they did not provide at least 30 days of water supply upon failure of both the Deep Creek and Deep Stream raw water pipelines (Scenario 3) during mean flow conditions.

It was determined that options which did not meet the above criteria would not allow sufficient time to reinstate a temporary flow of water from Deep Creek or Deep Stream and would therefore not provide adequate mitigation of the single biggest risk.

Options were also discarded following this initial assessment if they provided no tangible benefit over a subset which provided equal or greater failure mitigation at a lower lifecycle cost.

Based on these criteria a number of options were able to be 'culled' from further investigation.

4.3 OPTION SELECTION

Dunedin City Council's New Capital Investment Decision Making Procedure was applied to the shortlisted options. For the purpose of this assessment the number of day's water supply was substituted for the Optimised Decision Making (ODM) score that is derived from the analysis of impacts on the four well-beings. The 'days of water supply' vs. project NPV graph for Scenario 3 (Loss of Deep Creek/Deep Stream) is shown for a present day scenario in Figure 7.

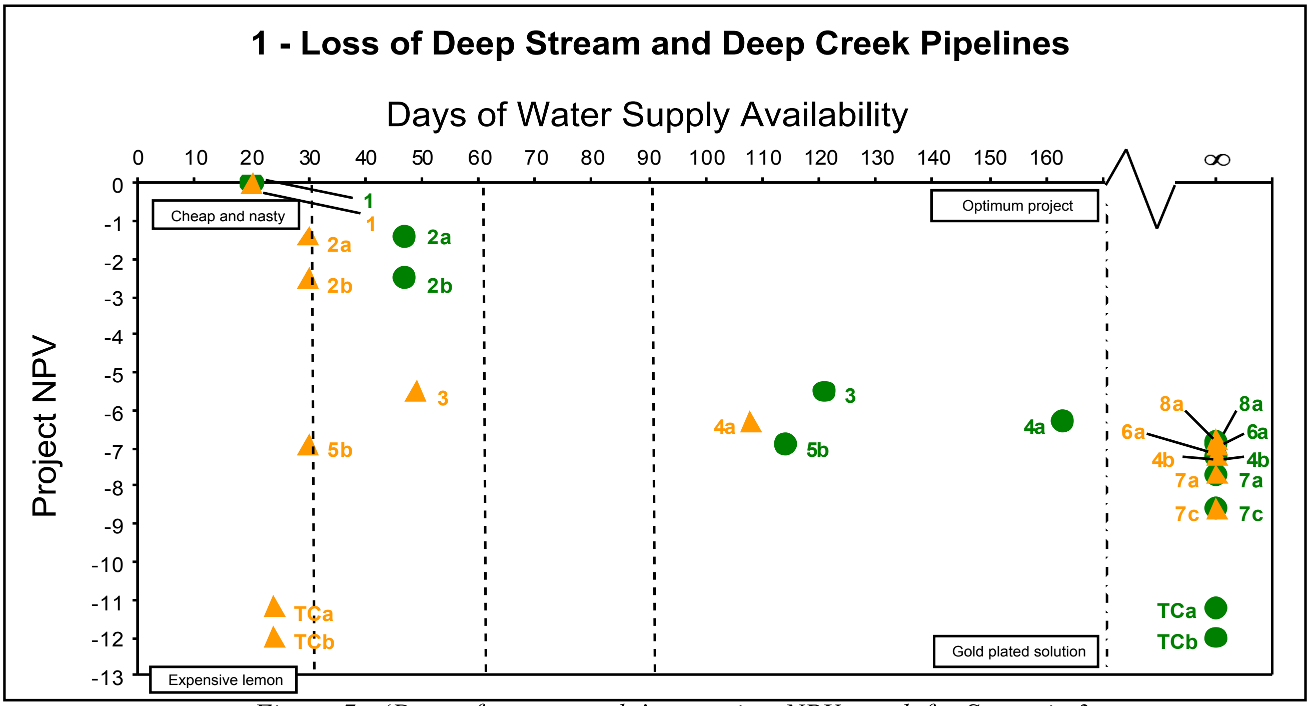

Figure 7 - 'Days of water supply' vs. project NPV graph for Scenario 3

Key: Green Dots represent No. of Days Supply under mean flow conditions.
Orange Triangles represent No. of Days Supply under drought conditions.

All shortlisted options with the exception of 'Status Quo' were able to provide at least 45 days of water supply to metropolitan Dunedin following total loss of the Deep Creek/Deep Stream pipelines under mean flow conditions but only certain options were able to meet this criterion should a drought occur during the period that the Deep Creek / Deep Stream pipelines are not in service.

As total failure of the Taieri River Pipe Bridge may result in the Deep Creek/Deep Stream pipelines being out of service for up to 12 months it is not unfeasible to imagine that the modelled drought event may occur during this period of time.

The number of day's water supply vs. project NPV was also plotted for Scenario 4 (Loss of all 4 current supply pipelines). The purpose of this was to illustrate the security that is gained through options which include additional storage. This is shown for a present day scenario in Figure 8.

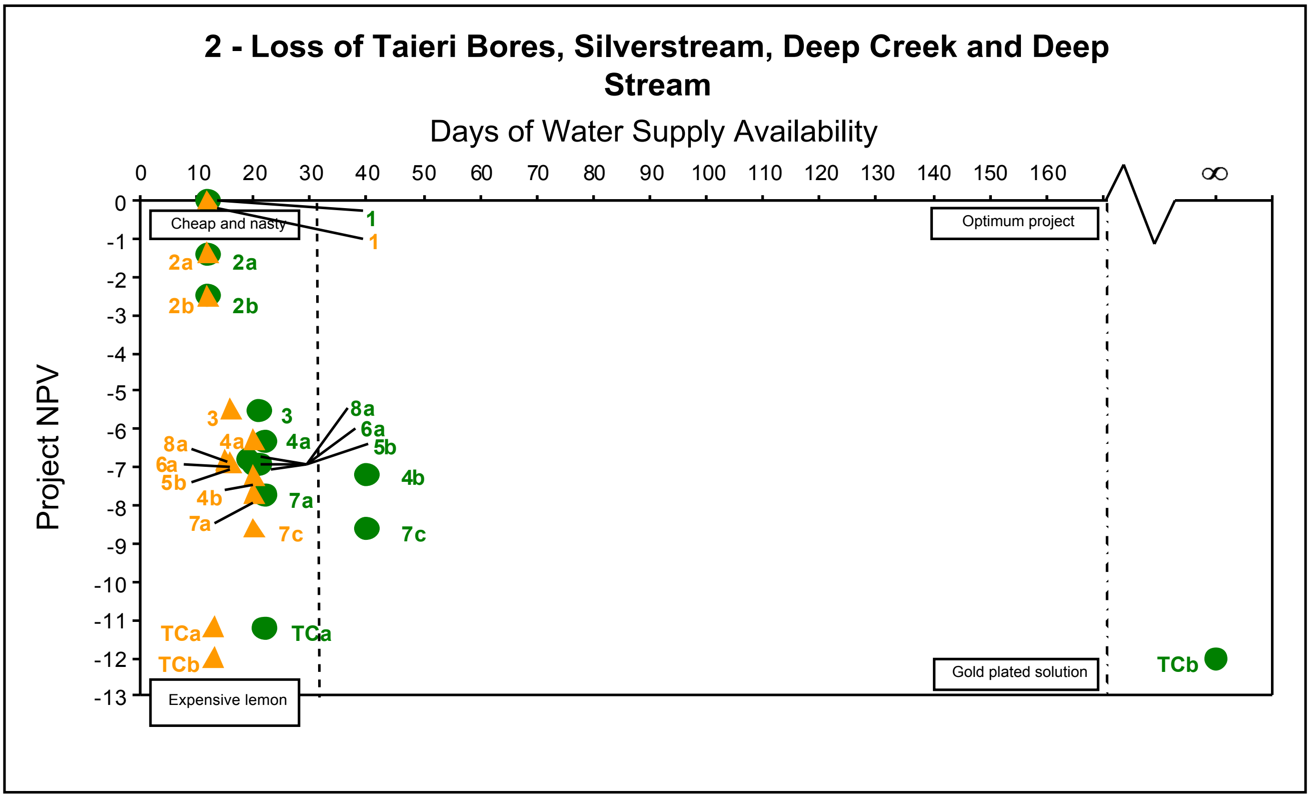

Figure 8 - 'Days of water supply' vs. project NPV graph for Scenario 4

Key: Green Dots represent No. of Days Supply under mean flow conditions.
Orange Triangles represent No. of Days Supply under drought conditions.

The above analysis indicated that a number of options were able to provide similar levels of mitigation for comparable costs. Therefore any additional benefits or liabilities associated with a particular option were examined to help determine a preferred option or staging of options.

Each option was summarised based on:

- Ability to meet supply requirements under each scenario;
- Additional operational flexibility / redundancy provided;
- Marginal increase in risk mitigation compared to marginal increase in cost; and

- Mitigation against 'double jeopardy' scenarios such as treatment plant failure during a 'Scenario'.

A number of the shortlisted options presented provide an acceptable timeframe for remediation works and several options provide adequate raw water supply for a potentially unlimited timeframe for modelled scenarios.

Subsequently the tolerances associated with each option against the single biggest risk (Scenario 3) whereby the Deep Creek/Deep Stream pipelines are lost for an extended period of time were analysed. These included:

- The Level of Service (LOS) impact associated with each mitigation option for example the level of water restrictions (if any) that would be required to allow each option to be feasible under Scenario 3 for both current and predicted future ADPW demand.

- The flow sensitivity associated with each mitigation option, account for the confidence in the data held at the time to confirm flow available in the 'idle' catchments.

- The drought resilience associated with each mitigation option, indicating whether each option provides adequate flow under the modelled drought event.

- The equitability associated with each mitigation option, indicating whether the option was 'fair', if water restrictions are required to be applied to the high levels of metropolitan Dunedin but not the low levels under Scenario 3 then an option is not equitable.

5 THE PREFERRED STRATEGY

The completion of this analysis left Dunedin City Council with a suite of options which mitigate the security of supply risk to metropolitan Dunedin. Each option presented a different level of risk mitigation for a given cost and not all options were able to sufficiently mitigate all risk scenarios considered.

Scenario 3, the loss of the Deep Creek/Deep Stream pipelines was considered as the single greatest risk and the strategy focuses on options that mitigate the risks presented by this Scenario.

It became clear that the preferred strategy should comprise a number of options/projects delivered sequentially, with the delivery of each project representing an advance towards the ideal ultimate position. This approach also allows staged investment and results in incrementally reduced risk exposure (see Figure 9).

The degree of risk accepted by Dunedin City Council is clearly linked to the level of investment and allows an association of expenditure to the risk appetite of decision makers or changes to perception of existing risks to the metropolitan water supply.

Renewals associated with the preferred strategy were also included in current renewals forecasting.

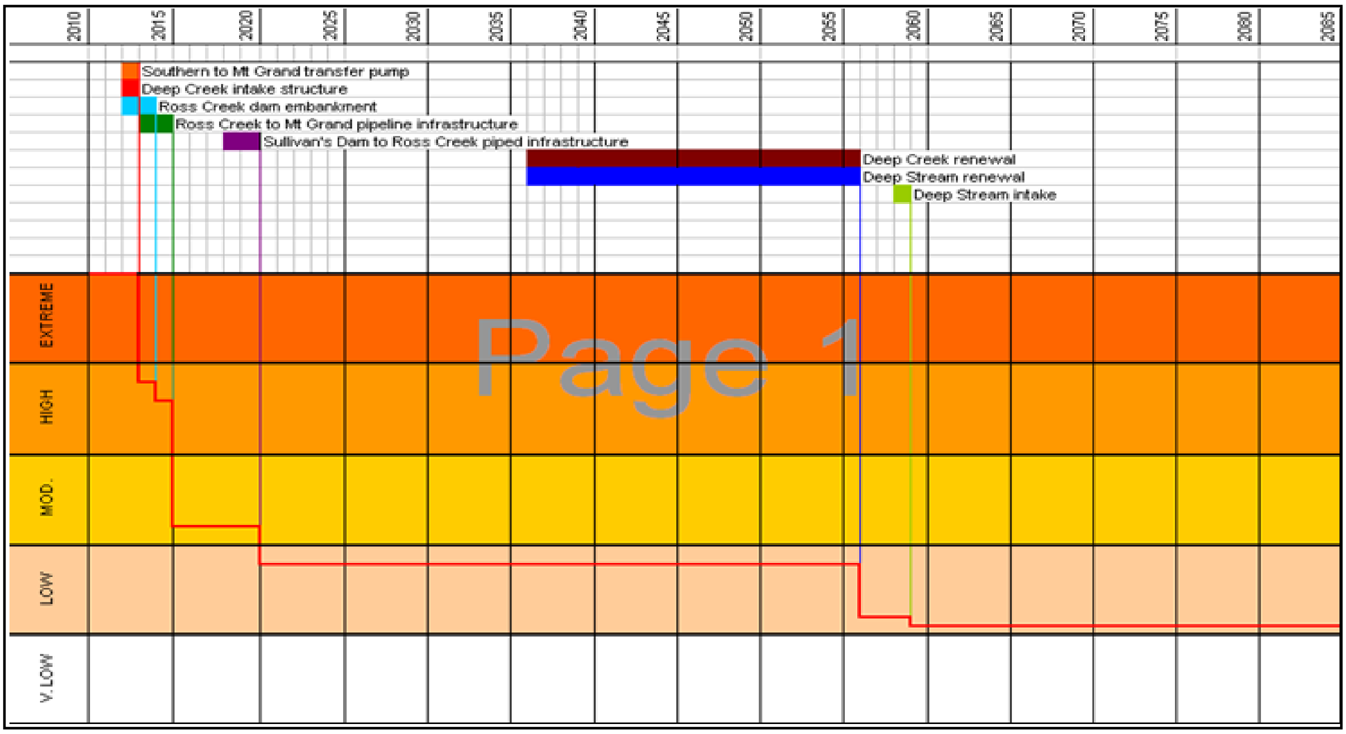

Figure 9 – Perceived risk reduction associated with the delivery of each stage of the Strategy

Risk key Extreme: <30 days supply under scenario 3; current ADPW demand + mean flow conditions
High: 30 to 180 days supply under scenario 3; current ADPW demand + mean flow conditions
Moderate: infinite supply under scenario 3; current ADPW demand + mean or drought conditions
Low: infinite supply under scenario 3; current and future ADPW demand + mean or drought conditions
Very Low: infinite supply under scenario 4; current and future ADPW demand + mean or drought conditions

Position within each risk band reflects the perceived integrity of the related infrastructure plus any associated redundancy afforded.

5.1 EARLY STAGE PROJECT

The early stage projects significantly reduce the risk of a prolonged interruption to supply for the metropolitan high levels areas and create an equitable risk exposure across the city by effectively linking the low level and high level zones (see Figure 10).

This will be achieved through the construction of a $1.2m pump station between the Southern and Mt Grand WTPs. The pump station is sized to deliver 211 litres per second at 207m of head.

This project has no sensitivity to flow conditions and once completed, water supply could be maintained to the entire city for an extended period of time following the loss of the Deep Creek/Deep Stream pipelines. With the use of modest water restrictions this period could be extended indefinitely, however the system would be highly vulnerable until full reinstatement of the Deep Creek/Deep Stream pipelines occurred.

This project is able to be funded from existing budgets and capital expenditure savings of up to $2.5m can potentially be realised from relevant existing budgets by 2012/13 under this preferred strategy. These savings are possible as the strategy negates the need to commence construction of an alternative crossing point of the Taieri River in 2012/13, for which partial funding was held.

Following completion of the early stage projects a decision point is reached. Providing results from the permanent flow monitoring of the Ross Creek / Sullivan's Dam catchments confirm current flow estimates; and unless there is a reduction in the perceived risk; the strategy will progress to the mid-stage projects.

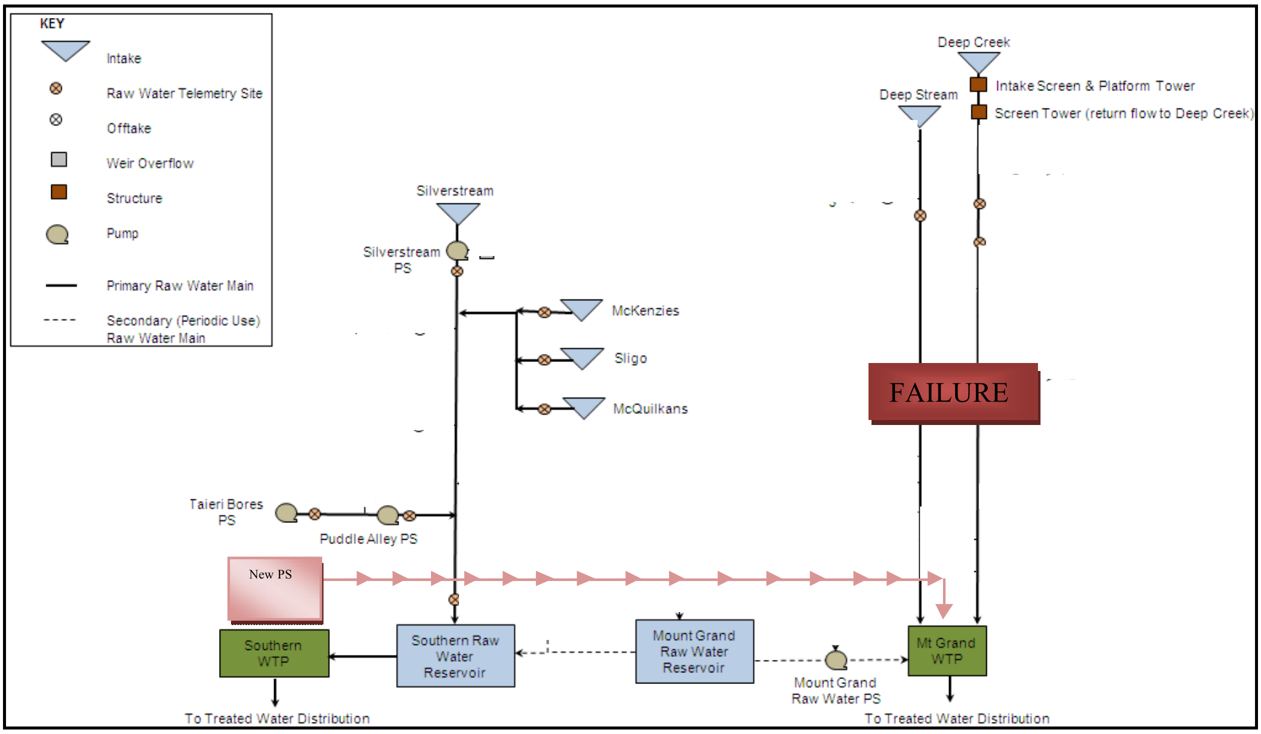

Figure 10 – Schematic showing pump station between Southern and Mt Grand WTPs

5.2 MID STAGE PROJECTS

The mid stage projects significantly further reduce the risk of a prolonged interruption to supply across the whole city and add redundancy to 'business as usual', allowing for low risk maintenance and shutdown of the Deep Creek/Deep Stream systems.

This will be achieved through a $2.1m renewal of the Ross Creek Reservoir Dam and the construction of a $3.4m pump station and pipeline between Ross Creek Reservoir and Mt Grand Reservoir (see Figure 12). The Dam renewal will retain the existing useable capacity of the reservoir at 130,000m^3; stabilise the embankment mitigating any risks posed by the existing unsafe structure; and install ultrasonic algal control at the reservoir. The smooth delivery of this project, the renewal of an historic earth dam around heritage listed structures (Figure 11), which also features as one of Dunedin's most frequented public spaces for recreation promises to be exceedingly challenging. *Figure 11 – Showing the historic Ross Creek Valve Tower*

The pump station is currently being designed and is proposed to deliver at least 162 litres per second at 220m of head and investigations are underway into the potential to run this system in reverse with excess raw water from the Deep Creek and Deep Stream systems for hydro-generation.

Projects in this stage have minimal sensitivity to flow conditions. Once completed, water supply could be maintained to the entire city indefinitely following the loss of the Deep Creek/Deep Stream pipelines without water restrictions. The remaining system would have a similar level of vulnerability to status quo following the failure of the Deep Creek/Deep Stream systems.

All projects are scoped and are able to be funded from existing budgets and capital expenditure savings a further $2.5m can potentially be realised from relevant existing budgets by 2014/15 under this preferred strategy. These savings are possible as the strategy negates the need to complete the construction of an alternative crossing point of the Taieri River in 2012/13, for which partial funding was held. The delivery of these projects also reduces the criticality of the Deep Creek/Deep Stream pipelines, allowing a deferral of the funded program of renewal for the Deep Creek pipeline. This effectively gives Dunedin City Council the confidence to 'sweat' the asset without concern over periodic failures.

Following completion of the mid stage projects there is a decision point. If there is still adequate budget to proceed and the appetite for further risk reduction is still present then the strategy will progress to the late-stage projects.

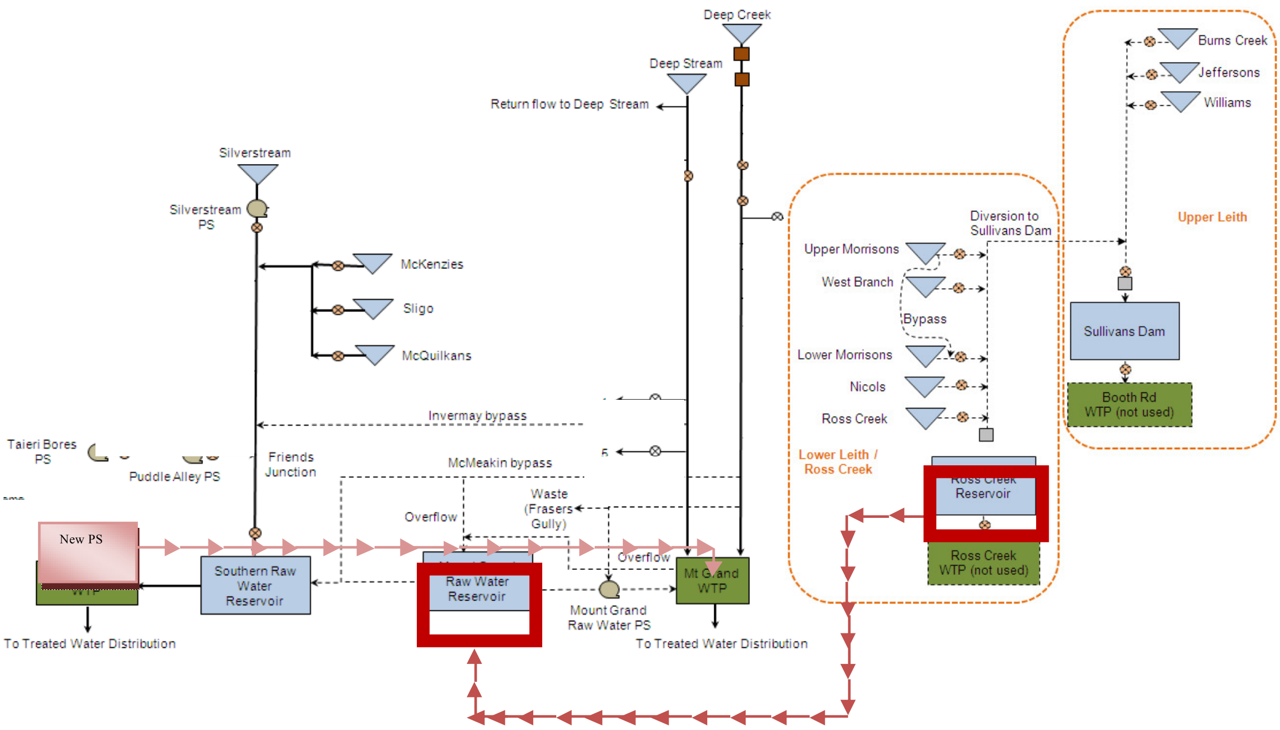

Figure 12 – Schematic showing pump station link between Ross Creek Reservoir and Mt Grand Reservoir

5.3 LATE STAGE PROJECTS

The late stage project further reduces the risk of a prolonged interruption to supply across the whole city and adds further redundancy to business as usual by linking the 'idle' Sullivan's Dam reservoir and catchments to that of Ross Creek. Capital expenditure would be $1.3m and would nominally be completed in 2020. This project is already scoped and able to be funded from existing budgets.

Projects in this stage have minimal sensitivity to flow conditions. Once completed, water supply could be maintained to the entire city indefinitely following the loss of the Deep Creek/Deep Stream pipelines without water restrictions. The remaining system would be significantly less vulnerable than status quo following the failure of the Deep Creek/Deep Stream systems.

5.4 LONG TERM RENEWALS SAVINGS

As the methodology developed by MWH in the High Levels Raw Water Supply Lifelines Risk Mitigation Project proved the concept of renewing the Deep Creek and Deep Stream pipelines as single pipe in the future; so the staged investment and incrementally reduced risk exposure presented in the resulting Security of Supply Strategy gives the confidence to implement it.

The renewal of these pipelines as a single pipeline is facilitated by the execution of the preferred strategy as the criticality of these systems and therefore the risk exposure is effectively reduced. Total capital expenditure estimated at $67.8m and may be staged any time from 2024 to 2057, nominally to commence 2036 depending on the performance of the two pipelines over the next decade. A series of condition assessments will occur over this period to help refine this renewal date.

Renewing the two pipelines as a single pipeline from the point where the alignments meet nominally realises a saving of at least $10m. This is in addition to the $11.2m in savings on existing budgets that is forecast by 2021/22 through the delivery of this strategy.

It is likely that a renewal of the Taieri River Pipe Bridge will be programmed to coincide with the renewal of the associated sections of pipeline. A recent estimate suggests that if the existing crossing point and abutments are able to be utilised the capital cost of this renewal may be a low as $1.5m.

Figure 13 shows the risk reduction per dollar associated with the 'Do Nothing' option; the alternate crossing point of the Taieri River option; and that achievable through delivery of the Strategy.

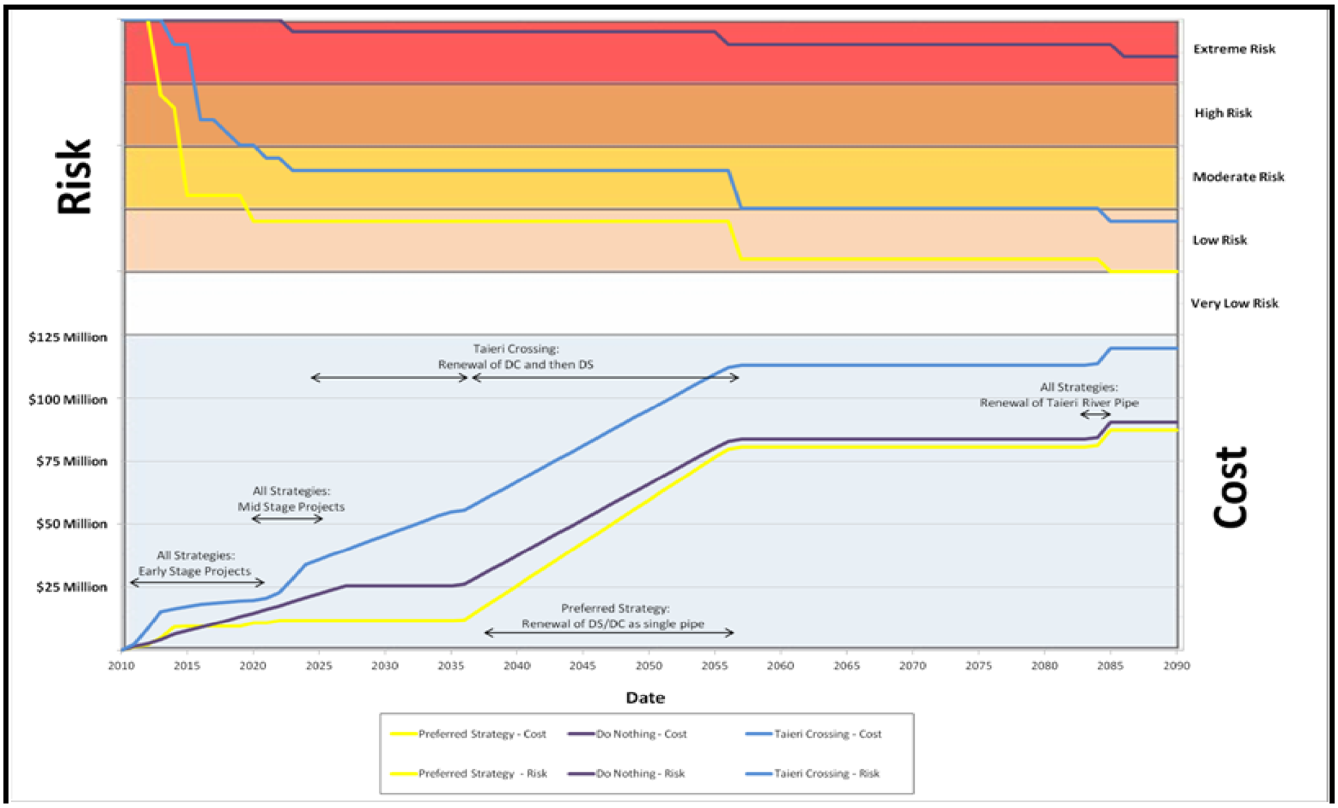

Figure 13 - Risk reduction per dollar achievable through the Strategy compared with other options

Figure 14 shows the proposed capital expenditure programme for the preferred strategy. It should be noted that all new capital aspects of this strategy are proposed to be funded from within existing budgets with potential savings on these budgets able to be realised year on year until 2021/22.

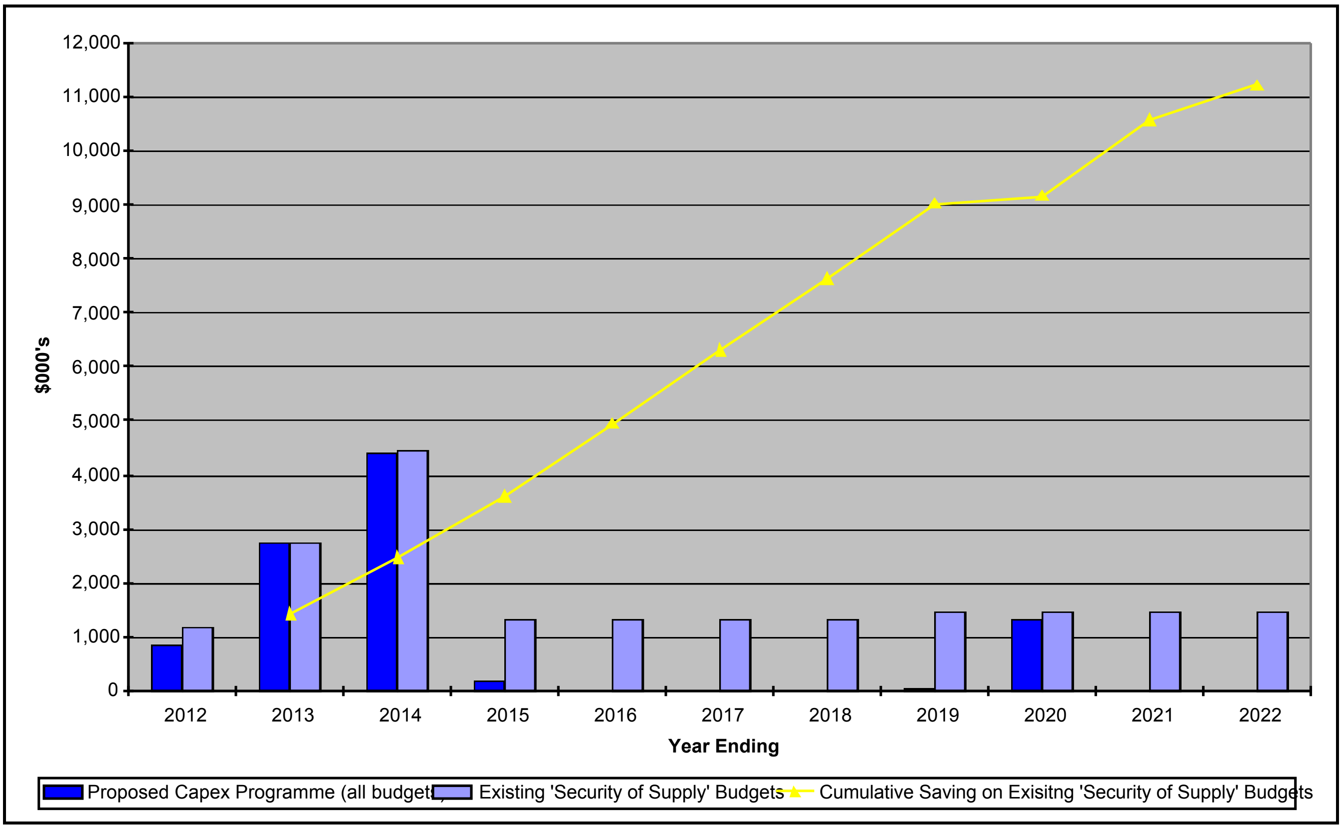

Figure 14 - Proposed capital expenditure programme and cumulative savings of the Strategy.

6 CONCLUSIONS

A long term, risk based strategy was required for determining the optimum timing; alignment; and configuration for renewal of the pipelines and an alternate crossing point of the Taieri River to mitigate risk to the security of Dunedin's raw supply.

This innovative process described in this paper produced a surprisingly affordable strategy for the security of this critical infrastructure by augmenting existing systems and resurrecting New Zealand's first major urban water supply, the iconic Ross Creek Reservoir.

Comprehensive analysis shows that execution of the Strategy allows rapid reduction to the risk of prolonged interruption to high levels supply and increases resilience of the entire metropolitan supply to a disaster event or severe drought.

This can be achieved within existing budgets and staging allows the potential for excess capital (up to $11.2m in total) to be realised as savings against relevant approved LTP budgets by 2012/22.

Further risk reduction could be achieved than is targeted, through the completion of further risk mitigation projects in addition to the preferred strategy. Such projects could include an alternative crossing point of the Taieri River for the Deep Creek/Deep Stream pipeline. However, the Strategy has shown that the marginal cost of completing such projects is prohibitive and that adequate risk reduction is achieved through the execution of the preferred strategy presented within.

The Strategy is particularly successful because it did not require full information about the pipelines; hazards; or alternative options up front and is staged and able to adapt to future changes in demand or risk appetite

7 FURTHER CONSIDERATIONS

Emergency Response / Asset Lifecycle Plans

The adoption of The Strategy fundamentally changes criticality of a number of key assets in the event of a failure scenario. The 'burden' of criticality is shifted away from the Deep Creek / Deep Stream pipelines alone and instead is distributed across the Taieri Bores, Ross Creek Reservoir, Sullivan's Dam and Deep Creek / Deep Stream systems. This distributed risk is a key benefit of the preferred strategy but appropriate emergency response plans and asset lifecycle plans must be developed for each of these systems. The development of these plans is already underway.

Algal Bloom Prevention:

It is recognised that both Ross Creek and Sullivan's Dam raw water reservoirs are vulnerable to algal blooms, events which are most likely to occur during drought conditions. These reservoirs will now be included in the raw water quality monitoring programme, currently in place for active raw water reservoirs in addition to ultrasonic algal control at each of the above reservoirs which is presently considered to be viable option for the prevention of algal blooms.

Local Risk Treatments:

There are a number of relatively minor works on the Deep Creek and Deep Stream system structures that would provide additional resilience against seismic damage at a relatively low cost. These local risk treatments are detailed in the Lifelines Risk Mitigation Project are also being programmed into future capital and renewals works.

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REFERENCES

DCC (2010) *'The 3 Waters Strategic Direction Statement 2010 – 2060'*

DCC (2012) *'Security of Supply Strategy for Metropolitan Dunedin'*

MWH (2010) '*Methodology Statement - High Levels Raw Water Supply Lifelines Risk Mitigation Project'*

MWH (2010) '*Base Case Assessment - High Levels Raw Water Supply Lifelines Risk Mitigation Project'*

MWH (2012) '*Strategy - High Levels Raw Water Supply Lifelines Risk Mitigation Project'*