Chlorine-Free Drinking Water Review

Options for the Provision of Safe Drinking Water to Napier City

Prepared for

Napier City Council

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Executive Summary

Background

Prior to 2017, the city of Napier operated its drinking water supply system without the addition of Chlorine. Napier's water is supplied entirely from groundwater and is currently pumped directly from seven operational bores into a distribution network of 480 kilometres (km) of pipelines, nine booster pump-stations and 11 storage reservoirs. Following the detection of *Escherichia coli (E. coli)* in the Napier City Council (NCC) water supply system and in light of the Havelock North waterborne disease outbreak, NCC took the decision to chlorinate the water supply to provide additional public health protection and reduce the risk of a similar incident occurring. The addition of chlorine to the water supply resulted in an increase in customer concerns and a significant increase in customer complaints, in particular Dirty Water Customer Complaints (DWCC). Since the onset of chlorination of the water supply, there has been questions from some sections of the community, and support from some councillors who have expressed a preference for NCC to remove chlorine and return to the pre-2017 situation. This can be described as the main driver why NCC is investigating moving to a chlorine-free water supply system under the future Drinking Water Standards New Zealand (DWSNZ).

A New Future

The current stance of the newly established drinking water regulator in New Zealand (Taumata Arowai) is that all water supplies must have a residual disinfectant at the customer's tap. This is to aid in the protection of public health from minor ingress into the water network through pipe leaks or backflow events, which have been shown to be associated with waterborne illness. Water supply entities can apply for an exemption to move to a chlorine-free water supply system where there is evidence to demonstrate that public health will not be compromised. On this basis, Pattle Delamore Partners Ltd (PDP) and their international partners have developed a pathway for NCC to move towards a chlorine-free future through the exemption process outlined in the Water Services Bill.

To develop an understanding of the issues and concerns of the community and responsible parties, we have consulted widely with major stakeholders and brought specific international expertise to develop an understanding of what would be required to modify the current water supply system in order to gain a chlorine-free exemption. It is important that a chlorine-free water supply system provides the same level of protection of public health as a chlorinated system and that the investment in capital projects, operational costs and organisational changes aligns with industry best practice from other chlorine-free supply systems from around the world. It should be noted that moving to a chlorine-free water supply system will require a change in how NCC and its customers manage, and value water and the infrastructure used to safely supply and distribute it.

Water Supply Risks

For both chlorine-free and chlorinated water supplies, risks to water quality must be understood, managed, and monitored. This is critical for a safe drinking water supply for the people of Napier and must be achieved to gain approval for a water safety plan (WSP). There are a number of risks to the current water supply system at the source, in the network and the reservoirs together with factors that can lead to DWCC. The addition of chlorine to the water at present provides one barrier to microbial risks. These microbial risks (together with other risks) need to be sufficiently understood, managed, and monitored before a chlorine-free system can be developed.

In terms of the source, there are currently seven operational bores, with screened at depths between 31 m and 121 m deep. NCC plan to consolidate the pumping to two new bore fields. The water bearing strata, which the bores are screened within, are overlain by low permeability strata including silts and clays which, together with an upwards pressure gradient, help to restrict direct surface influences on the groundwater and thus provides one of the barriers to microbial contamination.

Groundwater within the water bearing strata is considered to be recharged further inland, which correlates with the average estimated age of the water drawn from the city bores of between 18 years and 90 years. A proportion of younger water is present, but the bores are all classed as compliant with the current drinking water standards (DWSNZ).

Despite the presence of low permeability strata, the upwards gradient and estimated groundwater age indicating a low risk of microbial contamination for the source aquifer, microbiological water quality information suggests the bores may be at some risk of surface influences over a shorter time period, leading to an associated risk of microbial contamination. The detections of bacteria (total coliforms) in all the current supply bores, which implies that a source of young water is present which is not consistent with the current secure classification based on the age dating and bore condition assessments. The source of young water is not known at present. It could be due to leakage at the bores themselves, but the assessed condition of the bore heads suggests that it is unlikely. It could also be due to poor conditions of nearby bores providing a rapid pathway from the surface to the pumped strata. Alternatively, the bacteria could be being introduced during maintenance and other activities and potentially surviving within a biofilm in the bores. Further investigation and good hygiene and disinfection procedures, followed by further monitoring, would help establish whether this may be the reason for the total coliform detections, rather than a separate young water influence. Based on the current information, appropriate treatment for the source water is required for both chlorinated and unchlorinated systems in order for NCC to meets its obligations under the DWSNZ. NCC already have plans to provide for UV treatment to address these concerns and to ensure public health protection is maintained.

In addition to the microbial risks, minimising the number of dirty water complaints is an important factor to consider for Napier's supply. Chemical testing of the source water indicates that ammonia, iron, and manganese are prevalent in some of the bores, with the highest concentrations occurring in bores A1 and C1. The high manganese has led to the dirty water complaints, which have increased significantly with the addition of chlorine. Minimising ammonia, iron, and manganese in the source water from the production bores, where possible, is important as these parameters will affect the level of treatment required to minimise the occurrence of dirty water.

Distribution Network Integrity

A key issue for NCC is the historically low levels of investment in its water distribution network. The NCC water distribution network comprises approximately 480 km of pipe network, reservoirs, pump stations associated valves, hydrants, and service connections from water mains to the customer point of supply. Just over half the water network comprises cast iron and asbestos cement watermains which are known to be the source of leakage in most municipal water systems. NCC will need to establish an aggressive mains replacement program aimed at replacing these watermains with modern more flexible pipe materials.

The integrity of the distribution system is a key factor in supplying safe potable water to customers and is an area of contamination risk from mains breaks and non-revenue water (NRW) which includes system leakage , and backflow into the system through customer connections. A key indicator of distribution system integrity is system NRW and analysis of well managed chlorine-free systems shows low levels of NRW (<10%) as a common factor. Recent leak detection work undertaken by NCC indicates water loss of >30%. While this figure is not unusual in New Zealand, it is based upon initial results of the NRW detection programme for one suburb and will need to be corroborated. Due to the previous view that the aquifer water is available in abundance, there has not been a historic drive to conserve water and costs have been kept low by maximising the lifespan of underground assets. There has also been a previous drive to keep costs down and expenditure on the water supply network has been kept low.

In order to achieve system NRW rates comparable to other chlorine-free systems, NCC will need to undertake a series of activities aimed at including improving understanding of the likely location of leaks, better understanding pipe materials subject to NRW, and improved measurement of water production and consumption. These will include:

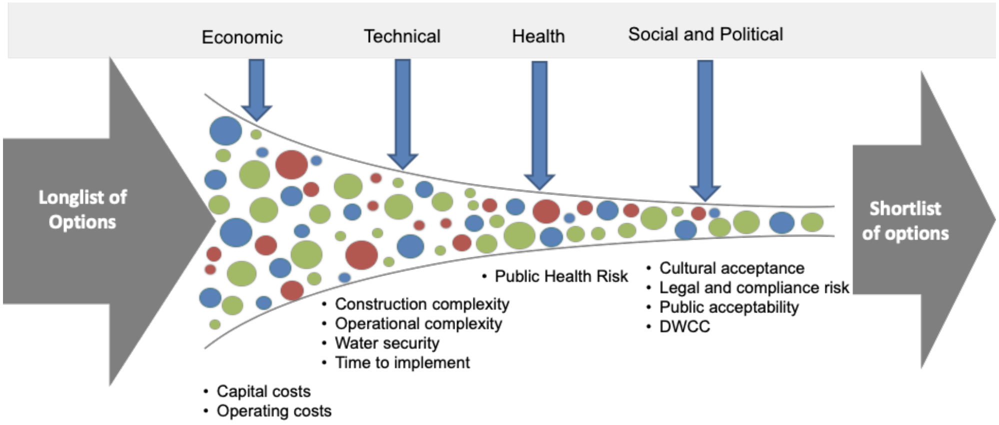
- Improved asset management (AM), including understanding the condition of buried infrastructure
- Proactive mains replacement (in older pipe networks) programme (>3% of total pipe length per annum)
- Active pressure and NRW management
- Establishment of District Metering Areas (DMAs)
- Universal household water metering
- Universal backflow prevention

Water Safety Plans

NCC is actively contributing to managing risks to the source in numerous ways, as outlined in the Water Safety Plan (WSP). Source protection zones (SPZs) have been defined around the bores by NCC and Hawke's Bay Regional Council (HBRC) provide controls on the activities that can take place within the mapped zones provided to them, which will further improve with new plan changes. Continual review and strengthening of measures being undertaken for source protection is important.

NCC undertake regular monitoring of the bore water quality, in accordance with their responsibilities as a drinking water supplier. Additional and more frequent water quality monitoring would aid in the understanding and managing of supply risks and assist in building a picture of the source water quality risks associated with microbial and chemical risks and the measures required to mitigate them.

The options assessment to get to the shortlisted options and finally identify the preferred route to a chlorine-free future is shown Figure 1.



Of the four options shortlisted, the point-of-use option was eliminated quickly due to excessive costs and little added value. The three remaining options, which would be expected to be able to obtain an approved WSP under the current and likely future water regulation in New Zealand were evaluated using a 20- year financial analysis. The analysis is summarised in Table 1

Table 1 Summary of three 20-year cost scenarios

STATUS QUO	STATUS QUO PLUS	ROAD TO CHLORINE-FREE
The total cost of this scenario is estimated at **$178 million over 20 years**.	The total cost of this scenario is **$221 million over 20 years.**	The total cost of this scenario is **$284 Million over 20 years**.

Ultimately the decision to go chlorine-free will be made by Council in consultation with the Napier community. Unfortunately, there is no quick fix that would enable Napier to return to a chlorine-free water supply in the short term.

Pathway to Chlorine-Free

There are numerous well managed chlorine-free systems around the world with examples in the Netherlands, Denmark, Germany, Austria, Switzerland as well as some in Canada and the United States of America (USA). There are some attributes that many of these chlorine-free water systems have in common:

- Low levels of non-revenue water (NRW)
- Proactive mains replacement (in older pipe networks) programme (>3% of total pipe length per annum)

- Proactive or SMART network operation and maintenance
- Active pressure management
- Active NRW management
- District Metering Areas (DMAs)
- Universal household water metering
- Universal backflow prevention
- Enhanced water hygiene procedures
- Source water protection
- Effective water treatment
- Biologically stable water
- Enhanced water quality standards - chemical and microbiological
- Enhanced water quality monitoring programme
- Trained and motivated workforce
- Clear public health policies and procedures
- Advanced asset management practices

NCC's current water network, in line with the majority of water systems in New Zealand, falls short in a number of the attributes outlined in the scope above. Moving from status quo (SQ) to Chlorine-Free (CF) involves a series of steps to make improvements from source to tap, and the extent of the investment required reflects the need to increase investment in underground assets, the management of those assets and to enhance the value placed on potable water in order to obtain a chorine free exemption from the water regulator (Taumata Arowai).

One of the major benefits of moving to a chlorine-free water supply system will be a new impetus to the investment in the NCC water supply system and its operation, which reflects the changing regulatory environment in the New Zealand water industry with a focus on the standard of care, water quality monitoring and reporting.

What should not be underestimated is the level of investment required, the time to implement the programme of works, the organisational changes, and the willingness of the citizens of Napier to accept moving to a universal water metering system.

As stated, we have developed a pathway to guide NCC to a chlorine-free future. This approach covers:

- Addressing source water protection
- Moving to two new bore fields
- Installing two new water treatment plants to remove iron and manganese, where required, and provide ultraviolet disinfection
- Installing new transmission mains that convey water to new purpose-built storage reservoirs
- Replacement of a significant portion of the current water network infrastructure to reduce leakage and assist with water conservation
- Installation of pressure and acoustic sensors to aid leak detection
- Automation of the monitoring and operation of the water network
- A universal water metering and backflow prevention programme for domestic customers
- An increase in numbers and upskilling of the current workforce
- Significantly improved data collection and management processes and systems
- An enhanced water quality and network monitoring programme

The investment outlined above is both significant and extensive and will need to be carried out in a programmed manner aligned with both affordability and availability of resources. As such, we have developed a roadmap which plots a route for NCC to go chlorine-free in a reasonable timeframe and which aligns with the likely requirements of obtaining an exemption from the water regulator (Taumata Arowai). It is important from the outset to have clear and open communications with Taumata Arowai and to set the intention and agree the key decision-making metrics along the roadmap.

Should NCC decide not to pursue the chlorine-free option, the roadmap includes the steps required to improve the current chlorinated system to a level required to meet the new water regulations in New Zealand. The chlorinated option is referred to in this report as “Status Quo Plus” or “SQ+”.

An outline of the roadmap is shown in Figure 1.

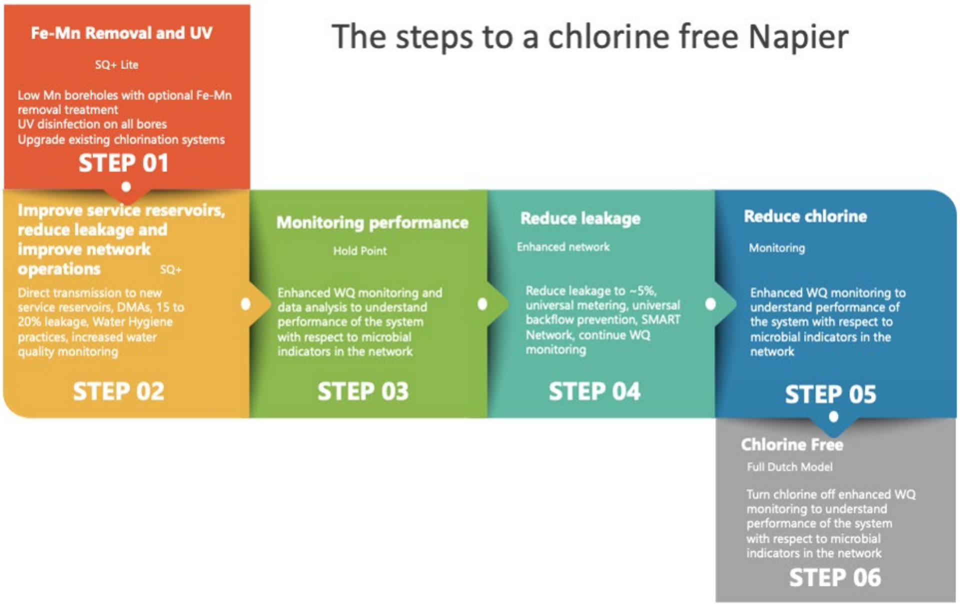


Figure 1: An outline of the steps to a chlorine-free Napier

Step 1. Status Quo Lite (2021 to 2031)

The first step is to improve the water quality entering the system by upgrading the existing chlorination systems and installing two new water treatment plants at the sites of the two new bore fields. The need for the two new treatment plants, to remove iron and manganese, will be based on further testing of the new bores and determination of the expected range of iron and manganese levels. It should be noted that to both manage DWCC effectively and transition to a chlorine-free system, the concentration of iron and manganese should be consistently below 10 micrograms per litre (µg/L). The primary disinfection process will likely be a combination of chlorine and ultraviolet (UV). Chlorination will have to be maintained until an exemption is approved by Taumata Arowai and will need to be kept available in the event of a contamination event. The removal of iron and manganese aligns with a chlorine-free water supply system since it both removes nutrients required for biofilm growth and prevents accumulation of material in the system responsible for DWCC.

Furthermore, an enhanced water quality monitoring programme needs to be developed and implemented to establish the baseline microbial and chemical fingerprint of the water supply system against which the impact of future improvements to the system can be compared. The water quality monitoring programme will need to be operational throughout the whole transition period over a number of years. This will require investment on both sampling and analysis and will increase the staffing requirements of the NCC Water Team.

Step 2. Status Quo Plus (2021 to 2031)

The next step is installing the required number of direct transmission pipelines to feed the city's new service reservoir(s). One or two new reservoirs will be required on Napier Hill to replace an end-of-life asset and to service growth. These will be built to ensure that they comply with local seismic requirements as well as being designed to minimise water age, provide adequate storage capacity, and prevent contamination from ingress.

In parallel with these works, NCC needs to start to reduce its non-revenue water, initially to between 15% and 20% from its current level of approximately 30% in some parts of the network. This can be achieved by replacing existing cast-iron, asbestos cement lined and ductile iron pipework with High Density Polyethylene (HDPE) pipework and an enhanced leak detection and repair programme. Furthermore, NCC should divide their water network into 12 District Metering Areas (DMAs) to improve network operation and non-revenue water accounting. It is also recommended that backflow prevention devices are fitted on all major water offtakes and all properties with swimming pools.

One of the pre-requisites for enhanced network performance and operation is updating NCC's approach to information management and asset management. This will allow for better investment decision-making and will establish baseline performance against which future upgrades can be benchmarked.

As part of the enhanced network operation, it is recommended that water hygiene training, practices, and procedures are improved across all water supply operations. To effectively manage the network, an increase in the number of staff will be required, covering both field operations and management. If the SQ+ option is the preferred future state this may be considered as an "end-point" in the major capital investment plan.

A step change improvement and investment in asset management processes and practices including data capture and management is required to support a well-managed system with or without chlorine.

Step 3. Establishing a New Benchmark (2031-2032)

We have recommended a HOLD-POINT as Step 3 to allow for the significant works undertaken to be fully evaluated and a new baseline of water quality and network performance to be established. It is necessary to understand the outcomes from this investment as it should inform the extent of future investment required, particularly, how improvements in non-revenue water reductions impact water quality. Furthermore, as NCC gets a better understanding of its "leakage hot-spots," targeted monitoring should be carried out to try to correlate microbial water quality with NRW. Based on the experience from our Dutch partner organisation, Waternet, a minimum one-year period of intensive sampling and analysis should provide sufficient information to allow for an evaluation and of the system performance to allow for any seasonal impacts from either water quality or changes in system demand putting stress on the network operation.

Step 4. Getting Serious about Non-Revenue Water (2032 - 2041)

To gain an exemption, senior government officials involved in the industry reform have indicated that a non-revenue water level of around 5-10 % or less needs to be achieved if a system is to be chlorine-free. Based on international experience, an aggressive water mains replacement programme will need to be implemented to achieve this, with replacement rates of between 2% and 3% of the water network replaced on an annual basis. It is expected that > 80% of the total network may need to be replaced to achieve the 5% non-revenue water target. It should be noted that the steps implemented earlier in the programme will aid in the better understanding of non-revenue water and allow for optimisation of the extent of water mains replacement. To improve the seismic resilience of the water network, it is recommended that all new water mains are HDPE.

The ongoing enhanced water quality monitoring should be used to continually understand improvements in the microbial and chemical quality of the water supply system against previously established baselines and performance targets continually updated based on latest information. By paying particular attention to water quality improvements, NCC will be clearly demonstrating to Taumata Arowai its commitment to public health.

Step 5. Reducing Reliance on Chlorine (2041 – 2042)

Once NCC is satisfied that they have a clear understanding of the water supply system and has in place the necessary resources, operational and emergency procedures, and that the agreed performance metrics are being achieved, in agreement with Taumata Arowai, a phased approached to reducing the level of chlorine in the system can be implemented. It is recommended that reductions of 0.1 milligrams per litre (mg/L) are made and that no deterioration in water quality should be observed over a minimum four-week period prior to consideration of a further 0.1 mg/L reduction being implemented. It is important that the water quality in the service reservoirs is monitored more closely during this period to ensure no deterioration in microbial quality is observed.

Step 6. Going Chlorine-Free (2043)

The final outcome will be a chlorine-free water supply system with ongoing enhanced water quality monitoring, a proactive approach to water network maintenance, a state-of-the-art water network with all necessary monitoring and control parameters to allow for effective and safe operation, a motivated and engaged workforce with enhanced public health and water hygiene awareness and a community that values water and appreciates the role of the NCC Water Team in ensuring their health and wellbeing.

The Cost of Chlorine-Free

The current changing regulatory environment is only increasing the “height of the bar” for water suppliers to legally operate systems free of residual disinfectant. Under the new Water Services Bill, Taumata Arowai has been given broad powers in relation to drinking water supplies.

This does not preclude NCC moving to a chlorine-free supply, but this will be at a considerable financial cost to the Napier community. A programme of activities and broad cost estimates (+/- 50%) has been prepared that outlines the investments required and a staged approach which involves an initial investment in moving from the SQ position to a SQ+ position. This involves a suite of projects aimed at getting improved understanding of how the water network is performing through enhanced monitoring of water quality, accelerated replacement of aging ‘leaky’ pipeline and reservoir assets, isolating the transmission and distribution networks – all aimed at reducing the public health risks associated with supplying safe and sustainable drinking water to Napier. The estimated cost of moving from the **current planned SQ position ($178 million) to a SQ+ position ($221 million)** is estimated to be an additional **$43M over a twenty-year timeframe, an increase of 24% over the SQ position.** SQ+ includes replacement of all cast iron, asbestos cement, and galvanised iron pipe at an estimated cost of $22M over a nine-year timeframe.

A second improvement step has then been outlined that moves Napier from SQ+ to an enhanced CF position where we are confident that Napier would be in a strong position to get approval from Taumata Arowai to operate chlorine-free. The second step includes the use of SMART technologies to monitor and operate the system in real-time, universal metering and backflow prevention devices, and an ongoing commitment to renewal of aging assets (to reduce and maintain NRW levels close to 5% we have suggested an ongoing aggressive programme of pipe replacement of 3% of the pipe network per annum while operating in a CF environment). The total additional cost of moving from **SQ to CF** is estimated to be an additional **$106M over a twenty-year timeframe, an increase of 60% over the SQ position.**

To **maintain CF status**, we believe an ongoing commitment of $4.8M per annum to maintain the pipe replacement programme at 3% and $0.4M per annum for water quality testing (total **$5.6M per annum**) will be required.

Summary

The steps outlined above show that there is a common approach to both achieving the status quo plus chlorine-based outcome and a chlorine-free future, and as such is seen as taking a strategic approach to investment. It is recommended that the first two steps are completed as soon as possible based on affordability criteria and the current committed capital programme. Once the impact on customer bills is understood, these steps should be expedited since they can be completed in a relatively short timeframe of under five years.

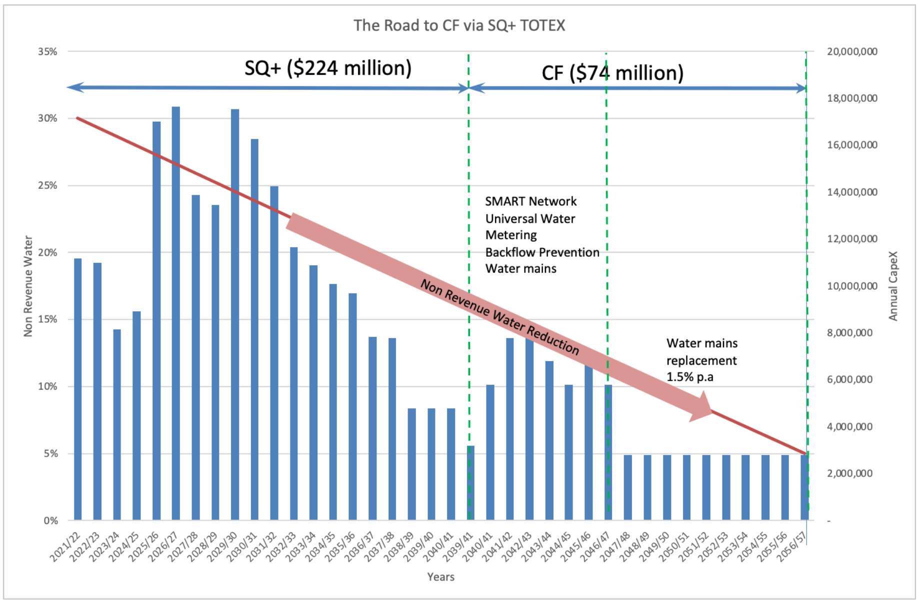
The paradigm shift required to go chlorine-free involves upgrading the current water network with up to 30% of the water lost (non-revenue water) to a system which operates at a leakage rate of around 5-10%. The strategy that we are suggesting for achieving this, is to upgrade the oldest parts of the water network by replacing all cast-iron, asbestos cement lined and ductile iron pipes, which account for over 30% of the pipework inventory. This will require replacing over 150 km of pipework and will take at least ten years to complete. Particular attention will need to be paid to the upgrade of the asbestos cement pipes as these should not be left in the ground and will require care in handling due to health and safety concerns with asbestos.

Parallel to this replacement programme, all 23,000 domestic properties will have SMART water meters installed and new service pipes with backflow prevention valves fitted; this will take between five to ten years to complete. Also, during this initial ten-year period the water network will be split into twelve DMAs to allow for the accounting of water into each DMA and ensure NCC can demonstrate the level of non-revenue water is at the rates required to go chlorine-free. Other investment during this phase will be the installation of pressure monitors and acoustic sensors and the transition of the current semi-automatic system to a fully automated water network. As this programme of works is being implemented, we recommend that NCC embarks on an extensive water quality monitoring programme to establish the baseline chemical and microbiological quality and enable the demonstration of improved water quality as the system transitions to a system suitable for chlorine-free operation.

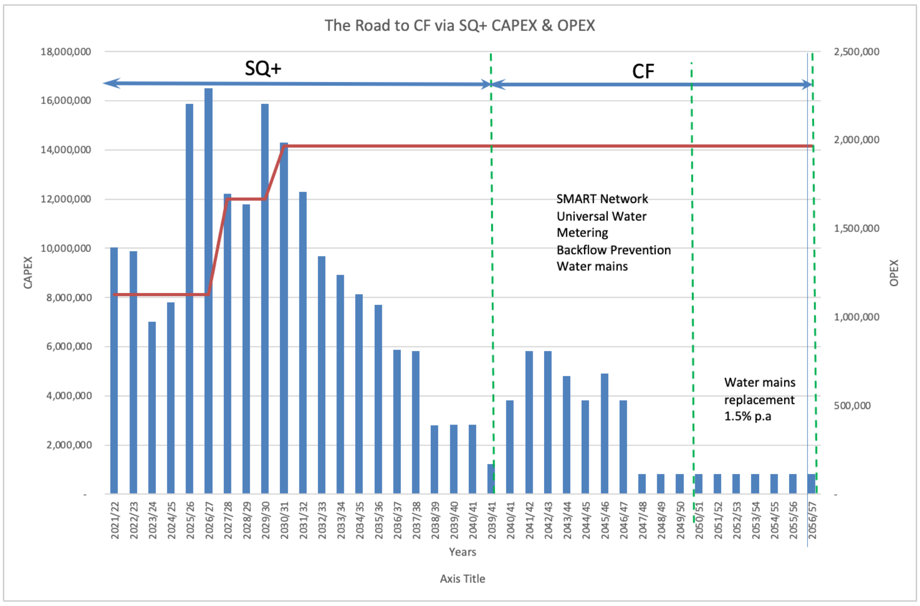
We have taken advice from Waternet on how to facilitate the decision to eventually turn the chlorine off. This is an evidence-based approach derived from water quality data and understanding the system operation on water quality. Once the city of Amsterdam decided to go chlorine-free, they did so on the basis of having sufficient confidence in the biological stability of their potable water system based on extensive microbial monitoring. The confirmation that high-quality water is maintained, within all parts of their water system, over an extended period of time, meant that a gradual approach to reducing chlorine, over a two-year period, and then eventually switching it off was taken whilst minimising public health risk.

The pathway to achieving a chlorine-free exemption is clear. The investment required is significant, the impact on customer bills substantial, and affordability may be an issue. Furthermore, the emerging structural reform of the New Zealand water industry puts at risk some of the long-term decisions that need to be made to transition to a chlorine-free system. The pathway we have developed takes a staged and strategic approach that operates within the financial constraints of NCC and a planned investment strategy in assets which will serve the citizens of Napier irrespective of future ownership models of New Zealand water utilities.

Ultimately the decision to go chlorine-free will be made by the elected members of Council in consultation with the Napier community. Unfortunately, there is no quick fix that would enable Napier to return to chlorine-free water supply in the short term whilst maintaining its obligations under the DWSNZ. The road to a chlorine-free Napier City Council water supply is a journey and requires the delivery of a series of infrastructure investment steps as outlined in this report. In evaluating the future scenarios for Napier's water supply we have looked at the TOTEX for three options and presented these as parallel alternatives for financial evaluation purposes. However, the reality is that the incremental approach, recommended, to achieve an acceptable chlorine-free outcome is based on following a set of sequential steps. What this means is that if NCC adopts this approach, then the time taken to reach the chlorine-free endpoint will be delayed and will follow on once the infrastructure investment in SQ+ has been delivered. This approach is based on a pragmatic approach to ensure a strategic approach to investment in NCC's assets. This, the infrastructure gap between the two options will be delivered in series rather than in parallel for the most affordable route. This approach, with the TOTEX implications, is outlined below.



The TOTEX numbers presented above are a sum of the annual CVAPEX and OPEX expenditure. The Figure below shows how the TOTEX numbers are derived.



In developing the initial approach, to achieve an acceptable chlorine-free option, we used an aggressive approach to water mains replacement based on an annual replacement rate of 3.5% so as to achieve the required level of non-revenue water losses within the same timeframe as all options. It should be noted that this is outside of industry norms and achieving such a rate of replacement may not be possible due to a number of factors, namely:

1. Unacceptable disruption to the operation of the City
2. Availability of competent contractors to deliver the works
3. Affordability

A more pragmatic approach would be to ensure that the mains replacement programme adopted ensures inroads into non-revenue water losses are made. As outlined in the report, water mains replacement programmes of between 1.5% and 2% are required to achieve demonstrable and sustainable reductions in non-revenue water and we would suggest that this is a target mains replacement programme following achievement of SQ+ is adopted to demonstrate a realistic timeframe for the achievement of conditions to achieve an exemption from TA. If this approach is adopted the time taken to achieve 80% of the current water mains infrastructure would be 38 years in total, meaning an additional 17 years following achievement of SQ+.

We have analysed how NCC can achieve a chlorine-free status, by which the likelihood of being granted an exemption, from both a financial viewpoint and also from a practical implementation view. The most prudent option is based on the stepwise approach discussed in this report, which identifies a date by which the criteria needed for an exemption are reached as being 2057.

It should be noted that the ongoing investment in water mains renewals may lead to achieving the 5% non-revenue water losses target earlier than stated and it is recommended that Napier City Council continues its current approach to more accurate accounting of water losses in their system. Further, as investment in the water supply system progresses the quality of information collected will improve significantly allowing for more informed decision making.

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Appendices

1.0 Background and Introduction (The Strategic Case)

1.1 The Structure of this Report

This report is loosely based around the New Zealand (NZ) Treasury Better Business Case (BBC) approach for a Programme Business Case. Programmes are about managing change with a strategic vision and a roadmap of key steps to get there. They typically comprise numerous related projects and activities that will be completed in tranches over an extended period to achieve outcomes that are greater than the sum of the parts, and are often highly complex, lengthy endeavours that span multiple years and are best broken down into a series of related projects and managed as individual projects within the context of a larger interrelated programme.

This report is organised around the five-case model which addresses five core questions:

- Is there a compelling case for change? (Strategic Case)
- Does the preferred investment option optimise value for money? (Economic Case)
- Is the proposed option commercially viable? (Commercial Case)
- Is the spending proposal affordable? (Financial Case)
- Can the proposal be delivered successfully? (Management Case)

The Better Business Case is a multi-stage document that builds over time. The Programme Business Case is focused on the Strategic Case and the Economic Case, with the Commercial, Financial and Management Cases given more emphasis over time as the projects that form the programme become more clearly defined.

The main output of a Programme Business Case is a preferred way forward. Therefore, costs outlined in this proposal are high level order of magnitude estimates at this stage with an estimated margin of error of +/- 50%.

1.2 Background

Napier City Council (NCC) has set out two future scenarios known as Status Quo plus (SQ+) and Chlorine-free (CF) to form the basis of this review. Moving to either SQ+ or CF will mean a change in several areas:

- Physical assets
- Operation and maintenance practices
- Organisational culture
- Stakeholder engagement and management
- Customer willingness to pay

The elements which make up either an SQ+ or CF future have significant commonality between them, and the approach taken ensures that the roadmap(s) developed are adaptive such that early and key decisions are aligned with both strategies to minimise unnecessary investment and that a prudent approach to investment is taken. Both strategies share common problems such as borehole contamination risk, the health of the current network, treatment mitigation measures and Dirty Water Customer Complaints (DWCC).

The primary concern of a responsible potable water supply organisation is to ensure that public health is not compromised. Consumers expect their water supply to be safe and reliable, reasonably priced and free from objectionable aesthetic characteristics such as taste, odour, and colour. For over 100 years, most public water supplies have achieved this using chlorine-based disinfection. More recently, concerns have been raised about the use of chlorine to disinfect water due to potentially harmful disinfection by-products (DBPs) and this has led to some European countries (the Netherlands, Denmark, Germany, Switzerland, and the Czech Republic) moving away from chlorine and adopting a risk-based approach including a multi-barrier approach, from source to tap, to ensure safe drinking water to customers. Since NCC is considering removing the use of chlorine-based disinfection, it is important to ask a few pertinent questions to establish a well-considered rationale and to ensure affordability is well understood.

1.3 Why Chlorine-Free?

When looking at why certain countries have moved to a chlorine-free potable water supply, several different reasons were identified. For example, in the Netherlands the move was driven by health concerns initially with trihalomethanes (THMs), which were first discovered in the 1970s by Dutch researchers. In Denmark, their system of secure groundwaters meant that chlorination was never part of their disinfection strategy. However, the Danes do physically treat their groundwater to remove contaminants such as iron, manganese and ammonium to levels which prevent problems in their network, thus limiting network maintenance and cleaning interventions.

Other European countries have similar approaches as to why chlorine is not needed or used. For NCC, the ***why*** needs to be clear and supported by all key stakeholders. Whether it is driven by taste, odour, DBPs or some other area(s) of concern, having a clear statement of purpose will enable NCC to get community “buy-in” and the journey can begin with common purpose.

What is apparent is that the reason for NCC to move to a chlorine-free system is based on recent increases in DWCC since the introduction of chlorine to the water supply system. This has been the trigger for certain parts of the community and councillors to raise concerns relating to other chlorine related issues such as taste and disinfection by-products (DBPs).

1.4 How to Get to a Chlorine-Free World

Lessons from history tell us that we should and must learn from the successes and failures of others. As such, NCC can draw on a wealth of experience on what a chlorine-free world will look like. The challenges will be how to transition, which model to follow, how long it will take, and what it will cost. The Czech Republic is one of the most recent countries to consider transitioning to a chlorine-free water supply and they have adopted the German Strategy (which is similar to the Netherlands) and is based on four tenets:

- Knowledge of all water quality source risks and protection of the catchment
- Multi-barrier treatment approach to produce biostable potable water
- A well-managed and monitored network (“good housekeeping”)
- Monitoring / surveillance from source to tap

Each of the above has several sub-categories dependent on the existing and future infrastructure needs.

It is impossible to move to a chlorine-free system without significant understanding of the source risks, the existing treatment adequacy, and the health of the current network. Measures, metrics, and monitoring will need to be developed that will be bespoke to NCC's existing set of circumstances and the current DWSNZ will not be adequate to provide suitable performance targets. As such, NCC will need to increase not only its end-to-end system water quality monitoring but also establish a new set of parameters to monitor. Significant investment in infrastructure is inevitable, with improvements in source water protection, drinking water treatment, water transmission, water storage, water pumping and water networks being required.

There will need to be a mindset shift of all those involved in the water supply system; including customers – since the cost of their water will inevitably increase, the key questions are by how much and over what time period?

1.5 Background and Key Issues

For transitioning from a chlorinated to a chlorine-free water supply system, some key areas that require specific attention have been identified:

- Risk from groundwater – how at risk from contamination is the groundwater, how is this assessed, and is it adequate
- Multi-barrier treatment approach – how to deliver the required Log Removal Value (LRV) and not rely on a single barrier approach, and how does this treatment regime meet the water quality requirements for CF and SQ+
- Maintenance and operation of the integrity of the whole water supply system, transmission mains, storage reservoirs, pumping stations, valves and hydrants, connections, the water pipework, instrumentation, NRW levels, and district and domestic metering
- Water quality monitoring and hydraulic integrity monitoring for timely detection of any failure of the system to prevent significant health consequences

1.5.1 Microbial Threats from Reticulated Water Systems

Public water supply systems have been recognised as a threat to public health since the mid-nineteenth century when John Snow recognised that cases of cholera in London were associated with the consumption of water from a particular water pump. When the pump was rendered inoperable, the number of cases declined. Further work showed conclusively that water drawn downstream from sewage treatment plants was more likely to cause enteric diseases such as cholera, and so began the link between faecal contamination of drinking water supplies and human disease. The diseases most commonly associated with faecal-contaminated water in the late nineteenth and early twentieth centuries were cholera, typhoid and bacillary dysentery.

After the development of the germ theory of disease by Robert Koch in Germany (the concept that bugs caused illness), initial attempts to improve the safety of public water supplies began with the introduction of sand filtration which was shown to reduce the total numbers of bacteria present by around 90%. During this period, there was much work being performed on antiseptics and disinfectants leading to greater survival of surgical patients and generally better health. Around 1910, chlorine disinfection of water supplies began, and this led to significant improvements in the safety of public water supplies. Thus, by the early twentieth century, the fundamentals of water treatment were established:

- Choose the best water source (e.g. not downstream of untreated sewage discharges)
- Filter the water to remove particles (including microbes)

- Disinfect the water to kill or inactivate remaining pathogens

These principles of water treatment still exist today, although with increasing knowledge and more advanced technology, some of the mechanisms of delivering safe water have changed.

In 2019, the World Health Organisation (WHO) estimated that almost 500,000 deaths occurred each year from diarrhoeal disease associated with drinking contaminated water. While most of these deaths occur in developing countries, there continue to be outbreaks of waterborne disease in developed countries, even where the standard of water treatment is high. During the Havelock North Inquiry, experts estimated that between 18,000 and 100,000 cases of illness occur in New Zealand annually due to consumption of unsafe water. Some experts believed the number to be even higher. There continue to be small outbreaks of waterborne disease in New Zealand post the Havelock North outbreak, and government have recognised the need for considerable improvement in water supply systems in New Zealand.

1.5.1.1 The Change in Causative Agents of Disease

Historically, the agents of gastrointestinal disease spread by consumption of inadequately treated water were *Salmonella typhi* (typhoid), *Vibrio cholera* (cholera) and *Shigella* species (bacillary dysentery). Polio, although not a gastrointestinal disease per se, was also spread through contaminated drinking water. In developed countries, these diseases have been largely eliminated as being contracted through consumption of drinking water. However, “new” organisms have cropped up to take their place. Since the 1970s, the role of *Cryptosporidium*, *Campylobacter* and the small round viruses in waterborne disease has become apparent. Of particular interest from this group is *Cryptosporidium*, a protozoan parasite that causes gastrointestinal disease that can be fatal in patients with immune deficiency. During the late twentieth and early twenty-first centuries, waterborne outbreaks of *Cryptosporidium* were relatively common, with an outbreak in Milwaukee, USA affecting 400,000 consumers and causing over 100 deaths. The are several reasons that this parasite became a prominent cause of waterborne disease including:

- It is completely resistant to chlorine disinfection
- It can survive in the environment for extended periods
- While it can be associated with human sewage, it is also abundant in animal faeces

Many studies showed that these organisms were prevalent in surface waters and their resistance to chlorine meant that other measures were required to remove or inactivate them. While conventional treatment (coagulation and sand filtration) removes a significant proportion from water, some water providers adopted the use of UV light treatment as a further barrier to consumer infection.

While there is no doubt that groundwater generally provides a higher quality source water than many surface waters, it is erroneous to believe that groundwater is free of risk from contamination by protozoa. The New Zealand Ministry of Health have funded a study into the occurrence of *Cryptosporidium* oocysts in groundwater and concluded that the occurrence is extremely rare. However, more comprehensive studies and epidemiological evidence suggest that reliance on groundwater to be free from *Cryptosporidium* is unwise. Groundwater contamination has been responsible for many outbreaks (Lee et al., 2002) (Barwick et al., 2000) (Moore, et al., 1993) including outbreaks of cryptosporidiosis within England and Wales (Willocks, et al., 1998) (Bridgman et al., 1995). Although the mechanism for the transmission of contamination from surface waters to groundwater was identified in one outbreak (Bridgman, et al., 1995), in another, the source was less clear (Willocks et al., 1998). Both these outbreaks were linked to heavy rainfall prior to the outbreak. In one outbreak, the source was found to be a surface water drain leading directly from a field containing livestock faeces (Bridgman et al., 1995), a very similar situation to that which occurred in Havelock North.

Recently published work from Ireland has reviewed the risk and occurrence of *Cryptosporidium* in groundwaters and has made some interesting observations:

- *Cryptosporidium* frequently occurs in groundwater sources and is a latent health concern
- Critical lack of understanding of *Cryptosporidium* transport into groundwater sources evident
- Highly applicable *Cryptosporidium* groundwater contamination 'baselines' estimated
- Need to integrate groundwater and public health research for improved prevalence insights

The research concludes that "a large geographical disparity in available investigations and lack of standardized reporting restrict the transferability of research findings. Overall, the mechanisms responsible for *Cryptosporidium* transport and ingress into groundwater supplies remain ambiguous, representing a critical knowledge gap, and denoting a distinctive lack of integration between groundwater and public health sub-disciplines among investigations."

Fate and transport studies of the majority of pathogens, particularly into groundwater are scant and do not provide a comprehensive picture of the likelihood of groundwater sources becoming contaminated. It is for this reason that the majority of regulatory bodies in developed countries do not consider that reliance on "security" of groundwater as being sufficient to ensure the safety of consumers. Furthermore, age testing of groundwater is not a reliable indicator that the water cannot be impacted by contaminated surface water. Age testing is a snapshot of the water that is sampled, and comprehensive monitoring programmes would need to be adopted to give any statistical validity to such a test. In fact, within New Zealand, age testing of the same source on different occasions has led to widely differing results and this was the case for the aquifer responsible for the Havelock North outbreak.

The application of ultraviolet light inactivation to groundwater has become widespread and if the correct dose is applied this will inactivate the majority of known waterborne protozoa, bacteria, and viruses. This technology is relatively inexpensive, easy to operate and has been installed in many locations within New Zealand. It forms an additional barrier to the natural filtration that occurs in groundwater formations. Given that groundwater conditions can change due to a variety of factors including drilling new bores, climate change, seismic activity and extreme rainfall events, it is prudent to adopt the approach of inclusion of ultraviolet treatment for all groundwater sources for primary protection against protozoa, bacteria, and viruses, including for supplies such as Napier that draw from aquifers beneath confining strata.

1.5.1.2 Groundwater Source Risks

The Stage Two Havelock North Inquiry recorded some insightful views on the security of groundwater sources based upon consultation with several experts from different disciplines:

- *By way of example, a groundwater source cannot reliably be classified as safe from surface contamination. Changes to the aquifer and surrounding hydrology can occur, bores can be* *placed into the aquifer and the aquitard can be compromised. Prevention of groundwater contamination through any of these mechanisms cannot be guaranteed.*

- *GNS advised the Inquiry that the permeability of aquifers and aquitards should be considered a dynamic variable which can change as a result of stress and strain. Earthquake shaking, or even more subtle influences, such as earth and ocean tide loadings, can influence groundwater flow pathways in the subsurface, fracture or breach aquitards, and turn confined aquifers to semi-confined as a result of changes in vertical permeability. Given the depth at which these changes can occur, contamination may exist long before a problem is recognised.*
- *In New Zealand, earthquakes pose a particular risk and have the potential to compromise the integrity of wells and reservoirs, alter the flow of an aquifer, cause an aquitard to fail, and damage piped distribution systems. GNS advised that large earthquakes can cause changes to pressure and flow of groundwater in aquifers at distances hundreds and even thousands of kilometres from the epicentre of an earthquake, and that there are many examples where shaking has induced long-term changes to water levels, aquifer performance, turbidity and chemistry, or caused damage to pumps and infrastructure.*
- *This links to the reality that New Zealand aquifers tend to be accessed by a large number of known and unknown bores in addition to the drinking water bores. The more holes drilled in the layer of protection of a secure aquifer, the more likely it is that there will be a failure, and therefore a contamination event. It is difficult for the water supplier to manage risks around bores it does not control. The Havelock North contamination highlighted these difficulties. There were numerous private bores across the catchment, some of them known, some of them not, and some providing risks of direct contamination pathways. Moreover, the drinking water bores themselves were in a condition typical for their age.*
- *Bores may allow contamination to enter the water, as cracks and holes may form in well casings, concrete seatings and aprons or covers through age, corrosion, seismic events, or wetting and drying cycles. Similarly, seals may fail around sections of bores, cable entries, and inspection covers. Maintenance may also introduce contamination, and the risks with below-ground bore heads are inherently greater, particularly with adverse weather. Loss of bore security, even for minutes, may allow levels of pathogens that are sufficient to cause infection to enter the bore such that waterborne contamination and disease outbreaks arise before that failure is detected. These issues are compounded by the fact New Zealand's public-sector investment in infrastructure has historically been lumpy and many bores are old and poorly maintained, and thus more susceptible to these events occurring.*

The Napier hydrogeological setting is different to that around the Havelock North bores, but the above points are important considerations for all groundwater sources.

1.5.1.3 The Shift in Causation of Waterborne Outbreaks

Waterborne outbreaks of disease have been recognised since the mid-nineteenth century, but documentation and investigation only really began in the early twentieth century. Even then, deficiencies in treatment and the distribution system have been noted. The focus of improving drinking water safety has for many years been the adequacy of treatment and the development of the multi-barrier approach to treatment whereby if one barrier should fail there are others to mitigate the failure. Put simply in the case of the Havelock North outbreak, only a single barrier was in place (the reliance on groundwater safety) whereas if a sufficient second barrier (e.g. adequate ultraviolet treatment or chlorination) had been in place, then the outbreak would never have occurred and 5,500 plus people would have been spared unnecessary illness. Treatment plants dealing with surface water tend to have more barriers than those dealing with groundwater simply due to the higher risk from the raw water. For most groundwater plants, ultraviolet light and chlorination forms an adequate multi-barrier approach.

The past forty years has seen an enormous effort in improving water treatment, both for chemical and microbiological parameters. For microbes, this has meant the implementation of ultraviolet treatment and in some cases the installation of membrane filters as absolute barriers to particles. This has resulted in a reduction in the number of waterborne outbreaks associated with inadequate or failures of treatment processes which is an important development as these have often accounted for large outbreaks affecting thousands of people. Consequently, as the number of treatment-related outbreaks have declined, the proportion of outbreaks caused by post-treatment contamination has increased. There are many examples of post-treatment contamination resulting in human disease, far too numerous to list here but they have involved large outbreaks such as that in the city of Nokia, Finland in 2007. Approximately 8,500 consumers became sick and 200 were hospitalised when backflow occurred from a cross-connected sewage pipe. Other outbreaks associated with deficiencies in the distribution system and its operation have been reported including Roros, Norway (2007) with hundreds of cases of campylobacteriosis due to distribution system deficiencies. This outbreak is particularly important as at no time, prior to, during or post the outbreak were *E. coli* isolated from the supply.

Fortunately, gross failures of water treatment are relatively uncommon but the improvement to water treatment seen in recent years has not always been accompanied by a concomitant improvement in the system used to distribute water to consumers. In many cases, there has been a lack of attention to system integrity, both in terms of leakage and the security of service reservoirs and other network components such as break pressure tanks. Pressure management has also often been neglected, particularly in small and medium sized systems, which is a major shortcoming since it has been conclusively proven that pressure fluctuations result in ingress of groundwater that may be contaminated with not only pathogens but also undesirable chemicals. More attention to distribution system management is required; this is addressed further in this report.

A summary of the microbial threat from reticulated water systems and waterborne diseases is provided in Table 1.

Table 1: A summary of microbial threats from reticulated water systems

Summary	Relevance to the Review
1. Chlorination of water has been in use for over one hundred years and is seen by many as one of the most significant public health advances ever.	1. Bore security status cannot be relied upon and treatment of source water is required.
2. As recently as 2019, the World Health Organisation estimated that 500,000 deaths occur annually due to consumption of contaminated water.	2. Microbial contamination of water continues to cause significant morbidity and mortality. It is paramount that

	appropriate measures are in place to prevent this.
3. The Havelock North Inquiry estimated that between 18,000 and 100,000 illnesses occur in New Zealand annually due to contaminated water.	3. Waterborne disease is common in New Zealand. Appropriate measures need to be in place to prevent such disease in Napier (a multi-barrier approach).
4. There has been a significant shift in the organisms responsible for waterborne disease, including some organisms that are resistant to chlorine treatment, thus requiring ultraviolet light disinfection.	4. Appropriate disinfection processes need to be in place in Napier, irrespective of the presence of a residual disinfectant.
5. Waterborne disease is frequently associated with deficiencies in the water supply network (e.g., ingress, backflow).	5. Risks in distribution systems need to be addressed to reduce risks of widespread illness (both sporadic and outbreaks) by reducing ingress in storage reservoirs and distribution pipework.

1.6 The Water Services Bill 2020

The Water Services Bill was introduced as a response to the Havelock North Inquiry and replaces Part 2A of the Health Act with a stand-alone Act to regulate drinking water. The Bill is complex and addresses many aspects of water supply, and this narrative is not intended as a detailed precis of the content but serves only to highlight some points that have particular relevance to NCC and the desire to provide a chlorine-free water supply system.

The government is very clear about the purpose of the Bill; it is to ensure the provision of safe drinking water within a regulatory framework that is consistent with international best practice. The emphasis throughout the document is on safety of drinking water supplies and in several instances, it is implied that aesthetic considerations will not be permitted to compromise safety. It is clear from the document that much of the intent is based around the drinking water regulations in place in England, Wales and Scotland, countries that have some of the best compliance rates for chlorine-based drinking water in the world

The fundamental outline of the regulatory framework has not changed significantly, with the basis for providing safe drinking water being:

- Protection of source water
- Provision of a multi-barrier approach to treatment
- Having a drinking WSP that identifies risk and documents mitigation strategies

These principles have been in place for many years in New Zealand but neither the principles nor the DWSNZ have been enforced effectively, an issue that was heavily criticised by the Havelock North Inquiry. The Bill makes it clear that there will be a change of approach and the appointment of the new water regulator (Taumata Arowai) comes with new powers of enforcement action for water suppliers that do not meet the DWSNZ or fail in some other way to provide a water supply system that is demonstrably safe. The meaning of "safe" in relation to drinking water is clarified within the Bill to mean water that is "unlikely to cause a serious risk of death, injury or illness" and includes both acute and chronic illness. Interestingly, the Bill goes on to say that this applies whether or not the serious risk is caused by:

i) the consumption or use of drinking water; or

ii) other causes together with the consumption or use of drinking water

The intent here is presumably to extend the definition of safe to cover industrial uses such as food manufacture but what is not clear is whether this is also intended to cover the supply of water to buildings where the microbiological safety of water is not merely around the absence of enteric pathogens but also respiratory pathogens (e.g. *Legionella* spp) that can replicate in the built environment and cause disease. *Legionella* in buildings is largely covered by the Building Act, but the responsibility for *Legionella* outbreaks is a grey area and water providers have been accused of providing unsafe water when there have been outbreaks of Legionnaires' disease. *Legionella* can proliferate in water distribution systems, particularly in the absence of chlorine. Any move to a chlorine-free system should be accompanied by a monitoring programme for *Legionella.* The organism is unlikely to be present in the source water, but it can find an ecological niche in water distribution systems, particularly in sediments in service reservoirs where it may grow, often inside of freshwater amoebae.

An additional critical clarification regarding safety is the statement that drinking water is not unsafe merely because –

a) a person objects to it, or substances in it, because of personal preference; or

b) it does not comply with aesthetic values; or

c) it contains substances that are within minimum or maximum acceptable values (MAV) for chemical, radiological, microbiological, or other characteristics of drinking water in the DWSNZ.

These statements clearly address the presence of chlorine in distribution systems, particularly with respect to the claims by some individuals that the presence of chlorine in drinking water has caused illness, often skin conditions. The Bill protects water suppliers with respect to any individual's reaction to chlorine, by stating that water containing chlorine (or any other compound) at levels below the MAV is not unsafe.

In Part 2 of the Bill, the duties of drinking water suppliers are described and again the safety of the water supply is stressed together with compliance with the DWSNZ. There is an emphasis on taking immediate action if the supply is or may be unsafe and this requires plans to be in place to deal with contamination events or failures of treatment. These should be cross referenced with the WSP. In chlorinated systems, the indicators that water may be unsafe are well documented (e.g. failure of primary disinfection, unexpected loss of chlorine residual, turbidity events) but in non-chlorinated systems, there are fewer useful indicators and so other parameters may be more helpful. One of these could be the use of rapid methods for the determination of total microbial activity. More attention needs to be paid to aesthetic complaints in non-chlorinated systems since taste and odour or discoloured water complaints may be indicators of ingress or backflow. If NCC transition to a chlorine-free system, then a system for rapidly assessing the cause of aesthetic complaints needs to be implemented.

The duty of water suppliers to protect against backflow is mentioned, but no guidance is given as to whether all connections require backflow devices or only those that are considered to be high risk. For a chlorine-free system, all connections should be provided with backflow prevention devices.

There is a requirement that drinking water suppliers and local authorities work together to address the safety of source water by minimising risks of contamination which was an issue highlighted by the Havelock North Inquiry. NCC already contributes to source water protection but should review its contribution to determine if there are further issues that can be addressed.

There is a small section that speaks to residual disinfectant within the distribution system. Essentially, the Bill states that a residual disinfectant is expected of a water supplier and if the supplier wishes to supply water without a residual, then a substantive case must be made to Taumata Arowai. There are no guidelines given as to what the application for exemption should include and this is wholly reasonable as each application will be unique in its requirements. In discussions with Taumata Arowai, both NRW and backflow prevention were prominent factors raised by the regulator. NCC should engage as early as possible with the regulator to outline the basis on which they intend to demonstrate the safety of the water that they will supply.

A summary of relevant requirements under the Water Services Bill for a transition to a chlorine-free system is provided in Table 2.

Table 2: A summary of requirements under the Water Services Bill relevant for transition to CF

Summary	Relevance to the Review
1. The Water Services Bill requires water suppliers to provide safe drinking water and to utilise source water protection, a multi-barrier treatment approach and a Water Safety Plan that documents risks and mitigation strategies to achieve this.	1. Chlorine cannot be removed from the Napier supply without having an agreed exemption plan with Taumata Arowai, of which this review is the starting point.
2. A disinfectant residual is expected to help protect against ingress, backflow, and cross-connections.	2. If there is no residual disinfectant, then NCC must demonstrate that they have other mechanisms to protect against ingress and backflow.
3. No specific guidance is given on what might be expected of a chlorine-free water system and early consultation with Taumata Arowai is recommended to determine what NCC's goals might look like.	3. NCC should prepare a robust submission and continue to seek advice from industry experts and establish a benchmark against international best practice for chlorine-free systems based on the Danish and Dutch approach.
4. Any move to a chlorine-free system should be accompanied by a monitoring programme for *Legionella* and other non-faecal organisms likely to cause respiratory disease.	4. Include *Legionella* and other non-enteric pathogens in any future monitoring plan.

5. NCC already contributes to source water protection but should review its contribution to determine if there are further issues that can be addressed.	5. Review NCC's current role in source protection.

1.7 Drinking Water Safety Plans

Section 31 of the Water Services Bill 2020 states the following:

(1) A drinking water safety plan must—

a. be proportionate to the scale and complexity of, and the risks that relate to, the drinking water supply; and

b. identify any hazards that relate to the drinking water supply, including emerging or potential hazards; and

c. assess any risks that are associated with those hazards; and

d. identify how those risks will be managed, controlled, or eliminated to ensure that drinking water is safe and complies with legislative requirements; and

e. identify how the drinking water safety plan will be reviewed on an ongoing basis, and how its implementation will be amended, if necessary, to ensure that drinking water is safe and complies with legislative requirements; and

f. identify how the drinking water supply will be monitored to ensure that drinking water is safe and complies with legislative requirements; and

g. include procedures to verify that the drinking water safety plan is working effectively; and

h. include a multi-barrier approach to drinking water safety that will be implemented as part of the plan; and

i. include a source water risk management plan under ***section 42****; and*

j. where a drinking water supply includes reticulation, provide for the use of residual disinfection in the supply unless an exemption is obtained under ***section 57****; and*

k. identify how a supplier will meet the supplier's duty under ***section 25*** *to ensure that a sufficient quantity of drinking water is provided to each point of supply; and*

l. identify how a supplier will respond to events and emergencies; and

m. comply with any requirements set out in compliance rules made under ***section 48****.*

(2) A ***multi-barrier approach to drinking water safety*** *is one that Taumata Arowai considers will—*

a. prevent hazards from entering the raw water; and

b. remove particles, pathogens, and chemical and radiological hazards from the water by physical treatment; and

c. kill or inactivate pathogens in the water by disinfection; and

> d. *maintain the quality of water in the reticulation system.*

Most of these points do not differ significantly from previous requirements, but some warrant further discussion, notably:

> b. *identify any hazards that relate to the drinking water supply, including emerging or potential hazards; and*
>
> c. *assess any risks that are associated with those hazards; and*
>
> d. *identify how those risks will be managed, controlled, or eliminated to ensure that drinking water is safe and complies with legislative requirements.*

These clauses relate to risks resulting from changes to the raw water quality and to potential risks in the distribution system. The available evidence, albeit limited, suggests that the quality of the source water utilised by NCC is stable. However, significant improvements could, and should, be made to confirm this and to provide a baseline for future assessments of change. Appropriate technology exists to monitor the physio-chemical consistency of the raw water and such technology should be fully utilised. Utilisation of such technology should be referred to in the WSP as a mechanism for monitoring changes to the raw water and in particular providing an early alert for potential rapid ingress of surface water into the aquifer.

With respect to the distribution system, there are many potential risks that need to be addressed within the WSP. These risks have been mentioned elsewhere, but include:

- Pressure fluctuation
- Major bursts
- Cross-connections
- Other ingress events

Taumata Arowai will expect to see detailed descriptions of how such events will be identified and how they will be dealt with to mitigate risks to public health. The risks from these issues are primarily of microbial origin, although there could potentially be chemical risks. Consideration should be given to all microbial groups, including a discussion relating to the remedial action required, covering whether chlorination is adequate or if a boil water notice would be appropriate. It should be noted that in a chlorine-free system, cross-connections and other ingress events may be harder to detect in a timely manner.

Pertaining to clauses (1)(f) and (1)(g) of Section 31 of the Bill:

In general, the approach that has been taken historically in New Zealand is to undertake the required amount of monitoring as described in the DWSNZ. It is unlikely that this will be acceptable moving forward and more thought will need to be applied to monitoring programmes to ensure that the water is demonstrably safe, that the WSP is working and to predict potential problems. This will be of particular concern in a chlorine-free system since chlorine residual cannot be used as an indicative parameter for identifying potential problems. Monitoring in excess of that prescribed in the DWSNZ will be necessary, but the focus should be on parameters of particular concern (information that can be gleaned from the catchment assessment and from any known deficiencies identified in the distribution system).

Pertaining to clause (1)(j) of the Bill:

This point is of particular interest and will require significant thought to determine how the risks from all distribution flaws will be mitigated. It will likely involve extensive additional monitoring to demonstrate that water quality is maintained. However, monitoring alone will be insufficient to mitigate risks and considerable capital expenditure will be required as outlined in other sections of this report.

Pertaining to Section 31(2) of the Bill:

Regarding a multi-barrier approach to drinking water safety, clauses (2)(a) and (2)(b) should be adequately covered by rigorously applied source protection zones (SPZs) and active management of activities within these zones. Clause (2)(c) implies a requirement for ultraviolet light inactivation since the word "pathogens" includes protozoa (including *Cryptosporidium*) which are not inactivated by chlorine. Current regulations allow for the physical removal of protozoa by filtration (either conventional or membrane) and it is likely that this will continue. Nonetheless, for a groundwater source, ultraviolet inactivation of protozoa may be mandatory (clause (2)(c)). Clause (2)(d) is somewhat vaguer and more difficult to interpret. Water quality generally deteriorates once it has left the treatment plant as it picks up materials within the distribution system and bacteria start to regrow. The Dutch system operates on the basis that water quality is maintained within the distribution system, with the exception of potential moderate increases in heterotrophic plate count (HPC). Maintenance of water quality within a distribution system is demonstrated by enhanced monitoring programmes focused on specific points within the system, those being service reservoirs, dead ends, and other areas where water age is maximum. The focus of the monitoring should be on microbial parameters, particularly total coliforms, *E. coli* and heterotrophs (either by plate count or one of the newer and faster tests) with other parameters added where necessary. For chlorinated systems, DBPs should form part of the suite together with pH and chlorine residual.

Section 32 of the Bill states the following:

(1) Taumata Arowai must review drinking water safety plans and monitor compliance with drinking water safety plans based on the scale and complexity of, and the risks that relate to, the drinking water supplies.

(2) The requirement is ***subsection (1****) includes—*

a. compliance of drinking water safety plans with legislative requirements; and

b. operational implementation of drinking water safety plans; and

c. compliance with source water risk management plans, including any undertakings made by third parties to the plan; and

d. ongoing review arrangements in place to ensure that risks and hazards that relate to drinking water supplies are being appropriately identified and assessed by drinking water suppliers and (if necessary) changes to the plans are made to reflect changes in the risks and hazards.

Clause (2)(a) is somewhat confusing since a WSP is a guidance document for water suppliers that explains what should be done to provide a sustainable supply of safe drinking water; it is not a compliance document. Clause (1) requires that Taumata Arowai review WSPs but does not state that "approval" of the WSP is required. It is likely that the new water regulator will move away from "approval" of WSPs which is a step change from the current situation where the Ministry of Health are extremely prescriptive about how a WSP should be written. WSPs should contain certain information that is required to ensure that water can be supplied safely, but the exact format is not important. They should be written to suit the individual water provider.

The Water Services Bill clarifies the requirements of WSPs without being prescriptive about how they should be written. This is well-aligned with regulatory authorities around the world. There has been much debate over the requirements of a WSP for a non-chlorinated system compared to one for a chlorinated system. In practice, there is little difference. Residual chlorine protects against the microbiological effects of small to medium intrusion events, but not against cross-connections. It also acts as an indicator of ingress of contaminated water as the organic matter present in such water reacts with free chlorine resulting in a drop (usually to below detection) of residual concentration. Thus, the major difference between a WSP for a chlorine-free system is that there needs to be documentation that describes how the system protects against small to medium ingress events and how these will be identified. Additionally, residual disinfectant can help to reduce regrowth of bacteria within distribution networks. This is considered to have no detrimental health effects, but can cause aesthetic problems particularly with taste, odour, and coloured water. These factors should also be addressed in the WSP.

A summary of relevant effects of the Bill and the authority of Taumata Arowai on WSPs is provided in Table 3.

Table 3: A summary of the effect on WSPs under the Water Services Bill

Summary	Relevance to the Review
1. Water Safety Plans that conform to current WHO guidelines will be required by Taumata Arowai.	1. More stringent operations and maintenance practices will be required for Water Safety Plans for chlorinated and non-chlorinated systems.
2. There is no requirement for Taumata Arowai to approve Water Safety Plans, but water suppliers are expected to have adequate plans in place and be able to demonstrate that operational activities conform to the description given in the plan.	2. NCC should prepare a robust submission and continue to seek advice from industry experts and establish a benchmark against international best practice for chlorine-free systems based on the Danish and Dutch approach. It is essential that all relevant NCC staff (including executives such as the CEO) are familiar with the WSP.
3. Monitoring in excess of that prescribed in the DWSNZ will be necessary, but the focus should be on parameters of particular concern.	3. NCC needs to develop a robust monitoring plan that gives substantive information about the whole system, from source to tap, including deterioration of water quality within the network.

1.8 Monitoring Water Quality

The majority of water quality monitoring in New Zealand is performed in response to the DWSNZ, and as such is focused on regulatory requirements rather than for operational reasons or for predictions of deterioration of water quality within distribution networks. Contrastively, in the

United Kingdom (UK) and many other jurisdictions, approximately 50% of the total monitoring that is undertaken is for non-statutory purposes. NCC have traditionally undertaken minimal monitoring, although in the last three years, certain aspects of the monitoring programme have been enhanced and more information is becoming available. Irrespective of the decision on whether to remove chlorine from the network, NCC needs to develop a robust monitoring plan that gives substantive information about the whole system, from source to tap.

When developing a monitoring programme, there are fundamental questions that need to be addressed before any changes are introduced. These questions are:

- Why are we monitoring?
- What should we monitor?
- Where should we monitor?
- How should monitoring be undertaken?

Further to these fundamentals, consideration should be given to reporting (mechanisms and formats) and to the utilisation of analytical data in future decision-making. This latter point is critical for NCC as they seek to find a way that offers a chlorine-free distribution system whilst minimising risk to consumers and protecting public health. Regarding public health, there is much misguided belief among non-water professionals that enhanced microbiological monitoring (i.e. monitoring more frequently than the regulations demand) in some way compensates for incomplete treatment. In fact, in their submission on 16 July 2020 (by Pauline Doyle on behalf of Guardians of the Aquifer), the Guardians of the Aquifer stated that in addition to removing residual chlorine from the system, they wanted NCC to "Maintain daily *E. coli* testing using a realistic testing regime, not the unrealistic regime with action alerts every time the reading is just above zero which was introduced in the panic after the 2016 Havelock North *Campylobacter* outbreak." There are two points here that require addressing, firstly, the frequency of monitoring and secondly, the level of *E. coli* that should trigger a response.

Daily monitoring of the raw and treated water (assuming that there is some treatment of the raw water) should indeed be monitored for the presence of *E. coli* on a daily basis, in addition to two other microbiological parameters, total coliforms, and heterotrophic plate count. There also needs to be regular monitoring of microbiological parameters in the distribution system at both predetermined and random points. This monitoring (together with other parameters such as chlorine residual and pH) is essential for building a picture of the microbiological quality of the system and any changes brought about by external influences (e.g. ingress, backflow, and cross-connections). Regarding the "unrealistic" regime of responding "every time the reading is just above zero," such a statement is not only incorrect but a failure to respond to any level of the faecal indicator *E. coli* would be in contravention of the DWSNZ and WHO guidelines and negligent. *E. coli* is an organism that is used as an indicator of faecal contamination and its presence is almost always a definitive indication that faecal material is present. The faecal material may be from human sources (municipal sewage or leakage from septic tanks) or can be from a wide range of warm-blooded animals (including birds) all of which have the potential to carry human pathogens. The Guardians of the Aquifer contend that a level of one colony forming unit (CFU) of *E. coli* per 100 millilitres (mL) of water is not significant and should not be cause for concern. One CFU per 100 mL is equivalent to ten million CFU per megalitre; in a bore producing 120 litres per second, this means 10^8 *E. coli* cells per day. The concentration of *E. coli* in human faeces varies but is around 10^6 cells per gram. By extrapolation, in such a bore, the daily production could contain 100 grams of faecal material. If that faecal material were from municipal sewage, it would contain more than sufficient pathogens to cause an extensive outbreak. While *E. coli* can be used as an indicator of the presence of faecal contamination, absence of *E. coli* (in 100 mL of water) does not mean absence of pathogens. There are many reports in the literature of waterborne outbreaks of disease where no *E. coli* were detected. One such outbreak occurred in Roros, Norway in 2007 where several hundred residents became sick from drinking contaminated water although no *E. coli* were recovered from the water. Similarly, during the Havelock North outbreak, while *E. coli* was detected on occasion, it was not present in all samples examined.

The purpose of microbiological monitoring needs to be clearly understood. It is not performed as an alternative to adequate treatment nor does it serve to prevent outbreaks of disease. With the currently available tests for the presence of *E. coli*, the minimum time required for routine test results to become available is 18 hours, thus if samples of treated water show the presence of contamination, by the time the results are available, the water has been consumed. Furthermore, microbiological monitoring is merely a snapshot in time, taking a miniscule proportion of the water being produced; therefore, since contamination of raw water or water within the distribution system is often sporadic, contamination events are frequently missed by routine sampling programmes.

1.8.1 The Reasons for Monitoring (Why)

With groundwater systems, the reasons for monitoring of the raw water are somewhat different than for surface water systems, although the ultimate goal of providing safe and aesthetically acceptable water remains. The focus for monitoring raw groundwater is to document any change to levels of key parameters in both the raw and distributed water, as well as to monitor any deterioration of water quality in the network. Of particular importance to NCC is to monitor any rapid changes in the raw water that may indicate a direct connection with surface water. Additionally, depending on the treatment that has been installed, changes in levels of iron and manganese may be important to inform of likely changes in DWCC. Microbial parameters are always of importance in groundwater, irrespective of the treatment installed, although if adequate disinfection systems are in place, the data are used more for Quantitative Microbial Risk Assessment (QMRA) than for highlighting any acute risk to public health.

NCC will likely be continuing with a chlorinated distribution system for some time, but if the intent is to move to a chlorine-free system, then additional monitoring needs to be in place, prior to, during the transition, and after the removal of residual chlorine. All the available evidence suggests that to remove residual disinfectant, NCC would need to improve many aspects of their water system in line with some of the measures that have been implemented recently. The move to chlorine-free should be a gradual process that is monitored carefully to generate data that demonstrates that the system is under control and that risks to public health are minimal. This should involve the demonstrable reduction of opportunities for non-treated water to enter the system followed by a stepwise reduction in the level of residual disinfectant. During this transition phase, enhanced microbial monitoring would be prudent to demonstrate the biological stability of the water and the lack of potentially contaminated ingress. It is considered that this is an essential step in the process of demonstrating to Taumata Arowai that the microbial risks to public health are minimal and under control.

1.8.2 What Parameters Need to be Monitored

For protected groundwater, which is not demonstrable under the direct influence of surface water, the range of parameters that need to be monitored on a routine basis is considerably less than, for example, a river that receives human, agricultural, and industrial waste. However, it is good practice to take samples at least once or twice a year to cover a wide range of analytes that may not be expected to be present (e.g. pesticides, herbicides, other organic contaminants and chemicals of concern, and a full metals suite). Routine monitoring involves a much smaller number of parameters and is primarily focused on microbial tests and physio-chemical characteristics such as pH, conductivity, turbidity, temperature, and colour. Additionally, some specific parameters that are relevant to the source based upon previous experience should be routinely monitored. For the Napier source water, this would include iron, manganese, and potentially other analytes of interest such as arsenic and nitrate. There has been increasing interest in the occurrence and significance of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in groundwater in recent years. These compounds are in widespread use and have been found in New Zealand waters. It would be prudent to undertake a monitoring programme for the occurrence of these substances if it has not already been undertaken.

Regarding microbial parameters, the basis for the microbial testing suite for raw water is total coliforms, *E. coli* and “total heterotrophs” with some level of protozoa monitoring. Other parameters may also be useful. For example, in the Netherlands, routine enumeration of the genus *Aeromonas* forms part of the analytical suite, but this may reflect the particular interest of a small group of microbiologists based there. Similarly, *Legionella* monitoring forms part of the routine analytical suite and there is a more scientific rationale for this, as disease due to *Legionella* (Legionnaires’ disease and Pontiac fever) is a substantial cause of morbidity and mortality in developed countries. Guidance should be sought by NCC on exactly what parameters should be included in their monitoring suites.

Within the distribution system, if there is residual disinfectant then this should be monitored regularly along with other physio-chemical parameters such as temperature, turbidity, and pH.

1.8.3 Where to Monitor

For groundwater systems, monitoring of source water is critical and monitoring of raw water should form a significant component of routine monitoring. If treatment is in place, then sampling should include both source and treated water daily for large systems. Within the distribution system, several fixed sites should be identified for routine monitoring. Typically, these include significant assets within the system such as service reservoirs and where applicable, bulk supply points. Additionally, samples from specifically installed sample taps positioned at strategic sites within the network should be taken regularly. For systems with residual disinfectant, the frequency of sampling may be less than for systems with no residual. Such sampling should cover all distribution zones and locations where water age may be high. For many large systems, many water providers include “random points” which are sample taps at customer’s premises.

1.8.4 When to Monitor

The monitoring frequency must be more than that required by the regulatory authorities, but in New Zealand that frequency is very low for all systems and historically been based on cost. The frequency of monitoring of the raw (and treated if applicable) water should be daily, regardless of a residual disinfectant being applied or not. Those samples should be analysed for microbes and appropriate physio-chemical parameters.

When monitoring in the network, the frequency of sampling is impacted mainly by the population, complexity of the system, the number of dead ends and areas of stagnation, and the potential for ingress. The frequency of sampling is usually increased when there is no residual disinfectant and during the transition period from residual to non-residual systems.

1.8.5 How to Monitor

This aspect of monitoring is often overlooked, with water suppliers choosing the least expensive or most convenient laboratory services for routine monitoring. NCC should satisfy itself that the organisations providing laboratory services, including sampling, are suitable for the task. As a minimum, laboratories should be International Accreditation New Zealand (IANZ) accredited and it is often useful to have laboratories audited independently, either by a member of staff or an external expert. NCC should also review all External Quality Assurance results for the laboratories that they utilise. Sampling and transport of samples is critical to obtaining high quality results, and NCC must ensure that these aspects of monitoring are under control.

For most raw water parameters, online data should be collected to include conductivity, pH, turbidity, and temperature. If disinfection is in place, then appropriate parameters (chlorine, pH, UV transmittance, and UV dose) should also be in line with appropriate alarms. Microbial parameters should be analysed in an appropriate laboratory. There are several instrument manufacturers that claim to have instrumentation for the online detection of *E. coli*. To date, none of these instruments have been shown to have the required level of sensitivity or specificity for drinking water purposes. While many water suppliers include an assessment of water quality based upon the HPC, the data are seldom utilised effectively. This is partly because of the long period before a result is available (the test typically takes three days), and because the results do not have a direct health significance. However, particularly in chlorine-free systems, a measure of microbial activity is vital in demonstrating that distribution networks are under control. The traditional HPC measures a proportion of the bacteria present in a water sample that can grow given a particular supply of nutrients and incubated at a specific temperature for a given period. Such tests may only recover a small proportion (<5% is not atypical) of the bacteria present. Other tests are available that are able to enumerate a much larger proportion of the total bacterial flora (although not always the 100% that is often claimed) and can do so in a matter of minutes rather than days; their utility was demonstrated in the UK over twenty years ago. Such tests (based on flow cytometry) are now the norm in the UK and the adoption of this approach by NCC is recommended if they progress to a chlorine-free system. Having results available rapidly would likely aid in persuading Taumata Arowai that NCC are managing risks from ingress and microbial regrowth.

Monitoring of water quality is an important aspect of water supply; it is often neglected by water providers, particularly if results show analyte concentrations below the respective MAV. Examination of the trends of all analytes is important for understanding the behaviour of a water network and can often avoid the development of significant problems. This includes the utilisation of data from unregulated parameters such as conductivity, heterotrophs, and total coliforms. Until recently, there was no requirement to monitor for total coliforms in drinking water systems in New Zealand, following their removal from the regulatory framework. Nonetheless, all analytical procedures approved in New Zealand for the examination of drinking water for *E. coli* afford the opportunity to detect total coliforms. During the Havelock North Inquiry, monitoring of raw water for the presence of total coliforms was instigated using two-litre samples (twenty times the volume required for regulatory *E. coli* testing). Over a period of only a few weeks, total coliforms were identified in all of Hastings District Council (HDC) groundwater sources that were tested, demonstrating that these bores were not "secure". Had these results been available prior to the outbreak, water professionals would have realised quickly that water treatment was required, and the outbreak could have been prevented, simply by the application of chlorine disinfection.

A summary of water quality monitoring actions in the future for NCC is shown in Table 4.

Table 4: A summary of water quality monitoring actions for NCC

Summary	Relevance to the Review
1. Microbial parameters are always of importance in groundwater, irrespective of the treatment installed. They are essential for Quantitative Microbial Risk Assessment.	1. NCC must review its current monitoring programme and implement more comprehensive monitoring whether or not it intends to pursue a chlorine-free strategy.
2. For the Napier source water, parameters that should be routinely monitored include iron, manganese, and potentially other analytes of interest (e.g. arsenic and nitrate). The basis for the microbial testing suite for raw water is total coliforms, *E. coli* and total heterotrophs with some level of protozoa monitoring.	2. If the decision is made to move toward a chlorine-free system, NCC must regularly review its monitoring plan to provide information on the safety of the system should residual disinfectant be removed.
3. The frequency of monitoring of the raw and treated water should be daily, regardless of a residual disinfectant being applied or not.	3. New parameters such as total microbial count, or other methods of assessing biological activity (e.g. total ATP) should be considered to enable a better understanding of the microbial quality of distributed water.

1.9 Characteristics of Napier's Drinking Water System

1.9.1 The Groundwater Source

To help achieve a clean and safe supply of potable water for Napier, a low risk, reliable water source is important, prior to any treatment with or without chlorine. Key requirements for the supply include minimising bacteria and pathogens within the source water (Smeets, Medema, & van Dijk, 2009). Additionally, requirements for the supply include minimising ammonia, iron, manganese, and total organic carbon (TOC) in the source water from the production bores, where possible, as these parameters will affect the level of treatment required to minimise the occurrence of dirty water.

A full review of the available groundwater information is provided in Appendix B.

The current bores for the Napier supply draw water from depths between 31 and 121 metres (m) beneath Napier city. These water bearing strata are overlain by lower permeability strata including silts and clays which, together with an upwards pressure gradient, help to restrict direct surface influences on the groundwater. The lower permeability strata are around 40 m thick in the area in NCC's eastern supply bores but become progressively thinner inland.

Groundwater within the water bearing strata is considered to be recharged predominantly via seepage from the Ngaruroro River inland from the supply bores and where the water bearing strata are not overlain by lower permeability material. As a result, the main flow path between the source water and the Napier city supplies is relatively long, and the average age of the water drawn from the city bores is between 18 and 90 years. A proportion of younger water is present, but the bores are all classed as compliant with the current Criterion 1 and 2 of the DWSNZ, implying that the bore heads are reasonably protected from surface contamination. Note that the criteria may change in the future.

Despite the presence of low permeability strata, the upwards gradient, and estimated groundwater age indicating a low risk of microbial contamination for the source aquifer, other information suggests the bores may be at some risk of surface influences over a shorter time period, leading to an associated risk of microbial contamination. A review of the water quality data available for the bores indicates that bacteria (total coliforms) are detected in the source water, and these have been detected in all the current supply bores. However, bacteria are not detected in the distribution system suggesting that existing disinfection procedures have been effective. It should be noted that the frequency of testing in the distribution system may not be sufficient to confirm this.

In addition to the total coliform detections, two events where *E. coli* were detected in the bores have occurred, although through NCC investigations, the *E. coli* detections in bore T1 have been attributed to most likely be due to a leak in the casing (this bore is no longer in service) and for bore T7 have been attributed to the removal and reinstatement of the pump during maintenance. The detection of total coliform bacteria in the source water implies that a source of young water is present which is inconsistent with the secure classification based on the age dating. The source of young water is not known at this stage as detections of *E. coli* are very rare in the wider Heretaunga Plains area and total coliforms are not regularly sampled for in other bores, but the assessed condition of the bore heads suggest that it is unlikely due to leaks in the casing of the bores, and may be caused by poor conditions in nearby bores providing a rapid pathway from the surface to the pumped strata. Alternatively, the bacteria could be being introduced during maintenance and other activities and potentially surviving within a biofilm in the bores. Further investigation and good hygiene and disinfection procedures, followed by further monitoring, would help establish whether this may be the reason for the total coliform detections, rather than a separate young water influence.

Chemical testing of the source water indicates that ammonia, iron, and manganese are prevalent in some of the bores, with the highest concentrations occurring in bores A1 and C1. These chemicals appear to be naturally occurring, although there is insufficient data to assess seasonal variations.

Source protection zones (SPZs) are defined around all the bores to add in the management of risks to groundwater from activities in the area. In keeping with national guidance, three zones are defined including an inner zone (SPZ1) around the immediate bore head, a one-year travel time zone (SPZ2), and a whole catchment zone (SPZ3). Additionally, a 100 m zone is also defined around the bores (SPZ2A) to help guard against rapid transport pathways from poorly sealed nearby bores.

There are a variety of protection measures in place for these zones, which provide controls on the activities that can take place in the zones and help reduce the risk to the supply bores. The controls will be enhanced as the Tūtaekurī, Ahuriri, Ngaruroro and Karamū (TANK) regional plan change comes into effect. NCC is actively contributing to source protection in numerous ways, as outlined in the Water Safety Plan (WSP). This includes review by NCC of the consents within the zones as well as the Joint Working Group (JWG), which seeks to provide governance and protection of drinking water in the wider Heretaunga Plains area. Continual review and strengthening of measures being undertaken for source protection is important. It would be prudent for a survey of bores within 500 m of each NCC bore to be undertaken to identify any nearby unsealed or poorly maintained bores that may present a pathway from the surface to the deeper, pumped aquifer. Understanding the number and location of these risk pathways will be helpful in determining the scale and extent of risks to the source water.

As outlined in Section 1.5.1.2 of this report, groundwater systems should also be considered as subject to change. Natural hazards, such as earthquakes, can affect the integrity of confining strata, including creating preferential flow pathways around existing bores, and alter water levels. Surface flooding due to heavy local rainfall, river breakout, or a tsunami can result in contaminated water reaching confined aquifers via preferential pathways, such as poorly sealed bores. A period of sustained low groundwater recharge, for example due to droughts, can also impact groundwater levels and gradients.

Although there are many controls in place to help reduce the risk to the Napier city supply bores and the hydrogeological setting reduces the risk of contamination via the confining strata and a general upwards hydraulic gradient, the available monitoring indicates that the source water should not be considered secure from surface influences based on current information. In particular, the occurrence of total coliform bacteria (and occasional *E. coli* detection, although this has been attributed to bore condition / maintenance) in the source water demonstrates that some appropriate form of treatment is required to control and reduce source risks. Further investigation, good bore hygiene and disinfection procedures, followed by further monitoring, may help establish whether the total coliform detections could be due to direct introduction to the bores themselves, rather than a separate young water influence.

In terms of monitoring, additional monitoring of HPCs within the source water and within the distribution network will also enable more detailed assessment of potential risks and effects downstream. Event-based monitoring is also highly recommended, particularly following high rainfall events. For investigational monitoring, it is recommended that larger volume sampling (e.g. two litres for total coliforms) and more intensive sampling is undertaken.

The analysis of the data provided for this report indicates that limited data is available for chemicals within the raw source water. Some bores have more frequent monitoring than others, but in general, frequent monitoring has only occurred since 2019, and not in all the supply bores. This data is insufficient to identify seasonal variations in the concentrations of key chemicals (e.g. ammonia, iron, manganese, and other general chemical indicators like nitrate and chloride). Although the age testing of the water drawn from the bores indicates a small proportion of young water, regular testing of the raw bore water for a general suite of chemicals on a monthly basis can help identify whether seasonal patterns are present. This testing will in turn help to indicate whether rapid pathways from the surface are present. Therefore, monthly testing of the bores for a suite of typical chemicals is recommended.

It may also be prudent to undertake some testing before, during, and after the pump in the bore is started. This could help identify whether rapid pump start-up has an impact on chemical concentrations. 'Soft starts' (i.e. starting to pump a lower rate using a variable speed drive) could help to alleviate some of these issues if they are identified.

As outlined in Section 1.8, some monitoring for contaminants that may not be expected to be present (e.g. a full metals suite, pesticides, herbicides and other organic contaminants including PFAS) is also recommended together with options for other microbes.

A summary of the groundwater source risks and implications for the Napier system is shown in Table 5.

Table 5: A summary of groundwater source risks and implications for the Napier system

Summary	Relevance to the Review
1. A review of the water quality data available for the bores indicates that bacteria (total coliforms) are detected in the source water, and these have been detected in all the current supply bores (but not in the distribution system).	1. Although there are controls in place to help reduce the risk to the Napier city supply bores, the available monitoring indicates that the source water should not be considered secure from surface influences based on current information.
2. Two events where *E. coli* were detected in the bores have occurred, although through NCC investigations, the *E. coli* detections in bore T1 have been attributed to most likely be due to a leak in the casing (this bore is no longer in service) and for bore T7 they have been attributed to removal and reinstatement of the pump during maintenance.	2. A fully engineered and appropriate form of disinfection is recommended based on chlorine and/or UV, even though in general the source waters are considered to be relatively low risk, and it is important to consider changes to the source water over time. The total coliform detections are of concern and further investigation is recommended.
3. Chemical testing of the source water indicates that ammonia, iron and manganese, are prevalent in some of the bores, with the highest concentrations occurring in bores A1 and C1 (these chemicals appear to be naturally occurring).	3. A more comprehensive water quality monitoring plan should be developed to cover physical, chemical and microbial parameters consistent with a chlorine-free system.

1.9.2 Dirty Water Customer Complaints (DWCC)

The history of DWCC from 2014 to 2020 for NCC are summarised in Table 6, there has not been significant increases in the number of connections over the time period shown and we have used a common number.

Table 6: DWCC Napier City Council 2014 to 2020

	2014	2015	2016	2017	2018	2019	2020
Number of Complaints	53	108	74	704	761	1701	755
Number of Connections	26,011	26,011	26,011	26,011	26,011	26,011	26,011
Complaints per 1000 Connections per annum	2.0	2.4	2.8	27.1	29.3	65.4	61.6

The data presented in Table 6 clearly shows a significant increase in DWCC in 2017 coinciding with the introduction of chlorine disinfection into the NCC water supply system.

The correlation between DWCC and the presence of iron and manganese is a well-established principle in chlorinated water systems and is discussed later in this section. What is not well understood is:

- What the levels of iron and manganese are that significantly impact DWCC; and
- Why in the absence of chlorine, DWCC were low in NCC.

Data showing the correlation between the number of DWCC per thousand population from the UK and the percentage of samples with a treated water manganese level of < 10 micrograms per litre (µg/L) is presented in Figure 2. All the UK water utilities utilise chlorine-based disinfection.

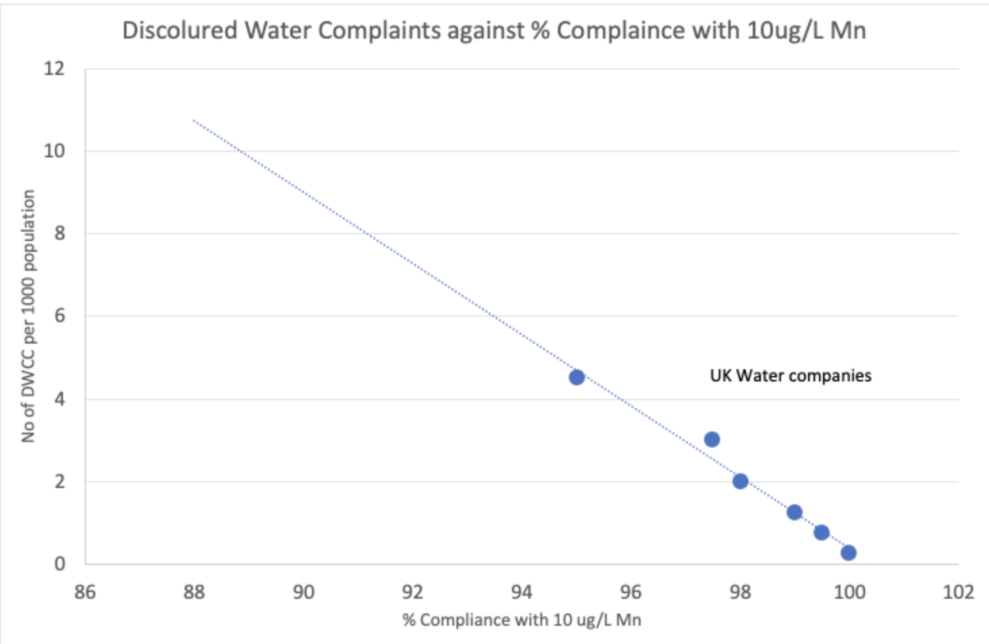

Figure 2: Correlation between the number of DWCC per thousand population and percentage compliance with a manganese level < 10 micrograms per litre (from water utilities in the UK)

The data presented in Figure 2 shows that the higher the percentage compliance with manganese concentration of 10 micrograms per litre, the lower the DWCC.

Figure 3 shows the number of DWCC for Napier Council based on 2.2 people per connection to allow for a comparison with the UK data.

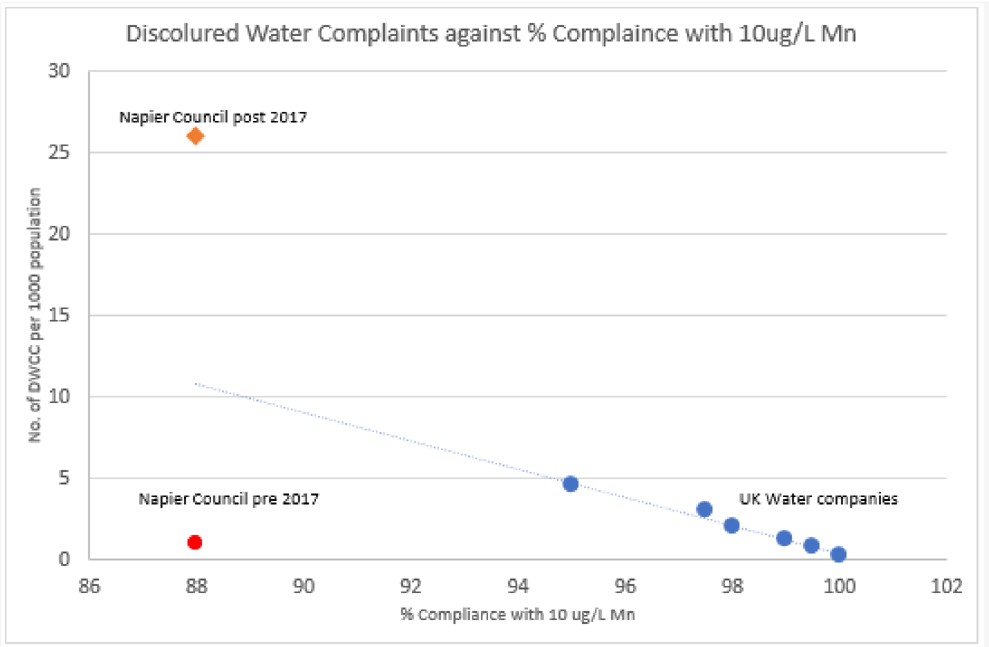

Figure 3: Comparison of the number of DWCC per 1,000 population of the UK with Napier (Notes: to determine the population for Napier, 2.2 people per connection was assumed; Manganese compliance level data was unavailable for Napier)

The data presented shows that the presence of chlorine in the Napier system (with no change to manganese in the system as no manganese removal process has been installed) caused increased complaints.

Historically, it was thought that unlined cast iron pipes were the main source of DWCC, along with accumulation of the low levels of iron leaving the water treatment works (WTW). However, recent works carried out in the UK has shown a direct correlation between manganese concentrations ex-works and DWCC levels.

The levels of manganese found in the UK water network were thought to be too low to cause discolouration in isolation. The hypothesis presented is that manganese catalyses the accumulation of iron deposits by adsorption of the iron particles onto the manganese dioxide layer (which deposits on the pipe wall in the presence of chlorine). Thus, removing manganese to levels well below the DWSNZ levels would be required in chlorinated systems to manage DWCC to levels of less than five DWCC per thousand population.

The absence of chlorine pre-2017 in the Napier system and the low level of DWCC supports the hypothesis that the presence of iron, manganese, and chlorine are required for DWCC and that it is the presence of chlorine that facilitates the accumulation of material which result in DWCC.

Further evidence to support the link between manganese and DWCC is presented in Figure 4, which shows data from an anonymous NZ utility from 2005 to 2019. A new manganese removal process was installed around 2011 and the number of DWCC per thousand population dropped from >20 in the preceding years to levels ≤1 from 2013 onwards.

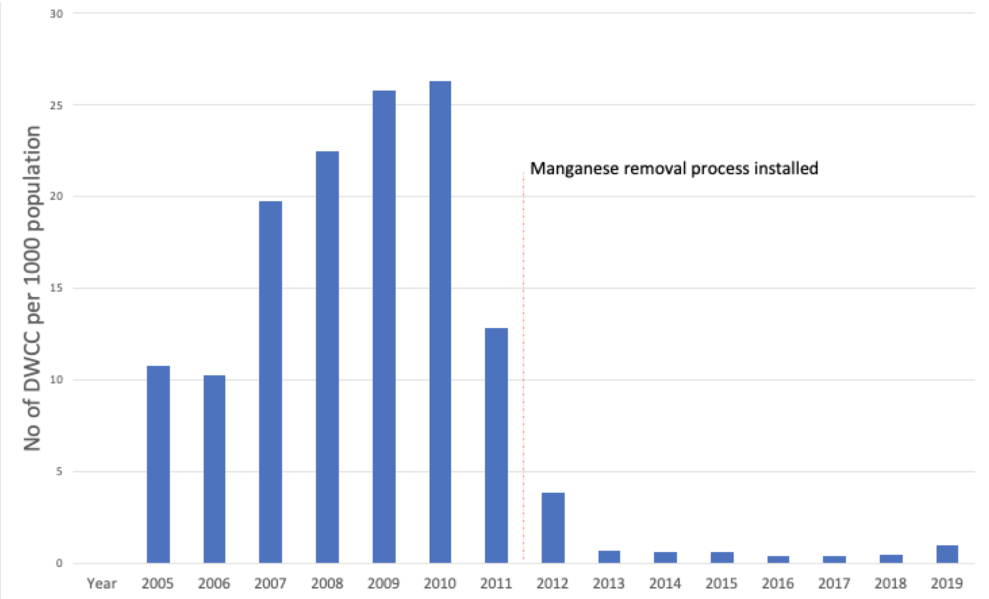

Figure 4: DWCC per 1,000 population in an anonymous NZ utility from 2005 to 2019

It is apparent, from all the information presented, that the removal of manganese from water in a chlorinated network has a dramatic impact on the number of DWCC. The fundamental mechanism is still not fully understood, but empirical evidence from the UK and New Zealand is compelling.

From Research Report 51 by CRC for Water Quality and Treatment (2007):

Research carried out by Gold Coast Water indicates that when water treatment plants fail to keep soluble manganese levels below about 0.02 mg/L in the treated water, there is an increase in discoloured water complaints within days. Sydney Water optimised manganese removal in the Woronora system from 0.020 mg/L down to <0.005 mg/L resulting in a considerable reduction in customer complaints (Research Report 51, CRC for Water Quality and Treatment, 2007).

Table 3.3 summarises the complaint rates for each of the Utilities over the 5-year period.

Table 3.3: Discoloured Water Complaint Rates Per '000 Properties

	97/98	98/99	99/00	00/01	01/02
Sydney Water	3.0	5.0	3.9	2.3	1.7*
Yarra Valley Water	3.6	3.4	2.8	3.9	4.4
Hunter Water	6.5	11.1**	5.6	6.1	6.8
South East Water	2.4*	2.3*	2.1*	2.1*	1.9
Power & Water (NT)	12.3**	5.7	4.8	4.5	1.8
Brisbane Water	Not available	3.8	5.0	3.6	2.7
Gold Coast Water	Not available	Not available	9.3	2.7	6.5
Water Corporation (WA)	Not available	Not available	12.4**	14.8**	11.9**

* Lowest complaint rate
** Highest complaint rate

It is important that the removal of iron and manganese at the current bores or the drilling of low manganese bores are part of the SQ+ and CF strategies. In the case of SQ+, it is for the reduction of DWCC to acceptable levels. In the CF case, the rationale is that in order to keep the microbial health of the network at an acceptable level, the removal of iron and manganese is important since iron in particular can be bioavailable for certain types of bacteria and promote biofilm accumulation which should be avoided in a CF system. Iron oxidising bacteria can grow in relatively low concentrations of soluble iron, provided there is available dissolved oxygen. This growth can lead to the deposition of iron oxide or iron hydroxide which can also lead to DWCC. Interestingly, the Dutch remove iron and manganese to very low levels in their CF systems to maintain the network in as clean and biologically stable a state as possible.

A summary of the correlation between iron / manganese and DWCC and sampling programme recommendation for NCC is shown in Table 7.

Table 7: A summary of iron / manganese correlation with DWCC and recommended sampling programme

Summary	Relevance to the Review
1. DWCC in chlorinated systems are strongly correlated with the presence of soluble manganese at concentrations significantly below values outlined in the DWSNZ.	1. It is recommended that an iron and manganese removal process is installed at the two new bore fields if the presence of manganese exceeds 10 µg/L at the 95th percentile.
2. In order to maintain DWCC at low levels soluble manganese levels entering the water supply network should be <10 µg/L 95% of the time.	2. An intensive sampling programme to determine the nature and concentration of total and soluble iron and manganese in the new and existing bore fields should be undertaken covering a minimum of 12 months with weekly samples being taken.
3. The presence of iron and manganese in a chlorine-free water network can facilitate the growth of biofilm, resulting in increased human interventions and the risk of contamination.	3. The target concentration for iron and manganese fed into the water network should not exceed 10 µg/L at the 95th percentile.

1.9.3 Disinfection By-Products

Disinfection by-products have been identified as a concern by some of the community stakeholders in Napier. This has been precipitated by the onset of chlorination of the water supply in 2017 and reference to some technical literature on current and emerging DBPs.

In his paper, Chlorination of Phenols Revisited: Unexpected Formation of α,β-Unsaturated C4-Dicarbonyl Ring Cleavage Products, Dr Carsten Prasse identified a significant number of new and emerging DBPs from the chlorination of water contaminated with various phenolic compounds. Dr Prasse stated:

"There's no doubt that chlorine is beneficial; chlorination has saved millions of lives worldwide from diseases such as typhoid and cholera since its arrival in the early 20th century," says Prasse, an assistant professor of Environmental Health and Engineering at The Johns Hopkins University and the paper's lead author.

But that process of killing potentially fatal bacteria and viruses comes with unintended consequences. The discovery of these previously unknown, highly toxic by-products, raises the question how much chlorination is really necessary."

The question raised is the balance between potentially competing short-term and long-term effects. Short-term, but more frequent, public health risks from pathogen-induced illness and long-term exposure to low levels of chlorinated organic compounds. Furthermore, it is the presence of precursor material (as well as chlorine) that is a prerequisite for the formation of DBPs.

The DWSNZ regulates DBPs by measuring the presence of the following organically derived DBPs:

- Trihalomethanes- THMs
- Haloacetic Acids – HAAs
- Haloaceto Nitriles – HANs
- Halophenols - HPs

Figure 5, from Watersource 2018 (the Journal of the Australian Water Association) shows the current status of a range of DBPs which are commonly monitored for in developed countries.

Class	Compound	Acronym	Aust.	US-EPA	Japan	EU	WHO
THMs	Trichloromethane	TCM	-	-	60	-	300
	Bromodichloromethane	BDCM	-	-	30	-	60
	Dibromochloromethane	DBCM	-	-	100	-	100
	Tribromomethane	TBM	-	-	90	-	100
	Total THMs	TTHM	250	80*	100	100	-
HAAs	Monochloroacetic acid	MCAA	150	-	20	-	20
	Dichloroacetic acid	DCAA	100	-	40	-	50
	Trichoroacetic acid	TCAA	100	-	200	-	200
	Monobromoacetic acid	MBAA	-	-	-	-	-
	Dibromoacetic acid	DBAA	-	-	-	-	-
	Sum of 5 HAAs	HAA5	-	60	-	-	-
HANs	Dichloroacetonitrile	DCAN	-	-	-	-	20
	Dibromoacetonitrile	DBAN	-	-	-	-	70
HA & HK	Formaldehyde	-	500	-	-	-	900
HP	2-Chlorophenol	-	300	-	-	-	-
	2,4-Dichlorophenol	DCP	200	-	-	-	-
	2,4,6-Trichlorophenol	TCP	20	-	-	-	200
CH	Chloral Hydrate	-	100	-	-	-	200
Inorganic	Bromate	-	-	10	10	10	10
	Chlorate	-	-	1000	-	-	700

Figure 5: Status of commonly monitored DBPs in developed countries (Watersource, 2018)

The DWSNZ sets out the allowable concentrations of the organically derived DBPs, which are shown in Table 8.

Table 8: Maximum Allowable Values of DBPs according to the DWSNZ

Class	Compound	Acronym	Concentration (µg / L)

THMs	Trichloromethane (chloroform)	TCM	400
	Bromodichloromethane	BDCM	60
	Dibromochloromethane	DBCM	150
	Tribromomethane (bromoform)	TBM	100
HAAs	Monochloroacetic acid	MCAA	20
	Dichloroacetic acid	DCAA	50
	Trichloroacetic acid	TCAA	200
	Monobromoacetic acid	MBAA	20
	Dibromoacetic acid	DBAA	50
HANs	Dichloroacetonitrile	DCAN	20
	Dibromoacetonitrile	DBAN	80
HPs	2-Chlorophenol	-	0.1
	2,4-Diclorophenol	DCP	0.3
	2,4,6-Trichlorophenol	TCP	2.0

From Table 8 and Figure 5, we see that the DWSNZ THMs, HAAs and HANs are more aligned with the WHO guideline values than the more stringent regulatory standards in the USA, for example.

In terms of NCC, samples for THMs and HAAs have been undertaken in the water network since December 2017. For HAAs, all samples have recorded individual HAA concentrations at levels less than five micrograms per litre (i.e. at the limit of detection of the analytical technique). For THMs, the total THM concentration was found to be less than seven micrograms per litre, compared to a value of 80 micrograms per litre (the US Environmental Protection Agency value) with the highest individual concentrations recorded for:

- BDCM – 1.2 µg/L c.f. 60 µg/L
- TBM – 1.0 µg/L c.f. 100 µg/L

For HANs, the highest recorded value was for bromochloroacetonitrile (BCN) at 0.69 micrograms per litre, which does not have a prescribed regulatory value but is at concentrations significantly below that of the regulated HANs.

From the data collected by NCC, there is not a DBP issue associated with the THMs, HAAs and HANs with the values being found near to or below the limits of detection of the analytical techniques. Furthermore, the concentrations found are significantly below the values in other developed countries with much tighter DBP regulatory standards. Data for the chlorinated phenolic compounds has not been collected to date and it is recommended that this be collected.

In the context of correlating DBPs with public health impacts, Cotruvo et al 2019, looked at national trends in bladder cancer and THMs in drinking water across numerous countries. The highlights from the paper are:

- *Numerous disinfection by-products (DBPs) are generated by chlorine and other disinfectants in drinking water*
- *Some epidemiology studies have associated a possible risk of bladder cancer with trihalomethane (THM) exposures*
- *Bladder cancer aetiology is complex, and there are multiple risk factors*
- *Trihalomethanes are not carcinogens in whole animal bioassays in water, so if there is a true correlation with bladder cancer it could be a secondary correlation with other DBPs present in much lower concentrations but with high potency*
- *Lifetime DBP exposure is extremely difficult to quantify, and it requires numerous assumptions that might determine the outcomes*
- *Observed national bladder cancer rate trends over 45+ years could be mostly smoking related, and they do not seem to parallel THM reductions in most cases at this time*

THMs have been used as a surrogate measure for wider DBPs since they are relatively easy to measure and their formation is well understood (in a similar manner to total coliforms or HPCs as a measure of microbial stability of water). Since 1974, the water industry has been reducing the presence of THMs in drinking water through enhanced treatment and removal of organic material which reacts with chlorine to form DBPs.

As Dr. Prasse stated, the beneficial aspects of chlorine and its contribution to public health protection should not be ignored. However, it is recognised that DBPs may have long-term adverse effects on public health. Water utilities have continued to improve their understanding of DBP formation and how to minimise its presence in drinking water. For NCC, the evidence is that their current water supply is from a catchment which does not appear to contain sufficient contaminants which react with chlorine to produce DBPs at concerning concentration levels for regulators and public health experts. Consequently, expensive water treatment technology to reduce DBP formation is not required.

It should be noted that NCC could improve the quantity of samples, increase the range of DBPs measured, and undertake testing of the bore water prior to chlorination to look for some of the precursor material Dr. Prasse refers to.

A summary of the findings from sampling in the NCC network for DBPs (at or near limits of detection) and sampling recommendations are shown in Table 9.

Table 9: A summary of DBPs sampling findings in NCC network and monitoring recommendations

Summary	Relevance to the Review
1. There is no evidence from the sampling data in the NCC water network to suggest that DBPs at concentrations approaching the current regulatory standards outlined in the	1. No additional treatment for TOC removal is required.

DWSNZ are present in the NCC water network. Furthermore, the concentrations found are at or near the limits of detection and well below concentrations seen in chlorinated water systems around the world.	
2. There is no evidence of sufficient levels of TOC in the bore field to suggest there is pre-cursor material at concentrations to form DBPs at levels outlined in the DWSNZ or those in other regulated systems globally.	2. It is recommended that further analysis of potential organic pollutants is undertaken within the new and existing bore fields.
	3. It is recommended that samples for chlorinated phenolic compounds be collected.

1.9.4 Assimilable Organic Carbon (AOC)

AOC forms a small fraction of natural organic matter present in the majority of water supplies. AOC is an indication of the biostability of water since it is the readily biologically degradable fraction of carbon present in water supplies and is a key factor in the development of biofilms in water supply networks. AOC analysis was developed by the Dutch water industry to assist with their approach to a chlorine-free water supply system to ensure that water entering their water supply network would not promote significant biofilm growth and the resultant risks assoc. AOC is of particular importance in water supplies, in particular those with elevated levels of Total Organic Carbon (TOC), where advanced oxidation processes such as ozone are used since they can increase levels of AOC. In these systems a biological treatment process is employed to remove the AOC present and therefore reduce its impact on biofilm formation in the water supply network. The measurement of AOC is not available in New Zealand and there are only two commercial laboratories in Australia which are capable of carrying out the analysis. Furthermore, there is a low demand for AOC analysis which calls into question the efficacy of the results and their usefulness. Since the Napier aquifer has low levels of naturally occurring TOC it is not expected that AOC levels are significant enough to require addressing through the installation of a treatment process. However, it would be prudent to carry out some analysis before and after chlorination to understand the background levels of AOC and to observe if the formation increases as a result of oxidation of ambient TOC by chlorine. The current COVID-19 pandemic made it infeasible to have samples transported to Australia and analysed.

It is recommended that NCC open discussions with Research Lab[1] to understand the sampling requirements and logistics once travel restrictions between Australia and New Zealand are lifted and samples can be transported.

A summary of recommendations for AOC sampling for the Napier network is shown in Table 10.

[1] Research Lab: http://www.researchlab.com.au

Table 10: A summary of recommendations for AOC sampling for Napier

Summary	Relevance to the Review
1. AOC is an indication of the biostability of water and is a key factor in the development of biofilm in water supply networks.	1. Napier aquifer has low levels of naturally occurring TOC, thus AOC levels are not expected to be significant enough to warrant the installation of a treatment process.
2. Measurement of AOC unavailable in New Zealand and only two commercial laboratories in Australia capable of undertaking the analysis.	2. It is recommended that NCC open discussion with Research Laboratory Services, Research, Victoria, Australia

1.9.5 Non-Revenue Water (Leakage)

NCC has, for a long time, reported NRW based on an annual water balance approach (Napier City Council, 2020) and this has reported non-revenue water (NRW) at around 25%. Recent work carried out by the water team was more rigorous and based on a more granular approach by looking at discrete areas of the network. The most recent work indicates that NRW is running at close to 32.8%. Figure 6 shows the water balance for Napier for the 2020 year provided by NCC.

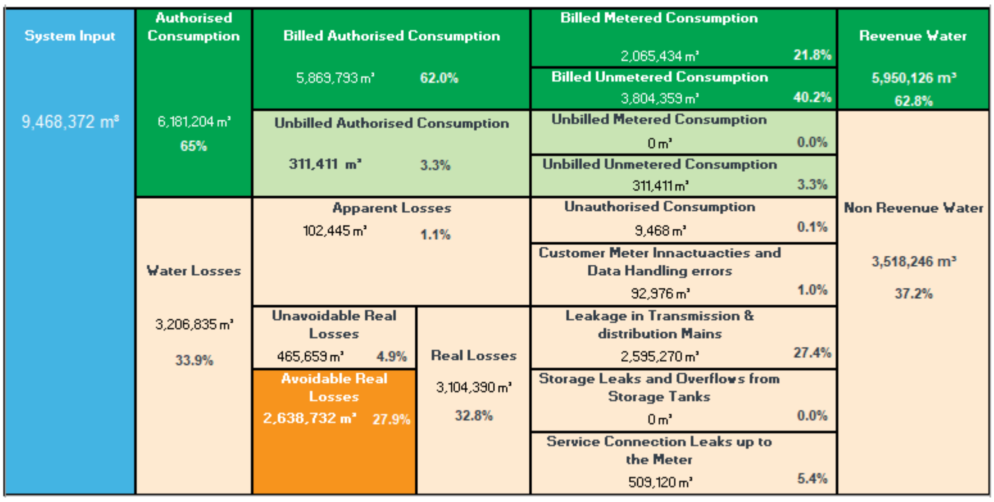

Figure 6: Napier City Water Balance 2020 (provided by NCC)

From discussions with senior government officials, it has become clear that NRW rates similar to those in the Netherlands and Denmark will need to be met before an exemption application to remove chlorine disinfection can be submitted. Table 11 shows NRW rates for a range of developed countries (Global Water Intelligence, 2018) (Lallana, 2002) (European Commission, 2018).

Table 11: Percentage of non-revenue water for developed countries

Country	NRW (%)	Chlorine-Free
The Netherlands	< 5	Yes
Denmark	7.8	Yes
Germany	5.1	Yes
The UK	23.4	No
Spain	18.9	No
France	21.3	No
Italy	34.7	No
Ireland	45.3	No
Australia	10	No

The challenge for NCC is how to move from its current position to that of other chlorine-free systems.

Many countries, such as the UK and Spain, have been set targets by their regulatory bodies to reduce NRW and have spent the last 25 years reducing their NRW rates from around 30% to close to 15-20%. However, this still leaves a significant gap compared to the expected level of 5% that Taumata Arowai would expect. Figure 7 (GWI, 2018) shows the percentage of NRW for six European Union (EU) countries from 1991 to 2017.

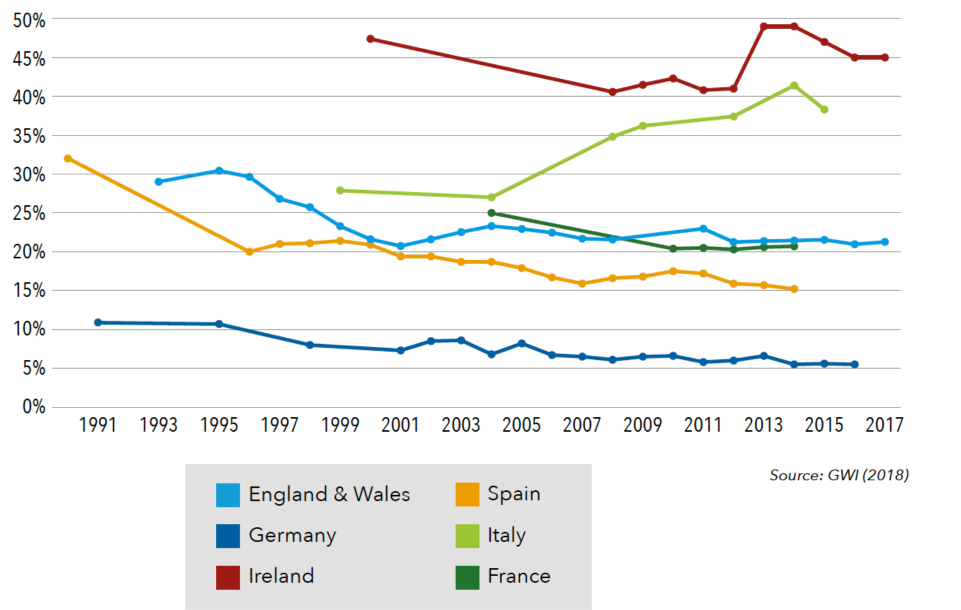

Figure 7: Percentage of NRW for six EU countries from 1991 to 2017

Of the six countries shown in Figure 7, only Germany has been able to achieve the levels of NRW that NCC expect to achieve to gain a chlorine-free exemption. However, the starting position for Germany was close to 10%, and it took 25 years to get to 5% from this relatively low starting position. According to the European Environmental Agency, Germany's low NRW is due to:

"a combination of favourable soil conditions, treatment to reduce the aggressiveness of the water supplied, easy access to repair mains and a high level of mains replacement"

The key lesson here is that it may take NCC several decades to get from where it currently sits to where it needs to be unless an aggressive NRW programme of detection, repair, replacement, and measurement is implemented.

One city which successfully reduced NRW from around 45% to <5% is Seoul, South Korea. Between 1962 and 1983, Seoul embarked on a pipe replacement programme focusing on replacing their non-corrosion resistant pipework such as cast iron, steel, and galvanised steel. Over this 21-year period, they replaced around 1,800 km of old pipe, equating to approximately 13% of their network (0.67% per annum). From 1983 to 2013, they refurbished or replaced an additional 13,192 km of pipework equating to 96.5% of their entire water distribution network. This is a rate of replacement of 3.2% per annum and indicates the sort of replacement rate required that will reduce (rather than maintain) NRW levels. The city of Seoul also implemented the following in parallel:

- District Metering Areas (DMAs)
- Upgraded their leak detection system to a multi-point noise correlation system (SOUNDSENS)
- Regular night-time flow measurements
- Real time data management

The lessons NCC can learn from the city of Seoul are:

- Prioritise the replacement of older and corrosion susceptible pipework – cast iron and AC (54% of the network)
- Develop a water mains replacement programme of >3% per annum (around 15 km)
- Implement DMAs
- Continue the current NRW quantification
- Move to a SMART water network
- Implement universal household metering

The timeline for the implementation of the city of Seoul's NRW reduction programme is summarised in Figure 8.

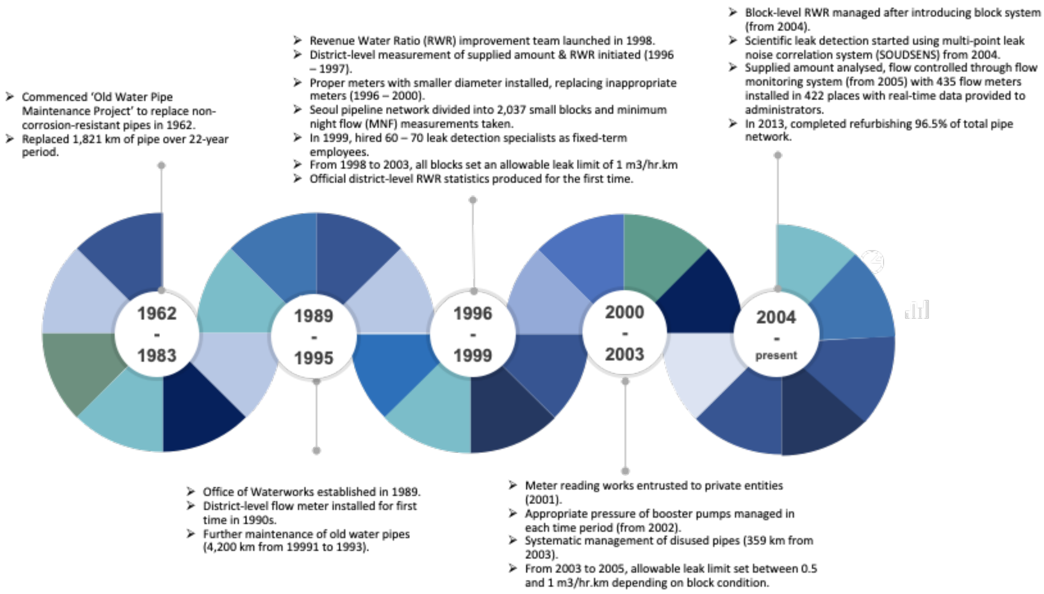

Figure 8: Timeline of Seoul's NRW reduction programme

The city of Lisbon in Portugal has also had success in substantially reducing non-revenue water. Climate change was the driver for the implementation of the NRW reduction programme which commenced in 2005 when non-revenue water stood at 23.5%. By 2015, non-revenue water was reduced to 8.5%, resulting in a saving of €68 million over the ten-year period.

To further understand where NCC sits in comparison to other developed countries, the Infrastructure Leakage Index (ILI) was used. The ILI was developed by the International Water Association (IWA) for technical comparison of individual utilities to give a broader overview of NRW management. There are four broad classifications:

- Category A1 – very low NRW, ILI < 1.5
- Category A2 - low NRW, 1.5 < ILI < 2
- Category A3 – moderate NRW, 2 < ILI < 4
- Category A4 – high NRW, 4 < ILI < 8

The ILI is a widely used indicator for NRW reduction potential by water utilities globally. It is commonly defined as:

$$ILI = CARL/UARL \qquad (1)$$

Where CARL is the current annual real losses (volume per year) from a water supply and distribution system and UARL is the unavoidable annual real losses (volume per year), a reference NRW level which represents the lowest technically achievable value for the system. CARL is determined from water balances, while UARL is estimated as a function of the network's structural characteristics (length of mains and number of service connections) (Lenzi, Bragalli, Bolognesi, & Fortini, 2013). Based on the 2020 data provided by NCC, using Equation 1, the ILI was evaluated to be 6.7. Figure 9 shows the range of ILIs calculated for water utilities around the world (European Commission, 2015).

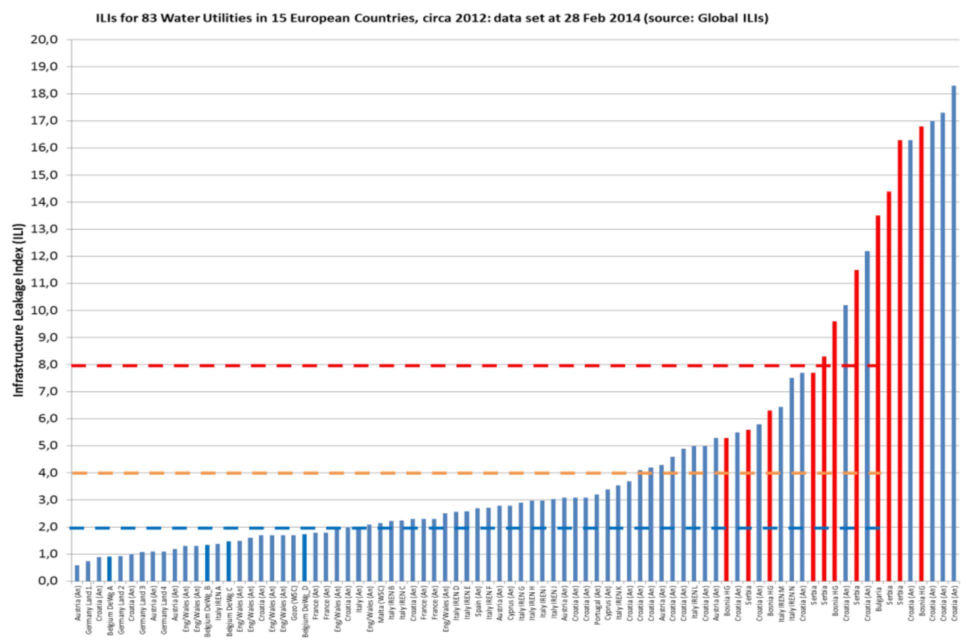

Figure 9: ILIs for 83 water utilities in 15 European countries

As a parameter that directly compares the current real losses and the achievable lowest real losses for the system, ILI is a useful indicator to assess the requirement for remediation works and the appropriateness of works for the level of NRW in the network. If the ILI is greater than 1, then the utility has NRW reduction potential (Ahopelto & Vahala, 2020). The higher the ILI value is, the greater the need for more comprehensive NRW reduction activities (Seago, Mckenzie, & Liemberger, 2005).

For very small utilities (defined as less than 3,000 service connections), it is easier to achieve lower ILIs as new NRW events are more easily identified from night flows (Leaksuite Library Ltd, 2019). The NCC network has over 26,000 service connections (Napier City Council, 2020), thus it is harder to achieve these lower ILIs from observing minimum night flows (MNF).

The suitability of using ILI as an indicator for all systems has been debated and these key conclusions have been drawn (Seago, Mckenzie, & Liemberger, 2005):

- ILI is an inappropriate measure for systems with less than 2,000 service connections
- ILI is an inappropriate measure for systems that operate under abnormally high or low pressures
- ILI is considered an appropriate indicator for utilities that operate at average system pressures between 30 and 90 m

The NCC system operates at an average pressure of 40 m (Napier City Council, 2020) which falls within the acceptable pressure range and there are more than 2,000 service connections in the network, thus, ILI may serve as a suitable NRW indicator for the system.

There are various proposals that categorise NRW performance and recommend management actions based on the ILI value. A summary of this is provided in Table 12 (Seago, Mckenzie, & Liemberger, 2005) (European Commission, 2015).

Table 12: Recommended NRW Management Actions Based on ILI categorisation

	Australian Investigation Recommendations (2005)	**WLSG Recommendations (2005)**
ILI Category	ILI > 3.5	ILI between 4 - 8
Grading	Unacceptable	High
Recommended Required Actions	Economic Pressure Management	Investigate Pressure Management Options
	Repair Policy Statement	Investigate Speed and Quality of Repairs
	Single Detection Intervention	Introduce/Improve Active NRW Control
	Regular Leak Detection Intervention	Identify Options for Improved Maintenance
	Peer Review of Leak Management Activities	Review Burst Frequencies
	Formulate and Implement Action Plan	5-Year Plan to Achieve Next Lowest Band (ILI between 2 - 4)

Regarding Table 12, the following must be noted:

- The Australian recommendations are based on an assessment of low ILI values due to relatively low levels of NRW experienced in Australian water supply systems, making the ILI bands used in the analysis narrow (highest category ILI > 3.5). This warrants caution when applying as it does not accommodate for a greater ILI range (which would require a more comprehensive / flexible management process) (Seago, Mckenzie, & Liemberger, 2005)
- Investigation of pressure management options is a clear priority (unless initial ILI is very high, i.e. ILI > 8) (European Commission, 2015)
- Am assessment of the economic level of leakage (ELL) is unlikely to be a priority if ILI exceeds four (European Commission, 2015)

The above recommendations can serve as a basis for a NRW management strategy based on the ILI.

NCC had previously estimated ILI to be 4.2 based on an NRW of 25%. Using the most recent estimate of real losses within parts of the network of 32.8%, the ILI is now estimated to be 6.7, keeping NCC as a Category A4 utility. Figure 10 gives an overview of developed country performance for ILI with average system pressure also indicated. Table 13 shows the utility groups in the dataset.

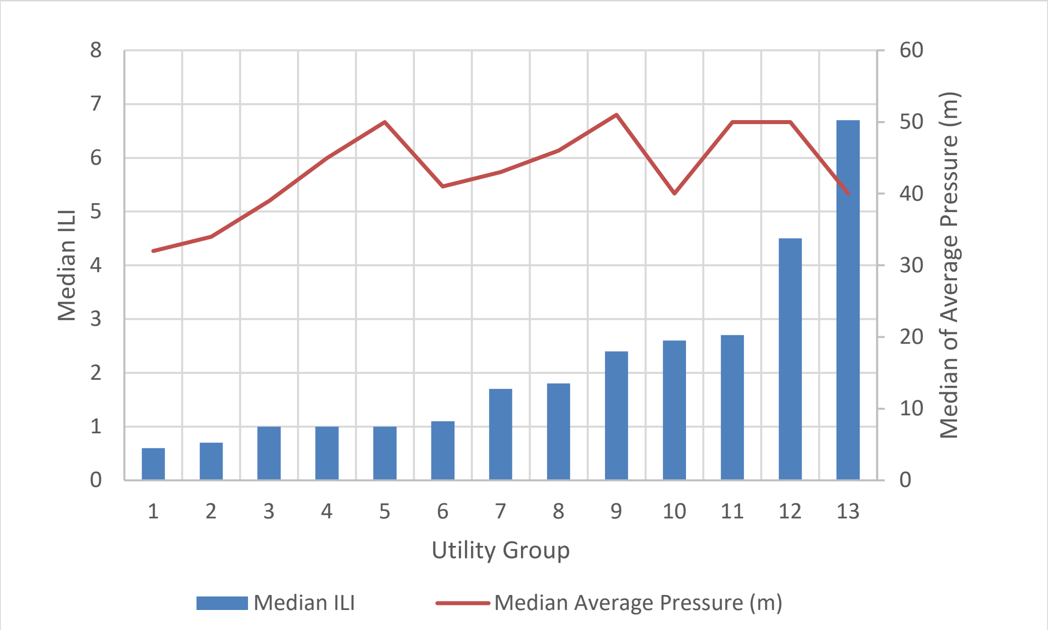

Figure 10: Global ILI indices and average system pressure

Table 13: Utility groups in ILI dataset	
Region	**Utility Group**
The Netherlands	1
Denmark	2
Flanders (Belgium)	3
Germany	4
Austria	5
Australia	6
England/Wales	7
Georgia (USA)	8
North America	9
Portugal	10
Canada	11
Croatia	12
Napier (NZ)	13

It is of no surprise that NCC sits as a Category A4 utility with respect to the ILI benchmarking system. The challenge of moving from NRW of 32.8% to < 10% should not be underestimated. Many countries with chlorinated systems operate at NRW rates of between 15 and 25% due to economic factors (i.e. the cost of reducing NRW is greater than the savings accrued). However, for NCC, the target is based on gaining an exemption from the use of chlorine and as such the economic level of NRW is not the main driver. The city of Seoul has provided a case study of how to move from being an ILI Category A4 to a Category A1 utility over a 30-year period by adopting a mains refurbishment and replacement programme of >3% of the total network per annum. Whether it will take NCC 30 years to achieve an acceptable level of NRW which allows for a chlorine-free system to be implemented will need to be continually assessed as network improvements are adopted.

A summary of the NRW estimated for the NCC network and recommendations to manage NRW is shown in Table 14.

Table 14: A summary of the NRW for the NCC network and management recommendations

Summary	Relevance to the Review
1. NCC's water network has NRW rates at levels over 30% putting it in the lowest performance Category 4 based on the ILI.	1. Indicative of the extent of infrastructure investment required.
2. Reducing NRW to levels required to move to obtaining an exemption from Taumata Arowai will require a water mains replacement programme at rates equal to or exceeding 2 to 3% per annum based on affordability.	2. The rate of investment in water mains replacement will be significantly increased compared to historic levels.
3. There are a limited number of case studies whereby NRW levels were reduced from those currently experienced in NCC to those likely to be acceptable to TA and also international benchmarks of between 5% and 10%. The city of Seoul, South Korea, reduced NRW from >40% to <5% over a 20-year period replacing >95% of their water mains.	3. The challenge of reducing NRW to 5% will require an increase in the rate of water mains replacement unprecedented in New Zealand.
4. It is recommended that NCC continues its current investigations to better understand its current NRW.	4. The point at which 5% NRW levels are achieved is based on assumptions and could be achieved earlier as investment and improved operations are implemented.
5. In order to achieve NRW levels likely to be acceptable to TA and thus gain an exemption to go chlorine-free, an aggressive water main replacement programme will be required increasing the annual capital and operating costs. Additional measures will be required including universal water metering, backflow	5. The extent and range of improvements required to go chlorine-free means that the programme of work will run for at least 20 years.

prevention, enhanced water network operation and water hygiene procedures and a move to DMAs.	

1.10 The Dutch Experience

The history of chlorine-free drinking water in the Netherlands dates to 1974 and the discovery of the presence of THMs in chlorinated drinking water by Dr. Joop Rook. These DBPs are formed by the reaction of chlorine with natural organic matter (NOM) and was the trigger-point to starting the process of removing chlorine-based treatment and disinfection. This forced the water utilities, such as Waternet, to focus on a multi-barrier approach to the production of drinking water, with a focus on:

1. Source protection – use the best source available
2. Multi-barrier treatment – ensure adequate treatment to reduce pathogens
3. Production of biologically stable water – that does not support regrowth
4. Maintaining water quality in the water distribution system – prevent ingress and detect early
5. Research and development – support operations with science

The Dutch describe this as a “whole of system” approach that allows for the production and distribution of drinking water whilst not compromising the public health of customers.

1.10.1 The Waternet Approach

Waternet is a water utility in the Netherlands supplying approximately 1.3 million customers through 750,000 connections. They are the only vertically integrated water utility in the Netherlands, supplying all water and wastewater services to their customers.

Following the second world war, the city of Amsterdam needed to supplement its water supply with surface water from the river Rhine. This river is heavily polluted by industrial and domestic wastewater discharges, as well as agricultural run-off. This meant using a conventional approach to water treatment involving coagulation, sedimentation, filtration, and disinfection using chlorine. The discovery of THMs in the water supply changed the Dutch approach and after much debate, it was decided to phase out the use of chlorine for disinfection of drinking water.

Historically, the chlorine dose used to provide a safe level of disinfection of the water supply was between 0.4 and 0.8 milligrams per litre, with a contact time of 20 minutes and a minimum chlorine residual requirement of 0.2 milligrams per litre. The decision to move away from chlorine initiated a nine-year research and development programme aimed at investigating what would be required in terms of water treatment and water distribution to abandon chlorination.

The philosophy developed and adopted was to produce drinking water in a more natural way, using physical and biological / biochemical processes without the use of oxidative chemicals. Besides the production of potentially carcinogenic DBPs, it was found that chlorination also resulted in the increase in biodegradable compounds which promote biofilm growth in the distribution pipework and reservoirs. Research showed that assimilable organic compounds (AOC), which is the primary source of food for biofilms, increased by as much as 40% after chlorination. The development of AOC analysis and development of AOC criterion for biologically stable water was developed by 1985, with an AOC < 10 µg C/L being established as the criterion for biologically stable water.

By 1983, Waternet was able to transition to the production of chlorine-free drinking water. From September 1982, Waternet were gradually reducing their chlorine residual in steps of 0.1 milligrams per litre every two months and monitoring the quality of water at customers taps at an increased frequency. It should be noted that no changes to the operation of the water distribution system were made since the system already had low levels of NRW. By August 1983, the residual chlorine in the water network was practically zero and chlorine dosing at the water treatment facilities was ceased. The decision was a balance between the risks presented from DBPs and protecting the public from microbial contamination. Waternet initially retained their chlorination as a standby option in case of an emergency or failure of the water treatment process. The whole process towards chlorine-free drinking water was carried out in close cooperation with the Drinking Water Inspectorate.

Between 1983 and 1985, the amount of sampling and analysis was increased and 70 sampling locations in the water distribution network were used to monitor microbiological water quality. Table 15 shows the microbial quality of the water before and after the move to chlorine-free drinking water.

Table 15: Microbiological drinking water quality with and without chlorination (n.d. non detectable)

	Drinking Water Ex-Works		**Drinking Water in Distribution Network**	
	With Cl_2	Without Cl_2	With Cl_2	Without Cl_2
Coliforms (37 °C) in 500 mL	n.d.	n.d.	n.d.	n.d.
Fecal streptococci in 500 mL	n.d.	n.d.	n.d.	n.d.
Sulfite reducing clostridia in 1000 mL	n.d.	n.d.	n.d.	n.d.

One of the key indicators of biological activity is HPCs. Figure 11 shows HPCs in the water distribution network before (met) and after (zonder) chlorination, with the differences being negligible.

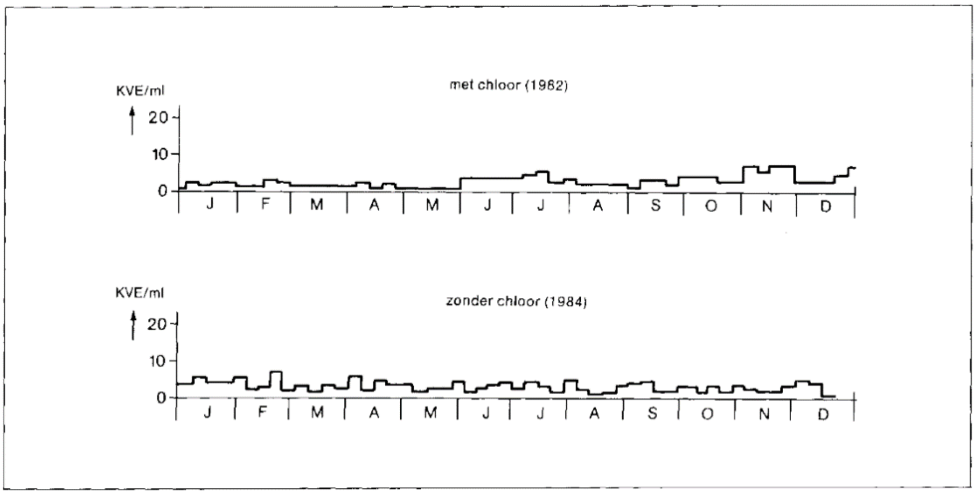

Figure 11: HPC in distribution network before (1982) and after (1984) ending chlorination

Waternet continued to develop their approach to water treatment to deal with emerging contaminants and micropollutants, such as pesticides and herbicides, and installed ozone and Granular Activated Carbon (GAC) at their Weesperkarspel Water Treatment Plant (WTP) in 1991 and their Leiden WTP in 1995.

In 2001, a new decree was established to adapt the Dutch drinking water regulations to include a QMRA for sites at risk (typically surface waters) to a risk of infection of 1 in 10,000 persons per annum for enteric viruses, *Cryptosporidium* and *Giardia* and any other relevant pathogens. In general, the Dutch drinking water regulations are more stringent than those in other EU states who operate under the 1998 European Commission Drinking Water Directive. The Dutch legislation includes no requirements for primary or secondary disinfection.

The adoption of QMRA refocused Waternet, and other Dutch water utilities, on microbial safety and led to increased monitoring and further research into treatment efficacy and distribution system safety.

Figure 12 shows the process undertaken by Waternet to achieve chlorine-free drinking water.

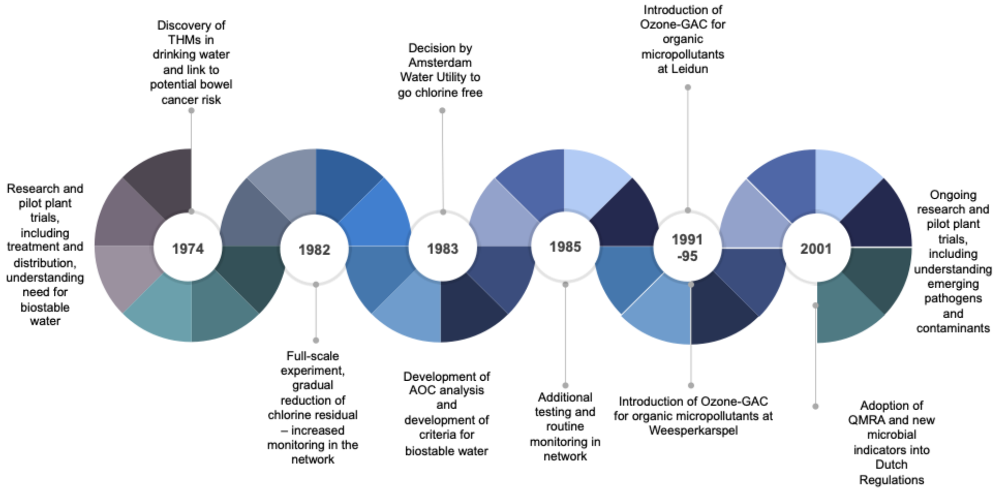

Figure 12: Timeline of Waternet's transition to a chlorine-free system

In terms of water quality monitoring and setting water quality objectives, the Waternet system focuses on some key parameters for the water supplied from the two main WTPs which have targets well below those contained in the Dutch water quality standards. Key parameters of particular relevance for NCC are:

1. Microbial indicators
2. Soluble iron
3. Soluble manganese
4. Turbidity

Several parameters are measured which are not regulated but are used to monitor biological efficacy and stability of the treated water (e.g. *Enterococci*, AOC, and UV extinction). Furthermore, the presence of other biological nutrients, such as phosphate and nitrogen compounds, are minimised to further ensure biofilm growth is minimised.

In terms of maintaining water quality in distribution water quality, the standards at the treatment plants are maintained. This is shown in Table 16.

Table 16: The water quality recorded for treated water and in distribution system

Parameter	Treated Water	Distribution System
Escherichia coli (CFU)	<1/100 mL	< 1/100 mL
Faecal Streptococci (CFU)	< 1/100 mL	< 1/100 mL
Clostridium perfringens (CFU)	< 1/100 mL	< 1/100 mL

Total coliforms (CFU)	<1/100 mL	< 1/100 mL
Heterotrophic Plate Count (CFU)	<100/mL	<100/mL
Aeromonas 30°C (CFU)	<1000/100 mL	<1000/100 mL
Legionella (CFU)	< 100/L	< 100/L

The data supplied by Waternet on the microbial quality during 2020 with respect to HPCs is shown in Figure 13.

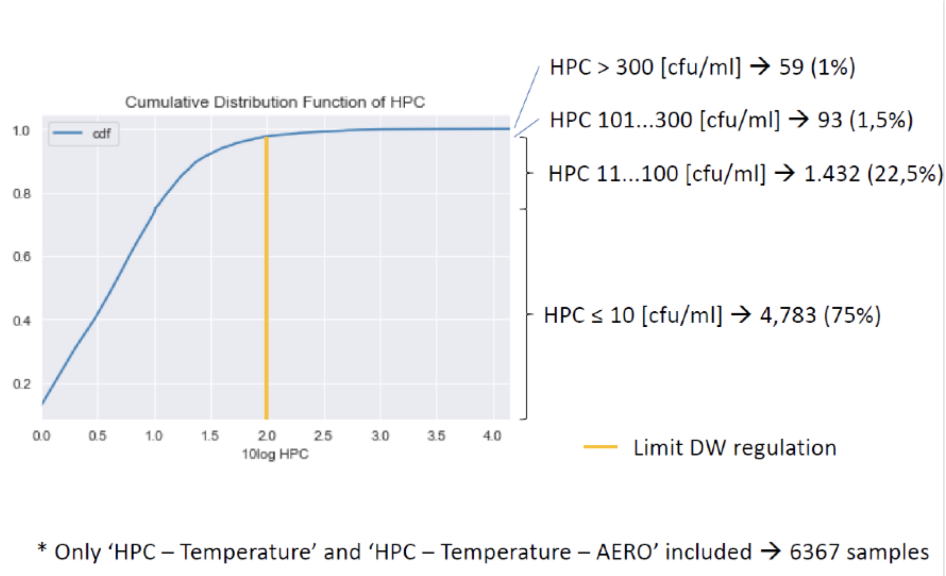

Figure 13: Frequency distribution of HPCs in the Waternet drinking water network

The data gives some good guidance and benchmark data on the water quality requirements for a chlorine-free water network. The Dutch guidelines have an HPC level of 2 log10 or 100 CFU per millilitre, Waternet had 97.5% of samples below this guideline value and 75% at 1 log10 or < 10 CFU/mL. This data can be used by NCC to establish both the current performance of their system and to set performance indicators for microbial health of the network.

Along with HPC, Waternet also sample for *Aeromonas* and temperate in the transport and distribution system. This data for the period from 2009 to 2020 is presented in Figure 14.

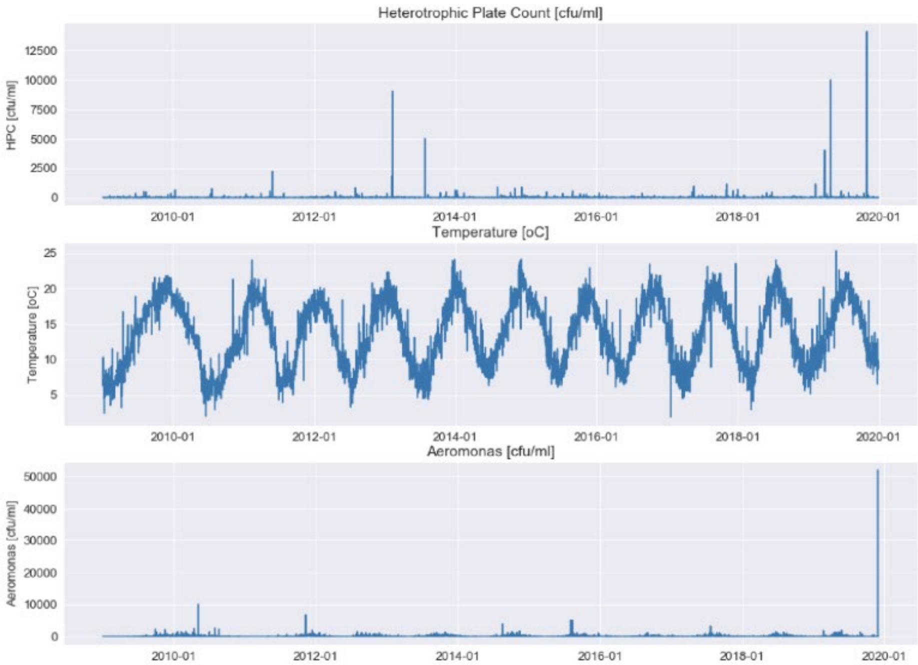

Figure 14: HPCs, temperature and *Aeromonas* in the drinking water network of Amsterdam from 2009-2020

The data presented show several spikes in both HPCs and *Aeromonas*. For *Aeromonas*, the slightly increased values are related to elevated temperatures in the summer. For the high spikes, no clear explanation is found. It may be an effect of contaminated samples. From other indicator sampling, *E. coli,* it was found that the water supply was clear of faecal contamination of the drinking water. All Dutch water utilities must comply with the Hygienic Code for Drinking Water prescribed under the Dutch Water Regulations 2010[2].

1.10.1.1 DWCC

Waternet does not sample for iron and manganese in the water network. The concentrations of manganese and iron for the past 12 months (2019-20) are shown in Table 17.

Table 17: Treated water quality of manganese and iron for 2019 to 2020

	Average	Min	Max	No. of Samples
Manganese (µg/L)	< 10	< 10	< 10	52
Iron (µg/L)	10	< 10	65	13

Due to the extensive treatment process used by Waternet, it is no surprise that levels of manganese and iron are very low. As discussed earlier, the absence of manganese and iron in the water system are conducive to maintaining a biologically stable water network and have a low incidence of DWCC.

[2] Dutch Water Act: https://www.helpdeskwater.nl/secundaire-navigatie/english/@176675/dutch-water-act/

Table 18 shows DWCC for Waternet from 2015 to 2019.

Table 18: DWCC for Waternet from 2015 to 2019					
Year	2015	2016	2017	2018	2019
DWCC (Total No. per annum)	32	24	30	18	61

The data presented gives Waternet a DWCC rate of 0.025 complaints per 1,000 population. This is well below the rate achieved by both NCC before and after the 2017 chlorination (and the UK water companies) as presented in Figure 3. As discussed earlier, the presence of chlorine, manganese, and iron correlates with high levels of DWCC and as such it is not surprising that in a chlorine-free system with very low levels of manganese and iron, the levels of DWCC are extremely low.

1.10.1.2 Prevention and Control of Contamination in Distribution

The water distribution system consists of four distinct areas:

1. Bulk transmission through large diameter pipes
2. Pumping stations, including booster pumps
3. Service reservoirs
4. Water distribution pipework

Waternet's approach to ensuring water quality is maintained is by ensuring potential opportunities for ingress are identified and adequate control measures are put in place.

Transmission Pipework

All transport pipes are underground. Pressure in the transport pipes are monitored continuously. The route of the pipes from Ir. Cornelis Biemond to Leiden are inspected regularly from the air (via helicopter flights).

Distribution Reservoirs

The volumes of water at the different plants are shown in Table 19.

Table 19: The volumes at the drinking water treatment plants and pumping stations in the Netherlands	
Location	**Volume (m^3)**
Drinking water treatment plant Leiden	13,400
Drinking water treatment plant Weesperkarspel	30,000

Pumping station Amstelveenseweg	35,000
Pumping station Haarlemmerweg	23,220

All reservoirs are constructed from concrete and are completely water tight (with an internal coating) and air vents have absolute filters to avoid any contamination. The use of frequent analysis of the microbial quality of the stored water is used to detect deterioration in water quality. The oldest storage reservoirs date prior to 1983 (Haarlemmerweg and Amstelveenseweg), and the newest were built in 1995 (Leiden).

Some basic design rules for clean water reservoirs:

- Avoid short circuiting and stagnant water; this may result in long residence times with subsequent deterioration of the water quality
- Based on that, a plug flow is better than complete mixing to control distribution of residence times
- Rule of thumb: the volume should be 25% of the daily production

Distribution Network

The water distribution network in Amsterdam is fully automated and operated form a central operational control centre (OCC). The OCC in manned only during the normal working day. The network uses a combination of flow meters and pressure sensors to maintain the system health. All pumping stations and booster pumping stations have flow and pressure sensors and there are an additional 40 pressure sensors in the network. Of the properties, 74% have a point of entry flow meters. The Dutch water regulations state that the minimum pressure at the point of delivery should be at least 15 m.

The flow and pressure are used to identify leaks and the system can respond automatically to isolate compromised pipework. In the case of a major leak, the pipe is disconnected and since the network is configured in a “branch and loop-system,” the number of properties affected when a leak is detected is minimised.

Transport systems are designed as looped systems while distribution systems are designed as branched systems.

There are no direct household connections to the transport system. A transport system should be designed as a looped system to increase the reliability of the system. When there is a break in a transport pipe, the system can still be operated and only a very small portion of the customers are affected.

The water transmission system is comprised of a series of loops. This means that the water can follow several “routes” during transport, depending on pressure and demand. In the case one route fails (through a break), other routes are still available.

Figure 15 shows an example looped transport system.

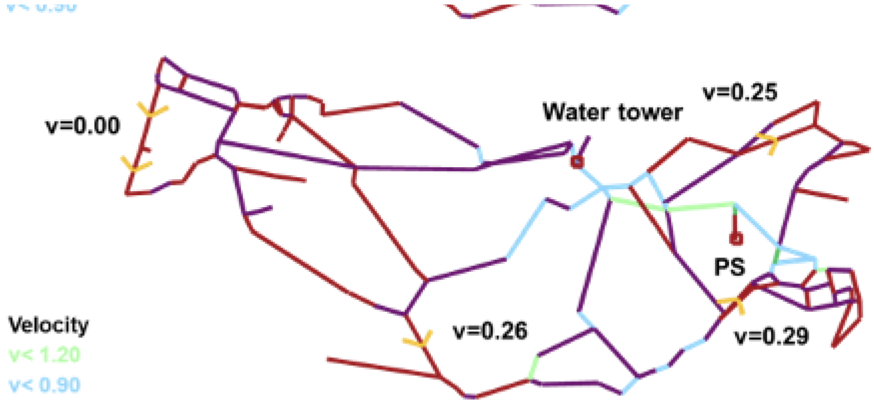

Figure 15: An example of a looped transport system

The household connections are connected to the distribution system. A modern distribution system is a branched system because this offers the possibility to create a self-cleaning network. This involves:

- A unidirectional flow, no commuting water
- A flow rate of 0.4 metres per second, once a day, to prevent sedimentation and accumulation of material in the system

An "old fashioned" distribution system, based on a looped system, is shown in Figure 16.

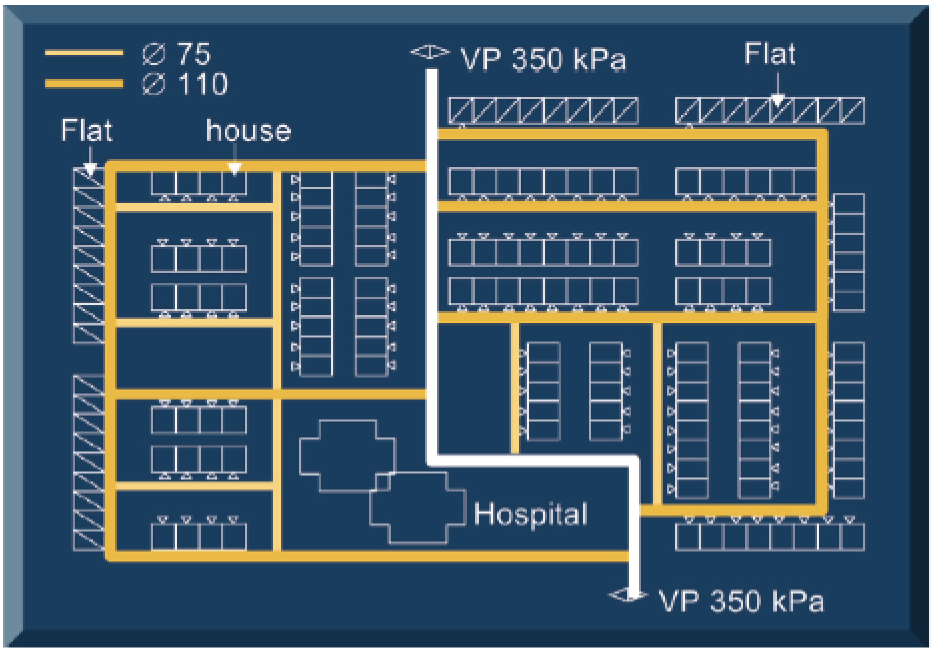

Figure 16: A conventional (looped) distribution system

A modern, self-cleaning distribution system is shown in Figure 17.

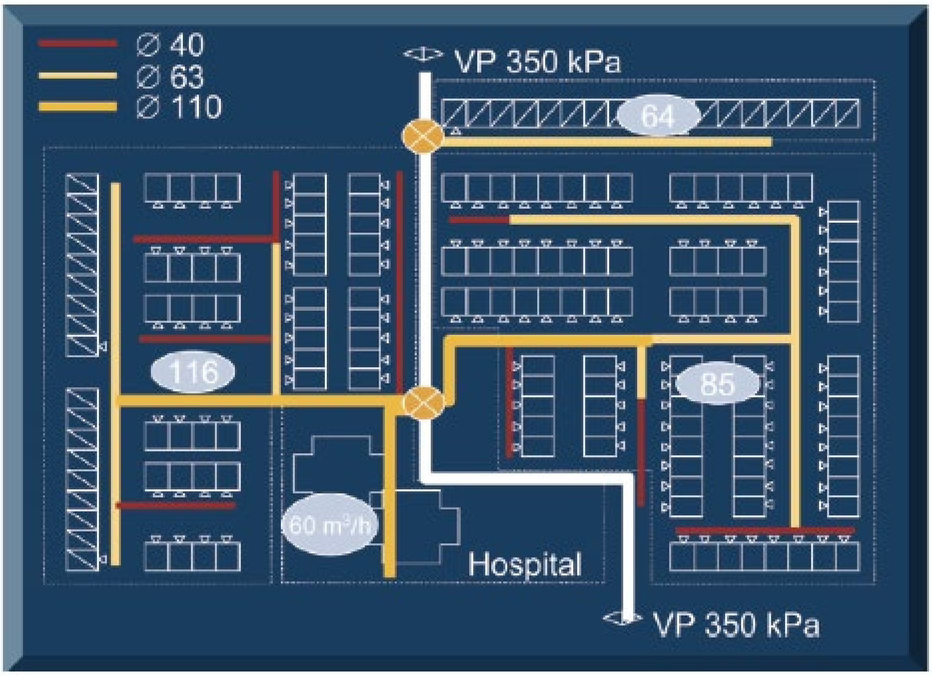

Figure 17: Redesigned distribution network (branched and self-cleaning)

The disadvantage of a looped distribution system is that the water may stay for a relatively long time in the system since it can circulate within the loop. Furthermore, based on demand, the flow direction may reverse, and the velocities reduce resulting in the loss of the "self-cleaning" velocity requirement.

In a branched distribution system, the flow is unidirectional and higher flows can be maintained. This prevents deterioration of the water quality and sedimentation of material.

Leak Detection and Response

Major leaks can be isolated automatically from the OCC. Leaks are generally detected by:

- Pressure changes in the network
- Public notification by telephone
- Social media

Acoustic sensors are not used in the Waternet system since low levels of NRW have been historically low and adoption of this approach is not deemed to be necessary.

Avoidance of fluctuations in pressure and transient pressure surges that would result in negative pressure in the distribution system are minimised by use of variable speed pumps, pressure dampening devices, and automated distribution control to prevent large variations in flow (e.g. when filling reservoirs). Negative pressures (back-siphonage) and excessive pressures in elevated areas are controlled by defining pressure zones and controlling pressures such that pressure variations are limited.

The prevention of cross-connections and backflow is extremely important. Connections to installations that could present a risk, (e.g. through the connection of pumps or from high levels of pathogens at the location) are only allowed through a backflow prevention valve or a break tank. Examples of this are high-rise buildings with local pressure systems, industry, and hospitals.

There is a “Quantitative guideline for reliability” embedded in the Dutch Drinking Water Regulations. New and repaired pipe use chlorine as part of the replacement / repair procedure prior to returning to service. These procedures are laid out in the Hygienic Code for Drinking Water. Water quality is monitored at more than 200 locations with samples taken weekly or monthly measuring physical, chemical, and microbiological parameters.

Table 20 shows that the number of leaks detected on annual basis in the Waternet system run between 10 and 11 leaks per day.

Table 20: The number of leaks per annum from the Waternet system

Year	2015	2016	2017	2018	2019
Defects & Leakages	3,644	3,996	3,997	4,062	3,748

Materials - Drinking Water Transport and Distribution

Table 21 shows the current status of the water network in terms of pipe materials and the average age of pipework.

Table 21: The current status of the Waternet water network

Material	Length (m) 2019	%	Average Age 2019
PVC	996,357	31	32.10
Cast Iron	698,584	22	70.29
Ductile Iron	527,991	17	46.16
Concrete	355,392	11	52.91
PE	260,304	8	32.61
Copper	181,360	5	33.73
Steel	116,615	4	25.30
Asbestos Cement	60,519	2	46.16
Total	3,168,858	100	40.15

Asset Management

Figure 18 shows the rate of mains renewal and replacement for Waternet’s distribution system from 1990 to 2020. The chart shows metres of main replaced per annum for various pipe materials.

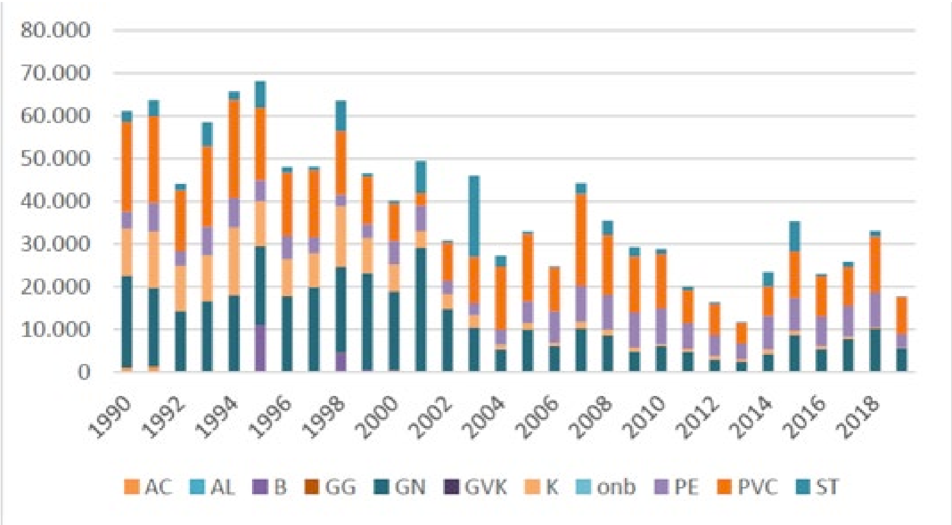

Figure 18: Water mains replacement length 1990 to 2020 in Waternet system

Figure 18 shows that between 1990 and 2003, Waternet installed on average 52 km of water mains, which equates to 1.7% per annum and 23.5% of the total network. From 2004 to 2019, the rate dropped to 26.5 km per annum (i.e. 0.85%) which is approximately 13.7% of the water network.

The total pipe replacement programme from 1990 to 2020 equates to almost twice the size of the NCC below ground water infrastructure.

A summary of the Waternet approach and the key lessons for Napier to transition to a chlorine-free network is shown in Table 22.

Table 22: A summary of the Waternet approach and key lessons for transition to CF

Summary	Relevance to the Review
1. The move to a chlorine-free water supply system in the Netherlands was driven by perceived public health concerns relating to DBPs, more specifically THMs.	1. Key parameters from the Waternet system of relevance for NCC are microbial indicators, soluble iron, soluble manganese, and turbidity.
2. The transition to a chlorine-free water system was based on significant research and the development of an understanding of the important water quality parameters on both waters entering the system and also the how water quality is maintained within the water network.	2. It is recommended that NCC learn the key lessons from over 25 years of chlorine-free operation from the Waternet system, in particular in relation to understanding the importance of water quality monitoring and maintaining water quality within the supply and distribution network, and the set-up and operation of the water network to ensure maintenance of safe drinking water and avoidance of contamination through ingress or operational practices.

3. Levels of NRW in the Waternet system were low prior to the move to chlorine-free and this may be due to the nature of the sub-surface soil condition and relatively flat hydraulic profile. Interestingly, the mix of pipe materials is similar to that seen within the NCC system. The average age of the network is >30 years.	3. NCC will have to undertake a significant water mains replacement to achieve an NRW level of 5%.
4. The Waternet water supply system has water quality and water hygiene at the core of its principles with extensive water quality monitoring in place as well as an engaged workforce with a comprehensive understanding of water hygiene practices and their potential impact on contamination of potable water throughout the whole water production and supply cycle.	4. NCC should adopt the principles of water hygiene in its water operations and engage with industry experts to develop a training programme.
5. The Waternet water network operates at NRW levels of <5%. This is achieved through the proactive management of the water network using pressure and flow monitoring to detect leaks and pipe bursts and the ability to isolate compromised pipes to minimise disruption to customers.	5. NCC should implement a SMART approach to the management of its water supply, storage, and distribution system.
6. The Waternet distribution network operates as a branched system based on a self-cleaning velocity. This reduces any buildup of sediment and thus minimizes the number of unnecessary human interventions in water mains cleaning this potential contamination events.	6. The move to a branched system should be considered but is not essential for NCC.
7. Waternet maintains a water mains replacement programme of 0.85%, which can be used as a benchmark number to maintain, rather than reduce, NRW levels once a 5% NRW rate is achieved.	7. Once NCC achieves an NRW of 5%, an ongoing water mains replacement program of close to 1% should be maintained.
8. Waternet maintains low levels of iron and manganese within their water supply system in order to minimise deposition of materials throughout the water network. DWCC levels are at industry leading levels of <1 DWCC per thousand population.	8. The NCC system should aim to have levels of iron and manganese of <10 µg/L at the 95th percentile in the water supply and distribution system.

1.11 Napier's Water Network & Recommended Improvements

Napier's water supply is pumped directly from a series of bores into a distribution network of 480 km of pipelines, nine booster pump-stations and 11 storage reservoirs. The Enfield and Taradale Reservoirs constitute the bulk of water storage, with other smaller reservoirs and pump stations in place to provide supply to higher elevations. The NCC Water Supply Network Master Plan, Stantec Nov 2019 (the Water Supply Master Plan), recommends $60M of improvement projects aimed at improving the safety, resilience, and operating pressure of the water network. These projects are budgeted for in the latest draft version of the NCC long-term plan, that is currently under development.

1.11.1 Transmission

A key characteristic of Napier water supply system is the lack of a fully separated transmission and distribution network. Presently, the water is pumped from the bores into a 'combined' network and the reservoirs are filled through pumping pressurised water into the combined network which fills the reservoirs at times when demand is low and allows stored water back into the distribution system at times of high demand. The Enfield and Taradale Reservoirs are built at the same top water level (TWL) to assist this process.

With this type of configuration, there is a risk of contamination in the distribution network making its way back into service reservoirs and compromise the ability to isolate parts of the distribution network during contamination events. The Water Supply Master Plan provides for the rationalisation of the existing pipe network to create two separate and dedicated bore fields, two new treatment plants, and transmission mains for both proposed bore fields/ treatment plants. From a chlorine-free perspective these projects should form the foundation of any programme to safely move to a chlorine-free environment.

1.11.2 Water Storage Reservoirs

There are 11 reservoirs in the Napier water supply network. The two largest reservoirs are the Taradale (2 x 9 ML) and Enfield (11 ML) reservoirs. The Taradale reservoirs are relatively new while the Enfield reservoir is due for replacement either at its current location or in another nearby location. The Water Supply Master Plan provides for upgrade or replacement of the Enfield reservoir and associated pipe work changes.

1.11.3 Distribution

The NCC water distribution network comprises approximately 480 km of pipe network, pump stations associated valves, hydrants, and service connections from water mains to the customer point of supply.

The integrity of the distribution system is a key factor in supplying safe potable water to customers and is an area of high contamination risk from mains breaks and NRW, and backflow into the system through customer connections. A key indicator of distribution system integrity is system NRW.

Analysis of well managed chlorine-free systems shows low levels of NRW (<10%) as a common factor. Recent leak detection work undertaken by NCC indicates water loss of >30%. While this figure is not unusual in New Zealand, it is based upon initial results of the NRW detection programme for one suburb and will need to be corroborated. Due to the previous view that the aquifer water is available in abundance, there has not been a historic drive to conserve water and costs have been kept low by maximising the lifespan of underground assets. There has also been a previous drive to keep costs down and expenditure on the water supply network has been kept low.

It could be argued that this view has been assisted by the widespread use of chlorine as the residual disinfectant in public drinking water, which has enabled water providers to safely operate systems with high levels of NRW and this view permeating the New Zealand water industry psyche.

In order to achieve system NRW rates comparable to other chlorine-free systems, NCC will need to undertake a series of activities aimed at including improving understanding of the likely location of leaks, better understanding pipe materials subject to NRW, and improved measurement of water production and consumption. These will include:

- Improved asset management (AM), including understanding the condition of buried infrastructure
- Proactive mains replacement (in older pipe networks) programme (>3% of total pipe length per annum)
- Active pressure and NRW management
- Establishment of District Metering Areas (DMAs)
- Universal household water metering
- Universal backflow prevention

1.11.3.1 Asset Data and Information

Like many New Zealand water suppliers with buried infrastructure, NCC has imperfect information on the condition of its buried pipe infrastructure. In many instances primary data such as the pipe location, size, material, installation date, and location are based on limited records and is implied by the age of the suburb in which the pipe is located. Furthermore, data on asset condition is often limited to age-based assumptions or data collected in events such as pipeline breaks, repairs, or installation of new connections.

What is known is that there is a substantial amount of NRW from the distribution system. Whether this relates to older pipe materials and the nature of the NRW (pipe corrosion, leaking joints, leaking service connections or even on the customer's internal plumbing) is not well understood.

In general, older pipes (and subsequently older pipeline technologies subject to corrosion, such as cast iron) are generally thought to contribute more to NRW than modern materials such as High-Density Polyethylene (HDPE) pipes, which are more resistant to ground movement and soil types, with superior joint and tapping systems, and are expected to exhibit lives well in excess of 100 years.

There is also sufficient evidence in other supplies that private side NRW can be very high in unmetered supplies.

1.11.3.2 Distribution Pipe Replacement Planning

To move to chlorine-free operations, NCC must get NRW under control. It is recommended that NCC embark on an ambitious accelerated programme of pipe replacement focused on the replacement of cast iron water mains. Research into the attributes of well managed chlorine-free water suppliers shows that an initial rate of pipe replacement of 3% of the pipe network is appropriate.

Cast iron pipes are estimated to represent 14-17% of the pipe network. At this rate, all cast iron pipe could be replaced within six years, with 15 km of pipeline being replaced annually. The total cost of the replacement programme would be approximately $22M or $5.6M per annum.

Without this aggressive approach the existing pipe network is going to deteriorate at a rate faster than the rate of replacement meaning that NRW rates will remain at high levels. Current levels of expenditure are insufficient to bring NRW under control.

1.11.3.3 Water Loss and Leak Detection

It is difficult to estimate the reduction in NRW that would be achieved, but an initial programme focused on cast iron pipe replacement supported by acoustic leak detection (as a means of prioritisation) would be appropriate.

NCC has recently undertaken a leak detection trial in the Westshore, Bayview and Ahuriri areas that indicates water losses of 33.9%. This is substantially more than the NRW rates of <10% achieved by well managed chlorine-free systems.

In addition to the initial acoustic survey of cast iron pipe, it is recommended that NCC expand this programme to implement a rolling annual programme of leak detection (comprising both minimum night flow testing and where necessary acoustic detection) by DMA (see district metering below) that covers the entire city on a periodic cycle. The recent acoustic leak detection work included acoustic testing of 200km of watermains at a cost of $275 per km. We recommend that this project is expanded to cover the entire NCC water distribution system and is undertaken on a regular basis. Based on 480km of watermain the cost of leak detection $132,000.

1.11.3.4 District Metering Areas (DMAs)

An effective way to manage water NRW within a distribution system is to divide the network into DMAs.

The key principle behind DMA management is the use of flow data to determine the level of NRW within a defined area of the water distribution network.

The establishment of DMAs enables current levels of NRW to be determined in any one part of a system, and consequently, leak location activities can be prioritized accordingly. Water entering each DMA is monitored and logged; this data is used to calculate usage within each DMA. Key Performance Indicators (KPIs) measuring the acceptable flow rate are set for each DMA, and are calculated by several variables, such as customer connections and length of water main. The data received from each DMA is used to compare one part of any system against another, while the historic data of any given DMA is used to compare the flow today versus previous day(s). Repeatability of flow and pressure data, in conjunction with historical data, is crucial to differentiating between problematic and healthy DMAs.

By monitoring flows in DMAs, it is possible to identify the presence of existing and new bursts, so that NRW can be maintained at the optimum level for that area. This data allows the utility to react quickly to areas with high NRW and confirm and repair leaks instantaneously. Unexpected and noticeable increases in water can indicate potential NRW.

NRW is energetic and while initially significant, reductions can be made. Levels of NRW will continue to rise as time elapses unless an ongoing NRW control programme is implemented. Fundamental to DMA management is the correct analysis of flow data to determine whether excess NRW exists, and to identify the presence of new leaks.

The extent of NRW can be gauged by assessing the 24-hour flow pattern of a zone. A limited variation between the minimum and peak flow, particularly in a network with little industrial night use, is indicative of a leaky network. However, this approach does not allow the NRW level to be directly quantified. NRW is most accurately determined when customer consumption is at a minimum during the night (minimum night flow). In addition to the daily data / trends, a water balance check can also be executed each month to gauge the actual water losses in any given DMA.

DMAs are not an alternative, but rather a preceding and enhancing tool to standard leak detection practices. DMAs allow leak detection efforts to be targeted as they indicate the problem areas where a leak is known to exist, eliminating the need to sound detect the whole distribution system in search of NRW. Also, DMAs are a more permanent solution for reducing and maintaining targeted levels of NRW, as data is received continuously, and NRW can be monitored after leak detection efforts are deployed and have been completed.

The design of a series of DMAs is very subjective, and it is unlikely that two utility engineers working on the same network would come up with the same design. A typical a set of criteria to create a preliminary DMA design using a network model and tested in the field are.

- Size of DMA (e.g. number of connections—generally between 500 and 3,000)
- Number of valves that must be closed to isolate the DMA Number of flow meters to measure inflows and outflows (the fewer meters required, the lower the establishment costs, and more accurate reading.)
- Ground-level variations and thus pressures within the DMA (the flatter the area the more stable the pressures and the easier to establish pressure controls)
- Location of visible structure that can serve as logical boundaries for the DMA, such as rivers, drainage channels, roads

It is recommended by WHO that DMAs are in the range of 500 to 3,000 properties. For Napier, twelve DMAs would equate to an average initial DMA size of 2,350 properties. As the information on areas with high NRW becomes available subdivision of the high NRW areas into smaller sub-DMAs to enable the sources of NRW to be pinpointed accurately.

1.11.3.5 SMART System Monitoring, Control and Automation

A SMART water network is an integrated set of products, solutions and systems that enable water utilities to remotely and continuously monitor and diagnose problems, prioritise, and manage maintenance issues and use data to optimise aspects of the water distribution network.

SMART water networks generally focus on:

- NRW detection and management
- Metering consumption
- Network optimisation
- Real time water quality monitoring
- Real time flow monitoring

NCC's water network has a simple SCADA system that currently monitors water reservoir levels and pump status. There is significant potential to improve and optimise the water network through the use of smart meters, real time pressure, flow and water quality information. Our research has indicated that use of smart systems and real-time monitoring is a key attribute of well managed water utilities and in particular those organisations who operate chlorine-free systems. Implementation of a SMART network would follow the move to delineating the current system to a fully functioning DMA based network.

Smart networks take many forms, from simple universal metering through to real time monitoring and control systems. Technologies in this area are changing rapidly as wireless technology such as 5G cellular enables data to be shared at locations and speeds that were unachievable only a few years ago. Most water utilities in New Zealand have a SCADA system that enables users to monitor and control information such as reservoir levels, remotely operate pumps and valves, and provide alarms when system parameters are out of normal operating ranges. Some more advanced water utilities undertake pressure and flow monitoring of their water.

1.11.3.6 Universal Metering

Universal metering is needed to provide accurate information on water use - a critical building block in establishing an environment in which water is efficiently used. It is a common feature of well managed chlorin-based and chlorine-free water providers around the world.

Universal metering reduces (generally discretionary) water use by:

- Improving customers' awareness of their water use
- Identifying customer water loss, particularly from private plumbing
- Improving understanding of the overall network water balance which can enable water suppliers to reduce water losses in their network

Additionally, water metering can help to reduce peak demand during summer months when water resources are most stretched. Reduced demand can defer the need for network upgrades and / or new supply sources, leading to both capital and operational savings. This is particularly relevant where the development of new water supplies is considered costly or obtaining a resource consent is challenging.

We recommend that NCC move to SMART meters that allow metering and consumption data to be collected in real time or at discrete intervals.

1.11.3.7 Universal Backflow Prevention

One essential (but often overlooked) aspect of maintaining safe drinking water in the distribution system is the need for a thorough, effective, risk-based Backflow Prevention Programme. Backflow means the unplanned reversal of flow of water or mixtures of water and contaminants into the water supply distribution system.

Clause 27 of the Water Services Bill expected to be enacted next year will require a drinking water supplier whose supply includes reticulation to ensure that the supply arrangements protect against the risk of backflow and provides for the installation of backflow prevention devices. Discussions with Taumata Arowai have provided some insight into the likely requirements. This includes the installation of backflow prevention devices on all connections, for which the level of protection provided by the devices commensurate with the level of risk. Most domestic connections would therefore require a simple double check valve, with higher risk connections requiring more sophisticated devices.

Our understanding is that NCC's current backflow prevention policy is:

- At least a testable double check valve on all commercial and industrial connections for medium hazard and lower
- Reduced Pressure Zone (RPZ) backflow prevention device on all high hazard (i.e. commercial and industrial hazardous, elevated sites, and rural supplies etc)
- All other non-testable double check valve
- We recommend the backflow prevention programme is undertaken in conjunction with installation of water meters. This would improve the efficiency by reducing the number of visits to the site saving costs and unnecessary temporary disruptions to supply.

2.0 The Investment Options (The Economic Case)

2.1 Overall Evaluation Methodology and Approach

2.1.1 Background and Context

NCC has set out two future scenarios known as SQ+ (Status Quo plus) and CF (Chlorine-Free). Moving to either SQ+ or CF will mean investment in several key areas:

- Physical assets - treatment plants, reservoirs, water network
- Operation and maintenance practices - water hygiene, public health policy
- Organisational culture - training and recruitment
- Stakeholder engagement and management – community consultation
- Asset management data, practices, and processes

The discrete elements which make up either an SQ+ or CF future have significant commonality between them, and an adaptive approached was developed based on a "shopping list" of elements which incrementally move towards a sustainable and responsible approach to achieving a CF future. This approach ensures that early and key decisions are aligned with both a CF and SQ+ future state and this minimises unnecessary investment and an economically prudent approach is taken.

Both strategies will have to address common areas such as the likely change in borehole status from secure, suitable treatment mitigation measures for pathogens and reducing DWCC to an acceptable level.

The primary concern of the NCC water supply team is to ensure that public health is not compromised and that its legally binding regulatory obligations are met. Customers expect their water supply to be safe first and foremost, followed by reliable and meets aesthetic parameters such as taste, odour, and colour.

It is impossible to move to a chlorine-free system without significant understanding of the source risks, the existing treatment adequacy, and the health of the current network. Measures, metrics, and monitoring will need to be developed that will be bespoke to NCC's existing set of circumstances and the current DWSNZ will not be adequate to provide suitable performance targets.

As such, NCC will need to increase not only its end-to-end system water quality monitoring but also establish a new set of parameters, outside of those contained in the current DWSNZ, to monitor. Capital investment in infrastructure is inevitable, with improvements in source water protection, drinking water treatment, water transmission, water storage, water pumping and water networks being required.

2.2 Options Assessment

The Options Assessment consisted of three distinct phases:

1. Development of a longlist of options
2. Development of assessment criteria
3. Shortlisting of options

The approach is illustrated in Figure 19.

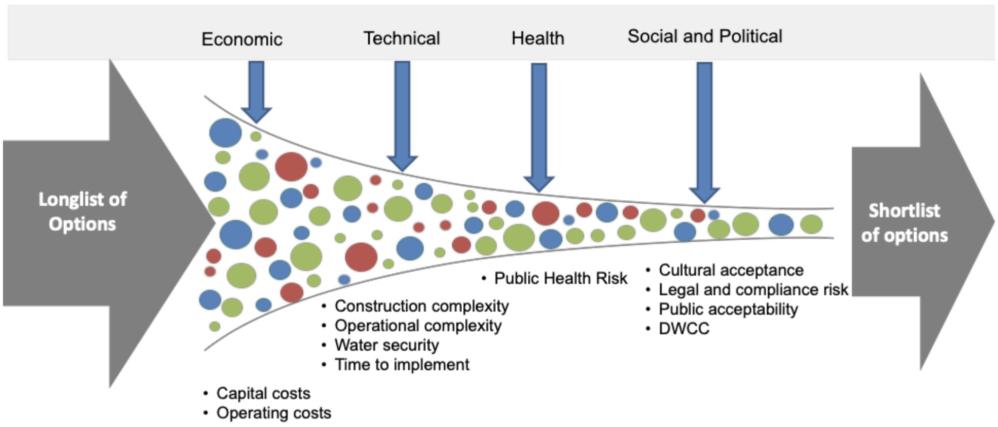

Figure 19: The Options Assessment approach undertaken

The assessment criteria were grouped into four main categories:

- Financial - CAPEX and OPEX
- Technical - construction complexity, operational complexity, water security, time to implement

- Health and Environment - health and safety, public health risk, environmental risk
- Social and Political - cultural acceptance, legal and compliance risk, public acceptability, DWCC

2.2.1 Development of Long List of Options

Eleven viable options consisting, of both CF and chlorine-based, were initially developed:

- Option 1 – pre-2017 (CF)
- Option 2 – pre-2017 plus iron and manganese removal and UV disinfection (CF)
- Option 3 – Status Quo (Chlorine-based)
- Option 4 – Status Quo with iron and manganese removal (Chlorine-based)
- Option 5 - Status Quo with iron and manganese removal plus UV disinfection (Chlorine-based)
- Option 6 – Status Quo plus (Chlorine-based)
- Option 7 – Dutch Model (CF) < 5% NRW
- Option 8 – Dutch Model (CF) 5 to 10% NRW
- Option 9 – Dutch Model (CF) 10 to 15% NRW
- Option 10 – pre-2017 plus point of use treatment (CF)
- Option 11 – Status Quo plus optional de-chlorination at point of use (CF)

The scope and descriptions of each of the options is described in Appendix C. This includes an outline of the new assets for each option and also the asset management systems and practices.

Following consultation and presentation of the options with NCC councillors, an additional chlorine-free option was added as part of the Council resolution:

- Option 12 – pre-2017 with new service reservoirs, acoustic sensors, and enhanced water hygiene procedures

The options represent an incremental approach to achieving a water supply system which provides safe drinking water which will comply with the current and future DWSNZ.

The evaluation criteria were grouped under four separate categories and are listed below:

- Capital Cost - Economic
- Operating Cost - Economic
- Construction Complexity - Technical
- Operational Complexity - Technical
- Water Security - Technical
- Time to Implement - Technical
- Public Health Risk - Health and Environment

- Cultural (Iwi) Acceptance - Social and Political
- Legal & Compliance Risk - Social and Political
- Public Acceptability - Social and Political
- Drinking Water Customer Complaints - Social and Political
- Council Liability - Social and Political
- Workforce Impact - Social and Political

The options were scored initially based on the non-cost criteria and the raw (unweighted) scores and weighted scores assessed. Following this, a sensitivity analysis was carried out investigating the impact of weighted cost criteria to identify the best value options to take forward to shortlisting and more rigorous evaluation.

The evaluation criteria definitions and scores are shown in Appendix D.

2.2.2 Options Scoring and Assessment

The options were evaluated during a workshop with NCC and scored based on the evaluation criteria and definitions. A sensitivity analysis was carried out to look at the impact of both cost and non-cost criteria. The removal of the cost-based criteria from the scoring represents the relative value of each of the options and is an assessment of their performance against the requirements of the project.

The cost-based criteria weightings were adjusted to check the sensitivity of the scoring to capital and operating costs. It should be noted that low capital cost solution will score highly but they generally score lower in the performance-based criteria. Furthermore, if options score 1 in the hurdle criteria then it is highly unlikely that they would meet the primary objectives of the project, undermine NCC’s responsibility under the current DWSNZ and be unable to meet the exemption criteria from Taumata Arowai and as such would be deemed non-viable.

2.2.2.1 Raw Scores

The 12 options scores were collated, and the top four options ranked, with the maximum score for any option being 50, in the following order:

- Dutch Model 1 – 39.5/50
- SQ including Mn removal and UV– 38.5/50
- SQ plus – 37.5/50
- Pre-2017 – 37/50

The pre-2017 option ranks at number 4 due to it scoring highly due to the low investment costs, the construction complexity and the time to implement.

When the economic criteria are removed the performance aspect of the options can be assessed. The performance based raw scores show the top four options to be:

1. Dutch Model 1 – 35.5/40
2. SQ including Mn removal and UV – 31/40

3. SQ plus - 31/40
4. Dutch Model 2 – 30/40

The pre-2017 option drops out of the top four based on its impact on water security (high non-revenue water), public health risk (no chlorine residual to protect form ingress) and the legal and compliance risk (inability to achieve an exemption from Taumata Arowai) of the option.

2.2.2.2 Weighted Scores Non-Cost

In the assessment undertaken the non-cost criteria describe the performance of each of the options based on the criteria outlined earlier. This allows the best performing options to be assessed independent of economic considerations.

The non-cost criteria were weighted as follows:

- Technical – 20%
- Health and Environment – 20%
- Social and Political – 60%

When the percentage weightings are applied the maximum score for any option is 5. Applying the non-cost weighting gives the following top four options:

1. Dutch Model 1 – 4.45/5
2. SQ plus – 3.83/5
3. SQ including Mn removal and UV – 3.65/5
4. SQ plus with optional point of use – 3.45/5

Of the top four options, the two chlorine-free options are those with the highest likelihood of achieving an exemption. All other chlorine-free options fail to achieve the hurdle criteria for the exemption based on feedback from Taumata Arowai.

2.2.2.3 Cost-Based Sensitivity

In order to determine the best value option, it is important to understand the trade-off between performance and cost. The options were assessed using a 30% and 50% weighting of costs to the overall scores.

Under the 50% cost weighting the evaluation criteria had the following weighting:

- Capital Cost – 25%
- Operating Cost – 25%
- Technical – 15%
- Health and environment – 15%
- Social and Political – 20%

When the cost criteria weighting is at 50% the following options are the top four:

1. Pre-2017 – 3.76/5

2. Pre-2017 plus – 3.55/5
3. SQ – 3.56/5
4. SQ including Mn removal and UV – 3.56/5

As expected, the options with the lowest capital and operating expenditure are the highest scoring options. It should be noted that these options are generally the poorest performing options against the non-cost criteria.

Under the 50% cost weighting, the evaluation criteria had the following weightings:

- Capital Cost – 15%
- Operating Cost – 15%
- Technical – 20%
- Health and environment – 25%
- Social and Political – 25%

When the cost criteria weighting is at 30%, the following options ranked as the top four:

1. Dutch Model 1 – 3.53/5
2. SQ including Mn removal and UV – 3.46/5
3. SQ plus – 3.43/5
4. Dutch Model 2 – 3.30/5

When the influence of the costs is reduced to 30%, the higher performing options moved into the top four.

2.2.2.4 Option Shortlisting

In order for an option to be shortlisted, it has to score consistently in the top four under the various scoring approaches. Further options that rank lowest for the most impactful criteria relating to public health risk and NCC's compliance with its obligations under legal and compliance criteria are judged to be unacceptable.

The Dutch Option with <5% NRW (Option 7) ranked highest under all evaluation scenarios and was thus shortlisted. This was based on the consistent high scores in the non-cost criteria. On a purely financial basis, Option 7 was at the higher end of capital and operating costs.

Three Status Quo options scored consistently in the top four options, and these were Status Quo plus (Option 6), Status Quo with iron and manganese removal plus UV disinfection (Option 5) and Status quo plus optional de-chlorination at point of use (Option 11).

The new Option 12 was put through the same assessment and scored relative to the other options. The option scored relatively highly but not sufficiently to change the shortlisting decision as it did not reach the minimum hurdle criteria – ability to obtain a chlorine-free exemption from Taumata Arowai. This was mainly due to the limited improvement in Public Health Risk. When applying the weightings to Option 12 for both cost and non-cost criteria, the option did not rank in the top four options.

The options scoring assessment and sensitivity analysis are shown in Appendix D.

Thus, the shortlisted options selected for further analysis are:

- Option 7 – CHLORINE-FREE
- Option 6 – CHLORINE-BASED
- Option 5 – CHLORINE-BASED
- Option 11 – CHLORINE-FREE OPTIONAL

The methodology, MCA and outcomes were presented to a specially convened meeting of the Napier City Council and its councillors, and at separate meetings with key community advocacy groups, drinking water assessors and regulators and other key stakeholders prior to the more detailed financial assessment of the shortlisted options.

2.2.3 Shortlisted Options

The four shortlisted options cover a range of approaches, each of which would be expected to be able to obtain an approved WSP under the current and likely future water regulation in New Zealand. Furthermore, the options shortlisted have many elements which are common, and which allows for a strategic and adaptive approach to be taken to move NCC to an informed decision-making framework to reach a point in time when chlorine could be turned off in a safe and robust manner. This approach is similar to that adopted by Waternet and the only limiting factors are time, money, and information.

The major scope items for each option are listed in Table 23.

Table 23: Major scope items for each option

	Option 5	Option 6	Option 7	Option 11
Bore Protection	✓	✓	✓	✓
Low Mn Bores	✓	✓	✓	✓
Bore WQ Online Monitoring	✓	✓	✓	✓
Fe-Mn Removal	✓	✓	✓	✓
Chlorination	✓	✓		✓
UV	✓	✓	✓	✓
Direct Transmission to SRs		✓	✓	✓
Upgrading SRs – Watertight and Air Filters		✓	✓	✓
Backflow Prevention on all PS			✓	
Backflow Prevention on Air Valves			✓	
District Metering Areas		✓	✓	✓
Pressure Management Zones			✓	
Universal Water Metering			✓	✓
Universal Backflow Prevention			✓	
Acoustic Sensors			✓	
< 5% NRW			✓	

15 to 20% NRW		✓		✓
Current NRW levels	✓			
Automated Distribution Network			✓	
Water Hygiene Practices	✓	✓	✓	✓
Enhanced WQ Monitoring in Distribution System	✓	✓	✓	✓
Point of Use Device – GAC + UV	✓			✓

An initial screening of the four shortlisted options was carried out to understand the costs of the point-of-use Option 11. The main purpose of Option 11 is to allow for individual property owners to opt into having a point-of-use device fitted to their property to remove chlorine and ensure microbial water quality is maintained. The point-of-use system consists of a granular activated carbon (GAC) filter and UV system capable of treating the full flow to the property. The system would be located external to the property and would require installation of a SMART water meter to ensure the replacement frequency of GAC filters and UV lamps can be predicted. Further, access to the point-of-use system will be required for an annual service and maintenance visit.

There are approximately 23,000 properties in Napier, this would require about 12 FTE's to manage the replacement of UV bulbs, filter cartridges and GAC cartridges based on an annual replacement of consumables. Furthermore, there will be a requirement to have a sampling programme, which could be four samples per property per annum – will need to get advice on this – based on USEPA guidance – this could be a massive requirement unless it can be avoided, suggest we take one sample per property per annum as a minimum. A breakdown of costs for the 23,000 properties is shown in Table 24.

Table 24: A summary of CAPEX and OPEX costs

CAPEX	OPEX
Cost of POU treatment system $1000 Cost of SMART meter $500 Cost of plumbing materials $250 Cost of installation $1000 – 2 days @ $60/h	Replacement parts: $255 per annum per household - $5.9 million per annum Replacement time 1h per property per annum – 23,000h or 575 person weeks = 12 FTE's @$90,000 p.a. - $1 million per annum Sampling based on one sample per annum per property – 23,000 samples – 0.5h per sample – 6 FTEs - $500k per annum

	Annual sample Analysis – Coliforms, *E. coli*, HPC - $200 per sample - $4.6 million
Total CAPEX for 23,000 properties: **<u>$80.5 million</u>** or **$3,500 per property**	Annual OPEX 23,000 properties: **<u>$12 million or $521 per property</u>** Annual OPEX 11,500 properties: $6 million Annual OPEX 6,000 properties: $3 million

Furthermore, there will be additional environmental concerns as well as costs relating to the disposal of spent GAC filters and UV lamps past their useful operation. The additional costs per property would be expected to be covered by the property owner and would be in addition to the costs associated with implementation of SQ+ and thus be an additional cost on their water bill. Finally, the legal responsibility for the water quality of the point-of-use system is not clear under the DWSNZ and as such the option is not deemed practicable.

3.0 The Commercial Case

The commercial arrangements surrounding delivery of the proposed programme are yet to be determined. However, delivering the programme effectively and efficiently will be an important aspect to consider once the decision is made whether to proceed.

3.1 High Level Procurement Strategy

The assessment of procurement options would need to focus on several key factors, particularly:

- Market competition – the procurement strategy maximises the competitive bid process within capacity and constraints of the market and early engagement of key subcontractor resources
- Innovation and incentive – the procurement strategy incentivises the introduction of best practice and innovation in delivering the desired outcomes, achieving lower whole-of-life project costs
- Outcomes – the procurement strategy is conducive to achieving investment objectives
- Timing – the procurement strategy can deliver the project within the deadlines (and earlier if possible)
- Flexibility – the procurement strategy accommodates unexpected changes to scope or original specification during procurement due to potential changes such as the structure and governance of the New Zealand water industry
- Accountability – the procurement strategy provides an optimal level of accountability of service providers and contractors (single point and multiple point accountability)
- Risk – the procurement strategy allocates risks to the party best placed to manage them
- Cost certainty – the procurement strategy provides certainty over cost to completion, cost over the life of the facilities and infrastructure, and support of whole-of-life considerations

4.0 The Financial Case

4.1 High Level Financial Cost Model

We have prepared a financial model that outlines three 22-year cost scenarios as shown in Table 25.

Table 25: Outline of three 22-year cost scenarios

STATUS QUO	STATUS QUO PLUS	ROAD TO CHLORINE-FREE
Investment as per the NCC Long Term Plan (and WS Network Master Plan) which is cash constrained with slow incremental improvement in renewals.	Investment as per the NCC long-term plan (and WS Network Master Plan), plus aggressively replace cast iron pipe by 2030, then ongoing investment at 2% of network per annum.	Total investment as per the NCC long-term plan (and WS Network Master Plan) but accelerated timing, plus aggressively replace cast iron pipe by 2030, then ongoing aggressive investment at 3.5% of network per annum.
Maintain AM practices at the “core” level.	Lift AM practices to “intermediate” level by 2030.	Lift AM practices to “advanced” (ISO 55000) by 2030.
New staff (three) limited to operation of new bore fields and treatment plant.	New staff (three ops and three AM).	New staff (three ops and four AM).
Acoustic leak detection of entire network on a 3-year cycle as per current levels, establish DMAs, universal metering, backflow prevention, upgrade SCADA.	Reduce leakage to 22% by 2030 and 18% by 2040 through cast iron mains replacement, aggressive leak detection, formation of DMAs, enhanced backflow prevention.	Reduce leakage to 15% by 2030 and 10% by 2040 through SMART water network / automation, leak detection, DMAs, universal metering, and backflow prevention.
This level of investment is unlikely to ever achieve the level of network integrity required to go chlorine-free as pipeline replacement rates are initially too low to get on top of deterioration.	Unlikely to get regulatory approval to go to chlorine-free but deterioration of network under control.	Likely to be in a strong position to get approval from Taumata Arowai to operate chlorine-free.
The total cost of this scenario is estimated at **$178 million over 20 years**.	The total cost of this scenario is **$221 million over 20 years.**	The total cost of this scenario is **$284 Million over 20 years**.

These detailed costs scenarios are included as Appendix A.

Figure 20 shows the financial forecast for the three scenarios. Of note is the large up-front investment required in pipe replacement to get on top of NRW and move to chlorine-free operation.

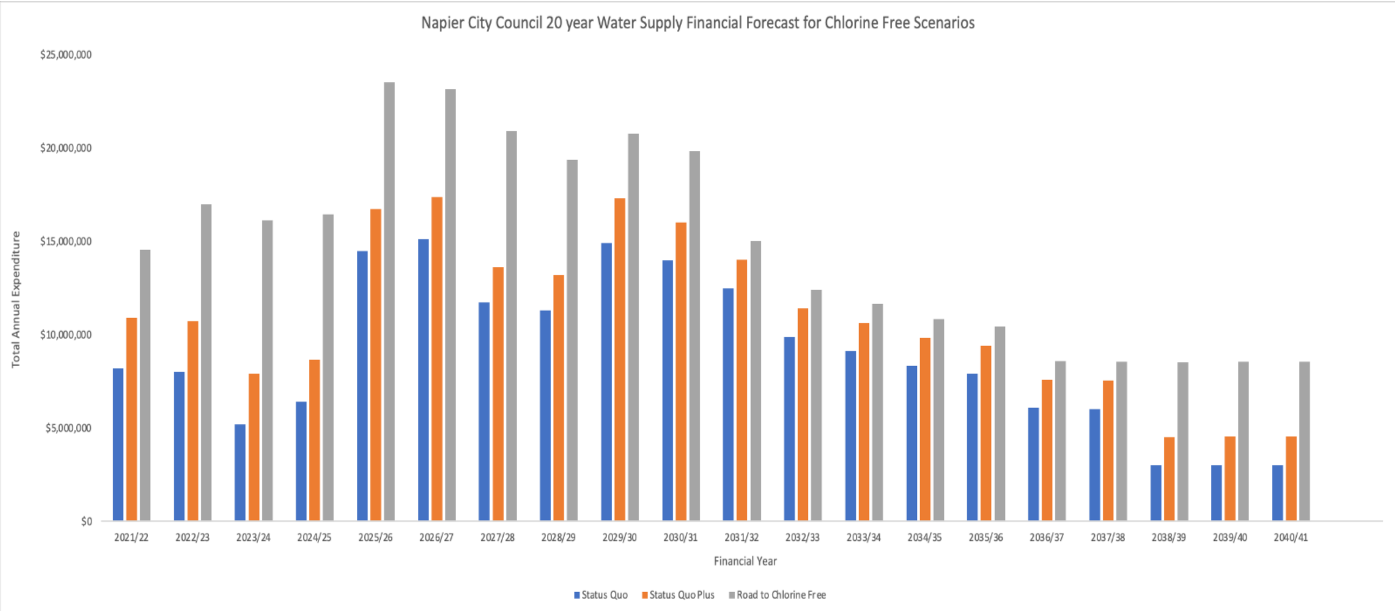

Figure 20: Twenty-year water supply financial forecast for SQ, SQ+ and CF

4.2 Affordability and Funding

Ultimately the decision to go chlorine-free will be made by Council in consultation with the Napier community. Unfortunately, there is no quick fix that would enable Napier to return to a chlorine-free water supply in the short term.

The current changing regulatory environment is only increasing the "height of the bar" for water suppliers to legally operate systems free of residual disinfectant. Under the Water Services Bill, the water regulator (Taumata Arowai) has been given broad powers in relation to drinking water supplies.

This does not preclude NCC moving to a chlorine-free supply, but this will be at a considerable financial cost to the Napier community. A programme of activities and broad cost estimates (+/-50%) has been prepared that outlines the investments required and a staged approach which involves an initial investment in moving from the SQ position to a SQ+ position. This involves a suite of projects aimed at getting improved understanding of how the water network is performing through enhanced monitoring of water quality, accelerated replacement of aging 'leaky' pipeline and reservoir assets, isolating the transmission and distribution networks – all aimed at reducing the public health risks associated with supplying safe and sustainable drinking water to Napier.

The estimated cost of moving from the **current SQ position to a SQ+ position** is estimated to be an additional **$43M over a twenty-year timeframe** and includes replacement of all cast iron, asbestos cement lined and galvanised iron pipe at an estimated cost of $22M over a nine-year timeframe.

A further set of improvement steps have been outlined that moves Napier from SQ+ to an enhanced CF position, where we are confident that Napier would be in a strong position to get approval from Taumata Arowai to operate chlorine-free. The additional improvements includes the use of SMART technologies to monitor and operate the system in real-time, universal metering and backflow prevention devices, and an ongoing commitment to renewal of aging assets (to reduce and maintain NRW levels close to 5% we have suggested an ongoing aggressive programme of pipe replacement of 3% of the pipe network per annum while operating in a CF environment). The total additional cost of moving from **SQ to CF ($284 million)** is estimated to be an additional **$106M over a twenty-year timeframe, an increase of 68% over the SQ position.**

To maintain CF status, we believe an ongoing commitment of $4.8M per annum to maintain the pipe replacement programme at 3% and $0.4M per annum for water quality testing and leak detection (total **$5.6M per annum**) will be required **to retain CF status**.

Council staff are currently developing the capital plans for the next ten-year period and due to overall Council capital planning costs, the timing of delivery of part of the status quo projects is being reviewed and is likely to be pushed out due to affordability issues. This is to allow for other key infrastructure such as wastewater and stormwater projects to be included. This is particularly important following the delivery of the master plans, the expected tightening of environmental requirements and following the extreme flooding event that occurred in November 2020.

Council staff originally put forward a ten-year programme of **$103 million** that would see the development of the bore fields, reservoir replacements, treatment plants, DMAs, and transmission mains. Due to the financial constraints following COVID-19 and to limit the impacts on rates rises, particularly at this time, a large proportion of these projects have been pushed out to the end of the ten-year programme. Key water quality improvements such as low manganese water and online monitoring have been prioritised as well as key Water Safety Plan projects.

This current plan has not been endorsed by Council as the prioritisation process was underway at the time of writing of this report.

The updated phasing of this work has the impact of pushing out the delivery of the building blocks of the chlorine-free network and again highlights the issues of affordability versus time to complete.

5.0 The Management Case (The RoadMap)

5.1 Staged Approach to a New Future

Whatever the "endgame" for NCC's decision on being able to move to a chlorine-free water system, there will be a programme of work and investment prioritisation decisions to be developed and implemented.

There are several priority actions which need to be implemented to inform the debate and to allow for an evidence-based decision-making process to be undertaken. For example, current NRW rates are estimated to be over 30% compared to chlorine-free systems which operate at <10%, and what the minimum NRW rate at which water quality is not compromised is not well understood.

What is known is the water quality that is required to go chlorine-free (based on the water quality delivered into and maintained in a chlorine-free water network). Therefore, the first action would be to implement a more rigorous water quality monitoring programme. This will be required to demonstrate to the water regulator that the NCC system water quality is well understood and how it compares to chlorine-free systems. Furthermore, as changes are made to the system, they can be benchmarked against the baseline water quality performance. It is important to set metrics on water quality that need to be achieved to go chlorine-free.

As presented earlier, the microbial quality standards and the actual performance of the Waternet system should be used as the standard required, although the actual parameters may vary (e.g. by using total microbial load rather than HPC as an indicator for microbial water quality). Other water quality parameters which require setting new standards for a chlorine-free system are iron and manganese. The current disinfection by-product performance demonstrates that the bore water has almost zero disinfection by-product formation potential, indicating the likely biostability of the water.

In terms of capital investment, there are five main areas requiring new or upgraded assets:

- Bore security
- Water treatment
- Bulk transmission
- Water storage
- Water network

The first stage of the journey to chlorine-free involves improving the current system to reduce the risk of water quality entering the system, which could compromise both public health and microbial stability. This would entail installation of an iron and manganese removal process followed by UV disinfection. Improvements to the current chlorine disinfection system to improve reliability and control should also be undertaken. Once this has been implemented, the impact on water network quality can be assessed through the ongoing water quality monitoring programme.

Stage 2 of the journey involves addressing the transmission and storage of treated water and involves dedicated transmission pipework to new modern service reservoirs, built to ensure ingress and external contamination are eliminated. Again, once this has been implemented the impact on water network quality in the network can be assessed through the ongoing water quality monitoring programme.

In parallel with Stages 1 and 2, NCC should carry out ongoing improvements to the water network to better understand its operation and performance and the extent of NRW. It is important not only to understand the quantity of the losses but also where the losses are occurring so that future investment in the replacement programme can be effectively targeted. Implementation of DMAs and Pressure Management Zones should also be part of a parallel programme of network improvements, as well as a programme of backflow prevention and universal water metering, in preparation for a chlorine-free decision. At this point, NCC will be able to fully understand water losses and water consumption as well as pressure transients and impacts on water quality. A training and development programme to raise the awareness of water hygiene practices and improvements to water mains replacement procedures should also be carried out.

The third stage to going chlorine-free is to begin addressing NRW and ingress into the water network. By this point, NCC will have collected a significant amount of data to understand the impact of the current levels on water quality deterioration in the system and make an informed decision on the extent of water mains replacement required to reach a chlorine-free decision point. Once a period of sustained water quality is achieved in line with the performance benchmarks, NCC and its water regulators will be able to have an informed discussion on the final stage - the gradual reduction of chlorine in the system to a point of being able to achieve a chlorine-free, approved WSP.

The staged approach is shown in Figure 21.

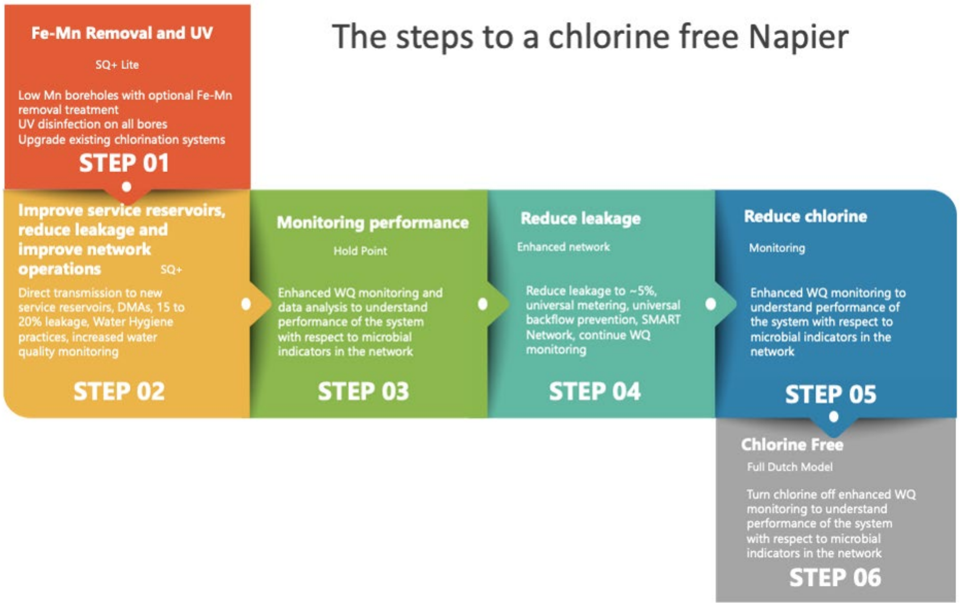

Figure 21: The staged approach to a chlorine-free Napier

5.2 Asset Management

Asset management is an approach water utilities can use to make sure that planned maintenance can be conducted and capital assets (pumps, motors, pipes, etc.) can be repaired, replaced, or upgraded on time and that there is enough money to pay for their replacement

For example, like many water utilities, NCC have used a wide variety of pipe materials (from old brittle cast iron to modern flexible polyethylene) over time for their buried assets, and these materials do not fail in the same way. The different materials used to manufacture pipe and distribution system components have different specifications and are manufactured through various techniques. These different specifications and techniques impact the likelihood of failure and the types of failures. Other issues also impact the possible longevity of the pipe, including its handling, installation, and use. The fact that a pipe may be able to last 100 years under certain conditions does not mean that the pipe can be reasonably expected to live that long. It comes down to specifics, and most particularly, data that relates to the pipe or other asset to be managed.

Asset management is the practice of managing infrastructure assets to minimise the total cost of owning and operating these assets while delivering the desired service levels. Many utilities use asset management to pursue and achieve sustainable infrastructure. A high-performing asset management program includes detailed asset inventories, operation and maintenance tasks, and long-range financial planning.

Each utility is responsible for making sure that its system stays in good working order, regardless of the age of its components or the availability of additional funds. Asset management programmes with good data—including asset attributes (e.g., age, condition, and criticality), life-cycle costing, proactive operations and maintenance, and capital replacement plans based on cost-benefit analyses—are an efficient method of meeting this challenge.

Asset management is centred on a framework of five core questions, which provide the foundation for many asset management best practices:

1. What is the current state of my assets?
2. What is my required "sustainable" level of service?
3. Which assets are critical to sustained performance?
4. What are my minimum life-cycle costs?
5. What is my best long-term funding strategy?

NCC undertook a maturity assessment of its AM practices and processes in February 2019. This assessment concluded that NCC AM maturity was core to achieving the levels of service and asset stewardship required.

5.3 Change Management Planning

5.3.1 Stakeholder Change Management and Communication

Stakeholder engagement and communication is an important tool for ensuring transparency, accountability and effectiveness of programmes and projects that include significant levels of public investment and / or significant opposition to the proposal. We recommend the development of a stakeholder engagement strategy for engaging interested and affected stakeholders. During the preparation of this report, we consulted with the following stakeholders:

- NCC Mayor, Council and Staff
- Ex-NCC Council 3-Waters Management
- Ministry of Health / DWAs
- HBDHB / Medical Officer of Health
- Taumata Arowai Establishment Unit (New Drinking Water Regulator)
- Department of Internal Affairs
- Hawkes Bay Regional Council
- HB Drinking Water Governance Joint Committee
- Guardians of the Aquifer and Other Chlorine-Free Advocates

The Stakeholder Engagement Plan (SEP) would outline in detail the commitment and actions of NCC with regards to engaging the stakeholders of the project. Timely and two-way information sharing, and communication will help to mobilize and maintain stakeholder support for the project and advance the overall project goals.

It is important to recognize that not all stakeholders will agree with the approach NCC chooses, and past experiences tell us that issues surrounding the addition of chemicals to drinking water can create highly emotional responses.

Key stakeholders consulted for this report are summarised in Table 26.

Table 26: Key stakeholders consulted for this report

Stakeholder	Key Issues / Role	Actions Required
Mayor & Councillors	The main audience of this review	Involve closely in process. Workshopped options short list on 9 July
Iwi	Meeting cultural requirements regarding treatment, particularly, the use of chemicals	Work through NCC Maori committee in conjunction with other 3 waters projects. Engage in discussion early in process
Council Staff	Driving the review process for Council	Update regularly
Ex-Council 3-Waters Management	Obtain historical context of 3 waters	Met with Bill McWatt and Derek Wood on 5/10/20 to inform of review and seek feedback
Ministry of Health / DWAs	Set framework for and approve water safety plans. To become part of Taumata Arowais remit.	Met with DWAs on 17/06/20. Keep informed Meet with MoH policy makers re application of WSP framework in a chlorine-free environment. Met with MOH on 17 June
HBDHB / Medical Officer of Health	Public health advice, boil water notices, wider public health aspects	Met with MoH on 17/06/20. Keep informed
Taumata Arowai Establishment Unit (New Drinking Water Regulator)	New water regulator	Engage in discussion and keep informed. Met with Taumata Arowai
Department of Internal Affairs	Recommend water industry structure to Minister of Local Government	Engage in discussion and keep informed
Hawkes Bay Regional Council	Environmental regulator, issue consents to take groundwater	Meet and keep informed of progress. Tentatively planned for 17 September
HB Drinking Water Governance Joint Committee	Committee has governance and oversight on regional drinking water matters	Keep informed
Guardians of the Aquifer and other chlorine-free advocates	Lobby group advocating for healthy, safe drinking water with no chlorine added	Meet and listen to issues, and address in report. Involve in the report review process
Pro-Chlorine Lobby Groups	N / A	
Industry Groups		Monitor
Supply Chain (suppliers, contractors)	Bayliss Brothers	Met on 5/10 and discussed this project
Local News Media		Monitor
Hawkes Bay Councils 3 Waters Review	Investigating options for new service delivery arrangements for three waters	Engage in discussion and keep informed
Residents of Napier	The end customer	Engage though Annual Plan LTP consultation process

A wide-ranging programme of customer consultation initiatives aimed at inviting all residents of the city to engage in the decision-making process to define the future of Napier’s water supply system would be ideal.

5.3.2 Internal Workforce Upskilling and Change Management

To move to Status Quo plus or chlorine-free environments, it is important to ensure that adequate staffing and training exists to over-see the development of and support the improved systems. These will include:

- Ongoing training on safe and hygienic work practices in a chlorine-free water network
- The operation, maintenance, and management of the new water treatment plants
- The preparation and implementation of Water Safety Plans
- Programme management and co-ordination of the CF program
- Change management and public outreach
- Enhancement of asset management of the water network including business process improvement, data collection, management of assets, their condition, and performance, and oversight of the implementation.

Depending on the level of sophistication of the asset management programme, we recommend the following additional staff are included in the budget to support the programme:

Treatment Plant Operators (3)

Asset Management Staff (5)

6.0 Summary

The current stance of the newly established drinking water regulator in New Zealand (Taumata Arowai) is that all water supplies must have a residual disinfectant at the customer's tap. This is to aid in the protection of public health from minor ingress into the water network through pipe leaks or backflow events, which have been shown to be associated with waterborne illness. Water supply entities can apply for an exemption to move to a chlorine-free water supply system where there is evidence to demonstrate that public health will not be compromised. On this basis, Pattle Delamore Partners Ltd (PDP) and their international partners have developed a pathway for NCC to move towards a chlorine-free future through the exemption process outlined in the Water Services Bill.

The steps outlined in this report show that there is a common approach to both achieving the status quo plus chlorine-based outcome and a chlorine-free future, and as such is seen as taking a strategic approach to investment.

The pathway to achieving a chlorine-free exemption from Taumata Arowai is clear. The investment required is significant, the impact on customer bills substantial, and affordability may be an issue. Furthermore, the emerging structural reform of the New Zealand water industry puts at risk some of the long-term decisions that need to be made to transition to a chlorine-free system. The pathway we have developed takes a staged and strategic approach that operates within the financial constraints of NCC and a planned investment strategy in assets which will serve the citizens of Napier irrespective of future ownership models of New Zealand water utilities.

The estimated cost of moving from the **current planned SQ position ($178 million) to a SQ+ position ($221 million)** is estimated to be an additional **$43M over a twenty-year timeframe, an**

increase of 24% over the SQ position. SQ+ includes replacement of all cast iron, asbestos cement, and galvanised iron pipe at an estimated cost of $22M over a nine-year timeframe.

To move Napier from SQ+ to an enhanced CF position that is likely to achieve a chlorine-free exemption would require the use of SMART technologies to monitor and operate the system in real-time, universal metering and backflow prevention devices, and an ongoing commitment to renewal of aging assets. The total additional cost of moving from **SQ to CF ($284 million)** is estimated to be an additional **$106M over a twenty-year timeframe, an increase of 66% over the SQ position.**

To **maintain CF status**, we believe an ongoing commitment of $4.8M per annum to maintain the pipe replacement programme at 3% and $0.4M per annum for water quality testing (total **$5.6M per annum**) will be required.

Ultimately the decision to go chlorine-free will be made by the elected members of Council in consultation with the Napier community. Unfortunately, there is no quick fix that would enable Napier to return to chlorine-free water supply in the short term whilst maintaining its obligations under the DWSNZ.

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Appendix A: Financial Forecasts

STATUS QUO – investment as per the NCC Long Term Plan (and WS Network Master Plan) which is cash constrained with slow incremental improvement in renewals . Maintain leakage at 30%. Maintain AM practices at the "core" level. New staff (3) limited to operation of new bore fields and treatment plant. Acoustic leak detection of entire network on a 3 year cycle, as per current, establish DMAs, universal metering, backflow prevention, upgrade scad,.However this level of investment is unlikely to ever achieve the level of network integrity required to go chlorine free as pipeline replacement rates are initially too low to get on top of deteriotration.

STATUS QUO

Item Number	Capital Project	Total Cost FY 2021/2022 - 2039/2040	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	Notes
1	Air vents on Reservoirs	200,000	40,000	40,000	40,000	40,000	40,000	-	-	-	-	-											Source NCC LTP
2	Booster Pump Station switch/controls upgrades	1,080,000	25,000	200,000	200,000	250,000	15,000	15,000	15,000	15,000	15,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	Source NCC LTP
3	Connect Taradales Reservoir to New Enfield Reservoir	2,700,000	-	-	-	-	-	-	-	-	-	-	200,000	1,100,000	1,400,000	-	-	-	-	-	-	-	Source NCC LTP
4	Connect Treatment Plant 1 supply to Taradale Reservoirs	2,700,000	-	-	-	-	-	-	-	-	-	-	-	-	200,000	1,100,000	1,400,000	-	-	-	-	-	Source NCC LTP
5	Delineate Taradale / Enfield Systems	100,000	-	-	-	-	-	-	-	-	-	-	100,000	-	-	-	-	-	-	-	-	-	Source NCC LTP
6	Development of Borefield 1	5,100,000	500,000	1,500,000	-	-	-	-	100,000	1,500,000	1,500,000	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
7	Development of Borefield 2	5,500,000	-	-	-	-	-	-	500,000	1,000,000	2,000,000	2,000,000	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
8	Development of District Water Supply Monitoring Areas (DMA & Quality)	3,600,000	-	-	-	-	-	-	-	720,000	720,000	720,000	720,000	720,000	-	-	-	-	-	-	-	-	Source NCC LTP
9	Emergency Water Tanks in case of contamination.	100,000	-	-	-	-	-	-	100,000	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
10	Enable growth	3,250,000		250,000	250,000	250,000	250,000	250,000	500,000	500,000	500,000	500,000	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
11	Enable Growth - Te Awa Structure Plan	1,997,130	773,599	130,205	65,102	514,112	257,056	257,056	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
12	Enable Growth - Water extension Bay View	1,200,000	-	-	-	-	-	-	-	-	-	-	100,000	500,000	500,000	100,000	-	-	-	-	-	-	Source NCC LTP
13	Enable Growth - Water extension Meannee	1,900,000	-	-	-	-	-	-	-	-	-	-	200,000	600,000	600,000	500,000	-	-	-	-	-	-	Source NCC LTP
14	Enfield Reservoir Replacement	18,000,000	400,000	400,000	400,000	800,000	8,000,000	8,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
15	Ensure FW2 Fire Flow Availability	2,000,000		1,000,000	1,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
16	Ground Water Modelling	325,000	50,000	50,000	50,000	-	-	35,000	-	-	35,000	-	-	35,000	-	-	35,000	-	-	35,000	-	-	Source NCC LTP
17	Minor Reticulation Asset Replacements	1,000,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	Source NCC LTP
18	Mission Reservoir - New	9,000,000	500,000	750,000	750,000	500,000	500,000	1,500,000	4,500,000	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
19	NCC New Water Take Consent	800,000	400,000	400,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
20	New Enfield - Rising and Falling Trunk Mains	10,000,000	500,000	500,000	500,000	2,000,000	3,500,000	3,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
21	New Reticulation Rider Mains	2,450,000	-	-	-	-	-	-	-	-	350,000	350,000	350,000	350,000	350,000	350,000	350,000	-	-	-	-	-	Source NCC LTP
22	New Taradale - Rising And Falling Trunk Mains	15,663,000	-	-	-	-	463,000	600,000	3,000,000	3,500,000	2,000,000	1,500,000	4,600,000	-	-	-	-	-	-	-	-	-	Source NCC LTP
23	Rationalise Thompson Reservoir pipework	800,000	-	-	-	-	-	-	100,000	700,000	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
24	Reduce the Manganese Load	2,650,000	2,650,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
25	Reservoir & Reservoir Booster controls upgrades	700,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	100,000	-	-	-	-	100,000	-	-	-	-	Source NCC LTP
26	Reservoir Inlets and Outlets improvements	1,200,000	-	-	-	-	-	-	-	-	200,000	1,000,000	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
27	Reservoir Roof Lining	900,000	-	-	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	-	-	-	-	100,000	-	-	-	-	-	Source NCC LTP
28	Reservoir Seismic Valves	800,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000		-	-	-	-	-	-	-	-	-	Source NCC LTP
29	Reticulation Water Quality Monitoring	1,000,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	Source NCC LTP
30	SCADA - Server Renewals	200,000	50,000		-	-	-	-	50,000	-	-	-	-	50,000	-	-	-	-	50,000	-	-	-	Source NCC LTP
31	Survey and Install back flow preventers on Industrial and High Risk Sites	300,000	100,000	100,000	100,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
32	Taradale Reservoir 2 - Internal Lining	500,000	-	-	-	-	-	-	-	-	-	-	50,000	450,000	-	-	-	-	-	-	-	-	Source NCC LTP
33	Te Awa Watermain Extension - Philips-Awatoto Rd	2,000,000	1,000,000	1,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
34	Thompson Reservoir 3 Roof Replace and Upgrade	470,000	-	400,000	70,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
35	Thompson Reservoir Control Upgrade	150,000	-	150,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
36	Thompson Reservoir Main Upgrade	1,100,000	-	-	500,000	600,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
37	Water Air Valves Survey and Replace	300,000	100,000	100,000	100,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
38	Water Bore and Booster pump replacements	420,000	65,000	15,000	15,000	15,000	15,000	15,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	Source NCC LTP
39	Water Meter Installation	21,400,000	-	-	-	-	-	-			200,000	200,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	-	-	-	Source NCC LTP
40	Water Meters Survey and Replace	100,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	Source NCC LTP
41	Water Pipes Renewals	21,950,000	300,000	300,000	300,000	750,000	750,000	750,000	1,000,000	1,000,000	500,000	1,000,000	1,530,000	1,530,000	1,530,000	1,530,000	1,530,000	1,530,000	1,530,000	1,530,000	1,530,000	1,530,000	Source NCC LTP
42	Water Supply Building Renewals	600,000	100,000	100,000	100,000	-	-	-	-	-	-	-	100,000	100,000	100,000	-	-	-	-	-	-	-	Source NCC LTP
43	Water Supply Network Hydraulic Model	150,000	50,000	50,000	50,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
44	Water Take Point Site - Contractor Water Take	250,000	-	-	-	-	-	-	-	-	-	-	-	-	-	250,000	-	-	-	-	-	-	Source NCC LTP
45	Water Treatment Plant 1	6,000,000	-	-	-	-	-	-	500,000	500,000	5,000,000		-	-	-	-	-	-	-	-	-	-	Source NCC LTP
46	Water Treatment Plant 2	6,000,000	-	-	-	-	-	-	-	500,000	500,000	5,000,000	-	-	-	-	-	-	-	-	-	-	Source NCC LTP
47	Water Treatment Plant Renewals	450,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	-	-	-	50,000	50,000	-	-	-	50,000	50,000	Source NCC LTP
	TOTAL	**159,055,130**	**7,863,599**	**7,695,205**	**4,850,102**	**6,079,112**	**14,150,056**	**14,782,056**	**10,745,000**	**10,315,000**	**13,900,000**	**12,680,000**	**11,205,000**	**8,590,000**	**7,835,000**	**7,035,000**	**6,620,000**	**4,785,000**	**4,735,000**	**1,720,000**	**1,735,000**	**1,735,000**	
	CHLORINE FREE COMPONENT	105,670,000	4,660,000	3,635,000	1,855,000	2,685,000	9,050,000	9,010,000	2,615,000	6,185,000	10,885,000	10,200,000	5,755,000	6,505,000	6,235,000	5,785,000	6,185,000	4,735,000	4,685,000	1,635,000	1,685,000	1,685,000	

Opex Item Number	Additional Opex Items	Total Cost FY 2021/2022 - 2039/2040	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	
1	Treatment Plant Operating Costs	7,500,000							300,000	300,000	300,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	5% of capital value
2	Additional O&M Staff for Treatment plant (3 FTEs)	5,040,000							360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	3 FTEs assuming automated plants (salary x1.2)
3	Leak Detection at current levels	1,000,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	Current spend of $50k per annum
4	Water Quality Monitoring and Testing	5,600,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	Maintain current spend of $280K per annum
	TOTAL ADDITIONAL OPEX	**19,140,000**	**330,000**	**330,000**	**330,000**	**330,000**	**330,000**	**330,000**	**990,000**	**990,000**	**990,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	**1,290,000**	
	TOTAL EXPENDITURE	**178,195,130**	**8,193,599**	**8,025,205**	**5,180,102**	**6,409,112**	**14,480,056**	**15,112,056**	**11,735,000**	**11,305,000**	**14,890,000**	**13,970,000**	**12,495,000**	**9,880,000**	**9,125,000**	**8,325,000**	**7,910,000**	**6,075,000**	**6,025,000**	**3,010,000**	**3,025,000**	**3,025,000**	

SQ + lite Status quo plus at reduced 1.5% pipe replacement rate

SCENARIO X – investment as per the NCC long-term plan (and WS Network Master Plan) , plus ongoing pipe replement investment at 1.5% of network per annum. Lift AM practices to "intermediate" level by 2030. New staff (3 ops and 3 AM). **Reduce leakage to 25% by 2030 and 20% by 2040** through mains replacement, aggressive leak detection, formation of DMAs, enhanced backflow prevention. Unlikely to get regulator approval to go to chlorine free but deterioration of network not getting worse.

Capex Item Number	Capital Project	Total Cost FY 2021/22 - 2040/41	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	
1-47	**STATUS QUO CAPITAL PROJECTS**	159,055,130	7,863,599	7,695,205	4,850,102	6,079,112	14,150,056	14,782,056	10,745,000	10,315,000	13,900,000	12,680,000	11,205,000	8,590,000	7,835,000	7,035,000	6,620,000	4,785,000	4,735,000	1,720,000	1,735,000	1,735,000	
48a	Additional cost associated with program with maximum pipe replacement rate of 1.5% pa	12,035,000	1,665,000	1,665,000	1,665,000	1,215,000	1,215,000	1,215,000	965,000	965,000	1,465,000	965,000	435,000	435,000	435,000	435,000	435,000	435,000	435,000	435,000	435,000	435,000	
																							CI & GI =17% of pipe ntwk with total network rep vlue of $131M*0.17 Source isc 2013AM Plan), replace by 2030
	TOTAL CAPEX	**171,090,130**	9,528,599	9,360,205	6,515,102	7,294,112	15,365,056	15,997,056	11,710,000	11,280,000	15,365,000	13,645,000	11,640,000	9,025,000	8,270,000	7,470,000	7,055,000	5,220,000	5,170,000	2,155,000	2,170,000	2,170,000	

Opex Item Number	Additional opex items	Total Cost FY 2021/22 - 2040/41	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	
	STATUS QUO OPEX ACTIVITIES	17,460,000	330,000	330,000	330,000	330,000	330,000	330,000	870,000	870,000	870,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	
	Backflow prevention audits and test high and medium risk connections	600,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	Ongoing tgesting
	Additional leak detection	1,000,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	Thsi would result in total spend of 100K p.a and would cover 60% of the network pa
	Progamme Management Staff (1 FTE)	3,600,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	$150K *1.2
	Asset Management Staff (3 additional FTEs)	7,920,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	3*$110k*1.2
	Additional water quality testing (Increase 280K by 50%)	2,800,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	Total spend is $420k pa
	TOTAL OPEX	**33,380,000**	1,126,000	1,126,000	1,126,000	1,126,000	1,126,000	1,126,000	1,666,000	1,666,000	1,666,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	
	TOTEX	204,470,130	10,654,599	10,486,205	7,641,102	8,420,112	16,491,056	17,123,056	13,376,000	12,946,000	17,031,000	15,611,000	13,606,000	10,991,000	10,236,000	9,436,000	9,021,000	7,186,000	7,136,000	4,121,000	4,136,000	4,136,000	

STATUS QUO PLUS

STATUS QUO PLUS – investment as per the NCC long-term plan (and WS Network Master Plan) , plus aggressively replace cast iron pipe by 2030, then ongoing investment at 2% of network per annum. Lift AM practices to "intermediate" level by 2030. New staff (3 ops and 3 AM). **Reduce leakage to 22% by 2030 and 18% by 2040** through cast iron mains replacement, aggressive leak detection, formation of DMAs, enhanced backflow prevention. Unlikely to get regulator approval to go to chlorine free but deterioration of network under control.

Capex Item Number	Capital Project	Total Cost FY 2021/22 - 2040/41	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	
1-47	**STATUS QUO CAPITAL PROJECTS**	159,055,130	7,863,599	7,695,205	4,850,102	6,079,112	14,150,056	14,782,056	10,745,000	10,315,000	13,900,000	12,680,000	11,205,000	8,590,000	7,835,000	7,035,000	6,620,000	4,785,000	4,735,000	1,720,000	1,735,000	1,735,000	
48	Additional cost associated with accelerated removal of all cast and galv iron by 2030	16,620,000	2,174,444	2,174,444	2,174,444	1,724,444	1,724,444	1,724,444	1,474,444	1,474,444	1,974,444												
49	Additional cost of ongoing pipe replacement 2% per annum 2031-2040	12,520,000										1,620,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	CI & GI =17% of pipe ntwk with total network rep vlue of $131M*0.17 Source isc 2013AM Plan), replace by 2030
	TOTAL CAPEX	**188,195,130**	10,038,043	9,869,649	7,024,547	7,803,556	15,874,500	16,506,500	12,219,444	11,789,444	15,874,444	14,300,000	12,295,000	9,680,000	8,925,000	8,125,000	7,710,000	5,875,000	5,825,000	2,810,000	2,825,000	2,825,000	

Opex Item Number	Additional opex items	Total Cost FY 2021/22 - 2040/41	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	
	STATUS QUO OPEX ACTIVITIES	17,460,000	330,000	330,000	330,000	330,000	330,000	330,000	870,000	870,000	870,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	1,170,000	
	Backflow prevention audits and test high and medium risk connections	600,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	Ongoing tgesting
	Additional leak detection	1,000,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	Thsi would result in total spend of 100K p.a and would cover 60% of the network pa
	Progamme Management Staff (1 FTE)	3,600,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	$150K *1.2
	Asset Management Staff (3 additional FTEs)	7,920,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	396,000	3*$110k*1.2
	Additional water quality testing (Increase 280K by 50%)	2,800,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	Total spend is $420k pa
	TOTAL OPEX	**33,380,000**	1,126,000	1,126,000	1,126,000	1,126,000	1,126,000	1,126,000	1,666,000	1,666,000	1,666,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	
	TOTEX	221,575,130	11,164,043	10,995,649	8,150,547	8,929,556	17,000,500	17,632,500	13,885,444	13,455,444	17,540,444	16,266,000	14,261,000	11,646,000	10,891,000	10,091,000	9,676,000	7,841,000	7,791,000	4,776,000	4,791,000	4,791,000	

ROAD TO CHLORINE FREE

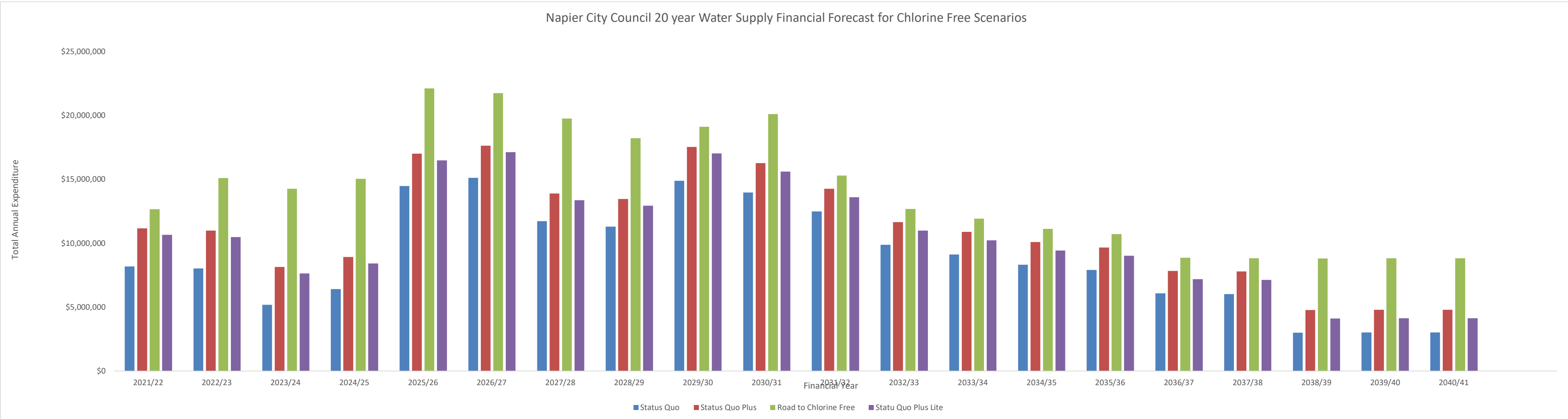
ROAD TO CHLORINE FREE -Total investment as per the NCC long-term plan (and WS Network Master Plan) but accelerated timing, plus aggressively replace cast iron pipe by 2030, then ongoing aggressive investment at 3.5% of network per annum. Lift AM practices to "advanced" (ISO 55000) by 2030 and staff accordingly (3 ops and 4 AM) **Reduces leakage to 15% by 2030 and 10% by 2040** through smart water network/automation, leak detection, DMAs, universal metering and backflow prevention.

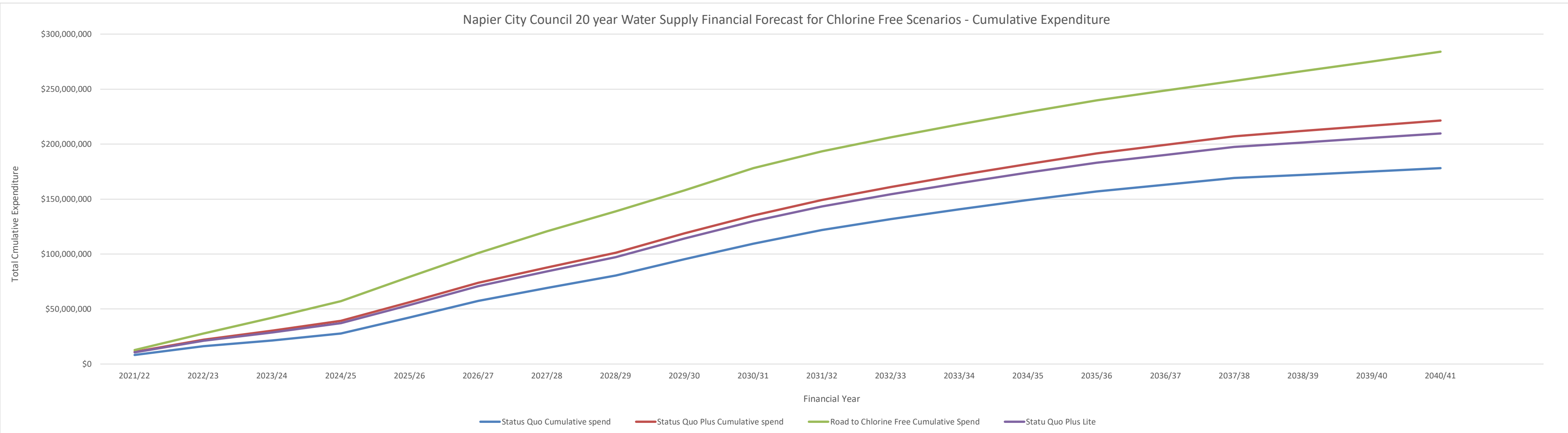
Capex Item Number	Capital Project	Total Cost FY 2021/22 - 2040/41	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	
1-47	**STATUS QUO CAPITAL PROJECTS**	159,055,130	7,863,599	7,695,205	4,850,102	6,079,112	14,150,056	14,782,056	10,745,000	10,315,000	13,900,000	12,680,000	11,205,000	8,590,000	7,835,000	7,035,000	6,620,000	4,785,000	4,735,000	1,720,000	1,735,000	1,735,000	Status quo total bought forward
48-	**STATUS QUO PLUS CAPITAL PROJECTS**	29,140,000	2,174,444	2,174,444	2,174,444	1,724,444	1,724,444	1,724,444	1,474,444	1,474,444	1,974,444	1,620,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	1,090,000	status quo plus total bought forward
	Additional cost (over abnd above SQ+) of ongoing pipe replament 3.5% per annum 2031-2040	21,615,000										1,965,000	1,965,000	1,965,000	1,965,000	1,965,000	1,965,000	1,965,000	1,965,000	1,965,000	1,965,000	1,965,000	Additional cost
	SMART NETWORK Pressure smoothing, pump control, leakage management, real-time quality monitoring	6,095,000							3,095,000	3,000,000													$265 per connection x 23000 connections
	Accelerate Water Meter/Backflow checkvalves Installation	-	400,000	3,000,000	5,000,000	5,000,000	4,000,000	3,000,000	1,000,000	-	- 200,000	- 200,000	- 3,000,000	- 3,000,000	- 3,000,000	- 3,000,000	- 3,000,000	- 3,000,000	- 3,000,000	-	-	-	adjusting timing - costs from NCC LTP
	TOTAL CAPEX	215,905,130	10,438,043	12,869,649	12,024,547	12,803,556	19,874,500	19,506,500	16,314,444	14,789,444	15,674,444	16,065,000	11,260,000	8,645,000	7,890,000	7,090,000	6,675,000	4,840,000	4,790,000	4,775,000	4,790,000	4,790,000	

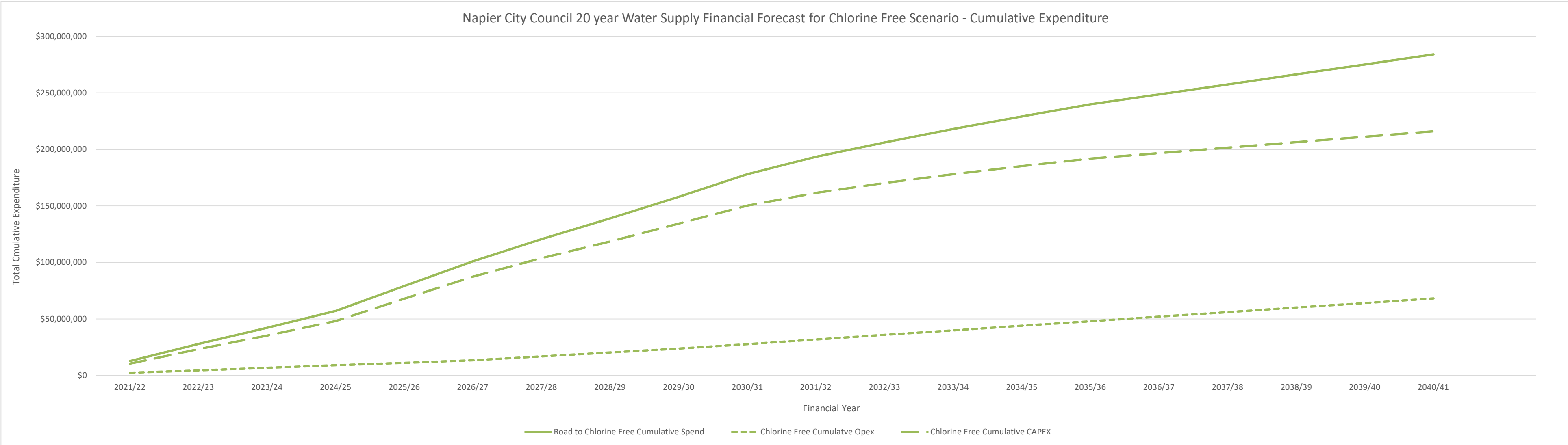
Opex Item Number	Additional opex items	Total Cost FY 2021/22 - 2040/41	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	
	STATUS QUO OPEX ACTIVITIES	19,140,000	330,000	330,000	330,000	330,000	330,000	330,000	990,000	990,000	990,000	1,290,000	1,290,000	1,290,000	1,290,000	1,290,000	1,290,000	1,290,000	1,290,000	1,290,000	1,290,000	1,290,000	
	STAUS QUO PLUS OPEX ACTIVITIES	33,380,000	1,126,000	1,126,000	1,126,000	1,126,000	1,126,000	1,126,000	1,666,000	1,666,000	1,666,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	1,966,000	
	Additional leak detection	1,000,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	
	Progamme Management Staff (2 FTEs total), 1 addtional	3,600,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	
	Asset Management Staff (4 FTEs total, 1 additional)	7,200,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000	
	Enhanced Hygiene Practices - ongoing training	1,000,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	$50K per anum
	Additional Water quality monitoring (Now $560k per annum)	2,800,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	140,000	
	TOTAL OPEX	68,120,000	2,236,000	2,236,000	2,236,000	2,236,000	2,236,000	2,236,000	3,436,000	3,436,000	3,436,000	4,036,000	4,036,000	4,036,000	4,036,000	4,036,000	4,036,000	4,036,000	4,036,000	4,036,000	4,036,000	4,036,000	
	TOTAL EXPENDITURE	284,025,130	12,674,043	15,105,649	14,260,547	15,039,556	22,110,500	21,742,500	19,750,444	18,225,444	19,110,444	20,101,000	15,296,000	12,681,000	11,926,000	11,126,000	10,711,000	8,876,000	8,826,000	8,811,000	8,826,000	8,826,000	

FY	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31
Status Quo	8193599	8025205	5180102	6409112	14480056	15112056	11735000	11305000	14890000	13970000
Status Quo Cumulative spend	8193599	16218803	21398906	27808018	42288074	57400130	69135130	80440130	95330130	109300130
Status Quo Plus	11164043	10995649	8150547	8929556	17000500	17632500	13885444	13455444	17540444	16266000
Status Quo Plus Cumulative spend	11164043	22159692	30310239	39239796	56240296	73872796	87758241	101213685	118754130	135020130
Status Quo + Capex	10038043	9869649	7024547	7803556	15874500	16506500	12219444	11789444	15874444	14300000
Status Quo + Cumulative Capex	10038043	19907692	26932239	34735796	50610296	67116796	79336241	91125685	107000130	121300130
Status Quo + Opex	1126000	1126000	1126000	1126000	1126000	1126000	1666000	1666000	1666000	1966000
Status Quo Plus Cumlative Opex	1126000	2252000	3378000	4504000	5630000	6756000	8422000	10088000	11754000	13720000
Road to Chlorine Free	12674043	15105649	14260547	15039556	22110500	21742500	19750444	18225444	19110444	20101000
Road to Chlorine Free Cumulative Spend	12674043	27779692	42040239	57079796	79190296	100932796	120683241	138908685	158019130	178120130
Chlorine Free CAPEX	10438043	12869649	12024547	12803556	19874500	19506500	16314444	14789444	15674444	16065000
Chlorine Free Cumulative CAPEX	10438043	23307692	35332239	48135796	68010296	87516796	103831241	118620685	134295130	150360130
Chlorine Free OPEX	2236000	2236000	2236000	2236000	2236000	2236000	3436000	3436000	3436000	4036000
Chlorine Free Cumulatve Opex	2236000	4472000	6708000	8944000	11180000	13416000	16852000	20288000	23724000	27760000
Statu Quo Plus Lite	10654599	10486205	7641102	8420112	16491056	17123056	13376000	12946000	17031000	15611000
Straus Quo +Lite Cumulative Spend	10654599	21140803	28781906	37202018	53693074	70816130	84192130	97138130	114169130	129780130

FY	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	TOTAL	
Status Quo	12495000	9880000	9125000	8325000	7910000	6075000	6025000	3010000	3025000	3025000	178195130	Status Quo
Status Quo Cumulative spend	121795130	131675130	140800130	149125130	157035130	163110130	169135130	172145130	175170130	178195130		
Status Quo Plus	14261000	11646000	10891000	10091000	9676000	7841000	7791000	4776000	4791000	4791000	221575130	Status Quo Plus
Status Quo Plus Cumulative spend	149281130	160927130	171818130	181909130	191585130	199426130	207217130	211993130	216784130	221575130		
Status Quo + Capex	12295000	9680000	8925000	8125000	7710000	5875000	5825000	2810000	2825000	2825000		
Status Quo + Cumulative Capex	133595130	143275130	152200130	160325130	168035130	173910130	179735130	182545130	185370130	188195130		
Status Quo + Opex	1966000	1966000	1966000	1966000	1966000	1966000	1966000	1966000	1966000	1966000		
Status Quo Plus Cumlative Opex	15686000	17652000	19618000	21584000	23550000	25516000	27482000	29448000	31414000	33380000	221575130	
Road to Chlorine Free	15296000	12681000	11926000	11126000	10711000	8876000	8826000	8811000	8826000	8826000	284025130	Road to Chlorine Free
Road to Chlorine Free Cumulative Spend	193416130	206097130	218023130	229149130	239860130	248736130	257562130	266373130	275199130	284025130		
Chlorine Free CAPEX	11260000	8645000	7890000	7090000	6675000	4840000	4790000	4775000	4790000	4790000		
Chlorine Free Cumulative CAPEX	161620130	170265130	178155130	185245130	191920130	196760130	201550130	206325130	211115130	215905130		
Chlorine Free OPEX	4036000	4036000	4036000	4036000	4036000	4036000	4036000	4036000	4036000	4036000		
Chlorine Free Cumulatve Opex	31796000	35832000	39868000	43904000	47940000	51976000	56012000	60048000	64084000	68120000	284025130	
Statu Quo Plus Lite	13606000	10991000	10236000	9436000	9021000	7186000	7136000	4121000	4136000	4136000	209785130	Scenario x
Straus Quo +Lite Cumulative Spend	143386130	154377130	164613130	174049130	183070130	190256130	197392130	201513130	205649130	209785130		







Napier City Council 20 year Water Supply Financial Forecast for Chlorine Free Scenario - Cumulative Expenditure
$300,000,000
$250,000,000
$200,000,000
$150,000,000
$100,000,000
$50,000,000
$0
Total Cmulative Expenditure
2021/22
2022/23
2023/24
2024/25
2025/26
2026/27
2027/28
2028/29
2029/30
2030/31
2031/32
2032/33
2033/34
2034/35
2035/36
2036/37
2037/38
2038/39
2039/40
2040/41
Financial Year
Road to Chlorine Free Cumulative Spend
Chlorine Free Cumulatve Opex
Chlorine Free Cumulative CAPEX

Appendix B: Groundwater Source Information Review and Microbiological Testing Information

1.1 Groundwater Sources

1.1.1 Bore Details

Napier's water is supplied entirely from groundwater and is currently pumped directly from seven operational bores. A map showing the locations of the bores that supply the city is provided below (Figure 22) and details of the bores are included in Table 27 together with disused supply bores with relevant information. The more recently drilled Meeanee bore, located on Sandy Road, is shown on the map but the bore is incomplete. An additional bore in Meeanee (Meeanee School bore) is also shown on the map and listed in Table 27. However, the Meeanee School bore is not part of the NCC city supply network. It is shown here because water quality results were collected from that bore as part of investigations by NCC to identify a suitable location for a new bore, as part of NCC's plans to consolidate pumping to two bore fields, rather than the current seven bores which are spread across different areas. All the bores in Table 27 are located within the confined Heretaunga Plains Aquifer (as indicated by the green dashed line on Figure 22).

Table 27: Napier city bore supplies and other bores referred to in report including disused bores

NCC Source Name[1]	HBRC Bore Number	DWO Code		Depth (m)	Screened Interval (m)	Yield[2] (L/s)
A1 Bore (current supply bore)	5913	G02037		90	74-76 and 78-84	113
A2 Bore (not yet commissioned)	16352	-		113.25	110.9 - 120.7	-
C1 Bore (current supply bore)	4671	G00067		88.5	72-76 and 77-80.5	73 (81)
Meeanee bore (not yet commissioned)	-	-		120 (proposed)	-	-
T1 Bore (disused)	472	G00061		89.92	35.7 - 39.51	50
T2 Bore (current supply bore)	480	G00062		-	37.2 - 43.3	96
T3 Bore (current supply bore)	872	G00065		42.85	36.9 - 42.9	60 (116)
T4 Bore (disused)	1389	G00063		41	32.5 - 38.5	65
T5 Bore (current supply bore)	1998	G00064		51.2	39.9 - 49.4	115 (81.6)

T6 Bore (current supply bore)	4144	G01151		74.5	60 - 72	127
T7 Bore (current supply bore)	4595	G01395		38.5	31 - 37	129
Tannery Bore (decommissioned)	2390	-		64.3	55.7 - 59.7	-
Meeanee School bore (not part of NCC supply)	1443	-		62	61.8-62	-

Notes:

1. *The A2 bore is not yet commissioned but is shown here due to available water quality data. Bores highlighted in grey are disused or private bores, but again, water quality data is available and is discussed later in this report. Note that bore P1 is also decommissioned, but no water quality data was available for that bore for review.*
2. *From GHD (2018) report. These represent the consented take rates, and at this stage we have assumed that this is representative of the yield from the bore in the absence of further information. However, the actual yields may be higher, as indicated by the bore log for C1. Yields reported on bore logs, where available, are provided in brackets.*

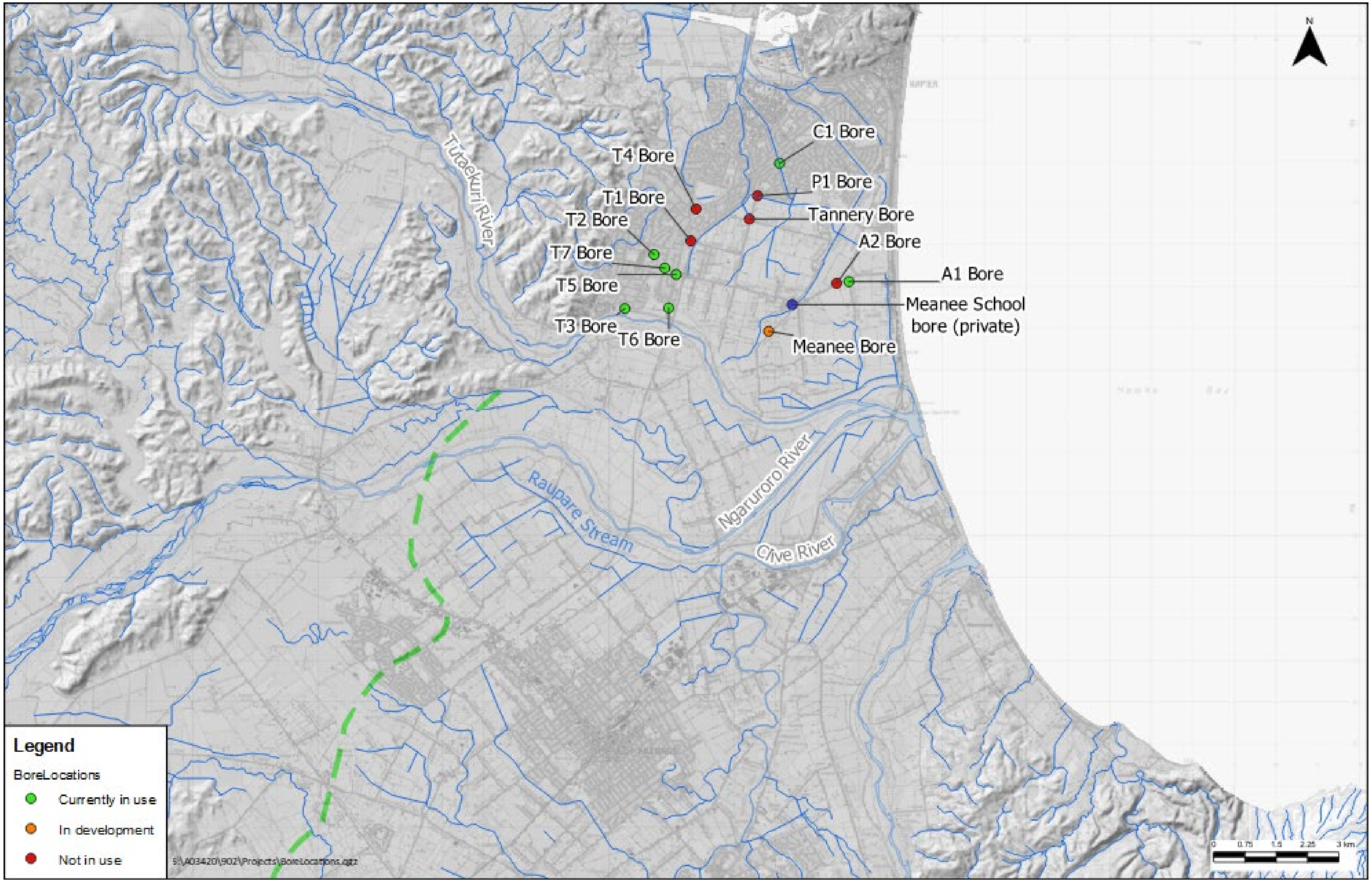


Figure 22: Napier city water supply bore locations and other bores referred to in report including disused bores

1.1.2 Bore Status and Bore Head Security

Groundwater community drinking water supply sources are required to regularly undergo bore head inspections as part of compliance checks under the DWSNZ. The bore head security as assessed by GHD (2018) is shown in Table 28. All the bores have been classed as fully compliant with Criterion 1 and 2 of the DWSNZ (2005, updated 2018), which indicates that the bore heads are generally sealed from surface contamination. All the bores utilise submersible pumps, however, they are generally operated to maintain above ground water pressures in each bore or water pressures are maintained above the base of the conductor casing (for example bore T3). Local pumping and drawdown effects around the Napier supply bores are important for NCC to consider in their management of risks.

Table 28: Bore head security status (after GHD, 2018)

NCC Bore Number	Security status	Issues noted (GHD, 2018)
T2	Compliant with Criterion 1 and 2	
T3	Compliant with Criterion 1 and 2	Below ground wellhead (now sealed) and water levels in the bore are occasionally below ground level
T5	Compliant with Criterion 1 and 2	
T6	Compliant with Criterion 1 and 2	
T7	Compliant with Criterion 1 and 2	Below ground wellhead (now sealed)
A1	Compliant with Criterion 1 and 2	
C1	Compliant with Criterion 1 and 2	Below ground wellhead (now sealed). Pressure test suggested possible casing leak (but report noted water pressure in bore should prevent shallow water ingress).

1.1.3 Hydrogeological Setting

Geology

Figure 23 Figure 23 shows a geological map of the Heretaunga Plains (Lee, 2011), including the line of major rivers and the location of the NCC bores. Generally, the Plains represent a fault controlled sedimentary basin which has been infilled with river and marine sediments and is surrounded by topographically higher limestone and mudstone sediments.

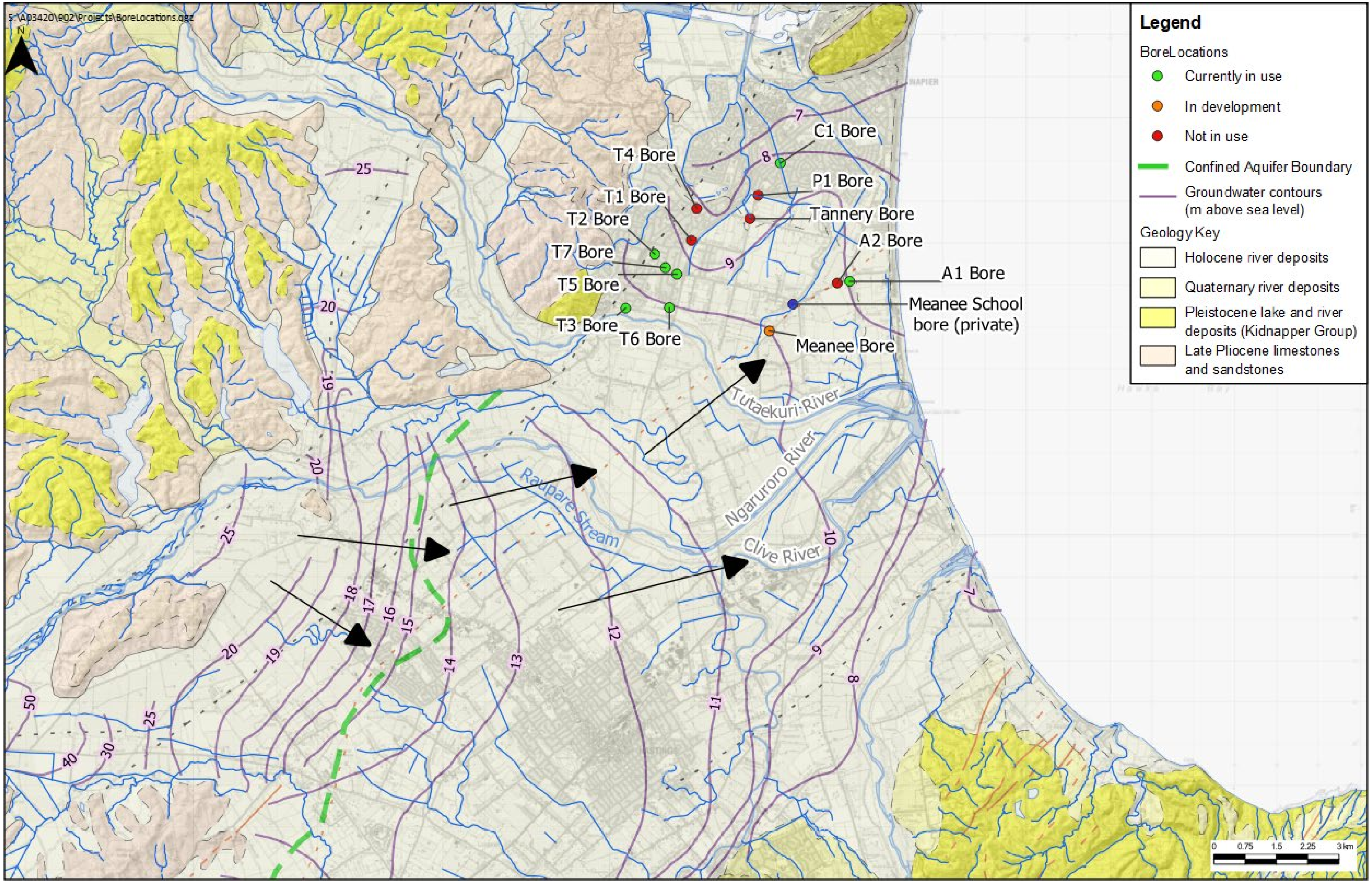


Figure 23: Geological map of Heretaunga Plains

Figure 23 shows the Plains as a single, uniform geological unit, representing Holocene aged strata. However, there are important variations across the Plains (Dravid, 1997). East of the confined aquifer boundary (indicated by green dashed line on Figure 23), the Holocene aged strata at the ground surface are typically dominated by finer grained silts and sands. These finer grained silts and sands were deposited by the most recent marine transgression across the Plains and form a low permeability wedge that thickens (up to 50 m) towards the coast and provides a confining cap over the more permeable gravel aquifer strata underneath and at the ground surface to the west of the green dashed line. The gravelly strata were deposited by alluvial processes driven by the Ngaruroro River, as well as other rivers across the Plains. Gravelly strata extend towards the coast beneath the silts and sands and may terminate offshore within Hawke Bay.

The NCC supply bores are located within the area to the east of the green dashed line and draw groundwater from a confined or semi-confined aquifer overlain by low permeability strata. However, the degree of confinement generally increases towards the coast to the east, with thinner confining strata present around the NCC supply bores located further west. In addition, aquifer testing reported on by GHD (2018) indicates that vertical leakage was observed during the testing. There was some suggestion that this could have been a recharge signature from a large lateral distance, however, from our review of the drawdown responses, this indicates the strata overlying the aquifer permit vertical flow (i.e. the aquifer is semi-confined), so there is potential for downwards migration of contaminants, albeit slowly on average, if the hydraulic gradient is reversed.

The gravel deposits extend to a considerable depth beneath the Heretaunga Plains, with an exploratory bore indicating gravel deposits occurring at depths of 400 m below ground level. These gravel deposits represent the main water bearing strata used for groundwater abstraction within the Heretaunga Plains. In contrast, the silts and sands that occur at the ground surface to the east do not permit rapid groundwater movement and are generally not used for groundwater abstraction.

Groundwater Levels

Groundwater levels in the gravelly strata vary. Groundwater pressures across the inland part of the Plains are typically a few metres below the surface. However, moving east towards the coast, groundwater levels in the gravelly strata are closer to the ground surface. Beyond the inland extent of the low permeability layer of surface silts and sands, groundwater pressures in the deeper strata may be above the ground surface (Brooks, 2006 & Dravid, 1997), a situation referred to as flowing artesian groundwater pressures. Around the NCC bores, groundwater pressures at the depth of those bores are understood to be typically above the ground surface, although there are seasonal and spatial variations. These above ground pressures and vertically upwards groundwater gradients help to restrict the downwards movement of contaminants into the deeper strata.

Above ground pressures occur because of the presence of the silts and sands that overlie the gravelly strata, particularly across the eastern part of the Heretaunga Plains. The lower permeability silts and sands confine the underlying gravels restricting the vertical movement of groundwater. This is an important conceptual feature of the groundwater system around the NCC bores because it will help to protect the strata that those bores target from surface influences (although the strata reduces rather than removes the risk of surface contamination).

Seasonal groundwater level variations occur due to groundwater responses to rainfall recharge events. The levels are typically higher in winter when little evapotranspiration occurs, and lower in summer when more evapotranspiration and groundwater abstraction occur. The seasonal change in groundwater levels can be up to two metres in some locations, although greater variations can occur where abstraction from bores occurs. Variations due to abstractions are also important; as noted above, the vertically upwards gradients help to prevent the downwards movement of contaminants into the deeper strata. However, where those upwards gradients are locally reversed (due to natural variations, effects due to pumping or a combination of the two), there is a potential for downwards movement of contaminants into the deeper strata. This represents a risk to the Napier city water supply, although the confining strata provide more protection than would occur in an unconfined aquifer. Local pumping and drawdown effects around the Napier supply bores are also important for NCC to consider in their management of risks.

In general, the overall lateral groundwater flow direction is easterly. However, there are local scale variations around groundwater recharge and discharge points (e.g. around rivers, springs, and large-scale groundwater abstractions).

Surface Water and Groundwater Interaction

Groundwater and surface water are closely linked in some parts of the Heretaunga Plains. Surface water forms the major recharge source to the groundwater resource (Wilding, 2018). Groundwater discharge is the key source for several spring-fed streams that flow across the Plains, including the Raupare Stream and the Irongate Stream.

Flow gauging along the Ngaruroro River indicates that there is considerable seepage of surface water to groundwater in the reach between Roys Hill and the Fernhill gauging station close to the State Highway 50 bridge across the river.

Downstream of the Fernhill gauging station and upstream of the boundary of the low permeability confining strata, surface water losses to groundwater are described as variable (Wilding, 2018), and the changes in flow measurements are typically within the margin of error for the gauging measurements. Recent work by the Hawke's Bay Regional Council (HBRC) (Wilding, 2018) does not describe flow gains along the Ngaruroro River downstream of Fernhill due to groundwater seepage.

Total seepage from the river to groundwater in this area is estimated at around 4.5 cubic metres per seconds (Wilding, 2018) and forms the major (around 52%) source of recharge to the Heretaunga Plains groundwater system. Other sources of recharge include rainfall recharge across the plains, as well as losses from the Tukituki River. Rakowski (2018) notes that the Tūtaekurī River has little interaction with groundwater where it enters the Heretaunga Plains and in general, that appears to be correct.

Piezometric contours showing the likely directions of groundwater movement in the aquifer are shown in Figure 23. These contours are based on data from summer 1995 and are representative of lower groundwater levels. Lateral groundwater movement occurs in a direction that is perpendicular to these contours, as shown by the arrows in Figure 23. The contours indicate that groundwater moves towards the Napier city area from the south west, most likely originating as seepage from the Ngaruroro River, together with some recharge from infiltrating rainwater and irrigation water across the land surface.

As noted above, the dominant source of water recharging the aquifer is seepage from the Ngaruroro River. The piezometric contours show that recharge flows south east and east away from the river, together with the component noted above flowing north east towards Napier city. There are several discharge points from the aquifer, including:

- Discharge to springs that represent the source of the Raupare Stream and the Irongate Stream (estimated by HBRC as 42% of total discharges)
- Discharge via groundwater abstraction used for irrigation and public supply, amongst other uses (estimated by HBRC as 29% of total discharges)
- Discharge to offshore springs and seeps (estimated by HBRC as 29% of total discharges)

A summary of the groundwater balance for the Heretaunga Plains is shown in Table 29 (after Rakowski, 2018).

Table 29: Calculated groundwater balance (HBRC, 2018)

	Source	Approximate Flow Rate (Mm^3/year)	Comment

Inflows	River seepage to groundwater	188.6 (71%)	Includes seepage from Ngaruroro River (138.8 Mm^3/year) and seepage from the Tukituki / Tūtaekurī Rivers
	Land surface recharge	78.5 (29%)	
Total inflows		*267.1*	
Outflows	Spring discharges	111.0 (42%)	
	Groundwater abstraction	78.1 (29%)	
	Offshore discharge	78 (29%)	Estimated
Total outflows		*267.1*	

It is important to note that the water budget described above does not identify groundwater discharge to any surface waterways other than the spring-fed streams. There is limited information on springs in the Napier city area, which suggests that the confining strata has limited weaknesses through which deeper groundwater could discharge. Therefore, in the Napier city area, groundwater discharge is likely to be to groundwater abstraction and offshore. Consequently, a water quality risk to the supplies is from saline intrusion, although this risk would not differ in impacts to a chlorinated or chlorine-free water supply. Preliminary modelling undertaken by GNS based on HBRC aquifer modelling suggests that this risk may be low, but we would recommend continued monitoring for possible indicators of saline intrusion, for example for conductivity, given the proximity to the coast.

1.1.3.1 Currently Defined Source Protection Zones

Source protection zones around the proposed Taradale (around bore T6) and Awatoto bore fields (around bores A1 and A2) were defined as part of work investigating new sources at those locations (Tonkin and Taylor, 2019 & PDP, 2019). Draft SPZs have been defined for the other bores, including the C1 bore to the north (Tonkin and Taylor, 2018). It is noted that the zone defined for the proposed Taradale bore field encompasses the other existing bores in the Taradale area, although the draft combined zone for those individual bores was slightly larger. The currently defined SPZs are split into three categories:

- Source protection zone 1 (SPZ1) is defined as the land parcel within which the bore situated. The minimum recommended zone is a five-metre radius around the bore, but Tonkin & Taylor (2019) note that this is a minimum distance and may be larger.
- Source protection zone 2 (SPZ2) is defined as the microbial protection zone. In this case, SPZ2 has been defined as a zone in which groundwater is expected to take less than one year to reach the source. However, an additional source protection zone is also defined around the bores (SPZ2a), which is a 100 m protection zone. Tonkin and Taylor (2019) indicate that this zone accounts for potential contamination pathway risk by allowing for greater controls to be placed on land uses in close proximity to the bore that have the potential to contaminate groundwater.
- Source protection zone 3 (SPZ3) consists of the part of the catchment upgradient of the takes which contributes groundwater recharge into the aquifer. Tonkin and Taylor (2019) defined this zone considering ten-year particle travel times and by using hydrogeological judgement considering groundwater dynamics from age data and the effect of no-flow or recharge boundaries. We note that these areas are difficult to define precisely.

The zones defined for the Coverdale bore, and the Awatoto and Taradale proposed bore fields, are considered broadly appropriate and represent an estimate of the potential area where surface influences could affect the bores. The Taradale SPZ2 extends west and south west and intersects the Ngaruroro River. The Awatoto bore SPZ is slightly smaller and does not extend as far west but does appear to extend offshore to the east. The draft Coverdale SPZ2 is somewhat more localised and notably extends in a more general circle around the source.

The SPZs were defined by simulating the pumped strata as an unconfined aquifer that is vulnerable to surface contamination. That is a conservative approach as in reality, the pumped strata are overlain by a relatively thick unit of lower permeability material. However, the detections of total coliforms in the NCC supply bores that are discussed further in Section 1.1.4 indicate a conservative approach is warranted in the absence of a clear direct pathway via the NCC bores having been established. The extent of the zones was based on a one-year time of travel and uses relatively conservative aquifer parameters.

The SPZ2 areas do not extend into the unconfined area of the aquifer, implying some protection from direct surface influences. However, weaknesses in the confining strata (e.g. caused by poorly sealed bores across the area), will present a risk by which contaminants at the surface can reach the deeper more permeable strata. Given the regular occurrences of total coliforms detected in several of the bores, as well as the elevated concentrations of dissolved reactive phosphorus, further consideration of this pathway should be undertaken, including a survey of bores within around 500 m of the bore heads.

The effectiveness of an SPZ relies on management of activities within it. In general, we agree with the definition of the SPZs around the bores, however, they should not be viewed as a passive control on risks to the sources. Management controls within these zones is discussed in the following section.

1.1.3.2 Controls on Source Risks

Hawke's Bay Regional Council are in the process of changing the regional plan (the TANK plan change), which includes updates to improve protection of the sources of drinking water, including in the Heretaunga Plains area. While the current plan does address risks to water supplies for numerous activities, the proposed plan change includes requirements for more detailed assessment of various activities including HBRC (2019):

- Activities that increase the amount of pathogens in the source area (e.g. wastewater disposal)
- Activities that increase the amount of chemical or other contaminants in the source area (or have the potential to)
- Activities that shorten the connection between the contaminants and the drinking water supply (e.g. poorly sealed deeper bores)
- Activities that impact on water treatment efficiency (e.g. sedimentation)

Typical activities that will require new consent requirements and be subject to higher performance standards if they occur within an SPZ include:

- Rural land uses (e.g. sheep dips, pesticide uses, and onsite wastewater)
- Industrial land uses, including the storage and use of hazardous chemicals (which is also controlled under the Hazardous Substances and New Organisms Act).
- Urban land uses (e.g. landfills, wastewater and stormwater reticulation)

HBRC have several programmes and controls in place to help achieve the outcomes sought relating to improved source protection. It is understood from consultation with HBRC, that a bore safety programme has been implemented such that the condition of bores used for groundwater take consents is assessed either as part of new consents or replacement consents. Furthermore, discharge consents may require that the applicant assesses the condition of nearby bores with respect to the possibility of overland flows entering the bore or casing. These actions will help to ensure that bores with water take consents or on properties with other consented activities are suitably sealed. However, unconsented bores (e.g. domestic supplies) may not always be captured through this process and may represent a risk. NCC report they have encountered bores that are not on HBRC's database.

There are no specific proposed rules in the TANK plan change related to the maintenance / security of existing bores in use, so some bores may not be captured. However, there are rules in the current plan and proposed TANK plan change around the drilling of new bores, alteration of bores, unwanted or leaking bores and decommissioning of bores. The TANK plan strengthens these rules in terms of potential effects on community drinking water supplies. For new water takes, there is a requirement that backflow of water or contaminants shall be prevented.

Wastewater discharges are given increased scrutiny under the TANK plan change and onsite discharges will require greater levels of treatment in SPZs. HBRC inform NCC of discharge consent applications that are lodged within their mapped SPZs. However, it is important to note that existing domestic wastewater discharges (i.e. from septic tanks) may not have the same level of controls. These activities represent a risk, particularly if they are located close to a community supply bore. Some ongoing effort should go into identifying the likely location of existing onsite wastewater treatment discharges within the SPZs to help control this risk. This could be achieved by plotting the location of the wastewater reticulation system, compared to existing residential areas. An initial assessment of this data (based on the HDC Geographic Information System) indicates that there are extensive areas within the SPZs that are not served by wastewater reticulation systems. However, it is acknowledged that a wastewater reticulation system can also present a risk to water supplies; ideally, wastewater reticulation infrastructure should be located away from supply bores. This risk has been identified in the WSP, and it was noted that the T4 bore was decommissioned for this reason. It is important for NCC to consider and identify, where possible, all activities that may present a risk to a supply bore, and monitor changes in activities over time.

Microorganisms represent a key risk to community drinking water supplies in terms of health impacts; it is important to note that other chemicals can also have an impact on drinking water supplies. For example, phenols can lead to DBPs (and 'dirty water') in water supplies. Sources of phenols can include landfills, wastewater, and industrial sources such as petrol refining.

Sources of chemical contamination are also controlled under the regional plan. Significant plumes of industrial contaminations are not thought to be present in the Heretaunga Plains water bearing strata. However, it is an issue that needs to be carefully managed. NCC's WSP identifies the closed Redclyffe landfill at 2.2 km distance from the closest T3 bore. However, low permeability outcrops (comprising the hills to the west of Taradale) are concluded to ensure there is negligible groundwater contribution to the Heretaunga Plains.

NCC are also currently involved with source protection via reviews of consent applications within the SPZs and also involved with the Hawke's Bay Drinking Water Governance Joint Committee (which includes the district authorities, the regional council, iwi and the Ministry of Health). The committee was established as a result of the Havelock North Inquiry, to provide governance oversight to the Joint Working Group (JWG) (consisting of staff representatives from the members of the committee) regarding the implementation of recommendations from the Inquiry Panel and then the evolution of the JWG into a more permanent official working group. There are also actions from the WSP prepared by NCC that assist with the management of activities within the SPZs. One of several measures includes input from the 3 Waters Team into the district plan to control future activities within SPZs.

1.1.3.3 Summary of Groundwater Source Information, Source Risks and Recommendations

Based on the data reviewed above, the following key information related to source risks has been identified:

- All bores currently comply with Criterion 1 (age) and 2 (bore head protection) of the DWSNZ. Following the current approach in the DWSNZ, this implies that in the immediate vicinity of the bore head, there are limited risks from surface contamination.
- The hydrogeological setting of the bores, where the recharge to groundwater is generally located several kilometres inland and the pumped strata around the bores are overlain by a thick sequence of lower permeability strata, suggests that the source water has a degree of natural protection from surface contaminants. The long travel path from the source water to the NCC bores, conjunctively with the upwards vertical hydraulic pressures, should generally restrict surface contaminants from reaching the pumped strata at significant concentrations.
- However, as is detailed further in Section 1.1.4 of this report, the microbiological testing data from the bores shows frequent detections of total coliforms have occurred and occasionally *E. coli* (although the *E. coli* has been attributed to bore damage / maintenance rather than surface contamination from another pathway). This implies that despite the natural protection of the pumped strata, there are some rapid pathways by which bacteria from the land surface may be reaching the pumped aquifer. Acknowledging the degree of protection provided by the confining strata, the distance to the expected recharge sources and the upwards gradients present, in our opinion, these pathways could be via nearby poorly sealed bores within the general area around the NCC bores, but other pathways cannot be ruled out based on the information

currently available and the condition of the NCC bores may change. A survey of nearby bores is suggested as part of further investigations together with ongoing monitoring of the NCC bore integrity. Local pumping and drawdown effects around the Napier supply bores are also important for NCC to consider in their management of risks. Additionally, NCC should ensure that all activities on or within the bores are undertaken with good hygiene and disinfection procedures to avoid introducing bacteria to the bores directly. There is some potential for total coliforms to survive within a biofilm within the bores, and good hygiene and disinfection procedures, followed by further monitoring, would help establish whether this may be the reason for the total coliform detections. Further investigation into the timing of past detections could also be helpful. Whatever the pathway for these organisms to gain entry to the groundwater, their presence indicates the passage of bacteria into groundwater. Given this there is a risk that protozoan parasites that are infectious for humans and completely resistant to chlorination may be present. Application of ultraviolet disinfection to these sources should be progressed promptly. However, based on the current information and consideration of current and future risks to the supply, including the number of other bores in the area that create a potential contaminant pathway to the source water, some appropriate form of treatment is recommended to control and reduce source risks.

- SPZs have been defined around some of the bores, with draft zones for others, but the effectiveness of an SPZ relies on management of activities within it. In general, we agree with the definition of the SPZs around the bores, however, they should not be viewed as a passive control on risks to the sources. Management controls within these zones is discussed in the preceding section. It would be prudent for a survey of bores within 500 m of each NCC bore to be undertaken to identify any nearby unsealed or poorly maintained bores that may present a pathway from the surface to the deeper, pumped aquifer. Understanding the number and location of these risk pathways will be helpful in determining the scale and extent of risks to the source water.

As outlined in Section 1.5.1.2 of the main report, groundwater systems should also be considered as subject to change. Natural hazards such as earthquakes can affect the integrity of confining strata, including creating preferential flow pathways around existing bores, and alter water levels. Surface flooding due to heavy local rainfall, river breakout or tsunami can result in contaminated water reaching confined aquifers via preferential pathways, such as poorly sealed bores. A period of sustained low groundwater recharge, for example due to droughts, can also impact groundwater levels and gradients.

Impacts from seismic events are discussed in the NCC bore security report by GHD (2018) and some control measures are noted such as NCC having committed to a lock out level for each bore pump with headworks located below ground, where the lock out would shut down the bore pump automatically if the level was reached. NCC have an improvement action (no. 55) in the current WSP to develop a detailed document on lock out levels and reset procedures related to seismic events. A loss of supply due to damage from a natural event such as an earthquake is also identified in the WSP, with an associated improvement action (no. 29) to update the plan to isolate bores. Reference is also made in the WSP to implementation of the Emergency Management Plan following earthquake, flood or other natural disaster.

Tonkin and Taylor (2019) also recommend NCC review the source protection zone extents following changes in groundwater conditions, such as due to major floods or earthquakes.

The dynamic nature of groundwater systems is an important consideration for management of source risks. Aquifers that may have previously not knowingly been contaminated by microbial pathogens may become contaminated following changes to the system, including following natural hazard events. This is important to consider for all aquifers, including confined aquifers with upwards gradients, as in Napier.

The implications of the above information for Napier is that an appropriate form of treatment is recommended, even though in general the source waters are considered to be relatively low risk, and it is important to consider changes to the source water over time. Further investigation of the cause of the total coliforms is recommended.

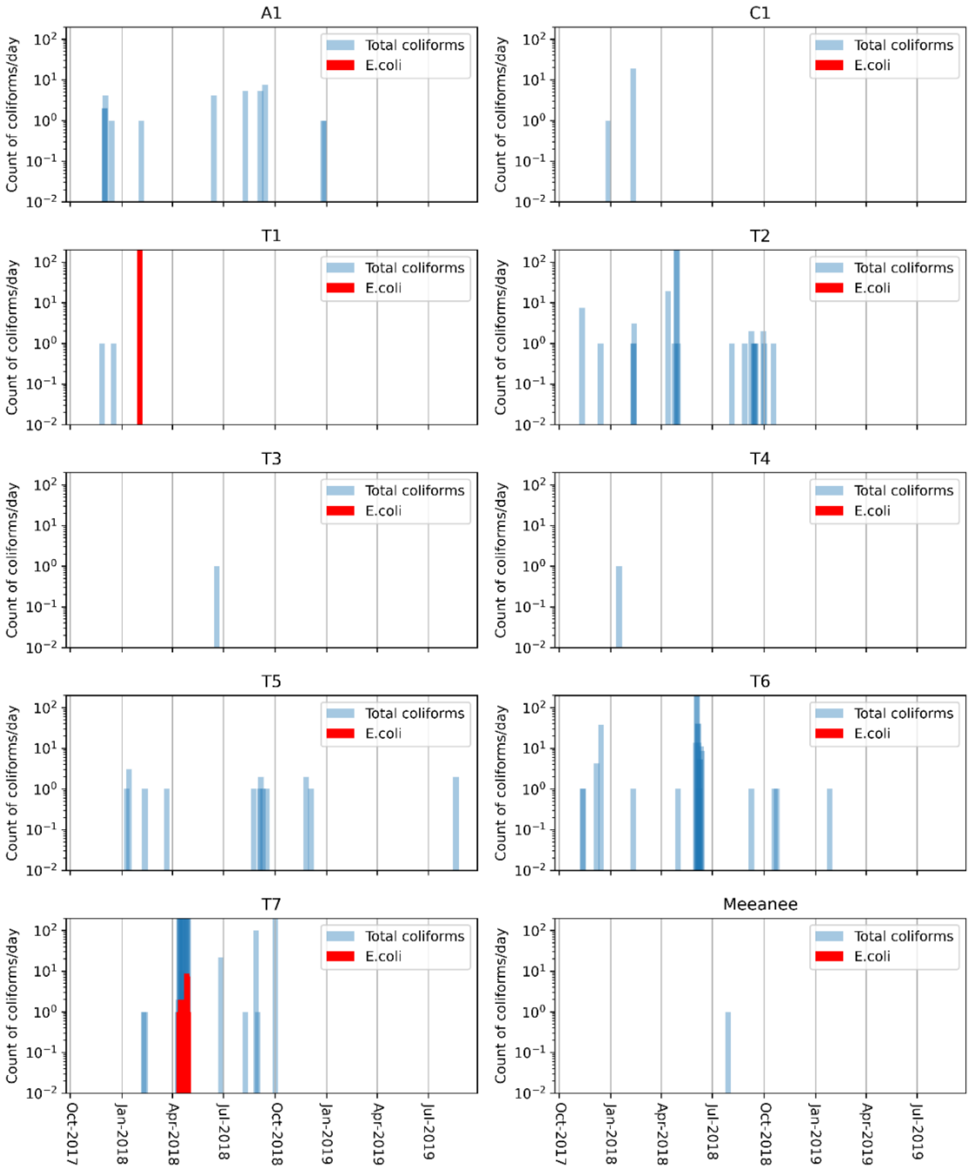
1.1.4 Groundwater Quality Data

Source water quality data has been provided by NCC and is based on the testing that occurs in each bore. Water quality testing falls into two categories; one category covers microbiological testing which occurs weekly for each bore, and the other covers more general water quality testing that occurs less frequently. Note that the water quality data for the Meeanee bore represents the results of testing from the Meeanee School bore and does not represent the results from the new NCC bore.

NCC have provided data for microbiological testing since 2017 and general water quality data for the source water are available since 2015. However, general water quality data prior to 2017 are sparse. The following sections describe the available data.

Some data are also available from the reticulation system. The additional data are described below. Note that the data provided from the reticulation network are generally limited to microbial analyses (except for Freely Available Chlorine data which is not described here). Total coliform data are available from 2017 for the reservoirs and from 2018 for the distribution network.

1.2 Microbiological Testing (Source Water)



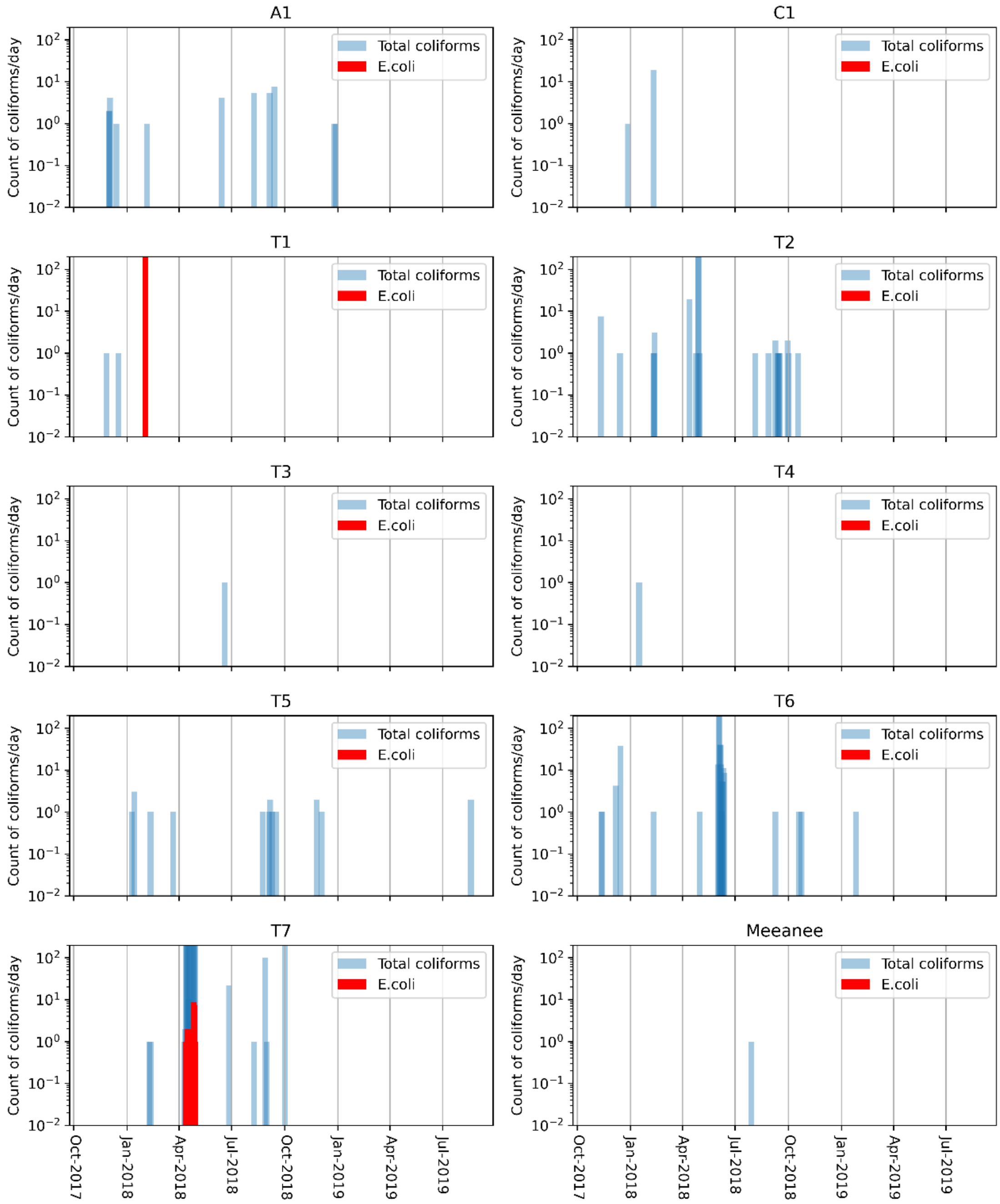


Figure 24 Figure 24 shows the occurrence of total coliform and *E. coli* detections in the raw source water (i.e. before disinfection with chlorine) from each of the bores where data is available. These indicate that total coliforms (which indicate the probable contamination of water by surface derived material) are detected relatively frequently, but *E. coli* (which indicate the contamination of water specifically by faecal material) have been detected in two isolated incidents. The *E. coli* detections have been attributed through NCC investigations to one specific

bore damage incident and another specific maintenance incident rather than surface contamination from another pathway. The occurrence of total coliforms may reflect a connection between the surface and the pumped aquifer which can occur via preferential transport pathways, such as existing nearby poorly maintained bores. The bore head security inspections of NCC bores indicate that they are in good condition, so the most likely pathway would appear to be via nearby, poorly maintained bores, but other pathways cannot be ruled out based on the information currently available. It is possible that total coliforms could be being introduced to the bores during maintenance or other activities. Coliforms could survive within a biofilm within the bores. It is important that all activities on or within the bores are undertaken with good hygiene and disinfection procedures.

Data are available for the following bores: A1, C1, T1, T2, T3, T4, T5, T6, T7 and Meeanee (which represents the Meeanee School bore). The results of testing at each of these bores since October 2017 is presented in Figure 24. The current active Napier city supply bores are A1, C1, T2, T3, T5, T6 and T7.

All the bores show detections of total coliforms from time to time, with the greatest detections occurring in bores T2, T6 and T7 where detections of 200 CFU per 100 mL (or greater) have been observed. In general, the other bores appear to show lower levels of total coliforms, although repeated detections in bores A1, T2, T5 and T6 suggest a consistent source. It is noteworthy that since the start of 2019, the detection of total coliforms appears to have markedly reduced, although further follow up to investigate the cause of the detections should be undertaken together with ongoing bore hygiene measures and monitoring.

E. coli has only been detected in bore T1 on one occasion in March 2018 (> 200.5 CFU per 100 mL) and on successive days in bore T7 in April 2018 (up to 8.7 CFU per 100 mL). The detections of *E. coli* in bore T7 appear to be associated with elevated concentrations of total coliforms (which is typical of faecal contamination), although elevated concentrations of total coliforms do not always appear to result in *E. coli* detections. For example, concentrations of total coliforms in bore T6 reached 200 CFU per 100 mL in June 2018, but no *E. coli* was detected. Through NCC investigations, the *E. coli* detections in bore T1 have been attributed to most likely be due to a leak in the casing allowing wastewater contaminated groundwater to enter the bore. As a result of this, the T1 bore has subsequently been removed from service. The elevated concentrations in bore T7 have been attributed to removal and reinstatement of the pump during maintenance and the bore was offline at this time. The total coliforms detected in T6 in June 2018 have also been explained by NCC to be due to the bore being offline for maintenance, with the bore pump removed prior to these results, CCTV and pressure testing undertaken.

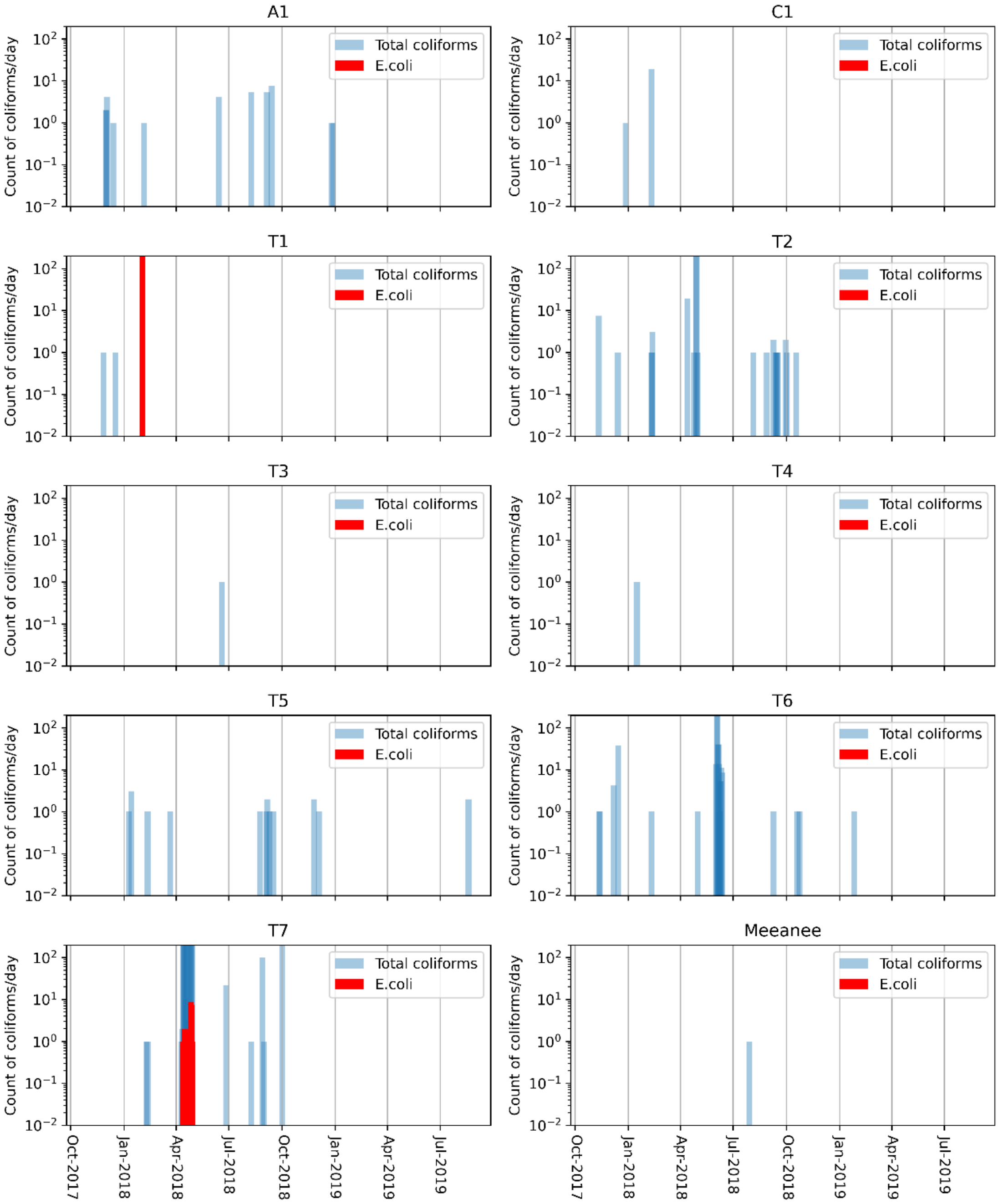


Figure 24: Daily microbiological testing results since October 2017 (Note: Log y scale)

The data suggests that all the bores have experienced detections of bacteria to some extent. It should be noted that the detection of total coliforms and *E. coli* in groundwater is typically sporadic, even when sampling is undertaken regularly. While the *E. coli* detect in the only bore in service (T7) has been attributed to maintenance, the presence of total coliforms is of concern and indicates that treatment is required, including an appropriate barrier for protozoa such as UV, given the unknown nature of the source of total coliforms. Follow up by NCC to ensure appropriate bore hygiene measures are in place to ensure these bacteria are not being introduced directly to the bores is advised. Further investigation of the detections compared to timing of maintenance by NCC would be warranted. For example, total coliform detections in three of the bores (A1, T2 and T6) occurred at a similar time at the beginning of September 2018. Maintenance records could be checked together with weather information at the time (there appeared to be reasonable rainfall in the days prior).

1.2.2.1 Microbiological Testing (Reticulation System)

NCC also undertake testing at various locations within the reticulation system, including the main supply reservoirs and points within the distribution network. The data collected include microbiological sampling for total coliforms and *E. coli*, together with sampling from HPC, which are rapid onsite tests for bacteria. Additionally, data regarding DBPs are also collected, albeit at less frequent intervals.

Figure 25 shows a summary of the microbiological testing results from the reservoirs.

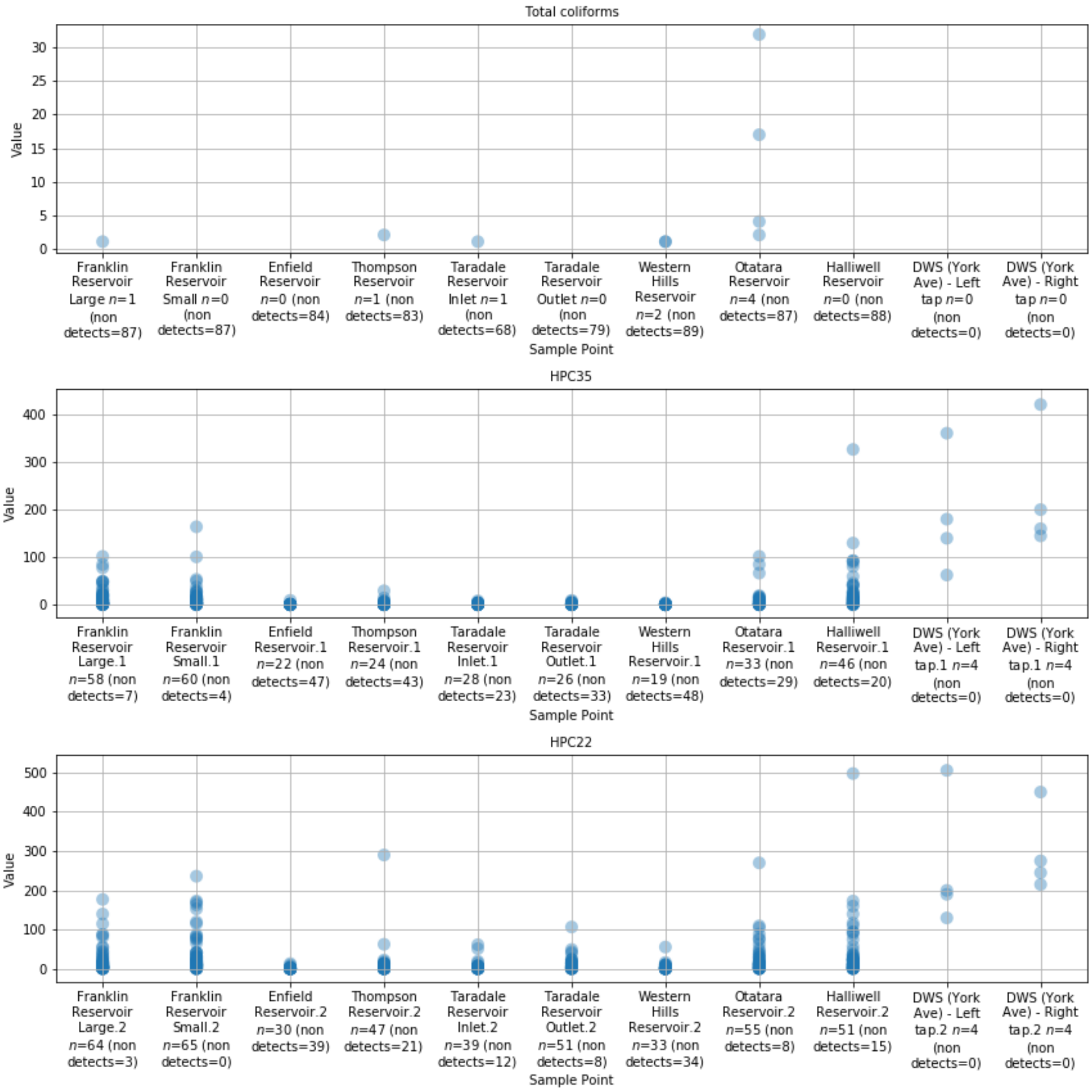


Figure 25: Microbiological testing results for the supply reservoirs

The data indicates that bacteria are occasionally detected within the reservoir system. Total coliforms are detected relatively infrequently but indicate either ingress or microbial regrowth. The “spikes” in numbers of both total coliforms and HPC suggest that ingress is occurring, but both ingress and regrowth may be factors. In any event, these data should be investigated by in-depth sanitary surveys and more intensive monitoring where appropriate.

Figure 26 shows the results of testing for total coliforms in the distribution system.

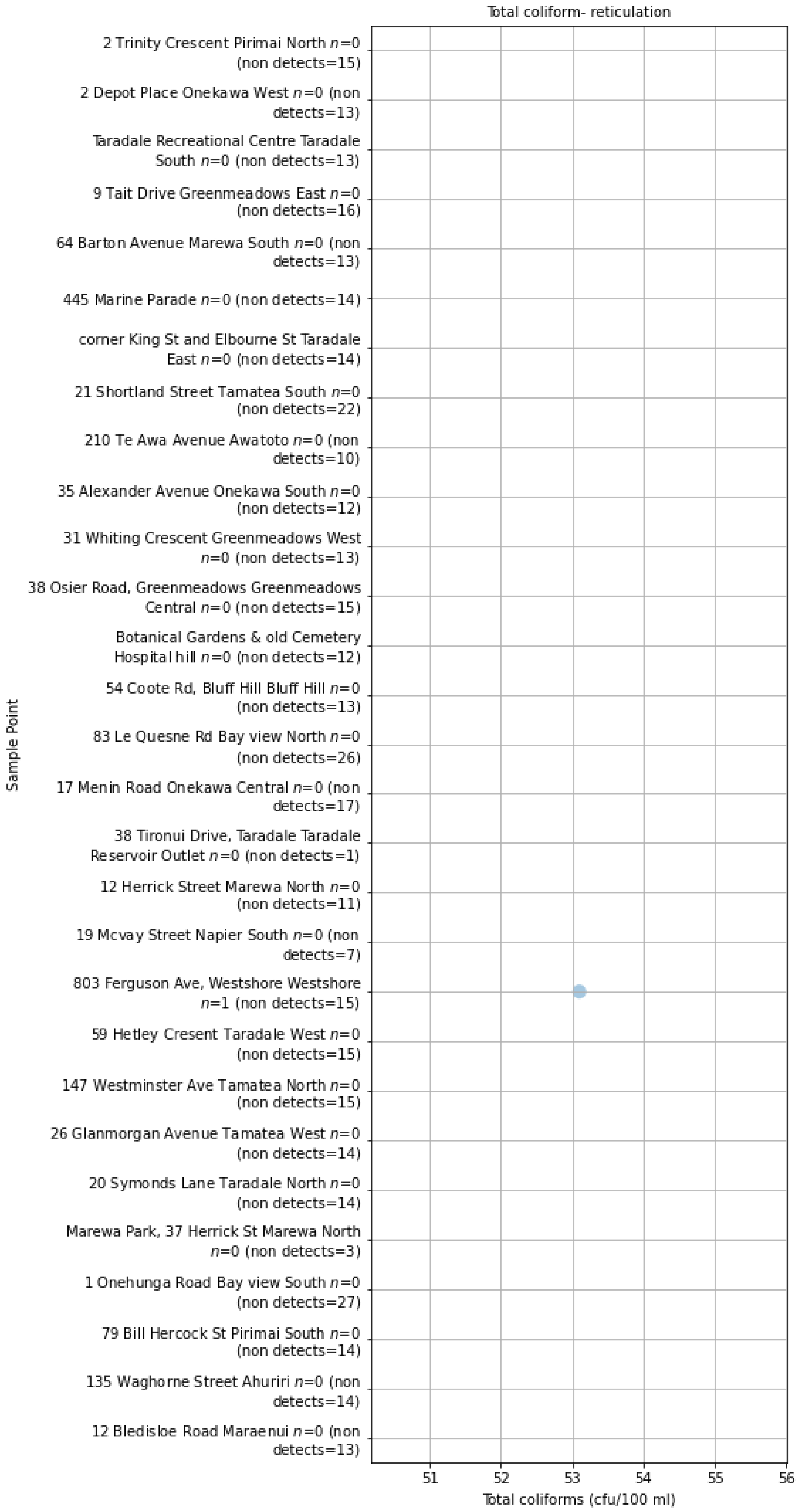


Figure 26: Microbiological testing results for the distribution network

Figure 26 shows that in general, bacteria are almost never detected (based on the sampling data provided since July 2018 to May 2020) except on one occasion at 803 Ferguson Ave.

Taken together with the testing from the source water, these results show a reduction in total coliform counts from the source water to the distribution network. This suggests that disinfection procedures are generally working effectively.

1.2.2.2 Comparison with Other Water Suppliers

We have also assessed data from other drinking water suppliers who use groundwater in similar hydrogeological settings to the NCC bores. These include the Christchurch City Council (CCC) supply bores as well as the HDC supply bores. A brief summary of the data provided by these councils is as follows:

- **Christchurch City Council** abstract groundwater from a large number of shallow and deep groundwater bores across the city. Many of these bores are screened within permeable gravel strata that is overlain by extensive thicknesses of silts and fine sands that provide a degree of protection from surface influences. The data available indicate that total coliforms are detected from time to time. Between 2015 and September 2020, 51 detections of total coliforms and three *E. coli* detections occurred in the data set of 13,661 samples provided. This frequency of total coliform detections is lower than that seen in the NCC bores. It is noted that due to the large number of total bores (more than 140 bores spread across more than 50 bore fields and pump station sites), in addition to a small subset taken from individual bores, CCC take composite samples from the pump station sites, which reflect groundwater from several bores and aquifers, depending on which bores were in operation when the sample was taken.
- **Hastings District Council** abstract groundwater from a series of bores located within the confined part of the Heretaunga Plains Aquifer. Daily sampling data from 2017 provided graphically by HDC indicates that total coliforms are detected in their bores including occasional detections in the HDC bores at Eastbourne and Frimley, which are beneath an extensive thickness of confining strata. However, generally, the data from those bores suggests that total coliforms are detected less often compared to some of the NCC bores.

1.2.2.3 Heretaunga Plains Microbiological Data

It is useful to consider whether the detections of total coliforms and *E. coli* are consistent with the broader water quality information for the Heretaunga Plains, as represented by the HBRC State of the Environment (SoE) monitoring network. This is because the SoE monitoring network helps to provide information on the general source water quality (in terms of bacteria) and could help to narrow the possible source of bacterial detection in the NCC bores.

The data from the HBRC SoE network suggest that detections of bacteria are rare in the Heretaunga Plains, however, sampling has only occurred for *E. coli* to date and excludes total coliforms. The most recent SoE report for groundwater quality (Barber, 2019) indicates that of the 22 monitoring bores across the Heretaunga Plains, only one (bore 611, screened from 33-39 m below ground level) has shown a detection of *E. coli* in the last five years. Bore 611 is located at the southern outskirts of Taradale. Other SoE monitoring bores in the same general area (and the same area as the NCC bores) have not shown detections of *E. coli* over the last five years.

At a broad scale, the data appears to suggest that groundwater in the source areas for the NCC bores does not contain significant concentrations of bacteria. This could mean that the source of bacteria in the NCC bores is more localised and further work to investigate is advised. However, the HBRC data is limited, particularly in that it excludes total coliforms and is by no means conclusive.

1.2.2.4 Chemical Testing

Chemical testing has also been carried out in each of the bores since 2014 and a summary of the data availability is shown in Figure 27. Figure **27** 27 indicates that the Tannery, T4 and T1 bores were last tested in 2017, 2019 and 2018 respectively. We understand this reflects the time when the bores were disused. In the data from the remaining bores, there is a large data gap from late 2014 to 2017, and another data gap from 2017 to 2018. Since 2018, data has been collected more regularly, but apparently not at the same intervals in each bore.

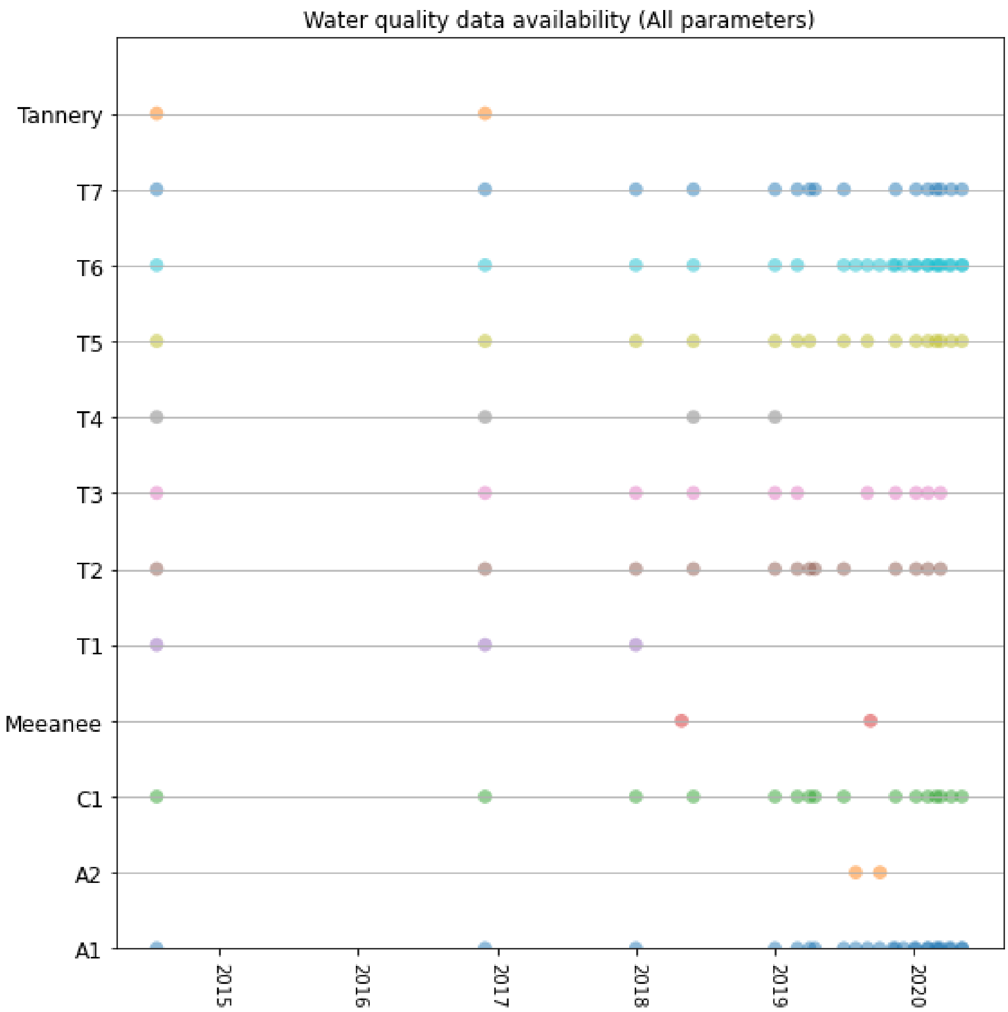


Figure 27: Chemical data availability in the bores since 2014

The most intensive sampling appears to be from bores T6 and A1, with generally less frequent sampling overall in other bores. However, since at least 2020, sampling appears to have taken place at monthly intervals in most bores, except for T2 and T3. It is not clear why less frequent sampling has occurred in bores T2 and T3 compared to the other bores.

Figure 28 summarises the data from the bores as a series of plots for different parameters. The results of the sampling indicate relatively varied water chemistry in terms of differences between the bores, as well as in terms of differences between individual samples from each.

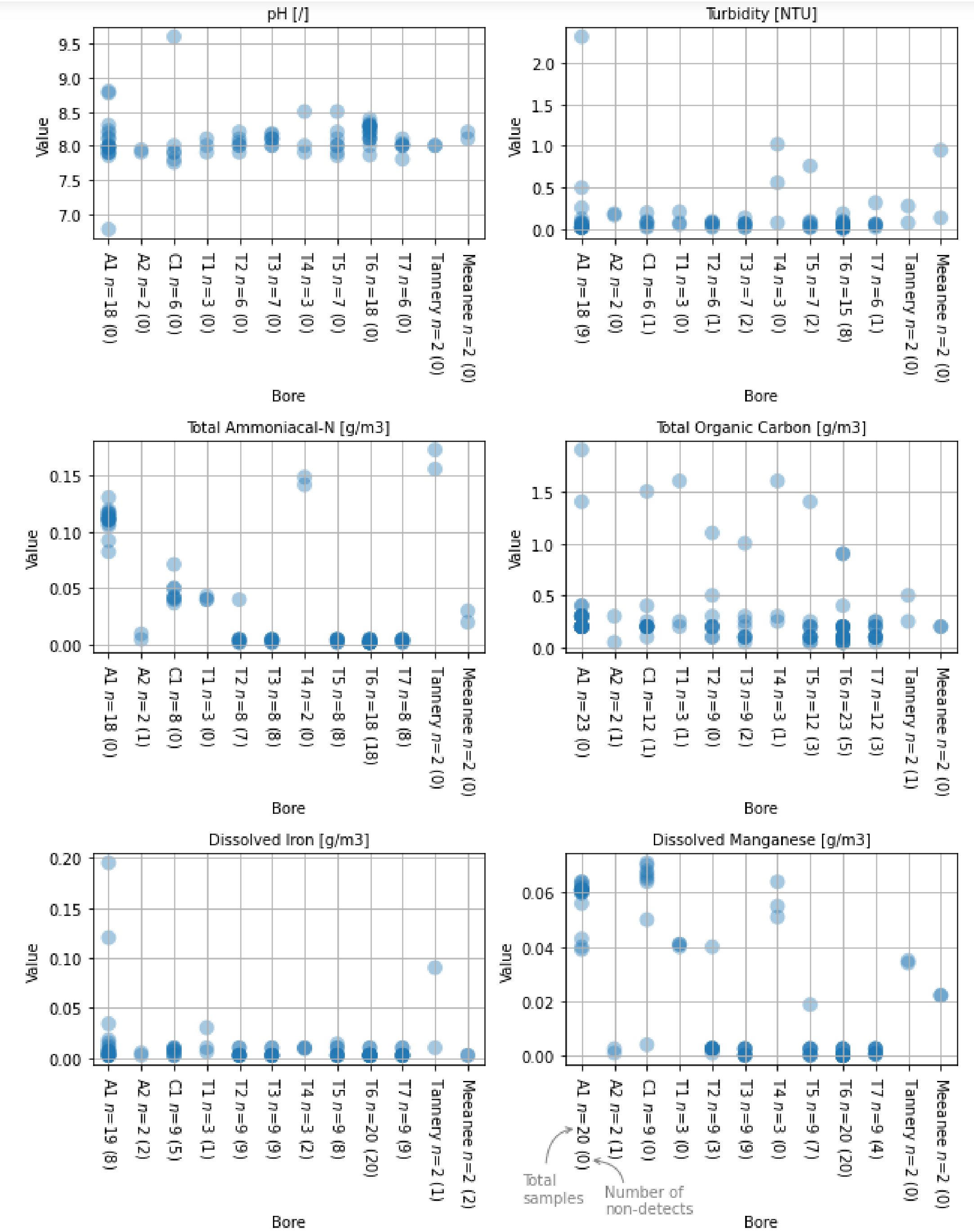


Figure 28: Chemical data sampling results for the bores

In Figure 28, the data from each bore is shown as a solid circle, with multiple data points overlapping shown as darker coloured points. The number of samples for each bore are shown as (for example) 'T7 *n* = 9 (4)', where *n* represents the total number of samples from a bore and the number in brackets represents the number of non-detects for a particular parameter. Non-detects are shown on the plots as half the detection limit, but the detection limit is inconsistent between samples.

We note that the number of samples are inconsistent across different parameters and in part this represents non-detects in samples. However, it also appears that in some cases the parameters analysed are inconsistent across all samples. Overall, there is a very limited dataset on which to assess trends and variability and the interpretation of the data requires considerable caution.

The data shown in Figure 28 are for a selection of parameters based on known issues with manganese and iron, along with parameters such as ammonia and total organic carbon which can cause issues with chlorination of the source water. In summary, the data shows that:

- Iron concentrations were generally low (< 0.05 milligrams per litre), although there is limited sampling in most bores. Occasional higher values were noted in bore A1, where more samples were analysed for iron.
- Manganese concentrations were elevated above the DWSNZ guideline value (GV) of 0.04 milligrams per litre in several bores including A1, C1 and T4 (now disused).
- Concentrations of manganese in bore A1 are persistently greater than the DWSNZ GV (note that this bore has the greatest number of samples). Concentrations in other bores were generally below the manganese GV, although some of these bores included less samples than the bores with elevated concentrations (A1, C1 and T4). In bores with greater numbers of samples (e.g. A1 and C1) a greater range of values were encountered; therefore, it is recommended that limited weight is given to the results from bores where only one or two samples are available.
- The threshold determined for this project for manganese treatment is understood to be 0.01 milligrams per litre at the 99th percentile. There is insufficient data to calculate realistic 99th percentile values, but the only bores where a threshold of 0.01 milligrams per litre is potentially achieved are A2, T3 (9 samples with non-detects of manganese), T6 (20 samples with non-detects of manganese) and T7. However, bores A2 and T7 have limited data so further information is required, recognising that A2 is not a current supply bore.
- Concentrations of ammonia are greatest in the now disused Tannery bore, followed by bores T4 and A1. Concentrations in all three of these bores are consistently more than 0.05 milligrams per litre.
- Concentrations of total organic carbon are variable, although generally the values are less than 0.5 milligrams per litre. However, all bores show spikes of greater than 1 milligram per litre except for A2, Tannery (now

disused) and the Meeanee bore (note that these three bores have very few samples).

Figure 29 shows a plot comparing manganese concentration with the depth (shown as the top of the screened interval) in each bore.

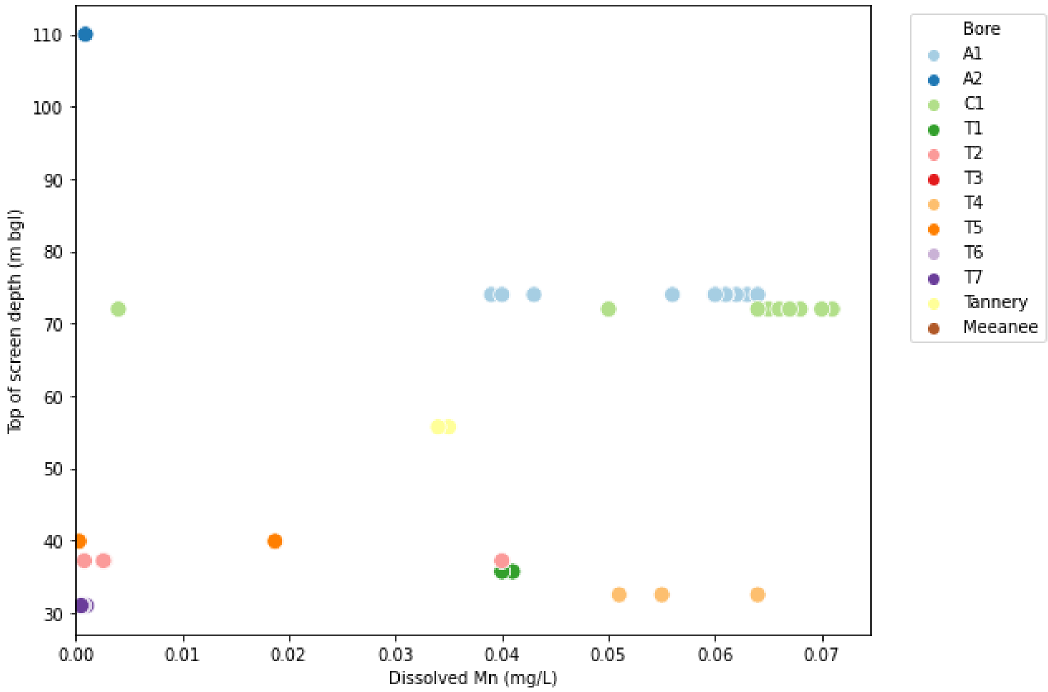


Figure 29: Manganese (Mn) concentration versus depth of bore top screen

A clear relationship between manganese concentrations and the depth of bores is not discernible from Figure 29; high concentrations are recorded in both shallower and deeper bores. The deepest bore (A2) shows the lowest concentrations of manganese but it important to note that there are very few samples from this bore.

Data for turbidity and pH are also collected daily from each bore; the daily data is summarised in Figure 30.

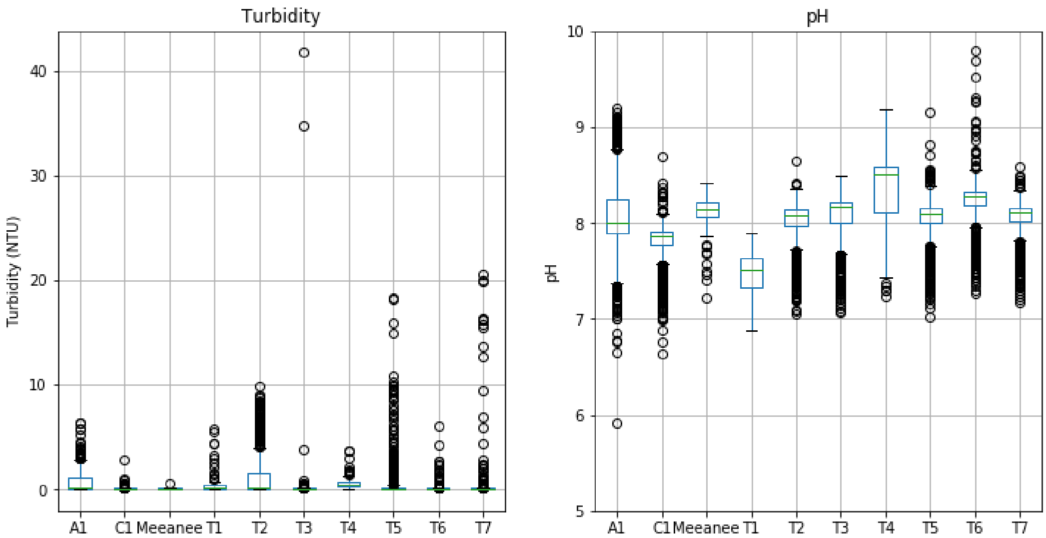


Figure 30: Box and whisker plots for daily turbidity and pH samples

The data indicate that, typically, turbidity is low, at less than one nephelometric turbidity units (NTU) at the 95th percentile for most bores. However, greater turbidity occurs in some bores and there is considerable variation in turbidity in all bores and elevated values can occur for sustained periods of time. Turbidity values compared to pumping rates are shown in Figure 31, which illustrates that high values typically occur at times when the bores are not being pumped. NCC note that biofilms within the bores can contribute to elevated turbidity values, which are particularly an issue when the bores are not operational, and the data appear to be consistent with this explanation. Therefore, the higher turbidity values are unlikely to be related to the surrounding aquifer.

Figure 30 shows that pH values are typically around 8 in most bores. Bore T1 (now disused) shows notably lower pH levels compared to other bores, with less variation. The lower variation is likely a reflection of the lower number of samples as the bore is now disused.

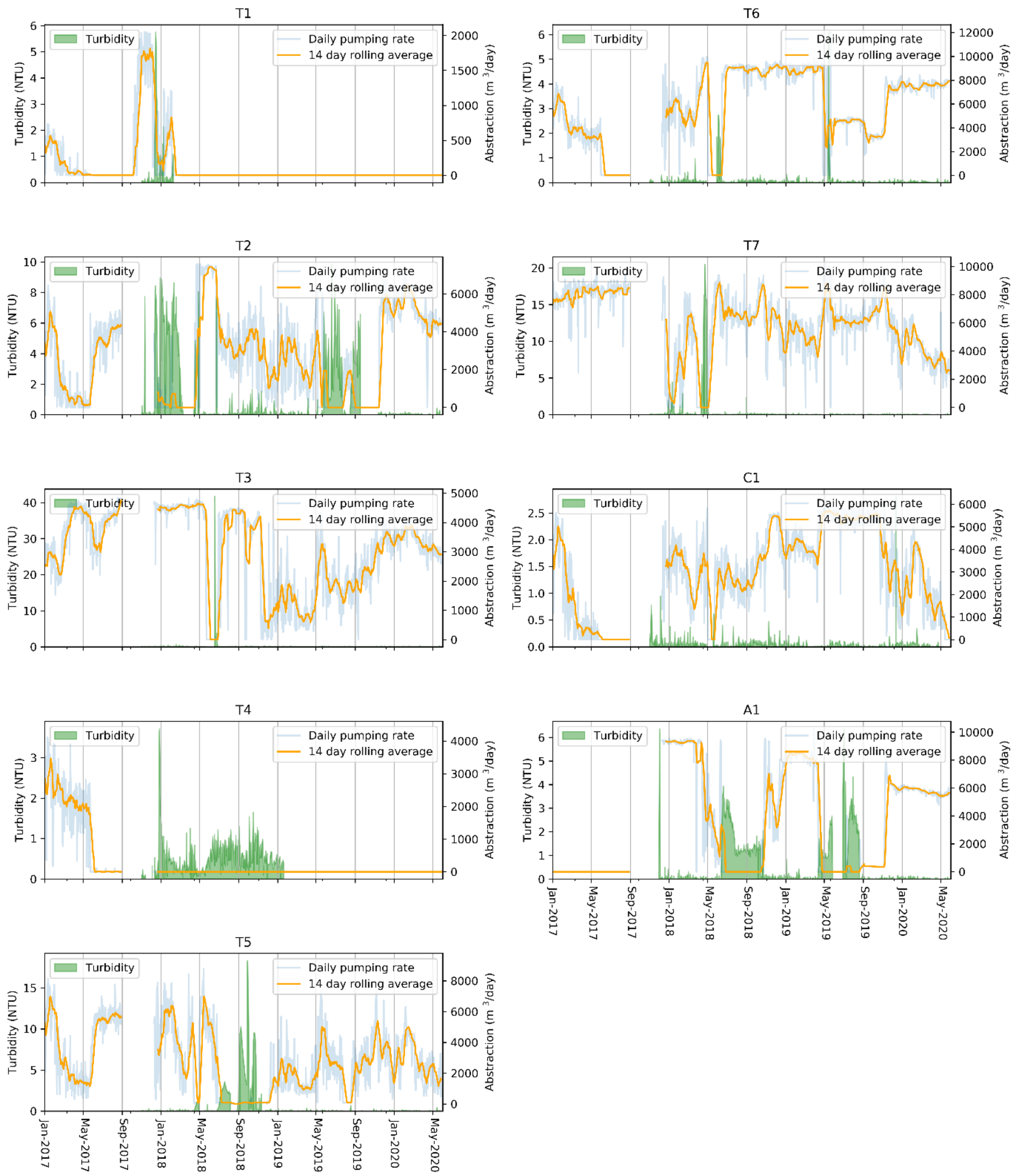


Figure 31: Daily turbidity compared to daily pumping rates

As previously stated, the 'Meeanee' bore shown in the plots above refers to the Meeanee School bore, which is not part of the NCC Napier water supply network. Drilling of the new NCC bore on Sandy Road at Meeanee is incomplete, but some preliminary water quality results are available. This is shown in Figure 32.

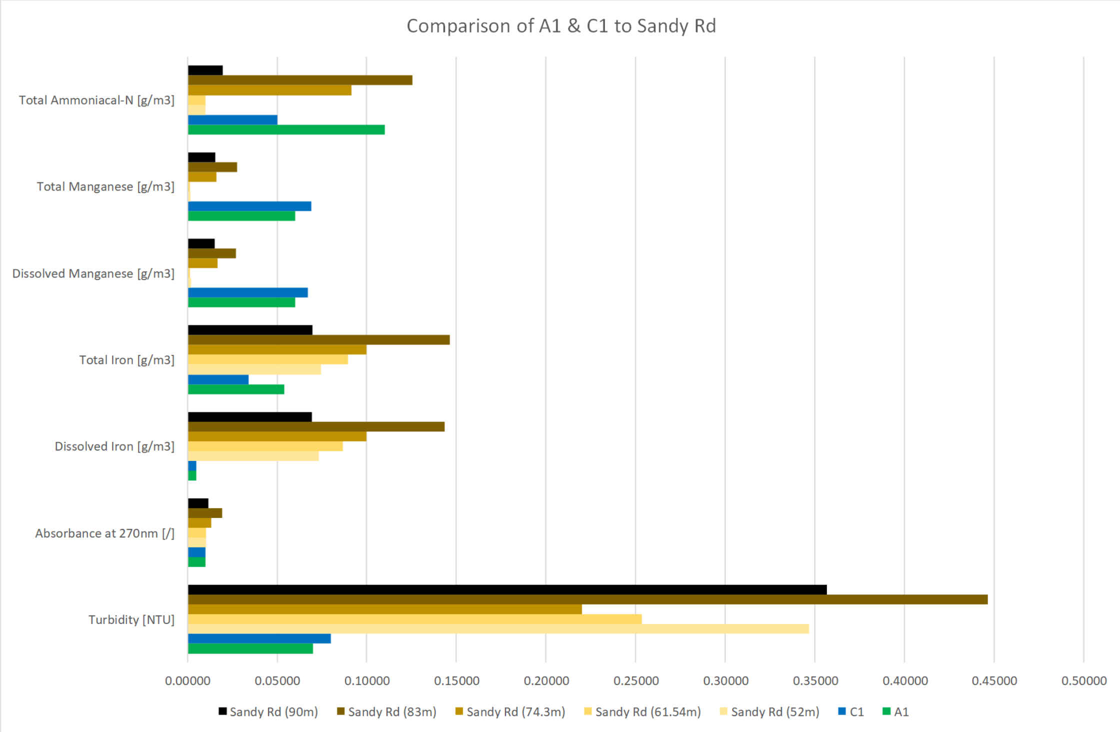


Figure 32: Preliminary water quality results provided from the new NCC bore at Sandy Road, Meeanee compared to A1 and C1 (*provided by NCC*)

The results suggest that dissolved manganese concentrations in the new NCC bore are relatively low compared to the A1 and C1 bores and may be generally comparable to the results from the Guppy Road bore field (i.e. T6 and T7). However, as shown by the elevated turbidity results, these results are from a bore that is not yet completed or developed. Therefore, the results should be treated with considerable caution. Future use of the bore would also be contingent on a resource consent.

1.2.2.5 Groundwater Age Data

Water from all the NCC bores has been aged tested by the Institute of Geological Sciences (GNS). Table 30 summarises the data from those tests.

Table 30: Groundwater mean residence times (after GNS, 2019)

Bore	Mean Residence Time	Minimum Residence Time	Young Fraction
T1 (disused)	27.8	3.6	<0.005%
T2	25.8-50	4-11.6	<0.005%
T3	21	2.6	<0.005%
T4 (disused)	21	14.1	<0.005%
T5	18.4	2	<0.005%
T6	18.1	2	<0.005%
T7	22	5.9	<0.005%
Tannery (disused)	25	5	<0.005%
A1	51	10.6	<0.005%
C1	94	6.6	<0.005%

All the bores fit the 'secure' criteria as defined in Criterion 1 of the DWSNZ because the young fraction of water indicates that almost all water drawn from the bores is more than a year old (based on the samples from the time of the tests). The bores currently have 'interim secure status' based on recommendations from GHD (2018).

Bores T3, T5 and T6 all have minimum residence times of around two years, suggesting that although they fit the definition of a 'secure bore' in the DWSNZ, there is a larger proportion of younger water abstracted by these bores compared to the other bores. The age testing data is not precise; therefore, it suggests that there is a higher risk in bores T3, T5 and T6 compared to the other bores. Note that generally, the bores located furthest from the edge of the confining strata show the greatest water ages (i.e. bores A1 and C1).

While the age dating above indicates older water, there is uncertainty in age testing data so age testing information should never be used in isolation and the detections of total coliforms in all the bores indicate young water is reaching the bores, or potentially that coliforms are being introduced to the bores during activities on the bores themselves (or via a combination of different pathways).

1.2.2.6 Summary of Quality Data and Recommendations for Ongoing Monitoring

The monitoring that is currently carried out gives a good indication of the existing risks to the supplies in terms of bacterial contamination. The data show that despite the age testing indicating a minimum age of more than 2 years, some rapid pathways allowing younger water into the pumped aquifer are likely to be present based on total coliform detections, although there is a possibility that bore maintenance activities on the bores themselves may be contributing to the detections. Good bore hygiene measures and continued monitoring of total coliforms and *E. coli* is recommended to help identify if changes to these pathways occur (e.g. due to development within the SPZs and / or due to changes in the source water). Monitoring of HPCs within the source water and within the distribution network will also enable more detailed assessment of potential risks and effects downstream. Event-based monitoring is also highly recommended, particularly following high rainfall events. For investigational monitoring, it is recommended that larger volume sampling (e.g. two litres for total coliforms) and more intensive sampling is undertaken.

The analysis of the data provided for this report indicates that limited data is available for chemicals within the raw source water. Some bores have more frequent monitoring than others, but in general, frequent monitoring has only occurred since 2019, and not in all the supply bores. This data is insufficient to identify seasonal variations in the concentrations of key chemicals (e.g. ammonia, iron, manganese, and other general chemical indicators like nitrate and chloride). Although the age testing of the water drawn from the bores indicates a small proportion of young water, regular testing of the raw bore water for a general suite of chemicals on a monthly basis can help identify whether seasonal patterns are present. This testing will in turn help to indicate whether rapid pathways from the surface are present. Therefore, monthly testing of the bores for a suite of typical chemicals is recommended.

It may also be prudent to undertake some testing before, during, and after the pump in the bore is started. This could help identify whether rapid pump start-up has an impact on chemical concentrations. 'Soft starts' (i.e. starting to pump a lower rate using a variable speed drive) could help to alleviate some of these issues if they are identified.

A one-off monitoring round of bores within 500 m of each supply bore could also be beneficial to identify the source of contaminants within the source water.

Ongoing monitoring of the potential source risks should continue (e.g. via the JWG and reviews of consent applications within the currently defined SPZs). This type of ongoing monitoring aligns with some that is already defined in the WSP.

As outlined in Section 1.8, some monitoring for contaminants that may not be expected to be present (e.g. a full metals suite, pesticides, herbicides, and other organic contaminants including PFAS) is also recommended together with options for other microbes.

Appendix C: Options and Scope Items

Item	Pre 2017	Pre 2017 Plus	Status Quo	SQ including Mn removal	SQ including Mn removal + UV	Status Quo plus	Dutch Model 1	Dutch Model 2	Dutch Model 3	Pre 2017 - Treatment at Point of Use	Status Quo Plus - Optional Chlorine removal at point of use	Pre 2017 Plus with acoustic sensors	Scope items	Estimating
	1	2	3	4	5	6	7	8	9	10	11	122		
Bore Protection						✔	✔	✔	✔		✔			
Low Mn bores						✔	✔	✔	✔		✔		New bores and associated equipment, VSD pumps, telemetry and SCADA upgrades	VSDs on pumps to all for soft-start and stop
Bore WQ Online monitoring						✔	✔	✔	✔		✔		online monitoring - pH, Turbidity, E.Conductivity,	$50K per site
Fe-Mn Removal				✔	✔	✔	✔	✔	✔		✔		Pressure filters, chemical dosing, chemical mixing, online monitoring, backwash treatment and disposal - sewer connection and balance tank.	pdp estimate from recent project, also use anything from Masterplan, sewer connection, buildings, roads etc.. Check footprint to see if sufficient land is available
Chlorination			✔	✔	✔	✔					✔		chemical storage and dosing, online monitoring and control	pdp estimate from recent project, also use anything from Masterplan, cost estimating curves
UV		✔			✔	✔	✔	✔	✔		✔	✔	duty-standby UV, 2 x 100% reactors, building, power upgrade, online monitoring, flow meters	pdp estimate from recent project, also use anything from Masterplan, cost estimating curves
Direct transmission to SRs						✔	✔	✔	✔		✔		Pipework construction, pressure monitoring	unit rate for pipeline, ensure scope incudes for High Frequency pressure sensors - $2,000/sensors on fire hudrants , pumping station, valve cahamber, air valves, NCC has some costs and pipeline routes for this, ensure contingency for geotech, seismic, check if pumps need to be upgraded
Upgarding SRs - watertight and air filters						✔					✔		new service reservoirs designed to latets standards, materials based on sizie of structure, maximum of 24h storage, water quality monitoring, possible external mixing, baffles, compartments, bypass	Replace with new tanks, minor costs associated with air filters etc.. Some WQ monitoring required, maybe some reservoir mixers, compartments and bypass, backflow prevention, overflow
Backflow prevention on all PS							✔	✔	✔				Installation of Non-return valves	No. of PS and No of valves and upgraded actuators, VSD pumps
Backflow prevention on air valves							✔	✔	✔				Installation of Non return valves	No. of PS and No of valves and upgraded actuators,
District Metering Areas						✔	✔	✔	✔		✔		Define number of zones and install flowmeters and pressure	Check Master plan and scope, will need to have magflow meters on inlets to all DMAs
Pressure Management Zones							✔	✔	✔				identify zones with different pressure requirements, install flow and presure management and booster pumping sations dedicatedto zones	Install HF Pressure sensors, one every 10km, but will need to have a contingency due to the changes in pipe diameter, may need to have additional in High Pressure zones
Universal Water Metering							✔	✔	✔	✔	✔		install water meters onall residentail properties- need to detrmine of SMART Metering is prferred	$500 per property for SMART meter which is required for SMART Newtork at a rate of 4,500 per annum
Universal Backflow prevention							✔						install non return valves on all connection to the distribution netwrok	incuded in smart meter
Acoustic sensors							✔	✔	✔			✔	Install acoustic sensors to detect leaks	install acoustic sensrs every 1000m @$1000 per sensor plus $1000 per isntallation - approx 700 sensors required at a cost of $1.4millon installed
Backflow prevention commercial properties an swimming pool owners								✔					install non return valves on all connection on al comecial ropoerties and any property with a swimming pool	$500 per property for SMART meter which is required for SMART Newtork at a rate of 4,500 per annum
Backflow prevention major users									✔				install non return valves on any user > xx L/day	$500 per property
<5% leakage							✔						Replace all residential service pipes, replace al cast-irom piepwork, replace all pipework >20 years old	Replace 10% of the network every year over a 5 year period, install 700 acoustc sensors @ $2000 per sensor
5-10% leakage								✔					Replace all residential service pipes, replace all cast-irom piepwork, replace pipework > 30 years old	Replace 5% of the network every year over a 5 year period
10 to 15% leakage									✔				Replace all residential service pipes, replace all cast-irom piepwork,	Replace 2.5% of the network over a 5 year period
15 to 20% leakage						✔					✔	✔	Replace all cast-irom piepwork,	Normal repalcement program
Current leakage levels	✔	✔	✔	✔	✔					✔			BAU	Reactive
Automated distribution network							✔	✔	✔				similar system based on either siemens or suez pressure and energy management, requires flow, pressue, acoustic sensors and automation of al valves in the newtork.	Install new software management system $100k set up $100k software purchase plus annual licence fee of $50k per annum
Water Hygiene practices				✔	✔	✔	✔	✔	✔			✔	Training of staff, development of processes and procedures, QA and audit of procedures, include in WSP	Training
Enhanced WQ monitoring in distribution system				✔	✔	✔	✔	✔	✔			✔	installation of E.Conductivity	Sampling
Point of use device - GAC + UV											✔		Installtion of point of use devices at 20% of residential properties	$1000 capital per system, $500 for SMART meter, $1000 per installtion, additional materials $500 - annual opex costs $521 per property as pr email of 18th June 2020
Point of use device Pre-filter + UV										✔			Installation of point of use dvices at all residential properties	$1000 capital per system, $500 for SMART meter, $1000 per installtion, additional materials $500 - annual opex costs $521 per property as pr email of 18th June 2020

Appendix D: Options Evaluation Criteria and Scoring

Scenarios and Options - Assets

Option			Assets						
			Source	Extraction	Treatment at Source	Transmission	Storage*	Distribution	Point of Connection
1	Pre 2017	**No Chlorine,moderate drinking water customer complaints, high public health risk, low cost**	10? active bores	Pumped at boreheads	No disinfection. Turn off suspect bores if contamination detected. Implement constant dose chlorination at bores until .....?	Transmission and distribution network not separated	Mix of new and old reservoirs with > 24 hours storage.	Fully reactive, replace pipes based on leaks. Water loss 20-30% and growing, Issue Boil Water Advice Notice in response to contamination events	Limited point of connection barriers. Identified high risk users may have a backflow prevention device.
2	Pre 2017 Plus	**Chlorine free, managese removal, low DWCC, high public health risk, low cost**	Two dedicated borefields with low Mn and Fe	Pump at Bore Heads	No residual disinfection	Dedicated transmission pipelines to Taradale and Enfield Reservoirs	Aging reservoirs replaced, with dedicated inlet and outlets, storage optimised for water quality. Inlet and outlet flows monitored and metered. Turnover and water quality monitored, enhanced water hygiene practices	Focused mains replacement program driven by condition knowlegde and risk of failure, water loss 15-20%	Limited point of connection barriers. Backflow prevention devices installed on high risk connections
3	Status Quo	**Chlorine,high drinking water customer complaints, moderate public health risk, low cost**	7? Active bores	Pumped at Bore heads	Full time constant dose chlorination at bore	Transmission and distribution network not separated	Mix of new and old reservoirs with > 24 hours storage.	Water loss 20% -30%	Limited point of connection barriers. Backflow prevention devices installed on high risk connection
4	SQ including Mn removal	**Chlorine, manganese removal, low DWCC, moderate public health risk, low cost**	7 Active Bores	Pumped at Bore heads	Full time constant dose chlorination at bore	Transmission and distribution network not separated	Mix of new and old reservoirs with > 24 hours storage.	Water loss 20% -30%	Limited point of connection barriers. Backflow prevention devices installed on high risk connection
5	SQ including Mn removal + UV	**Chlorine, manganese removal, UV, low DWCC, low public health risk, low cost**							
6	Status Quo plus	**Chlorine,low drinking water customer complaints, low public health risk, moderate cost**	Two dedicated borefields with low Mn and Fe	Pumped at Boreheads	Low Mn bores + Chlorination	Dedicated transmission pipelines to Taradale and Enfield Reservoirs	Aging reservoirs replaced, with dedicated inlet and outlets, storage optimised for water quality. Inlet and outlet flows monitored and metered. Turnover and water quality monitored, enhanced water hygiene practices	Focused mains replacement program driven by condition knowlegde and risk of failure, water loss 15-20%	Limited point of connection barriers. Backflow prevention devices installed on high risk connections
7	Dutch Model 1	**No Chlorine,low drinking water customer complaints, low public health risk,initial high cost then moderate long term cost**	Two dedicated borefields with low Mn and Fe	Pumped at boreheads	Low Mn bores + Mn removal + Dechlorination + UV	Dedicated transmission pipelines to Taradale and Enfield Reservoirs	Aging reservoirs replaced, with dedicated inlet and outlets, storage optimised for water quality. Inlet and outlet flows monitored and metered. Turnover and water quality monitored	Heavy investment in watermain renewal and replacement aimed at reducing leaks. Targeted a problem materials and locations, Water Loss <5%	Backflow prevention devices and meters on all connections. Rigorous and routine testing and inspection
8	Dutch model 2	**chorine free, low DWCC, low to medium Public Health risk, moderate to high cost**	Two dedicated borefields with low Mn and Fe			Dedicated transmission pipelines to Taradale and Enfield Reservoirs			Bacflow on swimming pools and non-residential,muti occuopancy
9	Dutch model 3	**chorine free, low DWCC, medium Public Health risk, moderate to high cost**	two dedicated borefields with low Mn and Fe			Dedicated transmission pipelines to Taradale and Enfield Reservoirs		5-10% leaks	BF everywhwre, metering everywhere
10	Pre 2017 - Treatment at Point of Use	**No Chlorine,low drinking water customer complaints, low public health risk, very high cost**	Two dedicated borefields with low Mn and Fe	Pumped at boreheads		Transmission and distribution network not separated	Mix of new and old reservoirs with > 24 hours storage.	Fully reactive, replace pipes based on leaks. Water loss 20-30% and growing,	Limited point of connection barriers. Backflow prevention devices installed on high risk connections
11	Status Quo Plus - Optional Chlorine removal at point of use	**No Chlorine beyond connection, low drinking water customer complaints, moderate public health risk, very high cost**	7? Active bores	Pumped at boreheads	Mn removal and Chlorination	Transmission and distribution network not separated	Mix of new and old reservoirs with > 24 hours storage.	Fully reactive, replace pipes based on leaks. Water loss 20-30% and growing	Limited point of connection barriers. Identified high risk users

*Possible to treat at reservoirs rather than boreheads once dedicated transmission lines in place

Scenarios and options -AM Systems and Practices

			Asset Management Systems & Practices				
			Leakage and Water Loss Management	Water Safety Plans	System Monitoring and Control	Maintenace and Renewal Processes and Systems	Water Network Model
1	Chlorine Free - pre 2017 configuration	**No Chlorine,moderate drinking water customer complaints, high public health risk, low cost**	No dedicated program. Reactive	Water safety plan not likely to be approived approved due to operation without residual disinfection	SCADA system monitors bore pumps and reservoir levels	Mainly reactive maintenance with pigging and flushing in problem areas.	No water network model. System opertated using gut-feel.
	Pre 2017 Plus						
2	Status Quo	**Chlorine,high drinking water customer complaints, moderate public health risk, low cost**	No dedicated program. Reactive	Existing WSP based on 2018 requirements.Water Safety Plan being prepparered for new 2018 framework	SCADA system monitors bore pumps and reservoir levels	Mainly reactive maintenance with pigging and flushing in problem areas. Fix leaks on reactive basis	Water Network Model developed and configured
	Status quo including Mn removal		No dedicated program. Reactive	Existing WSP based on 2018 requirements.Water Safety Plan being prepparered for new 2018 framework	SCADA system monitors bore pumps and reservoir levels	Mainly reactive maintenance with pigging and flushing in problem areas. Fix leaks on reactive basis	Water Network Model developed and configured
3	Status Quo plus	**Chlorine,low drinking water customer complaints, low public health risk, moderate cost**	DMAs implementeted with proactive leak detection and management	Approved Water Safety Plan under 2018 framework	Reatime system monitoring and control of district meters, mains pressure	Asset Replacement Programme driven by a sound understanding of asset condition and of risk . Proactive condition assessment programme drives maintenance and renewal. Moving towards ISO 55000 compliance	Real-time monitoring of flow used to calibrate model.
4	Dutch model 1	**No Chlorine,low drinking water customer complaints, low public health risk,initial high cost then moderate long term cost**	DMAs implementeted with proactive leak detection and management including minmum nightflow testing and acoustic location of leaks.	Approved water safety plan with dispensation fom the Drinking Water Regulator to operate without residual disinfectant as per Water Service Bill currently before parliament	Reatime system monitoring and control of district meters, mains pressure and key water quality indicators	Strongly proactive asset management approach, predictive models of deterioration of condition and leakage ISO 55000 accreditation.	Water modeling includes calibration of pressure and flow and includes modeling of water quality and time in system.
5	Dutch model 2		DMAs implementeted with proactive leak detection and management including minmum nightflow testing and acoustic location of leaks.	Approved water safety plan with dispensation fom the Drinking Water Regulator to operate without residual disinfectant as per Water Service Bill currently before parliament	Reatime system monitoring and control of district meters, mains pressure and key water quality indicators	Strongly proactive asset management approach, predictive models of deterioration of condition and leakage ISO 55000 accreditation.	Water modeling includes calibration of pressure and flow and includes modeling of water quality and time in system.
6	Dutch model 3		DMAs implementeted with proactive leak detection and management including minmum nightflow testing and acoustic location of leaks.	Approved water safety plan with dispensation fom the Drinking Water Regulator to operate without residual disinfectant as per Water Service Bill currently before parliament	Reatime system monitoring and control of district meters, mains pressure and key water quality indicators	Strongly proactive asset management approach, predictive models of deterioration of condition and leakage ISO 55000 accreditation.	Water modeling includes calibration of pressure and flow and includes modeling of water quality and time in system.
7	Chlorine Free - Treatment at Point of Use	**No Chlorine,low drinking water customer complaints, low public health risk, very high cost**	No dedicated program. Reactive	Water safety plan not likely to be approved due to operation without residual disinfection	SCADA system monitors bore pumps and reservoir levels	Mainly reactive maintenance with pigging and flushing in problem areas.	Water Network Model developed and configured
8	Status Quo Hybrid - Optional Chlorine removal at point of use	**No Chlorine beyond connection, low drinking water customer complaints, moderate public health risk, very high cost**	No dedicated program. Reactive		SCADA system monitors bore pumps and reservoir levels	Mainly reactive maintenance with pigging and flushing in problem areas.	Water Network Model developed and configured

Evaluation Criteria/Notes

Capital Cost	Realtive cale of capital investment required, low score = high investment, high score = low investment, 5= <$50 million, 4 =$50 t0 $100 million, 3 = $100 to $150 million, 2 = $150 to $200 million, 1 = >$200 million
Operating Cost	Realtive scale of operating cost increase, low score = high increase, high score = little or no increase, 5= no increase, 4 =, 3 = , 2 = , 1 = significant increase in operating costs
Construction Complexity	Complexity in construction and management of the program, low score = highly complex, high score = low complexity, 5= minimal number of projects, 4 =, 3 = , 2 = , 1 = signifcant number of projects and interfaces
Operational Complexity	Realtive complexity in operation of new system - high level of automation would be viewed as less complex, low score = highly complex, high score = low complexity, 5= minimal change to current operations 4 =, 3 = , 2 = , 1 = signifcant increase in complex operations requiring highly skilled workforce
Water Security	Realative impact on ability to meet current and future warer demand, options which reduce leakage would be deemed to be high scoring - low score = unable unable to meet future demand low levels of leakage, high score = lhigh degree of water security, 5= high level of water security, 4 =, 3 = , 2 = , 1 = low level of reducndancy in water security and no impact on current leakage
Time to Implement	Relative Timeframe tofully implement strategy, low score = >10 years, high score = <1 year, 5= >< year, 4 = 2 1 to 2 years, 3 = 2 to 3 years, 2 = 5 to 10 years , 1 = >10 years
Proven Technology	Not recommending any technology that has not been successfully proven elesewhere, will be increase in technhnoloy for NCC but covered in other criteria
Employee Health and Safety Risk	All new installations would be compliant with best practice for OH+S. Some options will have increased number of operational duties but we would not recommend anything that would put employees at significant risk
Public Health risk	Ability of the strategy to protect public health from waterborne disease, low score = highest risk, high score = lowest risk, 5 = multiple barriers, 1= least number of barriers
Environmental Risk	Environmenatl risk has been considered and no significant risks identified associated with any of the options, it should be noted that Point of use devices would require significant increase in disposal of uv lamps and carbon filters
Cultural (Iwi) acceptance	Relative likelihood of option being acceptable to Iwi, options which conserve water (low leakage) and use minial chemical addition would score highly low score = highly unacceptable, high score = acceptable, 5 = no Iwi issues, 1 = not acceptable
Legal & Compliance Risk	Realtive Aability of option to have approved WSP and compliance with DWSNZ by Ministry of Healh and local DWA, low score = WSP unobtainable, high score = WSP approval highly likley, ANY OPTION SCORING A 1 IN THIS CATERGORY WOULD NOT BE ELIGIBLE TO MAKE THE SHORTLIST
Public Acceptability	Option has full support of the local community T+O and cost low score = unacceptable to majority of local resident, high score = acceptable to majority of local residents
Likelihood of Exemption	The is associated with chlorine free options, and is covered in Legal and compliance risk - would be double counting
Drinking Water Customer Complaints	Numbers of DWCC - it is accepted that Mn levles of <10 ug/L would score highly, historic levels of customer compliant pre-2017 indicate higher levels of soluble Mn give low levels of DWCC, low score = high number of DWCC, high score = low number of DWCC, 5 = <2, 000, 4 = 2 to 5, 1 = >20
Council Liability	Exposure of NCC to public liability claims, low score = signifcant risk, high score = reduced risk, 5 = reduction, 3 = no increase, 1 = significant increase
Workforce Impact	Need to increase workforce numbers and skill level, low score = significant increase in number and skill level, high score = no increase, 5 = no increase in staffing numbers, 1 = significant increase

Non-Cost

Weighted

	Economic		Technical						Health & Environment			Social & Political					Performance						
	Capital Cost	Operating Cost	Construction Complexity	Operational Complexity	Water Security	Time to Implement	Proven Technology	Employee Health & Safety Risk	Public Health Risk	Environmental Risk	Cultural (iwi) acceptance	Legal & Compliance Risk	Public Acceptability	Likelihood of Exemption	Drinking Water Customer Comp.	Total Raw Scores	Ranking	Raw Non-Cost	Ranking	Weighted Non Cost	Ranking	# Si
Weighting			5%	5%	5%	5%			20%		10%	20%	15%		15%							
Pre 2017	●●●●●	●●●●●	●●●●●	●●●●●	●●	●●●			●		●●●	●	●●●		●●●●	37	4	27	5	2.5	9	●●
Pre 2017 Plus	●●●●◐	●●●●◐	●●●●	●●●●	●●	●●●●			●◐		●●●	●	●●●		●●●●	35.5	5	26.5	9	2.55	8	●
Status Quo	●●●●●	●●●●◐	●●●●●	●●●●●	●●	●●●●●			●●		●●	●	●		●	33.5	8	24	10	1.95	11	●●●
SQ including Mn removal	●●●●◐	●●●●	●●●●	●●●●	●●	●●●●			●●		●●	●	●●●		●●●●●	35.5	5	27	5	2.7	7	●
SQ including Mn removal + UV	●●●●	●●●◐	●●●◐	●●●◐	●●	●●●●			●●●		●●	●●●●●	●●●		●●●●●	38.5	2	31	=2	3.65	3	
Status Quo plus	●●●◐	●●●	●●●	●●●	●●●	●●			●●●◐		●●●	●●●●●	●●●◐		●●●●●	37.5	3	31	=2	3.83	2	
Dutch Model 1	●●	●●	●●	●●●	●●●●●	●			●●●●◐		●●●●●	●●●●●	●●●●●		●●●●●	39.5	1	35.5	1	4.45	1	●
Dutch Model 2	●●●	●●◐	●●●	●●●	●●●●	●●			●●●●		●●●●	●	●●●●		●●●●●	35.5	5	30	4	3.35	5	●
Dutch Model 3	●●●	●●●	●●●	●●●	●●●●	●●			●●●		●●●	●	●●●		●●●●●	33	9	27	5	2.9	6	
Pre 2017 - Treatment at Point of Use	●	●	●	●	●●	●			●●◐		●●●	●	●		●●●●	18.5	11	16.5	11	2	10	●●●●●●●
Status Quo Plus - Optional Chlorine removal at point of use	●●	●●	●●	●●	●●●	●●			●●●		●●	●●●●●	●●●		●●●●●	31	10	27	5	3.45	4	
Pre-2017 with acoustic sensors	●●●●	●●●●	●●●●	●●●●	●●●	●●●●			●●		●●●	●	●●●		●●●●	36		28				

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Cost

50% Weighted Average

Category	Criterion	Weighting
Economic	Capital Cost	25%
	Operating Cost	25%
Technical	Construction Complexity	4%
	Operational Complexity	4%
	Water Security	4%
	Time to Implement	4%
	Proven Technology	
Health & Environment	Employee Health & Safety Risk	
	Public Health Risk	15%
	Environmental Risk	
Social & Political	Cultural (Iwi) acceptance	5%
	Legal & Compliance Risk	5%
	Public Acceptability	5%
	Likelihood of Exemption	
	Drinking Water Customer Comp.	5%

Option	Total Raw Scores	Ranking	Raw Non-Cost	Ranking	Weighted Non Cost	Ranking	50% Weighted Non Cost	Ranking	# Single	Avg weighted po	Rank
Pre 2017	37	4	27	9	1.3	9	3.8	1		5	4
Pre 2017 Plus	35.5	5	27	8	1.3	8	3.6	2		5	4
Status Quo	33.5	8	24	10	1.2	10	3.6	3		6.5	8
SQ including Mn removal	35.5	5	27	7	1.4	7	3.5	5		6	7
SQ including Mn removal + UV	38.5	2	31	4	1.7	4	3.6	3		3.5	1
Status Quo plus	37.5	3	31	2	1.8	2	3.4	6		4	1
Dutch Model 1	39.5	1	36	1	2.1	1	3.1	8		4.5	2
Dutch Model 2	35.5	5	30	3	1.8	3	3.1	7		5	4
Dutch Model 3	33	9	27	6	1.5	6	3	9		7.5	9
Pre 2017 - Treatment at Point of Use	18.5	11	17	11	1	11	1.5	11		11	11
Status Quo Plus -Optional Chlorine removal at point of use	31	10	27	5	1.5	5	2.5	10		7.5	9
Pre-2017 with acoustic sensors	36		28								

Cost

30% Weighted Average

	Economic		Technical					Health & Environment			Social & Political					Performance										
	Capital Cost	Operating Cost	Construction Complexity	Operational Complexity	Water Security	Time to Implement	Proven Technology	Employee Health and Safety Risk	Public Health risk	Environmental Risk	Cultural (Iwi) acceptance	Legal & Compliance Risk	Public Acceptability	Likelihood of Exemption	Drinking Water Customer Comp.	Total Raw Scores	Ranking	Raw Non-Cost	Ranking	Weighted Non Cost	Ranking	30% Weighted Non Cost	Ranking	# Single	Avg weighted p	Ran
Weighting	15%	15%	5%	5%	5%	5%			25%		6%	6%	6%		6%											
Pre 2017	●●●●●	●●●●●	●●●●●	●●●●●	●●	●●●			●		●●●	●	●●●		●●●●	37	4	27	9	1.69	9	3.19	5	●●	7.00	6
Pre 2017 Plus	●●●●◖	●●●●◖	●●●●	●●●●	●●	●●●●			●◖		●●●	●	●●●		●●●●	35.5	5	26.5	8	1.76	8	3.11	7	●	7.50	7
Status Quo	●●●●●	●●●●◖	●●●●●	●●●●●	●●	●●●●●			●●		●●	●	●		●	33.5	8	24	10	1.66	10	3.09	8	●●●	9.00	10
SQ including Mn removal	●●●●◖	●●●●	●●●●	●●●●	●●	●●●●			●●		●●	●	●●●		●●●●●	35.5	5	27	7	1.89	7	3.16	6	●	6.50	5
SQ including Mn removal + UV	●●●●	●●●◖	●●●◖	●●●◖	●●	●●●●			●●●		●●	●●●●●	●●●		●●●●●	38.5	2	31	4	2.34	4	3.46	2		3.00	3
Status Quo plus	●●●◖	●●●	●●●	●●●	●●●	●●			●●●◖		●●●	●●●●●	●●●◖		●●●●●	37.5	3	31	2	2.46	2	3.43	3		2.50	2
Dutch Model 1	●●	●●	●●	●●●	●●●●●	●			●●●●◖		●●●●●	●●●●●	●●●●●		●●●●●	39.5	1	35.5	1	2.93	1	3.53	1	●	1.00	1
Dutch Model 2	●●●	●●◖	●●●	●●●	●●●●	●●			●●●●		●●●●	●	●●●●		●●●●●	35.5	5	30	3	2.48	3	3.30	4	●	3.50	4
Dutch Model 3	●●●	●●●	●●●	●●●	●●●●	●●			●●●		●●●	●	●●●		●●●●●	33	9	27	6	2.10	6	3.00	9		7.50	7
Pre 2017 - Treatment at Point of Use	●	●	●	●	●●	●			●●◖		●●●	●	●		●●●●	18.5	11	16.5	11	1.44	11	1.74	11	●●●●●●●	11.00	11
Status Quo Plus -Optional Chlorine removal at point of use	●●	●●	●●	●●	●●●	●●			●●●		●●	●●●●●	●●●		●●●●●	31	10	27	5	2.14	5	2.74	10		7.50	7
Pre-2017 with acoustic sensors	●●●●	●●●●	●●●●	●●●●	●●●	●●●●			●●		●●●	●	●●●		●●●●	36		28								

Appendix E : Slides from Council Workshop on 28 January 2021

Chlorine Free Review

Options for the Provision of Safe Drinking Water to Napier City

1

Agenda

- Introduction and Update – Cath Bayly
- Chlorine Free Review Process - Tony Urquhart
- A Roadmap to Move Forward - Tony Urquhart/Peter Hillis/Colin Fricker
- Review Findings, Options and Costs - Peter Hillis
- Peer Review Process - Peter Free
- Feedback and Discussion
- Next Steps

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Introduction

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- December 2019 – Council meeting resolved to proceed with review with decision on consultant appointment to come back to Council
- 2 Stage Procurement Process, ROI and shortlist RFP
- 7 Registrations of Interest
- 4 invited to RFP stage
- Probity Advisor – McHale Group
- Councillor Simpson observed procurement process
- RFP Responses Covid impacted
- 20 May 2020 – Extraordinary Meeting of Council for approval to engage Pattle Delamore Partners
- Thursday 9th July Workshop with Councillors

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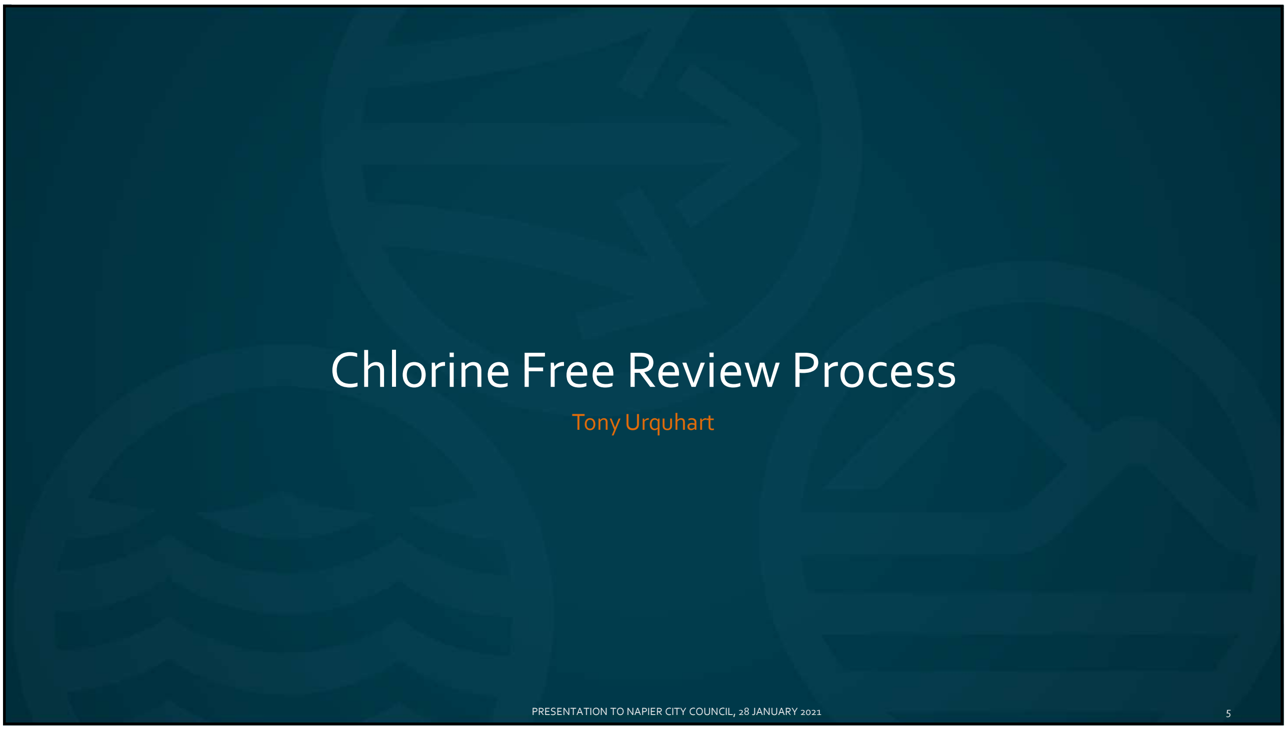
Chlorine Free Review Process
Tony Urquhart
PRESENTATION TO NAPIER CITY COUNCIL, 28 JANUARY 2021
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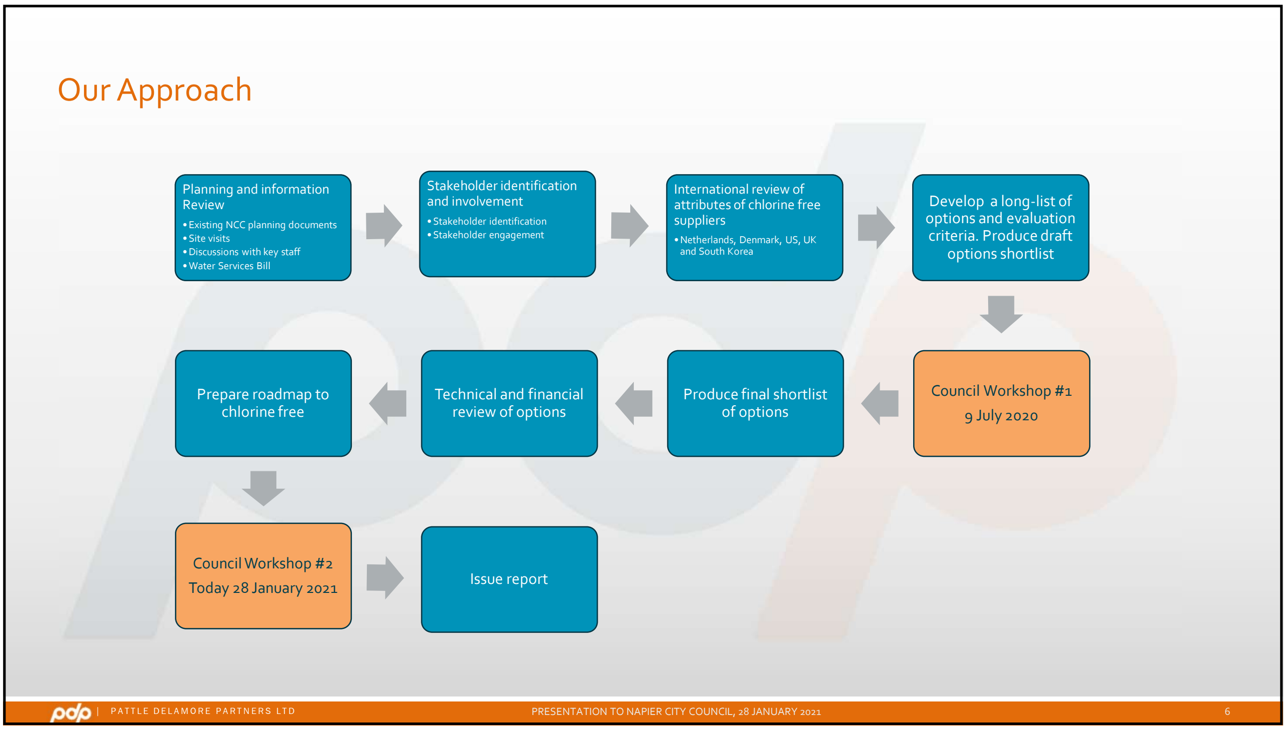
5


Our Approach
Planning and information Review
• Existing NCC planning documents
• Site visits
• Discussions with key staff
• Water Services Bill
Stakeholder identification and involvement
• Stakeholder identification
• Stakeholder engagement
International review of attributes of chlorine free suppliers
• Netherlands, Denmark, US, UK and South Korea
Develop a long-list of options and evaluation criteria. Produce draft options shortlist
Council Workshop #1
9 July 2020
Produce final shortlist of options
Technical and financial review of options
Prepare roadmap to chlorine free
Council Workshop #2
Today 28 January 2021
Issue report
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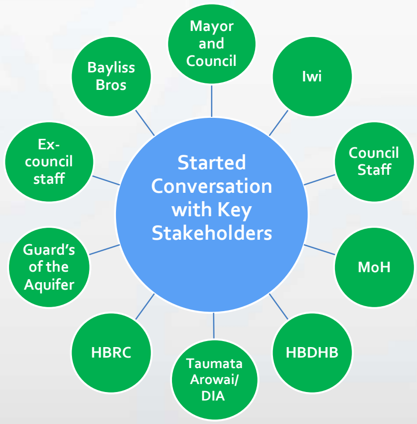
6

Stakeholders

Initial consultation has been undertaken with a wide group of stakeholders. It is important to continue to involve these interested parties in decision-making



7

Review Findings, Options and Costs

Tony Urquhart/Peter Hillis

8

Water Industry Reform Regulatory Changes

- The Havelock North Drinking Water Inquiry recommendations are being implemented via the Water Services Bill.
- A new water industry regulator Taumata Arowai has been established and will take effect on 1 July 2021.
- Napier City Council has a number of duties , obligations and functions under the bill. A key obligation is the production and implementation of an approved water safety plan.
- Residual disinfection (chlorine) is a mandatory requirement with exemptions only where the supplier can satisfy Taumata Arowai that the water supplied is safe.
- Our team met with representatives from the Ministry of Health, HBDHB and the Taumata Arowai Establishment Unit /Department of Internal Affairs to seek clarification on the likely requirements for an exemption.
- While the final policy is still to be developed it is likely that to achieve an exemption, suppliers must demonstrate that:
  - **Multiple barriers against contamination** of drinking water are being maintained
  - That the existing **drinking water system must be demonstrably secure** from contamination and managed in a manner that demonstrates a deep understanding of system condition, performance, and risks - consistent with international best practice.
  - That **high levels of monitoring** of drinking water quality will be required.
  - **Backflow prevention devices will required** on all connections
  - **That 'leakage' levels of around 5%** are indicative of the level of system integrity and security required to gain an exemption to operate without residual disinfection

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Characteristics of Napier City Councils Drinking Water System

- All water sourced from local artesian bores
- Chlorination currently at source using 'temporary' chlorination facilities. Pre-2017 drinking water was chlorine free.
- Dirty water customer complaints (DWCC) exacerbated by chlorination
- Significant concern from some residents/groups on use of chlorine
- Very high peak summer demand – reservoir and system capacity issues
- Seismically active zone - pipe network and service reservoirs potentially vulnerable.
- Currently planned system improvements:
  - Consolidating bore-fields
  - UV disinfection
  - Installing new dedicated transmission mains
  - Reservoir upgrades and replacements (e.g. Enfield)
  - Mains replacement programme
  - Universal water metering
  - Backflow prevention on high risk connections
  - Leak detection, DMAs and non-revenue water management – initial works shows system leakage could be higher than expected

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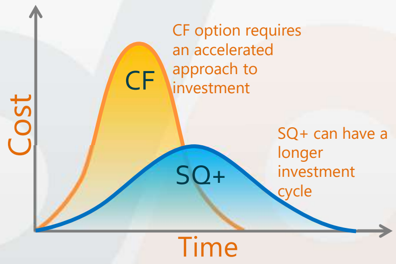
Does the proposed investment (Status Quo+) get us to Chlorine Free?

- Moving to chlorine free drinking water is achievable
- CF will require significant up-front investment in accelerating network re-configuration, reservoir and pipeline replacement (and asset management).
- Expenditure at current levels is insufficient
- There is a lack of performance and condition data on the distribution network to enable staff to make evidence based decisions on system renewal and replacement.
- NCC must also invest in better asset management systems and processes to ensure expenditure is directed to the assets that present the highest risk.
- The largest constraints are:
  - Affordability and willingness to pay
  - Availability of resources to undertake the work
  - Customer tolerance of disruption



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A Roadmap to Move Forward

Colin Fricker/Peter Hillis

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The Water Services Bill

- There are three fundamentals that are crucial to chlorine-free
- Protection of source water
- Provision of a multi-barrier approach to treatment
- Having a drinking water safety plan that identifies risk and documents mitigation strategies

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Public health risks from chlorine-free water

- The occurrence of pathogens in raw water can change rapidly even in apparently "secure" groundwater
- The presence of chlorine in the water in Havelock North would have prevented the outbreak
- More waterborne disease is now caused by post-treatment contamination then by failure of treatment
- Chlorine protects against growth of bacteria (including pathogens) in the distribution network

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Mitigation steps for chlorine-free

- Install alternative robust primary disinfection (uv)
- Appropriate uv would also have prevented the outbreak at Havelock North
- Ageing infrastructure and improvements in treatment have led to both sporadic disease and outbreaks being more frequently caused by post-treatment contamination – improve the infrastructure
- The contribution of regrowth bacteria to disease has been clearly established; worlds best practice – prevent regrowth

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Key Findings

- Existing system
  - Source
  - Treatment
  - Transmission
  - Distribution
- Global lessons
  - What does a CF look and feel like?
  - What is relevant to NCC?
  - How do we get to 5% leakage?
- What is required under NZDWS?

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Existing system

- Source
  - Not 100% secure – under new regulations
  - Evidence of surface contamination – from NCC data
  - Fe and Mn present at levels which cause DWCC in chlorinated system - >10 ug/L
- Short-term Actions
  - Improved water hygiene practices - training
  - Enhanced water quality monitoring – large volume
  - Provision of UV disinfection
  - Upgrade/replace existing chlorine systems – fail safe, H+S
  - Primary objective – Public Health Protection

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Global Lessons

- What does a CF system look and feel like?
  - Source protection - QMRA
  - Adequate treatment – chemical and microbial contaminants, biologically stable water
  - Enhanced water hygiene practices
  - Secure transmission and storage – no contamination
  - District Metering Areas
  - Household water meters
  - Backflow prevention
  - <5% leakage
  - SMART Network
  - Enhanced water quality monitoring
  - Enhanced Asset Management
  - >1% per annum mains replacement
  - Customer and community buy-in and willingness to pay

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Global Lessons

- What is relevant to NCC?
  - All of it?
  - Source – specific to local aquifer
  - Treatment – specific to local water quality, likelihood existing supply is biologically stable – high quality bore water – low organic carbon content – low risk of DBPs, low Mn borehole investigation, UV treatment and upgraded chlorine system
  - Transmission and storage – new service reservoir(s), air-filters/screens on vents, hydraulic performance (water age and mixing)
  - Distribution system – understand leakage and NRW, significant replacement programme, SMART network operation (monitoring, control, automation), DMA's
  - Customers – metering and backflow prevention
  - Enhanced water quality monitoring – establish baseline and link improvements to investment
  - Enhanced water hygiene practices – training of all involved in water supply
  - Asset Management – review of current practices and implementation of World Class Asset Management Plan

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Global Lessons

- How do we get to 5% leakage
  - Who has achieved this?
    - Dutch, Danes, Germans, South Koreans
  - Who is the most relevant?
    - South Korea
    - Historic high levels of leakage (>30%)
  - How do you get there?
    - Understand the problem – where?, how much? Quick wins
    - Aggressive mains replacement programme - >1.5% per annum, up to 80% of total network
    - Selection of pipe materials – HDPE
    - Targeted replacement – cast iron, AC
    - Long term sustainable approach – 1% per annum
  - How long will it take?
    - Depends where you start!

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Options and Costs

What are the options?

- Chlorine
  - Status Quo plus
  - Staus Quo lite
- Chlorine-Free
  - Dutch Model
  - Point of Use
  - Pre 2017
  - Pre-2017 plus - acoustic sensors, service reservoirs, water hygiene

20-year financial modelled 4 scenarios

Scenario	Details	Estimated 20-year total cost
Status Quo	Investment as per the NCC Draft Long Term Plan (and WS Network Master Plan) which is cash constrained with slow incremental improvement in renewals . Maintain water loss at current levels (23%). Maintain AM practices at the "core" level. New staff (3) limited to operate bore fields and treatment plant. Acoustic leak detection of entire network on a 3 year cycle, as per current, establish DMAs, universal metering, backflow prevention, upgrade SCADA. Level of investment is unlikely to achieve the level of network integrity required for chlorine free as pipeline replacement rates are initially too low to get on top of deterioration.	$178M
Status Quo +	Investment as per the NCC long-term plan (and WS Network Master Plan), plus aggressively replace cast iron pipe by 2030, then ongoing investment at 2% of network per annum. Lift AM practices to "intermediate" level by 2030. New staff (3 ops and 3 AM). Reduce water loss to 15% by 2030 and 12% by 2040 through cast iron mains replacement, aggressive leak detection, formation of DMAs, enhanced backflow prevention. Unlikely to get regulator approval to go to chlorine free but deterioration of network under control.	$221M
Status Quo + Lite	Status quo plus at reduced 1.5% pipe replacement rate after 2030	$209M
Chlorine Free (Dutch model)	Total investment as per the NCC long-term plan (and WS Network Master Plan) but accelerated timing, plus aggressively replace cast iron pipe by 2030, then ongoing aggressive investment at 3.5% of network per annum. Lift AM practices to "advanced" (ISO 55000) by 2030 and staff accordingly (3 ops and 4 AM) Reduces water loss sto less than 10% by 2040 through smart water network/automation, leak detection, DMAs, universal metering and backflow prevention.	$284M

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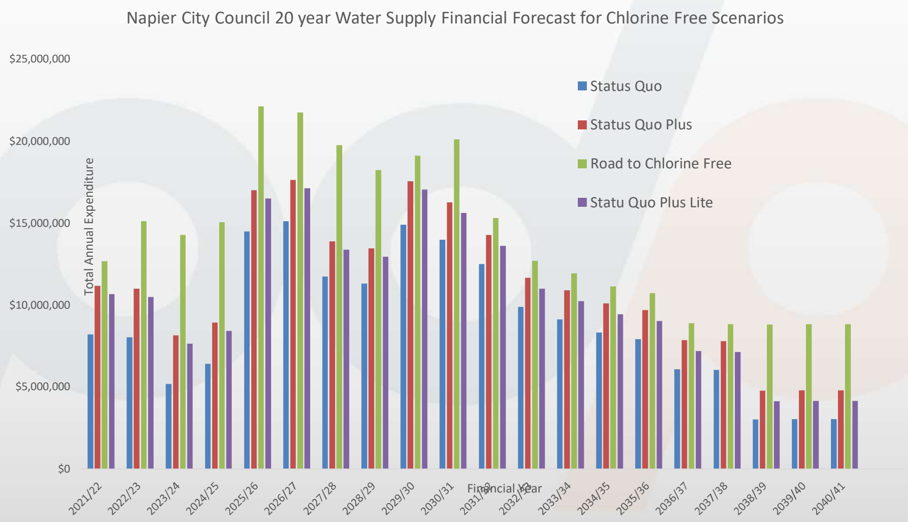
Modelled 4 scenarios over 20 years



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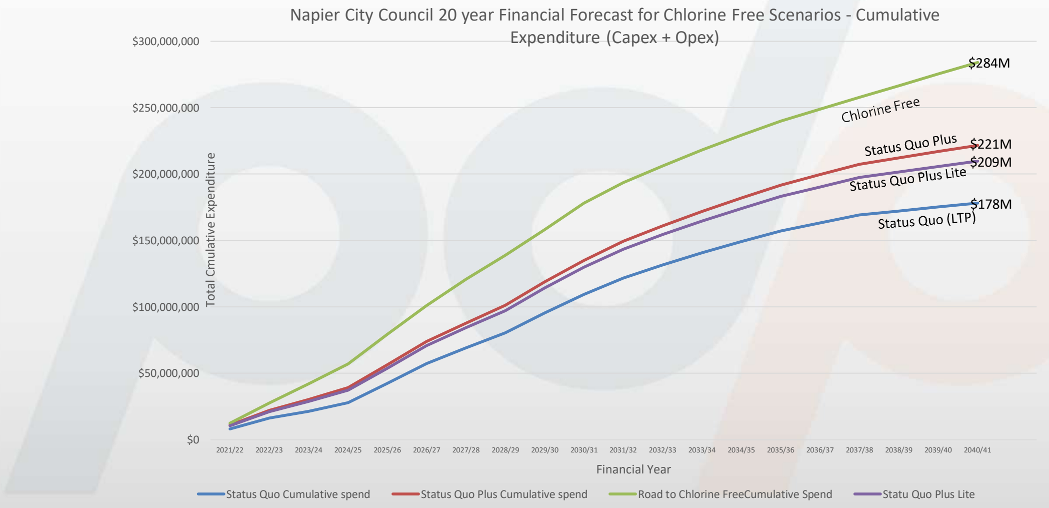
Total costs of options over 20 years



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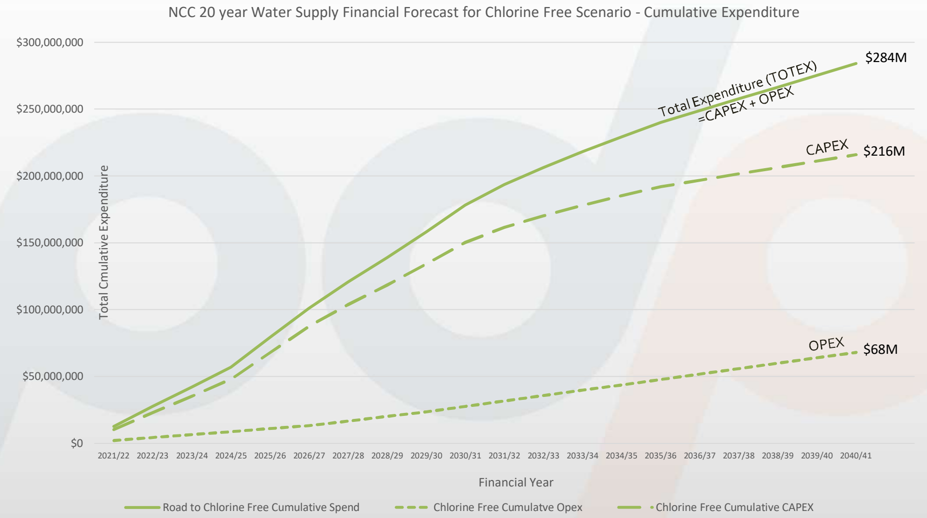
Chlorine Free Option – Capex and Opex



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What are the evaluation criteria?

- CAPEX
- OPEX
- Chlorine-free exemption – legal and compliance risk- **hurdle criteria**
- Public Health risk
- Time
- Complexity
- Water security
- Public acceptability
- Cultural acceptability

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Option 12

- Did not make the top four under all sensitivities
- Does not meet the hurdle criteria - <5% leakage
- Improves pre-2017:
  - Water security through reduced leakage
  - Public Health through early leak detection
- Part of other options and the recommended strategy to reduce and maangement leaskage in the water network

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Item	Option 5 5	Option 6 6	Option 7 7	Option 11 11
Bore Protection		✓	✓	✓
Low Mn bores		✓	✓	✓
Bore WQ Online monitoring		✓	✓	✓
Fe-Mn Removal	✓	✓	✓	✓
Chlorination	✓	✓		✓
UV	✓	✓	✓	✓
Direct transmission to SRs		✓	✓	✓
Upgrading SRs - watertight and air filters		✓	✓	✓
Backflow prevention on all PS			✓	
Backflow prevention on air valves			✓	
District Metering Areas		✓	✓	✓
Pressure Management Zones			✓	
Universal Water Metering			✓	✓
Universal Backflow prevention			✓	
Acoustic sensors			✓	
<5% leakage			✓	
15 to 20% leakage		✓		✓
Current leakage levels	✓			
Automated distribution network			✓	
Water Hygiene practices	✓	✓	✓	✓
Enhanced WQ monitoring in distribution system	✓	✓	✓	✓
Point of use device - GAC + UV				✓

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What is the outcome?

- Dutch based model is preferred CF option
  - Ability to obtain an exemption
  - Public Health protection
- SQ+ is preferred Chlorine-based option
- What is the preferred strategy?
  - Short-term - <5 years
  - Medium-term 5 to 10 years
  - Long-term - >10 years
- What is the preferred approach?
  - Phased and targeted
  - Evidence based
  - Safe and secure water

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Getting to Chlorine Free

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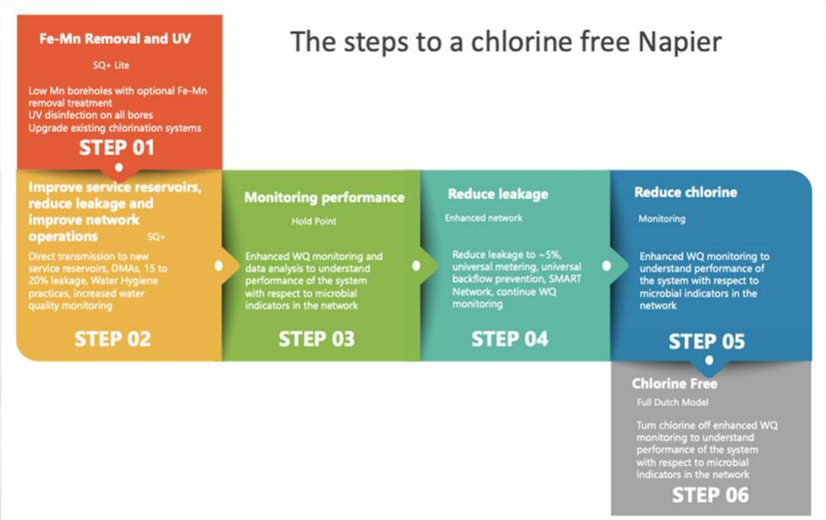

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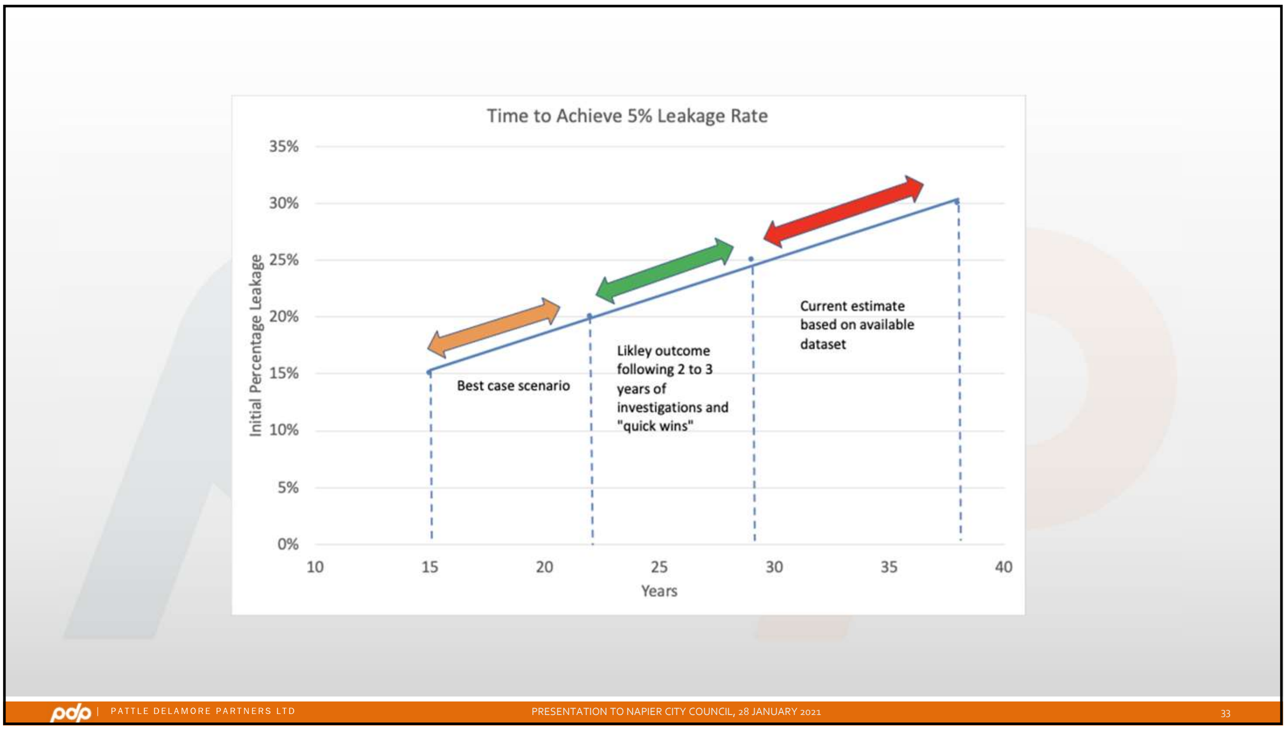

Time to Achieve 5% Leakage Rate
Initial Percentage Leakage
35%
30%
25%
20%
15%
10%
5%
0%
10
15
20
25
30
35
40
Years
Best case scenario
Likley outcome following 2 to 3 years of investigations and "quick wins"
Current estimate based on available dataset
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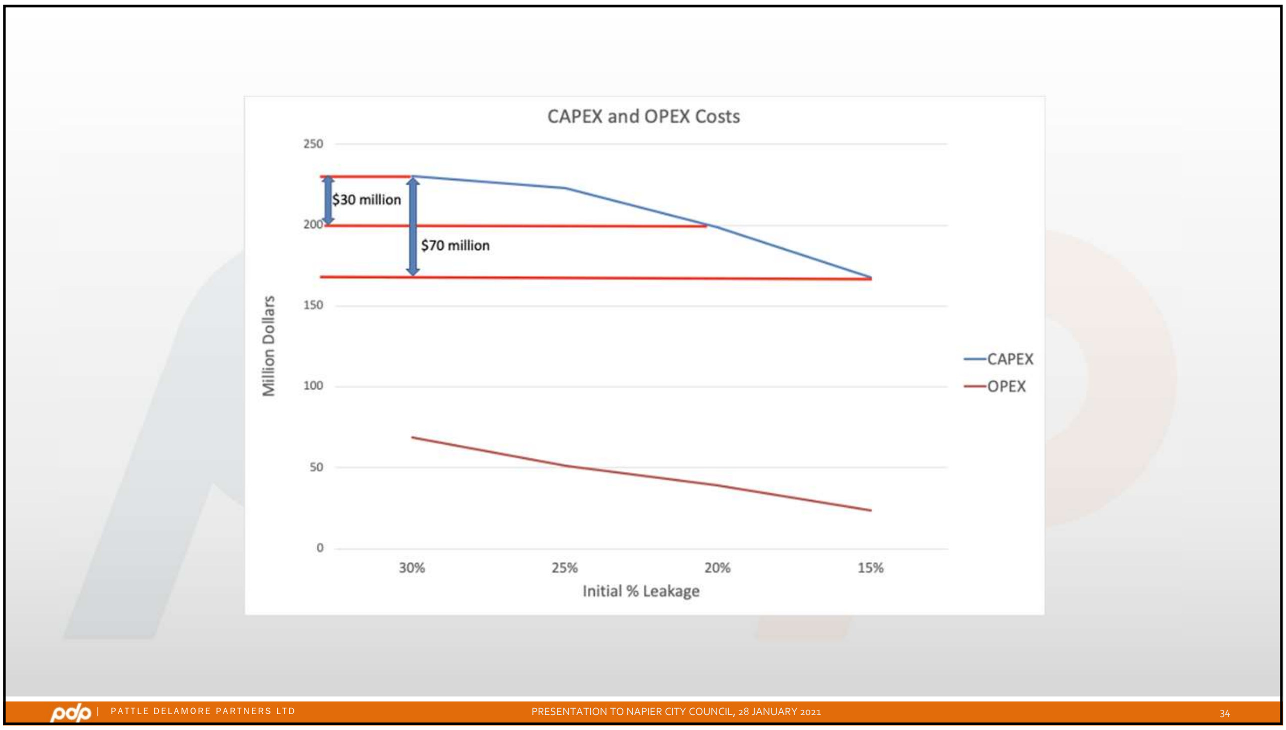

CAPEX and OPEX Costs
Million Dollars
250
200
150
100
50
0
$30 million
$70 million
30%
25%
20%
15%
Initial % Leakage
CAPEX
OPEX
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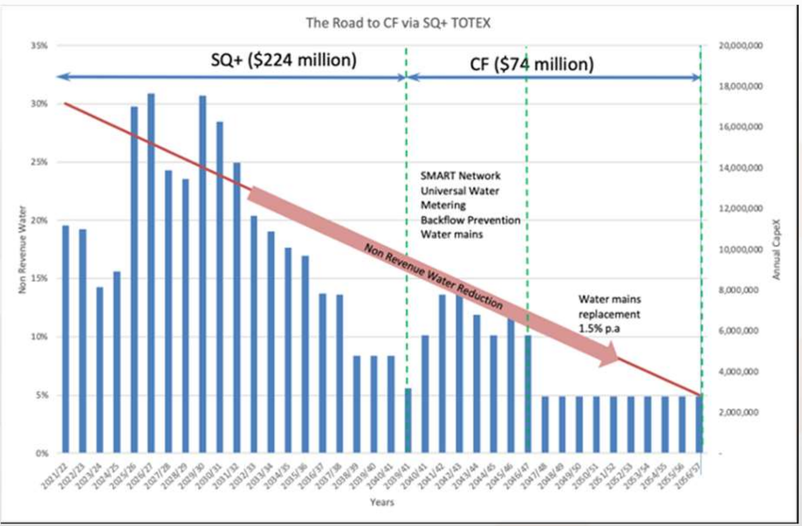

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Summary

- There is a clear path to a chlorine-free water supply for Napier
- There is no "quick-fix"
- There are clear criteria that must be met to gain a chlorine-free exemption
- There are constraints – financial, workforce etc..
- There are knowledge gaps – known and unknown
- Three pillars:
  - Public Health
  - Infrastructure
  - Asset Management
- There is opportunity for NCC to create a world class chlorine-free water supply system based on evidence, competence, collaboration, compliance, patience and clarity of purpose

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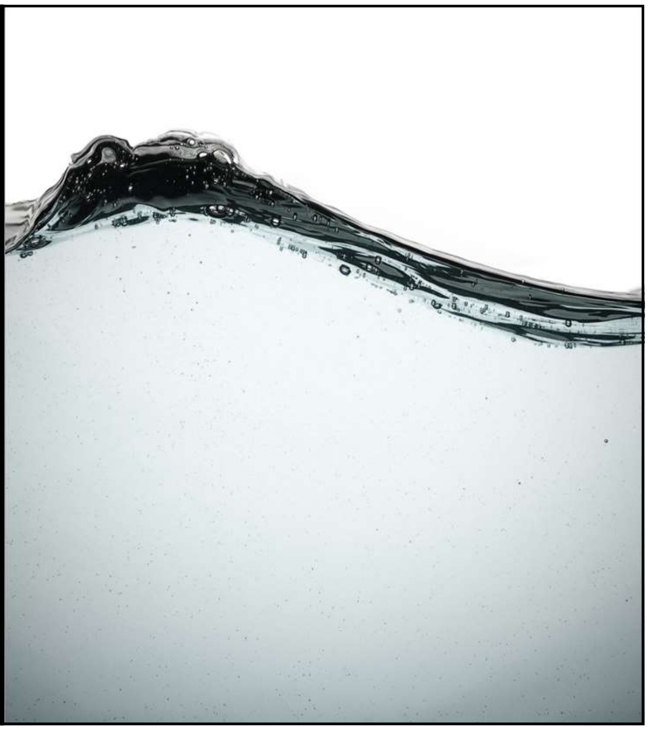
Napier City Council Chlorine Free Strategy

Peer Review by GHD
Royal Haskoning DHV
and Henk Ketelaars (ex Evides)



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Chlorine Free is possible

The water quality is very good.
"A drinking water engineer's dream" Royal Haskoning DHV

Napier has natural advantages to achieve a Chlorine free status

- Generally a good starting point in terms of water sources
- A compact city service area
- Their own physical works unit where improved hygiene practices are more easily promoted

However the regulatory environment is changing

- The three waters industry is currently starting the largest change in more than 40 years.
- Establishment of Taumata Arowai – Water Regulator
- Water Services Bill
- An evidence based approach is required
- Drinking water suppliers will be held to account

A chlorine free water supply is possible, but not be easy and will take staff / contractor dedication, time and large cost

Chlorine Free Strategy Peer Review I **GHD**

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Peer Review

Peer review team

- Two senior/process water engineers from GHD (NZ)
- Principal process engineer Royal Haskoning (Netherlands)
- Principal Water Quality Manager from Evides Water Company (Netherlands)

Summary of our Peer review assessment

- Overall we are in agreement with the direction taken by PDP and the conclusions made regarding achieving a chlorine free water supply
- PDP provided a thorough assessment of the options, risks, and a possible pathway forward to becoming chlorine free
- The report identified the risks and ability to gain approval from Taumata Arowai
- It is clear that being chlorine free is possible, but is a long term goal that requires a mindset shift of all those involved in the water supply system

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Our Initial Peer review assessment

A collaborative approach allowed early input and discussion of peer review assessment. Points raised that were discussed and addressed in subsequent revisions included:

- Clarity was needed on how the options are presented and what is involved
- Some concern that the water quality data used was based on sampling from both online and offline bores
- Discussion on understanding bore security and current drawdown effects seen in NCC bores
- Dutch decision to go chlorine free is on the basis of biologically stable water. No comment was made on biological stability of Napier water
- Dutch networks have branched networks whereas NZ networks are often looped, partly due to fire fighting requirements
- The effects of earthquakes and resilience of materials
- Initially there was not enough detail in the initial report for GHD to review the cost data and the pathway to chlorine free was not communicated well enough to understand the key decision points within the strategy

Chlorine Free Strategy Peer Review I **GHD**

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Final Review Comments

Know your supply

Bore security

- more work required to confirm the reason for the occasional poor result before labelling bores as insecure

Iron and manganese

- there is a risk that the problem may partially continue despite treatment in the short term as problems are partially historic

Know your network

Water balance

- Current water losses are high, but very uncertain
- > 30% non-revenue water is likely overstated
- Improvements are needed in metering to know what real losses are and therefore the renewal investment level needed

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Know where you are going

Leakage target

- 5% or perhaps a higher target if online network loss monitoring is implemented

Know how to get there

Rate of renewals

- 3% per year is ambitious and may not be achievable or required
- A greater understanding of leakage and network water quality risk is required as a more targeted approach is needed

Cost of renewals and water quality measures

- Generally we are in agreement with PDP although we believe more understanding of leakage and usage and risk potential for a poor water quality event is needed before a renewal programme level of expenditure is possible

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Feedback and Discussion/Next Steps

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Key Messages

- Extensive analysis and consultation has been undertaken including a review of chlorine free networks in other countries. The key finding from this work is that 'unaccounted for' water in these systems is very low due to a strong focus on leak reduction and measurement of water use.
- Napier's water network is at a threshold i.e. we have temporary chlorination and some aging bores so we need to get over the hump from the organically grown system of a small city to a modern, future proofed system for a growing city that meets future standards.
- The regulatory environment is changing with dispensation required from Taumata Arowai required to operate a public water supply without residual disinfectant. Although the policies are still being developed early indications are that unaccounted for water in the region of 5% will be required to achieve dispensation. Current unaccounted for water in Napier is estimated at 25%-30%.
- Moving to chlorine free drinking water is possible but will require significant investment in accelerating network re-configuration, reservoir and pipeline replacement. Expenditure at current levels is likely to see the overall water network to continue to deteriorate.
- There is a lack of performance and condition data on the distribution network to enable staff to make evidence based decisions on system renewal and replacement. NCC must invest in better asset management systems and processes to ensure expenditure is directed to the assets that present the highest risk.
- Turning off the current chlorination facilities is **not recommended** until the aging cast iron and AC pipes are replaced and unaccounted for water is under control and better understood.
- The marginal costs of going CF are about $70 million above the current planned investment, however, the barriers to an expeditious route are achieving challenging NRW targets, availability of resources, managing disruption to city road network, demonstration to Taumata Arowai of key metrics, future organisational arrangements and community acceptability.

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Agenda

1. **Introduction and update – NCC (Cath)**
   - Background
   - Procurement
   - Peer review process
2. **Review process – PDP**
   - Overall evaluation process- TONY
   - Assumptions and limitations
3. **Review findings, options and costs – PDP**
   - Water industry reform and regulatory changes - TONY
   - Napier's drinking water network and challenges - TONY
   - Key stakeholder views – TONY
   - Source, treatment, transmission and distribution overview - PETER
   - Global review of chlorine free experience (Netherlands, Denmark and South Korea) - PETER
   - Review of NCC water infrastructure (Source, treatment, transmission and distribution) - PETER
   - Options evaluation and results - PETER
   - Scenario comparisons and costs - PETER
3. **The realistic roadmap forward - PETER**
   - Overview of recommended approach PETER
   - Asset management activities to support CF - TONY
4. **Peer review process - GHD**
5. **Feedback and discussion - NCC**
   - Questions
   - Community engagement
6. **Next steps and close -NCC**

Deferred investment in water infrastructure

THE PRESS

Water infrastructure in need of catch-up funding

24 Nov 2020 Mike Yardley

As Christchurch residents are implored to play their part in the just-launched summer water conservation campaign, concerns are escalating about the evercreaking state of the city's water infrastructure.

As The Press reported earlier this month, the amount of water lost in Christchurch through leaks, breaks and faults within the city's network has billowed by 33 per cent in the past two years.

In the past financial year, 20 per cent of the city's reticulated water supply was lost in leaks, far exceeding the council's own leakage target of 15 per cent.

But the council is adamant that even if we achieved a zero leak rate, it would still launch summer conservation campaigns, when demand for water is at an extreme and the network is pushed to its limits, particularly in the early evenings.

The council's head of Three Waters, Helen Beaumont, tells me that ''during peak demand, people use water faster than we can pump it into our reservoirs, leading to pressure losses in the network''.

''That said, network leakage is a concern, and we are prioritising our pipe renewals programme to address this.''

I canvassed the views from a range of city councillors.

Yani Johanson sums it up best. ''It's hard to convince citizens to save water when the council is failing to meet its level of service targets to fix the leaks.''

Cr Aaron Keown bluntly claims the leaking has got so bad, ''they now need to conserve to make up the balance''.

Cr James Gough decries the failure to get the fundamentals right as a dereliction of duty.

''You don't get much more fundamental than having your water infrastructure network up to scratch.''

Cr Pauline Cotter, who chairs the Three Waters Infrastructure Committee, concedes that ''there's been an element of underinvestment''.

Cr Sam Macdonald argues that far too much of the half a billion dollar annual capital budget has been frittered away on non-core projects. ''We have accepted continual cost blowouts on projects like the Town Hall.''

Macdonald is rightly calling for baseline funding for three waters and roading.

A 2019 leak in Ilam. The estimated cost of pipe replacement over the next 30 years tops $2 billion, Mike Yardley writes.

''We need bottom lines which say we need to invest 'x amount' to ensure we aren't going backwards. Had we done this, we could have avoided these years of neglect.''

No-one disputes that the council's capital budget has been under colossal pressure, whether it be the enormous investment in the wellheads programme or in honouring its obligations under the Anchor Projects cost-share agreement.

But the council has also opted to expend megabucks on over-sized cycleways and the proliferation of pools and libraries.

Nor did it embark on partial asset sales.

In a searing reality check, Beaumont confirms that since 2010, ''the investment in the water supply network has been approximately a third of that required to maintain the standard of the network. As a result, 14 per cent by length or 26.2 per cent by cost of the water supply pipe network is in 'very poor' condition. The leakage is increasing as a result.''

> We need bottom lines which say we need to invest 'x amount' to ensure we aren't going backwards.

Beaumont reveals that, based on the latest recalculated estimates, 375km of water mains and 110km of submains are in poor or very poor condition. The council also factors in the ''failure rate'' of pipe breakages to formulate its renewals workstream.

Based on that, Beaumont is signalling that in the 2022-24 period, 311km of network mains and submains need to be renewed, at a cost of $150 million, while between 2025-27, a further 221km of renewals will be required at a cost of $ 176.7m.

So how many years could it take for the council to play catch-up on water infrastructure to get its house in order, factoring in the ability of the qualified contractor base to deliver?

Beaumont is proposing the best-case scenario is to increase current budget levels by 15 per cent per year.

''This pattern would see water supply infrastructure up to date by approximately 2033. It would see wastewater pipes up to date by 2040 and stormwater pipes by 2048.''

The estimated figure, solely for the replacement of pipes due to their condition and breakage rates over the next 30 years, is over $2 billion.

Increasing the capital budget allocation so extensively will be a central narrative in next year's Long Term Plan.

But it's got to be done.