WATER TREATMENT FOR SMALL SUPPLIES – BALANCING RISKS AND COSTS

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ABSTRACT

Over the last two decades New Zealand has made significant strides in the quality of its drinking water in our large and medium-sized supplies. There remains, however, a major backlog of small supplies that need to be improved to bring them up to compliance with the *Drinking-water Standards for New Zealand*, and achieve levels of risk acceptable to the communities they serve.

This paper draws on the authors' 80 years of combined experience in the design and implementation of water treatment plants to help frame the industry's thinking about how to cost effectively design water treatment for small supplies, while balancing the risks of non-compliance and waterborne disease outbreaks.

The paper includes a number of case studies of small water treatment plants from across New Zealand, and compare and contrast the wide range of capital costs for these plants. It will show what is included and not included in each of these plants, and how that has and could flow through into the public health and other risks to the communities served.

It also includes a review of how a design can be well integrated with, or at odds with, the operational and asset management capabilities of the owner of the supply. This is a subject that often does not receive nearly enough attention in the design process.

This paper highlights affordability as the prime reason why small water supplies are lagging behind larger supplies in terms of compliance. The reality is that for many small supplies if conventional approaches are taken the supplies are be not economically sustainable. Alternative approaches are discussed to enable small communities to achieve a water supply of an acceptable quality.

KEYWORDS

Water treatment, small water supplies, capital costs, risk

PRESENTER PROFILE

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1 INTRODUCTION

Small water supplies face bigger challenges achieving compliance requirements than large supplies. Although most of New Zealand's medium and large water supplies now achieve compliance with the *Drinking-water Standards for New Zealand* (DWSNZ), and achieve levels of risk acceptable to the communities they serve, many small supplies are neither achieving compliance nor providing a quality of supply acceptable to the community.

For the minor supplies (serving 501 – 5,000 people) about 60% are not fully compliant with DWSNZ and about 55% are not compliant with the protozoal requirements of DWSNZ. For the minor supplies (serving 101 – 500 people) about 70% are not fully compliant, and about 70% are not compliant with the protozoal requirements. (Ministry of Health, 2017).

The cost of a household water supply to communities in our smaller towns is greater than 400% higher than the cost to households in our larger centres. Combined with the reduced financial resources in many small communities, affordability is a real issue for small water supplies, and is a significant factor behind the gap in compliance between our small supplies in comparison to the medium and large supplies in New Zealand.

This paper considerers case studies from a number of small water supplies to draw out the challenges and success factors to assist in identifying technology and other means by which safe water supplies can be provided to all our communities.

All supplies in this paper are at or under 1,000 m^3/day, which is the limit we have used to define small.

2 CASE STUDIES

2.1 WHIRINAKI

2.1.1 BACKGROUND

The Whirinaki Water Supply was established under a project known as Nga Punawai o Hokianga (Safe Drinking Water in the Hokianga Pilot Project) which was a central government initiative to improve the drinking water at marae and small communities in Hokianga area in the Far North of New Zealand, established following a flood event in January 1999. The Whirinaki Water supply was completed in 2000, and has been operating continuously since.

The supply serves the predominantly Maori community, originally supplying to 64 households, and under an upgrade and expansion project completed in 2017 this has been expanded to 89 households.

The supply is community owned and operated, under the Whirinaki Water Board, on a largely volunteer basis.

The supply has a number of unique features:

- The entire system operates entirely off grid, with the treatment plant using a pelton wheel to generate energy, supplemented by solar photovoltaic panels, added under the recent upgrade to provide a reliable supply for the UV disinfection.

- The intakes are at RL 430 m, with many consumers close to sea level, an unusually high level change over a short distance.
- The supply uses a microfiltration membrane treatment system.

The recent upgrade and expansion project included:

Intake - A new intake, from a second larger stream than the original source, providing improved reliability in dry periods as well as providing additional capacity to supply more households. The intake screen is embedded into the face of a waterfall, rather than the more common approach of construction of a concrete weir, aiding constructability in an area accessed by a 2.4 km walking track.

Raw Water Pipeline – 3.5 km, including 2.4 km raw water pipeline, on a bush track with only access on foot, with materials lifted in by helicopter.

Diversion to Waste – diverts raw water from supply under high turbidity.

Treatment Plant Expansion – The membrane plant capacity has been doubled and UV disinfection has been added.

Extension of Distribution – approximately 9.5 km of treated water pipe extension, including forming a loop with the existing supply. Water is supplied into a tank at each household, providing resilience if the supply is out of service, and reducing peak demand. Water is metered at each household, but this is used to monitor consumption rather than for charging.

Design fees were under 3.5% of the total project budget. By typical measures this is very low. This was achieved by as much of the organization and the detailed work being completed on the ground by the community, which has the benefits of not only keeping the project cost down, but also empowers and maximizes the knowledge retained in the community.

2.1.2 DISCUSSION

The membrane technology used in this treatment plant could be seen as a high technology solution for a remote plant of this type. The benefits of membrane treatment is that it provides a high quality treated water and copes well with viable water quality, producing a consistently safe water supply. In comparison to commonly used media and cartridge filtration at this scale, the treated water quality is substantially higher. No disinfection has been used, enabled by the high quality of the treated water, although UV disinfection has now been added to improve the safety of the treated water. The chemical free treatment (other than membrane CIP) is a significant attraction to this technology for the community. Membrane technology could be seen as an advanced technology, and there are many examples where advanced technology has failed to be maintained in remote areas. The community has proven itself capable of operating this technology, with 17 years operation to date.

Hokianga Health Enterprise Trust, who provide health services in the Hokianga including running the Rawene hospital take a holistic approach to health, and see safe water supplies as part of the health equation. They take an active role in promoting improvements in water supplies and sharing of information between supplies.

Working with communities of this type you appreciate that the value of the community water supply goes deeper than the provision of a reliable and clean water supply, and the

Whirinaki supply is a very good example of this. To clearly articulate the value in the supply to the community you would need to talk to those in the community directly, but it is apparent to an observer that it goes beyond the benefits of a safe and reliable water supply.

2.1.3 CHALLENGES AND SUCCESS FACTORS

The Whirinaki Water Supply has been operating now since 2000, and has clearly been a successful supply. There are many attributes that have contributed to this success, and the two key factors we consider are the most significant are:

- Commitment of community member's to running the supply. Many of the same people involved in creating the original supply are still actively involved in running the supply.
- High quality of the source water. A high quality source water simplifies treatment requirements, and is frequently a factor that differentiates between successful community water supplies.

This supply is a good example of membrane filtration being proven as a suitable technology for small supplies. A high quality treated water is provided, has the ability to cope will poor water quality during flood events, and is not reliant on chemical dosing. Although there is increased complexity with mechanical and electrical equipment that will require maintenance, the operation of the process is relatively simple.

2.2 SHANNON

The Shannon WTP serves a population of 1,400 and was a basic chlorination-only plant drawing its raw water from the Mangaore Stream, which is typically 2 – 4 NTU but can rapidly rise to in excess of 100 NTU in flood conditions. In late 2011 the plant's owner, Horowhenua District Council (HDC), committed to upgrading to meet its obligations to take best practicable steps to comply with DWSNZ.

Previous work by others had selected a membrane-based filtration process for the upgrading. This work studied three options: direct filtration, conventional treatment and membrane filtration. For a capacity of 1.2 ML/day it found that the capital cost of direct filtration was $0.4 million less than conventional or membrane (both equal). The NPV of capital and operational costs was $4.3 million for direct filtration and membranes, and $4.8 million for conventional. Membranes were favoured in an evaluation of non-economic attributes. The decision to adopt membranes was not revisited when CH2M Beca was engaged to undertake design and construction management.

The selected process consisted of membrane filtration, pH correction and chlorination. The plant is completely automated and is integrated with Council's wider SCADA network.

While the new plant was built on the site of the existing, it was essentially a greenfield project as the existing plant was very basic.

The method of delivery was a two contract system:

1) **Membrane Contract** - A contract for the supply, installation and commissioning of the membrane package.
2) **Balance of Plant Contract** - A contract for the construction of the balance of plant, including typically the buildings, intake works, balance of plant process including pre/post dosing, flocculation, waste treatment, reservoirs and all services outside of the building.

The key advantages with a membrane-based process for the Shannon WTP was in our view:

- Membrane technology is well suited to unattended operation, and this is advantageous for a small and relatively remote WTP. The need for additional attendance during flood/poor water quality events is lower than with conventional treatment.
- Simplicity of operation of a membrane process particularly during flood events suits HDC.
- Membrane technology has proven itself as able to cope with short term high turbidity events, avoiding the need for a clarifier and additional complexity that that involves.

The plant was constructed during 2012/2013 at a cost of $2.6 million (membrane contract and balance of plant contract), and commissioned in late 2013.

Over the period July 2016 to June 2017 the WTP has performed well, although there have been some SCADA errors that have needed to be resolved. Apart from two brief events (one of 15 minutes and one of 60 minutes) the treated water turbidity has always been less than 0.10 NTU, despite many flood events and 8 of greater than 50 NTU raw water turbidity.

2.3 TOKOMARU

The Tokomaru water supply is owned by Horowhenua District Council, and operated by Downer.

The supply had chlorination only, and did not comply with the DWSNZ protozoal requirements. Elevated natural organics in the water when chlorinated were giving rise to elevated levels of disinfection by product formation.

The plant was designed 2013, constructed in late 2014 and commissioned early in 2015. The constructor was Filtec, PLC by AFI, and project manager was H2ope (now Lutra).

This water supply had received some bad press from residents as a traditional WTP was estimated to be $2.5M, and based on this cost the council considered treatment of this supply could not be implemented for another 20-25 years. A collaborative design between HDC, Downer, Filtec and H2ope looked at the best risk versus reward analysis and the decision was made to build a WTP that could treat the raw water presented 99% of the time.

The peak daily flow is up to 300 m^3/day with an average of 150m^3/day

The treatment plant cost $350,000 (+GST) including pipework, housed in a shipping container, with multimedia sand filtration followed by carbon filtration to remove natural organics, then a 3M Hiflow cartridge 1-micron absolute, and the process finished off with UV disinfection. Instrumentation includes pre and post turbidity, post UVT & flow.

Note costs excluded chlorination and reservoir storage as this was existing.

The treatment plant is designed for selective extraction, shutting down at 2 NTU. Typical source turbidity is approximately 0.6NTU. The lack of coagulant chemicals meant a discharge consent was not required.

The process was trialled at pilot scale for 6 months prior to construction to confirm performance, carbon and cartridge life. The length of trial was extended as flood events did not occur until late in the trial.

To minimize capital costs and site construction costs, the compact plant was housed in a shipping container.

Operational costs compare well to conventional coagulation plant, average cartridge use per year was $8000 plus $10,000 of carbon for the first year. Note exceptional rainfall in the past 2 years has caused costs to increase by the order 50% higher. Compliance has generally been maintained, with the exception of one boil water notice, however this may not have been necessary in hindsight.

In order to negate the impacts of large flood events that appear to be occurring with increasing frequency, a decision has been made to install an extra storage reservoir to hold 200 m^3 of water providing an additional days storage, reducing the vulnerability to flood events.

2.3.1 CHALLENGES AND SUCCESS FACTORS

The community now has a treated water supply, considered unaffordable using conventional treatment previously.

To achieve this affordability a process has been utilised that is reliant on good source water quality, and the ability to stop treatment and rely on storage during significant rainfall events. This approach has some risk with extended duration events or changes such as slips in the catchment. Additional reservoir storage is being added now to reduce this vulnerability.

2.4 EKETAHUNA

This supply is owned by Tararua District Council, and the new treatment plant was designed and constructed by Filtec and Tararua District Council.

The key to the delivery of this plant was the trust built by all parties on previous projects, which allowed risks to be better shared and costs thereby reduced.

The raw water source is a bush catchment stream in the foothills of the Tararua Ranges, with very little grazing. The intake is an infiltration gallery, which improves the raw water quality with an average 0.5 NTU turbidity and a requirement for 3 log protozoa removal.

The design is based on selective abstraction, as this allowed water to be taken when less than 2 NTU. This plant combines a media filter to provide particle removal with UV to achieve DWSNZ compliance at higher NTU as per 5.16.4.a.

The design peak capacity is 690 m^3/day, with an average of 450m^3/day. Construction cost was $490,000 (+GST) including a high-lift pump to pump treated water up 40m to storage.

The treatment process included Macrolite filter media, to provide filtration down to 1 micron with 2 log protozoa reduction followed by UV. The backwash is fully automated with pre- and post-filter turbidity monitoring, and UVT monitoring.

Chlorine dosing and reservoir storage was existing and is not included in the costs above.

Capital costs were kept to a minimum by using a local contractor to build the 12m x 12m shed.

The plant was designed in November 2011, and commissioned in April 2012.

One of the interesting outcomes of the project was ensuring everyone understood the requirements of DWSNZ, including operators and DWA. The operational costs of this plant have been very low, by using Macrolite 70/80 there are no cartridge replacement costs.

Further enhancement is being considered with the addition of extra storage to cover periods when raw water quality is poor.

2.4.1 CHALLENGES AND SUCCESS FACTORS

Similar to Tokomaru, a low cost treatment solution has been implemented, providing improved treated water quality at an affordable cost. This is reliant on good raw water quality, and ability to use storage during periods where the source is not treatable. This solution balances the costs and risks.

2.5 SEDDON

The Seddon water supply is part of the Awatere water supply scheme. The scheme is made up of the Seddon township and the Awatere rural/agricultural supply. The supply is sourced from two infiltration galleries in the Black Birch Stream, which is a tributary of the Awatere River. The water for the whole scheme is partially treated at Blairich by a MIOX disinfectant dosing plant, which was commissioned in mid-2012. This disinfection process is capable of meeting the bacterial compliance requirements of DWSNZ, as long as the turbidity of the water being disinfected does not compromise the effectiveness of the process. There is no treatment for the removal or inactivation of protozoa, or turbidity removal, and as such the supply is not currently compliant with the DWSNZ.

It was deemed unaffordable to treat the full volume of water in the Awatere water supply scheme, in part as CAP funding was only available for the Seddon township with its poorer deprivation index.

The funding challenges were significant. Based on Council contributing 50% of the total capital cost from its reserves, receiving a subsidy from the government from CAP funding, and the treatment plant's operating costs being spread across all of Council water supply areas; the projected impact on Seddon ratepayers as presented to a public meeting in November 2014 based on cost estimates at that time was an annual increase in costs per household of $543. To make the scheme more affordable, Council subsequently decided to spread all the costs – this new funding formula brought the cost for Seddon households down to an increase of $240 each and added about $8 to other areas. Note that this cost is in addition to existing uniform annual charge of $427 for the first 275 m^3 of water, and $1.88 per m^3 thereafter (all $ incl. GST).

Following several years of investigation and community engagement, and a successful CAP application, in 2106 MDC commenced implementing a project to provide a compliant drinking water supply to just the township of Seddon by hydraulically separating the Seddon supply from the rest of the scheme (but still receiving its raw water from the scheme). The project is being delivered by a Design & Construct (D&C) contract.

Key features of the basis of design are:

- Greenfield site on the hills at the southern end of town
- Capacity of 700 m^3/day
- Raw water ex the infiltration gallery is prone to turbidity spikes (up to 80 NTU measured), which are associated with rainfall events in the catchment.
- 3-log protozoa removal/inactivation required
- Able to be operated automatically and unattended
- Structures designed to AS/NZS 1170 Importance Level 3

The specimen design prepared by CH2M Beca, which formed part of the D&C tender documentation, was based on a conventional treatment process with a lamella clarifier and pressure media filters. This process was selected for the specimen design because it was:

- considered likely to be more cost-effective than a membrane plant, and
- the basis of the Ministry of Health CAP funding approval.

Tenderers were invited to offer alternative process trains, so long as it achieved the design objectives. During the Expression of Interest stage of the procurement (for which 9 submissions were received), many of the respondents stated they would submit D&C tenders for both conventional and membrane processes. However, all the shortlisted tenderers who finally tendered (three in total) only offered a membrane-based process.

Feedback from tenderers was that although the conventional treatment was lower cost, the risk to the contractor was lower with the membrane option. This reduced risk is primarily due to the pre-engineering of small membrane skids, reducing risk of performance in addition to project costs.

The D&C contract for the WTP was awarded to Filtec in late June for $2.6 million.

2.5.1 CHALLENGES AND SUCCESS FACTORS

One of the key problems Council faced was convincing the local community their untreated water supply is creating health risks for them, with the familiar refrain "I've been drinking this water for 40 years and it has never made me sick ". In Seddon this claim only stopped when the supply had a very dirty water event generated from a flood which went on for two weeks - it was only then did Council start to get a groundswell for change.

The fact that the wider Awatere supply will remain untreated was a disappointing outcome, but there was little interest from those consumers to pay for the cost of treatment. Point-of-entry treatment is being considered.

The tendering process ending up favouring a membrane-based process over conventional clarification/filtration one. This is considered to be due, in part, to the availability of pre-engineered membrane plants, reducing both the performance risk and the project cost.

2.6 LITTLE RIVER

2.6.1 BACKGROUND

The Little River Water Treatment Plant supplies the township of Little River and Cooptown on Banks Peninsula with drinking water.
Prior to the upgrade in 2015, the plant was supplied by a surface water source which was treated by slow sand filtration and chlorination. The catchment is partially protected, and requires bacterial and 3-log credit protozoal treatment to meet DWSNZ.
This process regularly had filtered water turbidity spikes exceeding 1 NTU associated with rainfall events, which meant it did not comply with the slow sand filtration requirements in DWSNZ. Even if the slow sand filtration operation complied with DWSNZ it would only achieve 2.5 log credits which would be insufficient for protozoal compliance. In addition, there were periods where there was insufficient flow from the surface water source to meet demand. Therefore the sources needed to be augmented and the WTP needed to be upgraded to meet DWSNZ.

2.6.2 UPGRADING

To provide a more reliable source, a well was drilled near the WTP. Water quality analysis showed the well had elevated hardness and salinity (up to 320 mg/L hardness which exceeds the DWSNZ guideline value of 200 mg/L) and bromide (up to 0.6 mg/L).
As the well does not have secure status yet, it required treatment for bacterial and 3-log credit protozoal compliance. Softening was also required to reduce the high hardness.
UV was selected to achieve protozoal compliance as it is a relatively reliable and low cost option for good quality water. However, due to the presence of bromide in the bore water, chlorination was not considered to be a suitable disinfection method due to the risks of brominated disinfection by-products, and thus UV disinfection was selected as the primary method of achieving both DWSNZ protozoal and bacterial compliance.
The capacity of the new plant is 230 m^3/day.

2.6.3 CAPITAL COST

The total cost of the upgrade was approximately $2 million. The biggest components of this cost were $650,000 for a new concrete treated water reservoir, $170,000 for the demolition and construction of new timber tank slow sand filters and associated pipework and chambers, $210,000 for the process building, softening and UV process equipment, and $470,000 for the electrical, instrumentation and controls.

2.6.4 PERFORMANCE

In the first six months after the WTP was commissioned, the filtered water turbidity generally remained less than or equal to 2 NTU for 99.7% of the time, despite some high turbidities in the raw water (up to 150 NTU). There were some treated water turbidities of up to 10 NTU recorded, but all the turbidity readings above 2 NTU only occurred as a single data point (a data collection fault). Note that the raw water should normally be diverted to waste if the turbidity was greater than 5 NTU, however there was a problem with entrained air affecting the raw water turbidity readings. These results enabled the UV disinfection to comply with the turbidity requirements of DWSNZ (not exceeding 1.0 NTU for more than 5% of the compliance monitoring period, and 2.0 NTU for any 3 minute period).

Since commissioning the WTP has performed to a good and reliable standard. The bore water is consistently less than 0.2 NTU.

2.6.5 CHALLENGES AND SUCCESS FACTORS

The quality of the bore water has increased the complexity of the treatment required. The blending of surface and groundwater sources has provided a more resilient supply, with this diversity countering the negatives of both sources (elevated turbidity in surface water supply following flood events and high total dissolved solids in the bore supply).

The costs of this supply are uniformly funded by Christchurch City Council, and hence although the costs for this small supply are relatively high for the size of community, the cost impact on the larger population is small.

2.7 DUVAUCHELLE

In 2011 Christchurch City Council (CCC) installed a new treatment facility on the Duvauchelle water supply. The plant had a capacity of 500 m^3/day, with a treatment process that consisted of:

- Abstraction from Pipers Stream and basic settling

- Automatic diversion of high turbidity water (>8 NTU)
- Primary filtration (Macrolite Kinetico media pressure filters, 5 µm nominal, 2 No. in parallel)
- Secondary filtration (Z-core 1 µm nominal cartridge filters, 3 No. in parallel)
- UV disinfection (Wedeco Spektron 25, 2 No. in parallel)
- Gas chlorination

DWSNZ protozoal compliance (3-log) was intended to be achieved through UV disinfection, with the upstream filtration needed to meet the UV feedwater turbidity requirements.

By 2012 is was clear that there were performance issues with the Duvauchelle Water Treatment Plant (WTP), with the key issues identified in an investigations report in 2013 being:

- WTP finding it difficult to produce water compliant with DWSNZ
- Finer particulates not being removed by the media and cartridge filters, and consequently the plant could not meet the UV feedwater turbidity requirements
- The UV lamps regularly alarm due to low intensity, caused by fouling of the lamps as well as low UVT (requiring CCC to clean the lamps on a regular basis)
- Media filters clog rapidly when turbidity is high (>3-4 NTU), causing increased backwashing and difficulties producing sufficient treated water.

Experience has been that the plant is unable to maintain compliance above 6 NTU, and hence the plant is shut down. For extended duration events water has to be tankered at significant cost.

A trial was conducted in October 2013 in which the diversion setpoint was reduced from 8 NTU down to 5 NTU, but it was found that the loss of volume of raw water meant the plant could not always meet demand.

In 2014 CCC was considering options for making process improvements to the WTP to:

- Achieve compliance with DWSNZ
- Provide a minimum of 4-log protozoa removal (because of concerns about the results of a new 5-yearly catchment risk assessment)
- Remedy other process issues.

The options considered were:

- Option 1a – installation of tertiary cartridge filters
- Option 1b – installation of tertiary cartridge filters with an additional media filter and new UV
- Option 2 – coagulation and direct filtration
- Option 3 – installation of coagulation and a lamella settler
- Option 4 – membrane plant.

Taking account of capital and operating costs, as well as risks, Option 1a (tertiary filters) was recommended for investigation, subject to CCC being prepared to:

- Commit funds to the investigations to confirm the viability and risk profile
- Delay the resolution of the treatment problems so that the investigations can take place.

If the trials were unsuccessful or inconclusive, CH2M Beca recommended proceeding with the implementation of Option 3 (coagulation and sedimentation), because it was lower in cost than Option 4 (membrane plant) and offered a more robust treatment process with lower risk than Option 2 (coagulation and direct filtration).

Council in fact decided to progress with Option 3 (coagulation and sedimentation), but after completing detailed design found it to be too expensive with an estimated cost of $1.6 million (significantly more than the CH2M Beca concept level estimate of $0.6 million). This led to a re-think; and consideration of the option of an infiltration gallery, replacing the media in the media filter with an alternative, and replacing the UV reactor with an automatic wiping model.

CCC is currently reassessing all options with a view to finding a long term cost-effective upgrade.

2.7.1 CHALLENGES AND SUCCESS FACTORS

This supply is an example where the simpler cartridge filtration and UV disinfection technology has not been suitable for the higher turbidity and colour water that occurs after flood events. There are times where the available storage is insufficient to meet the supply requirements during these events and water has had to be tankered in, at significant cost.

2.8 OHURA WATER SUPPLY

The Ohura water supply is a small supply owned by Ruapehu District Council. The plant is a conventional coagulation, clarification media filtration treatment plant supplying a population of approximately 141 people.

A combination of declining population, aging assets and remote location has made the cost of operation of the supply high, at greater than $2,000 per annum per property. 77% of people aged 15 and over in Ohura have an annual income of $20,000 or less.

A referendum was held in 2014 proposing to close the current Water Treatment Plant and scheme that supplies drinking water to Ohura. Water supply would need to revert to individual roof water based household water supplies. The majority opposed the referendum and the water supply operation has been continued.

Ohura may be an extreme example, but the reality is not far off for many of our small water supplies.

2.8.1 CHALLENGES AND SUCCESS FACTORS

This supply is facing significant challenges as to how the supply can continue operating on an economically sustainable basis, in addition to how upgrading the treatment process to achieve compliance could be achieved. The small and shrinking population, remote location making it an expensive plant to service by the council's contract operator, asset renewal costs and upgrade costs are compounding to make it a challenge to operate this supply economically.

2.9 KAEO WATER SUPPLY

The Kaeo community has a treated water supply supplying a population of 72 in 27 households. The water demand is 15-18m3/day, increasing to 20-25m3/d in summer.

The supply was transferred from Far North District Council to private ownership by in about 2001 when operating at an annual loss of $38,000, which when divided by the number of consumers is a substantial loss. In addition, at this time the plant required significant capital expenditure to upgrade the treatment system to achieve a compliant water supply, which would further impact the affordability.

The supply was subsequently transferred to a community organisation Wai Care Environmental Consultants once the private operator wanted to walk away from the supply.

Water is abstracted from a shallow bore with very high levels of iron (17 mg/L). The water treatment plant is a Deferum iron removal plant to remove iron and manganese from the raw water abstracted from a shallow bore close to the plant, which was installed in 2011, with a Ministry of Health CAP grant applied for in 2009.

Challenges with this supply include:

- The very high iron levels make treatment challenging.
- The installed treatment plant uses ozone, which is complex to maintain, and has had reliability issues and servicing is expensive in this relatively remote location.
- The installed treatment plant is not capable of achieving acceptable iron removal and treated water quality.
- The non-conventional treatment plant is challenging to maintain.
- The bore source and treatment plant are in a flood plain and can flood (including the treatment building) several times per year, although this has been improved with the installation of flood diversion works in the township.
- The small number of consumers makes the supply not financially sustainable. More consumers would like to connect if a good supply was available.

The need for a public water supply in the area is significant. A number of small businesses such as food outlets in the township are reliant on a water supply, and with small roof areas roof water is not viable. The nearest public water supply is 21 km away. The lack of a community water supply within reasonable distance is a significant issue for areas such as this. Outlying rural communities will always be reliant on individual household water supplies, which are vulnerable during dry periods and frequently need tankered supplementary supplies. The lack of economically available supplementary supplies frequently leads to poor quality untreated water being used, with potential health risks.

The Kaeo community applied for MoH CAP funding with two options in 2015:

- Option 1: Upgrade the existing treatment process at an estimated cost of NZ$200,000

- Option 2: Implement a new groundwater source, replacing the existing source and treatment at an estimated cost of NZ$750,000.

Unfortunately Kaeo was not awarded funding for either option. The larger new source scheme would have been a major undertaking for the organisation currently running the supply, which they were uncomfortable with.

Issues with this water supply came to the public attention early 2016, with media attention focusing on the non-compliance and poor aesthetic quality of the water (due to the high iron levels). Options were considered again with the Ministry of Health's assistance and the council also having an interest. The preferred option identified at this time was to work cooperatively with the school and move the supply to the main Kaeo River, upgrading the existing school supply to serve the school and community, including relocating equipment from the existing community supply. The Ministry of Education was unwilling to support the proposal and hence this was not able to proceed.

A redundant pressure filter has been donated by South Taranaki District Council which is being installed, and will improve the quality of the existing water supply. Challenges will remain however with this supply, with the poor raw water quality being a core issue that makes treatment challenging.

A lesson learnt from this supply is the need to implement simple, robust solutions. Treatment of poor quality raw water requiring complex treatment is frequently beyond the financial and/or technical resources available to small communities. Affordability can be challenging for small water supplies, but for those with complex treatment processes the challenges can be unsustainable.

2.9.1 CHALLENGES AND SUCCESS FACTORS

The poor quality water, a complex treatment process and small scale of this supply are making it a challenge to provide a quality community supply and be economically sustainable.

3 TREATMENT TECHNOLGY DISCUSSION

The commonly used technology options available are:

3.1 MEDIA FILTRATION, CARTRIDGES AND UV

Commonly used for small supplies and effective where water quality is consistently good, this relatively simple technology can struggle with poor raw water quality, meaning compliance is not consistently achieved and cartridge life can be short. This paper has provided examples where this simple and low cost treatment has been an economic solution and the risks have been manageable. It also provides examples where the periods of poor quality water following floods are such that storage does not cover the time period and water has to be tankered in at significant cost. This technology has its place in consistently good quality sources, particularly for smaller supplies, and where applicable it is a simple and low cost solution.

3.2 COAGULATION AND MEDIA FILTRATION

The requirement for maintaining optimal coagulant dosing under varying water quality conditions can be a significant issue with small supplies, with the expectation that visits to the treatment plant may be days apart, and the experience needed to maintain optimal dosing.

In comparison to its main alternative, membrane filtration, conventional treatment may have a similar cost to membrane filtration at small scale. As plant capacity increases conventional technology tends to have the lower capital cost. This is in part due to conventional plants tending to be one off plants rather than genuine pre-engineered packages.

However when other factors such as the level of attendance and experience required by operators are factored in, membrane filtration can be favoured particularly for small supplies.

3.3 MEMBRANE FILTRATION

Membrane filtration is capable of producing consistent high quality water even with varying raw water quality. This technology fits well as the next step up in technology for situations where cartridge filtration and UV are unsuitable, particularly where elevated turbidity occurs following flooding. Although more technically complex than cartridges and UV, it has been proven to be workable in remote areas as demonstrated in the Whirinaki case study.

Membrane technology can provide a greater certainty of compliance for these sources under varying conditions.

With the greater availability of pre-engineered small membrane plants, we can see membranes being a significant part in the future of small water supplies. This pre-engineering reduces both cost and risks during commissioning.

3.4 OTHER TREATMENT CHALLENGES

The above discussion focusses primarily on typical surface or spring water sources without other treatment challenges such as elevated organics, iron and manganese, nitrate or arsenic.

Providing treatment to small communities can be challenging enough, even with good quality surface waters or springs. Where additional treatment challenges exist, such as those listed above, the viability of the supply needs to be carefully considered in terms of the financial sustainability and available skills.

4 CONCLUSIONS

There are challenges in the operation of small water supplies. Some of the technology and non-technology factors are:

4.1 NON-TECHNOLOGY FACTORS

The costs of providing potable water to our smaller communities are 400% or higher than costs in our larger metropolitan areas. At the same time many of the smaller communities are economically disadvantaged. Combining these factors can make providing potable water services unaffordable for small communities. Some of the options that enable affordable water supply to be provided include:

- **Scale / Uniform Funding** – Where small community schemes can be funded on the same charging basis as the larger centres, and costs shared, the cost to the small communities can be substantially reduced, with a low cost increase to the larger communities.
- **Community Run Schemes** – The use of paid staff that travel from outside of the area to operate a supply on behalf of a community adds a significant cost to the operation of a community water supply. Community operated schemes can aid the affordability significantly. Support from health organisations and councils can be helpful in providing access to technical support and testing, and can assist with providing these community operators the resources needed to operate their water supply.

4.2 TECHNOLOGY

The main technology options for small water supplies are:

- **Cartridge filtration and UV Disinfection** – suitable for consistently good quality water supplies, this is a low cost and simple from of treatment. However, this technology is not suitable for elevated turbidity water sources, and operation is frequently reliant on selective abstraction, and relying on storage during poor water quality periods following flooding.
- **Membrane Filtration** – Membrane filtration provides a higher quality and more robust level of treatment in comparison to cartridge filtration and UV disinfection. In particular compliance is more readily maintained during poor water quality following flood events. Although more complex than cartridge filtration and UV disinfection, it has been proven to be maintainable, including in small remote supplies. The pre-engineering of these systems is improving both the economics and operability of these systems.
- **Conventional Coagulation/Filtration** – Conventional treatment takes a greater level of optimisation to maintain effective treatment under varying raw water quality. Although at larger scale conventional treatment is more economic, at small scale the capital cost difference can be low, and the membrane option can have operational advantages.

The above discussion is focused on typical good quality surface water and spring supplies. Where additional treatment challenges such as elevated organics, iron and manganese, nitrate or arsenic exist, more complex treatment systems will be required. These can be challenging both economically and in terms of resources to maintain for small community supplies, and hence the viability of using such sources needs to be carefully considered.

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