GROUNDWATER QUALITY INVESTIGATIONS and

OPTIONS for SOFT WATER SUPPLY

Technical report

14 February 2007 (2)

1. Introduction

The Wanganui District Council has substantially completed its assessment of the feasibility and costs of providing softer water to the City whilst also providing a back up bore for Kaiiwi which provides the City with the bulk of its water.

Investigations to date include looking at the characteristics of the water in newly drilled pilot bores, analysing treatment requirements, checking how far water has to be piped, as well as deciding whether various supplies can be blended.

WDC's understanding of the complex geology under the Wanganui area is now developing to the stage that there is some higher certainties as to what depths water of various qualities may be found, the treatment likely required, and whether that water is hard or at various levels of softness.

The following provides a background to the City's water supply and current programme of testing and results.

2. Background

Wanganui City currently takes its water supply from three groundwater bores at Kaiiwi and one groundwater bore at Aramoho. The water from Kaiiwi is hard but no treatment other than chlorination is required. The Aramoho water is soft but treatment to reduce ammonia prior to chlorination is required. The Aramoho Bore specifically replaced the aging Waitahinga Dam supply.

The Kaiiwi water travels some 12km through dual pipelines across country prone to slipping and across pipe bridges also vulnerable to damage. Investigations to find an alternative source closer to the city were commenced in 1995 including the specific objective of finding a replacement supply for the Kaiiwi number 1, bore which supplies about 30% of supply. Security of supply was improved by the construction of a third reservoir in 1998.

An investigation bore on Brunswick Road at Aramoho yielded soft water and this was developed into a production bore with an associated treatment plant. This provides about 15% of the city supply. A further investigation bore was drilled at Wanganui East at Lenihan Street. Water from this bore was found to be even softer than that from the Brunswick Road bore but had high ammonia levels, high temperature and high sulphate levels, odour and colour. Treatment options have been identified but unit costs are high and at this stage no decision has been made to develop a supply based on this bore. The requirement for a replacement for the Kaiiwi number 1 bore still remains.

Residents receiving the soft water supply anecdotally prefer it to the Kai-iwi water. The Aramoho supply generated positive responses when introduced into the system. Since then there are complaints when the supply is shutdown for any reason. In Referendum '06 the community signalled that the supply of soft water to the entire city should be investigated.

Previous studies into providing soft water dealt with water treatment plants softening the hard Kaiiwi supply but costs were such that replacement of the Kaiiwi number1 bore with a soft water bore at a site near the reservoirs was likely to have significant savings. Existing knowledge of the groundwater resources of the area was improved but understanding the changes from hard to soft water was no further advanced because of insufficient geological knowledge (not enough bores). Further investigations began in August 2006 with the dual objectives of understanding the changes in water quality from hard to soft, and finding a suitably located site of soft water able to supply at least as much water as that from the Kaiiwi number 1 bore.

Three new deep bores have been drilled into the aquifer that supplies city water and analyses of all bores has led to a better understanding of the groundwater system and provided the information necessary to confidently predict the water quality and quantity available from the aquifer in the area of interest.

2. Geohydrology

Contained within the general sedimentary strata that surrounds and underlies Wanganui City is a layer of limestone or shellrock known as the Nukumaruan formation. The strata dips gently in an almost north-south direction towards the coast. The shellrock outcrops at the surface about 5.5km north of the city and because of its thickness, varying between 80 and 120m, the area exposed to infiltration from rainfall is about 180 square km. Strata above and below are essentially impervious and the shellrock and interspersed sands act as an aquifer. The infiltrating rainwater passes slowly down the aquifer undergoing chemical changes as it dissolves the shellrock, comprised mainly of calcium and magnesium carbonate. This gives the water its property commonly known as hardness derived from how hard it is to get a good lather with soap. Temperature and pressure increases along the flow path, and this also affects the groundwater quality.

Faulting that disrupts the strata exist beyond Maxwell but of more significance is the Upokongaro fault zone and a fault zone crossing the Whanganui River Valley extending towards Brunswick and mapped between the Aramoho bore and the Blueskin Road bore. Seismic surveys done by Geological and Nuclear Sciences (GNS) show the displacement where they cross the Upokongaro faulting, but no GNS surveys crosses the Aramoho-Brunswick fault trace. The top of the aquifer at Aramoho is about 60m deeper than to be expected by extending the general regional dip of the strata from Blueskin bore to Aramoho bore. A recent seismic survey carried out along a line from Blueskin bore to the reservoir site does not show the fault extending to that line. Both fault zones disrupting the aquifer could have an impact on the water quality.

The depth to the aquifer beneath the city is 600-700m depending on location, but the primary source of water for the city is drawn from the aquifer where it outcrops at the surface in the Kaiiwi Valley. Bores there need only be about 100m deep to tap the full aquifer thickness.

Figure 1 below shows the positions of all bores into the aquifer with known water quality, estimated distribution of the key hardness and ammonia levels and the approximate area (hatched) where ion exchange has occurred. The approximate recharge boundary is also shown.

A hardness of 100-120 and ammonia level less than 0.3 would be ideal.

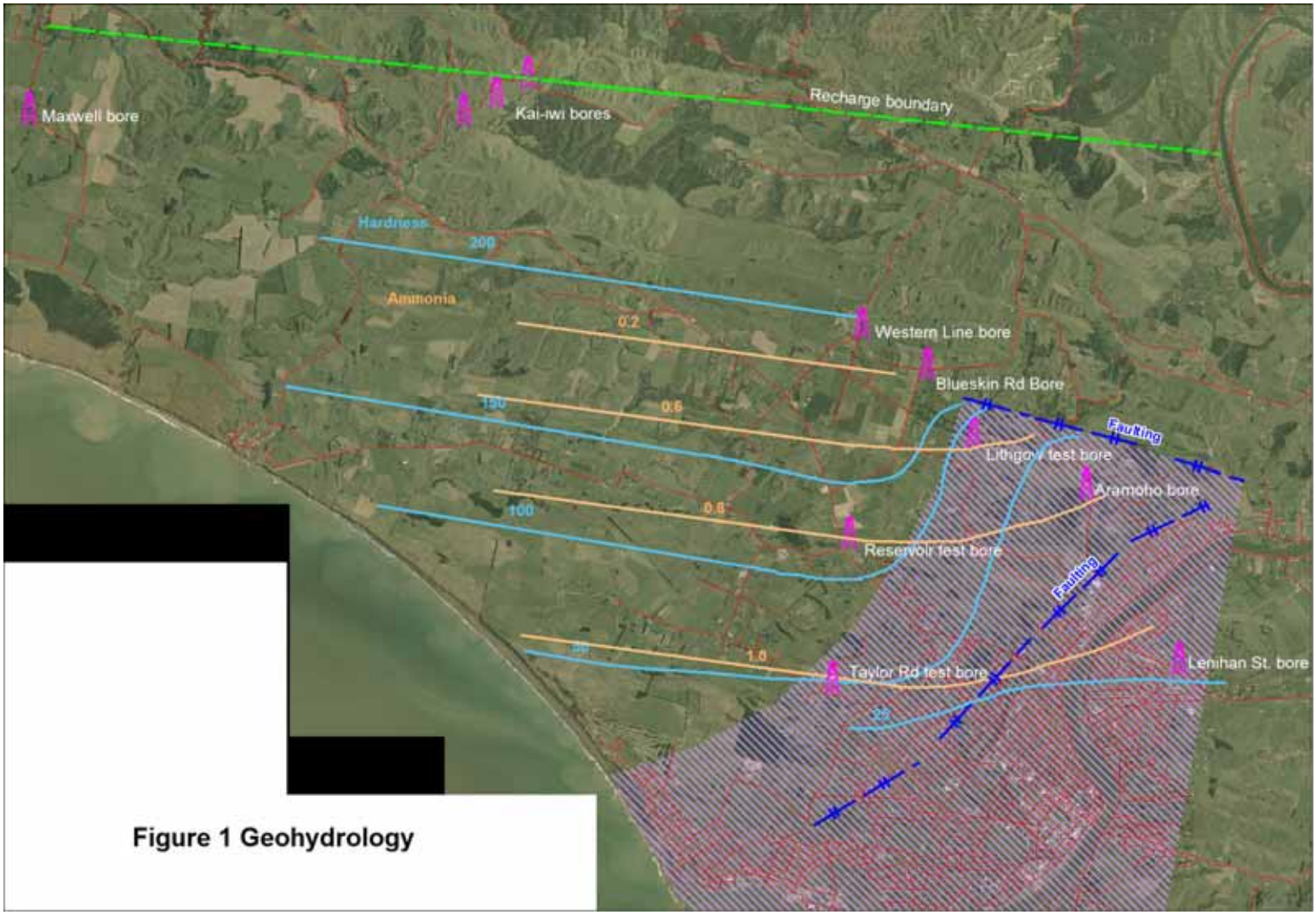


Figure 1 Geohydrology

3. Groundwater Chemistry

The current groundwater investigations involving drilling three new bores and obtaining water samples has provided an explanation as to the sudden change from hard to soft water that occurs between the Western Line and Blueskin Road bores, and the Aramoho and Lenihan Street bores.

A normal gradual evolution of groundwater sees the chemistry change from that of the infiltrating rainwater affected firstly by soil zone processes then by the dissolution of aquifer minerals and depth related increases in temperature and pressure. These changes are reflected in the water quality data from the Maxwell, Kaiiwi and Western Line bores, and the Blueskin Line, Reservoir and Taylor Road bores. A gradual change occurs from hard water with high calcium levels and low sodium levels, to soft water with low calcium and increased sodium levels as the groundwater travels from near its source to 10km or more through the aquifer. There is also a steady increase in ammonia levels.

The soft water with low calcium and high sodium levels found at Aramoho and Lenihan Street does not follow the normal evolutionary path. Geochemical exchange of calcium and magnesium ions for sodium ions has occurred. For this to occur sodium has to be available and the effect of the fault running between the Blueskin Road bore and the Aramoho bore provides a possible explanation. The strata overlying the aquifer is a clayey formation known as the Tewksbury formation. The groundwater travelling down the aquifer is confronted by a partial blockage of clays and siltstones and general colloidal material, a source of excess sodium. Under pressure,

the groundwater ‘squeezes’ past and continues on down the aquifer accompanied by a pressure drop of about 10m.

Table 1 lists key water quality parameters and distance from the recharge boundary.

Bore	distance from recharge zone	Calcium	Magnesium	Sodium	Total Hardness	Total Ammoniacal Nitrogen		pH	Temp.
	m	Ca^{2+} g/m^3	Mg^{2+} g/m^3	Na^{+} g/m^3	$CaCO_3$ g/m^3	NH^{3+} g/m^3	NH^{3+} g/m^3 (x 100)		^{0}C
Kai-iwi	100	67.8	5.17	16.4	191	<0.01	0.5	7.8	12.6
Maxwell	1400	58.1	6.3	21.8	171	<0.01	0.5	7.9	
Western Line	3300	68.1	6.53	17.2	197	0.08	8	7.8	
Blueskin Rd.	4060	59.4	8.63	20.2	184	0.27	27	8	14.6
Lithgow	5160								
Aramoho	5510	7.3	4.33	145	50	0.74	74	8.5	18.8
Lenihan St.	8150	8.8	3.35	189	36	1.61	161	8.7	35
Reservoirs	6750	27.2	13.3	21.2	120	0.8	80	7.9	17
Tayforth/Taylor	8950	12.4	1.99	41.9	39	1.00	100	8.3	29

Table 1

Figure 2 below is a plot of the water quality against distance from the recharge boundary with trend lines for general evolution. It can be clearly seen how the chemistry departs from the general trend for the Aramoho and Lenihan bores.

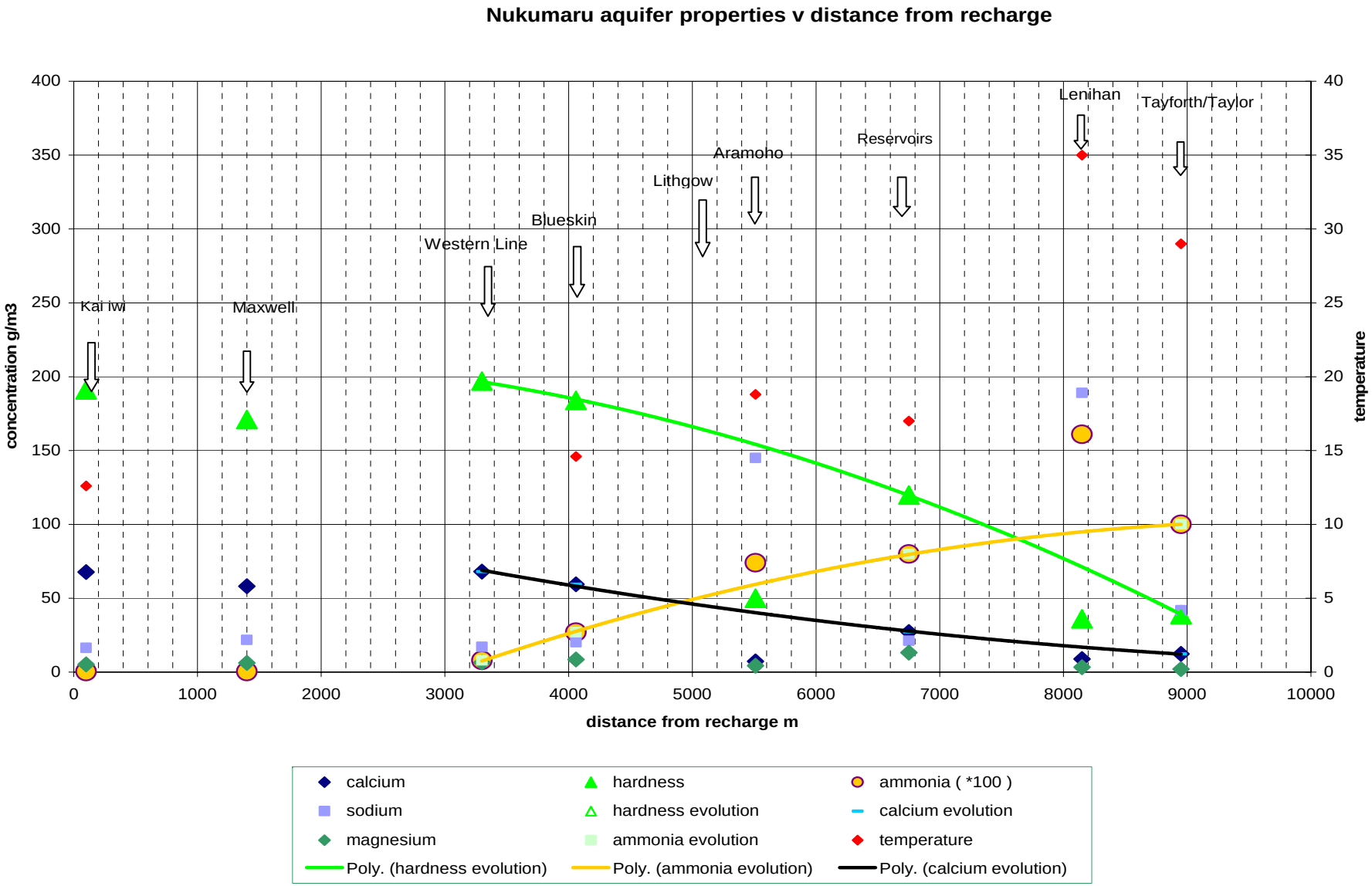

Nukumaru aquifer properties v distance from recharge
concentration g/m3
temperature
distance from recharge m
Kai Iwi
Maxwell
Western Line
Blueskin
Lithgow
Aramoho
Reservoirs
Lenihan
Tayforth/Taylor
calcium
hardness
ammonia (*100)
sodium
hardness evolution
calcium evolution
magnesium
ammonia evolution
temperature
Poly. (hardness evolution)
Poly. (ammonia evolution)
Poly. (calcium evolution)

Figure 2

A much fuller description of the geohydrology and comments on groundwater quality and chemistry is contained within the MWH report Groundwater Resources of the Wanganui District June 2005

4. Water supply issues

Water quality is of paramount importance in the supply of potable water but the issue of security of supply is also important. Groundwater from the shellrock aquifer requires no treatment to satisfy public health drinking water standards but the supply is chlorinated to protect against contamination within the reticulation system. Although the hardness of the water is not an adverse health issue the scaling that occurs as the water is heated creates a maintenance issue for appliances and is aesthetically unpleasant.

Three bores at Kaiiwi provide 85% of the city's current supply, the water then being conveyed in pipelines laid in the same corridor for some 12km through hill country and over watercourses. Slips and washouts can, and do, occur and the more severe of these has lead to water supply restrictions in the past. The bores themselves are constructed into the shellrock and collapses around the bore casing can occur leading to failure and/or expensive maintenance of equipment.

Apart from the normal asset maintenance of bores and pipelines, security of supply has been addressed in the short term by building a third reservoir. However the condition of the Kaiiwi number 1 bore has been of concern for some time and investigations to find alternative sources closer to town were started in 1995. Replacement of the supply from Kaiiwi number 1 with a new bore, and at a source independent of the pipelines, would improve the security situation. A new source would also provide an opportunity to assist with softening.

An investigation bore on Brunswick Road at Aramoho yielded soft water and this was developed into a production bore with an associated treatment plant. This provides about 15% of the city supply but less than half that of the flow from Kaiiwi number 1 bore.

A further investigation bore was drilled at Wanganui East at Lenihan Street. Water from this bore was found to be even softer than that from the Brunswick Road bore with high ammonia levels, high temperature, high sulphate levels with odour and colour. Treatment options have been identified but costs are high and at this stage this option has not been pursued.

Basing a fully softened supply on water withdrawn from a small area of the aquifer in the zone where natural ion exchange has occurred may have some risk associated with changing water quality over time, particularly if a treatment plant is required. The risk is likely to be less using water subject to natural evolution.

5. Soft Water Supply Options

The suburb of Aramoho and part of Wanganui East receives soft water from the Brunswick Road treatment plant (ammonia reduction). This is about 15-20% of the city's population.

The remainder of the population receive hard water from three bores at Kaiiwi with no treatment other than chlorination at the reservoir site.

The ideal solution would be to make use of the two good bores at Kai-iwi and add a new source replacing Kai-iwi No 1 with water soft enough and low enough in ammonia that when blended produced satisfactorily soft water needing no ammonia treatment before chlorination. However, current findings indicate that some treatment is required and there are costs to feed water to the reservoirs.

Options involve:

a. Softening the existing supply from Kaiiwi, not replacing number 1 bore
b. Provide an all new supply from an area of suitably soft water that would not require any treatment prior to chlorination.
c. Replace the Kaiiwi number 1 bore supply with water that has some hardness and soften this, which will also deal with any ammonia, then blend with Kaiiwi water.
d. Replace the Kaiiwi number 1 supply with soft water of similar quality to that at Aramoho and treat to remove ammonia, then blend with Kaiiwi water.
e. Build a treatment plant for the Lenihan Street supply along with reticulation improvements. This would provide a further 20% of the city with soft water.
f. Provide enough water soft enough and low enough in ammonia to blend with Kaiiwi water, adding additional chlorine to control ammonia issues.

6. Discussion of Alternatives

a. An ion exchange plant was estimated to cost $**6.1m**. This does not provide a replacement for the Kaiiwi number 1 bore ($1M-$2M)
b. Current testing has not found such a source.
c. The water quality at the reservoir site if softened and blended with Kaiiwi water would provide an option for full city supply of soft water. The capital cost is estimated at **$5.5m** and net operating costs at **$400k** per annum. Additional costs of $0.5M are likely to be required to deal with existing structures and facilities and pipelines at the Westmere reservoirs. This option does provide a replacement for the Kaiiwi number 1 bore.
d. This would be a plant similar to that at Aramoho but several times larger (similar to costs of (c) above).
e. The estimated capital cost is **$5.0m** with annual operating costs of **$500k.** The volume is about 25% of the city supply. This is not preferred. This does not provide a replacement for the Kaiiwi number 1 bore.
f. If water in the ion-exchange zone (Kaikokopu Road) is soft and low in ammonia, then building two new bores and a pipeline to deliver this water to the reservoir site, could have a capital impact cost of about **$6.0m** and using chlorine to control ammonia would have net operating costs of about **$0.4m** which is similar to some options above but includes backup for number 1 bore at Kaiiwi. The costs include dealing with facilities at Westmere Reservoir, ammonia reduction, pipelines, reticulation cleaning, some pipework renewal.

7. Estimates

The current estimates providing both new sources and soft water is:

- $6.0M capital including bore(s)
- $0.4M per annum operating (this is the net cost as savings from Kaiiwi reduction of use would occur)

- The proposed ion exchange system plus softer bore source (s) can be augmented with bolt on technology in 3 – 5 years if growth occurs or further softening is required.
- These existing estimates are being refined as further data from the test programme comes to hand.

8. Additional Technical and Asset Considerations

One technical question not easily answered is what effect soft water will have on the existing water pipe network in terms of potentially accelerating corrosion of the steel pipes that exist in the network.

Wanganui's pipe network is under constant surveillance: repairs are made when leaks found and sections of pipe that have too many leaks or are considered to be at risk of failure because they are corroded as a result of water flowing through them or from groundwater that's surrounds them are replaced.

Typically across any water system there is water that is lost from leakage in the order of 15% for a reasonably maintained system. Consideration must be given when commissioning a new water source to ensure losses are not unacceptably increased or water quality issues from removal of the protective calcium layer inside pipes is not excessive.

In Wanganui, the hard water has left pipes internally coated with a shell like layer called calcium carbonate. Many water supplies rely on feeding chemicals in at the treatment plant to try and form a protective lining on the inside of pipes. Wanganui is lucky in the sense that the existing hard water coats the pipes naturally but is unlucky in that the hardness is so high it has the detrimental excessive scaling issues.

Based on the results of Aramoho, the blended water is a guide for acceptability and performance. One good technical reason for not reducing hardness to very soft levels is to prevent or minimise the impacts on steel mains of reducing the protective layer that exists.

In time all pipes in Wanganui would have been renewed with dominantly plastics. A number of previously targeted renewal programmes have replaced large areas with plastic pipes.

So how does Council solve the technical issue of providing a water quality that is enjoyed by Aramoho, Wanganui East and Durie Hill, while at the same time protect the underground albeit aged steel pipe network.

There are a number of technical tools available during the evaluation and feasibility assessment of the water bore pilot programme and softening assessment. These tools, particularly the Langelier and Ryznar Indices allow comparison of various waters to contribute to the lining in the pipes or alternatively their propensity to leach material from the pipe lining. This information is used to optimise the process of new source selection and treatment.

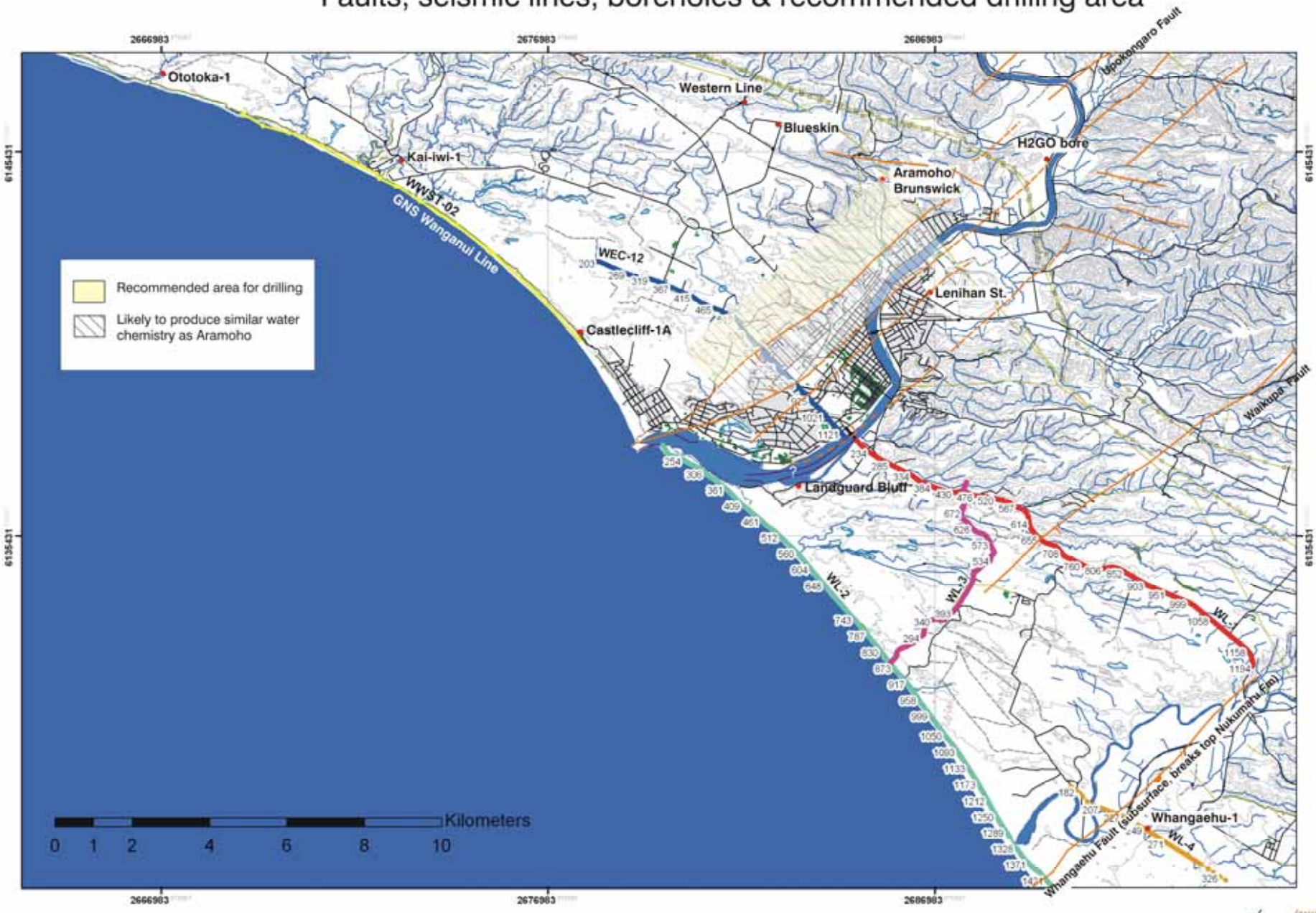
In addition, the current records of pipe deterioration in Aramoho have shown no emerging issues. Leaks are not accelerating.

8. Summary

Based on the current pilot programme which is nearing completion, an option exists to soften the City supply and also provide a replacement supply for the aging bore at Kaiiwi. An ion exchange process which is essentially a series of large tanks with a special resin beads that strips the hardness content of the water and replaces it with sodium so that the completely softened water can then be blended with other bore supplies to produce a water with the preferred hardness content. In addition to hardness, ammonia content is also treated and dealt with in the same process.

Although the pilot programme has not yet been fully completed, any further information that the programme brings to light will allow optimisation of existing assumptions and bore locations.

Faults, seismic lines, boreholes & recommended drilling area



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