

# **Wanganui District Council**

## **Water Softening Benefit Cost Assessment**

12 February 2007

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# Wanganui District Council

## Water Softening Benefit Cost Assessment

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## 1 Introduction

The city of Wanganui is primarily supplied water from three artesian bores at Kai Iwi and one bore at Aramoho. The Kai Iwi bores provide the city with a reliable and high quality supply; however the water has a hardness level of 200mg/l (as calcium carbonate). The New Zealand Drinking Water Standards 2005 rate water with a hardness level greater than 200mg/l as "hard". Wanganui is the only city (Free, 2006) in New Zealand with a reticulated "hard" water supply. The Aramoho bore has a hardness level of around 40mg/l and supplies softer water to the Aramoho area as well as parts of Wanganui East.

Wanganui District Council has engaged MWH to review the costs to consumers of a hard water supply in order to quantify the benefits of water softening, following a referendum in 2005 in which 75% of residents voted in support of council continuing to investigate options to provide soft water. This report documents the results of investigations into possible annual savings to residents from provision of a soft water supply to be used in a further referendum item.

## 2 Hard Water and Its Effects

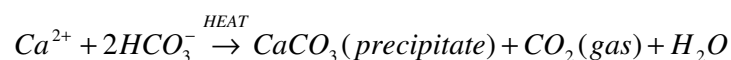
### 2.1 What is Hard Water?

Hard water contains significant concentrations of ions such as calcium and magnesium in solution. It is typical of groundwater which has passed through strata rich in limestone or calcareous deposits. Hardness is usually expressed in terms of calcium carbonate equivalent concentration, as calcium carbonate is the main component of water hardness and the least soluble salt found in drinking water.

Wanganui water hardness (around 200mg/l) is mainly in the form of carbonate hardness. Total hardness is the carbonate hardness plus the other salts of calcium and magnesium such as sulfates, silicates and chlorides. The main components of hardness in Wanganui water are:

- Calcium carbonate ( $\text{CaCO}_3$ )
- Calcium bicarbonate ( $\text{Ca}(\text{HCO}_3)_2$ )
- Magnesium carbonate ( $\text{MgCO}_3$ )
- Magnesium bicarbonate ( $\text{Mg}(\text{HCO}_3)_2$ )

Carbonate hardness is sometimes called temporary hardness, because significant proportions of hardness can be removed from the water by increasing the temperature, most noticeably through scale production during boiling. Boiling releases the carbon dioxide ( $\text{CO}_2$ ) in the water; causing the pH to rise, leading to formation of carbonate ions which are less soluble than the bicarbonate form. The carbonates precipitate out forming deposits on boiler elements or heat transfer surfaces. The chemical reaction can be expressed crudely as:



The deposition of calcium carbonate will only take place where there are suitable sites present for crystallisation. These sites can include existing scale, rough material surfaces, micro crystals and suspended particles in the water. Water turbidity has a significant effect on the rate and ease of calcium carbonate precipitation as the suspended particles provide sites for calcium carbonate precipitation.

## **2.2 Disadvantages of Hard Water**

Hard water is known to have a range of negative impacts for the consumer. Impacts identified in Water Softening Assessment (MWH, 2003) included:

- Increased consumption of soaps and detergents
- scale formation on hot water cylinder elements or heat exchangers leading to premature failure
- loss of heating efficiency in water heaters
- increased labour associated with cleaning
- increased incidence of fires caused by sparking following failure of hot water cylinder elements
- reduced lives for clothing
- clogging of water pipes and taps associated with scale formation

This report sets out costs for the first three of the listed impacts, as quantifiable data was not available for the remaining items.

### **2.2.1 Soap Use**

The effectiveness of soap is reduced when used in hard water. The mineral salts in the hard water react with soap to form an insoluble precipitate known as soap film or scum. Hard water causes reduced soap lathering in dishwashers, washing machines, and hand/body washes. Consequently more soap must be used to produce an 'acceptable' amount of lather. Hard water has a smaller negative effect on the ability of detergents to lather, because of their chemical composition. However, more detergent than normal must be used in hard water to get the same lathering or achieve equivalent cleaning effectiveness.

### **2.2.2 Premature Failure of Hot Water Cylinder Elements**

Scale precipitation is accelerated on the high surface temperatures of electric elements. As the scale precipitates, it tends to deposit on the electric element where it forms an insulating layer. Scale is a poor conductor of heat. The insulating scale layer causes the element to heat up internally, because heat flow from the element to the water is inhibited by the scale. The element eventually fails by overheating because it cannot operate under the high internal temperature caused by the scale layer.

### **2.2.3 Loss of Heating Efficiency in Water Heaters**

Hard water causes a layer of scale to form on the heating element (electric cylinders) or the heat exchange surface (gas heaters). The local high temperature causes the carbonates to precipitate out. A rough surface causes the precipitation to deposit faster – the more scale present, the more will precipitate due to the roughness of the surface. Scale does not form uniformly over the whole heating surface. The level of scale production is dependent on the temperature at which the cylinder is run as well as the level of use. This scale insulates the heating surface and provides a resistance to heat transfer, thus requiring more energy or electricity/gas to heat the water to the required temperature.

### 3 Assessment Methodology

#### 3.1 Overview

Following consideration of the wide range of negative impacts to consumers of hard water outlined in Section 1, this assessment has focussed on three areas where the most significant costs are thought to lie. For each of these three areas, it was felt that verifiable and measurable data could be obtained to enable valid cost estimates to be made. The three areas comprise:

- level and cost of additional soap and cleaning products
- impact of scale formation on life cycle costs for electric and gas hot water heating appliances
- impact of hard water and scaling on heating energy efficiency

#### 3.2 Soap and Cleaning Product Consumption

Rather than try to establish differences in consumption at the household level, the approach taken was to source data on accumulated soap and cleaning product sales likely to be impacted on by hard water, for Wanganui and another urban centre of comparable size with a soft water supply. While a wide variety of factors have the potential to influence the validity of household consumption data including socio-economic factors, regional climatic differences and brand preferences, it was felt that data of this nature could provide a high level indication of soap and detergent sales trends in Wanganui.

A number of urban centres were identified for comparison to Wanganui (summarised in Table 3.1) and represent centres with similar total populations and a similar socio-economic profile. The average household size is 2.7 people (Statistics New Zealand, 2007). In the final instance New Plymouth was chosen for the comparison, because data was readily available for this urban centre, and its close proximity to Wanganui was assumed to negate some of the above mentioned issues. New Plymouth has a surface water supply, with a hardness level of 30-70mg/l after lime dosing (Cook, 2007).

**Table 3.1 Similar sized cities in New Zealand, their population & number of households**

City	Population *	No. Households*
Wanganui	39,423	15,300
New Plymouth	47,763	18,417
Gisborne	31,719	11,178
Invercargill	46,305	18,102
Whangarei	46,047	17,187

\*Source: Census 2001

While Countdown, New World, Woolworths and Pak'n Save supermarkets in Wanganui, and Progressive Ltd. were initially approached for sales information, the difficulty of using discrete sales information from one or more of the stores providing data, in the absence of data on market share, required a different approach. Instead, product suppliers Colgate-Palmolive and Unilever were approached for sales data for the Wanganui area as

compared to New Plymouth. Colgate-Palmolive has been able to supply data for sales of products to both Wanganui and New Plymouth Pak'n Save. It is this supermarket stock supply volume data which has been used for the assessment. Their relative market share was approximated using toothbrush sales – a common item to both shops and the supplied data.

### **3.3 Life Cycle Costs for Electric and Gas Hot Water Appliances**

To identify life cycle costs for hot water elements and effects of hard water, plumbing suppliers in Wanganui (MasterTrade, Zip Plumbing Plus, My Plumbing Depot, Mitre 10 Mega and Placemakers) were contacted for sales figures of replacement 1.5kW electric elements. Local suppliers indicate that 1.5kW elements are used more frequently as replacement elements than 2kW elements.

Alongside sales data for replacement electric elements the following interviews were also undertaken:

- Jim Raybold of Wanganui Gas. Mr Raybold reported the numbers of gas water heating connections in Wanganui, sales of gas water heating units and servicing arrangements.
- Peter Selwyn of Selgas. Mr Selwyn is the service agent for four gas water heating suppliers in Wanganui (Rheem, Rinnai, Abergas, Bosch).
- Mark Norris of Hermetic New Zealand. Hermetic NZ is the element manufacturer for Rheem electric hot water cylinders. Mr Norris provided information to establish typical element lives.
- Telephone conversations with Wanganui plumbers, including Mike Buchanan, Mike Bates, John Buchanan, Kevin Bates, and Rivercity Gas. They provided information to establish the cost for electric element replacement and estimates for the typical life of an electric hot water element in the Wanganui area.

### **3.4 Hard Water and Scaling Effects on Heating Efficiencies**

Assessments undertaken to establish energy efficiency impacts include:

- A telephone interview with Mark Norris of Hermetic NZ Ltd to determine the insulation effect of scale on electric elements.
- Internet site search for refereed studies on hard water heating efficiency – US Department of Energy, Union Gas Ltd, New Mexico State University
- Emails from Dr Clive Davies of Massey University, specialising in heat exchangers and their performance, on how hard water effects heating efficiency

## 4 Effect of Hard Water on Domestic Consumers

### 4.1 Soap and Cleaning Product Use

Using data for sales of equivalent groups of Colgate-Palmolive products in the Pak'n Save stores for both Wanganui and New Plymouth, the relative percentage levels of products sold have been compared across a range of product lines. The product lines that were investigated are:

- Bars of soap
- Liquid Dishwashing Detergent
- Laundry Powder
- Toothpaste
- Shampoo/Conditioner
- Liquid Hand/Body Washes
- Cleaning Products

The data is summarised in Table 4.1 below. The sales of toothbrushes were considered a standard item to compare the data from Colgate-Palmolive and standardise it to the relative store sizes. Wanganui Pak'N Save sells 3% more Colgate-Palmolive toothbrushes than the New Plymouth Pak'N Save. The benchmark toothbrush sales percentage is removed from the percentage increase in sales. The costs were prepared from consideration of typical household usage of these products and their standard purchase price from the Woolworths Online Shopping website. The approximate extra cost could then be calculated for a household in Wanganui.

**Table 4.1 Costs of the Increase of Soap/Detergent Colgate-Palmolive Products sold in Wanganui compared to New Plymouth Pak'N Save.**

Item	Estimated Typical Annual Usage	Unit Price	Percentage Increase in Sales in Wanganui (%)	Extra Cost to Wanganui Residents
Bars of Soap	26 bars (100g)	\$1.00	50	\$13.07
Liquid Dishwashing Detergent	15 bottles (750ml)	\$2.99	43	\$19.14
Laundry Powder	26 boxes (1kg)	\$4.07	42	\$44.61
Shampoo/Conditioner	26 bottles (400ml)	\$6.29	26	\$41.68
Toothpaste	15 tubes (120g)	\$3.50	50	
Hand wash/Shower Gel	(400ml)	\$4.00	-60	
Cleaning Products	(500ml)	\$4.50	2	
<b>Total Cost/Annum</b>				<b>\$118.50</b>

The following observations are made about the method of analysing the soap and detergent cost:

- There is no adjustment made in the Wanganui sales figures for the population of Aramoho who have a softer water supply.
- The market share of Colgate-Palmolive is unknown for each of the categories, and the two stores.
- The cost associated with toothpaste has been excluded because toothpaste usage is not expected to vary considerably with water hardness.
- Hand wash and shower gel products show a marked decrease of sales in Wanganui compared to New Plymouth. This may show variation in Colgate-Palmolive market share in different lines or in the overall city market share.

- Cleaning products have a minimal increase in sales in Wanganui compared to New Plymouth.
- The hand wash/shower gel and cleaning product categories were not included in the extra cost to Wanganui resident's calculation.
- A product line not included in the analysis, although data was provided, were Fabric Conditioners as they are assumed to be a product sold on account of socio-economic factors, rather than water conditions.

## **4.2 Costs for Electric and Gas Hot Water Cylinders**

### **4.2.1 Electric Water Cylinders**

Data from Statistics New Zealand and Wanganui Gas indicates that there are:

- 15,300 households in Wanganui,
- 6000 gas hot water heaters.
- 9,300 households electric hot water systems (by calculation).

Data from the main suppliers of electric elements in Wanganui extracted the following information:

- Total sales in the range of 2250 electric elements per year.
- An assumption that these figures cover 90% of electric elements replaced in Wanganui.
- Predicted total replacement elements are therefore 2500 electric elements/year.
- This gives an average electric element life of 3.7 years or 3 years and 10 months per element.

An element should last 10 years in soft water conditions (suggested typical life by Hermetic NZ), and an installed cost of \$150 for a new element (\$74.40 for element). The replacement cost outside Wanganui is \$150 every 10 years or \$15/year. The replacement cost for Wanganui is \$150 every 3.7 years or \$40.54/year. The additional cost for a typical householder in Wanganui is around \$25.32 per year.

While the plumbers surveyed anecdotally commented that "elements can fail in a couple of months", or "elements don't last much more than 18-24 months", there is no consistent data to support this as a general trend. The frequency of element failure depends to a significant extent on the temperature at which the cylinder is run, as the hotter the water, the faster the scale precipitates and builds up on the element so leading to element failure. No reference relating relationship between temperature, degree of scale formation, and element failure was found.

The assessed life of 3.7 years for an element in Wanganui, is at best be a very conservative estimate and in individual cases costs could be up to twice this value. The annual cost of \$25.32 is significantly less than the \$120 stated in the "Water Softening Assessment" (MWH, 2003) because of differences in assumptions of life length and numbers of elements in Wanganui. However the figures in this report are based on actual element sales, and are therefore more realistic.

### **4.2.2 Gas Hot Water Storage Cylinders**

Gas hot water storage cylinders work on the principle of heat transfer from the gas burner through the metal bottom of the cylinder to the stored water and appear to be less impacted on by hard water than electric hot water cylinders. Major effects include:

- Scale formation appears to reduce heating efficiency (outlined in Section 4.2.4).
- Superheated scale explodes or pops off the heat exchange surface requiring more regular cleaning by a professional serviceman, however, the frequency for servicing is difficult to quantify.
- Reduced lives for gas storage cylinders in respect of hard water are claimed but not substantiated with any firm data or by variations in the warranty periods or conditions offered for systems installed in the Wanganui supply area.

In the absence of any other effects, costs to consumers are estimated at \$70 for a service at 5 years, instead of 10 years in soft water areas, which represents an additional cost of \$7 per year for storage gas cylinders.

#### **4.2.3 Continuous Flow Gas Water Heaters**

Interviews with suppliers and installers listed in Section 3.3 elicited the following comments in regard to hard water effects on continuous flow gas hot water heaters:

- Precipitated scale scours out the heat exchanger pipe network, especially in the bends, and is the major cause of premature failure in hard water areas. A case of this fault was sighted at Rivercity Gas, along with the same observation made by suppliers Abergas and Rheem. This fault is not covered by the 10 year limited warranty covering mechanical defects provided by most manufacturers.
- Manufacturers stated a number of instances of premature failure in Wanganui (but no records taken) after 3 to 5 years due to erosion from hard water scale.
- Suggested lifetimes for continuous gas water heaters are quoted at 10 to 15 years, however suppliers were not willing to make firm recommendations because of the relative newness of the technology.
- The severity of any hard water effects can be minimised by the use of controllers to control water temperature to that optimum for shower (e.g. 42°C) or kitchen use (e.g. 55°C).
- Indications from Wanganui Gas are that around 80% of gas water heater sales are now continuous flow systems – reflecting their recent popularity.

In the absence of specific data on the performance of individual systems, it is not possible to conclude that there is any additional cost to households of continuous flow gas hot water systems.

If the shorter life of the heat exchanger under hard water conditions became an issue, potential costs will be considerable. Based on early replacement of the heat exchanger and controller at 8 years instead of a more typical 12 years, the additional cost is likely to be as much as \$1200 or \$50 per year.

#### **4.2.4 Inefficiencies in Water Heating due to Scale Formation**

Information for efficiency impacts were cited from a range of sources including:

- US Department of Energy states efficiency can be reduced by 10% for scale 1mm thick to 40% for 6mm scale.
- Clive Davies, Professor of Energy at Massey University quoted literature from Union Gas, a major Canadian Natural Gas provider, which stated a decrease in efficiency of 30%.
- Water Quality Research Council, conducted at New Mexico State University, states water heaters work 22-30% less efficiently.

Mark Norris, of Hermetic NZ, stated that electric elements have a layer of insulation approximately 1mm thick. Therefore a layer of precipitation 1 mm thick on the element is providing significant additional insulation to heat transfer. Scale does not precipitate evenly on the element, but can build up to 3-4mm in some locations.

Based on the above sources and understanding of the mechanism involved, we suggest that an average 10% efficiency reduction be used for Wanganui households, given the variability in scale build up thickness on all water heating surfaces.

Using Statistics New Zealand information for average household spending estimates of the additional energy costs are given below in Table 4.2.

**Table 4.2 Energy Efficiency Estimates (Statistics New Zealand, 2003-04)**

Item	Amount / Annum	Notes:
Household Energy Expenditure (2003/04)	\$1456	Includes daily charge
Household Energy Expenditure (2006/07)	\$1768	Increase by 20%
Energy Expenditure net of Daily Charge	\$1456	Daily charge of \$0.85
Hot water heating cost	\$626	43% of total energy use
Additional 10% cost to overcome inefficiency	\$62.60	

No distinction between gas and electric hot water energy has been made in this assessment, and it is believed this additional cost is conservative.

### 4.3 Other Effects

Quantifiable data was not available for the following impacts of hard water; however, these effects are noteworthy.

#### 4.3.1 Hot Water Cylinder Fires

The 2003 Water Softening Assessment report mentioned the significantly higher instance of 4.4 call outs/year in Wanganui relating to fires starting in electric hot water cylinder cupboards in the period 1995-2000. This represented 24% of the national total of hot water cylinder callouts in the period 1997-1998. The New Zealand Fire Service commented that (Stewart, 2007):

- The NZ Fire Service recognises hot water cylinder failure as a fire hazard; however
- There is no statistically sound information to link fires originating in electric hot water cylinder cupboards with the hard water supply.
- Wanganui is a high fire risk area, potentially because of the lower socio-economic profile of the community.

#### 4.3.2 Miscellaneous Effects

Scale build up occurs in any appliance which heats water including hot water jugs, irons, and coffee machines. It was considered too difficult to quantify these individual effects, although in individual cases they can be very significant. No allowance has been made for the reduced life of these appliances due to hard water effects, as data is not readily available to support anecdotal evidence of this problem.

There is some evidence supporting premature failure of appliances due to hard water. Appliances most commonly affected include washing machines and dishwashers. Hard water scale can spread through the appliance, causing blockages and general wear and tear due to the abrasiveness of the scale. Appliances which use hard water may wear out 30% earlier than in soft water areas (Reverse Osmosis of Florida, 2007).

These effects have been roughly estimated at a cost between \$50 to \$100 per year to Wanganui households.

Other effects claimed to be caused by hard water include:

- The wearable life time of clothes. Clothes feel more stiff and dull after prolonged washing in hard water because the soap scum and precipitated minerals collect in the clothes fibres, and do not rinse out.
- Skin and hair has a tendency to dry out, and the symptoms of eczema are more prevalent. It has been suggested that negative impacts on skin and hair from hard water could be due to the requirement to use more soap or detergent which itself impacts negatively on skin and hair condition (Gunson, 2007).

#### 4.4 Domestic and Small Commercial Costs for Softening

Telephone interviews with suppliers and installers of domestic water softening units in Wanganui suggest that there may be as many as 1000 installations, however this data is not exhaustively known. Typical running costs for the brine regenerated ion exchange units which are most common are of the order of \$70 for the salt and \$5 for the modest additional electricity costs. A typical water softener costs approximately \$2500 (installed). Estimates of life-cycle costs have been based on a life of 20 years, and an interest rate of 8%. Based on this, costs for domestic softening have been estimated in Table 4.3.

**Table 6.2. Domestic Water Softening Expenditure**

<b>Item of Expenditure</b>	<b>Cost</b>
Amortized annual installation cost	\$255
Annual running cost	\$75
<b>Total annual cost</b>	<b>\$330</b>

The annual cost of a water softener is high compared to the studied annual costs in this report. However the perceived benefits apparently exceed the annualised cost, due to the steady sales of water softeners in Wanganui.

## **5 Effect of Hard Water on Non-Domestic Water Users**

Non-domestic users of hard water who will benefit from water softening will include:

- Industries that heat water using boilers for various applications
- Motels
- Cafes and restaurants with coffee machines, dish washers, etc.
- Laundry services

Most local industries using large quantities of hot water (e.g. meat processing) have water softening and demineralisation equipment in place. Estimates of the potential benefits of softening to these users will depend on a wide variety of factors and is beyond the scope of this assessment.

Smaller non-domestic water supply users have been contacted to establish current issues and practices with regard to water softening. Key findings include:

- New motels generally have water softening equipment installed. Costs appear to be 2-3 times higher than a typical domestic installation and relate to volume of hot water used.
- Motels without water softening reported difficulties with keeping linen clean and white.
- Coffee machine vendors recommend that cafes install water softening equipment to protect against scaling of the small diameter heat exchanger piping. Coffee machines cost approximately \$10,000 and a de-scaling treatment costs around \$1,000 which would be required approximately twice yearly.
- Annual water softening costs were in the range of \$100-\$250 for the softener excluding the annualised capital cost of investment.
- The sole laundry service contacted had only been operating for 6 months and had not experienced any problems with its un-softened water supply. They noted that a water softener had not been recommended at the time of the installation of the washing machines.

## 6 Summary of Costs to Domestic Users of Hard Water

Based on the work completed to date, Table 6.1 shows the estimated costs of hard water for an average Wanganui household, for the three different types of water heating.

**Table 6.1 Summary of Costs per Household**

Item	Electric Water Heating	Gas Storage Water Heating <sup>a</sup>	Continuous Flow Gas Water Heating
Water Heater Repair/Maintenance	\$25.32	\$7.00	\$50.00 <sup>b</sup>
Soaps/Detergents	\$118.50	\$118.50	\$118.50
Additional energy use for Water Heating	\$62.60	\$62.60	\$62.60
<b>Total</b>	<b>\$206.42</b>	<b>\$188.10</b>	<b>\$231.10</b>
<b>Rounded Total</b>	<b>\$205</b>	<b>\$190</b>	<b>\$230</b>

**Notes:**

- a. The cost of replacing the gas cylinder earlier than usual has not been investigated in this report but could be significant.
- b. Based on assumption of a normal life of 12 years, however no expected lifetime is known.

Table 6.2 summarises the cost of a domestic water softening unit installed in individual households.

**Table 6.2. Domestic Water Softening Expenditure**

Item of Expenditure	Cost
Amortized annual installation cost	\$255
Annual running cost	\$75
<b>Total annual cost</b>	<b>\$330</b>

Water softening equipment and running costs have a higher annual cost than the quantified hard water costs described in this report.

However, there are several impacts which have not been quantified in this report which could lead to significant additional costs to the Wanganui household such as the cost of replacing jugs, irons and other household appliances that fail due to scale build up. These costs could be in the magnitude of \$50 to \$100 per year, in addition to the costs summarised in Table 6.1.

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## Appendix A

### List of Contributing Parties

Allen Stains, Plumbing Department – Mitre 10 Mega, Wanganui  
Astral Motels & Apartments  
Bunnings  
Caroline Galloway, Anna Boyle - AC Neilsen  
Consumer Magazine  
Cooks Gardens Motor Lodge  
David Waite - Rheem  
Gareth, Manager – Pak’N Save Wanganui  
Grant Pepper – Unilever.  
Hugh Gilbert – MWH Wanganui  
Jim Raybold – Wanganui Gas Ltd.  
John Buchanan – Wanganui Plumbing  
Kevin Bates – Limebusters  
Linda Marks – Rivercity Gas  
Mark Norris - Hermetic  
MasterTrade Plumbing Supplies  
Michelle Hamilton, Laundry – Progressive Enterprises Ltd.  
Mike Bates – Mike Bates Plumbing  
Mike Buchanan – Mike Buchanan Plumbing Ltd  
Mitre 10 Mega Café Manager  
My Plumbing Depot  
Paul - Abergas  
Peter Selwyn, Selgas.  
Placemakers  
Richard Manniton, Marketing – Progressive Enterprises Ltd.  
Stu Clarke – NZET Ltd.  
Statistics New Zealand website  
Undies Laundromat  
Wayne Law, Manager – Countdown Wanganui  
Vish Sarma – Colgate Palmolive  
Zip Plumbing Plus