AN ASSESSMENT OF PEAK DAILY DEMAND IN TAURANGA CITY AND IMPLICATIONS FOR WATER SUPPLY MANAGEMENT

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ABSTRACT

The capacity and timing of future water supply infrastructure requirements in Tauranga is based on knowledge of current demand (especially peak daily demand - PDD) and prediction of population growth. PDD and population growth is also used to determine impact fee contributions and to evaluate future impact on water resource availability.

A statistical predictive model has been developed to explain relationships between daily water demand and factors such as previous rainfall, number of consecutive dry days, soil moisture deficit, temperature, resident population and visitor numbers. There is potential to use this model as an operational tool to predict water demand.

The impact of universal metering and other demand management initiatives has been assessed and is graphically demonstrated in this model. The reduction of average and peak daily demand has allowed Tauranga City Council to defer major capital investment in a new water source.

The current PDD design figure is reasonable for Tauranga City but is influenced by climate and the ongoing impact of metering. The predictive model allows Tauranga City to understand factors that influence daily demand so that supply management programmes can be developed with more confidence.

KEYWORDS

Peak daily demand, water demand prediction, universal metering impact

1 INTRODUCTION

1.1 REASONS FOR STUDY

Tauranga City Council ('TCC') has adopted a design peak daily demand figure of 500 l/c/d for the development of future water supply infrastructure. The Council decided to examine the causes or influencing factors on the peak day water demand in Tauranga, with a view to substantiate whether the current peak daily demand of 500 l/c/d remains appropriate. This figure is based on historical data that recognises the reduction in peak daily demand that has occurred since the advent of universal metering. The future provision of water treatment capacity in Tauranga, and development contributions that partly fund new water supplies, are both based on the peak daily demand estimate. Hence this figure is of considerable importance to TCC water supply planning.

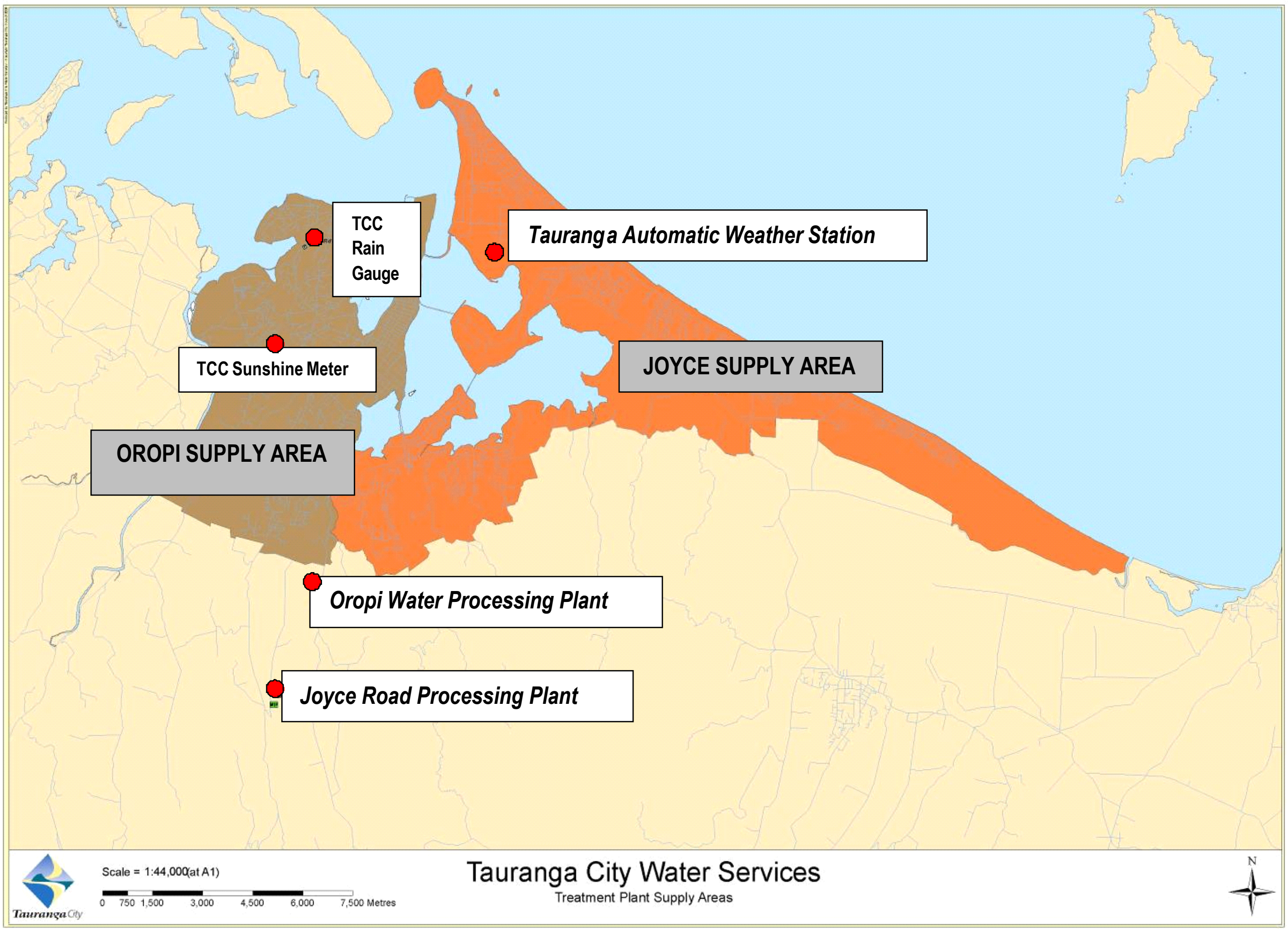
Once TCC has an understanding of the variables that impact daily demand and the extent of the change in sensitivity to these variables brought about by metering, there was an opportunity to use these variables as an operational tool for forward prediction of daily demand

1.2 TAURANGA WATER SUPPLY

The domestic water supply in Tauranga is provided by two water treatment plants at Joyce Road and Oropi Road. Oropi Road supplies the central city and western suburbs, and Joyce Road supplies Mount Maunganui, Papamoa and Welcome Bay areas.

Figure 1 below shows the area which is supplied by each plant, the location of the plants, and the location of the automatic weather station from which climate data was obtained to complete this study.

Figure1: Tauranga Water Supply and Weather Stations



Water leaves each treatment plant and flows into clear water reservoirs on each of the sites. From the clear water reservoirs, water flows into several other storage reservoirs in each system through the trunk mains. These reservoirs provide balancing storage for the bulk system and/ or service storage for the distribution network, depending on the configuration and location of the reservoir. The volume of water leaving each treatment plant is measured and recorded.

Water volumes in all the reservoirs are monitored daily by telemetry by measuring levels and reservoir outflows. The consumption varies depending on use within the network by residential, commercial and non-revenue (including leaks) users.

1.3 TAURANGA WATER CONSUMPTION

Daily total production and consumption figures for Oropi and Joyce Road supply areas for the period 1987 to 2006 were derived and converted to litres/capita/day. Population data was obtained from census information and for 2006, from the census estimate. For years between census, population was interpolated. This method calculated gross per capita consumption to include commercial/industrial users and non-revenue water - the basis of the 500l/c/d design figure. In using gross per capita consumption, comparisons with other communities can be made.

Water consumption figures were provided for the two separate supply areas, but since there was only one set of weather data, the figures were added together to give an overall consumption figure for Tauranga.

The variability in consumptive patterns for Tauranga is also attributable in part to the high ratio of domestic to commercial/ industrial customers. Table 1 below contains a breakdown of residential and commercial metered users for 2004/05.

Table 1: Breakdown of residential and commercial metered users.

	2004/05		
	Number of metered connections	**Average annual consumption per connection (cubic metres)**	**Estimated volume of water sold (cubic metres)**
Domestic	39,637	195	7,729,215
Commercial	3,337	1,038	3,463,806
Total	42,974		11,193,021

Based on figures provided directly to Opus or to Hamilton City Council (Raewyn Simpson), the following most recent water consumption figures have been tabulated for comparison in Table 2 below.

Table 2: Most recent water consumption figures for other locations.

Community	Population	Average gross consumpn (l/c/d)	Peak daily demand (gross) l/c/d	Comment
Metered Supply:				
Waitakere City	186,930	235	271	
Manukau City	337,200	306	367	
Hibiscus Coast	38,519	172	399	
Tauranga	**103,632**	**335 (since metering)**	**500**	
Nelson	44,900	491	679	Ratio reduced from 2.0 to 1.5 since metering
Christchurch	345,000	363	690	
Unmetered Supply:				
Dunedin	109,580	391	591	
Wanganui	40,000	599	875	
Gisborne	32,700	413	963	
Rangiora	12,073	484	1202	
Palmerston North	72,650	378	Not provided	

2 VARIABLES AFFECTING PEAK DAY DEMAND

2.1 POSSIBLE INFLUENCES ON RESIDENTIAL WATER DEMAND IN TAURANGA

Tauranga is located in a sub-tropical climate zone, with warm humid summers and mild winters. Temperatures show a marked seasonal cycle peaking in summer (Jan/Feb) and at their lowest in winter (Jul/Aug). Typical summer daytime maximum air temperatures range from 22°C to 26°C, but seldom exceed 30°C. Winter daytime maximum air temperatures range from 12°C to 17°C. Sunshine can be prolonged at all times of the year and the overall total sunshine hours recorded is high, usually reaching at least 2200 hours. South westerly winds prevail for much of the year, and sea breezes often occur on warm summer days. Winter usually has more rain and is the most unsettled time of year. Rainfall in Tauranga tends to fall sporadically but heavily. The area is therefore prone to droughts but also to flooding.

This type of climate can lead to pressure on water supplies as the sporadic rainfall struggles to match the demand created during the warm, very dry periods. Watering of outside areas in summer to maintain landscaping/gardens is likely to increase demand. The area (in particular, Mount Maunganui and Papamoa) is also a popular holiday destination and at a convenient distance for weekend trips from Auckland. This can mean a temporarily increased population during holiday periods, adding extra demand to the water supply.

Prior to water metering, water restrictions were frequently used in Tauranga to manage the water supply during dry periods. Restrictions are still an option in extreme summers where they have an effect on reducing non-essential use, such as garden watering (sprinklers/hoses) and washing cars. Display boards sited around the city are used to communicate the level of water restrictions in place.

Water metering was introduced throughout the supply area over the period 1999-2002, and water charging based on volumetric usage commenced in July 2002.

2.2 WEATHER DATA

The meteorological variables that have been used for this investigation are those which have been shown in other studies to be linked to water consumption. (Davies and Dandy (1995), Maidment and Parzen (1984), Tillman and Bryant (1998)). These include daily rainfall (mm), sunshine (hours), maximum and minimum daily temperature, and soil moisture deficit (mm). These variables were recorded at the Tauranga Automatic Weather Station which is located at Mount Maunganui airport in the city of Tauranga (see Figure 1).

The recordings from the Tauranga Automatic Weather Station at Mount Maunganui airport have been used for this study as representative of the weather experienced over the whole city area. During periods of high pressure over the east of the North Island, Tauranga's weather would not differ greatly across the city. This is the type of weather that occurs during periods of high water demand. Hence the airport climate station in settled and fine weather can be relied upon as representative of the whole of Tauranga City for this analysis.

2.2.1 RECORDED VARIABLES

- **Maximum temperature:** This is the highest temperature recorded during the 24 hour period 0900hrs on the day to 0900hrs on the following day. Because of the diurnal variation in maximum temperature the highest temperature usually occurs in the mid-afternoon and will therefore occur on the day that it is reported.
- **Minimum temperature:** This is the lowest temperature recorded during the 24 hour period 0900hrs on the previous day to 0900hrs on the day. Because of the diurnal variation in minimum temperature the lowest temperature usually occurs just before dawn, and will therefore occur on the day that it is reported.
- **Sunshine:** For Tauranga this has been recorded since 1994 and is given in total hours for the day.
- **Rainfall:** This is measured using a standard rain gauge and is given as a total for the day in millimetres.

- **Soil moisture deficit ('SMD'):** This is a measure of the water content in the soil and gives a good indication of how dry the soil is and therefore the requirements for garden watering. It is given in millimetres and is shows how much water is needed to return the soil to field capacity, which is the maximum amount of water a soil can hold under free drainage conditions. It takes into account temperatures, sunshine, evaporation, rainfall, wind speeds and humidity.

2.2.2 DERIVED VARIABLES

These recorded variables were used to derive several other variables, below.

- **Raindays:** This is a measure of frequency of rainfall, where any day recording more than 0.0mm rainfall counts as '1' day. So for example, raindays can be calculated for a period, say a week, and will show the number of days in the week in which rain fell. In this study, rainday counts were used for 1 week (7 days) and 2 weeks (14 days).

- **SMD > 120 mm**: This is a threshold count measure. Every day in a given period when the SMD is high (above the threshold of 120 mm, which is approximately the 90th percentile for SMD over the year as a whole, i.e. on average, soil moisture only exceeds this figure 10% of the time) represents '1' occurrence. So for example, if the period is a week and every day the threshold SMD was exceeded, will give a value of 7 for the week, therefore indicating prolonged dry soil conditions. In this study, SMD counts were used for 1 week (7 days) and 2 weeks (14 days).

- **Number of drought periods:** For each summer, the number of consecutive days recording zero rainfall was counted. If four or more were recorded, this was counted as a 'drought' period. For each summer, the overall number of separate droughts was recorded.

- **Number of drought days:** The number of drought periods for each summer was calculated as above. The total number of days involved overall in these droughts was totalled, to give an overall indication of the number of days drought that were experienced in each summer (Nov – March).

- **Preceding dry days:** The total number of dry days preceding the day in question.

- **SMD Sun:** SMD multiplied by sunshine total to give a compound variable.

2.2.3 LAGGED VARIABLES

The variables described above were also lagged so that the effect of time could be investigated to see whether there was a time delay, for example perhaps the temperature preceding the actual day/week would be important. All the variables were lagged by 1 and 2 days/weeks (depending on the time period of the analysis).

The water consumption figures themselves were also lagged, to see whether there was a link between water consumption the day/week preceding the day/week in question. This preceding consumption is not a driver of demand but may reflect other, unidentified and perhaps unquantifiable influences on water consumption.

2.2.4 3.2.4 PERIOD

The Tauranga automatic weather station has been operational since 1992. It was decided to look at demand and weather data from 1992 onwards, since in statistical terms this is an appropriately sized dataset for analysis purposes.

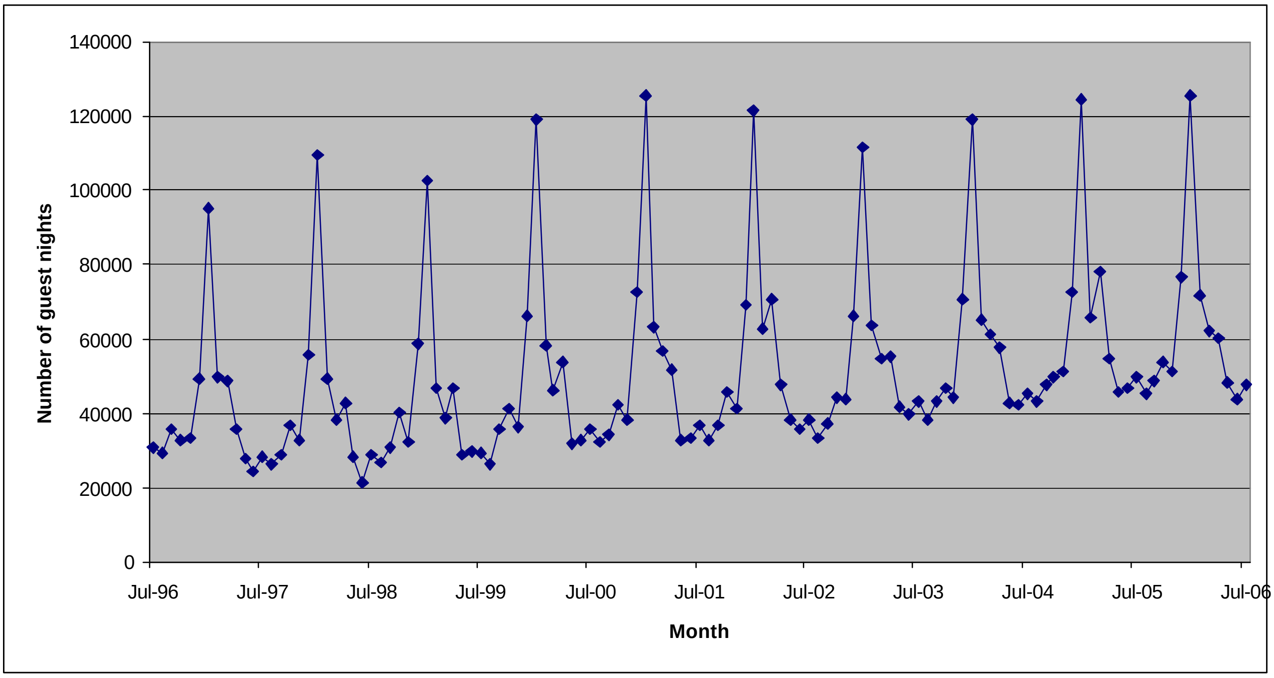
2.3 GUEST NIGHTS

This variable was used as a monthly total, so for example, for all days in January 2005, the guest night variable would be equal, then in February it would change.

It is possible that the seasonal influx of tourists to the Tauranga area may influence water demand during holiday periods. In order to investigate this further, guest night data were obtained from Stats NZ. These figures are available on a monthly basis since July 1996. Other information was also provided, such as the number of establishments offering accommodation, the overall capacity and the occupancy rate.

Figure 2 below shows the change in the total number of guest nights recorded each month for Tauranga City. On this graph the gradual increase in visitors to Tauranga can clearly be seen. The peak month for visitors is January, which has a significantly higher total than any other month.

Figure 2: Number of guest nights each month, Tauranga City.



In order to take the effect of varying numbers of visitors on water demand into account, the monthly guest night data was included in the regression models to see whether it was identified as significant, explaining variability in the data.

2.4 POPULATION GROWTH

Population data were provided by TCC for meshblocks corresponding to the two supply areas for 1991, 1996 and 2001. This data was useful but was ultimately amalgamated into one figure for population for each of these years and data was also obtained from the most recent (2006) census. This figure was used to represent the number of residential consumers in the city supply area. Figure 3 shows the growth in population in Tauranga since 1991:

Figure 3: Population in Tauranga for the last four census years (based on census data).

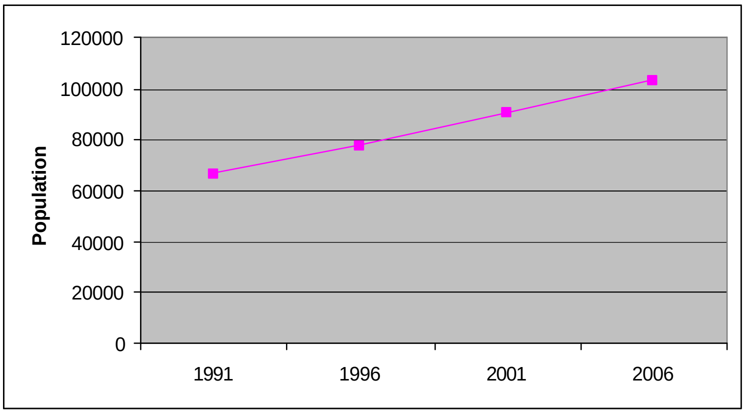


Figure 3 clearly illustrates the increasing pressure that has been exerted on the water supply by the growing population. High growth has occurred since 1991, and this trend looks likely to continue.

2.5 LIMITATIONS AND ASSUMPTIONS

The data that has been used is the total of all water consumed in Tauranga City by residential, commercial, industrial and non-revenue uses. Commercial/industrial uses are also included in the demand data, and have been assumed to be constant for the purposes of this study. Effectively we have assumed that variations in demand that create the peak day demand are caused by residential outdoor use. Clearly this may not be the case as commercial users demand may vary depending on external factors. However Tauranga City does not have significant agricultural or industrial users (whose usage may be weather related).

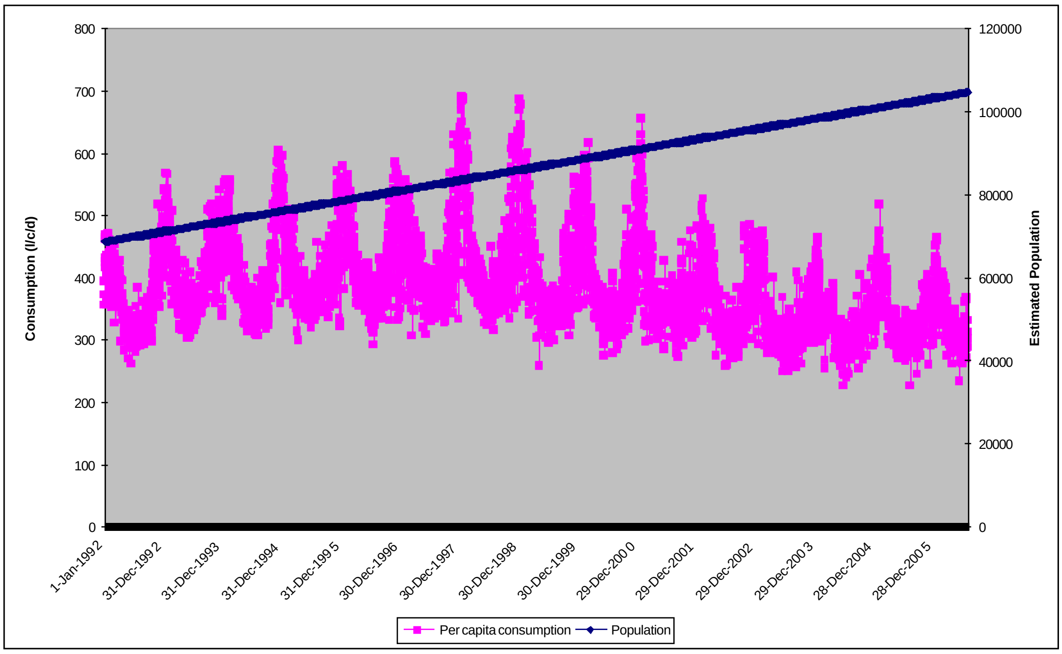
Non-revenue water is also part of the daily demand dataset. This is primarily water lost to the system through leakage, hence per capita figures could be less than those used in the study, but Tauranga City is still required to supply this extra water which is lost through leakage. Water loss benchmarking carried out by Tauranga City has estimated the non-revenue water component to be 62 - 83 l/connection/ day over the preceding three years.

In dealing with population data, it was assumed that population had increased in a linear fashion. This was indicated by the census data, however the census points are every 5 years and it could be that in between census years population did not increase in a linear fashion. For example, there could be certain years when growth was more rapid. This has not been investigated at this stage.

3 HISTORICAL TRENDS OF WATER DEMAND

Figure 4 shows the per capita consumption figures that were obtained when daily consumption volumes were divided by estimated population. The population is also shown on this graph and can be clearly seen to be rising. Despite this increase in population, water consumption per capita can be seen to be stable/decreasing in recent years.

Figure 4: Water Consumption (l/c/d) and Population



The strong seasonal cycle in water consumption can be seen with each peak representing a separate summer period. Three phases have been identified from this graph which share similarities.

Early phase: This covers the first six summer periods for which data is available (1991/92 – 1996/97). During this period, there is a gradually increasing peak daily demand, with each summer peak equalling or exceeding the one previous. This is likely to correspond to the rising population at this time.The opening of the new Joyce Rd water treatment plant occurred in 1997 providing an upgrade to the existing plant in both capacity and quality. As a result, there was ample water available after the new treatment plant was commissioned. However, there was still a constraint in conveyance capacity and water restrictions were continued until January 1999. Conveyance capacity upgrades were completed by 2001, with Joyce trunk main upgrades to the coastal zone (Mount Maunganui) and Cambridge Rd pump station upgrade, which boosted the supply to Tauranga West. These events go some way towards explaining the discontinuity of water usage in the early phase and that of the middle phase

Middle phase: This covers the next four summers (1997/98 – 2000/01). During this period peak daily demand is significantly higher than it was previously, in excess of what might have been expected in light of the gradual rising trend that was present in the data prior to this time. The peak daily demand itself is roughly the same for this four years, the increasing trend appears to have ceased.

Late phase: This final period covers the final five summers (2001/02 – 2005/06) and clearly shows the effect that metering has had on per capita water consumption. The peaks for these summers have dropped back down to roughly the level reached at the end of the early phase, and there is no discernable trend during this period, merely fluctuations between years, indicating reasonably stable usage over this time.

Table 3: Average and peak consumption figures for each year, and the ratio of peak demand to average demand.

Year	Annual average consumption per capita (l/c/d)	Peak per capita consumption for each year	Ratio of peak demand to average demand (highlighted in red when above 1.50)
1992/93	380	570	1.50
1993/94	413	558	1.35
1994/95	409	605	1.48
1995/96	420	581	1.38
1996/97	421	588	1.40
1997/98	435	693	1.59
1998/99	431	688	1.60
1999/00	401	618	1.54
2000/01	392	657	1.67
2001/02	369	528	1.43
2002/03	344	486	1.41
2003/04	331	466	1.41
2004/05	335	518	1.55
2005/06	331	466	1.41

3.1 EFFECT OF UNIVERSAL METERING ON RATIO OF PEAK DAY DEMAND TO AVERAGE DEMAND

Prior to universal metering, the average demand was 407 l/c/d, and the peak day demand (averaged over years available) was 595 l/c/d. This represents a ratio of 1.46. Following metering, the average demand was 335 l/c/d, and the peak day demand (averaged over four years) was 484 l/c/d, representing a ratio of 1.44. This potentially illustrates that metering has decreased both average and peak day demand but their relativity has remained similar.

4 REGRESSION MODELS

Scatterplots were produced of peak daily demand against key variables of rainfall, number of drought days, average SMD, number of days with SMD exceeding 120 mm, number of raindays.

This investigation proved very revealing. It was found that on every scatterplot **without exception**, the peak daily demand values for the years since universal metering has been introduced have been much lower, despite similar weather conditions.

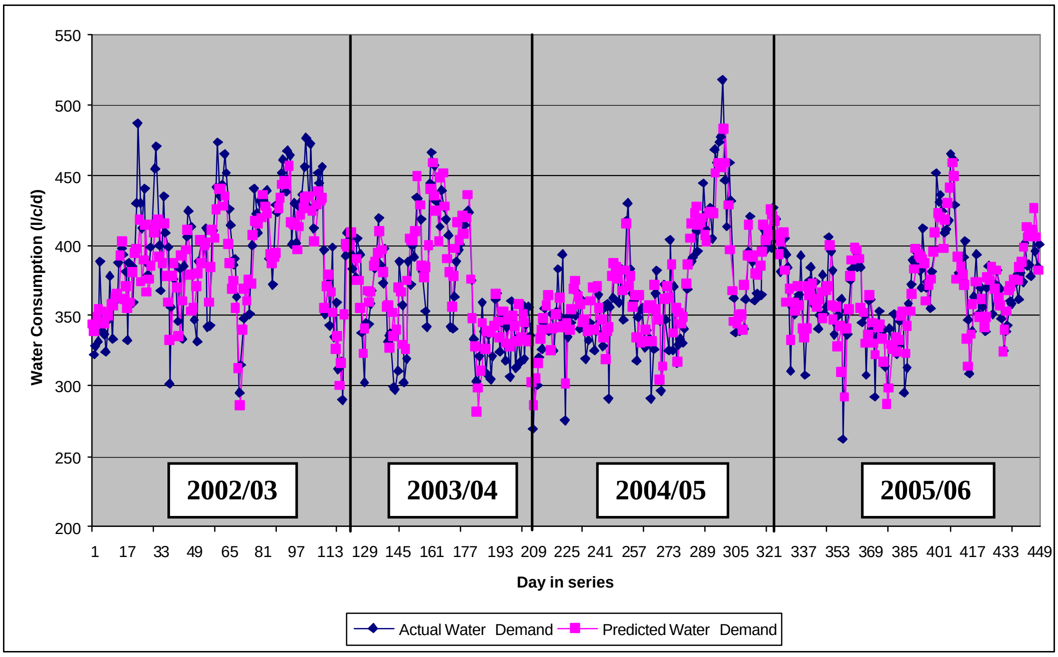
4.1 EXAMINING THE AFTER-UNIVERSAL METERING PERIOD, 2002 TO DATE

Data for the summer periods from 2002 to date was examined, and scatterplots and multiple regression analysis carried out. Multiple regression was carried out using all the weather variables. From this, variables with significant coefficients (at the 0.05 level, which means there is 95% confidence that the relationships are not due to chance) were retained and used to perform a multiple regression analysis. The resulting regression recorded an r^2 of 0.72, and showed that the independent variables which, when combined could explain 72% of the variation in consumption data, were:

- rainfall total from one day previous (rain1);
- rainfall total from two days previous (rain2);
- the number of dry days preceding the day (drydays);
- the total number of guest nights for the month (guestnights);
- maximum temperature from one day previous (max1);
- SMD from one day previous multiplied by sunshine total from one day previous (smdsun1); and
- water demand from the previous day (water1).

Figure 5 below shows the actual daily demand compared to the daily demand predicted by the regression formula.

Figure 5: Actual and predicted daily demand for summer periods.



The regression formula predicts the general pattern in daily consumption reasonably well. However, it does not predict the peaks and troughs so well. It was therefore decided to do some further investigations to see whether a better relationship could be identified.

Analysis determined that the key drivers for water demand in the post-metering summer periods are:

- weather conditions, including rainfall total from the previous day and two days before, the number of dry days preceding the day, SMD multiplied by sunshine from one day previous, and maximum temperature.
- number of guest nights recorded for the month, with higher guest night totals equating to higher water demand.
- water demand for the previous day.

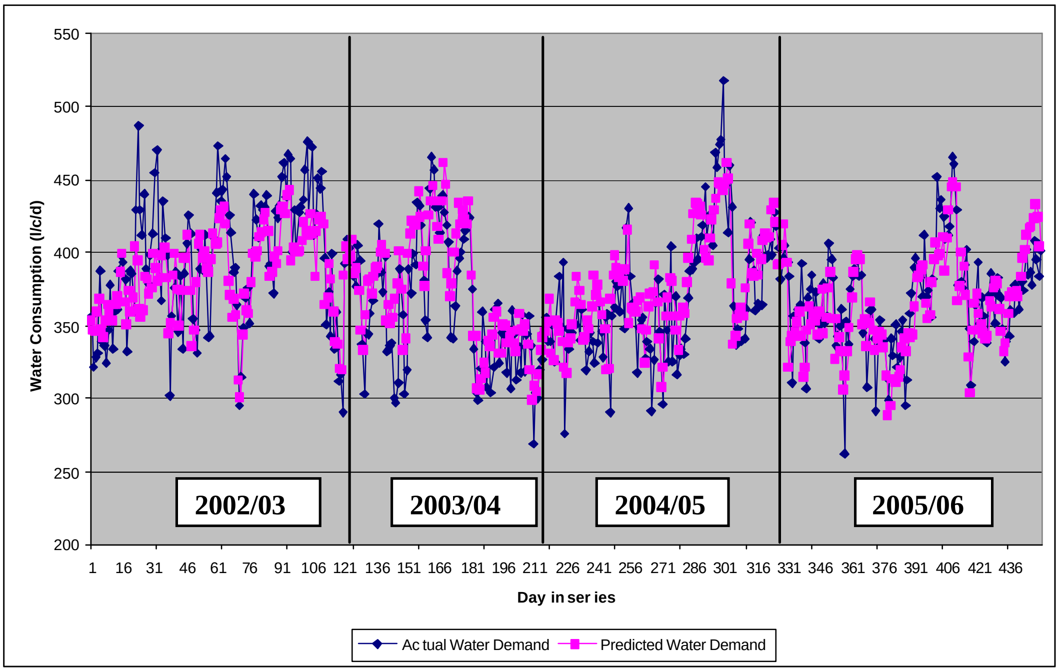
4.2 DAILY DATA ANALYSIS EXCLUDING WATER DEMAND FOR PREVIOUS DAY

In order to isolate further the effect of weather, the regression analysis was run again but this time without water demand from the previous day as an independent variable, since this is not a driver of demand, although it may ultimately be helpful in forecasting demand. The analysis this time included all previously tested weather variables, and guest night data.

Using these variables explained 65% of the variation in water consumption data. The significant variables were:

- weather conditions, including rainfall total from the previous day and two days before, the number of dry days preceding the day, SMD multiplied by sunshine from one day previous and two days previous, maximum temperature from the preceding day and soil moisture deficit from two days previous.
- number of guest nights recorded for the month, with higher guest night totals equating to higher water demand.

Figure 6: Actual and predicted water consumption using model based on weather and guest night data.



4.3 WEEKLY SUMMER DATA

In reviewing the daily demand figures and the rainfall data it could be seen that there was a large amount of variability from day to day that did not seem to match variations in the weather. It is possible that this is caused by a 'human behaviour' factor, which was more complicated than a simple diurnal pattern.

It was decided that, to take the analysis a step further, it would be useful to amalgamate the summer data into weekly totals. Weather data was also amalgamated either into weekly totals or averages. This also allowed the introduction of 'count' variables (described earlier). The data is displayed in Figure 7 (Note: In this graph the time sequence appears to be continuous but in fact it is four separate summer periods).

The weekly data are for the November to February period for each summer. The graph shows a fairly fluctuating pattern throughout each summer period.

A regression analysis was carried out with all the weekly weather variables along with the monthly guest night totals for each month as independent variables and the weekly total consumption as the dependent variable. The resulting regression achieved an r^2 of 0.72 and identified the following variables as having a significant influence on demand:

- **Raindays(14):** the total number of days for the week in question and the week before (a total of 14 days maximum) when rainfall was greater than 0 mm. If the number of rain days increased, this had a negative effect on total weekly demand (as you would expect).
- **SMD days(7):** the total number of days in the week in question (7 days in total) when SMD exceeded 120 mm. An increase in SMD days caused in increase in total weekly demand (again, as you would expect).
- **MaxT:** The highest maximum day temperature recorded over the 7 days of the week in question. Note this is not an average of each daily maximum, but the absolute maximum temperature recorded.

The predictive equation for this relationship, which explains 72% of the variability in the data is as follows:

Weekly total water demand (l/c/w):
2291 – 48*Raindays(14) + 34*SMD days(7) + 21*MaxT

Using this equation to predict the water demand for the summer periods in question and comparing this with the actual water demand gives the results shown in Figure 7.

Figure7: Actual and predicted weekly water demand.

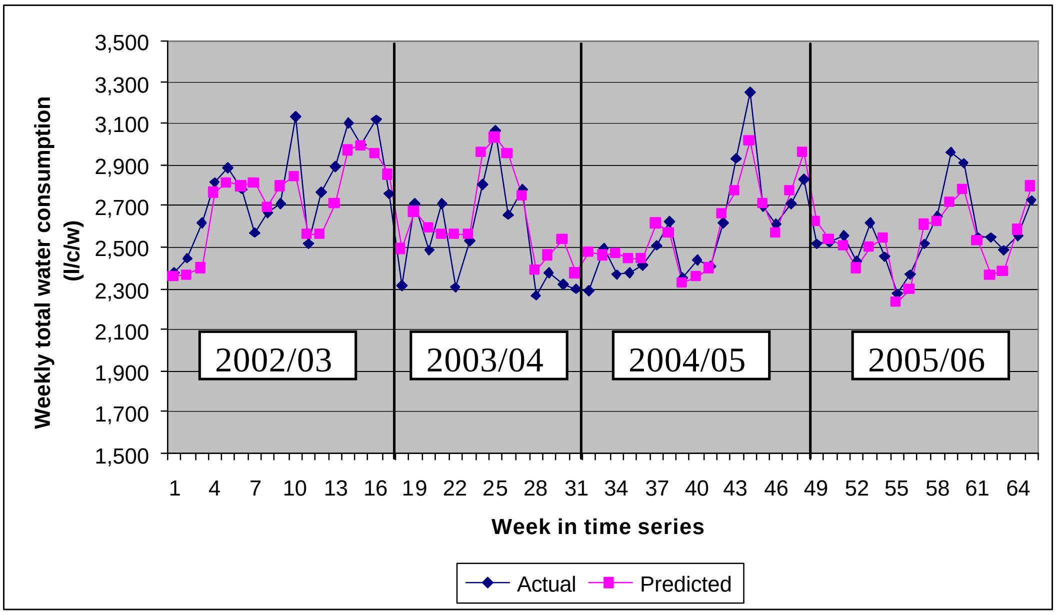


Figure 7 shows that the regression equation is fairly good at simulating the fluctuations in demand. There are three occasions when the fitted equation is conservative – the actual demand is significantly higher than the weather conditions identified by the equation would suggest. It is possible that for the later two such periods in the summers of 2004/05 and 2005/06, the influx of visitors for the anniversary day holiday at the end of January affects the water demand making it higher regardless of the weather conditions.

For the first period however, although falling within the New Zealand summer holiday period, it is not clear why demand should be so high. For this period, looking at the weather data suggests this was a very dry period and the SMD was high for a number of weeks consecutively. There is not sufficient data to model this effect but it does suggest that when weather conditions are very dry, water demand increases to a level beyond that which you would expect based on the regression model.

Another important point to note is that, the most recent four summers, in climatological terms, have not been as dry as some summers before the advent of universal metering. In particular, the summer of 1997/98 was extremely dry, with the rainfall total for the summer period falling well below the 10th percentile. This poses the question, if there is a more extreme summer, similar to that of 1997/98, will the relationships described above still hold in a metered environment? Or will there be a particular combination of dry, warm weather that, when taken to extremes, will force peak day demands back to the levels that were recorded prior to the advent of universal metering?

4.4 TESTING THE MODEL ON A MORE EXTREME SUMMER (1997/98)

The daily summer model was tested on the more extreme summer of 1997/98. This was done by using the weather data recorded during this historic period, and inserting the figures into the regression equations that were calculated using the data from 2002 onwards. This then gave a set of predicted values.

The actual relationship with the weather variables for this extreme summer was investigated further, and a new regression model was developed. The same variables were used as for previous regressions, including guest night data, and the following variables were found to be significant, explaining 72% of the variability in the data:

- Monthly total guest nights
- Rainfall on the day, and the day before
- The number of consecutive dry days preceding the day
- The SMD on the day and two days previous
- SMD two days previous multiplied by sunshine total two days previous

Comparing the actual water demand with demand predicted by this tailored model gives the results in Figure 8.

Figure 8: Actual and predicted water demand for 1997/98 using tailored model for this period

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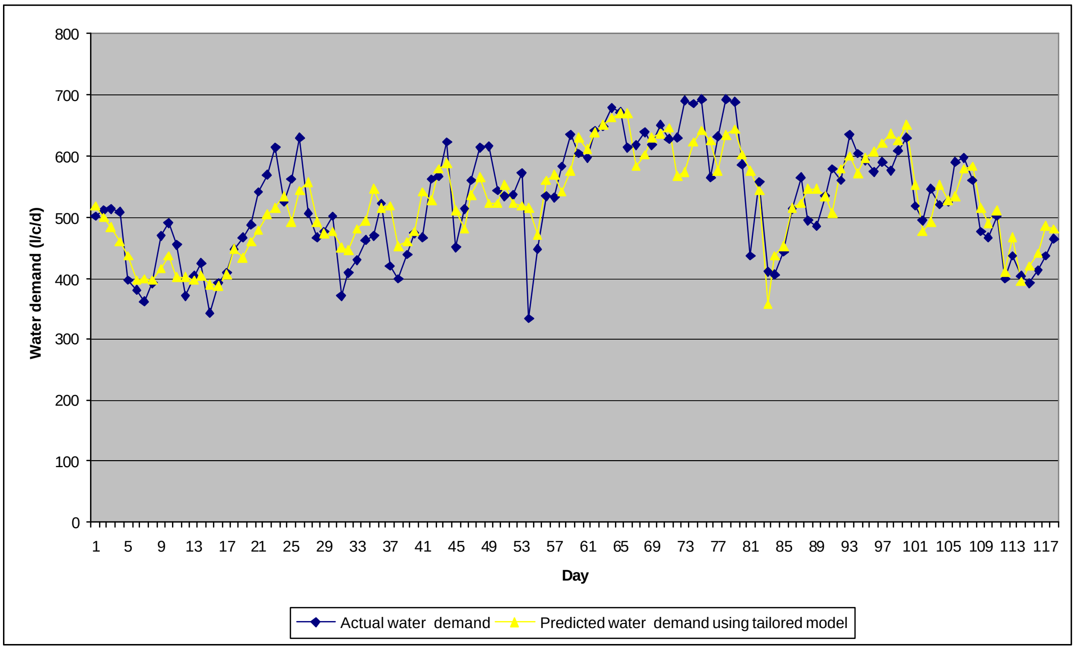

Clearly the relationship with weather is persistent throughout the data. The same model cannot be used for before and after the advent of post universal metering period because the relationship has changed with the introduction of universal metering. Weather still influences water demand, but not to such a great extent as it did prior to the introduction of universal metering.

Analysis identified that the key drivers identified from this weekly analysis are:

- The number of days in the fortnight (the week in question and the week before) when rainfall has occurred. An increase in the number of dry days causes an increase in water demand.
- The number of days in the week when SMD exceeds 120 mm. An increase in the number of days when this condition is met results in an increase in water demand.
- The absolute maximum temperature for the week in question. As this increases, so does water demand.
- The late January anniversary day holiday is likely to be a driver although this has not been proved statistically. This would be due to an influx of people as well as normal residents being off work and possibly undertaking more outdoor watering activities

5 CONCLUSIONS

This study has identified three regression models from the water demand data provided by TCC. The independent variables included in the analysis consisted of weather parameters, guest night data, and water demand for the previous period. Table 4 below summarises the models that were developed.

Table 4: Summary table of models developed.

Period	Data	Percentage of variability explained (r^2)	Significant variables identified from the regression analysis
Post universal metering period	Daily data	72%	• Consecutive dry days preceding the day • Rainfall on previous day and two days previous • SMD one day previous multiplied by sunshine total one day previous • Maximum temperature previous day • Water demand for previous day • Monthly total guest nights
Post universal metering period	Daily data	68%	• Consecutive dry days preceding the day • Rainfall total on the day and previous day • SMD two days previous • SMD one day previous multiplied by sunshine total one day previous, and two days previous • Maximum temperature previous day • Monthly total guest nights
Drivers identified: current and preceding weather conditions, total guest nights, water demand for previous day			
Post universal metering period	Weekly data	72%	• Total number of days when rain was recorded over previous 2 week period • Total days when SMD exceeded 120mm during the previous week • Absolute maximum temperature for the week

Period	Data	Percentage of variability explained (r^2)	Significant variables identified from the regression analysis
Drivers identified: current and preceding weather conditions			
Extreme summer of 1997/98, before advent of universal metering	Daily data	72%	• Consecutive dry days preceding the day • Rainfall on the day and the previous day • SMD two days previously • SMD two days previously multiplied by sunshine total two days previous • SMD for the day • Monthly total guest nights
Drivers identified: current and preceding weather conditions, total guest nights			

It is worth noting that the significant variables for the three daily models are very similar, they share all but one of the variables (where the post metering model has maximum temperature, the 1997/98 summer has SMD for the day). These have been identified by analysis from all 16 variables included in the analysis and because these variables are significant for pre and post metering periods it suggests that the same weather variables are driving water consumption. However, in the post-universal metering period they do not increase/decrease demand by such a significant amount as for the extreme summer of 1997/98.

5.1 METERING AND BILLING

The advent of universal metering in Tauranga has resulted in an overall reduction in consumption, as well as a reduction in the peak day consumption

The use of the 500 l/c/d design figure is appropriate for weather conditions that have been experienced in the period since the introduction of universal metering. However, since the introduction of universal metering, there has not been a really 'extreme' summer, such as that of 1997/98.

Analysis of each separate summer as a whole revealed a relationship between water consumption and weather variables such as number of dry days, rainfall totals and soil moisture deficit. However, the analysis, and in particular the visual interpretation, showed very clearly that there were two separate sets of data – water consumptions figures before the advent of universal metering, and those following universal metering. Paying for the quantity of water used had a significant impact on water demand, and is clearly one of the key drivers of demand. Further work is still required to get a better understanding of the sensitivity of water demand to the structuring of water tariffs (seasonal, block use etc) and tariff increases. Although there is scope to reduce peak water consumption further using the key driver of price, the acceptance of such an approach by customers needs careful consideration.

5.2 HOLIDAY PERIODS

The relationship between consumption and holiday periods was analysed by including the total number of guest nights each month in all the regression analyses. This variable was found to be significant in the analysis of daily demand data in the post-universal metering period, and also in the daily analysis of the extreme summer 1997-98. The number of guests is therefore an important influence on water consumption.

It was observed that many of the annual peak daily demand events occurred in the anniversary day period towards the end of January. However, this was not true of all the years and it is likely that it depends, to an extent, on the weather. The influx of people on holidays creating a peak in water demand is not something that can be easily controlled.

5.3 WEATHER

The analyses revealed strong links between the weather and demand during summer periods. This was investigated in the period post advent of universal metering and a strong relationship was found when looking at daily demand data.

Multiple regression analysis showed the key variables influencing demand were:

- rainfall total from one day previous (rain1);
- the number of dry days preceding the day (drydays);
- SMD from two days previous; and
- SMD from two days previous multiplied by sunshine total from two days previous

When looking at data on a weekly basis, the relationship with weather was even stronger, with the number of rainfall days from the week and the previous week, the number of days when SMD exceeded a threshold of 120 mm, and the absolute weekly maximum temperature being significant. These three variables explained 72% of the variability in the weekly data during the summer period. Both the current and the preceding weather conditions were found to be important. This is especially true with the 'drydays' variable, which is a count of the number of consecutive dry days that precede the day in question. As expected, the persistence of dry conditions increases water demand.

5.4 PREVIOUS DAY'S WATER CONSUMPTION

This variable is likely to be significant because the water demand for the previous period will reflect other (unidentified) drivers such as socioeconomic and political trends and influences on people's behaviour.

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5.5 USE AS AN OPERATIONAL TOOL

The significant relationships established through regressional analysis provide opportunities for their use as operational demand prediction tools. TCC is planning to explore this application with access to 'on line' weather and demand data.

Furthermore, the influencing factors identified in this study could potentially be used by water managers to predict daily demand, using forecast weather data.

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