Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 2.5.2: Bulk Water Demand Trend Modelling for Climate Change

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1. Introduction

This tool is one of a number of reference and guidance documents designed to assist Councils, and others, in taking account of long-term climate change effects in their on-going management of the urban environment.

This document, Tool 2.5.2, outlines an approach for forecasting water demand taking into account potential long-term climate change effects.

1.1 Background

To adapt to climate change, water utilities generally need to complete four major steps:

1. **Understand** climate science and climate model projections;
2. **Assess** water system vulnerabilities to potential climate changes;
3. **Plan** to incorporate climate change into water utility planning; and
4. **Implement** adaptation strategies.

This Tool presents an approach to address steps 1 and 2 (understand and assess) of the demand portion of the water supply demand balance equation. After completion of steps 1 and 2, water utilities should incorporate the revised demand forecasts into a revised water supply demand balance forecast and, depending on the significance of the predicted climate change impacts, undertake steps 3 and 4 to plan and implement adaptation strategies.

An example analysis of the effects of climate change on the supply side of the water supply demand balance equation is presented in [Tool 2.5.3 "SYM approach to present-day and future potable water supply and demand"].

The suggested approach adopted in Tool 2.5.2 includes the application of two methodologies: the WaterTrac bulk water production trend tracking modelling tool, and ClimateTrac, a spreadsheet tool for automating the large number of calculations required for prediction of future climate change impacts[1].

WaterTrac and ClimateTrac form part of a number of tools developed to assist Councils, and others, in taking account of long-term climate change effects in their on-

[1] WaterTrac and ClimateTrac have been developed by MWH

going asset development and management. The tools have been developed with the broad aim of making urban infrastructure more resilient to climate change effects.

The tools are embodied within a 'Toolbox' comprising of software tools and various reference and guidance documents designed to assist in assessing asset development needs and solutions that will lead to more resilient urban infrastructure in the face of increasingly extreme weather events [see: Toolbox Overview and Case Study Examples].

Designing and developing infrastructure to be more resilient to climate change effects does not require fundamentally different solutions, rather designs need to be made taking account of changing climate-related effects. Detrimental climate change effects influence design through increased 'loading' requirements, and add to other uncertainties because the rate and magnitude of the changes in climate are not known with certainty. Increased uncertainty means that making the 'correct' design choice in any particular context is more challenging that it would otherwise be.

1.2 General Overview of Water Demand Forecasting

There are various methods employed by water utilities for water demand forecasting. These include:

1. The <u>water usage per capita per day</u> (litres per capita per day - LCD) method of analysing historical bulk water demand to determine an overall LCD figure, which is then multiplied by the projected population. Historical demand analysis techniques include allowance for the influence of climate to obtain a "climate corrected"[2] average LCD demand for forecasting.

2. A <u>sector-based approach</u> to support bulk water historical analysis. The approach draws on customer usage data to investigate residential demand (single and multi-residential properties), non-residential demand (commercial, industrial, institutional and rural sectors and subsectors) and non-revenue water (real and apparent losses). With a combined understanding of how water is being used, demand is then projected according to population growth or other sector-specific base units (for example, the number of properties, employment, floor space), as deemed appropriate.

3. An <u>end-use analysis</u>, which uses a "bottom-up" approach to balance historical demand in each sector associated with typical end uses such as toilets,

[2] Climate-corrected demands have had the influence of climate removed to show the underlying trends

washing machines etc. The demand for that end-use is translated into aggregate demand by multiplying an individual end-use demand by frequency of usage, projected demographic growth (population, single and multi-residential dwelling numbers, and occupancy as appropriate), and functions that reflect changes in the efficiency of the technology and mix of stock over time. Its key advantage is the ability to include in the forecasts the assessment of future demand management options such as conservation measures and source substitution approaches.

For more details of the above methods, please refer to publications such as the Guide to Demand Management published by the Water Services Association of Australia (Turner et al, 2008).

The approach described in this Tool combines elements of all three methods described above to estimate the impact of climate change on future demands on a bulk per capita (LCD) basis. ClimateTrac utilises a climate-driven demand relationship developed through the WaterTrac bulk water production trend tracking model. The relationship is developed though multi-variable non-linear regression analysis of historical water demands in WaterTrac. The bulk demands are then proportioned according to sectoral forecasts and internal/external end use breakdown. A fundamental assumption adopted in ClimateTrac is that the potential climate change impacts on future water demands follow the same climate variable responses observed in the WaterTrac model calibration.

It should be noted that a complete picture of urban water demand includes other factors that are not directly addressed by the above approach. Figure 1.1 depicts the complex array of factors that may need to be accounted for when generating a demand forecast. In addition, forecast spatial and temporal demand variations will be important is assessing the water supply system's reliability and security. The approach described in this Tool only addresses the influence of climate on demands. The user will need to consider the influence of other factors specific to their community when preparing demand forecasts.

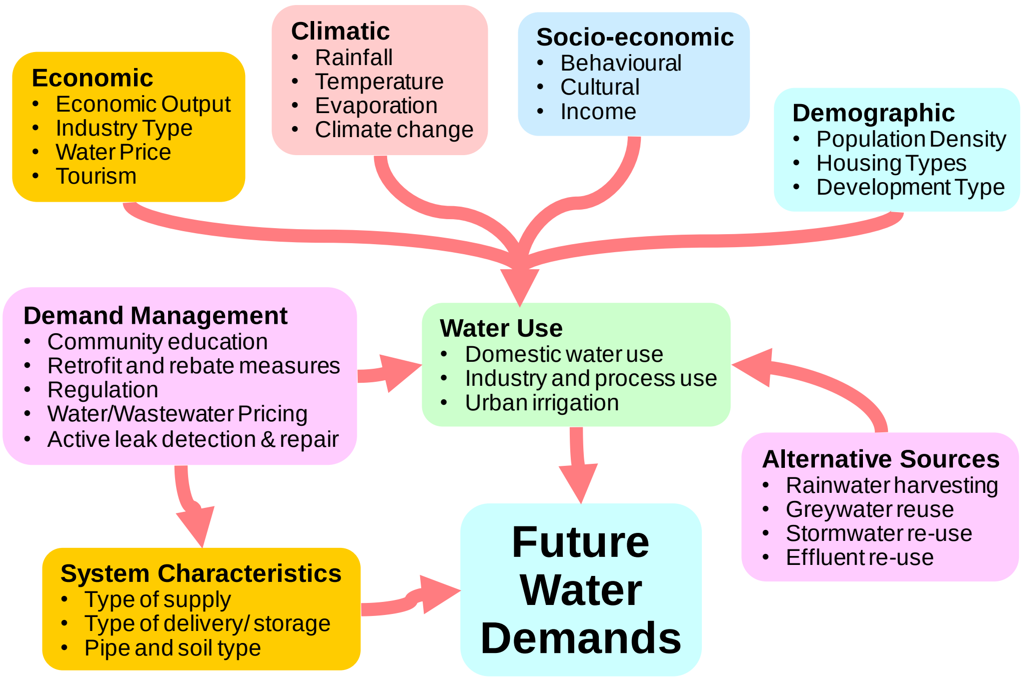

Figure 1.1: Overview of water demand drivers

1.3 Purpose of the Tool

The WaterTrac climate correction modelling tool is designed to monitor trends in bulk water production and to provide water utilities with information about climate influences on water demands and underlying trends in water demands after climate correction. Climate influences can have a significant impact on water demands, particularly seasonal outdoor demands such as garden irrigation.

The ClimateTrac modelling tool was developed for annual and monthly forecasting of the impacts of climate change on water demands and uses the relationship between climate and demand that is produced by WaterTrac as one of its inputs.

1.4 Using these Tools

Contact the authors of this report for further information about using the WaterTrac and ClimateTrac modelling tools, and for developing water demand forecasts that are influenced by climate change.

2. Overview of the Demand Forecasting Tools

The ClimateTrac modelling tool can be used as part of a five-step process to examine the impacts of climate change on water demands. This methodology was developed by

MWH to examine the impacts of climate change on communities across Queensland in Australia (MWH, 2010) and has been tested on a case study for the Wellington metropolitan region (MWH, 2011).

The five key steps are as follows:

1. Development and calibration of WaterTrac for the case study community. WaterTrac utilises a non-linear least square regression approach to determine the demand response to a variety of daily climate variables such as maximum temperature, rainfall, evaporation and soil moisture index.

2. Preparation of a baseline time series of per capita demands (hindcast) using the WaterTrac demand relationship and historical daily climate data provided by NIWA. This baseline is compared against the revised demand forecasts accounting for climate change to assess the significance of climate change impacts.

3. Prediction of the changes to climate variables based on the long-term climate change projections (see Section 2.2.1 for more details of the current approach).

4. Development of future climate time series through adjustment of the historical daily climate records according to long-term climate change projections. ClimateTrac is currently set up to consider forecast climate in Year 2040 and 2090, as per the New Zealand long-term climate change projections.

5. Disaggregation of total supply system water per capita demands, based on sectoral and internal/external end uses (and climate versus non-climate influenced), to estimate the impact of climate change on the water demand of specific sectors. Development of future per capita demand time series (in L/capita/day) in ClimateTrac using the WaterTrac based demand relationship for each climate change scenario and inputs from the previous steps.

Note that under point 5 above, ClimateTrac is currently set up to consider residential, non-residential and non-revenue forecasts. Changes in climate will not affect demand by sectors, or by end uses, equally across each sector. It is expected that changes in demand due to climate will be predominantly in external use.

This five-step methodology is outlined in Figure 2.1, along with suggestions for suitable tools.

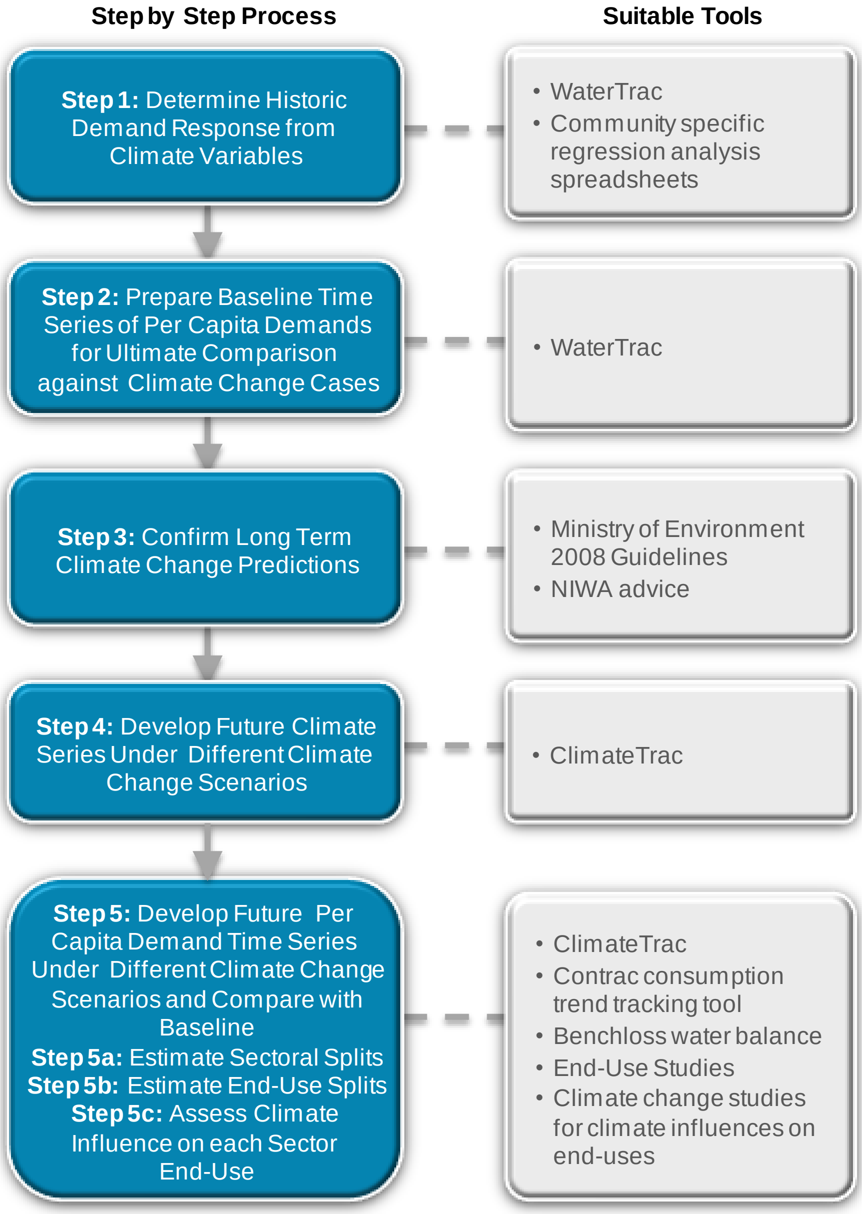

Figure 2.1: Five step methodology and suitable Tools for assessing impact of climate change on water demand.[3]

2.1 Basis of Process

The basis of the approach assumes that bulk water demand forecasts can be determined by climate variables. WaterTrac is the tool used to determine the demand/climate relationship and is described below. It may be that a water utility has

[3] ConTrac is a water consumption trend tracking and climate correction model developed by MWH and designed to track demand trends by customer type on a climate-corrected basis. ConTrac uses customer metered data (WaterTrac uses bulk production data only).

already established the relationship between climate and demands through development of a regression model specific to its community. In this case, the demand climate relationship output from its regression model could be used as an input to the ClimateTrac model.

2.1.1 WaterTrac

WaterTrac is used for steps 1 and 2 in the 5-step methodology outlined in Section 2. WaterTrac was originally established to estimate climate-corrected demand trends. This bulk water trend tracking model package has a 15-year development history and has been successfully used in over 100 separate applications in Australia, New Zealand and North America.

WaterTrac has proven useful in many aspects of historical demand analysis and can be used to provide information to assist answering questions like:

- "*I have to prepare forecasts of future water demand but I have been told that the last few years were cool with higher than average rainfall. What correction to the historical records do I need to make*?"

- "*We have had pay-for-use pricing in place for a number of years now, but demands seem to be trending up again. Is this a "rebound" effect or have the last few years just been hot and dry?"*

MWH has produced a user manual for the WaterTrac model but it is not available in the public domain. However, the New South Wales (NSW) Office of Water employs a similar approach of non-linear regression to draw a relationship between daily water demand and various daily climate variables in their water demand trend tracking model (or climate correction model as it is commonly called). For technical details of the WaterTrac approach, the interested reader is therefore referred to the Integrated Water Cycle Management (IWCM) Water Demand Trend Tracking Manual (NSW Office of Water, 2011), available online.

WaterTrac uses a non-linear multi-variable regression analysis approach to explain the day to day climate influences on water demands. Non-linear regression analysis better explains demand usage than typically applied linear approaches. WaterTrac also offers a simple soil moisture store model as a climate variable in the regression analysis. The soil moisture index is used to model the antecedent soil moisture effects on demand or flow. This particular soil moisture store model has been found to generate high correlations with water demand in many separate applications. The soil moisture index is derived by WaterTrac from the input daily climate data (previous period's rainfall, evaporation and soil moisture index) and is included as one of four independent climate variables (soil moisture index, maximum air temperature, rainfall and potential evapotranspiration).

All four climate variables can be significant in demand responses and tested in the calibration process.

The regression equation for the predicted demand (Dt) takes the form:

$$D_t = B_0 + B_1 \times f_1(v_1) + B_2 \times f_2(v_2) + \ldots\ldots + B_n \times f_n(v_n)$$

Where

$$f_n(v_n) = \tan^{-1}\left(\left(v_n - \frac{(v_U + v_L)}{2}\right) \times \left(\frac{\pi}{v_U - v_L}\right)\right) \quad \text{for non - linear regression}$$

Each variable v stands for an independent daily variable (e.g. maximum temperature, rainfall and evaporation):

Where B = model coefficient

v_U = Upper shape constant

v_L = Lower shape constant

and v_n = the climate variable data

Calibration is an important step in the establishment of the model. Guidelines for calibration and selection of the calibration period are provided in the WaterTrac User Manual.

2.1.2 ClimateTrac

ClimateTrac is a spreadsheet tool developed to complete steps 4 and 5 in the methodology outlined in Section 2. The fourth step in the methodology involves converting the historical daily climate record into a synthetic daily time series of future climate by applying the climate change predictions to each month.

The fifth and final step involves disaggregating the bulk demands into each sector and internal and external use, and applying the assumed climate influences; then using the predicted demand equation from the WaterTrac model to create a synthetic daily time series of future demands (in L/capita/day) for each climate change scenario. The daily results are then summarised on a monthly basis to determine the predicted impact of climate change on water demands. The predicted impacts on a monthly basis are then averaged to provide an annual average impact.

Comparison of these annual average demands with the baseline annual average demand forecasts will identify the potential impact of climate change on demands.

A simplified approach can be taken to estimate the climate change impact on peak day demands by applying the historic peak day ratio to the predicted annual average daily demand under each climate change scenario. Peak day demands are also likely to be influenced by an increase in the number of consecutive days with hot and dry weather. Limited information is available from existing long term climate forecast models on the future number of consecutive days with hot and dry weather. As such it is difficult to assess peak demand periods and this topic is not covered in this paper.

2.2 Data Needs

The basic data needs for the WaterTrac and ClimateTrac methodology to be applied to the prediction of future climate change impacts on potable water demand are as follows:

1. Historic daily readings of maximum temperature, rainfall and potential evapotranspiration (24-hour Penman potential evapotranspiration or PET) from the NIWA virtual climate station for the community of interest (longest available record). A full climate record is preferred with no data gaps. Virtual climate station data from NIWA can be used as it provides a full climate record by interpolation between defined climate measurement stations (see Tait et al., 2006). The NIWA soil moisture data are not used as this variable is derived by WaterTrac.

2. Daily bulk water production data corrected for reservoir fluctuations for the community of interest (longest available record).

3. Annual estimates of the historic population served by the water supply for the community of interest (ideally covering the full time period of the bulk water production data provided).

4. Population growth projections covering the climate change period of interest (i.e. to 2040 or to 2090).

5. Long-term climate change projections for maximum temperature, rainfall and PET for the community of interest. The suggested approach for obtaining this information is discussed in Section 2.2.1.

6. Estimates for the current percentage split of bulk demand by sector and by internal versus external use, i.e. Residential (internal and external), Non-Residential (internal and external), and Non-Revenue Water (real losses, apparent losses and unbilled authorised consumption). A suggested approach for estimating this information is discussed in Section 2.2.2.

7. Estimates for the current percentage of each demand category (listed in point 6 above) that is influenced by climate. A suggested approach for estimating this information is discussed in Section 2.2.3.

2.2.1 Climate Change Projections

Each water utility will need to select a set of climate change scenarios. Selected scenarios typically cover high and low case climate change scenarios, as well as a medium case scenario. The medium case scenario should represent the best estimate of climate change for the community of interest. The high and low cases should represent dry/hot and wet/cool extremes, respectively, for future climate. These cases can be used for testing longer term water planning. Table 2.1 summarises the different types of climate change scenarios and their recommended use in water supply-demand planning.

Table 2.1: Climate change scenarios and recommended uses (National Water Commission, 2011).

Type of Climate Change Scenario	Recommended Use in Water Supply-Demand Planning
Medium or 'best estimate' climate change scenario	To represent the most likely climate change scenario for the supply-demand balance
Extreme wet and dry future climate change scenarios	To test high and low cases in the supply-demand balance to account for uncertainty in climate change projections
Worst climate change scenario	To test adaptive planning, including readiness strategies and drought contingency plans

For New Zealand applications, the predictions for seasonal and annual changes in temperature and rainfall are based on Tables 2 and 3 of the Ministry for the Environment (MfE) guide for local government, “Preparing for Climate Change” (MfE, 2008).

Tables 2 and 3 provide, respectively, the 2040 and 2090 seasonal and annual predictions for a "mid-range" scenario for each regional council area, along with a "low" and "high" range (i.e. the probable temperature and precipitation changes for the two future periods lie within these values). The mid-range estimates are the average of all emissions scenarios and all circulation models. The low and high ranges are the extremes from separate models for each climate variable. Combination of the low and high ranges for rainfall and temperature would result in an extreme worst case climate change scenario.

The above-referenced MfE climate change guide does not include predictions for changes in PET. A simplified approach can be taken to predict the future seasonal and annual changes in PET due to climate change. This approach assumes that there is a linear relationship between temperature and PET, as demonstrated using a plot of historic mean monthly values.

This plot provides a slope which describes the change in PET (delta PET) as a function of the change in temperature (delta T). For example, the slope equation for the Wellington region is:

Delta PET = 12.36 x delta T

i.e. a 1°C increase in temperature for Wellington implies a 12.36 mm increase in PET

It is recognised that there is debate about the linearity of the PET response to temperature increases due to a number of other influencing factors (particularly radiation, vapour pressure and wind). An area for possible future research would be to test the sensitivity of the climate change impacts on demands to changes in PET.

2.2.2 Developing Sectoral and Internal/External End-Use Estimates

Water utilities with universal metering will find it straightforward to determine the proportion of water produced that is used in each of the three key sectors (residential, non-residential and non-revenue water) through analysis of customer meter records. Water utilities without universal metering will also need to estimate the proportion of unmetered water that is used by each sector (typically residential versus non-residential). Methods for estimating these proportions include:

- analysis of data from metered areas for residential customers;
- night-time flow monitoring to estimate the level of real loss or leakage (the primary contributor to non-revenue water).

There is limited information on the end uses of water available in New Zealand in either the residential or non-residential sectors. The Building Research Association of New Zealand (BRANZ) has conducted two residential end-use studies in recent years; a small pilot study on the Kapiti Coast in 2007 (Heinrich, 2007) and a larger study in the Auckland region in 2008 (Heinrich, 2008). The combined results of these two studies are shown in Figure 2.2.

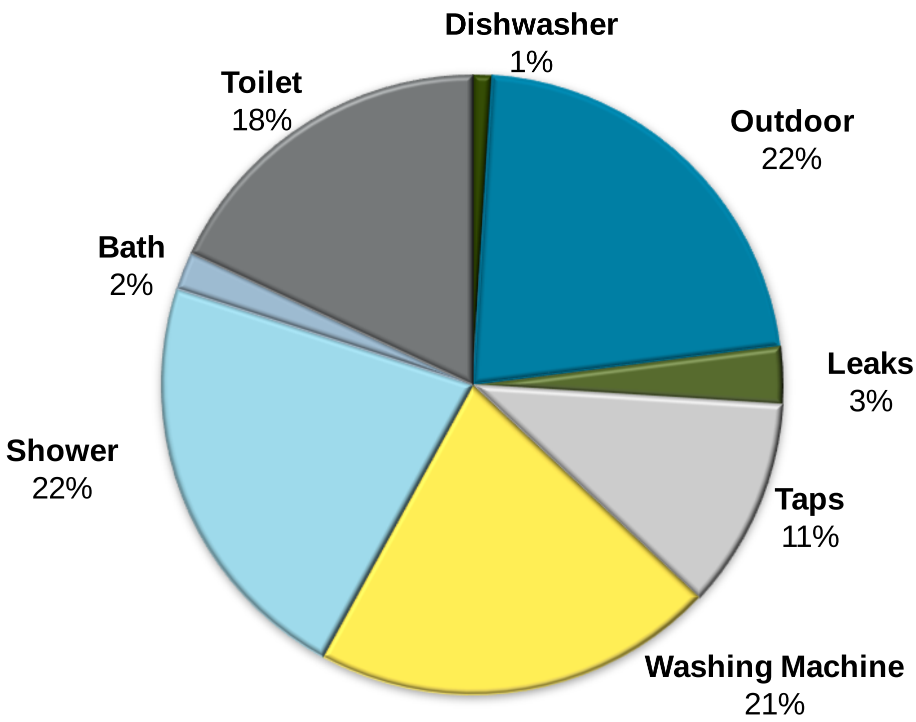

Figure 2.2: Estimated New Zealand residential end use breakdown (combined data from BRANZ studies).

The pie graph shows a residential external use of 25% (outdoor and leaks) and internal use of 75% which could be used in the absence of any community-specific information. A suggested non-residential internal/external split is 80% to 20% which could be used in the absence of any community-specific information.

The MWH customer consumption trend tracking model, ConTrac, could be used to define the internal/external use split for each sector if customer metered data is available.

A suggested non-revenue water split is real losses 72%, apparent losses 25% and unbilled authorised consumption 3% which could be used in the absence of any community specific information.

2.2.3 Estimating Climate Influence on Each End-Use

The climate influence factors for each sector end use that were assumed for the Wellington case study are shown in Table 2.2 and are based on assumptions from other MWH studies on climate change impacts on water demand.

Table 2.2: Assumed climate influence factors for each sector end use from Wellington case study.

Sector		Climate Influence Factors	
Residential	Internal	Climate Influenced	40%
		Non Climate Influenced	60%
	External	Climate Influenced	90%
		Non Climate Influenced	10%
Non Residential	Internal	Climate Influenced	20%
		Non Climate Influenced	80%
	External	Climate Influenced	80%
		Non Climate Influenced	20%
Non Revenue Water	Real Losses	Climate Influenced	75%
		Non Climate Influenced	25%
	Apparent Losses	Climate Influenced	90%
		Non Climate Influenced	10%
	Unbilled Authorised Consumption	Climate Influenced	90%
		Non Climate Influenced	10%

2.3 Assumptions and Limitations

The fundamental assumption in applying the ClimateTrac Tool in this context is that the potential climate change impacts on future water demands follow the same climate variable responses observed in the WaterTrac model calibration i.e. the demand responses to climate variables will remain the same in the future. In addition, climate correction of the bulk water demands is a simplified approach. Ideally, the sectoral water demands would be corrected separately for climate as each may have different responses to the four climate variables.

The model outputs will also be dependent on the validity of other assumptions made when applying the ClimateTrac tool such as:

- Long-term climate change projections for rainfall and temperature;
- The long-term climate change projections for PET based on the assumed relationship with temperature;
- The estimated percentage split of bulk demand by sector and by internal versus external use.
- The estimated percentage of each demand category (by sector and internal versus external use) that is influenced by climate.

The WaterTrac approach is limited by available historical data which, if insufficient, may result in poor explanatory models. A further point to note is that these models require specialist input in their development for each location and in interpreting results.

3. How to Apply the Tools for Climate Change Impacts

The application and use of the WaterTrac Tool is illustrated using a case study performed on the Wellington metropolitan region bulk water supply [MWH, 2010b], as outlined below.

3.1 Wellington Case Study Tool Structure and Content

The WaterTrac and ClimateTrac modelling tools were used as part of a five-step process to examine the impacts of climate change on water demands in the Wellington metropolitan region. The case study used the Ministry for the Environment (2008) seasonal climate change projections for the Wellington region and converted them into monthly climate change projections (see Tables A1 and A2 in the Appendix). These monthly temperature projections were used to estimate the projected change in evaporation. The projected monthly increase in temperature is up to 2.5°C for 2040 and 5.7°C for 2090. Significant variation in rainfall patterns arises from the low and high projections (the projected monthly rainfall lies between a decrease of 21% and an increase of 14% by 2040 and a decrease of 38% and an increase of 26% by 2090).

The case study results showed a potential increase in demands under the mid-range climate change scenario of 0% to 3% by 2040 and 0% to 6% by 2090. The climate change impacts on peak day demands were estimated by applying the historic peak day ratio of 1.2 to the predicted annual average daily demand under each climate change scenario. The results showed a potential variability in peak day demands compared to baseline of 1% by 2040 and 3% by 2090 under the mid-range climate change scenario.

3.2 Outputs Generated to Aid Decision Making

The WaterTrac model produces a number of outputs to confirm the appropriateness of the selected calibration period and to identify the significance of each of the four climate variables.

The key statistics produced by the model calibration are:

- R^2 statistic for the model (e.g. a model statistic of 0.72 means that 72% of the variations in daily per capita water production could be explained by the fitted model).

- The T-test statistic for each of the independent variables. This is used to determine the significance of each variable. As a rule of thumb, in the regression analysis of water demand, a T statistic of absolute value greater than 2.0 suggests that the variable is significant in the regression and should be included in the regression model.

The model also produces a graph of the modelled variable responses for the four climate variables, as shown in the example in Figure 3.1. The vertical axis on the plot in Figure 3.1 represents the per capita response in L/capita/day from each of the four depicted climate variables. The horizontal axis shows the corresponding percentage of the range for each of the four climate variables.

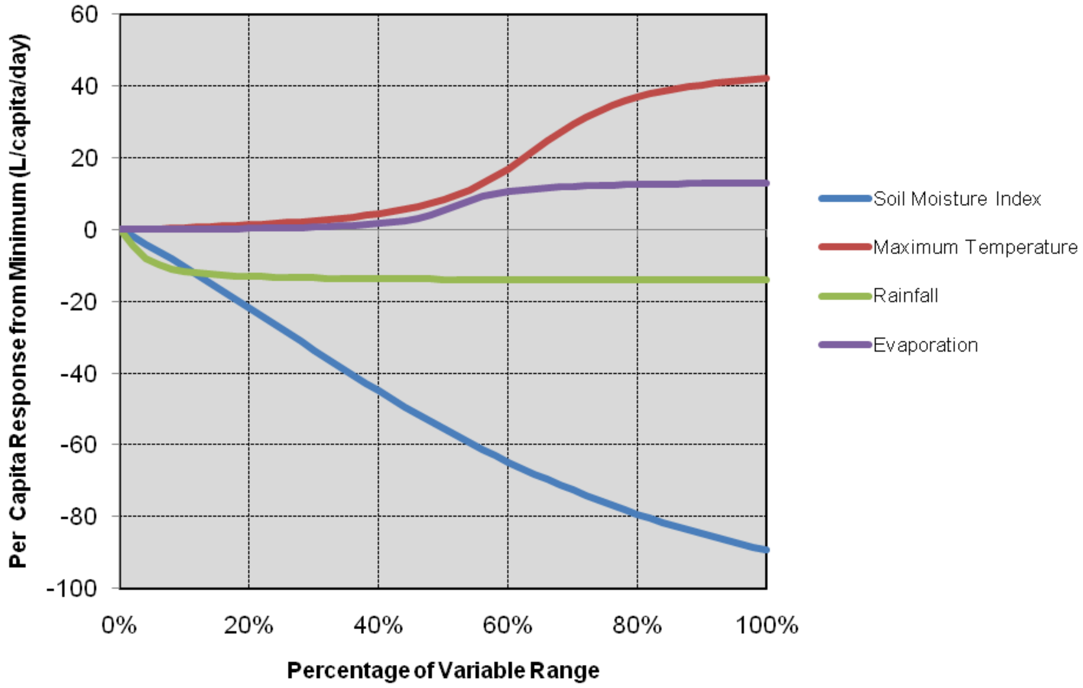

Figure 3.1: Example graph of the Variable Responses for the four climate variables using the WaterTrac Model

The plot shows that the four climate variables produced the expected responses for the Greater Wellington model. Maximum temperature and evaporation show a positive response with water demands (e.g. as maximum temperature increases, water demands increase and the highest range of maximum temperature corresponds to a maximum response of approximately 40 L/capita/day).

The plot also shows that maximum temperature has a greater climate response on demands than evaporation. Conversely, rainfall and soil moisture index show a negative response with water demands (e.g. with initial rainfall, there is a decrease in water demands). Figure 3.1 also shows that soil moisture index has a greater climate response on demands than rainfall.

The higher the value of the T-test statistic for each of the climate variables, the more significant that climate variable is in its influence on water demands for that community of interest. This gives the first indication of the potential impacts of climate change on water demands for this community. For example, if maximum temperature is found to be the most significant climate variable (i.e. with the highest T-test statistic value) for that community, then the potential impact of climate change on future water demands will be more significant if the community is in an area which is predicted to become warmer (rather than wetter or cooler).

For the case study example of the Wellington metropolitan area, soil moisture index was found to be the most significant climate variable, followed by maximum temperature. The ClimateTrac model output plot in Figure 3.2 shows the impact of climate change on the average daily demands on a monthly basis for each of the evaluated scenarios in 2090. The impact of soil moisture index as the most significant climate variable is evident in the distinctive "M" shape of the curve for scenario 2, the hypothetical extreme low (wet/cool) climate change scenario.

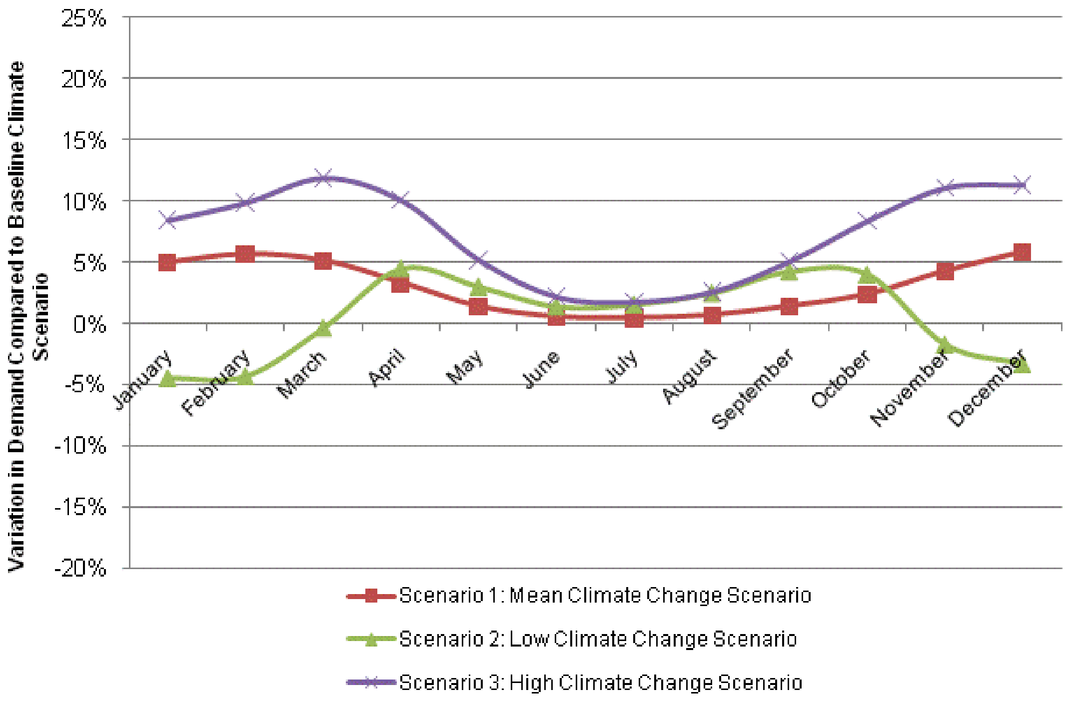

Figure 3.2: Forecast impact on monthly average day demands for Greater Wellington Region (2090).

The envelope of scenarios in Figure 3.2 shows a hypothetical extreme worst case variation in demand from -4% to 12% for the Greater Wellington Region in 2090 due to climate change impacts, with over 5 months of the year experiencing a worst case increase of 10% or greater (under the hypothetical extreme high climate change scenario).

3.3 The Next Steps

Each water utility may assess the potential impacts of climate change on future demands using an approach such as that outlined in this paper. The revised demand predictions should then be combined with revised supply forecasts to enable the assessment of the long-term supply demand balance under potential climate change scenarios. Depending on the significance of the difference between the projected climate change case when compared to the baseline case, the water utility should then undertake to plan and implement adaptation strategies for climate change (for example water supply diversification, source substitution etc.).

The demand forecasting approach described in this paper considers long-term climate changes on per capita demands. To develop system demands the planner should consider the impacts of other demand drivers such as growth (see Figure 1.1) and any future demand regime changes such as through demand management measures (e.g. universal metering and pricing, proactive leakage reduction). The impact of demand management on demands can be predicted through the use of tools such as end-use models.

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Appendix A: Projected Effects of Climate Change for Wellington Region

The following two tables outline the projected effect of climate change on the climate conditions for the Greater Wellington Region. The temperature and rainfall data are sourced from Ministry for the Environment (2008). The evaporation data are estimated based on the temperature change projections.

Table A1: Predicted Climate Change for the Greater Wellington Region for 2040

		Month	Mid-Range	Low Range	High Range
Temperature (°C)	**Annual**		0.9	0.3	2.2
	Summer	Dec	1.0	0.2	2.2
		Jan	1.0	0.2	2.2
		Feb	1.0	0.2	2.2
	Autumn	Mar	1.0	0.3	2.5
		Apr	1.0	0.3	2.5
		May	1.0	0.3	2.5
	Winter	June	0.9	0.2	2.1
		July	0.9	0.2	2.1
		Aug	0.9	0.2	2.1
	Spring	Sept	0.8	0.1	1.9
		Oct	0.8	0.1	1.9
		Nov	0.8	0.1	1.9
Rainfall (%)	**Annual**		2.0	-3.0	10.0
	Summer	Dec	0.0	-21.0	13.0
		Jan	0.0	-21.0	13.0
		Feb	0.0	-21.0	13.0
	Autumn	Mar	4.0	-3.0	14.0
		Apr	4.0	-3.0	14.0
		May	4.0	-3.0	14.0
	Winter	June	4.0	-1.0	13.0
		July	4.0	-1.0	13.0
		Aug	4.0	-1.0	13.0
	Spring	Sept	2.0	-5.0	14.0
		Oct	2.0	-5.0	14.0
		Nov	2.0	-5.0	14.0
Evaporation (mm)	**Annual**		0.3	0.1	0.7
	Summer	Dec	0.3	0.1	0.7
		Jan	0.3	0.1	0.7
		Feb	0.3	0.1	0.7
	Autumn	Mar	0.3	0.1	0.8
		Apr	0.3	0.1	0.8
		May	0.3	0.1	0.8
	Winter	June	0.3	0.1	0.7
		July	0.3	0.1	0.7
		Aug	0.3	0.1	0.7
	Spring	Sept	0.3	0.0	0.6
		Oct	0.3	0.0	0.6
		Nov	0.3	0.0	0.6

Table A2: Predicted Climate Change for the Greater Wellington Region for 2090

		Month	Mid-Range	Low Range	High Range
Temperature (°C)	**Annual**		2.1	0.6	5.2
	Summer	Dec	2.2	0.9	5.7
		Jan	2.2	0.9	5.7
		Feb	2.2	0.9	5.7
	Autumn	Mar	2.1	0.6	5.1
		Apr	2.1	0.6	5.1
		May	2.1	0.6	5.1
	Winter	June	2.1	0.6	5.0
		July	2.1	0.6	5.0
		Aug	2.1	0.6	5.0
	Spring	Sept	1.8	0.3	4.8
		Oct	1.8	0.3	4.8
		Nov	1.8	0.3	4.8
Rainfall (%)	**Annual**		3.0	-7.0	14.0
	Summer	Dec	-1.0	-38.0	16.0
		Jan	-1.0	-38.0	16.0
		Feb	-1.0	-38.0	16.0
	Autumn	Mar	2.0	-12.0	14.0
		Apr	2.0	-12.0	14.0
		May	2.0	-12.0	14.0
	Winter	June	9.0	0.0	26.0
		July	9.0	0.0	26.0
		Aug	9.0	0.0	26.0
	Spring	Sept	2.0	-15.0	26.0
		Oct	2.0	-15.0	26.0
		Nov	2.0	-15.0	26.0
Evaporation (mm)	**Annual**		0.7	0.2	1.6
	Summer	Dec	0.7	0.3	1.8
		Jan	0.7	0.3	1.8
		Feb	0.7	0.3	1.8
	Autumn	Mar	0.7	0.2	1.6
		Apr	0.7	0.2	1.6
		May	0.7	0.2	1.6
	Winter	June	0.7	0.2	1.6
		July	0.7	0.2	1.6
		Aug	0.7	0.2	1.6
	Spring	Sept	0.6	0.1	1.5
		Oct	0.6	0.1	1.5
		Nov	0.6	0.1	1.5