Chapter 8

A Regional Water Demand Model

> "Most, especially industrialised, countries still make all the same mistakes with water as they made with energy. They deplete non-renewable supplies and seek more water instead of using inexhaustible sources more productively and enhancing their capture by restorative grazing, farming and forestry. They rely on the highest quality water for every task, flushing toilets and washing paths with drinking water. They build big dams and water projects by reflex, rather than asking what's the best solution and the right size for the job" [P. Hawkens, A.B. Lovins and L. H Lovins, 1999].

8.0 Introduction

It has been shown in Chapters 2, 3, 6 and 7 that rainwater tanks installed on allotments and used to supply domestic hot water, toilet and outdoor uses will significantly reduce mains water demand. The widespread use of rainwater tanks to supplement mains water supplies for domestic hot water, toilet and outdoor purposes may significantly reduce regional water demand resulting in the deferral of new water supply headworks infrastructure.

Mains water consumption in dwellings that are partially reliant on water supply from rainwater tanks is dependant on climatic and socio-economic conditions for each household (Chapter 6). The impact of the use of rainwater tanks to supplement domestic water supply on regional water supply headworks systems will be dependant on the implementation rates of the rainwater tanks, and climatic and socio-economic conditions in various zones within the region.

Many authors including Maidment [1985], Kuczera and Ng [1994] and Zhou et al. [2000] have developed models of regional water demand that are derived from total urban water use in a region. Maidment [1985] and Zhou et al. [2000] analysed total water demand as base, seasonal and weather-dependant proportions of total demand. Kuczera and Ng [1994] modelled total water demand as three components: total domestic indoor, domestic outdoor and industrial/commercial demands.

The spatial distribution of urban water demand in a region is often ignored in the analysis

Copyright © P.J. Coombes All rights reserved

of water supply headworks systems in preference to the use of total regional demand. However, Maidment and Miaou [1986] found that water use at different locations within a region was dependant on spatially averaged rainfall series, ambient air temperature and established water use patterns. The use of rainwater tanks is expected to increase the spatial variability of mains water demand in a region.

In this Chapter a method to include rainwater tanks and the spatial variability of mains water demand in water supply headworks simulation is described. The method relies on the use of the Allotment Water Balance model (Chapter 6) to develop water use patterns for different household types in zones within a region, and socio-economic and demographic data to compile regional domestic demand. Non-domestic water demand is determined using the methods developed by Kuczera and Ng [1994] and combined with the compiled domestic demand to create total regional water demand. The method is used to simulate total regional water use for the Lower Hunter and the Central Coast regions of New South Wales using hundreds of thousands of years of synthetic climate data as an input to the Monte Carlo water supply headworks simulation modelling to be described in Chapter 9.

8.1 Development of a Monthly Regional Demand Model Using Non-Parametric Aggregation

A method was required to simulate regional water demand using synthetically generated monthly climate data for use in water supply headworks modelling at monthly time steps. To accurately determine the impact of the use of rainwater tanks on water supply headworks systems the correlation between climatic conditions, domestic water use and streamflows must be maintained. In particular the correlation between hot dry conditions, high domestic water use and low streamflows and vice versa must be preserved because it has a significant impact on the reliability of water supply headworks systems.

The widespread use of rainwater tanks in a region was also expected to increase the spatial variability of domestic mains water use due to varying climatic conditions within a region. A model to predict regional demand was also required to account for domestic water use in a number of different climate zones. The Allotment Water Balance model can be used to simulate daily domestic water use in different dwellings with different occupation rates that are in different climate zones. However monthly water demand was required that was consistent with monthly synthetic climate replicates generated in the water supply headworks model to maintain the correlation with climatic conditions, domestic water use and streamflows.

Two approaches could be used to match daily water use data generated in the Allotment Water Balance model to monthly climate replicates generated in the water supply headworks model. The method of fragments could be used to disaggregate the generated monthly climate replicate data into daily climate data for use in the Allotment Water Balance model to generate domestic water use data for each dwelling type in each climate zone. The continuous record of daily mains water use for each dwelling type in each climate zone for each replicate would then be summed to monthly mains water use and used in the water supply headworks model. Alternatively a method of non-parametric aggregation could be used to generate daily domestic water use for each dwelling type in each climate zone using historical climate records. The daily water use results from the Allotment Water Use model could be compiled into monthly totals and combined with the historical monthly climate data (such as rain depth, number of days with rainfall and average ambient air temperature). Water use for each dwelling type in each climate zone could be selected at each time step in the water supply headworks model by matching the monthly historical climate data and the synthetic climate data generated in the water supply headworks model.

The method of fragments approach involves the disaggregation of monthly climate replicates into daily data (such as daily rainfall and ambient air temperature) for use in the Allotment Water Balance model for each climate replicate. This process would use historical patterns of daily rainfall and temperature for each month to disaggregate synthetic data. Unfortunately the computational burden of simulating daily water use for hundreds of thousands of years is very considerable. For this reason this study adopted the method of non-parametric aggregation that is presented below.

Daily water use from different dwelling types (Table 6.16) with and without rainwater tanks is generated in the water balance model (Chapter 6) using historical climate data. Two resource files of domestic consumption with and without rainwater tanks are created for use in the regional demand model. The resource files are created by compiling the daily water use data into monthly totals for each dwelling type (H1 – H5, C1 and C2). The monthly water use totals are stored with the corresponding historic monthly average temperature ($AveTemp_m^R$), total rainfall depth ($Rdepth_m^R$) and number of rain days ($Rdays_m^R$) for month (m) in the resource file. The process is repeated for each climate zone (i) used in the regional model.

In the headworks modelling let $AveTemp_m^H$ be the monthly average temperature (ºC), $Rdepth_m^H$ be the monthly rainfall depth (mm) and $Rdays_m^H$ be the number of raindays for month m for each zone used in the regional demand model. These climate variables may be synthetically generated or replicated by sampling from a stochastic model or may be historically observed. Importantly they are temporally and spatially consistent with the rainfall and streamflows in the water supply catchments. The difference between climate data used in the headworks simulation and the resource file $Diff_m^{i,j}$ for each value j in the resource file for zone i in month m is shown as follows:

$$\begin{aligned} \mathrm{Diff}_m^{i,j} &= w_1 \,|\, \mathrm{AveTemp}_m^H - \mathrm{AveTemp}_m^{R,j} \,| + w_2 \,|\, \mathrm{Rdays}_m^H - \mathrm{Rdays}_m^{R,j} \,| \\ &\quad + w_3 \,|\, \mathrm{Rdepth}_m^H - \mathrm{Rdepth}_m^{R,j} \,| \end{aligned} \tag{8.1}$$

where w_1, w_2 and w_3 are weights. The weights were set to 1 for this study.

For each month m and zone I, the $Diff_m^{i,j}$ is found and the corresponding values for water use with and without rainwater tanks for cluster C1 (C1W and C1T), cluster C2 (C2W and C2T), house H1 (H1W and H1T), house H2 (H2W and H2T), house H3 (H3W and H3T), house H4 (H4W and H4T) and house H5 (H5W and H5T) are selected from the resource file. The domestic demand Dem_m^i (ML) in month m in zone i is:

$$\begin{aligned} \mathrm{Dem}_m^i &= (1 - \mathrm{inst}_m).\mathrm{Pop}_m.(F_1C1W + F_2C2W + F_3H1W + F_4H2W + F_5H3W + F_6H4W + F_7H5W) \\ &\quad + (\mathrm{inst}_m).\mathrm{Pop}_m.(F_1C1T + F_2C2T + F_3H1T + F_4H2T + F_5H3T + F_6H4T + F_7H5T) \end{aligned} \tag{8.2}$$

where the factors $F_1 - F_7$ indicate the proportion of the population (Pop_m) in a zone that occupies a particular dwelling type and the installation fraction for rainwater tanks is $inst_m$. The total regional domestic demand $DomDem_m$ (ML) in month m is:

$$\mathrm{DomDem}_m = \sum_{i=1}^{n} \mathrm{Dem}_m^i \tag{8.3}$$

where n is the number of zones in the region.

Non-domestic monthly demand for a region also needs to be accounted for. The simple model of commercial and industrial water use developed by Kuczera and Ng [1994] was adopted. The model of monthly non-domestic demand is defined as follows:

$$Q_{IC} = [A + B(Yr - Byr)]\left\{1.0 + Amp * Sin\left[\frac{2\pi}{12}(m + Phase)\right]\right\} - C * Rdepth \quad (8.4)$$

where Q_{IC} is the non-domestic demand for month m and year Yr, A, B and Byr are parameters defining the long-term trend in consumption, Amp and Phase are parameters defining the seasonal cycle, and C is a parameter accounting for the effect of monthly rain depth Rdepth (mm).

The regional demand model implements Equations 8.1 to 8.4 to produce total domestic and non-domestic demand for a region.

8.2 Monthly Carryover of Rainwater Tank Volumes

The method of non-parametric aggregation may introduce some uncertainty about the carryover of rainwater tank volumes from one month to the next because a continuous record of rainwater tank performance at each dwelling type is not used. The volume of water use from a rainwater tank in any month will be dependant on the volume of domestic water use and the capture of rainwater in the tank and the carryover volume from the previous month. During a hot dry month the volume of water stored in a rainwater tank may be exhausted. This may impact on the volume of water use that is possible from the rainwater tank in the following month. This is referred to as the carryover effect.

The discriminate variables, monthly rain depth, number of rain days and average ambient air temperature, were chosen for selection of monthly water use in the regional demand model to reduce uncertainty about the carryover effect. The use of rain depth will determine the volume of rainfall available to fill a rainwater tank in each month. However the period over which rain falls will determine how much of the rainfall is available for domestic water use. If the total rainfall for a month fell in one day the majority of roof runoff may overflow unused from the rainwater tank. The number of rain days in a month is used in the regional demand model to indicate the capture of roof runoff in a rainwater tank. The depth of rainfall, frequency of rainfall and ambient air temperatures in a month will indicate the volume of water use in any month.

These considerations suggest that the discriminate variables monthly rain depth, rain days and average temperatures should select high mains water use (low rainwater use) months from the resource file coincide with hot dry conditions and vice versa. This will ensure that the water supply headworks model accounts for the climate dependant impact of the use of rainwater tanks on regional water demand. In a sequence of consecutive dry months in the headworks simulation the aggregation method will select from the reference file months with low rainwater tank use. This ensures that in drought sequences the contribution from rainwater tanks is small when compared with mains water consumption.

The rainfall regime in the Lower Hunter and Central Coast regions shows a relatively uniform distribution of rainfall throughout the year (see Figure 8.1). However in climates with distinct wet and dry seasons, and lower rainfall the carryover effect of volumes in rainwater tanks from month to month may be more significant.

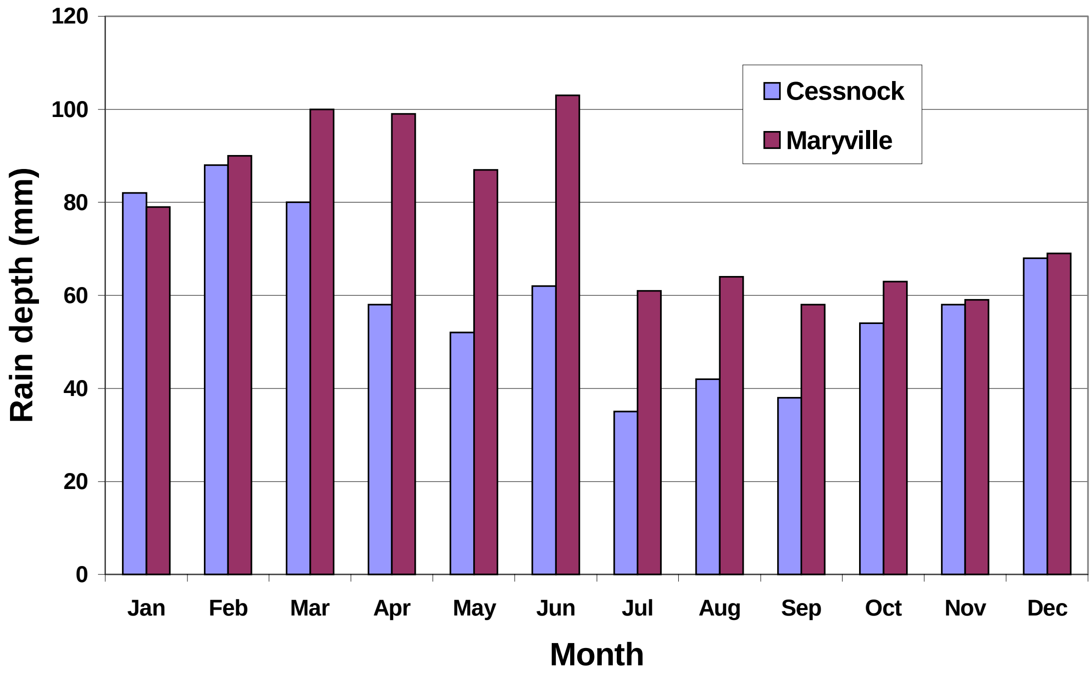

Figure 8.1: Monthly average rainfall totals for Cessnock and Maryville

This potential problem can be overcome by altering Equation 8.1 to include the climate conditions from the previous month in the selection process for water use ensuring that water use from the rainwater tank in the current month allows for climatic conditions from the previous month on rainwater tank volumes. The following equation would be used in such cases:

$$\begin{aligned} Diff_{m}^{i,j} = {} & w_1 \mid AveTemp_{m-1}^{H} - AveTemp_{m-1}^{R,j} \mid + w_2 \mid Rdays_{m-1}^{H} - Rdays_{m-1}^{R,j} \mid \\ & + w_3 \mid Rdepth_{m-1}^{H} - Rdepth_{m-1}^{R,j} \mid + w_1 \mid AveTemp_{m}^{H} - AveTemp_{m}^{R,j} \mid \\ & + w_2 \mid Rdays_{m}^{H} - Rdays_{m}^{R,j} \mid + w_3 (Rdepth_{m}^{H} - Rdepth_{m}^{R,j} \mid \end{aligned} \quad (8.5)$$

where sub-script m-1 refers to the previous month.

This strategy is similar in concept to block resampling strategies used in non-parametric statistical methods to deal with time dependent data.

8.3 The Lower Hunter Regional Water Demand

The water demand in the Lower Hunter region is calculated in this Section for use in an analysis in Chapter 9 of the region's water supply headworks scheme that includes domestic rainwater tanks. The regional model is calibrated to observed water demand to establish the values of the parameters in Equation 8.4 and then used with replicated climate data to provide replicates of regional water demand for use in a water supply headworks model.

8.3.1 Calibration of the Regional Demand Model to Observed Water Demand in the Lower Hunter Region

The regional demand model was calibrated by altering the parameters in Equation 8.4 to achieve the best fit between observed annual domestic and total demand for the period 1992 to 1997. Annual demand data was used for the Lower Hunter Region because monthly demand data was not available to the author.

Population data from the nine zones shown in Table 6.14, and occupation ratios and housing categories from Table 6.15 are used in the model. This data was used to define the parameters F_1 – F_7 that determine the proportion of each dwelling type from Table 6.16 that is used in Equation 8.2. The parameters in Equation 8.4 required to achieve a good fit between observed and simulated annual data are presented in Table 8.1.

The results of the calibration are shown in Figure 8.2. The regional demand model was able to achieve good agreement between the predicted and observed values for domestic and non-domestic demand.

Table 8.1: Calibrated parameters from Equation 8.4 for the Lower Hunter region

Parameter	Value
A	5300
B	-200
C	2.96
Amp	0.0685
Phase	1.83
Byr	1992

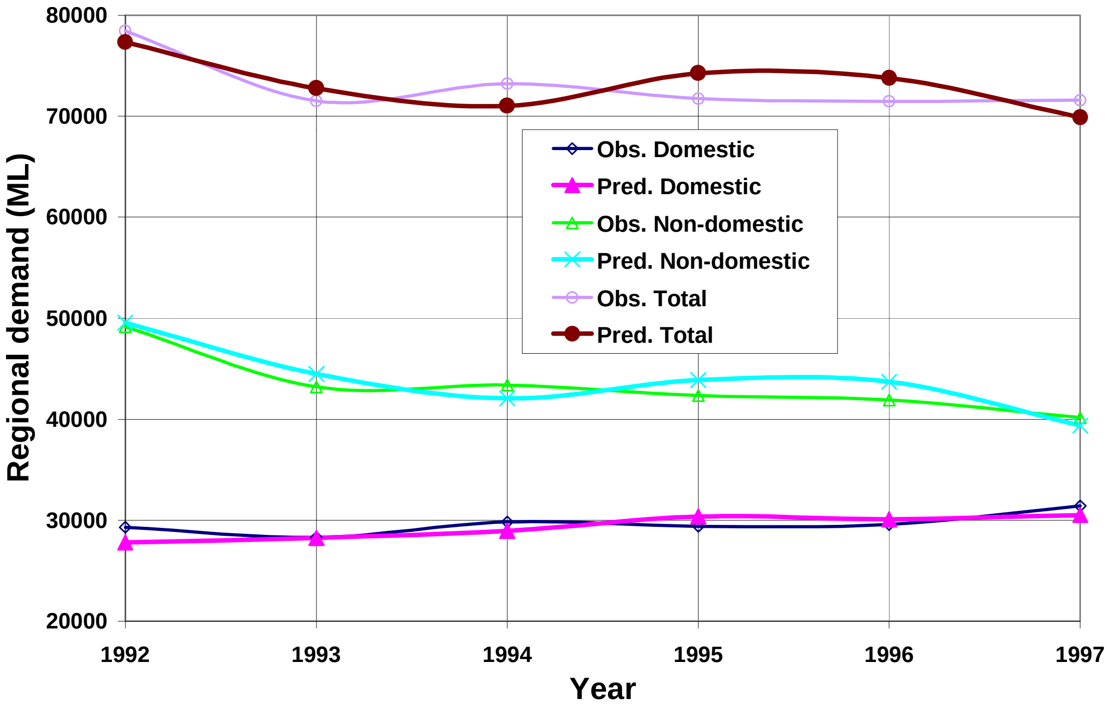

Figure 8.2: Calibration of the regional demand model to demand data from the Lower Hunter region.

Reasonable agreement to the observed data was achieved that will allow a comparative analysis of the impact of rainwater tanks on regional water demand. However, it is important to note that the Lower Hunter region was subject to drought, water restrictions and structural adjustment to industry during the period 1992 to 1998 that has resulted in a reduction in water demand. Indeed significant reductions in non-domestic water demand were observed. Non-domestic water demand was seen to increase in the period following 1998.

8.3.2 The Impact of Rainwater Tanks on Water Demand in the Lower Hunter Region

One thousand 100-year replicates of monthly climate data were used in the regional demand model to develop replicates of water demand for the period 2000 to 2099 in the Lower Hunter region that is used in the headworks model described in Chapter 9. The non-domestic demand was assumed to remain at 57% of total water demand to ensure that non-domestic demand grows at the same rate as domestic demand during the period 2000 to 2099.

The population growth rates shown in Table 6.14 and data from the Australian Bureau of Statistics [ABS, 1999] were used to estimate growth in domestic demand. One thousand 100-year replicates of monthly climate and streamflow data were generated at multiple sites within the urban zones and the water supply catchments. The data included rain depth, rain days, average daily temperature, streamflow and evaporation. The concurrent generation of climate and streamflow data at urban and water supply catchment sites is necessary to preserve the spatial dependence that associates drought (low streamflow and rainfall) with high outdoor water demand and vice versa. The replicates were generated using the methods described by Kuczera [1992] that employ the multisite lag-one Markov model [Matalas, 1967] to generate annual values that were then disaggregated using the method of fragments [Svanidze, 1960].

The values used in Equation 8.4 to maintain non-domestic demand at 57% of total water demand are shown in Table 8.2.

Table 8.2: Values used in Equation 8.4 to generate demand replicates for the Lower Hunter region

Parameter	**Value**
A	4985
B	39.6
C	2.96
Amp	0.0685
Phase	1.83
Byr	1992

A number of demand scenarios were simulated using the 1000 100-year replicates of future climate data. The Base scenario considers provision of additional mains water supply by further regulation of river systems. Seven alternative scenarios were considered: In the Growth scenario (denoted as G) rainwater tanks are installed for all new housing. In the other six scenarios (denoted as G +0.25% to G +3%), source controls are installed for all new housing and existing housing is retrofitted with water tanks at rates varying from

0.25% to 3% per year until 90% of dwellings have a rainwater tank.

Figure 8.3 and Appendix I display the growth in annual mains water demand averaged over 1000 replicates of water demand for selected demand scenarios. The results demonstrate the very significant reduction in mains water demand that can be achieved by using rainwater tanks to supplement mains water supply for outdoor, toilet flushing and hot water use.

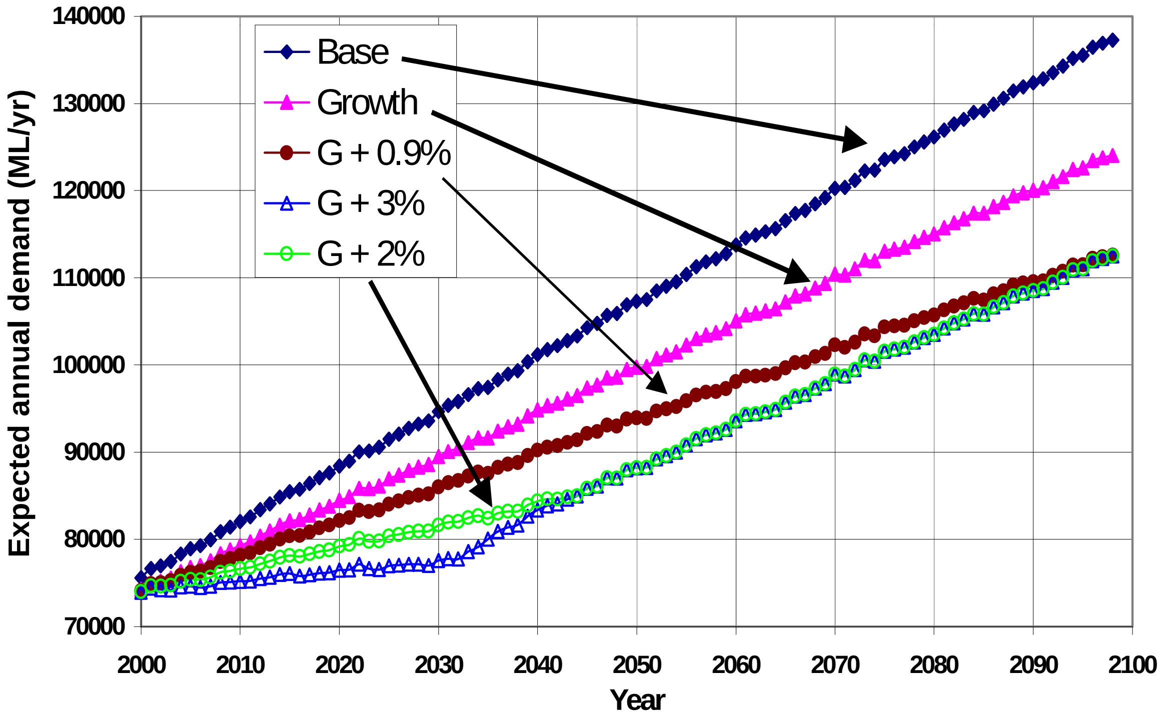

Figure 8.3: Mains water demand for the Lower Hunter Region with different levels of rainwater tank use

Figure 8.3 shows that the slope of the G+2% and G+3% demand curves changes in the years 2032 and 2045 respectively after the installation of rainwater tanks ceases when 90% of dwellings have a rainwater tank. By the year 2032 the G+3% scenario has reduced annual mains consumption from 95,800 ML to 77,700 ML, a 19% reduction in demand on the headworks system. It needs to be stressed that domestic water demand is only about 43% of total water demand in the Lower Hunter region. In urban areas with a similar climate but a higher domestic demand component, larger savings in mains water demand would be expected.

8.4 The Central Coast Regional Water Demand

The Central Coast Region of NSW includes the Wyong and Gosford local government areas. The region is situated between Sydney and the Lower Hunter regions with the City of Gosford adjacent to the Sydney region and Wyong Shire extends to Lake Macquarie in the north. The water demand in the Central Coast region is calculated in this Section for use in an analysis of the region's water supply headworks scheme that includes domestic rainwater tanks in Chapter 9. The regional demand model was calibrated to observed water total demand to establish the values of the parameters in Equation 8.4 and then used with replicated climate data to provide replicates of regional water demand for use in a water supply headworks model.

8.4.1 Calibration of the Regional Demand Model to Observed Water Demand in the Central Coast Region

The regional demand model was calibrated using observed monthly total demand for the period 1996 to 2000. The region was divided into two zones, namely: Gosford and Wyong, to facilitate calibration to observed water demand. Domestic indoor and outdoor monthly average daily water use was estimated for use in the Allotment Water Balance model using Equations 6.1 and 6.2 because there was no monitoring data for domestic household water use in the Central Coast region.

8.4.1.1 Population and Housing Statistics

Population and numbers of dwellings for the Gosford and Wyong zones were estimated from data provided by the NSW Department of Urban Affairs and Planning [DUAP, 1995], Australian Bureau of Statistics [ABS, 2000] and Wyong Shire Council [1999]. Estimated population and numbers of dwellings in the Gosford and Wyong zones are shown in Tables 8.3 and 8.4.

Table 8.3: Estimated population and number of dwellings in the Gosford zone

Year	Population			Estimated dwellings
	DUAP [1995]	ABS [2000]	Estimated	
1986	109,278	109,278	109,278	
1991	128,941	128,941	128,941	
1996	144,840	150,220	150,220	54,886
1997		153,024	153,024	55,910
1998		154,946	154,946	56,613
1999		158,172	158,172	57,791
2001	151,500		159,412	58,244
2006	154,600		167,724	61,281
2011	157,000		170,124	62,158
2016	158,400		171,524	62,760
2021	159,300		172,424	62,999
2031			174,224	63,667
2099			187,458	68,492

Table 8.4: Estimated population and number of dwellings in the Wyong zone

Year	Population				Estimated dwellings
	DUAP [1995]	ABS [2000]	WSC [1999]	Estimated	
1986	82,368	82,368	82,368	82,368	
1991	100,457	100,457	100,457	100,457	
1996	115,999	120,185	120,296	120,185	44,783
1997		123,108	123,125	123,108	45,976
1998		125,946	125,929	125,946	46,660
1999		129,309	128,735	129,309	47,532
2001	124,600		134,424	134,424	49,622
2006	133,900		150,146	150,146	55,952
2011	142,600		165,685	165,685	61,430
2016	150,900		182,526	182,526	68,019
2021	158,600		199,435	199,435	74,320
2031				233,253	86,845
2099				249,347	92,920

The dwellings in the two local government areas were categorised as either a detached house or a housing unit (Table 8.5). The housing unit category includes flats and apartments. All dwellings in the two zones were also categorised by number of occupants allowing water use modelling for different numbers of occupants and different dwelling types. This data was used to define the parameters F_1 – F_7 used in Equation 8.2 that determine the proportion of each dwelling type from Table 6.16 are used in the model.

Table 8.5: Occupation rates and housing categories for local government areas in the Central Coast region

Area	Houses (%)	Units (%)	Occupants per dwelling by area population (%)				
			1	2	3	4	5+
Gosford	91.6	8.4	24	34	15	16	11
Wyong	91.6	8.4	25	35	15	15	10

8.4.1.2 Climate Statistics

The New South Wales Bureau of Meteorology provided daily rainfall and temperature data for the Central Coast Region. Long-term rainfall stations at Gosford, Norah Head (Wyong) and Kulnura North were selected for use in the water supply analysis.

The Gosford and Norah Head stations were chosen because they are within the Gosford and Wyong local government areas. Data from these rainfall stations is used to generate household water use. The Kulnura North rainfall station was selected because it lies between the upper reaches of the Wyong River and Mangrove Creek water supply catchments. Data from this station is used in conjunction with past stream flow information to generate future stream flow in the water supply catchments in Chapter 9.

An additional rainfall station at Cooranbong was chosen for use in regression relationships to infill missing data from the Gosford, Norah Head and Kulnura North rainfall stations. The availability of daily rainfall data at these stations is summarised in Table 8.6.

Table 8.6: Availability of rainfall data in the Central Coast region

Station	Period available	Missing periods
Cooranbong	1943 to date	up to 7 months, some multiple days
Gosford	1877 to 1993	up to 10 months, some single days
Kulnura North	1959 to date	up to 1 month, some single days
Norah Head	1932 to date	up to 5 months, some single days

Gaps in the rainfall records from the Gosford, Kulnura North and Norah head stations were filled using the regression relationships shown in Table 8.7.

Table 8.7: Daily rainfall regression relationships for the Central Coast region

Station	Relationship	R^2
Gosford	0.948*Norah Head	0.727
Kulnura North	0.275*Gosford + 0.326*Norah Head + 0.15*Cooranbong	0.65
Norah Head	0.5984*Gosford + 0.286*Cooranbong	0.773

The annual rainfall and rain days per month for the selected stations are shown in Table 8.8. The Kulnura North location within the water supply catchments has less annual rainfall and days with rain than the residential areas of Gosford and Wyong. Rainwater tanks installed in the residential areas will have greater potential to capture rainfall than in the water supply catchments.

Table 8.8: Rainfall statistics from selected locations in the Central Coast region

Location	Annual rainfall (mm)			Rain days per month		
	Min	Max	Average	Min	Max	Average
Gosford	721	2266	1339	0	23	10
Norah Head	723	1996	1212	0	23	12
Kulnura North	589	1904	1093	0	22	9
Cooranbong	385	1943	1105	0	22	8

Temperature data from Gosford and Norah Head (Wyong) were selected for use in the simulation of household water use in the water balance model. Additional temperature data from Newcastle and Sydney was chosen for use in regression relationships to infill missing data from the Gosford and Norah Head sites. The availability of daily temperature data at these stations is summarised in Table 8.9.

Table 8.9: Availability of temperature data for the Central Coast region

Station	Period available	Missing periods
Gosford	1877 to 1993	up to 10 months, some single days
Newcastle	1957 to date	some single days
Sydney	1859 to date	some single days
Norah Head	1932 to date	up to 5 months, some multiple days

Gaps in the temperature records from the Gosford and Norah head stations were filled using the regression relationships shown in Table 8.10.

Table 8.10: Daily maximum temperature regression relationships for the Central Coast region

Station	Relationship	R^2
Norah Head	1.062*Sydney + 0.032*Newcastle	0.83
Gosford	0.95*Sydney + 0.089*Newcastle	0.65

The minimum, maximum and average daily maximum temperatures are summarised for the selected sites in Table 8.11.

Table 8.11: Daily maximum temperature statistics from selected locations

Location	Daily maximum temperature (^{0}C)		
	Min	Max	Average
Gosford	9.9	43.7	22.9
Norah Head	9	46.3	24.1
Newcastle	8.9	42	21.4
Sydney	9.3	45.3	21.9

8.4.1.3 Household Water Use

The Gosford Wyong Council's Water Authority does not have a monitoring program that disaggregates household water use into indoor and outdoor components. Accordingly, methods were developed to transfer results from the Lower Hunter to the Central Coast region. Monthly daily average domestic water uses for the Gosford and Wyong zones were estimated using climate and socio-economic data (shown in Table 8.12) in Equations 6.1 and 6.2 for use in the Allotment Water Balance model. A linear regression relationship for total monthly outdoor water use (L/month) was also developed:

$$\begin{aligned} \text{exDem}_m = {} & 10203 - 977.6\text{m} - 4.7\text{Rdepth}_m - 3.53\text{Inc} - 209.8\text{Rdays}_m \\ & + 606.8\text{G} + 14.02\text{AveTemp}_m \end{aligned} \qquad (8.6)$$

Equation 8.6 produced a relatively poor fit to the HWC data yielding an R^2 of 0.36. However, its primary purpose is to calibrate the model of daily outdoor water demand described in Section 6.4 that is within the Allotment Water Balance model to zones within the Central Coast water supply region. The calibration was accomplished by simulating monthly outdoor water use using a long sequence of daily climate data in the Central Coast zones and searching for parameters that reproduced the total of the monthly average outdoor water use given by Equation 8.6.

Table 8.12: Climatic and socio-economic data for the Central Coast region

Zone	Average weekly income ($/person)	Average daily rainfall (mm/day)	Population growth rate (%/year)	Average maximum daily temperature (°C)	Average days with rainfall
Gosford	251	3.33	2.35	24.1	10
Wyong	293	3.67	1.84	22.9	12

The estimated monthly average daily indoor and outdoor water use for the Gosford area used in the water balance model for different household sizes is shown in Table 8.13.

Table 8.13: Monthly average daily water use for Gosford

Month	Average water use (L/day)					
	Outdoor	Indoor				
		1 person	2 people	3 people	4 people	5+ people
January	271	151	296	442	588	734
February	254	140	286	431	577	723
March	232	147	292	438	584	730
April	207	141	287	432	578	724
May	162	137	283	428	574	720
June	119	133	279	424	570	716
July	121	137	282	428	574	719
August	173	143	289	434	580	726
September	224	144	290	435	581	727
October	272	148	294	440	586	731
November	292	151	296	442	588	733
December	331	152	297	443	589	734

The estimated monthly average daily indoor and outdoor water use for different house sizes in the Wyong Zone used in the Allotment Water Balance model is shown in Table 8.14. The monthly average daily water use results shown in Tables 8.13 and 8.14 were used in the Allotment Water Balance model to create resource files of domestic water demand for use in the regional demand model.

Table 8.14: Monthly average daily water use for the Wyong zone

	Average water use (L/day)					
	Outdoor	**Indoor**				
Month		1 person	2 people	3 people	4 people	5+ people
January	317	165	311	456	602	748
February	302	152	297	443	589	735
March	285	163	309	454	600	746
April	256	153	299	444	590	736
May	188	156	302	447	593	739
June	136	143	289	434	580	726
July	157	150	296	442	587	733
August	197	152	298	443	589	735
September	252	154	300	446	592	737
October	309	162	308	453	599	745
November	344	161	307	453	598	744
December	392	159	305	450	596	742

8.4.1.4 Calibration to Observed Water Demand in the Central Coast Region

The regional demand model was calibrated to monthly total demand for the Central Coast region by altering the parameters of Equation 8.4. The values used in Equation 8.4 to achieve the calibration to observed data are shown in Table 8.14.

Table 8.14: Values used to calibrate Equation 8.4 for the Central Coast region

Parameter	Value
A	1430
B	5.62
C	3.45
Amp	0.1
Phase	1.83
Byr	1995

The results of the calibration are shown in Figure 8.4. The regional demand model was able to achieve reasonably good agreement between the predicted and observed values for monthly total demand in the Central Coast region.

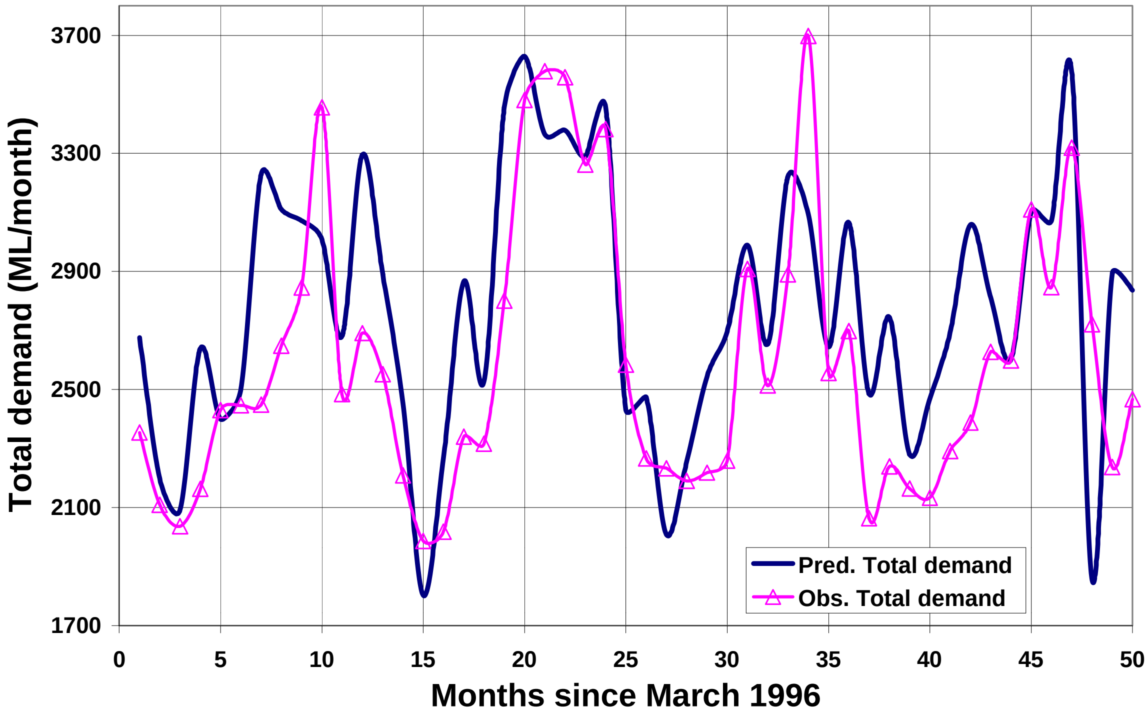

Figure 8.4: Calibration of the regional demand model to demand data from the Central Coast region.

In Figure 8.4 it is shown that the regional demand model was also able to predict the seasonal trends in water demand for the Central Coast region. The ability of the regional demand model to predict the seasonal cycles in total water demand was due to the use of the Allotment Water Balance model to estimate domestic water use and the use of the non-domestic water use model by Kuczera and Ng [1994] that includes parameters that account for the seasonal cycle. The Allotment Water Balance model includes the outdoor water use model developed in Section 6.4 that was able to replicate the strong seasonal trends in outdoor water use in the Lower Hunter region (see Figure 6.7). The coefficient of determination (R^2) for total demand was 0.57. Reasonable agreement to the observed data was achieved that will allow a comparative analysis of the impact of rainwater tanks on regional water demand in the Central Coast region.

8.4.2 The Impact of Rainwater Tanks on Water Demand in the Central Coast Region

One thousand 100-year replicates of monthly climate data were used in the regional demand model to develop replicates of water demand for the period 2000 to 2099 in the Central Coast region that are used in a headworks model in Chapter 10. The non-domestic demand is about 38% of total water demand. Growth in non-domestic demand was assumed to remain constant throughout the modelling period. The populations shown in Tables 8.3 and 8.4 are used to estimate domestic demand.

Figure 8.5 and Appendix I display the growth in annual mains water demand for selected demand scenarios.

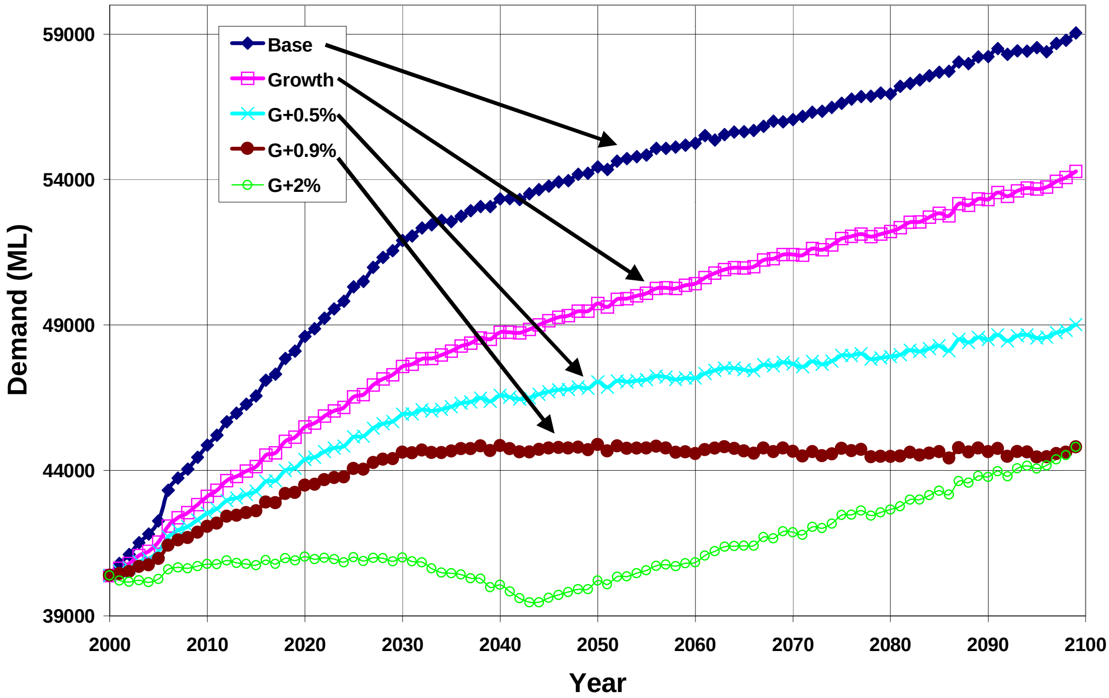

Figure 8.5: Mains water demand for the Central Coast Region with different levels of rainwater tank use

Use of rainwater tanks in the Central Coast region results in considerable demand reduction (Figure 8.5). By the year 2042 the G+2% scenario has reduced annual mains consumption from 49,700 ML to 35,500 ML, a 28% reduction in demand on the headworks system.

Figure 8.5 shows that the slopes of the water demand curves for the Central Coast region change in the year 2031 due to an expected decline in the population growth rate (see Tables 8.3 and 8.4). Figure 8.5 shows that the slope of the G+2% demand curve changes in the year 2045 after the installation of rainwater tanks ceases when 90% of dwellings have a rainwater tank.

8.5 Summary

A regional demand model was developed that can simulate efficiently over hundreds of thousands of years the impact of domestic rainwater tanks on regional water demand thereby allowing analysis of the impact of rainwater tanks on water supply headworks infrastructure. The model differs from traditional methods of predicting regional water demand that rely on regression relationships using historical total regional water use. The spatial variance of mains water use is captured in the model by using the expected mains water use in dwellings in selected climatic and socio-economic zones throughout a water supply catchment.

The regional demand model uses the Allotment Water Balance model (Chapter 6) to create reference files of historical mains water use in difference climate zones within a water supply catchment. Water demand for every dwelling in each climate/socio-economic zone at each time step is selected by matching the values of climate variables that coincide with streamflow and evaporation in the water supply catchment. The concurrent generation of climate and streamflow data at urban and water supply catchment sites preserves the spatial dependence that associates drought (low streamflow and rainfall) with high outdoor water demand and vice versa.

The simple model by Kuczera and Ng [1994] was used to estimate regional non-domestic demand in the regional demand model. The non-domestic demand model is calibrated to past demand trends or it is assumed that non-domestic demand will account for a given proportion of total mains water demand. The regional demand model was calibrated to historical regional demand for the Lower Hunter and Central Coast regions. Calibration was achieved by altering the parameters in the non-domestic component of the model.

Monitoring data of household water use from a number of different zones in the Lower Hunter region was used to calibrate the Allotment Water Balance model to create reference files for use in the regional demand model. The regional demand model was calibrated using annual demand observations for the Lower Hunter region because monitoring data for monthly water demand was not available. The annual water demands for the Lower Hunter region were reproduced with a fair degree of accuracy by the model.

Socio-economic and climate data was used in Equations 6.1, 6.2 and 8.6 to estimate indoor and outdoor water use parameters for use in the Allotment Water Balance model to make reference files for the regional demand model because the Central Coast region does not have a monitoring program for household water use. The regional demand model was calibrated using monitoring data for monthly total water demand for the Central Coast region. The regional demand model was able to reliably reproduce the seasonal trends for total water use in the Central Coast region.

Replicates of future climate data were used in the regional demand model to predict expected mains water demand from the year 2000 to 2099 in the Lower Hunter and Central Coast regions. The impact of different rates for installation of rainwater tanks on regional water demand was examined for both regions. The widespread installation of rainwater tanks to supplement mains water supplies for domestic hot water, toilet and outdoor uses was shown to produce substantial reductions in regional water demand. The impact of the reductions in regional water demand on water supply headworks infrastructure will be analysed for the Lower Hunter and the Central Coast regions in Chapter 9 using the regional demands created in this Chapter.