BROCKWATER:
Municipal Water Demand Simulation and Projection Project

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Introduction

This document provides an introduction to the features of BROCKWATER - the Brock Water Demand Simulation software created by researchers at Brock University. The purpose of the software is to provide a user-friendly, spreadsheet-based demand forecasting and simulation tool that can provide water agencies with the capacity to forecast medium-term demands while simultaneously accounting for planned or expected changes in important demand drivers such as water rates or conservation programs (e.g. retrofitting, education campaigns, etc.).

How the program works

BROCKWATER is written in Microsoft Excel 2010 and runs on Windows and Apple systems. The user inputs a series of initial conditions for her own municipality and then makes a number of selections regarding model parameters (e.g. population and income growth rates, future water rates, price and income elasticities, etc.). The program accommodates both uniform and block rate pricing schemes, and affords users considerable flexibility in inputting future water rate changes. Based on the user's input, the model then simulates and reports the expected future growth in residential water demands. Simulations may be either deterministic or probabilistic (i.e. generated with a Monte Carlo algorithm). In the latter case the user must also input coefficients of variation for key parameters.

Specific features of BROCKWATER

The program leads users through a series pages and pop-up windows, where information on initial conditions, future water rates, conservation programs, and simulation parameters must be inputted. The following describes each stage of the process.

The Guide: The first page introduces the program and provides an overview of its workings.

The user then clicks "Start Forecasting" to begin inputting information.

1. Initial Conditions:

In this page, the user is asked to input information regarding initial residential water demands and demand drivers (e.g. number of households served, household income, and climate conditions). The latter values are used by the program to calculate future levels of water demands. The user is also asked to specify the pricing structure and input starting values for residential water prices.

  1.1. Community Statistics: Here the user is asked to input values on initial residential demands and demand drivers. Water demand parameters are defined as follows: *Annual WD (m³)* refers to the total volume of water consumed by residential customers during the initial simulation year, *Daily WD (m³)* refers to the total volume of water consumed by residential customers on the day of the year with the highest consumption of water (e.g. July 20ᵗʰ), *Average daily WD (m³/h)* refers to the average volume of water consumed per hour by residential customers on the day of the year with the highest consumption of water (i.e. the same day as above), and *Peak daily WD (m³/h)* refers to the maximum volume of water consumed per hour on the day of the year with the highest consumption of water (i.e. the same day as above).

  The demand drivers are defined as follows: *Initial Number of Households* refers to the number of residential households served by the municipal water provider during the initial simulation year, *Average Household Income ($)* refers to the average income of households served by the municipal water provider during the initial simulation year, *Average Temperature (°C)* refers to the municipality's average summer daytime

temperature (May – August), and *Average Precipitation (mm)* refers to the municipality's average summer precipitation (May – August).

1.2. Pricing Structure: The pricing structure allows the user to input their current price structure. The program allows for fixed, uniform, and block rate pricing.

- If there is a fixed component to price structure (i.e. a monthly or quarterly fee that is independent of water consumption), the user may enter the fixed monthly charge in the *Fixed Connection Fee*.

- Volumetric charges enter into the next section. If there is a uniform price structure (i.e. the price per m^3 is constant for all levels of consumption) the user will input information in the row labeled *Block 1*. The user enters a 1 for the *Initial Proportion of Users under Given Block Rate* to indicate that all consumers are subject to same volumetric price. The volumetric price (e.g. $1.00/m^3$) is then entered for the *Price*. In the case of a uniform price, the *Max Consumption Threshold* is left empty.

- If there is a nonlinear pricing schedule (e.g. increasing or decreasing block rates), water consumption is divided by consumption blocks which correspond to a unique maximum water consumption threshold and specified price. A user may input as many blocks as necessary. For the *Initial Proportion of Users under Given Block Rate*, the user enters the proportion of residential customers (between 0 and 1) whose consumption falls into each block (e.g. if 30% of the population consumes from Block 1 then the user will input 0.3 for the first block). The user then inputs the maximum consumption threshold and volumetric price for each block. The consumption threshold is left empty in the last block.

For a real-world example, we can refer to information from Ontario's Halton Region's webpage. The Halton Region uses a block pricing structure (see below), and includes a fixed monthly service fee of $25.84 for a 20mm sized water meter.[1]

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[1] http://www.halton.ca/living_in_halton/water_wastewater/your_water_bill/breakdown_rates_water_bill/

Halton Region Water Rates - Volumetric Portion of charge based on the amount of water used each month			
Block	From (m³)	To (m³)	Rate ($ per m³)
1	0	25	2.1247
2	26	45	2.274
3	46	60	2.4456
4	61	460	1.1997
5	Greater than	460	0.9773

There is no public information of the proportion of the population that consumes from each block, so for this example we will assume 40% of the population consumes from Block 1 (0-25m³), 20% consumes from Block 2 and 3 (26-45m³), 15% consumes from Block 4 (46-60m³), and 5% consumes from Block 5 (>460m³). The Halton Region's fixed fee and volumetric pricing structure would enter the spreadsheet as follows.

1.2 Pricing Structure

i. Residential

Fixed Connection Fee ($)	25.84

Block	Initial proportion of users under given block rate.	Max Consumption Threshold (M³ per Account)	Price ($/M³)
1	0.4	25	2.1247
2	0.2	45	2.274
3	0.2	60	2.4456
4	0.15	460	1.1997
5	0.05		0.9773
6			

After inputting all values on this page of BROCKWATER, the user will click on the "Price Increase Schedule" and choose one of the three options for the type of price change she wants to simulate.

2. Price Adjustment: In this stage, users input the desired changes to fixed and volumetric prices. The program allows users to easily define a one-time or reoccurring increase in prices. A custom price increase feature allows users to design more complex price increases schedules. All price changes enter into the model as percentage increases/decreases from existing rates.

2.1 One Time Price Increase: If the user wishes to simulate the impacts of a one-time change to the pricing schedule then she inputs the needed values on this page. This option is available for fixed, uniform and block rate price structures. To simulate a fixed connection fee or volumetric rate increase of 5%, the user inputs a proportional increase of 0.05 in the appropriate field. The user must also indicate the year that the price and/or connection fee change takes effect (i.e. the *Effective Date*). The change is assumed to last for the remainder of the simulation.

For example, the following screen capture shows a one-time price increase of 5% starting 2015.

2. Price Increase Schedule

2.1 One Time Increase
Complete the table to simulate a one-time price increase (across all blocks).

Connection Fee Increase (p)	0
Block Rate Increase (p)	0.05
Effective Date (YYYY)	2015

Next Step: Demand Side Management Policies

2.2 Constant Recurring Price Increase: If the user wishes to simulate the impacts of a consistent and ongoing series of changes to the pricing schedule then she inputs the needed values on this page. This option is available for fixed, uniform and block rate price structures. To simulate a reoccurring increase of 5%, for either a fixed fee or volumetric rate, the user would enter the value 0.05 in the appropriate field. The user must also indicate the year when price changes begin to take effect, as well as the frequency and duration of these changes. Frequency refers to how often the price change occurs and duration refers to the span of time over which all price changes occur. For example, (as seen in the following screen capture) to evaluate the effects of a price increase that occurs every 5 years beginning in 2020 and ending in 2040, the user would enter the 2020 for *Effective Date*, 5 for *Frequency*, and 20 for *Duration*. The latter value is the difference between the beginning and ending dates. Notably these dates represent the duration for price changes and not the duration of the simulation. The beginning and ending dates of the simulation are defined elsewhere.

2. Price Adjustment

2.1 Constant Recurring Increase

Complete the table to simulate a recurring price increase (across all blocks). The increases are compounded, and can be applied for a finite duration, or for the entire simulation.

Connection Fee Increase (p)	0
Block Rate Increase (p)	0.05
Initial Effective Date (YYYY)	2020
Frequency (Years)	5
Duration (Years)	20

Next Step: Demand Side Management Policies

2.3 Custom Price Increase: If the user wishes to simulate the impacts of an ongoing series of changes to a more complex water price schedule then she inputs the needed values on this page. This option is available for fixed, uniform and block rate price structures. The custom price increase page allows price adjustments to each (preexisting) block. The user may input their desired years for price changes and the proportional price change on that year. Each block may have varying price increases across years. The maximum consumption threshold values are carried over from the initial conditions section. Please note that these block thresholds **cannot be changed** from their original values.

Using the same Halton Region pricing structure from above, we can create an example of a custom price increase. There are 5 blocks included in the simulation. The user is able to adjust volumetric charge for each block and the fixed connection fee. In the example below, the fixed connection fee increases by 0.05 (i.e. 5%) in 2024. The volumetric price for *Block 1* increases by 3% in 2020 and 2024. Likewise, the volumetric price for *Block 2* increases by 4% in 2020 and 2% in 2024 and 2028. Various pricing schedules have been entered for the remaining blocks.

2.1 Custom Price Increase

Complete table below to simulate a custom price increase schedule. Increases can be distinct between blocks, and can vary across years.

	Year	2020	2024	2028	2030
	Connection Fee Increase (p)	0	0.05	0	0
Block	Max Consumption Threshold (M³ per Account)				
1	25	0.03	0.03	0	0
2	45	0.04	0.02	0.02	0
3	60	0.05	0.03	0.05	0.03
4	460	0.06	0.02	0.03	0.04
5		0.06	0.02	0.01	0.03
6					

After inputting information about price changes, the user will click on "Demand Side Management Policies" button.

3. Demand-Side Management Policies: On this page, the user may investigate the impacts of alternative demand-side management policies (e.g. retrofit programs, educational campaign, etc.) by inputting values for the following parameters:

(i) Effective Date: As with the price adjustments, the effective date refers to the year when the policy change takes effect.

(ii) Target Population: The target population refers to the proportion of residential accounts in the region which are expected to be affected by the policy. For example, if 80% of residential accounts are expected to reduce their water consumption due to a citywide education program, then 0.8 is inputted into the spreadsheet.

(iii) Assumed Residential Demand Reduction: This values refers to the expected reduction in water demand based on the policy. It represents the assumed percentage reduction in water use for those residents who are targeted. If it is assumed that, for those residents who are targeted, a reduction of 5% will likely occur, then a value of 0.05 is inputted into the spreadsheet. Note that the combination of a targeted population of 80% and a 5% reduction of those targeted results in a 4% reduction in total residential water demand ($80\% \times 5\% = 4\%$). The default number of policies for which information may be inputted is one but the user may add more policies if desired using the *Add New DSMP* button. Policies can be deleted using the *Delete Last DSMP* button.

After inputting information about demand management policies and their expected impacts, the user will click on the "Simulation Parameters" button.

4. Simulation Parameters: On this page, the user selects the parameter values for the demand projection. These values include the simulation period, assumed growth rates for demand drivers, and assumed values for demand elasticities.

4.1 Horizon: Here the user inputs the date they wish the simulation to start (*Initial Date*), the length of the forecast (*Length of Forecast*), and the number of simulation runs (*Number of Simulations*). The length of forecast determines how many years ahead the user would like to project (e.g. a forecast length of 25 years projects water demand for 25 years after the chosen start date). The number of simulations allows the user to choose how many times to run the simulation. If the user wants a deterministic forecast that does not account for future uncertainty, then a value of 1 should be entered for *Number of Simulations*. In this case, the simulation will be run only once. If the user wants to account for future uncertainty of demand drivers, then a value greater than 1 should be entered for *Number of Simulations*. In this case, a Monte Carlo algorithm is used estimate expected water demands and the corresponding standard deviation of water demands. We recommend that a minimum of 100 simulations be used when employing a non-deterministic approach.

4.2 Growth Rates: The user inputs the region's expected annual population (*Population*) and income (*Income*) growth rates in this section, along with any expected growth rates in temperature (*Temperature*) and precipitation (*Precipitation*). Coefficients of variation may also be inputted in this section. The coefficient of variation is a measure of the 'spread' or uncertainty regarding future values that is used for Monte Carlo simulations. If a value of population growth rate of 0.05 (i.e. an expected growth rate of 5% per year) is combined with a coefficient of variation of 0.01 for 100 simulations, then the program will report the results of 100 simulations in which the rate of population growth varied between 0.04 (4%) and 0.06 (6%). If a value of 1 has been chosen for the number of simulations then the program ignores any values input for the coefficients of variation. Thus, by choosing the coefficient of variation for the demand driver growth rates, the user may generate confidence intervals for the projected levels of water demands.

4.3 Elasticities of Demand: The most important feature of BROCKWATER is that it allows the user to easily simulate future water demand growth while accounting for how households are likely to respond to the chosen price increases. This is done by choosing the "elasticity" values for the fixed connection fee, volumetric price, income and the climate variables. The price elasticity of demand represents the responsiveness of consumers demand for a good from a change in the price. For example, an elasticity of -0.2 indicates that a 1% increase in prices leads to a 0.2% reduction in water demands. In other words, households reduce water demands by approximately 2% when the price of water rises by 10%. The income elasticity of demand reflects the change in water demand as a households income changes. A value of 0.2 indicates that households are predicted to increase water demands by approximately 2% when their income rises by 10%. Likewise, the elasticities of temperature and precipitation reflect the change in water demand resulting from a change in temperature or precipitation. A list of elasticities from published water demand studies is provided in Appendix A. The user may refer to and select values from this list if they do not know the elasticities of demand for their municipality. We recommend using elasticity from cities with similar characteristics (e.g. size, household income, climate, etc.) to that of the municipality being evaluated.

We have looked at the research literature and can provide the following suggested ranges for the values of the non-price elasticities:

Income: 0.20 to 1.0

Daily Summer Temperature: 0.5 to 1.0

Summer Precipitation: -0.05 to -0.2

Lastly, we have included an option that allows the user to reduce the size of the price elasticity over the course of whatever simulation is being run. The reason for this option is to allow the user to simulate what would happen if households become less willing (or less able) to respond to successive price increases. Specifically, the *Rate of Decrease* is the rate at which the elasticities decay or diminish in their effect on demand. A rate of decrease of 0.05 implies the effects of the next price increase will decrease by 5% per year (e.g. if the elasticity is -0.2 one year it will be -0.475 the next year). In order to make use of this option, the user will input the proportion of the decrease (e.g. a 5% decrease = 0.05).

At this stage, the user will click on the "Next Step: Run Simulation" button. BROCKWATER will provide its output in a separate file in graphical and tabular format.

Interpreting the Graphs: The resulting graphs from the users input includes the "Forecasted Annual Water Demand with Average Price of Water", which displays the changing trend of water demanded over the forecast, along with the changing price of the first consumption block. The "Forecasted Average Temperature and Precipitation" graph displays the trend of both temperature and precipitation over the length of the forecast, based on the user's inputted growth values. The third graph "Forecasted Population and Average Household Income" projects future population and household income based on the initial growth rates inputted. Note that when Monte Carlo simulations are employed there is a random component to population, income, temperature, and precipitation variables. Subsequent tables report the initial and final volumetric prices for each block and the initial and final distribution of households across blocks.

If you have any questions about the program or to provide feedback on the program (including suggestions for future versions), please contact Steven Renzetti srenzetti@brocku.ca or (905) 688-5550, x.3121.

BROCKWATER and this user manual may be downloaded free of charge from www.brocku.ca/wepgn

Appendix A: Library of Elasticities for Demand Drivers

A list of elasticities from published water demand studies is provided in Appendix A. The following tables list elasticities of demand from published water demand studies. Users may select values from these lists when the elasticities for their municipality are unknown. We recommend using elasticity from cities with similar characteristics (e.g. size, household income, climate, etc.) to that of the municipality being evaluated.

Library of Price Elasticities of Demand		
City	Price Elasticity	Date
East Los Angeles, California[e]	-0.39 to -0.437	2015
South San Francisco, California[e]	-0.218 to -0.425	2015
Phoenix, Arizona[p]	-0.661 to -1.155	2014
Reno, Nevada[f]	-0.2	2014
Chapel Hill, North Carolina[o]	-0.43 to -1.14	2014
Western Riverside County, California[a]	-0.58 to -0.76	2014
Wisconsin, US[b]	-0.096	2012
Chicago, Illinois[h]	-0.112 to -0.1982	2011
Santa Cruz, California[j]	-0.12	2011
Phoenix, Arizona[m]	-0.38 to -0.41	2010
Aurora, Colorado[d]	-0.6	2008
Colorado, US[n]	-0.3	2004
Santa Barbara & Goleta, California[j]	-0.33	1998
Denton, Texas[c]	-1.57 to -1.63	1995
New England, US[l]	-0.1 to -0.69	1992
Columbia, North Carolina[g]	-0.49 to -0.70	1992
Vancouver, British Columbia[k]	-0.0137 to -0.6487	1991

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