DEMAND-SIDE MANAGEMENT OF RESIDENTIAL WATER USE IN VANCOUVER

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Abstract

This study considers policy alternatives that the City of Vancouver could explore to encourage water conservation among residential water users. Using both quantitative and qualitative data, the study identifies the factors that influence per capita residential water demands in Canadian cities and the relevant policy instruments applied to encourage water conservation. Primary data sources are Environment Canada surveys of municipal water systems and case studies from the United States of best practices with respect to water conservation. The data analysis reveals that the price of water, metering, educational conservation policies, and non-price incentives are significant factors affecting per capita residential water demand. Following that, this study proposes and assesses policies to reform water management in Vancouver. Policy recommendations to the city include: (i) introducing a universal water metering programme and (ii) applying increasing block rate pricing to encourage water conservation among the public.

Keywords: Vancouver residents; water consumption; water efficiency; demand-side management; water conservation; universal metering

Subject Terms: water consumption – Canada; water meters – cost-effectiveness; water supply – British Columbia; water conservation; municipal water supply – rates – Canada; Canada – water supply – economic aspects

Executive Summary

This study considers policy alternatives that the City of Vancouver could explore to encourage water conservation among residential water users. In particular, demand-side management policy instruments are analyzed as an alternative approach to the traditional supply-side focus that builds increasingly sprawling water infrastructure.

Vancouver per capita residential water use is nearly 25 per cent higher than the average urban centre in Canada (Environment Canada, 2004). This study uses both quantitative and qualitative data to examine water use patterns and effective demand-side policy instruments. Data from the Environment Canada Municipal Water and Wastewater Survey (2004) are applied in an empirical estimation to identify the factors that influence the per capita residential demand for water. The key findings of the quantitative analysis include:

- Metered water use is associated with lower per capita water consumption.
- The price of water is negatively correlated with water consumption;
- The existence of educational policies and non-price economic incentives are associated with lower per capita water demand.

Case studies of best practices in the United States are analyzed to determine the relevant policy instruments associated with each of the statistically significant factors identified in the empirical estimation. This analysis identifies the pricing structures, educational instruments, and economic incentives that are most effective in reducing per capita water demand in the residential sector.

Results from all data analyses are used to identify policy alternatives to reduce water demands among Vancouver residential users. The following policy alternatives are identified as potential reforms:

- A mandated, universal metering initiative that employs an increasing block rate pricing structure.
- A subsidized voluntary metering programme, combined with an enhanced informational and educational campaign to encourage water conservation.
- A subsidized voluntary metering programme, combined with an economic incentive to replace old toilets with more efficient, ultra low flow toilets.

The proposed policy alternatives are mutually exclusive and thus should be considered discrete policy directions. To assess the broad viability of the proposed alternatives, each one is evaluated using a set of criteria: (i) cost, (ii) effectiveness in reducing demand, (iii) equity, (iv) administrative feasibility, and (v) acceptability by stakeholders. The multi-criteria analysis results in the following two recommendations for the City of Vancouver to consider:

1. Implement a fully subsidized universal metering programme that is mandated for all residential users in single-family detached homes, and
2. Implement an increasing block rate pricing structure, where prices increase in successive blocks of the rate structure; this provides a strong incentive for residents to conserve water.

Dedication

To my parents, whose support has been vital to my academic success.

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Glossary

Constant unit charge (CUC)	The simplest volume-based charge, whereby X litres of water have a price of $Y and is constant for all consumption levels.
Decreasing block rate (DBR)	Volume-based charge in which water use is divided into successive volumes and each successive block is charged at a lower price per unit than the previous block.
Fixed annual fee	A fee paid, equal for all residential water consumers, for an unlimited amount of water.
GVRD	Greater Vancouver Regional District (now Metro Vancouver)
GVWD	Greater Vancouver Water District
Increasing block rate (IBR)	Volume-based charge in which water use is divided into successive volumes and each successive block is charged at a higher price per unit than the previous block.
OECD	Organization for Economic Cooperation and Development
Rate structure	The manner in which the per unit price of water changes with increasing consumption.

Introduction

Residents of Vancouver consume significantly more potable water per capita than comparable urban areas across Canada. Indeed, nearly all municipalities within Metro Vancouver rank among the highest per capita consumers in North America (Brandes, 2004). Vancouver's level of water use is even more pronounced when one compares Canadian averages to the rest of the industrialized world (Maas, 2003). Among OECD countries, Canadians have the second highest per capita water consumption rates. Canadians consume two times more water than the average person in France and eight times more than the average person in Denmark. This global perspective raises the policy question: why is the per-capita consumption of water by residential consumers in Vancouver so high relative to other Canadian urban centres, and the rest of the industrialized world?

The municipal share of all water consumption in Canada is about 12%; the remaining share is divided between agricultural and industrial sectors. The residential component of municipal water services typically amounts to half of the water consumed in cities. The percentage of total water in Canada used by households is thus relatively small. However, there are several reasons to justify the study of urban residential water consumers: increasing urbanization, rising urban water use, infrastructure needs, and ecological impacts. More than 80% of Canadians live in urban areas and urbanization is an indicator of economic growth and rising incomes, which tend to expand water consumption patterns (McNeil and Tate, 1991). Furthermore, water shortage is already a reality for many Canadian cities. For instance, 26% of Canadian cities reported water shortages in a five-year period starting in 1994 (Brandes, 2003). Vancouver is not immune to this trend; the low precipitation during summer months and high demand for water drains reservoirs (Clift, 2004). While there has been a general trend in Canada towards lower per capita water use since the mid-1990s, an Environment Canada study has found that between 1991 and 1999 the only group for which per capita water use increased are domestic users (Environment Canada, 2001). Increasing water consumption places stress on the aging infrastructure in many Canadian urban centres.

With such pronounced levels of residential water consumption in Vancouver (and Canada more generally), residential consumers could use less water and consume water more efficiently without substantial utility loss. In other words, conservation and efficiency gains should be made in Vancouver. Reasons for this assertion include: supply limitations, water treatment costs, and environmental impacts of large water withdrawals. In addition, reducing residential water consumption can both delay costly infrastructure upgrades and expansions, as well as reduce the occurrence of water shortages.

The purpose of this study is to identify the factors that influence the residential demand for water and suggest alternative policies that Vancouver municipal government can consider to reduce per capita domestic water consumption. This research combines empirical estimations, case studies of best practices in water conservation, and interviews with experts in water management to develop the proposals for reform. Additionally, this study tests the relative effectiveness of the various conservation measures typically used in cities in Canada. This provides insight into an under-researched element in the literature on water conservation. The results confirm established findings in the literature that metering water use is a critical component of most water conservation efforts.

This study is organized in the following way: Section 1 provides the context of municipal water management in Vancouver outlining the traditional role of supply-side approaches and the corresponding successes and failures. Section 2 outlines approaches to water management and in particular the emerging - and promising - role of demand-side management theory. In Section 3, I estimate parameters for residential water demand using empirical analysis for a sample of 54

Canadian cites in 2004. The empirical estimation, combined with elite interviews, informs the policy alternatives and criteria for policy analysis presented in Section 4. In Section 5, I evaluate the policy alternatives against the established criteria and make recommendations to the City of Vancouver. Finally, in Section 6, I summarize recommendations to the City of Vancouver and identify opportunities for further research on water management reforms.

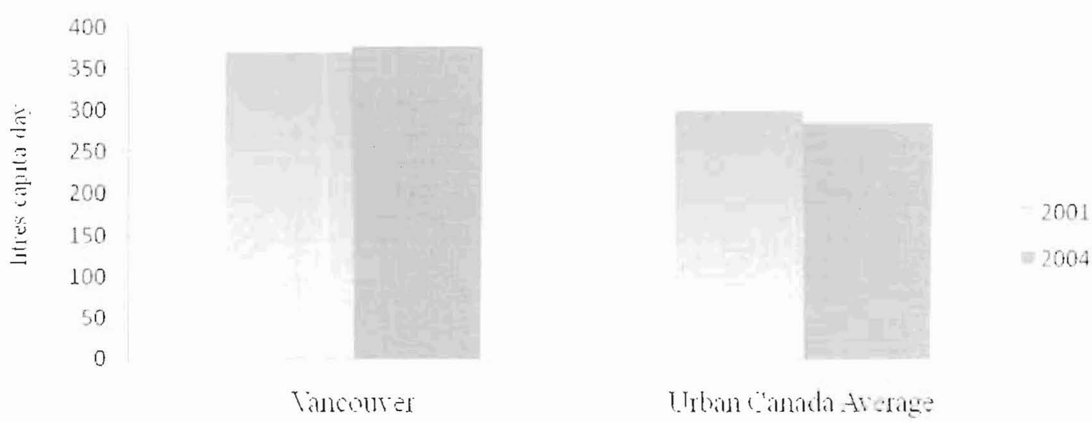
1: Water Use and Governance in Vancouver

To understand water policy in Vancouver, it is essential to provide the context of water management at the municipal level. This section outlines the water use patterns of Vancouver residents and draws comparisons with other cities in Canada and OECD countries. After providing evidence that Vancouver residents are comparatively heavy water users, this section describes the governance structure of water management in Vancouver. This provides the context of the division of powers and mandates among regional and municipal governments, and establishes the relevant stakeholders in municipal water management.

1.1 Water Use in Vancouver

Vancouver residents consume much more potable water per capita than most urban centres in Canada. Compared to the average Canadian in municipalities with a population over 50,000, the average Vancouverite uses approximately 100 litres more per day at home, as shown in Figure 1.

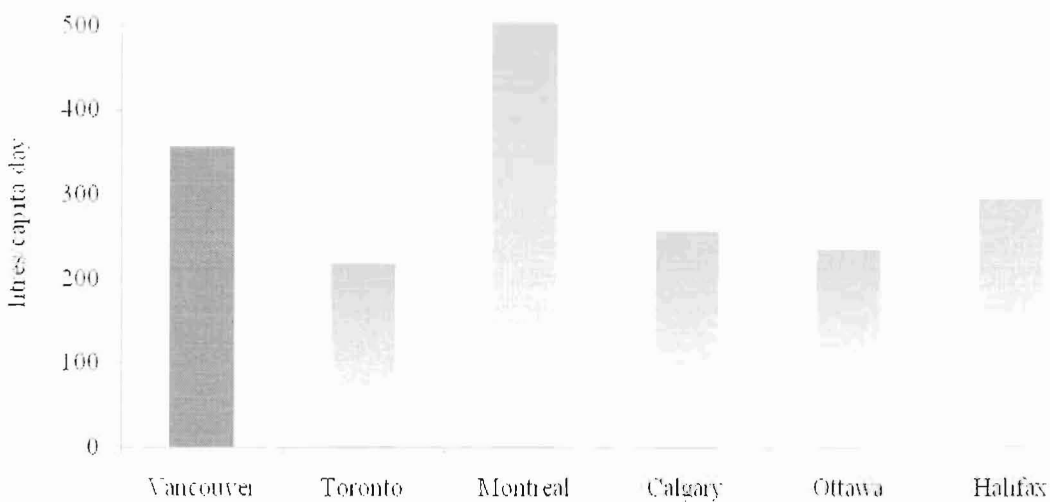
Figure 1: Average Daily Residential Water Consumption in Vancouver and Canada.



Source Environment Canada, 2004

In addition, Figure 1 shows that while the average residential water consumption in Canadian urban centres decreased by 6% from 2001 to 2004, it increased slightly among Vancouver consumers. Among the largest urban centres of Canada, Vancouver residential water use is also comparatively high, as shown in Figure 2. With the exception of Montreal, per capita domestic water consumption in Vancouver exceeds that of other major Canadian urban centres by a significant amount.

Figure 2: Average Daily Residential Water Consumption in Canadian Urban Centres, 2004.



Source Environment Canada, 2004

Figure 2 shows that in 2004, for example, the per capita residential consumption in Vancouver was 357 litres per day, while it was 218 litres per day in Toronto. Thus per capita residential water use was nearly 40% higher in Vancouver than in Toronto. Similarly, compared to Calgary, Ottawa and Halifax, the consumption patterns among residents in Vancouver are high.

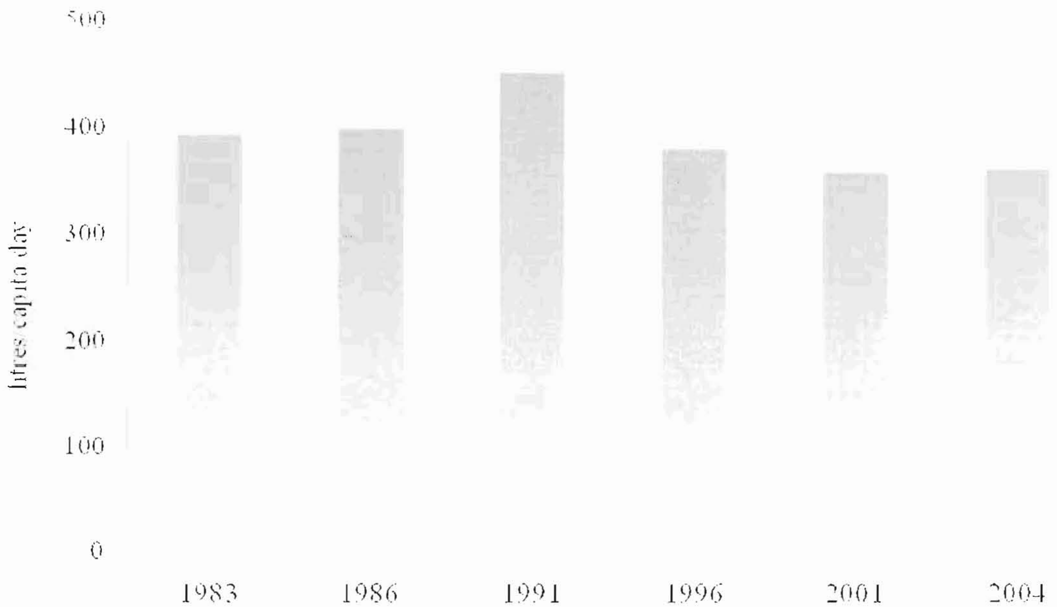
It is even more evident that residential water use in Vancouver is abnormally high when one compares Canada to the OECD member average for household use. Figure 3 shows that average residential consumption in Canada far exceeds the household water use patterns of comparable countries in Europe. For example, Canadians use more than twice the amount of water as the Dutch and 35 per cent more than Italians.

Figure 3: Average Daily Residential Consumption in Canada and Sample OECD Countries (1997).

The excessive water use in Canada is recognized throughout the world. An assessment by the World Water Council in 2002 ranked Canada 129 out of 143 in an index measuring how efficiently a country uses water (MacFarlane, 2003). Thus, since Canada is a high water consumer among OECD nations and Vancouver is a high water consumer in a Canadian context, Vancouver residential water use can be considered excessive.

As seen in Figure 1, the per capita residential water consumption in Vancouver increased slightly from 2001 to 2004, while the average Canadian municipality has experienced reductions. In an administrative report from the City of Vancouver, officials cite a slow, but steady decline in per capita water use in Vancouver from 1985 to 2003 (Clift, 2004). This trend, however, represents all municipal water users, from households to industry and commercial uses. When isolated, the trend for residential users is less clear. Figure 4 shows that there have been only slight reductions in per capita residential water consumption in Vancouver from the period of 1983 to 2004, as it was growing until 1991.

Figure 4: Per Capita Vancouver Residential Water Consumption, Selected Years 1983-2004.



Source: Environment Canada, 2000, 2002; 2004

To summarize, not only is the per capita residential water use high in Vancouver relative to other Canadian urban centres and among OECD countries, but the trend over time is relatively flat.

1.2 Water Governance in Vancouver

Ensuring the safe and reliable supply of water to residents is a shared responsibility of the Greater Vancouver Water District[1] (GVWD) and the Metro Vancouver municipalities, which include the City of Vancouver. The GVWD, a subsidiary of the Metro Vancouver regional

[1] The Greater Vancouver Water District (GVWD) is a governing body under the Metro Vancouver organization, formerly called the Greater Vancouver Regional District (GVRD).

government, is the bulk seller and manager of freshwater supply for the region. The guiding principle of the GVWD for bulk sale to municipalities has been to set a price that recovers the costs of ensuring the supply, based on the previous year's expenditures (Archibald and Woods, 2007; GVRD, 2006). The GVWD also has a role in providing support to municipalities in terms of policy research, subsidizing pilot programmes, and coordinating conservation efforts. The individual municipalities however have a significantly broader range of responsibilities with respect to water management. These powers include metering consumption, pricing mechanisms, regulations on buildings, fixtures and outdoor water use, and any other conservation measure they wish to implement.

While the GVWD has a limited role in municipal water conservation policy, it is the monopoly supplier of water to the 21 member municipalities of Metro Vancouver, and it services a population of about two million people (GVRD, 2005). There are three mountain lakes from which water is drawn to service Metro Vancouver: the Capilano, Seymour and Coquitlam reservoirs. The GVWD has access to an additional three alpine lakes to supplement the primary reserves (GVRD, 2005). These mountain reservoirs are replenished naturally from the average 366 centimetres per year of rain and the melting of snow packs (City of Vancouver, 2004). The Metro Vancouver area is not generally prone to severe water shortages as are some other areas of Canada. However, the reservoirs have been occasionally drawn down to 50% of their capacity (Bruce et al., 2000). The water supply problems in Metro Vancouver tend to occur during summer months when precipitation is low and demand is high. Climate change is expected to affect the snow pack elevation in this area. Under some scenarios, there will be no snow pack storage left to fill the reservoirs, particularly if the snow pack level rises to 1,700 metres from its present level of 900 metres (Bruce et al., 2000). The City of Vancouver predicts that, given water consumption trends, a new source of water will be required by 2050 (City of Vancouver, 2004). The capital costs according to city officials, although unspecified, will be substantial.

The waterworks system of Vancouver operates as a self-financing utility. The costs associated with providing safe drinking water and disposing of wastewater for Vancouver residents must be recovered through charges to users. The combined water and wastewater budgets for 2007 for the City of Vancouver total $145 million, which equals $247 per capita (Wong, 2006a,b). The case for more efficient water use is thus most compelling when argued in terms of the costs of supplying and treating water. From a short-term perspective, the major variable cost is water treatment. From a long-term perspective, rising per capita residential water use combined with population growth will require the GVWD to incur investments to secure new supplies of water. The largest savings from more efficient use are the interest savings on financing capital projects that would be deferred. Indeed, a 1999 GVWD cost-benefit study on a broad hypothetical conservation programme found that the savings to the region in terms of reduced capital and operating expenditures would be over $100 million from the period of 2000-2021 (GVRD, 1999).

The City of Vancouver is implementing some water conservation policies, because of the supply-side issues with respect to summer demand, climate change, and the costs of securing new supplies. For example, there are restrictions, according to the resident's address, on lawn sprinkling from June to September. It is estimated that this policy alone results in reductions in per capita water use of 25% for peak days (GVRD, 2007). There are also plumbing regulations introduced by the City of Vancouver (and later by the British Columbia government) requiring 6 litre per flush toilets in new construction (GVRD, 2007). The city is also a party to the Drinking Water Management Plan (2005) of the GVWD, which when fully implemented will deliver a region-wide education programme promoting behaviour change and sustainable use of water (GVRD, 2005). Additionally, the City of Vancouver has an educational programme for elementary school students (called A to Z of H_20), a rain barrel programme to reduce gardening water usage, and it offers water saver kits to residents (City of Vancouver, 2007). While these various conservation programmes have some effect, the city acknowledges that existing programmes have "peaked in effectiveness and that it is an appropriate time to explore new conservation initiatives" (City of Vancouver, 2004).

1.3 Stakeholders

There are several important stakeholders in water management at the municipal level. Civil servants and elected officials in Vancouver are key stakeholders, as water management is primarily the responsibility of municipal governments. The Greater Vancouver Water District authorities, the wholesaler of water to Metro Vancouver, are also relevant stakeholders. Municipal and regional government officials in Vancouver are particularly important to consult on the issue of demand management because they are responsible for long-range water management plans. Environmental non-governmental organizations are stakeholders given the ecological impacts related to securing new water supplies, sprawling infrastructure, and water conservation policies. Environmental groups are important because they act as a barometer for general environmental consciousness and communicate environmentally positive and negative policies to the community effectively. Finally, the residents of Vancouver are critical stakeholders to because demand-side management policies aim to change their behaviour as water consumers.

The large difference between water consumption in Vancouver and comparable Canadian and international jurisdictions indicates that conservation and efficiency gains can be made among residents in the city. While the municipal governments possess the dominant powers in water management, the City of Vancouver has implemented a relatively small portfolio of water conservation policies, focusing on supply-side policy only. The next section outlines the merits of the two theoretical approaches to water management, contrasting supply-side solutions with demand-side policy instruments.

2: Water Management Theory and Practices

Water management in Canada has historically focused on supply-side management, continuously providing more freshwater to meet growing demand. Demand-side management (DSM), by contrast, focuses on changing the behaviour of the consumer to achieve more efficient water use. It is important to note that these two approaches can be thought of as complementary, not contradictory policy directions. That is, there will always be a role for supply-oriented considerations, and similarly, a need for policies that seek to control the demand for water. Both approaches are reviewed below.

2.1 Supply-side Management

Supply-side management of water resources has been the dominant approach throughout the industrialized world. Its application in Canada originates from the perceived abundance of freshwater, which has led governments to focus on adjusting water supplies to meet ever-growing consumer needs. Supply-side practitioners hold the assumption that 'water needs' are exogenously determined and are insensitive to policy and behavioural changes (Maas, 2003). Thus, municipalities acquire new water supplies and build infrastructure to satisfy demand. This approach has produced an extensive array of infrastructure in Canada which places strains not only on the long-term finances of municipalities, but also on the aquifers used as the source of the water (Gleick, 2000).

There are several problems associated with supply-dominated management approaches. Two of the most significant issues are economic constraints and ecological concerns. First, population growth in Canadian urban centres and growing water use places significant stress on water infrastructure. Many cities face heavy financial burdens from infrastructure maintenance, upgrades, and expansion (Gleick, 2000). The National Round Table on the Environment and Economy in 1996 estimated that capital costs for the next 20 years could approach $90 billion to simply maintain the infrastructure that supplies current levels of consumption (Maas, 2003). Additionally, high-quality supplies of freshwater in close proximity to urban centres have become increasingly sparse or over-extended. Thus, costs associated with securing the new and often inconveniently located freshwater sources are much greater than with past developments.

Second, the ecological impacts associated with supply-dominated approaches are the following: degradation of return flows of water, fragmentation of aquatic ecosystems, and disruption of natural hydrological processes and flow patterns (Brandes, 2003). Additionally, increasing wastewater flows means that more effluent must be disposed of, often with environmental impacts (Maddaus, 2002). At a time when municipal governments are financially constrained and ecological concerns are paramount among the public, supply-dominated solutions are increasingly unviable (Maas, 2003).

2.2 Demand-side Approach

The concept of demand-side management (DSM) requires policy makers to focus on changing people's behaviour with respect to water consumption rather than altering the environment to meet consumption patterns. Demand-side management assumes that water needs are in part endogenously determined; that is, government policy can induce behavioural changes through education, regulation, or economic incentives. Demand-side policies are intended to reduce or stop the growth of municipal water use by influencing the demand. Less water will be withdrawn from reservoirs and thus the need to secure new supplies of water can be delayed into the future by persuading water consumers to use it more efficiently.

There are three broad categories of demand-side management policy instruments: educational, economic, and regulatory measures. Each is described below with its relative effectiveness in reducing demand and its potential drawbacks identified. Table 1 provides a summary of typical programmes and policies for each instrument.

Table 1: Common Programmes and Policies Using Demand-side Policy Instruments

POLICY INSTRUMENT		POLICIES AND PROGRAMMES
Educational measures		Advice given on municipal website Media campaigns (newspaper, TV, radio) Outdoor advertising (billboards, etc) Information with billing School curriculum programmes
Economic measures	Price	Water metering
	Non-price	Rebate programmes for efficient fixtures Retrofit programmes Efficiency kits
Regulatory measures		Voluntary restrictions Plumbing code Lawn sprinkling bylaws Customer water audits

Educational measures can take several forms: public awareness campaigns in the media, school-based information sessions, or bill inserts by the utility. The assumption with educational tools is that with more information, consumers will be more prudent in their water use (Syme et al., 2000). Educational instruments are commonly used in Vancouver and other Canadian cities, because of the ease with which the policies can be implemented and the relatively low cost (Waller et al., 2001). However, these tend to be the least effective demand-side instrument, largely the result of the fact that they rely on voluntary adoption (Maas, 2003). Additionally, the effects on water demand are typically temporary – in other words, the campaign is effective only while it is running (Inman et al., 2006).

The economic measures provide monetary incentives to reduce water consumption. Economic instruments are widely considered to be the most effective demand-side management tool (PRI, 2005a,b). There are two types of economic measures to reduce water demand: direct pricing incentives and subsidies. Direct pricing incentives are instruments that encourage efficient use of water through the price and rate structure. Pricing incentives typically require water use to be metered to determine patterns of consumption. Note that metering is widely believed to be a necessary step in promoting consumer awareness of water use, as it allows the utility to charge the consumer based on usage. Economically efficient pricing measures are those that charge the consumer a price that approaches the marginal cost of providing the water (Maas, 2003). Marginal cost refers to the incremental change in cost resulting from an incremental change in output. The GWVD currently charges the municipalities a unit price for water based on the average cost of the provision of water from the previous year (GVRD, 2005). That is, they calculate the total cost of water provision and divide that by the volume of water withdrawn from their sources in the region. It is then the prerogative of each municipality to determine how to recover costs from their residents. The current pricing policy of Vancouver is an equal, fixed annual fee of $358 for all single family households (Wong, 2007). Fixed fees create a disincentive to conserve because with each additional unit of water conserved, the lower the effective price per unit of water becomes[2].

Designing a rate structure (how the per unit price evolves with amount consumed) once metering is in place, is equally important to setting the price level (PRI, 2005a,c). There are two general rate types: a fixed annual fee and a volume-based rate. Fixed fees are generally associated with higher water use because there is no financial incentive to monitor or control one's use (the

[2] The average household in Vancouver uses 821 litres per day (litres/capita/day*average household size). The family that consumes 600 litres per day effectively pays more per unit of water than the family that uses 1200 litres per day.

marginal cost of water is zero to the consumer). Within the volume-based category, there are three sub-types: constant unit charge, declining block rate, and increasing block rate. The constant unit charge rate type is the simplest: a constant unit price for all consumption levels. The declining block rate schedule divides into successive volumes and each successive block is charged at a lower price per unit than the previous block. This represents a disincentive to conserve, but is justified by some municipalities for pricing water in the commercial sector, as a means to reduce industry costs. The increasing block rate schedule increases the price for successive blocks and provides a stronger incentive to conserve.

The other type of economic instrument commonly used by municipalities is to subsidize conservation by water consumers. The subsidy typically involves the municipality offering to pay a portion of the cost of upgrading fixtures or appliances around the home. Frequently used subsidies in North America include toilets, showerheads, faucets, dishwashers, laundry machines, and garden sprinklers. Unlike the pricing measures, metering is not a prerequisite. For example, in a non-metered scenario, a subsidy programme for showerhead replacement appeals to individuals who would purchase new more efficient fixtures for aesthetic or even conservation-minded reasons, but without the subsidy would feel the costs of replacement to be too high. From the perspective of the city, a subsidy programme can encourage individuals to upgrade household fixtures by sharing costs. Thus, the individual is better off with new fixtures and the city reduces wasteful water use, which can lower system costs. Note that in a metered scenario the benefits of subsidies to the water consumer are even greater, as reduced water use by upgrading old and inefficient fixtures would result in a smaller water bill.

Regulatory measures, in contrast to passive educational measures and incentive-creating economic measures, involve mandatory restrictions on the direct use of water or on household appliances that require the use of water. Examples of regulations include plumbing codes, efficient bathroom devices, and lawn sprinkling restrictions. Regulatory measures are generally considered to be less effective in reducing consumption than economic measures, but more successful than educational measures (Maas, 2003). They tend to be less effective than economic incentives because regulations often do not bring direct benefits to water consumers. Regulatory measures are seen as more effective than educational measures because of the mandated nature of their implementation. The major downside to such policies is that people tend to be less supportive of rules-based water conservation measures (Inman et al., 2006).

All the categories of demand-side policy instruments described above are increasingly considered important in the broader management of municipal water services. In fact, in 2004 more than 60% of Canada's 54 large cities had demand-side policies in operation (Environment Canada, 2004). There are, however, still barriers to the widespread adoption of such policies in many Canadian municipalities. The major barriers are oppositional attitudes (among consumers), financial cost of implementation, and administrative complexity. In terms of consumer attitudes in Canada, not only is there a myth of water 'superabundance', but also a perception that reducing water use lowers living standards (Brandes, 2004). From a budgeting perspective, traditional water management is attractive to municipal officials because of the predictable and stable revenues associated with fixed fees per household for water use. The revenue generation from demand-side pricing policies are not as financially stable for governments as fixed annual fees because of the potential uncertainty in revenues associated with a reduction in water use (Brandes, 2004). As shown above in the discussion of water governance in Vancouver, there are several levels of government involved in water policy: the provincial government manages the reservoirs; the regional government (Metro Vancouver) is the bulk seller of water, and the municipal government recovers costs from consumers. Thus, some of the governance challenges of demand-side management result from the fragmented administration among levels of government.

It is evident in the discussion in this section of supply and demand-side water management approaches that supply-dominated solutions are increasingly unviable. Demand-side policy instruments, from education to regulations to economic incentives, are an appropriate and effective complement to supply considerations. The next section describes the methodology for the data analysis and the statistical technique that helps identify the relevant factors influencing the residential demand for water.

3: Data and Methodology

This study employs both quantitative and qualitative data analysis. The quantitative portion includes empirical estimations using data from Environment Canada's *Municipal Water and Wastewater Survey, 2004*. The purpose of the econometric analysis is to identify variables that influence the demand for water in Canadian municipalities.

Data in the 2004 Environment Canada survey are provided by municipalities, which submit information on water use patterns, pricing methods, and conservation policies. While there is data available for nearly all of Canadian municipalities with a population greater than 1,000, this study limits the analysis to cities in the two largest population categories: Category 1 consists of municipalities with a population greater than 500,000 and Category 2 covers municipalities with populations between 50,000 and 500,000. Using these two categories narrows the analysis to Canadian cities with a population greater than 50,000, which is consistent with the urban focus of this study. The dataset includes 87 municipalities that have a population greater than 50,000. However, 33 of them are not included in my sample because of missing observations for the dependent and/or independent variables[3]. Thus, the final sample for the data analysis consists of 54 observations. It is important to note that cities from the province of Quebec are disproportionately excluded from the analysis because of low response rates to the survey. Supplementary data from the Meteorological Service of Environment Canada is used for climate-related variables and the Statistics Canada 2001 Census information is used for demographic and income data.

[3] The excluded municipalities and missing variables are listed in Appendix A.

3.1 Basic Model

The general model for estimating water demand is the following:

$$Water^{d} = f(P^{w}, Z),$$

where P^{w} is some measure of the price of water and Z represents other independent variables thought to influence residential demand (Worthington and Hoffman, 2006).

It is critical to recognize the factors influencing the demand for water if one is to understand the impact of policy instruments for demand-side management. There is considerable literature estimating the influences on residential demand for water. The variables most commonly found to be statistically significant include the price of water, and household income (Arbués et al., 2003). Other variables that have produced ambiguous findings include population density, frequency of billing, climate and rate structure (Arbués et al., 2003). There has been little attempt to quantify the impact of demand-side conservation programmes, in part because of the lack of quality data in this regard. Researchers nonetheless emphasize the value of measuring the impact of conservation programmes on residential water demand (Maas, 2003). This study uses all the above variables in the estimation of residential water demand. A detailed discussion of each variable follows.

3.2 Dependent and Independent Variables

The dependent variable is the average domestic water consumption per capita per day ($Water^{d}$). Environment Canada officials derive these values by dividing the total water use in the municipality by the percentage of water services delivered to domestic users. This is a customary form for the dependent variable in similar studies, as household-level consumption data is rarely available (Mazzanti and Montini, 2005; Renzetti, 2002). Figure 5 shows the distribution of the dependent variable for the 54 Canadian cities used in the estimation.

Figure 5: *Dependent Variable: Daily per Capita Residential Water Use in 54 Canadian Urban Cities, 2004.*

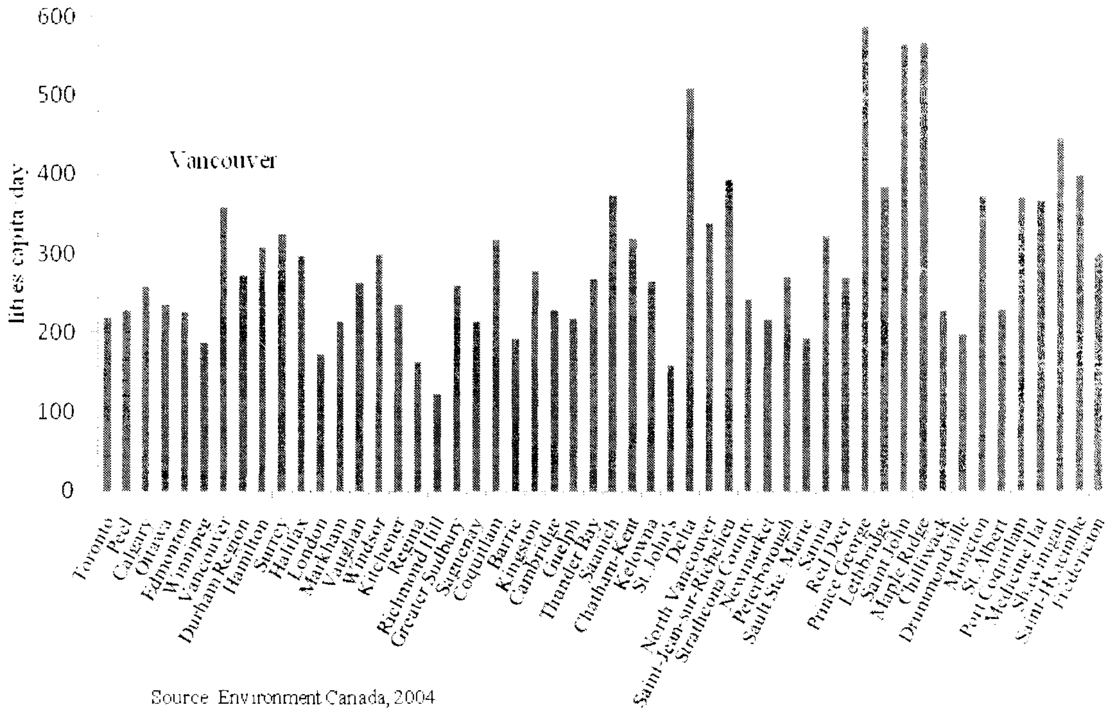


Figure 5 shows that residential water demand ranges from 100 to 600 litres per capita per day among Canadian urban centres. The cities in the sample are ranked according to population, with the highest on the left side of the graph. The figure illustrates that there are cities in the sample with per capita consumption higher than Vancouver's. However, among the 26 largest urban centres in the sample, Vancouver residents have the highest per capita water demand.

Turning to explanatory variables, two are consistently found to demonstrate a significant relationship to water use: (i) price and (ii) household income. The price a consumer pays for water has been widely shown to influence consumption (Renzetti, 2002; Inman et al., 2006; Arbués et al., 2003). Consistent with the contradiction between theory and practice, there is considerable debate in the literature as to whether the price variable should be measured as 'average price' or 'marginal price'[4]. However, the data available for this study are 'average prices'.[5] It is expected that as the price per unit of water increases, consumption decreases. The amount of water an average household consumes also depends on the average income of the household. Average annual household income is obtained for each municipality from the Canada Census 2001. The hypothesis is that as the average household income rises, consumption increases.

There are four additional explanatory variables for which studies reveal inconsistent findings as to their impact on water use: population density, frequency of billing, rate structure, and climate. The population density of a municipality is considered important because it serves as a proxy for the size of gardens and lawns, which require regular watering (Arbués et al., 2003). Density is measured as the population per square kilometre. The hypothesis is that as population density increases, consumption of water decreases (Nague and Thomas, 2000).

The frequency with which a consumer is billed for water has been found to be an important explanatory variable in some studies (Arbués et al., 2003). The argument is that if consumers are more frequently billed, they may understand the tariff structure better as well as the relation between consumption and size of the bill. This study uses the number of water bills per year. A negative relationship is expected with water consumption.

The structure of the water pricing is an additional explanatory variable that studies have found differing results. As described in Section 2, there are several ways to structure water prices: fixed annual fee, constant-unit charge (CUC), increasing block rate (IBR), and decreasing block rate (DBR). Fixed fees and decreasing block pricing offer no incentive to conserve, while the other two water pricing types do because the price paid is based on the amount of water consumed, and in the case of increasing block prices, penalizes excessive water use (Arbués et

[4] For a brief summary of the econometric debate surrounding price variables, see Appendix B.

[5] Many studies in the literature use average price values as well; see Imnan et al. (2000) for summary of recent studies using average and marginal price values.

al., 2003). A dummy variable, defined as '1' for municipalities with CUC/IBR pricing and '0' for a municipality with fixed fee/DBR pricing, is used. The hypothesis is that with the conservation rate types, consumption decreases (Mazzanti and Montini, 2005).

Local climate has also been shown to influence the average daily consumption of water, as climatic variables have been shown to have a psychological effect on water users (Agthe and Billings, 1997). There are several indicators for the local climate conditions including average temperatures, rainfall, and evapo-transpiration rates. This study uses the number of days per year where measured temperature is greater than 20 degrees Celsius. This measure was chosen as a compromise between two competing features: (i) the threshold temperature needs to be high enough such that one might expect it would have an influence on water use, and (ii) a temperature low enough such that it provides enough variation among the sample cities. It is expected that as the number of high temperature days increases, consumption increases.

The final explanatory variable used in this study is a measure of the conservation programmes implemented in a municipality. There has been little evaluation of these programmes in the empirical literature, partially because of the lack of quality data, but such evaluation is critical to include in the estimation (Maas, 2003). The Environment Canada database allows for a quantification of conservation programmes, because it contains numerical measures for the extent of implementation. As described in Table 1 in Section 2, conservation programmes are divided into three categories: educational, regulatory, and economic incentive instruments. Each programme is assigned a numerical score of 1-5 based the extent of implementation, and is reported by each municipality in the survey. The implementation values for the policies are summed to produce a numerical score for each category of conservation policies. I define my variables for conservation policies in the following way: in the educational category, I include media campaigns, school curriculum, outdoor advertising, and information with billing; for the regulatory category, lawn-sprinkling bylaws and plumbing code policies are included; for the economic incentive category, the single policy measured is efficiency-oriented water metering. It is expected that as the conservation score (based on the extent of implementation) for each category increases, consumption decreases.

Table 2 provides a summary of the hypotheses with respect to the effect of an increase in the independent variables on the average domestic water consumption per capita per day.

Table 2: Hypotheses for Explanatory Variables

EXPLANATORY VARIABLE	HYPOTHESIS (EFFECT ON $WATER_D$)	SOURCES
Average Price (P_w)	-	Renzetti (2002); Arbues et al. (2003).
Household Income (Inc)	+	Mazzanti and Montini (2005); Arbues et al. (2003).
Climate Temperature (Temp)	+	Agthe and Billings (1997); Griffin and Chang (1990).
Population density (Den)	-	Nague and Thomas (2000); Arbues et al. (2003).
Frequency of billing (Bill)	-	Arbues et al. (2003).
Rate Structure (Rate)	-	Mazzanti and Montini (2005); Arbues et al. (2003).
Conservation policies (Cons)	-	Maas, 2003.

3.3 Empirical Implementation and Results

There are three steps in the empirical estimation, summarized in Table 3. *Model A* includes only the variables that have consistently affected water demand in a significant way: price and household income. *Model B* adds the variables that have produced inconsistent findings in previous studies: population density, frequency of billing, rate type, climate, and a broad score for conservation policies. Finally, *Model C* focuses on specific conservation policies, distinguishing between educational ($Cons^{EDU}$), regulatory ($Cons^{REG}$), and economic incentive

($Cons^{EI}$) policies[6]. In the estimation, all the variables are in log form except dummies, hence the coefficients represent elasticities.

Table 3: Estimation Models Applied in the Statistical Estimation.

Model A	$Water^d = f(P^w, Inc)$ $\ln(Water^d)_i = c - \beta_1 \ln(P^w)_i + \beta_2 \ln(Inc)_i + \varepsilon_i$
Model B	$Water^d = f(P^w, Inc, Temp, Den, Bill, Cons_{RATE}, Cons_{TOT})$ $\ln(Water^d)_i = c - \beta_1 \ln(P^w)_i + \beta_2 \ln(Inc)_i + \beta_3 \ln(Temp)_i - \beta_4 \ln(Den)_i - \beta_5 \ln(Bill)_i - \beta_6 Cons^{RATE}_i - \beta_7 Cons^{TOT}_i + \varepsilon_i$
Model C	$Water^d = f(P^w, Inc, Temp, Den, Bill, Rate, Cons^{EDU}, Cons^{REG}, Cons^{EI})$ $\ln(Water^d)_i = c - \beta_1 \ln(P^w)_i + \beta_2 \ln(Inc)_i + \beta_3 \ln(Temp)_i - \beta_4 \ln(Den)_i - \beta_5 \ln(Bill)_i - \beta_6 Cons^{RATE}_i - \beta_7 Cons^{EDU}_i - \beta_8 Cons^{REG}_i - \beta_9 Cons^{EI}_i + \varepsilon_i$

Table 4 presents the empirical results for Model A and the extended Model B with a simple global measure for the conservation policies.

[6] Correlation tables, descriptive statistics and distribution graphs for all variables in Models A, B and C are provided in Appendix C.

Table 4: *Results for Models A and B.*

Variable	MODEL A	MODEL B					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant[†]	9.666 (2.31)	11.144 (2.61)	11.126 (2.60)	11.011 (2.60)	11.126 (2.63)	10.875 (2.55)	11.061 (2.67)
$Price_{AVG}$	-0.0527*** (-3.59)	-0.0609* (-1.50)	-0.0441** (-2.15)	-0.0407** (-1.98)	-0.0454*** (-2.90)	-0.0407*** (-2.42)	-0.0407*** (-2.45)
Income	-0.369 (-0.99)	-0.417 (-1.16)	-0.413 (-1.14)	-0.392 (-1.10)	-0.413 (-1.15)	-0.398 (-1.11)	-0.418 (-1.21)
$Cons_{RATE}$	-	0.133 (0.49)	-	-	-	-	-
$(Price_{AVG})$* $(Cons_{RATE})$	-	-	0.0047 (0.11)	-0.0025 (-0.06)	0.0056 (0.13)	0.0066 (0.16)	0.0065 (0.16)
Density	-	-0.0091 (-0.24)	-0.0089 (-.0.24)	-0.0158 (-0.42)	-0.0082 (-0.22)	-0.0082 (-0.22)	-
Temp	-	-0.189 (-0.93)	-0.168 (-0.83)	-0.170 (-0.84)	-0.170 (-0.85)	-0.141 (-0.69)	-0.143 (-0.71)
Bill	-	-0.0142 (-0.23)	-0.0061 (-0.10)	-0.0195 (-0.31)	-	-	-
$Bill_D$	-	-	-	-	-	-0.0705 (-0.79)	-0.0705 (-0.79)
$Cons_{TOT}$	-	-0.0175*** (-3.23)	-0.0179*** (-3.31)	-0.0319*** (-2.82)	-0.0180*** (-3.45)	-0.0176*** (-3.35)	-0.0178*** (-3.53)
$(Cons_{TOT})^2$	-	-	-	0.0006 (1.41)	-	-	-
N	54	54	54	54	54	54	54
DoF	51	46	46	45	47	46	47
Adjusted R^2	0.224	0.331	0.332	0.350	0.352	0.348	0.354
Schwarz	0.594	0.704	0.710	0.742	0.649	0.701	0.628
Chi-square[‡]	2.541	19.565	15.774	13.334	20.237	13.388	15.282

[†]t-values are given in parentheses. One-sided test for significance: *** 1% significance level, ** 5% significance level, * 10% significance level. [‡]The critical value for chi-square with 51 DoF is 35.6; critical value for chi-square with 45 DoF is 30.6.

Tests for multi-collinearity, serial correlation, and hetroskedasticity are performed in order to ensure that the relationships found in column 1 are statistically valid. There is no evidence of severe multi-collinearity among the explanatory variables, as the simple correlation coefficient between any two explanatory variables never exceeds 0.70 (see Table C.1 in Appendix C for the complete correlation table for Model A). Serial correlation is not anticipated to be an issue, because the data is cross-sectional, and the Durbin-Watson test confirms that there is no evidence of serial correlation. Similarly, the chi-square value of 2.54 suggests that there is no evidence of heteroskedasticity[7].

Model A is a specification of water demand with only the average unit price of water and the average household income of the municipality. In column 1 there is a statistically significant relationship between the average price of water and the per capita water demand and the price elasticity is -0.0527. This implies that a 1% price increase per unit of water results in a 0.05% decrease in water demanded. Compared to similar studies this is a low value, but not outside the range of estimated price elasticities of water in the literature[8]. The income variable is not significantly related to water demand. The adjusted R^2 value for column 1 is 0.22; this means that the model explains 22% of the variation of the dependent variable.

Model B includes additional explanatory variables: the extent of metered water use, population density, climate, frequency of billing, and a global measure of conservation programmes in the municipality. As in Model A, the estimations using Model B are tested for multi-collinearity, serial correlation, and heteroskedasticity. As no simple correlation coefficient between any two explanatory variables exceeds 0.70, there is no evidence of severe multi-collinearity. The Durbin-Watson and White tests find no evidence for serial correlation and heteroskedasticity, respectively. An important change in column 2 from the initial estimation is that the price of water is no longer statistically significant at 1%, but rather at 10%. The introduction of the metered variable may have affected the price variable, given the significant disparities in per unit prices of water depending on whether the water consumption is metered. As mentioned in Section 2, the average user charged a fixed annual fee for water use pays much less per unit of water than those users who are charged on a unit basis. This hypothesis is plausible when one considers that the simple correlation coefficient between the metered variable and the price variable is 0.64, approaching the level where multi-collinearity is likely to severely affect

[7] Based on the chi-squared values for all estimations, there is no evidence of heteroskedasticity in any of the estimation models.

[8] Inman et al. (2006) finds that price elasticities vary between regions from -0.005 in Eastern United States to -0.28 in Europe.

the significance testing in the estimation (see Table C.2 in Appendix C). The issue of potential multi-collinearity of the two variables is addressed in subsequent estimations. Note that in column 2, only the global conservation programme variable ($Cons^{TOT}$) is found to have a significant correlation to per capita water consumption at the 1% level.

Column 3 tests the hypothesis that price variable is affected by the introduction of the metered variable by removing the metered variable ($Cons^{RATE}$) and by introducing an interactive dummy variable. The interactive dummy variable allows the relationship between the dependent variable and price variable to be different depending on whether the residential water users are metered or unmetered. The interactive dummy variable is appropriate in this context because there are large and systematic differences in price between metered and unmetered municipalities (recall that non-metered consumers on average pay much less per unit of water consumed). The empirical results validate the hypothesis that the metered variable is influencing the price variable. Column 3 demonstrates that the average price of water and conservation programmes are statistically significant at 5% and 1% respectively. Model B also has considerably more explanatory power than Model A; the adjusted R^2 value for Model B is 0.33.

The results in column 3 provide evidence of the association between lower water consumption and the presence of conservation programmes. An added squared $Cons^{TOT}$ variable, tests whether residents with many conservation programmes get overwhelmed and the programmes lose effectiveness or whether more programmes increase the incremental impact. The results in column 4 provide some evidence that the former case might be true. The positive coefficient for the squared $Cons^{TOT}$ variable indicates that there may be diminishing returns to conservation programmes. However, it is only significant at slightly over the 10% level and the effect in my sample is weak. An anecdotal comparison between Toronto and Guelph, both with low per capita residential water use, illustrates an example of this phenomenon: Toronto has implemented 14 conservation programmes and Guelph has a total of 5, yet they have equivalent per capita residential water use demand (Environment Canada, 2004).

The estimations in columns 5, 6, and 7 were conducted to check the possibility that the frequency of billing and population density affect the estimations of the other explanatory variables. The rationale for checking these variables stems from the very low t-values of both the bill and density variables in the regression outputs (0.31 and 0.42 respectively). A low t-value indicates that the variables provide little explanatory power with respect to the variation of the dependent variable. In column 5, the frequency of billing variable is removed and there is no considerable change to the coefficients or t-statistics of the remaining explanatory variables. In column 6, the bill variable is transformed into a dummy variable. Transforming the frequency of billing into a dummy variable is appropriate because the values of billing only range from 1 to 12, the number of months a household receives a bill per year. By converting the variable into a dummy, it differentiates between those who get billed frequently (six times or more per year) and those who are billed infrequently (less than six times annually). While the bill variable in column 6 is not found to be statistically significant, the t-value of the variable is greater than the earlier estimations. In column 7, the density variable is dropped due to the very low t-value of the variable (0.22). Removing the density variable does not alter the coefficients or t-statistics of the remaining explanatory variables. The adjusted R^2 for the model however, increases to 0.35 and is thus considered the best specification for Model B.

Estimating Model A and B has determined that in this sample of Canadian cities, a higher price for water and the presence of conservation policies are associated with lower per capita water consumption among residential users. Given that Model B identified the global measure of the conservation policies as exhibiting a statistically significant relationship with water demand, next I estimate what specific conservation policies are more likely to affect the demand for water than others. Model C divides the aggregated conservation variable into three categories, as defined earlier in Table 1 in Section 2: educational ($Cons^{EDU}$), regulatory ($Cons^{REG}$), and economic incentive ($Cons^{EI}$) policies. Table 5 presents the results.

Table 5: Results for Model C.

Variable	MODEL C	
	(1)	(2)
Constant	12.1943 (2.79)	12.1739 (2.81)
$Price_{AVG}$	-0.0387** (-2.20)	-0.0412** (-2.35)
Income	-0.4821 (-1.32)	-0.4784 (-1.32)
$(Price_{AVG})$* $(Cons_{RATE})$	0.0073 (0.17)	0.0082 (0.44)
Temp	-0.2195 (-1.06)	-0.2213 (-1.07)
$Bill_D$	-0.0710 (-0.79)	-0.0706 (-0.80)
$Cons_{EDU}$	-0.0210** (-2.04)	-0.0448** (-2.25)
$Cons_{REG}$	-0.0004 (-0.02)	-0.0045 (-0.02)
$Cons_{EI}$	-0.0318* (-1.57)	-0.0291* (1.44)
$(Cons_{EDU})^2$	-	0.0015 (1.40)
N	54	54
DoF	45	44
Adjusted R^2	0.33	0.35
Schwarz criterion	0.75	0.78
Chi-square	10.27	12.46

There is reason to believe that the three categories of conservation initiatives are correlated, and thus, influence the statistical significance of the results. That is, a municipality that has educational programmes for conservation is likely to also have conservation policies that involve regulation and economic incentives. Highly correlated explanatory variables have the potential to impact the standard errors of the estimates, which can lead to erroneous conclusions of significance between variables. Analysis of the three conservation variables reveals that no pair wise correlation coefficient exceeds 0.70. The $Cons^{EDU}$ variable has a simple r correlation coefficient of 0.51 with the $Cons^{REG}$ variable; the $Cons^{EDU}$ variable has a correlation coefficient of

0.28 with the $Cons^{EI}$ variable; the $Cons^{REG}$ has a correlation coefficient of 0.16 with the $Cons^{EI}$ variable[9]. Thus, while intuitively one might expect high correlation between conservation programmes, data correlation is unlikely to impact the hypothesis testing.

In column 1, when categories of conservation policies are identified separately, tests show that there is no evidence of severe multi-collinearity, serial correlation, or heteroskedasticity. The results show that average per unit price of water ($\beta = -0.0387$) is negatively correlated with water use, as well as the educational category of conservation policies ($\beta = -0.0210$). Both are significantly different from zero at 5%. Additionally, the economic incentives ($\beta = -0.0318$) are negatively correlated with water consumption at 10% significance. As done in Model B, column 2 tests whether the effectiveness of more educational programmes reaches a maximum after which additional educational initiatives offer diminishing returns. The results suggest that this indeed might be true, given the positive coefficient of the squared $Cons^{EDU}$ variable, but it is not significant and the effect in my sample is weak.

3.4 Summary of the Significant Factors

Statistically significant variables must meet both the statistical measure at the 90% confidence level or better, and exhibit the hypothesized sign based on the literature review. The following explanatory variables are found to significantly influence water consumption in Canadian municipalities:

- Average price per unit of water
- Conservation policies (generally)
- Educational conservation initiatives
- Economic incentive conservation policies

[9] See Table C.3 in Appendix C for full correlation table for Model C.

The following explanatory variables were not found to be statistically significant at 90% or better or exhibited a sign opposite to what was hypothesized:

- Average household income
- Population density
- Climate
- Frequency of billing
- Regulatory conservation policies

As with all statistical inferences, there are qualifications in the interpretation of results. There are notable factors, such as the type of dependent variable data and missing data for most Quebec cities, which have contributed to the limitations of the estimation. With respect to the type of dependent variable data, the estimation of residential water demand is considered stronger if the water consumption data is at the household level. This study, like most others, uses per capita data derived from dividing total residential water consumption divided by the population of the city. Thus, caution must be taken to not over-extend the interpretation of the results in terms of individual consumer response to the independent variables. Despite the minor limitations, the estimation is substantive and an important indicator of the significant factors to consider with respect to water conservation policy.

The statistical analysis provides valuable insight into the significance of the various conservation policies. Further study is required, however, in order to make conclusions with respect to the effectiveness of specific policies within the categories of educational, regulatory and economic measures. For instance, the estimation found that educational measures are significant at the 95% confidence level. However, it is not possible to discern which educational measures are superior to others. A qualitative study of North American municipalities with notable water demand reductions allows for more specific analysis of the relevant conservation policies.

3.5 Best Practices Analysis across North America

Given the limits of statistical analysis to yield specific lessons on policy, I have supplemented with qualitative analysis of geographically dispersed North American cities that have achieved notable successes in reducing the demand for water. The analysis here focuses on finding commonalities in pricing methods, educational programmes, and economic incentives of the successful cities as a means to devise potential policy options for the City of Vancouver. The specific policies associated with each of the three categories of policy instruments are chosen based on best practices in case studies and on the general literature. Table 6 provides a summary of the selected North American cities and conservation policies.

Table 6: Summary of U.S. Cities' Pricing, Educational and Economic Incentive Policies

Municipality	Price/Rate Structure		Educational Policies			Economic Incentives		
	(1) Metered	(2) Increasing Block Rate	(3) Media	(4) School Curriculum	(5) Bill Inserts/ Newsletter	(6) Rebates	(7) Retrofit	(8) Water Saver Kits
San Diego, CA[†]	√	√	√	√	√	√	√	
Albuquerque, NM[‡]	√	√	√		√	√		
Cary, NC[‡]	√	√	√	√	√	√		
Houston, TX[‡]	√	√	√	√		√	√	√
IRWD, CA[‡]	√	√	√		√	√	√	
MWRA, MA[‡]	√	√	√	√			√	
Vancouver, BC[¶]				√		√		√

[†]City of San Diego Urban Water Management Plan (2005). [‡]Cities are among those studied in a report by the EPA (2002) highlighting best practices in water conservation strategies in the U.S. [¶]City of Vancouver (2004).

Metered water use and increasing block rate pricing for residential consumers is associated with all the U.S. cities that have achieved substantial water demand reductions, as shown in columns 1 and 2 of Table 6. The effect of metered water use is similarly evident in

Canadian data; among the urban centres used in the empirical estimation, the municipalities that do not meter residential users have per capita consumption levels that are 44% higher than municipalities that meter residential users (Environment Canada, 2004). Simply introducing universal metering, however, without the appropriate pricing signals will not achieve the desired demand reductions (EOEA, 2006). Increasing block rate pricing is most likely to encourage water conservation among users. In Cary, North Carolina, for example, the municipal officials estimate that the increasing block rate structure reduces consumption by 51 million gallons (193 million litres) of water per year (EPA, 2002). In contrast, the City of Vancouver does not meter residential users, but charges an annual fixed fee for an unlimited supply of water. There is also a secondary effect of metering on residential water demands: it enhances the effectiveness of educational and other economic incentive conservation policies (EOEA, 2006). For instance, a media campaign making an appeal to reduce discretionary water use in the summer is more likely to be effective if part of the benefit of conserving water is a reduced water bill for the consumer.

While it is evident that price and rate structures are key to achieve reductions in water consumption, educational policies appear to be similarly important. In columns 3, 4 and 5 in Table 6, educational conservation policies for best practices case studies are listed. They are commonly implemented in the form of media information campaigns appealing for conservation, school programmes to target children, and literature provided in bill statements offering advice to reduce water use around the home. In column 3 in Table 6, the widespread use of media campaigns is associated with the U.S. municipalities with successful conservation programmes. The city of Cary, North Carolina, for example, estimates that the media campaigns during the summer months result in 3.5% water savings of the total demand (EPA, 2002). The city also uses bill inserts as a relatively inexpensive means to convey conservation advice to residents. Vancouver uses neither a media campaign nor bill inserts; this may stem from an engineering consulting report prepared for the GVRD on water conservation that claimed that public education would only result in 0.4% water savings of the total demand (GVRD, 2002). It is unclear how the researchers derived this value, but it is a markedly lower estimate than typically found in reports from U.S. cities.

Municipalities that use economic incentives also appear to achieve considerable water demand reductions. Typical economic incentives are rebates on appliances including more efficient laundry machines and low-flow toilets, retrofit programmes for older buildings, and subsidized 'water saver kits' that consist of efficient shower heads, garden hose nozzles, and leak detection equipment. Offering rebates on efficient appliances and low-flow toilets appears most common among those U.S. cities that have reduced demand considerably (column 6). Retrofitting older buildings and homes has also been demonstrated to be a powerful tool to reduce water demands. In Houston, a pilot retrofit programme replaced 5 gallon (19 litre) toilets with 1.6 gallon (6 litre) toilets, fixed leaks, and installed aerators on faucets in 60 units of a low income housing development. These retrofits resulted in a 72% reduction in household water use, and consequently, dramatically lower water bills for the residents (EPA, 2002).

The brief examination of selected U.S. cities with exemplary water demand reductions offers insight into the potential policy options available for the City of Vancouver. There are several policy areas that appear critical in achieving significant demand reductions among residential users in which the City of Vancouver has yet to take action. The most prominent policy gap is the lack of metering, and thus, conservation-oriented pricing. Additionally, despite evidence that suggests media campaigns and bill inserts can result in cost-effective demand reductions, Vancouver is similarly without an active policy. Finally, among the economic incentives, Vancouver does offer rebates for appliance and low-flush toilets, but does not offer retrofit incentives for older buildings, which often have inefficient fixtures and significant leakage. These gaps in policy when comparing Vancouver with high-performing U.S. cities, combined with the results from my estimation for water demand in Canadian cities, inform the policy alternatives proposed in the next section.

4: Policy Alternatives and Criteria for Measurement

This section develops the policy alternatives that the City of Vancouver could consider to reduce the residential demand for water. It is critical that the policy options derived from the data analysis and literature review are relevant and specific to the policy problem: why is the per-capita consumption of water by residential consumers in Vancouver so high relative to other Canadian urban centres and to the rest of the industrialized world? Thus, this study identifies several short and long-term policy objectives to establish the desired outcomes of water management reforms in Vancouver. In this discussion, the short-term is defined as within the next ten years (from 2008 to 2018) and the long-term is defined as the subsequent ten years (from 2018 to 2028. Table 7 summarizes those objectives.

Table 7: Short and Long-term Policy Objectives for Water Management Reforms

Long-term (20+ years)	• Reduction in residential water demand in Vancouver to meet OECD average (40% reduction from 2004) • Delayed investment on infrastructure expansion
Short-term (next 10 years)	• Reduction in residential water demand in Vancouver to meet Canadian average (15-20% reduction from 2004) • Build an environmentally sustainable perception among the public toward water consumption

The key long-term policy objective is to reduce per capita residential water demand in Vancouver to that of the average OECD nation. This represents a reduction of approximately 40% from 2004 per capita water consumption levels. This is not an unreasonable goal for Vancouver, as OECD countries are comparable in terms of standard of living. An additional policy objective in the long-term is to defer infrastructure expansions to the water system. As mentioned at the onset, a primary rationale for water conservation from the perspective of the city is to reduce the capital costs associated with securing new supplies of water.

In the short-term, a primary policy objective is a reduction in residential water demand in Vancouver to meet the Canadian average for large urban centres. Figure 1 in Section 1 shows the disparity between per capita residential water use in Vancouver and the sample of Canadian urban centres and a reduction of 15-20% from 2004 consumption levels would result in Vancouver residents matching the urban average in Canada. An additional policy objective in the short-term is to establish in the public a relationship with water use consistent with environmental sustainability. The short and long-term policy objectives provide a coherent basis for formulating the proposed policy alternatives.

4.1 Policy Alternatives

The policy alternatives are developed from my estimation of residential water demands and best practices analysis of North American cities and are consistent with the short and long-term policy objectives. Each of the proposed alternatives is described below.

4.1.1 Status Quo

The status quo serves to inform how residential water management in Vancouver would evolve without change to the existing policy. While City of Vancouver documents indicate that there is a desire to explore new conservation initiatives, the status quo provides an important perspective in the policy analysis. The status quo is defined as follows: no universal water metering for residential users, continued annual fixed fee for unlimited water, and continued funding of the elementary school educational play (A to Z of H_20), the Rain Barrel Programme, the Grow Natural programme for lawn care, and the subsidized water saver kits (City of Vancouver, 2007).

4.1.2 Policy Alternative #1: Universal Metering and Increasing Block Rate Pricing

This alternative involves a city-subsidized universal metering programme for all single family detached homes in Vancouver and applies increasing block rate pricing for all residential consumers. The estimation in Section 3 identified price, which is heavily dependent on whether one is metered, as being statistically significant with respect to water demand. Additionally, the best practices analysis reveals that all the successful water conservation programmes studied incorporate both metering and increasing block rate pricing. Evidence of the impact of metering and the associated use of conservation-oriented pricing (increasing block rates) on water consumption is established in practice and the literature, and therefore, must be considered as a viable policy alternative.

The primary benefits of water metering are the following: (i) it can enhance all water conservation initiatives because there is a financial incentive for the consumer to reduce water use, (ii) it represents a more equitable billing system among users, and (iii) it can help reduce water loss due to leaks (Industry Canada, 2003). Water leakage is estimated to constitute 15% of all municipal water use in Vancouver (Interview #4, 2007). The short-term economic benefits of universal metering stem from identifying and fixing leaks throughout the city, and thus reducing water purchases that the City of Vancouver must make to the GVWD. In the long-term, lower per capita water consumption associated with metering can contribute to delayed infrastructure upgrades and costly supply expansion projects. There are also environmental benefits that are difficult to quantify associated with less water withdrawn from aquifers and delay of infrastructure construction on new water bodies. The main costs associated with universal metering are the relatively high capital costs of installation and annual operating costs for monitoring.

4.1.3 Policy Alternative #2: Voluntary Metering Programme Plus Enhanced Information

This alternative involves a city-subsidized metering programme implemented on a voluntary basis, plus an enhanced information and media campaign promoting water conservation to all residential users. The metering component of this alternative is a scaled-down version of the universal metering alternative. This results in lower upfront costs for the utility but also reduced benefits in terms of reductions in total water use. In contrast to mandated universal metering in all homes, a voluntary metering programme is a slower approach to user-pay principles in water pricing, but avoids the substantial upfront capital costs of mandated metering. Currently, all residential users can install meters at their own expense and pay a unit-based rate. They often choose not to because of the high installation costs, and thus, the relatively low economic payback. A voluntary metering programme would subsidize all, or a significant portion, of the costs of installation, which can range from $600-$800.

The voluntary programme proposed here for Vancouver assumes an aggressive installation drive of 3,000 meters per year. In this programme, the city pays the entire cost of installing the meters. This is modelled after the voluntary metering programme in Surrey, which is considered to be particularly successful in terms of encouraging households to install meters. In fact, ever year approximately 2,000 households in Surrey apply to get meters installed (City of Surrey, 2007). Residential users that are metered subsequently pay a fixed monthly charge of $11 plus a unit-based price of $0.53.m^3. The motivation for residents to acquire meters and accept unit-based pricing has increased in recent years as the flat rate charges for water for Surrey residents have risen dramatically.

The voluntary metering programme is complemented by an enhanced information and educational campaign. This alternative involves a package of media and information distribution. First, it includes a summer radio and print campaign highlighting water supply issues for the region and tips for reducing water use around the home, in particular discretionary use outdoors.

The second component is a twice-yearly, stand-alone glossy print newsletter explaining water use in Vancouver, the rationale for conservation, and tips for conserving water. Third is water conservation information in annual billing statements. Ideally, three annual mailings would be distributed at four-month intervals throughout the year.

4.1.4 Policy Alternative #3: Voluntary Metering Programme + Toilet Rebate Programme

This alternative incorporates a voluntary metering programme identical to the second alternative, but is complemented by a toilet rebate programme instead of an enhanced information campaign. The different feature of this alternative to the previous one is that it involves an additional economic incentive in the form of rebates for toilet upgrades. While Vancouver made bylaw changes in 1995 requiring ultra-low flow toilets, efficient showerheads, and aerating faucets on all new building construction in the city, there is no conservation policy for fixtures in older buildings[10]. Given that toilets constitute 35% of indoor household water use, offering a rebate on upgrading this fixture alone is appropriate. This rebate is modelled on the pilot programme in West Vancouver that offers a $50 rebate for the replacement of inefficient toilets with 6 litre low flush toilets.

The metering initiative and the toilet rebate provide mutual incentive effects. That is, a household interested in reducing water bills by having a meter installed is also likely to consider upgrading the toilets in the home with the available rebate. Some may argue that metering alone will provide the incentive to the household to replace inefficient fixtures, thus making the toilet rebate an unnecessary expenditure for the city. This is not persuasive, as the water savings from metering will reduce water bills for low water users by about $20-60 annually (City of

[10] In part because of the flat rate charge for water and the cost of replacing fixtures, these older buildings have no incentive to upgrade these fixtures in order to reduce wasteful water use.

Vancouver, 2004)[11]. Given the costs of upgrading toilets, which can range from $100-1000, an additional incentive in the form of a rebate is justified.

Next, I describe the criteria and associated measurements by which I assess the proposed policy alternatives for residential water management reform in Vancouver.

4.2 Criteria and Measurements

The policy alternatives outlined for water management reforms are assessed and compared using a set of five criteria: (i) cost, (ii) effectiveness in reducing residential water demand, (iii) equity among consumers, (iv) administrative feasibility, and (v) acceptability to stakeholders. Each criterion is assigned a measure, which is then ranked on the following scale: high (score = 3), medium (score = 2), and low (score = 1). For measures that are quantitative, indices are developed from which rankings of high, medium, and low are made. For the measures that are qualitative, a high score means that the alternative ranks well against the criterion, while a low score indicates that the alternative ranks poorly against the criterion. Table 8 provides a summary of the criteria and measures applied in the policy analysis.

[11] Current fixed annual fees for water in Vancouver are $349 and the average household water use is 821 litres per day. A family that uses 500 litres of water per day would have a bill of approximately $290 under a metered scenario (assuming no charge in consumption behaviour) based on the calculation: (fixed monthly charge)*(12 months)*(volume-based charge)*(volume consumed) = ($11/month)*(12 months) + ($0.53/m^3$)*($299m^3$) = $290.

Table 8: Criteria and Measures for Analysis of the Policy Alternatives

Criterion		Definition	Measurement	Evaluation Index
Cost		The capital and operating costs for the period of implementation.	Annual capital and operating dollars (2008) to be spent over the period of implementation (10 years).	High (3) = < $1M Med (2) = $1M - $3M Low (1) = > $3M
Effectiveness	Residential demand	The savings in water purchases by the city from reduced residential water demand.	Dollars per year of avoided water purchases from the GVWD by the City of Vancouver.	High (3) = > $3M Med (2) = $1M - $3M Low (1) = > $1M
	System-wide	The savings in water purchases by the city from decreased system leaks.	Dollars per year of avoided water purchases from the GVWD by the City of Vancouver.	High (3) = > $3M Med (2) = $1M - $3M Low (1) = > $1M
Equity		To what extent does the policy alternative affect different segments of the population?	An estimate of the differential impact of the policy on various income groups and neighbourhoods from literature and elite interviews.	High = 3 Med = 2 Low = 1
Administrative feasibility		How acceptable is this to city administrators in terms of the requirements of implementation?	The bureaucratic personnel required for, and efficiency of, implementation as indicated in elite interviews with Metro Vancouver municipal officials.	High (3) = no additional staff Med (2) = 1-2 add. staff Low (1) = 3+ add. staff
Acceptability to stakeholders		Would a majority of the citizens of Vancouver be supportive of the policy alternative? Would environmental NGOs support the policy?	Estimate of public opinion from municipal officials. Commentary from environmental NGOs in literature and media.	High = 3 Med = 2 Low = 1

Cost: The City of Vancouver, like other municipalities, faces constraints in terms of revenue-raising opportunities. Hence, expensive alternatives that would drastically alter the City of Vancouver's water services budget – however attractive the policy may be – are likely to be considered impractical. The cost criterion in this study captures the capital and operating costs of the policy over the 10-year period of implementation.

Effectiveness: The effectiveness of the policy alternatives will be assessed in two ways: (i) the expected reduction in residential water demand, and (ii) the identification and repair of system leaks. The measure of effectiveness for both components is the dollars per years of avoided water purchases from the GVWD by the city as a result of the policy. The savings to the city as a result of aggregate demand reductions associated with the policy is an important component to consider, because it allows for an estimate of the payback of the policy.

Equity: A policy alternative that adversely affects certain groups while benefiting others is less desirable than an alternative that has near equal effects across the population. The equity criterion entails two elements: horizontal equity and vertical equity. Horizontal equity is the notion that similar groups should be treated equally. Vertical equity is the idea that different segments of the population should be treated differently. Impacts on equity can result from price changes, regulations on fixtures, and conservation subsidies.

Administrative feasibility: The anticipated response from the municipality government civil service is necessary to consider because they are the group responsible for implementing policy. The analysis must take into account the alternatives that may require, for example, technical expertise not readily available or extensive monitoring by municipal staff. Also, the plan of implementation is important to consider, as policy alternatives may differ in terms of the requirements of strategic planning and bureaucratic coordination. The scoring for this criterion is developed through elite interviews with municipal water managers.

Acceptability to stakeholders: The analysis of policy alternatives must take into account the expected response from the citizens of Vancouver. An alternative that would face fierce and widespread opposition from the public can be immediately eliminated, as municipal politicians presumably would not consider such a policy. This does not mean that mildly unpopular alternatives, like price increases for instance, are ruled out. The important considerations for acceptability criterion are the characteristics of those opposed, or in favour, and the strength of their opposition, or support. Similarly, the viewpoints of environmental NGOs are taken in account in the acceptability criterion.

5: Policy Evaluation

This section evaluates the proposed policy alternatives using the criteria outlined in the previous section. The quantitative and qualitative data used to conduct the policy analysis are derived primarily from municipal government administrative reports, case study analysis and from interviews of experts in the field of municipal water management. Five key informants were interviewed to provide input into the assessment of the policy alternatives. For the purposes of confidentiality and the desire to elicit honest and complete responses, the names of the participants are withheld; the informants are all municipal officials in the Metro Vancouver area.

The alternatives are compared against a consistent set of criteria in order to present the relative merits of the proposed policies. With each criterion, the rankings of low, medium and high are translated into numerical scores of one, two and three, respectively. The criteria are all given equal weight in the evaluation. Table 9 provides a summary of the policy evaluation.

Table 9: Assessment of Policy Alternatives.

Criteria		Status Quo	Alternative #1: Universal Metering and IBR Pricing	Alternative #2: Voluntary Metering + Enhanced Information	Alternative #3: Voluntary Metering +Toilet Rebate
Cost		Total cost for conservation programme in 2006 was $179,000 (3) High	$5.0million/yr for 10 years $1.1 million/yr operating Total: $6.1 million/yr (1) Low	3000 installations/year, is $1.8 million/year capital costs $440,000/yr operating Enhanced information = $200,000/yr Total = $2.4 million/yr (2) Medium	3000 installations/year, is $1.8 million/year capital costs $440,000/yr operating Toilet Rebate = 2000 installations/year = 100,000/yr Total = $2.3 million/yr (2) Medium
Effectiveness	Residential demand	$0.7 million/yr in water savings (1) Low	$2.0 million/yr after full implementation[‡] (2) Medium	$0.9 million/yr after full implementation[‡] (1) Low	$0.8 million/yr after full implementation[‡] (1) Low
	System-wide	$0 (no mechanism to identify leaks) (1) Low	$3.5 million/yr after full implementation[†] (3) High	$1.4 million/yr after full implementation (2) Medium	$0.7 million/yr after full implementation (1) Low
	Average score	(1) Low	(2.5) Medium-high	(1.5) Low-medium	(1) Low
Equity		Low water users subsidize high volume users; low users tend to be poor and small households, making cross – subsidization highly inequitable (1) Low	User-pay principle treats high consumers differently than low; high consumers will have larger water bills (3) High	Promotes user-pay principle; will attract small and poor families wanting to reduce water bills (selection bias); those still charged fixed annual fee likely to have increased bills (3) High	Promotes user-pay principle; will attract small and poor families wanting to reduce water bills (selection bias); those still charged fixed annual fee to have increased bills (3) High
Admin. Feasibility		Limited bureaucratic involvement in operations (3) High	Requires extensive bureaucratic operations and monitoring; but can be planned to achieve efficient installation of meters (2) Medium	Requires maintaining two billing systems; patchwork installation of meters throughout city (1) Low	Requires maintaining two billing systems; patchwork installation of meters and toilets; more personnel to process applications (1) Low
Acceptability to Stakeholders		The annual flat rate charges have doubled in the last 5 years (1) Low	Mandated likely not popular among public; environment groups like mandate (2) Medium	Those who anticipate benefits enter programme; environment groups want mandate (2) Medium	Those who anticipate benefits replace toilets; environment groups want mandate (2) Medium
Total Score		9/15	10.5/15	9.5/15	9/15

[‡]Savings as a result of a decline in water purchases from the GVWD by reducing consumption by 20% via the price incentives; this does not include savings associated with delayed investment in infrastructure (Interview #4, 2007). [†] Savings as a result of a decline in water purchases from the GVWD by reducing system leakage from 15% to 7.5% of total water system consumption.

5.1 Evaluation of Status Quo

Cost: The status quo is ranked high for the cost criterion, due to the low capital and operating cost of the current policies. The ranking of high follows from the indices developed for the cost measures (Table 8). The total expenditure for all conservation initiatives underway by the City of Vancouver – which includes the school play, the Rain Barrel programme, the Grow Natural programme, and the Water Saver Kits – is $179,000 per year (City of Vancouver, 2006; City of Vancouver, 2007). Hence, the financial cost of maintaining the current policy and programmes is relatively small.

Effectiveness: In terms of effectiveness in reducing the demand for water, the status quo is ranked low, as estimated savings from demand reductions fall below the $1 million threshold in the index. In terms of cost savings to the city on water purchases, the status quo is unlikely to result in substantial savings. I estimate that the status quo results in $0.7 million per year in water savings[12]. Not only are the residential demand reductions predicted to be low, but also there is no mechanism to identify and repair system leakages, which are estimated to be 15% of total water use in the city.

Equity: The status quo is ranked low for the equity criterion. The current policy may seem equitable on a superficial level because every water consumer pays the same fixed fee for unlimited water. City of Vancouver officials claim that the fixed fee serves to provide the lowest average cost of water for all users (Clift, 2004). However, the status quo has a significant inequitable element because low water users, who tend to be poorer and smaller households, effectively subsidize high water users. Thus, this cross-subsidization results in poor and small families bearing a higher proportion of cost of water provision than their share of consumption.

[12] Water savings = (aggregate residential water use)*(average demand reduction)*(GVWD water rate) = $707, 848. Assumes residential demand reduction of 2.5% given that city administrative reports indicate that the current conservation programmes have "peaked in their effectiveness" (Clift, 2004).

Administrative feasibility: There is no anticipated additional staffing required to continue the existing policy, and by following the index developed, the alternative is given a rank of high. The city does not have a self-contained water conservation division in the administration, but rather calls upon personnel in Water Services division to administer the current policies when required (Interview #4, 2007).

Acceptability to stakeholders: The status quo ranks low in terms of acceptability to stakeholders. The ranking is established by understanding the characteristics of the water system if the City of Vancouver does not alter current policy. Over the last eight years in Vancouver, the fixed annual fee to consumers has risen by 45% (Wong, 2006a,b). Interviews with municipal officials in Metro Vancouver indicated that consumers are increasing calling and writing the city to protest the rising rates during this period (Interview #1, #4, 2007). Furthermore, the fixed annual fee is expected to increase dramatically in 2009, as the GVWD must increase bulk water rates to recover costs of the new Seymour-Capilano Filtration Project. Continually increasing fixed fee charges to pay for new infrastructure is expected to be unpopular with the public, especially if adjacent municipalities have implemented aggressive conservation policies that result in smaller average bills for their consumers. Environmental NGOs are likely to oppose the status quo, as it maintains a largely unmetered residential sector.

5.2 Evaluation of Alternative #1: Universal Metering and Increasing Block Rate Pricing

Cost: This alternative is ranked low for the cost criterion, given the relatively high capital and operating costs. With respect to financial cost, the programme certainly would be expensive for the City of Vancouver. According to a GVRD feasibility study, the installation costs of a mandated metering initiative would be $50 million and $1.1 million annual operating costs (City of Vancouver, 2004). In annualized terms, this is $6.1 million/year for the 10-year implementation period, and is ranked low according to the cost index[13].

Effectiveness: The universal metering alternative is accordingly ranked medium-high with respect to the effectiveness criterion, as per the index developed in Table 8. In a review of metering initiatives in the United States, Inman et al. (2006) estimate an average of 20% reduction in demand over a 10-year period. Environmental advocacy groups similarly estimate a 15-20% reduction in demand from universal metering (Maas, 2004). Significant water savings can be achieved through the identification and repair of system leakage. The water savings for the city in terms of avoided bulk water purchases from the GVWD are estimated to be $2.0 million per year from residential demand reductions and $3.5 million per year from reductions in system leakages[14].

Equity: This alternative is given a ranking of high for the equity criterion. The principle behind proposals to mandate universal metering of water is user-pay. Simply stated, this principle declares that people should pay for the good or service based on the amount they consume, effectively removing the cross-subsidization present in the status quo. Metering individuals is sometimes argued to disproportionately affect poor households, as a larger share of their income is spent on water services (McNeill and Tate, 1991). However, with an increasing block rate structure designed such that there is an inexpensive initial block of water, the negative effect on poor households is largely avoided. That is, the initial block would be priced relatively low for the water required for basic needs. It is important to note that high water consumers under this alternative, should they not alter their consumption habits, will pay more for water services than under the status quo.

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[13] This proposed alternative is presented under the assumption that the City of Vancouver would not seek provincial and federal funds to share the costs of the programme. While the City of Surrey established a cost-sharing agreement with the higher-level governments for water metering initiatives, interviews with municipals water officials revealed that it is not guaranteed that a similar agreement would be made with Vancouver (Interview #2, 2007).

[14] Water savings estimate assumes 20% reduction in residential demand, lowering of total system leaks to 7.5% of total water use in the city (from 15%), and uses the 2009 GVRD wholesale water rate of $0.40/m^3. This does not include savings associated with delayed investment in infrastructure (Interview #4, 2007).

Administrative feasibility: The universal metering programme would require extensive bureaucratic operational capacity and monitoring, and is thus ranked low with respect to administrative feasibility. Staff and expertise would be required to plan the implementation strategy, establish contracts with meter installation companies, process application forms, and monitor the water use for billing. There is an advantage to a universal programme in that it allows the city to install meters in a coordinated fashion (entire blocks in a given day), resulting in economies of scale for implementation. Mandating metering in every single-family home, however, would nonetheless require significant bureaucratic power.

Acceptability to stakeholders: In terms of acceptability to stakeholders, universal metering is ranked as medium. Most municipal officials agree, based on the evidence gathered in the elite interviews, that while there was opposition to metering in the past among the public, that opposition has largely faded (Interview municipal official #1, #2, #4, 2007). The mandated nature of the programme however, is certain to elicit opposition from some segments of the population. From the perspective of environmental NGOs, mandating metered water usage is widely considered to be an essential component of water conservation policies (Maas, 2003).

5.3 Evaluation of Alternative #2: Voluntary Metering Programme and Enhanced Information (EI)

Cost: This alternative is given a rank of medium with respect to cost, as both measures of cost receive rankings of medium by means of the indices developed in Table 8. Under this alternative the city would pay the entire cost of meter installation. The GVRD has estimated that the costs of installing a meter can range from $500-800 per household (City of Vancouver, 2004). The projection is that, with aggressive marketing of the programme, 3,000 Vancouverites will request a meter annually. Thus the cost of installing 30,000 meters over a 10-year period is estimated to be $1.9 million per year[15]. The cost of an enhanced information initiative is $200,000 per year for the summer media, twice-yearly publications and bill inserts, and is estimated based on the case studies in the United States (EPA, 2002). This brings the total financial cost of the alternative to $2.44 million per year.

Effectiveness: The voluntary metering and enhanced information alternative is hence given a rank of low for effectiveness in reducing residential water demand. The evidence in the literature suggests an average 20% reduction in residential water consumption (for those who are metered). It is important to note that the city can expect a selection bias under this policy. Residents who are conservation-minded and those who believe they can reduce their water bill will disproportionately apply to the programme. Also, given the inherently limited scale of the programme, as it is voluntary, the demand reductions at the city level are minor. Assuming 30,000 meters are installed, and the average household reduces consumption by 15%, the result is a 1.1% reduction in total residential demand[16]. The water savings to the city from residential demand reductions are estimated to be $0.9 million per year[17]. The other gains in terms of demand reductions in the aggregate will be achieved through the identification and repair of system leaks and the non-metered consumer's response to the enhanced educational campaign. It is estimated that this reduces GVWD bulk water purchases by $1.4 million per year[18]. This estimate is much smaller than the savings anticipated through the universal metering alternative because of a much lower rate of metering.

Equity: This alternative is ranked high with respect to equity. The households most likely to request participation in the programme are those that anticipate cost savings when

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[15] Estimate based on a cost of $600/meter.

[16] This value uses estimates of household (HH) demand reductions expected under the programme and calculates the impact of 30,000 meter installations on aggregate residential water demand. Daily per capita demand is estimated to be 500 litres/day for the household, and is lower than the average given the selection bias. Estimated reduction (%) = (daily per capita demand)*(average HH size)*(HH demand reduction)*(# meters)*(days/year)/(total water demand) = 1.1%.

[17] Water savings = (# meters)*(daily HH demand)*(HH demand reduction)*(365 days)*(GVWD bulk water rate) = $942,750.

[18] Water savings estimate assumes 5% reduction in residential demand, a reduction of system leakage from 15% to 12% of total water system consumption and uses the 2009 GVRD wholesale water rate of $0.40/m^3.

charged on a unit-basis rather than fixed annual fee. While there is no local level data available, a review of the literature indicates that, in general, more affluent people use more water per capita (Manzatti and Montini, 2005). As such, one can reasonably assume that smaller and poorer households have the most to benefit by participating in the programme, as they tend to use less water. In contrast to flat rate charges, where low water users subsidize high water users, the households under the voluntary metering programme achieve a fairer charge for water consumption. Note that the programme in Surrey has simultaneously raised the fixed annual fee for those who have not volunteered for meter installations. Given the selection bias inherent in the voluntary programme, it is reasonable to assume that households that choose not to participate in the programme are higher than average water users.

Administrative feasibility: The voluntary metering alternative plus enhanced information is ranked ow, based on information gathered from the experience of the Surrey Water Meter programme. Based on the interview with a municipal official, the Surrey programme did not require extensive bureaucratic involvement to implement and operate (Interview #1, 2007). In fact, only one employee was transferred from another division in the peak season (when consumers attention is high after fixed annual fees were issued in March) in order to process the applications. The installation and monitoring of the meters would likely be contracted out to a private firm, as would the enhanced information and media campaign. However, while the programme itself does not require extensive bureaucratic resources, it does require the city to maintain two sets of billing systems. Additionally, the voluntary programme will undoubtedly result in a patchwork of installations throughout the city. It thus represents a disorganized method of implementation (Interview #4 and #5, 2007).

Acceptability to stakeholders: The voluntary metering plus enhanced information alternative ranks medium on the acceptability to stakeholders criterion. While in the past metering proposals have faced public opposition in the Metro Vancouver area, interviews with municipal officials indicate that the tide is turning. Two interviewees indicated that the voluntary programmes in Surrey and Richmond have eased the opposition in the area, as people become more accustomed to user-pay for water use (Interview #1 and #5, 2007). All three elements of the enhanced information campaign are relatively passive in their approach to educating the public. That is, the three pieces of literature that each household will receive annually are unlikely to be controversial. Evidence from the literature and case studies does not indicate any significant dissatisfaction from the public when a municipality makes appeals for water conservation (Inman et al., 2006; EPA, 2002). Environmental NGOs are eager to have water users metered, but would likely argue that a voluntary metering programme would not capture high volume consumers.

5.4 Evaluation of Alternative #3: Voluntary Metering Programme and Toilet Rebates

Cost: This alternative ranks low for the cost criterion. For this alternative, it is assumed that the same number of meter installations would occur annually as with the second alternative. Thus, the cost for the metering component of the alternative is $2.24 million per year. For the rebates that encourage residents to upgrade their old toilets for more efficient toilets, I assume that 2,000 toilet rebates would be issued annually. I assume that many of the metering programme participants would opt to upgrade their toilets if provided an additional incentive. With a $50 rebate per toilet, the cost of the rebate programme is $100,000 per year. Hence, the total financial cost for the alternative is $2.34 million per year.

Effectiveness: The alternative is given a rank of low for effectiveness, as per the index used for measurement of the criterion. As with the second alternative, the scale of the programme and its voluntary nature result in minimal aggregate demand reductions. The metering component generates a 1.1% reduction in total residential demand[19]. With respect to the rebate for upgrading to more efficient toilets, the literature suggests that upgrading can reduce household consumption by 9-12% (Inman et al., 2006). Thus if 20,000 toilets are upgraded over ten years, the anticipated aggregate residential demand reduction for the city is 1.0%[20]. The water savings to the city from residential demand reductions are estimated to be $0.85 million per year[21]. In terms of the resulting cost savings to the city from identifying and repairing system leaks, I estimate that this alternative reduces GVWD purchases by $0.70 million per year after full implementation[22].

Equity: This alternative is ranked high with respect to equity considerations. To my knowledge, data are not available that can confirm the demographics of the households likely to participate in the metering programme and the toilet rebate. Anecdotal evidence suggests two groups in particular are most likely: poor and small households (Interview #1, 2007). Like the second alternative, voluntary metering promotes the user-pay principle, but will likely contain a selection bias in terms of participants. The equity implications for this alternative are equivalent to the preceding alternative, as the main feature of both alternatives is a voluntary metering programme.

Administrative feasibility: This alternative is given a rank of low with respect to administrative feasibility. The bureaucratic resources required to implement the voluntary metering component of this alternative are anticipated to be similar to the second alternative. Assuming similar volume of requests as the Surrey programme, only one or two employees will need to be diverted to process applications during the peak time. The city would still have to

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[19] Estimated reduction (%) = (daily per capita demand)*(average HH size)*(HH demand reduction)*(# meters)*(days/year)/(total water demand) = 1.1%.

[20] Estimated reduction (%) = (daily per capita demand)*(upgraded toilet demand reduction)*(# toilets)*(days/ year) /(total water demand) = 1.0%.

[21] Water savings = (# meters)*(daily HH demand)*(HH demand reduction)*(365 days)*(GVWD bulk water rate) + (# toilets)*(daily HH demand)*(toilet demand reduction)*(365 days)*(GVWD bulk water rate) = $855,414.

[22] Water savings estimate assumes system leaks are reduced from 15% to 12% of total system consumption and uses the 2007 GVRD wholesale water rate of $0.40/m^3. Note that this water savings estimate is nearly half of that for Alternative #2 because it does not contain estimated savings from the enhanced informational campaign.

operate two billing systems and will create a patchwork of metering like the second alternative. However, the toilet rebate component of this alternative adds more staffing and bureaucratic planning, as there would need to be an assessment system in place to prevent fraudulent claims for rebates.

Acceptability to stakeholders: The voluntary metering plus toilet rebate alternative is ranked medium for the acceptability criterion. As with the second alternative, the public opposition to metering has largely faded. Additionally, as the alternative has only voluntary components, the households that find appeal in the initiatives will participate and all others are not mandated. Like the preceding alternative, environmental NGOs are supportive of proposals that promote the user-pay principle among residential water consumers, but likely prefer a mandated metering policy that would include all residential users (Maas, 2004).

5.5 Policy Analysis Discussion

The two highest scoring alternatives in the initial evaluation are (i) the universal metering and increasing block rate pricing alternative, and (ii) the voluntary metering plus enhanced information alternative (Table 9). Given that one point separates the scores, further examination is necessary to definitively determine the superior policy alternative. Since the main feature of the two surviving alternatives is metering, some of the criteria developed in Section 4 warrant further consideration over others[23].

With regard to the equity and acceptability to stakeholders criteria, the two alternatives rank equally and require no further discussion. However, the cost criterion requires further analysis in the context of the water savings achieved the two policies. Furthermore, it is evident from interviews with municipal officials that cost, water savings (effectiveness) and administrative feasibility criteria are the most critical elements in water metering proposals.

[23] The initial policy evaluation treats all criteria equally in order to establish the broad viability of the proposed policy alternatives. The subsequent analysis focuses on the two highest scoring alternatives and discusses the most important criteria, as indicated by municipal officials given that the remaining alternatives are both metering proposals.

Thus, the subsequent policy analysis for the two remaining alternatives, given that they are both metering proposals, is a more detailed consideration of the following merged criteria: (i) cost-effectiveness, which is defined as the net of capital and operating costs minus monetized water savings and (ii) efficiency of implementation, which, using capital cost and administrative feasibility criteria, captures the varying economies of scale of implementation associated with the two remaining alternatives.

If the city decides to take a more aggressive approach to water conservation, it must first be confident that the chosen policy alternative is cost-effective. Cost-effective in this context is the payback (water savings) of the alternative relative to the cost. The importance that initiatives be cost-effective is similarly apparent in City of Vancouver administrative reports on water conservation (Clift, 2004). This study tries to capture the notion of cost effectiveness in the policy analysis by differentiating the financial (capital and operating) costs of the policy and the savings in bulk water purchases to the city resulting from the policy.

If one considers only the capital and operating costs of the universal metering alternative, it suggests that the spending for water services would rise dramatically. However, by estimating the savings in water purchases to the city resulting from the system leak identification and repair, and the reduction in per capita residential water demand, it is a more accurate representation of the costs of the policy alternative. Table 10 provides cost-effectiveness data for the two highest scoring alternatives by comparing the opportunity cost of capital (and operating costs) to the water savings anticipated on an annual basis at full implementation.

Table 10: Cost-effectiveness of the Highest Scoring Alternatives.

Policy Alternative	Financial Cost ($/year)	-	Water Savings ($/year)	=	Net Benefit ($/year)	# of meter installations
Universal Metering	$4.1 million†		$5.4 million		$1.3 million	80,000
Voluntary Metering + Enhanced Information	$1.7 million		$2.3 million		$0.6 million	30,000

†See Appendix E for the short-term cost-benefit analysis spreadsheet.

The universal metering alternative, as shown in Table 10, results in an estimated $5.4 million per year in water savings to the city at full implementation[24]. In an average year after full implementation, there is an annual savings of $1.3 million for 80,000 meter installations for the universal metering alternative. When compared to the voluntary metering plus enhanced information alternative, there are annual savings of $0.6 million for 30,000 meter installations. Thus, the universal metering alternative is superior in terms of achieving short-term water savings to the city compared the capital and operating expenditures for the policy. This short-term cost benefit analysis does not include the benefits to the city from delayed infrastructure expansion as a result of demand reductions, which are expected to be substantial for the universal metering alternative. The analysis also does not include an estimate of the monetized environmental benefits associated with fewer water withdrawals and infrastructure delay. Thus one can assume that the net benefits of both of the alternatives are underestimated.

Similar to understanding the relative cost-effectiveness of the two highest scoring alternatives, officials in Metro Vancouver governments place particular emphasis on the economic efficiency with regards to implementing a metering proposal. Economic efficiency in this context is the economies of scale associated with the ability to coordinate an efficient plan for installing thousands of meters. Under a voluntary metering programme, there will be requests from households scattered throughout the city. The cost to the city to send a work crew to install

[24] For the purposes of the short-term (10 year) cost-benefit analysis, I assume that all the meters are installed in the first year and thus all the water savings are achieved in the first year.

one meter, or even several in a neighbourhood, at a time is high compared to the return. This represents an economically inefficient method of installing 30,000 meters. In contrast, the universal metering alternative allows for the city to establish a coordinated action plan for installing meters. That is, the city can plan to install meters for an entire neighbourhood block simultaneously. While this study does not have specific cost data, the economies of scale associated with installing meters on an entire block is a logical conclusion, and confirmed through municipal officials (Interview #2 and #4, 2007). The ability to establish a coherent plan of installing meters is valued by municipal officials in their desire to achieve economically efficient implementation of policy.

5.6 Policy Recommendation

This section outlines the recommendations for the City of Vancouver based on the alternatives that the preceding analysis determined to be most viable. The policy alternatives considered in this study are mutually exclusive, and thus, should be interpreted as stand-alone policy directions. The first steps of the implementation process are briefly discussed for the recommendation.

Based on the scoring in the policy evaluation, the universal metering and increasing block rate pricing alternative is the best alternative for the City of Vancouver to consider. The statistical analysis, case study evaluation and literature review suggest that this alternative is the most cost-effective, economically efficient, and equitable proposal and does not contain high negatives on any of the remaining criteria used for the policy evaluation.

The universal metering alternative offers the economic incentive to households to reduce water consumption. The primary advantage of a mandated metering programme is that it would introduce the user-pay principle to residential water consumers. Compared to the other alternatives presented, this component is most likely to instil a strong water conservation ethic in the domestic water sector because it is does not rely on appealing to individuals' morality, but provides an economic incentive to reduce wasteful water use. Introducing this element into the residential water sector will have a powerful impact on how individuals use water in the home. The reality is that all water use in Vancouver is likely to be metered in the future as the cost of providing water continues to rise, and as additional water sources become more difficult to exploit.

Introducing a universal metering programme in Vancouver would represent a marked increase in expenditures for water conservation in the city. As such, the City of Vancouver should fully investigate in more detail the administrative requirements and costs of such a programme. The City of Vancouver has a unique opportunity to learn lessons from the successful universal metering programme of West Vancouver, should the city decide to explore this alternative further.

6: Conclusion

Through statistical estimations of residential water demand, case studies of best practices in water conservation, and a survey of the relevant literature, this study proposes policy options to the City of Vancouver to reduce per capita water demands among residential consumers. The statistical analysis of water demands among Canadian urban centres reveals that metered water use, the existence of educational conservation initiatives, and non-price incentives are associated with lower per capita demands for water in the residential sector. The case studies and literature review identify the relevant policy instruments associated with each of the significant factors in the statistical analysis.

Using complementary analytical methods, this study presented and evaluated several options for reform for Vancouver's water utility. The analysis identified three policy alternatives the City of Vancouver could consider to reduce per capita residential water demands. The alternatives presented were the following: (i) universal metering of all residential users and an increasing block rate structure, (ii) subsidized voluntary metering programme plus enhanced information, and (iii) a subsidized metering programme plus rebates on efficient toilets. These policy options are selected based on their ability to achieve the following long-term policy objectives: to reduce per capita residential demand to the OECD average and to delay water infrastructure expansion in the Metro Vancouver region.

The policy evaluation revealed that the universal metering programme and increasing block rate pricing is the most cost-effective and broadly viable option among the proposed alternatives. Importantly, in contrast to the status quo, this alternative offers a policy direction that is more fair and equitable to residential water consumers. It is more equitable than the status quo because it introduces the user-pay principle to water consumption. The City of Vancouver has argued in the past that an equal, fixed annual fee for all residents achieves the lowest cost to the average consumer. However, in addition to the fact that fixed annual fees for unlimited water does not reward low users, it also results in low water users effectively subsidizing high water users. This is a particularly inequitable system of recovering costs, because the literature indicates that more affluent people generally tend to use more water. The recommended alternative begins the process of establishing the user-pay principle in the domestic sector.

The primary rationale to adopt a more aggressive demand-management policy with respect to residential water use is the opportunity to delay costly water infrastructure expansion in the region. The GVWD estimates that at current demand projections, the region will require a new water source in 2050. If Vancouver, the most populous municipality in the region, is able to achieve significant demand reductions over the next 10 years, the total water consumption of the region will be reduced to such an extent that the infrastructure expansion could be delayed further into the future. The interest savings on financing the infrastructure project are significant. As mentioned in Section 2, a 1999 GVRD study estimated that with an aggressive water conservation programme, the region could achieve savings of $100 million in capital and operating expenditures. With the surrounding municipalities implementing aggressive water conservation policies to reduce water demands, the City of Vancouver must follow. Indeed, this involves a significant shift in policy and increased short-term expenditures, but the foundation for an accepting public has been laid by surrounding cities. It is time for Vancouver to join the coalition.

Appendices

Appendix A

Canadian municipalities with a population greater than 50, 000 included and excluded in the estimation.

Municipalities used in estimation	Municipalities excluded	Reason for exclusion
Toronto	Montreal	missing pricing data, rate type, billing period
Peel	Québec	missing rate type, billing period
Calgary	Niagara Region	missing rate type, billing period
Ottawa	Longueuil	missing rate type, billing period
Edmonton	Laval	missing rate type, billing period
Winnipeg	Gatineau	missing billing period
Vancouver	Burnaby	missing pricing data, rate type, billing period
Durham Region	Richmond	missing pricing data, rate type, billing period
Hamilton	Burlington	missing rate type, billing period
Surrey	Oakville	missing rate type, billing period
Halifax	Sherbrooke	missing pricing data, rate type, billing period
London	Lévis	missing pricing data, rate type, billing period
Markham	Abbotsford	missing pricing data, rate type, billing period
Vaughan	Trois-Rivières	missing pricing data, rate type, billing period
Windsor	Cape Breton	missing pricing data, rate type, billing period
Kitchener	Oxford	missing pricing data, rate type, billing period
Saskatoon	Waterloo	missing pricing data, rate type, billing period
Regina	Langley	missing pricing data, rate type, billing period
Richmond Hill	Brantford	missing rate type, billing period
Greater Sudbury	Kamloops	missing pricing data, rate type, billing period
Saguenay	Victoria	missing pricing data, rate type, billing period
Coquitlam	Saint-Jérôme	missing pricing data, rate type, billing period
Barrie	Norfolk	missing pricing data, rate type, billing period
Kingston	New Westminster	missing pricing data, rate type, billing period
Cambridge	Halton Hills	missing pricing data, rate type, billing period
Guelph	Wood Buffalo	missing pricing data, rate type, billing period
Thunder Bay	Terrebonne	no independent variable data
Saanich	Township and Royalty	no independent variable data
Chatham-Kent	North Bay	no independent variable data
Kelowna	Nanaimo	missing dependent variable data
St. John's	Repentigny	missing dependent variable data
Delta	Kawartha Lakes	missing dependent variable data
North Vancouver	Middlesex County	missing dependent variable data
Saint-Jean-sur-Richelieu	Muskoka Region	missing dependent variable data
Strathcona County		
Newmarket		
Peterborough		
Sault Ste. Marie		
Sarnia		
Red Deer		
Prince George		
Lethbridge		
Saint John		
Maple Ridge		
Chilliwack		
Drummondville		
Moncton		
St. Albert		
Port Coquitlam		
Medicine Hat		
Shawinigan		
Saint-Hyacinthe		
Fredericton		

Appendix B

Estimating the Demand for Water

A major divide in the literature surrounding the estimation of the demand for water is the specification of the price of water and Renzetti (2002) provides a good survey of the debate. Price is typically incorporated into statistical models in two forms: marginal price or average price. Economic theory suggests that marginal price – the price for an additional unit of water – is the most appropriate form. Several problems arise, however, when incorporating marginal prices in empirical estimations. Since water prices are not constant, the marginal price becomes a function of the quantity consumed, creating the possibility of misspecification and simultaneity bias in the estimated coefficient. Also, aggregate consumption data often preclude knowing a household's marginal price. To another group of econometric researchers, using the average price per unit of water is a preferred measure because some of the estimation problems that arise when using the marginal price are avoided (Renzetti, 2002). Additionally, they argue that average price, not marginal price, is what actually motivates consumer behaviour because perception is most important.

Appendix C

Data Analysis

Table C.1: Correlation Table for Estimation Model A

	WATER_D	PW_AVG	INC
WATER_D	1.000	-0.328	-0.241
PW_AVG	-0.328	1.000	0.180
INC	-0.241	0.186	1.000
Mean	295.269	0.603	76337.800
Median	267.805	0.515	75788.500
Maximum	587.253	2.830	95027.000
Minimum	122.310	0.001	60734.000
Std. Dev.	106.853	0.587	8958.340
Skewness	1.096	1.407	0.468
Kurtosis	3.779	5.932	2.590

Table C.2: Correlation Table for Estimation Model B

	WATER D	PW_AVG	INC	RATE	DEN3	TEMP	BILL	DBILL	CONSTOT
WATER_D	1.000	-0.328	-0.241	-0.488	-0.152	-0.324	-0.268	-0.357	-0.392
PW_AVG	-0.328	1.000	0.186	0.641	0.125	0.184	0.232	0.286	-0.020
INC	-0.241	0.186	1.000	0.247	0.248	0.006	0.093	0.145	-0.009
CONSRATE	-0.488	0.641	0.247	1.000	-0.043	0.483	0.533	0.469	-0.021
DEN3	-0.152	0.125	0.248	-0.043	1.000	-0.069	-0.070	0.013	0.295
TEMP	-0.324	0.184	0.006	0.483	-0.069	1.000	0.371	0.387	-0.022
BILL	-0.268	0.232	0.093	0.533	-0.070	0.371	1.000	0.842	0.082
DBILL	-0.357	0.286	0.145	0.469	0.013	0.387	0.842	1.000	0.083
CONSTOT	-0.392	-0.020	-0.009	-0.021	0.295	-0.022	0.082	0.083	1.000
Mean	295.269	0.603	76337.800	0.722	964.515	99.022	6.796	0.574	6.278
Median	267.805	0.515	75788.500	1.000	724.900	102.100	6.000	1.000	5.000
Maximum	587.253	2.830	95027.000	1.000	5039.000	135.900	12.000	1.000	38.000
Minimum	122.310	0.001	60734.000	0.000	44.000	48.000	1.000	0.000	0.000
Std. Dev.	106.853	0.587	8958.340	0.452	985.795	19.843	4.461	0.499	7.489
Skewness	1.096	1.407	0.468	-0.992	2.220	-0.442	0.110	-0.300	1.852
Kurtosis	3.779	5.932	2.590	1.985	8.815	2.381	1.381	1.090	7.578

Table C.3: Correlation Table for Estimation Model C

	WATER_D	PW_AVG	INC	TEMP	DBILL	CONSEDU	CONSREG	CONSFI
WATER_D	1.000	-0.328	-0.241	-0.324	-0.357	-0.299	-0.251	-0.395
PW_AVG	-0.328	1.000	0.186	0.184	0.286	-0.041	-0.066	0.101
INC	-0.241	0.186	1.000	0.006	0.145	-0.072	0.095	0.010
TEMP	-0.324	0.184	0.006	1.000	0.387	-0.103	0.127	0.069
DBILL	-0.357	0.286	0.145	0.387	1.000	-0.016	0.068	0.274
CONSEDU	-0.299	-0.041	-0.072	-0.103	-0.016	1.000	0.508	0.276
CONSREG	-0.251	-0.066	0.095	0.127	0.068	0.508	1.000	0.161
CONSFI	-0.395	0.101	0.010	0.069	0.274	0.276	0.161	1.000
Mean	295.269	0.603	76337.800	99.022	0.574	3.167	1.667	1.537
Median	267.805	0.515	75788.500	102.100	1.000	0.000	0.000	0.000
Maximum	587.253	2.830	95027.000	135.900	1.000	23.000	10.000	5.000
Minimum	122.310	0.001	60734.000	48.000	0.000	0.000	0.000	0.000
Std. Dev.	106.853	0.587	8958.340	19.843	0.499	5.001	2.426	2.255
Skewness	1.096	1.407	0.468	-0.442	-0.300	1.955	1.219	0.848
Kurtosis	3.779	5.932	2.590	2.381	1.090	6.856	3.712	1.778

Appendix D

Five key informants were interviewed to provide input into the assessment of the policy alternatives. For the purposes of confidentiality and the desire to elicit honest and complete responses, the names of the participants are withheld; the informants are all municipal officials in the Metro Vancouver area.

Interview #1	January 07, 2007
Interview #2	January 16, 2007
Interview #3	January 24, 2007
Interview #4	January 25, 2007
Interview #5	February 06, 2007

Appendix E

UNIVERSAL METERING	average year
COSTS	
capital cost (opp. cost)[†]	$3,000,000
operating cost	$1,100,000
total	$4,100,000
BENEFITS	
residential savings	$1,934,208
repaired leaks	$3,490,222
total	$5,424,430
(B-C)	$1,324,430
Assumptions:	GVWD water rate = $0.40/m^3 Capital cost is $50 million; using the WAOCC at 6%, this results in an opportunity cost of capital of $3,000,000/year Average residential water demand reduction is 20%. Average household demand is 828 litres/day System leakage reduced from 15% to 7.5% of total system water usage
VOLUNTARY METERING	
COSTS	
capital cost (opp. cost)	$1,080,000
operating cost	$640,000
total	$1,720,000
BENEFITS	
residential savings	$992,750
repaired leaks	$1,396,080
total	$2,388,830
(B-C)	$668,830
Assumptions:	GVWD water rate = $0.40/m^3 Capital cost is $18 million; using the WAOCC at 6%, this results in an opportunity cost of capital of $1,080,000/year Average residential water demand reduction is 15% Average household demand is 500 litres/day (smaller than universal metering because of the selection bias, those volunteering to the programme are more likely to be smaller water consumers) System leakage reduced from 15% to 12% of total system water usage Enhanced information component to reduce aggregate residential demand by 3% and is incorporated into residential water savings

[†] To calculate the opportunity cost of capital, this study applies a weighted-average opportunity cost of capital of 6% (Kohyama, 2006).

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