The Role of Price in Determining Residential Water Demand:

Water Pricing and Residential Water Demand in Municipalities in the Western Prairies

By

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A Thesis

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To my parents Edward and Natalie

Abstract

Municipal water systems in Canada generally are under financed to either replace depreciating systems or expand to meet growing demands. One method to increase revenues to finance water systems is on a user pay basis. This would result in municipal water rates increasing. However the relationship between price and water demand will influence the changes in demand to changes in price and ultimately system revenues. The extent of the price / water relationship is an empirical question that needs to be answered before municipal systems can accurately develop water rates that will serve the desired revenue needs.

Given that residential water usage on the prairies represents over half of municipal consumption this group will be studied as to the impact of price upon the quantity of water demanded. This thesis will review the literature dealing with estimating a residential water demand model, develop a model for the Western Prairies and determine the what impact price may have upon water usage.

The conclusions of the study are the following; water demand is inelastic with respect to water prices however it appears to be more responsive during outdoor demand periods when extra consumption is supplemental to the set of water consuming goods held by each household. Consumers in general face complex water rate schedules which complicates each consumers ability to determine the marginal water rate. On the average, water costs are a very minor

percentage of household income and that water rates do not reflect the actual costs involved with a water distribution system with respect to system replacement and service costs. Research results indicate that at observed values, water demand is inelastic and increased water prices will result in system revenues to increase.

Acknowledgments

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Chapter 1

Introduction

Capital for water distribution systems and water resources available for further development in Canada are becoming scarce. Many of the water distribution and waste treatments systems were built in Canada through funding from senior governments. However the design and implementation of municipal water rates were left up the local governments. Early studies like Howe and Linaweaver (1967) pointed out that usage is related to water prices and this information should be used in the context of designing and managing water systems. It was not until the mid 1980's in Canada, that governments (Federal and Provincial) started to investigate the economics of municipal water supply.

Many municipal water systems now need modernization; however a funding shortage exists. The Federation of Canadian Municipalities (FCM), documented in 1985 that there is a funding shortage of approximately $6 billion for water system repair and upgrading. A national survey by Environment Canada has demonstrated that municipal rates were artificially low (do not recover full system costs). At the same time there are many situations where consumption through municipal systems exceed sustainable supply levels.

Tate (1990) illustrated that Canada had the second largest water withdrawal rate per capita in the world, almost twice the consumptive rate of most European nations. These situations have precipitated a back to basics look at municipal water rate pricing schedules.

The re-evaluation of water rate pricing schedules has led to the belief that new rate schedules should consider the user-pay principle. The user-pay principle requires that users pay the full economic costs of the goods and services they consume. It is believed that application of this principle would promote cost recovery, equity, and efficiency in the allocation of water resources, Tate and Lacelle, 1992. Efficiency in the allocation of resources may lead to a side benefit of water conservation through the reduction of the water consumption with changes in the rate structure. However, many of these questions are empirical in nature and should be confirmed before implementation.

Municipal water systems are typically classified into the following groups; domestic, commercial, institutional and industrial. This study will focus on the domestic accounts represented by residential customers. Findings by Tate and Lacelle (1992) suggest that 49 percent of the water supplied by municipalities was used by residential customers. They also noticed that the ratio of residential volume to total volumes was lower in larger urban centers, probably reflecting the wider variety of uses rather than a reduction of residential use. In terms of the Western Prairies with many smaller municipal centers, the residential customer is, in most circumstances, the most important single consumer group.

Background: Water Pricing in Canada

There have been two major surveys of municipal water pricing conducted by Environment Canada (Tate, 1989a and Tate and Lacelle, 1992). Tate (1989a) reviews the study conducted in 1986 which included all municipalities with a population over 5,000 and a 10 percent sample of the communities between 1,000 and 5,000 residents. Of the 800 municipalities that responded, 470 offered rate schedules. A similar study was conducted in 1989 (see Tate and Lacelle (1992)). It consisted of 900 municipalities, who supplied 618 schedules. From this data, a database has been compiled for both unit costs and total water revenues from residential and commercial customers.

According to Kassem and Tate (1993), analysis of this data revealed five main factors concerning municipal water pricing in Canada:

1. There are wide divergences in water rate schedules in effect across Canada. Each municipality sets its own rate, usually consisting of more than one rate schedule. For the 1987 survey, more than 1,100 separate rate schedules were identified for residential and commercial customers while there were only 470 municipalities in the study. In the 1989 survey 1,449 separate residential and commercial rate schedules were identified.

2. Rate structures varied from flat charges to multi-block rate schemes. There are four rate structures common in Canada, a flat rate, a constant rate, a declining rate block structure, and an increasing rate block structure (see Figure 1). A flat charge consists of one price for an unlimited amount of

water. The constant rate is a fixed price for each unit of water consumed. In a block rate structure (set number of water units), the price per unit of water changes as the volume consumed moves into the next block. The most common rate system in Canada[1] is the flat rate (either as the sole form of pricing or as part of a block rate schedule in which the first block or a minimum bill applies to the majority of customers).

3. In terms of actual user fees, there again was a wide discrepancy across Canada. Based on an average monthly consumption per Canadian household of 35 cubic meters (m^3), a relative index of prices can be developed from the rate schedules. For 1989, mean water prices varied from a low of \$11.25 per 35 m^3 in Quebec (\$7.97 per 35 m^3 in Newfoundland for 1986) to a high of \$34.85 per 35 m^3 in Manitoba (\$31.91 per 35 m^3 in 1986) with Alberta and Saskatchewan having similar high prices[2]. In general across Canada, the better the quality and availability of water sources, the lower the price.

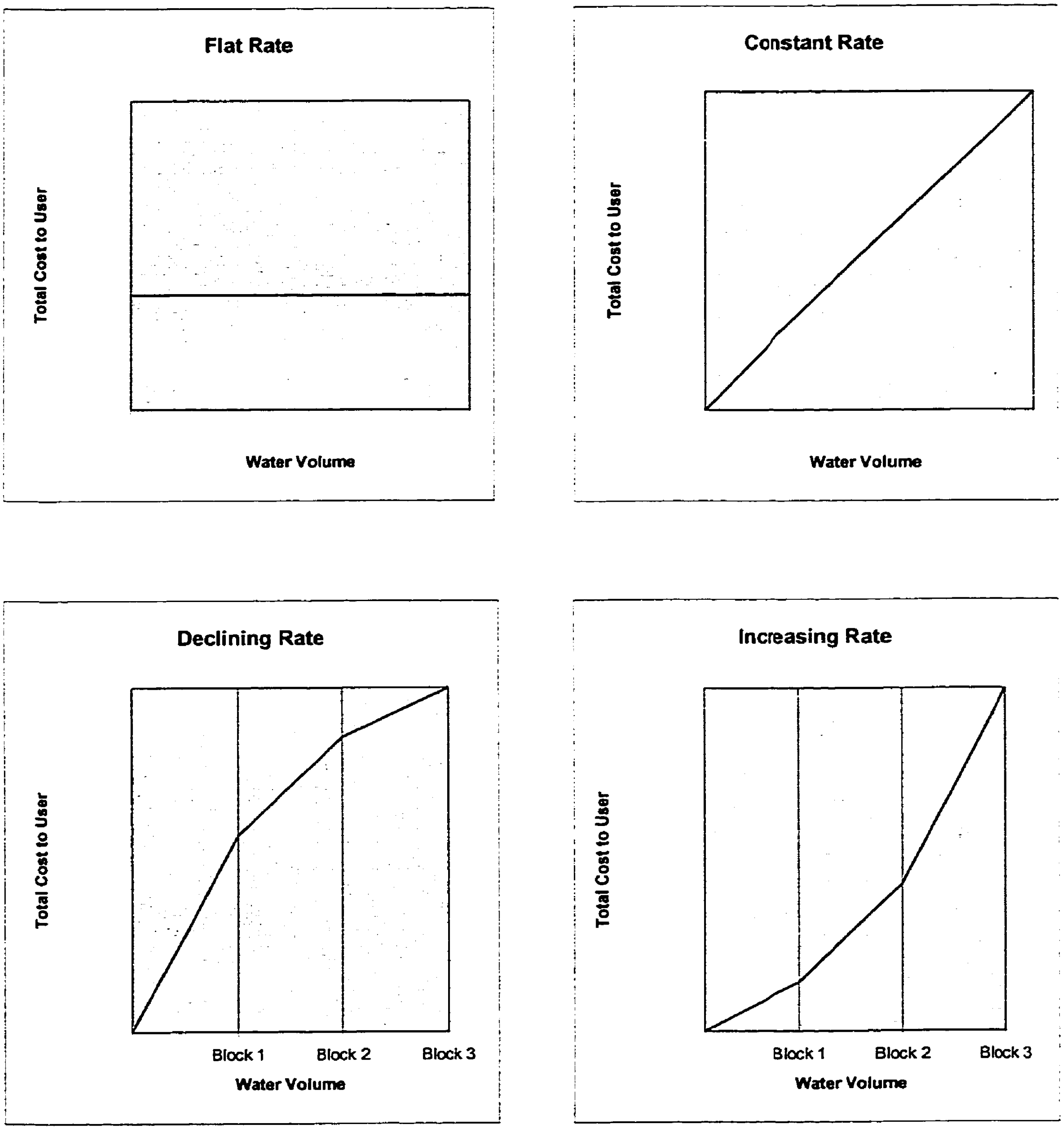
4. Tate and Klassem found that rate making practices in general fail to meet the criteria of cost recovery, equity and economic efficiency. It was noted by Tate and Lacelle (1992), that over 70% of the rate schedules in use in 1989 tend to be associated with high urban water demands. This was due to finding that almost none of the rate schedules provide financial incentives to conserve

[1]The flat or unit rate was found to be the most common in this study of Western Prairie Communities.

[2]It is interesting to note that the average survey consumption was 68.14 m^3 per quarter or 22.7 m^3 per month under the higher priced regime of the Western Prairies.

water, avoid wastage, or minimize the costs of providing water servicing. The prime criteria in setting water rates appear to be acceptability to local taxpayers, accompanied by a varying concern for cost recovery.

FIGURE 1: COMMON WATER RATE STRUCTURES USED IN CANADA



1. Nearly 70 percent of the rate schedules provided no or negative financial incentive to conserve water. The two rate structures in question are flat rates (no incentive to conserve) and decreasing block rates (negative incentive to conserve). As can be seen in Figure 1; for a flat rate, the marginal price (cost per unit of water consumed) is zero. In a decreasing block rate, the marginal price drops as consumption is increased to a higher block volume. In both rate structures, the average cost of water to the consumer decreases as more water is consumed.

The findings by Tate and Lacelle (1992) demonstrated that municipalities had not been setting prices for full cost recovery or as a method of water demand management. In order for rate structures to be changed to reflect the relationship between consumers and price, other structural impacts such as seasonal trends should be determined first.

Table 1: Domestic Municipal Use by Selected Country, 1983.

Country	Pumpage per capita-day (L)
United States	425
Canada	360
Sweden	200
United Kingdom	200
West Germany	150
France	150
Israel	135

Source: Tate (1990, Table 2)

In comparison to some other countries in the world, Canada is a relatively high water user, exceeded only by the United States. Table 1 illustrates comparisons between Canada and some other industrialized countries. While Table 2 shows a recent survey of water prices (excluding sewer charges) for several industrialized countries. It demonstrates the wide discrepancy between Canadian water prices and those of many other industrialized nations.

Table 2: A Sample of World Water Prices

Country	$ per cubic meter	% change from a year earlier
Germany	1.69	8.5
Australia	1.19	-14.1
Belgium	1.17	2.7
Holland	1.12	5.8
France	1.10	2.6
Britain	.91	4.7
Finland	.75	-3.1
Italy	.70	3.5
Sweden	.63	.2
Ireland	.60	6.7
USA	.53	4.6
South Africa	.50	10.9
Norway	.38	4.5
Canada	.35	4.5

Source: The Economist, Volume 333, Number 7886, page 126.

Table 2 illustrates that Australia and some European countries have water rates from 3 to 5 times that of Canada and that Canada has the lowest water rate among the industrialized nations included in the table. On a general basis (see Table 1), nations with the lowest water rates tended to have the highest water consumption.

Research Problem

The impact of prices upon residential water demand in the USA appears to vary by geography and household tastes, as demonstrated in the study by Foster and Beattie (1979). They report separate elasticity's for water prices and income based on geography[3]. McNeill and Tate (1991) report that for various studies, the price elasticity of demand for domestic water ranged from -.1 to -1.3, with the median falling between -.2 and -.3. Since the sensitivity of households to pricing is a prerequisite for user-pay pricing strategies in demand management, proper identification of elasticity values for a particular region would be crucial.

Given that the Western Prairies in general share water resources, have comparable climatic influences and have similar economic activities, it would appear that this geographic area is suitable for grouping. This study will determine what impacts current prices have on residential water demands in the Western Prairies. First, a demand function will be developed to test the

[3]Differences were hypothesized to be due to atmospheric conditions and differing levels of economic activity and household tastes.

hypothesis of price sensitivity. If consumers are price sensitive, then the proper specification of the pricing variable will be determined. Finally, any implications for pricing structures by the identified pricing specification will then be discussed.

Literature Review

There has been great debate over the specification of the water price variable in household demand functions. The specification of the pricing variable for utility products like water encompass many issues. The most predominant is the question of what price consumers perceive in their use of water. Are consumers reacting to the average price paid by households, or are they reacting to the price at the last unit of water consumed, or some combination of the two?

The issue is clouded due to differences in water rate schedules employed by the municipalities supplying water. Many municipal governments have chosen to use block pricing (see Figure 1), where the price changes for a unit of water as the volume (block to block) consumed changes. However the size of the blocks (number of water units) and the price difference between blocks varies between municipalities. Other municipalities employ a fixed unit charge (constant rate). Most municipalities employed a fixed charge for a minimum volume of water, but again the size of the basic charge and the volume of water included varied between municipalities.

Howe and Linaweaver (1967) suggested that the consumer will respond to marginal prices. The consumer will allocate expenditures so that the last dollar spent on each commodity yields the same satisfaction.

Taylor (1975) argues that both average and marginal price should be used. The marginal price should reflect the unit price of the commodity in the last block of consumption, while the average price should be that of the commodity consumed up to, but not including the last block. The use of marginal price is only sufficient for consumer behavior at that volume, however it does not determine why the consumer achieves that volume. This is solved by including either the average price for all units purchased prior to the marginal volume or by including a total cost prior to the marginal volume. Taylor goes on to argue that the determination of an average price ex post, calculated by dividing quantity consumed into total expenditure, is incorrect. Doing so, he argues, will result in a negative dependence between quantity and price that reflects nothing more than arithmetic and will lead to problems of simultaneity and identification. This problem can be overcome by relating average price to the actual rate schedule, since, in the short run at least, the rate schedule is independent of demand, thereby eliminating problems of simultaneity and identification.

Nordin (1976) proposed a modification of Taylor's price specification. He suggested that a better set of pricing variables would be to use marginal price and a price difference (PDIF) variable. The PDIF is the difference between the total cost of all blocks of water at the rate schedule versus the total cost of the same volume at the marginal price. The PDIF is equivalent to the lump sum the consumer must pay before they can purchase the water at the marginal rate. This has been referred to as the Nordin/Taylor specification.

However, Foster and Beattie (1981) put forward strong arguments for an average pricing specification. They argue that the complexity of the water billing schedule in a multi-block format, the inclusion of fixed service charges and the impact of sewer charges on the final bill impair the consumer's ability to determine marginal water prices. The theoretical supposition of consumers' reactions at the margin may have no bearing on the proper price specification with a complex billing structure, since the proper specification depends on the consumer's perception of price rather than what theory predicts. Consumers are likely to be more aware of total expenditure and consumption and thus average prices paid. The authors proposed that the proper price specification of water being either a marginal or an average price is an empirical question.

Opaluch (1982) agrees that the water pricing specification is an empirical question and develops a model for testing purposes. The models and hypothesis developed could be used to empirically test which prices consumers respond to. However, Opaluch does make a conditional statement as to the suitable application of this testing procedure. *"The hypothesis test suggested should not be considered a once-and-for-all test, since reaction may differ both over goods and over consumers. One would expect reaction to marginal price to be more likely for goods that represent a relatively large proportion of total expenditure. In this case consumers would likely see greater potential benefit to* *learning the block rate structure and correctly incorporating the structure into the decision process. For example, the marginal price model would more likely hold for a New England consumer of electricity who owns an all-electric home than for a consumer of water in Seattle."*

Polzin (1984) conducts a study of natural gas consumers (who face a similarly complex billing structure). Three pricing variables are tested: total monthly bill, average price and the Nordin/Taylor specification. There seemed to be no clear, superior pricing specification on statistical evidence. A conclusion was reached that the Nordin/Taylor specification may be considered to be inferior on the basis that it requires two variables to achieve the same results as the other two single price specifications.

Nieswiadomy and Molina (1989) conducted a study of water demand estimates under decreasing and increasing block rates. In their analysis they noticed that the Nordin/Taylor specification did not show the expected magnitude and sign. They suggest that perhaps if water bills were a larger portion of the household budget the results would be different. Nordin's theoretical model hypothesizes that PDIF variable should be equal in magnitude and opposite in sign to income variable. Some studies such as Billings and Agthe (1980) and Jones and Morris (1984) have reported the PDIF variable to be either not statistically significantly different from zero or not of the proper magnitude. Other studies such as Chicoine, Deller and Ramamurthy (1986) and Foster and Beattie (1981) have found the PDIF variable to be of the incorrect sign and not highly significant.

There are various theories as to why this may be occurring. Henson (1984) suggests that the hypothesis may not be true due to the PDIF variable being a very small portion of income. Chicoine, Deller and Ramamurthy (1986) assert that the problem may relate back to the consumer's lack of information on complicated rate structures and billing procedures, which fits with Foster and Beattie (1981) proposition.

Shin (1985) hypothesizes that consumers under a decreasing block rate scheme will use average prices in determining demand, and the empirical results support this theory. Shin concludes that by using average prices under a decreasing block scheme consumers are actually over estimating price and under utilizing the commodity in question. With perfect knowledge of the rate structure and their position in it, consumers could increase their utility by increasing demand.

Nieswiadomy and Molina (1991) follow up on Shin's (1985) model by applying it to water for both decreasing and increasing water rates. They agree with Shin's (1985) theory on decreasing block prices but offer the hypothesis that under an increasing block structure consumers' price perception will depend on the size of the fixed block. With a relatively small fixed charge (one where the average price is smaller than the marginal price) the consumers will under estimate the marginal price with the average price. As a result the household will consume excess water in relation to the actual marginal price, whereas with a substantial fixed charge (average > marginal price) consumers are more likely to under consume using an average price. Under consumption will happen because the marginal price is being over estimated in relation to the marginal price.

It would appear to be generally accepted that the complex nature of the water rate schedules and the relative size of the water bill in comparison to income may influence household perception of the water price. When water bills comprise a large portion of income and with a relatively simple water billing structure it would be expected that consumers react to marginal prices. Whereas, when water bills constitute relatively small portions of income and are relatively complex in structure, consumers may be more likely to react to average prices.

There does not appear to be a clear choice in the selection of the water pricing variable. However, theoretical indications are that since water prices are a small percentage of income and rate structures are complex in nature, average prices are likely the proper specification. In order to best determine the nature of the function, models utilizing average price and the two variable combination (marginal and PDIF) will be estimated. The model with the best fit to the theory will be selected.

Recent literature introduces some new views on the estimation of the demand model and provides supportive results on price and income elasticities as well as differences in elasticities between indoor and outdoor demand.

Hewitt and Hanemann (1995) use a previous database compiled by Niewadomy and Monlina (1989,1991) to test a Discrete/Continuous (D/C) model of residential water demand. The price variable they choose is of the PDIF form. The PDIF variable is necessary in order to develop the D/C model. The unique feature of the Niewadomy and Monlina (1989,1991) database is that it contains individual household observations rather than aggregated community observations. Given that individual observations are available, it is suggested that a marginal price model may be the appropriate specification.

While Hewitt and Hanemann do cover most of the recent research literature, they ignore the possibility that the average price could be the correct price specification. It appears that they base the assumption to use the PDIF on previous research testing multi-block price structures (some of which included an average price specification). While testing results were inconclusive as to correct price variable specification, the authors used the new database to further test marginal price as the correct specification. The authors go on to state that "the motivation for including [the] difference [variable] is that there must be some means of accounting for the fact that the marginal price is not necessarily the price of every consumed unit in a block rate situation".

However, the authors do not give note to work by Foster and Beattie (1981) who argue that the complexity of the water billing schedule in a multi-block format and the inclusion of fixed service charges on the final bill impair the consumer's ability to determine marginal water prices. Another notable missing reference is to work by Nieswaidomy (1992) who uses Shin's (1985) model, which indicates that consumers react more to average than marginal prices in a study of four separate regions in the USA. Nieswaidomy's (1992) study indicates a range of price elasticity of –0.22 to –0.60 and an income elasticity range of 0.02 to 0.25.

While marginal values appeal in economic theory, data suggests that the average residential consumer in Western Canada is not sufficiently aware of the marginal price structure, given the complexity of most water rates. Nor is the cost of water able to provide the incentive to warrant the additional effort by consumers to determine which block they are consuming in. That is not to say that the D/C model is not theoretically elegant or incorrect if the assumptions made are correct. Hewitt and Hanemann (95) readily admit there are costs involved with the assumptions required to construct the D/C model. In this case, one major assumption requires a level of consumer knowledge regarding water pricing structures that do not appear present in this current study of the water pricing variable and its impact on water demand.

It is interesting to note the results obtained when using the PDIF variable in regressions with OLS, IV models and 2SLS models. Hewitt and Hanemann (1995) obtain the same results with all three models (both price and income variables are positive with respect to water demand). This differs from Nieswiadomy and Molina's (1989) results with the same data. The difference in results between the D/C and earlier models suggests that using a marginal price specification when individual consumer data is available is not yet conclusive and further research is required.

In another study, Dandy et al (1997) reviewed residential demand in the presence of free allowance. In this study, free allotments of water are available, with the size of the allotment dependent upon the value of the residential property. For all residential water consumed in excess of the free allotment, the water unit price for each additional water unit was constant for all levels of additional consumption. In this situation, average price would certainly be the incorrect variable as the water rate structure is uncomplicated and additional cost only starts after the free allotment. After the free allotment, the price is simply a constant value, therefore the marginal price is the obvious choice.

The price elasticity values are estimated in the range of –0.63 to –0.77 and are noted to be greater than what was indicated as being the literature typical values in the range of –0.20 and -0.50. However, it was also noted that for the study region, ex-house use was around 50% which appears to be more price sensitive and is supported by Howe and Linaweaver (1967) who reported –0.23 for inhouse use and –0.70 for exhouse use.

Seasonal elasticities were estimated as –0.29 to –0.45 in winter to –0.69 to –0.86 for summer. Income elasticities were estimated by household value proxies, and results indicated that income was more responsive in the summer period. These findings further support the theory that outdoor demand is more income and price sensitive that indoor demand.

There have been other recent studies that have taken the level of research past the price specification question and on to the questions relating to consumers' willingness to pay additional water charges (Rollins et al - 1996) and management of water distribution systems (Schmit and Boisvert - 1996). These will only be briefly discussed as they are not directly related to research conducted in this particular study.

Rollins et al. (1996) utilize a contingent valuation methodology to determine consumers' average willingness to pay (over and above current servicing prices). The value determined is just over $26.00 per month to assure adequate water servicing. This would work out to an additional $78.00 per quarter, which would more than double the average quarterly expenditure measured at $68.00 for the communities in this water pricing study. Such an increase in price would be outside the range of values observed and therefore the results obtained may not be suitable for estimation of the impacts resulting from such a price change. However such a price level is not unprecedented on a world wide basis as illustrated in Table 2.

Schmit and Boisvert (1996) look at cost functions in the USA relating to small water system sizes and technology. The purpose of the study was to assist with the allocation of public funds when the amount of money required to upgrade small-scale water projects or new developments exceeds the available funds. The study assesses costs associated with different technologies and their application/suitability to communities of different sizes.

The fact that both the Rollins et al. and Schmit and Boisvert studies were conducted indicates that funding shortages for water projects are still problematic and that this problem has not yet been adequately addressed.

Chapter 2

Methodology

In order to test the hypothesis of price sensitivity, an econometric model was developed and data compiled for each of the variables in the model. An econometric model of water demand has two components: the dependent variable (volume of water consumed) and the independent variables (factors influencing water consumption). The selected independent variables will be ones believed to be important not only for water demand but also important in accounting for differential use between communities. Data will be collected for the following independent variables: population, single and multiple family dwellings, income, climatic data (net evapotranspiration), water use restrictions, and user rates schedules.

With respect to water use and rates, each observation or data point was supplied by the local public utility that served the respective community in the prairie provinces. In the survey, the utility was asked to provide data on water consumption by user group and charges for each user group for different years. The econometric model will be estimated by ordinary least squares. The climatic data could be critical in accounting for differential use for each community within a particular year.

To determine the water demand for a typical household in these communities, it is necessary to isolate various factors that may influence the level of consumption. This is achieved through statistically estimating the parameters for a water demand function. A description of the parameters included in determining the demand function takes place later in this chapter.

If price is an important determinant of water demand, then it becomes critical to a community's rate structure as this will have a bearing upon revenues and usage. If delivery capacity is to be financed by user fees, the revenue realized through water charges will be a major consideration. Lower water price elasticities will have a lessor effect upon design and operation budgets than larger ones.

Theoretical Model

To be able to understand the differences in water use between communities, the factors underpinning water use patterns must be determined. Economic theory of consumer demand sheds some light on the nature of these factors. The neoclassical theory of consumer behavior postulates that there are four variables for the quantity demanded of good x_i namely, (1) the price of the good in question, (2) prices of related goods, (3) income, and (4) tastes (Foster and Beattie, 1979).

Conventional consumer behavior postulates the maximization of a strictly quasi-concave utility function defined over n goods, $x=(x_1,...,x_n)$, subject to a budget constraint. This can be described mathematically as equation [1].

[1] $$\max_{x} \; u(x) \text{ subject to } \sum_{i=1}^{n} px_i = p \cdot x \leq y$$

where p_i are prices and y is income.

For purposes of this study, it will be assumed that water is weakly separable from other consumer expenditures. This assumption is based on the fact that water has no real substitutes and acts as a complement with other household goods in the normal course of human affairs (i.e. a cooking ingredient, a medium for removal of wastes, watering lawns, etc.). While water is used complementary to other goods in the sense that it is used with appliances (i.e. washing machines), once a household has a supply of these durable items, their price will not affect the household's use of water. In the very short run, therefore prices of complementary products need not be included.

It is assumed that aggregate residential demand per time period is a function of the number of households and the demand for water by each household. Each household consumes W_h. Tastes are assumed identical across all households, but household characteristics per community (number of rooms and environment) differ. These characteristics are summarized by the vector H_h.

The household seeks to maximize utility given in equation [2].

[2] $$U_h = U(W_h, H_h)$$

subject to exogenously determined prices and household income. Therefore differences in H_h imply that households will enjoy different levels of utility even if W_i is the same.

Maximum household utility subject to the budget constraint yields the household's uncompensated or Marshallian demand for water, equation [3].

$$[3] \qquad W_i = W\,(\,PW_i, PNW_i\,, INC_i, T_i\,)$$

where: W_i = the quantity of water demanded by the ith household.

PW_i = the water price paid by each ith household.

PNW_i = the price of related goods purchased by the ith household.

INC_i = the income of the ith household.

T_i = the tastes of the ith household (other factors affecting water demand).

Price of Good:

The first determinant, price (of the good in question), is believed in economic theory to be an important factor influencing the consumption of water. There appears to be some disagreement in the literature, however, as to which price is the proper specification. Some studies support using marginal prices while other studies support average prices.[4] The sign of this coefficient is hypothesized to be negative, since an increase in price is expected to lead to a decrease in quantity demanded (price will be further discussed in the next section).

Prices of Related Goods:

Neoclassical theory suggests that a demand equation should include prices for the good in question along with prices for substitutes and complements

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[4] Further discussion of this question occurs in Specification of Price Variable for Water.

as well. It has been argued that there are no close substitutes for water, and historical literature on this topic supports this arguement, (Foster and Beattie (1979) and Howe and Linaweaver (1967)). While water is used as a complement to other goods in the sense that it is used with appliances (e.g. washing machines), once a household has a supply of these durable items, their price will not affect the use of water. In the very short run, prices of complementary products need not be included.

Income:

The next determinant for water demand is household income. The household will purchase an assortment of goods and services subject to a budget set by the level of income. For normal goods and services, an increase in income will lead to an increase in the quantity consumed. If water is a normal good, demand for water could increase (decrease) depending on an increase (decrease) in income even though prices have not changed. It is expected that the relationship between income and consumption is positive.

Household income is expected to be a significant determinant of the residential demand for water. Some past studies [such as Nieswiadomy and Monlina (1989) and Primeaux and Hollman (1973)] have included variables such as the per capita value of homes, lawn area, etc., as explanatory variables in lieu of or in addition to income. However all of these variables are interrelated. An adequate income is required to purchase these items, and because of the household's budget constraint, the amount of each item purchased will affect the availability of funds to purchase other items. Therefore, only average household income was included as the explanatory variable in this study.

Tastes:

The last determent in household water demand is household tastes (socio-economic characteristics). The parameter tastes can be an array of factors such as:

(i) The amount of precipitation received in the community. In the summer time, residents will irrigate gardens and lawns more often if precipitation is below the consumptive requirements of the plants. If rainfall is plentiful, less water will be demanded so this coefficient is expected to be negative. The amount of watering will depend on a household propensity for a green lawn, etc.

(ii) It is expected that there are two types of household water demand comprising of indoor use and outdoor use. In the winter, residents have a pattern of consumption set by their water using appliances (capital stock) and habits.

In the spring and summer, residents will use water based on capital stock (indoor), but will also consume on the basis of outdoor activities. Therefore, it is expected that as residents go from months of indoor activity to outdoor activity there will be an upward shift in the demand for water (see Table 3). The relationships between indoor water demand (fall and winter) to outdoor (spring and summer) use is expected to be positive (will increase from indoor to outdoor).

Table 3: Breakdown of typical Municipal Domestic water usage.

Domestic	% water use
Lawn watering (outdoor)	30
Toilets	40
Bathrooms/personal	15
Laundry	10
Drinking/cooling	5

Source: Tate (1990), Table 3

Foster and Beattie (1979) in their continental United States study determined that the impacts of seasonal shifts depended upon geographic location which will then dictate temperature variation and moisture levels. The Reid Crowther and Partners (1992) study demonstrated a distinct seasonal peak that corresponds to spring and summer periods. This study also noted that an Aridity Index (relative dryness) correlated exceptionally well with municipal water demands. The seasonal variable is important, and the more distinct the difference (in temperature and moisture levels) between seasons, the more significant the variable is likely to be. This variable is likely to be more important for the Western Prairies as compared to some other geographic locations (example, the West Coast).

This list is not complete. There are other variables that could be added depending upon the circumstances. More variables will be added and explained when the empirical model is developed.

Data

Selection of Communities and Residential accounts:

Communities were selected in each Prairie province. In Manitoba and Saskatchewan, little prior knowledge was available as to the nature of the community profile. Therefore, with the help of the Manitoba Association of Urban Municipalities and the Saskatchewan Urban Municipalities Association, all communities fitting the desired profile were sent a questionnaire. In the case of Alberta, some prior knowledge was available[5] as to situations that may distort the data in terms of a price response. For all provinces, communities were excluded *a priori* if they did not have water meters or had a high percentage of mobile homes which were suspected to follow the procedure of winter bleeding (a technique to prevent water line freezing).

Survey Design:

A pretest sample survey was conducted in September 1993 and from this data the first survey form was developed. The primary objective of the survey

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[5]Ried Crowther & Partners Ltd. report.

was to extract records relating to household (hookup) numbers, volume, and expenditure for the community or by a sample of the community. The survey also contained questions relating the share of domestic usage to total water pumpage, the definition of the residential designation, any promotional programs to encourage conservation or any restrictions on consumption. There was also a section on meter sizes, which was to relate back to the rate schedule for some communities. Copies of the survey forms are in Appendix C.

Survey Mailing:

Once a letter of support was sent out by the relative provincial municipal association, the survey forms were distributed. The letters of support were important since they contributed to increasing survey responses; unfortunately the Alberta Urban Municipalities Association declined to send a letter. The surveys were changed slightly for Saskatchewan and Alberta because it became apparent that many locations in these provinces did not have any historical computerized records or printouts for 1986 to extract required data. In response, the survey forms were modified to include 1992 instead. All surveyed locations received follow up calls after the surveys were sent[6]. Survey responses were received by either mail or fax.

Survey Response and Sample size:

There were substantial complications in collecting the required data. While the surveys were developed on the basis of the sample community

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[6]All Alberta sites received a phone call prior to mailing requesting assistance with the survey.

records, not all communities record data in the same manner. Many smaller communities did not differentiate between residential and commercial customers in billing period totals. Another problem is even if the data could be extracted from printouts, the time requirement for this was significant. The response time to the surveys varied from several days to several months. A number of surveys were not completed due to a lack of available manpower to fill out the form. In order to facilitate the survey process, communities who were short manpower but thought that the data could be extracted from records were visited. Data was entered into a laptop computer on site and analyzed at a later date.

In total, 71 surveys were sent out to or conducted at various municipalities across the Western Prairies. The results of the survey are as follow in Table 4.

Table 4: Survey Response Statistics

Province	Total	Returned	Response Breakdown		
			Total	Useable	Not
Alberta	29	14	14	9	5
	41%	48%	48%	64%	36%
Manitoba	17	12	12	8	4
	24%	71%	71%	67%	33%
Saskatchewan	25	15	15	8	7
	35%	60%	60%	53%	47%
Total Surveyed	71	41	41	25	16
	100%	58%	58%	61%	39%

A number of locations surveyed did not respond with any data other than to state that data of the type required could not be determined from records. Several communities indicated they were in the process of organizing their records in a manner where such data could be extracted in the future.

As can be seen in Table 4, a large portion of the surveys were rejected. This occurred primarily because municipalities do not keep records in a standardized format. While all sites kept records of volumes and receipts, for many locations residential usage is indistinguishable from other uses and therefore was inextricable. Any community that did not meter water use or charged only a flat rate was deleted. Another large portion of surveys were rejected due to combining of institutional use and personal care homes in the residential categories. This combination of factors in the data set could bias the analysis, since the consumer in this situation would not face a water bill based on usage as rental charges will likely be all inclusive.

Several of the communities surveyed had split billing periods. In this case the community was divided in to sections and each section was billed on a rotating basis. For these communities, the section with the billing period that corresponded to the desired quarterly basis was selected. Communities that did not complete surveys containing data for residential demand totals and account numbers were rejected.

Data Entry and Initial Analysis

Once the surveys were received, the data was entered in Excel 5.0, a spreadsheet with database and statistical analysis capabilities. In Table 5, a listing of the survey communities and sample sizes are given.

Other data entered in to the database consisted of the corresponding net potential evapotranspiration estimates, population, income, and average household size.

Table 5 - Residential Water Demand Survey Communities and Sample sizes.

Location	Province	Years	Observations	Avg. # Hookups	Accounts SAMPLED as % Total Population
Blackfalds	AB	89,91,92	12	401	23%
Cochrane	AB	91,92	8	1,393	26%
Drayton Valley	AB	91,92	8	1,567	26%
Fort McMurrary	AB	91,	4	704	2%
Grimshaw	AB	89,91,92	12	975	35%
Innisfail	AB	91,92	8	734	13%
Lethbridge	AB	91,92	8	17,693	29%
Oyen	AB	89,91,92	12	555	54%
Ponoka	AB	91,92	8	1,581	30%
Beausejour	MB	91,	4	925	35%
Dauphin	MB	91,	4	2,791	33%
Morden	MB	86,89,91	11	1,777	34%
Portage	MB	89,91	8	1,552	12%
Roblin	MB	89,91	8	698	38%
Selkirk	MB	91,92	8	2,520	26%
Steinbach	MB	86,89,91	12	2,167	26%
Swan River	MB	89,91	8	1,326	34%
Biggar	SK	89,91,92	12	1,001	43%
Estevan	SK	89,91,92	12	1,007	10%
Kamsack	SK	92,	3	903	39%
Nipawin	SK	91,92	8	538	12%
North Battleford	SK	91,92	8	1,569	11%
Swift Current	SK	92,	4	4,767	32%
Tisdale	SK	91,	4	1,043	34%
Weyburn	SK	89,91,92	12	1,399	14%

Of the communities with useable surveys, very few had water supply problems or conducted water conservation education schemes during the survey period. However many did indicate that for post survey years, conservation education programming was put in to effect. Table 6 offers a listing of the data variables and their sources as entered in to the database, while Table 7 provides a listing of the database variable statistics.

Table 6 - Excel 5.0 Database Variables and Sources.

Variable	Source
Town	Survey Design
Quarterly Water Demand	Survey - Municipal Records
Number of Residential Hookups	
Average household Income	Statistics Canada
Average Household Size	
Total Population	
Plant water demand	Environment Canada

Table 7 - Summary of Database Variable Statistics.

Variable	Mean	Standard Deviation	Minimum	Maximum	Median
Household Income	$39,348	$7,899	$26,821	$69,300	$37,828
Water usage (m^3/Q)	68	21	31	203	64
Available moisture (mm)	-128	73	-291	-12	-133
Rooms per house	6.3	.32	5.5	6.9	6.4
# Accounts	1,996	3,377	397	18,125	1,269

Summary

In summary, the data set is comprised of a number of municipalities for different years as illustrated in Table 5. The database consists of 206 observations (each observation is an aggregate of a sample of the community per quarter) from 25 separate communities for years ranging from 1986, 1989, 1991, and 1992. The average household income varied from $26,821 to

$69,300, with a median value of $37,828. The A_moisture (net available moisture) variable for the spring and summer ranged from -291 millimeters (mm) to –12 mm (net quarterly deficit) with a median value of -133 mm. Finally, the average quarterly consumption per hookup ranged from a low of 31 m^3 in the winter quarter of 1991 to a peak of 203 m^3 in the summer quarter of 1991.

For a typical community, the yearly total household water consumption was 273.35 m^3. This amounts to 288 liters per capita per day (LPCD) which is quite close to the Kulshrestha (1987) study average of 290 LPCD for the South Saskatchewan River Basin. Tate (1990) lists the 1987 average water demand for the semiarid western interior areas of Canada to be around 250 LPCD. In comparison to these earlier studies, it would appear that the water consumption values observed fall within the ranges discovered in earlier studies.

Chapter 3

Introduction

As the analysis proceeded and hypotheses were tested, several other demand variables were evaluated and excluded along with some *a priori* variables. Results and conclusions from this testing are presented later in Table 8 and in Appendix A. The following is a summary of the *a priori* model development and testing results leading to the final model selection.

Empirical Model

The demand function is specified in the previous section, with the inclusion of dummy variables to correspond with changes in billing periods. It is hypothesized that there may be structural changes that occur in different billing periods that the other variables may not capture. The demand functional form (log-linear) is specified as:

Quantity = B_o + B_1 Price + B_2 A_moisture + B_3 Income + B_4 D_Fall + B_5 D_Spring + B_6 D_Summer + B_7 D_Month + B_8 D_Bi-month + B_9 Rooms + e

where:

- Quantitiy = average household water consumption per community per quarter in cubic meters (m^3).

- Price = average price per m^3 as determined by the rate schedule from observed volumes, the marginal price (last active price block as per rate schedule) and associated PDIF for each community observation.

- A_moisture = Available moisture (precipitation - potential evapotranspiration of grass), measured in millimeters (mm).

- Income = average income for the household for the community.

- D_Fall = dummy (binary) variable for water consumption in the fall quarter.

- D_Spring = dummy variable for water consumption in the spring quarter.

- D_Summer = dummy variable for water consumption in the summer quarter.

- D_Month = dummy variable for communities with a monthly billing period.

- D_Bi-month = dummy variable for communities with a bi-monthly billing period.

- Rooms = average number of rooms per household per community.

- e = normal error term.

- $B_o,\ldots,B_9$ = unknown ordinary least squares coefficients to be estimated.

The average price variable was developed by taking observed water consumption volumes and generating total charges from the rate schedule[7]. The

[7] Water rate schedules for each community are listed in Appendix B, the schedules are adjusted to include fixed and sewer charges.

total charges were then divided by the total volume consumed. The A_moisture variable[8] is measured from April 1 to September 30 of each year, for each site. The dummy (binary) variables for D_Fall, D_Spring and D_Summer distinguish between the quarterly seasonal periods. While the dummy variables D_month and D_Bi-month are designed to capture any structural changes due to differences in billing schemes. Income, rooms and CPI data are sourced from the Statistics Canada database.

All income and price (average, marginal and PDIF) variables were adjusted by the CPI which is indicated by a " * " in front of the variable.

In order to test the log-linear model the A_moisture variable needed further transformation. Because of the seasonal nature relating to weather, plant evpotranspiration needs drop to zero in the fall and winter quarters. As a result negative and zero values exist in the data set of which log transformation is not a valid function. Therefore on the basis of a paper by Johnson and Rausser (1971), a methodology[9] was developed to transform the data.

Results

There were two forms of the demand function experimented with, one was a linear function and the other was a log-linear function. Testing was also conducted with two forms of water price (average price from the rate schedule

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[9] Description of the A_moisture variable and how it is generated is listed in Appendix A.

[10] Description of the methodology is in Appendix A.

and marginal price with PDIF). The loglinear function was selected as it appeared to offer better information with *a priori* variables. The marginal price and PDIF variables were dropped as the model testing results were statistically weaker. Other variables; D_Month, D_Bi-month and D_Fall, proved to be insignificant and were also dropped from the model. The results from the regressions are in Table 8.

Table 8: Regression analysis results

	Final Model Log-linear		Test Model Linear - Marginal		Test Model Linear - Average		Test Model Log-Linear - Marginal		Test Model Log-Linear - Average	
F-Statistic	44.04		17.3		21.86		22.73		31.59	
Adjusted R-Square	0.51		0.39		0.42		0.46		0.51	
Standard Error	0.19		16.41		16.04		0.20		0.19	
	Coefficient	T-Stat	Coefficient	T-Stat	Coefficient	T-Stat	Coefficient	T-Stat	Coefficient	T-Stat
Intercept	-2.03	**-2.74**	-34.75	*-1.19*	-26.63	*-0.96*	-1.94	*-1.97*	-1.80	-1.99
*Price	-0.26	**-7.98**	n/a		-22.31	**-5.98**	n/a		-0.25	**-7.30**
*Marg $	n/a		-19.92	**-4.95**	n/a		-0.16	**-5.34**	n/a	
*~PDIF	n/a		-0.12	*-1.47*	n/a		-0.02	*-0.74*	n/a	
*Income	0.35	**4.07**	0.00	*1.55*	0.00	*1.31*	0.31	**3.15**	0.32	**3.45**
Rooms	1.26	**4.11**	16.32	**3.29**	14.93	**3.09**	1.51	**4.00**	1.35	**3.77**
D_Summer	0.26	**7.98**	20.65	**7.33**	19.73	**7.16**	0.27	**7.94**	0.26	**8.00**
D_Spring	0.15	**4.70**	11.09	**3.95**	10.08	**3.67**	0.17	**4.97**	0.15	**4.71**
D_Month	n/a		-1.30	*-0.37*	0.73	*0.22*	-0.16	*-1.40*	-0.02	*-0.48*
D_Bimonth	n/a		8.18	**2.36**	7.24	**2.17**	0.06	*1.36*	0.03	*0.70*

n/a - variable not applicable
Bold T-Stat indicates a significant value at 99% confidence.

The signs of all the coefficients in the final model were consistent with *a priori* theoretical expectations. The variables for D_Month and D_Bi-month were not significant at the 95 percent level for the log-linear model. The removal of these variables did not significantly impact the coefficients or T-Statistics for the other variables in the model.

It is interesting to note that the binary variables for spring and summer are able to capture a relatively comparable amount of information in relation to the complex evapotranspiration variable. After the required log transformation was applied to the evapotranspiration variable, multicollinearity between the binary variables and the moisture variable was observed[10]. Given that the binary variable captures a shift in demand and a significant increase in additional demand occurs during periods of plant growth, both the evapotranspiration and binary variables by their nature capture similar information. The evapotranspiration variable is inefficient (in terms of effort and resources required to develop) versus the binary variables and so is dropped in favor of the binary variables.

For clarification, once the moisture variable was transformed the relationships measured by the variable also transformed. The variable now describes the increase in the quantity of water required by plants for a given amount of excess evapotranpiration over rainfall rather than the quantity required due to a moisture deficiency. The new terms of reference provide little information as to changes in water needs over the spring and summer periods, unless the researcher knows the given short fall of available moisture relative to maximum plant evoptranspirtation. The binary variables offer simpler and more direct information relating to structural changes in demand during the outdoor season (spring and summer). If a study were to use time series data to focus on a particular community, the evapotranspiration variable may provide

[10] This is further explained in Appendix A.

additional information that a binary variable could not. When the final model was run, all variables were statistically significant [11] (see Table 9). These results suggest that all the tested variables are important factors in residential water demand in the Western Prairies.

There was a statistical indication that outdoor use months resulted in an increased shift in water demanded. It was noticed that 15 percent more water is demanded in spring than in the fall/winter periods. In the summer months, 26 percent more water is demanded compared to fall/winter water demand.

Table 9: Estimated coefficients for Western Prairie Households.

SUMMARY OUTPUT **Log Linear Model ~ Average Price**

Regression Statistics	
Multiple R	0.72
R Square	0.52
Adjusted R Square	0.51
Standard Error	0.19
Observations	206

ANOVA

	Df	*SS*	*MS*	*F- Statistic*
Regression	5	7.89	1.58	44.04
Residual	200	7.16	0.04	
Total	205	15.05		

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.03	0.74	-2.74	0.006635	-3.48	-0.57
*Price	-0.26	0.03	-7.98	1.13E-13	-0.32	-0.19
*Income	0.35	0.09	4.07	6.86E-05	0.18	0.53
Rooms	1.29	0.31	4.11	5.77E-05	0.67	1.91
D_Spring	0.15	0.03	4.70	4.91E-06	0.09	0.22
D_Summer	0.26	0.03	7.98	1.11E-13	0.20	0.32
Critical T-Stat	**0.05 ~ (95%)**	**0.025 ~ (97.5%)**	**0.01 ~ (99%)**			
Critical Values	1.645	1.96	2.326			

[11] This conclusion is based on the t-test results. A t-value larger than 2.326 signifies that the coefficient is significantly different from zero with a 99% confidence and therefore, the effect of these variables is not likely to be coincidental.

Price and Income Elasticities:

The elasticity value is a measure of a relative change in one variable causing a relative change in another variable. It is expressed as the percentage change in quantity and price. More specifically, price elasticity is the volume change in the dependent variable (residential water use) due to a relative change in the independent variable (water price per unit), while income elasticity is the relative change in water use due to a relative change in income.

Various goods differ in response to changes in price or income levels. So it is important to determine what are the responses for the observed prices and incomes. There are three basic categories of elasticity values (in absolute terms). Inelastic demand occurs when the values are less than one. This means that quantity demanded will change by a smaller percentage than the change in price. Or, a one percent change in price will change quantity demanded by less than one percent. Unitary elastic demand indicates that a one percent change in price will lead to a one percent change in demand. While an elastic demand indicates that a one percent change in price will cause demand to change by more than one percent.

With a log-linear model the elasticities are simply the corresponding coefficient values (see table 9).

$$\text{Price elasticity} = \eta_{Price} = \frac{\partial lnQuantity_W}{\partial lnPrice_W} = \beta_W = -.26$$

$$\text{Income elasticity} = \eta_{Income} = \frac{\partial lnQuantity_W}{\partial lnIncome_I} = \beta_{INC} = .35$$

The water demanded by representative consumers of each community is relatively price inelastic (-.26) and income inelastic (.35) at observed prices.

A price elasticity of -.26 means that a 10 percent increase in the price of water will result in a 2.6 percent reduction in household use. This has an implication for future revenues when a price change occurs. It suggests that higher water charges will result in a net increase of total revenues, even though a net decrease in consumption occurs. For example, increasing the average rate from $1.00 per cubic meter to $1.10 per cubic meter would reduce consumption from 272 cubic meters per year to 265 cubic meters, while total charges to each household will move from $272 to $291.50.

McNeil and Tate (1993) reviewed a number of studies estimating the price elasticity of demand for residential, industrial and commercial users. As a group the elasticity estimates ranged from -.1 to -1.0. The median price elasticities ranged between -.2 and -.3. Observing Prairie households with a price elasticity of -.26 appears to conform with other users in terms of their consumption response to prices paid.

The income elasticity of .35 is also inelastic and implies that household consumption will increase at a slower pace than an increase in income. For example, Prairie community (A) with a 10 percent higher average income level than community (B) will have an average water demand that is 3.5 percent higher than that of (B). Income or household affluence is an important consideration in estimating a community's demand for water. The observed average Prairie household income was approximately $40,000 per year with water usage averaging 272 cubic meters. If household income increased 25 percent ($10,000), consumption would be expected to rise from 272 cubic meters per year to 296 cubic meters per year.

A large increase in water use is associated with an increase in the number of rooms per household. Again, if community (A) had 10% more rooms per household than community (B), A would be expected to consume 12.9% more water. This suggests that with more rooms there may be more water consuming devices or people present. Referring to Table 3, it can be seen that an additional bathroom could lead to a substantial increase in indoor water use. Indoor water use is defined largely by the presence of water consuming devices.

Seasonal Testing:

Different models are used to measure the price and income elasticity (see Table 10) for outdoor (spring and summer) and indoor (fall and winter) demands and do not allow direct comparisons. However, there appears to be a strong indication that residents are more price and income sensitive concerning outdoor uses.

Table 10: Analysis of indoor versus Outdoor Sensitivities

	Indoor		Outdoor		Outdoor (Spring)	
F-Statistic	16.54		29.63		25.70	
Adjusted R-Square	0.31		0.46		0.49	
Standard Error	0.18		0.20		0.19	
	Coefficient	T-Stat	Coefficient	T-Stat	Coefficient	T-Stat
Average Price	-0.18	-4.06	-0.34	-7.00	-0.33	-7.19
Average Income	0.28	2.35	0.40	3.11	0.42	3.31
Average Rooms	1.35	3.12	1.30	2.77	1.25	2.75
D_Spring	n/a		n/a		-0.11	2.79
D_Summer	n/a		n/a		n/a	

Results indicate that residents become more sensitive to pricing in the outdoor period with a price elasticity in the range of -.34 versus the indoor price elasticity of -.18. There is also an increase in sensitivity to income. Income appears to have a larger impact upon water demand than the price of water with respect to outdoor use. For indoor demand, income elasticity is .28 while for outdoor demand income elasticity is .40. Intuitively, this makes sense since it would be easier for consumers to alter water demand in response to price at peak use levels (outdoor demand) rather than at average use levels (indoor demand) which are in part dictated by the capital stock held. Communities may wish to conduct local studies to determine if a separate summer pricing (i.e. seasonal specific) schedule may be appropriate in allocating costs when upgrading water distribution systems to meet peak demand periods.

Summary

The results of the log-linear model (see Table 9) indicate that marginal price, average income, average rooms per dwelling, and that seasonal factors represented by the spring and summer binary variables are important in residential water demand in the western prairies. The average price elasticity for representative consumers of each community is relatively inelastic, having an estimated value of -.26. While the income elasticity is estimated at .35, which is also relatively inelastic. From these results it can be concluded that water demand in the sampled communities is both price and income inelastic at current prices.

Water demand increases significantly (expect a 12.9% increase with a 10% increase in room number) as the average number of rooms per dwelling increases. It is hypothesized that a portion of the additional rooms per dwelling contains water using appliances (such as a toilet). Referring to Table 3, it can be seen that an additional bathroom could lead to a substantial increase in indoor water use.

There was a statistical indication that outdoor use quarters have higher water demand. It was noticed that 15 percent more water is demanded in spring than in the fall/winter periods. In the summer months, 26 percent more water is demanded compared to fall/winter water demand. On average, spring and summer water consumption increased for all the communities surveyed.

Results from separate models for indoor and combined indoor/outdoor demands are not directly comparable. However, residents appear to become more price and income sensitive concerning combined indoor/outdoor uses. The combined indoor/outdoor period had a price elasticity in the range of -.26 versus the indoor price elasticity of -.18. For indoor demand, income elasticity is .28 while for indoor/outdoor demand income elasticity is .40. Intuitively, this makes sense since it would be easier for consumers to alter water demand in response to price at peak use levels (outdoor demand) rather than at average use levels (indoor demand) which are in-part dictated by the capital stock held.

Chapter 4

Review

Study Summary

Water bills often do not indicate the total cost of water because they do not reflect the true cost of system depreciation (replacement value) of the water distribution system. This happens if the initial costs of the water system were covered in part with Federal or Provincial subsidy payments (a one time cost sharing transfer collected through general taxes). At the same time, future water distribution system replacement costs are not captured through water bills alone, but also through general municipal taxes whenever an upgrade is needed or new distribution system is built. Therefore even though the consumer pays for water directly through water rates a significant portion of distribution system costs are captured indirectly through general tax rates.

It is theoretically possible to determine the total expenditure for water, once subsidies and general taxes are taken into account. However, the actual total expenditure will not help the researcher determine the consumer's response to price changes (elasticity) since the consumer can only respond to what is perceivable. Monies collected for water distribution systems through general taxes are not likely to be noticed by the consumer in relation to water use.

Therefore the perceived utility value (reflected by the elasticity value) upon which a utility maximizing consumer allocates resources is unobservable by using the actual (theoretical) cost since the consumer has not perceived the price. If a community is going to allocate scarce resources such as water and capital for distribution systems through water rate structures on a user cost basis, the actual reaction to price (perceived price) must be measured.

Survey Data

In summary, the data set is comprised of a number of municipalities for different years. The database consists of 206 observations from 25 separate communities for years ranging from 1986, 1989, 1991, and 1992. The average household income varied from \$26,821 to \$69,300, with a median value of \$37,828. In 1991, the average income for 23 of the 25 communities surveyed was \$39,905. The 1991 yearly average household expenditure for water was \$252 dollars with a total water consumption of 268 m^3. The average quarterly consumption per hookup ranged from a low of 31 m^3 in the winter quarter of 1991 to a peak of 203 m^3 in the summer quarter of 1991.

For a typical community over the study period, the yearly total household water consumption was 273.35 m^3. This amounts to 288 liters per capita per day (LPCD) which is quite close to Kulshrestha (1987) study average of 290 LPCD for the South Saskatchewan River Basin. Tate (1990) lists the 1987 average water demand for the semiarid western interior areas of Canada to be around 250 LPCD. In comparison to these earlier studies, it would appear that the water consumption values observed fall within the ranges defined by earlier work.

Testing Results

The results of the log-linear model indicate that average price, average income, average rooms per dwelling, and seasonal factors represented by the spring and summer binary variables are all important in residential water demand in the western prairies. The water demand by representative consumers of each community is relatively price and income inelastic, having an estimated price elasticity of -.26 and income elasticity of .35.

Water demand increased (expect 12.9% increase with a 10% increase in rooms) as the average number of rooms per dwelling increased. It is hypothesized that a portion of the additional rooms per dwelling contains water using appliances (such as a sink). Referring to Table 3, it can be seen that an additional bathroom could lead to a substantial increase in indoor water use.

There was a statistical indication that seasonal outdoor use resulted in an increased shift in the quantity of water demanded. It was noticed that 15 percent more water is consumed in the spring than in the fall/winter periods. In the summer months, 26 percent more water is consumed compared to that in the fall/winter months. On average, spring and summer water consumption increased for all the communities surveyed.

Separate models for indoor (fall and winter) and combined indoor/outdoor (spring and summer) demand were developed. Results from the separate models are not directly comparable, however residents appear to become more price and income sensitive concerning combined indoor/outdoor uses. The combined outdoor period had a price elasticity in the range of -.34 versus the indoor price elasticity of -.18. For indoor demand, income elasticity is .28 while for indoor/outdoor demand income elasticity is .40. Intuitively, this makes sense since it would be easier for consumers to alter water consumption in response to price at peak use levels (outdoor demand) rather than at average use levels (indoor demand) which are in part dictated by the capital stock held.

Conclusions

The complexity of the billing structure and funding for water projects is such that the consumer is unable to determine the true cost or price of water. Yet the utility maximizing consumer must make some form of a price proxy. This proxy is thought to be a simple average price if the consumer is faced with complex water billing structures and a relatively (with respect to total income) small water cost. If water is a small percentage of total income then the consumer may not be willing to undertake the necessary effort to determine the true marginal cost of water.

Findings:

- Water costs are a small proportion of household income on the Prairies. In 1991 the average yearly income was $39,905 while the average yearly water expenditure was $252. This works out to be less than 1 percent of the average household income.

- Water rates were found to be higher in the Prairies than the Canadian average.
- Water consumption on the Prairies is lower than the Canadian average.
- Test results indicate that consumers appear to be reacting to average prices rather than marginal prices.
- The estimated income and price elasticities are similar to the average of those previously estimated in other studies (See reports by Kulshrestha and Tate).

Caveats:

Even though the demand equation is developed using microeconomic theory, there are limitations in using aggregate data for measuring individual responsiveness. It should be realized that in using aggregate municipal data, the study results are only valid in terms of analyzing municipal usage by all residential households. As stated by Taylor (1975) "the coefficients and elasticity must be interpreted for what they are, as representing effects for the aggregates involved, rather than effects for individual consumers".

The objective of the study was to determine the response of municipalities in the Western Prairies, as measured by changes in the quantity of water demanded to changes in price. Municipalities would need to conduct further studies to determine their individual user price and income elasticities. Also the results are valid for the range of prices observed; if prices were to change significantly from the values observed, the price elasticity may change.

Implications:

- Consumers may perceive prices in terms of water bill averages due to the complex nature of the design of water rate structures. This is more likely the case where a small proportion of household income is spent on water. Consumers are likely to inaccurately estimate the marginal price for water when averaging. The degree of error will depend on the size of the fixed block charge and volume in relation to the marginal charge and the size of the total volume consumed.
- If a community is to redesign their water rate structure they should note that demand changes may occur if the consumer is able to determine the true marginal rate where an average proxy was used in the past. The size of the demand change will depend on the degree of error in the consumer's proxy for the marginal price.
- Due to the inelastic nature of the estimated consumer price sensitivity, communities in the Western Prairies in general could raise revenues through increasing water rates. If the higher water rates lead to the water bill becoming a significant portion of the household income the nature of the price elasticity could change.

- On the basis of the separate models for indoor and outdoor water demand, consumers appear to be more price and income sensitive to outdoor demands (peak period) rather than indoor demands. Water pricing may be an effective tool to efficiently ration scarce water supplies in peak periods.
- Further investigation would be required if a community considered pricing as a method of controlling peak demand.
- As noted earlier, it is believed that the application of the user-pay principle would promote cost recovery, equity, and efficiency in the allocation of water resources. Efficiency in the allocation of resources may lead to a side benefit of water conservation as a result of the reduction of water consumption due to changes in the rate structure. With study results indicating that water demand is price inelastic (-.26) it would appear that only a small benefit in water conservation would result from higher prices alone – at least with respect to the range of prices observed.

Appendix A

Evapotranspiration Variable

Introduction

Both Foster and Beattie (1979) and Reid Crowther and Partners (1992) indicate seasonal shifts in water demand are dependent upon temperature and moisture levels. Evapotranspiration is a means of measuring external temperature and moisture influences on plant (lawn) water needs. This variable may be important in explaining differences in water demand between communities with similar water rates or for changes in water use by a community for different years.

Moisture Variable Equation

A_moisture values are a composite of daily values for quarterly periods for each survey location. The values are determined by taking precipitation and subtracting the calculated potential evapotranspiration and summing the net values for the quarterly period. A positive net value suggests that there is no need to water lawns because sufficient moisture is available. Negative values indicate that the lawns would need more water for maximum growth. Equation [2] calculates the potential daily evapotranspiration (PE).

Equation [2]

$$= 25.4 * .0034 * (.928 * dmax(nday) + .933 * (dmax(nday) \\ - dmin(nday) = .0486 * Solar - 87.03)).$$

Where:

nday = day number from January 1

dmax(*nday*) = maximum temperature (^{O}F) for (nday)

dmin(*nday*) = minimum temperature (^{O}F) for (nday)

Solar = daily radiation received at the top of the atmosphere

In relation to summer water demand, the environmental component of the demand equation is expected to play a large part. It is hypothesized that the household will water their gardens and lawns only if local precipitation falls below the potential need for water by the vegetation.

Rosenberg et al (83) defines potential evapotranspiration (PE) as the "evaporation from an extended surface of a short green crop which fully shades the ground, exerts little or negligible resistance to the flow of water, and is always well supplied with water. Potential evapotranspiration cannot exceed free water evaporation under the same weather conditions." There are two physical processes involved in evapotranspiration. Evaporation is the physical process where a liquid or a solid is transferred to the gaseous state. Evaporation of water to the atmosphere takes place on many surfaces, the soil being one of them. The second process is called transpiration. Most of the water that evaporates at the plant surface has first passed through the plant itself. This water has entered the plant through the root system. It then travels through the vascular tissue to the leaves or other organs, and then exits into the surrounding air through the stomata and the cuticle (Rosenberg et al 1983). Since both of these processes occur simultaneously it is difficult to separate their activity. Therefore, the term evapotranspiration is used to describe the total water loss from any vegetative and land surface.

Several methods have been developed to calculate PE. The chosen technique is that developed by Baier and Robertson (1965). While this method has a recognized larger error in the estimate of PE, it is the only one that can be used with the limited data from available climatological stations. These stations provide daily maximum and minimum temperatures as well as daily precipitation amounts. This technique requires daily maximum and minimum temperatures along with Qo, solar energy at the top of the atmosphere. Another factor in favor of this technique is a study (Street et al 1986) which compared various PE equations. The study concluded that the Baier and Robertson (1965) technique was the one best suited to the study area, which comprised mainly of the Canadian Prairies.

A_moisture is calculated by taking total precipitation over the quarter and subtracting potential evapotranspiration (PE), both volumes are measured in millimeters (mm). The equation coefficient variable measures changes in residential water use per cubic meter on a percentage (%) basis to changes in the A_moisture in mm.

A calculation of the A_moisture variable was conducted for outdoor use periods (spring & summer) on the Western Canadian Prairies. This leaves zero values for 2 quarters (fall and winter), also the majority of the A_moisture values are negative indicating a net moisture short fall for most communities studied on the prairies.

The presence of negative values in the data set has implications for the functional form of the model being used. The effects of miss-specification of log-linear functions when sample values are zero or negative are defined in Johnson and Rausser's 1971 paper by the same title. Johnson and Rausser state that the presence of zero or negative observations in the sample leads to a problem in obtaining variable estimates when utilizing the log-linear form. The logarithmic transformation of the data leads to error results as the non-positive values that exist in the sample are not defined in real space. Therefore the A_moisture variable must be transformed in order to allow the model to be estimated.

Data Transformation:

The A_moisture variable originally measured the amount of water shortage for lawns by taking actual precipitation less potential plant evapotranspiration which resulted in negative values for all but two observations. There were also data points (Fall and Winter quarters) containing zero values indicating outdoor use for watering plants was negligible.

By using a reverse measure for plant water needs i.e. measuring how much potential evapotranspiration exceeded actual precipitation, positive values are generated for all but two observations which were considered outliers and removed. The problem of zero values was solved by adding a very small positive constant to all observations. The "~" designation in front of the variable indicates it was transformed with a positive constant. It is realized that this may introduce a measurement bias to the regression coefficients.

While the transformation process of the moisture variable introduces a measurement bias to the model it is still more desirable than the problem caused by miss-specification. However, transformation of the moisture variable also results in multicolinearity with the binary variables (spring and summer) in the model. Upon running the model separately with the two variables in question, it appears that the transformed evapotranspiration variable does not have significantly different results than when the binary variables are substituted.

Regression results are in Table 1 demonstrate that the coefficients from Net_Potevap (transformed A-moisture) variable are similar to those generated by the binary variable. It can also be seen that for each individual regression, all model variables are of the correct sign, magnitude, and significance. The model also appears to be robust as coefficients change little between the use of binary variables or the moisture variable.

	Final Model		Full Model		Net_Poteva	
Adjusted R-Square	0.55		0.55		0.53	
Standard Error	0.182		0.182		0.185	
	Coefficient	T-Stat	Coefficient	T-Stat	Coefficient	T-Stat
Intercept	-2.96	-4.09	-1.64	-1.54	-2.80	-3.81
***Price**	-0.31	-9.33	-0.30	-9.01	-0.31	-9.17
***Income**	0.42	5.06	0.42	5.06	0.42	4.98
Rooms	1.41	4.66	1.42	4.71	1.43	4.64
D_Spring	0.15	4.77	-1.31	-1.51	n/a	n/a
D_Summer	0.25	8.08	-1.22	-1.39	n/a	n/a
~Net_Potevap	n/a	n/a	0.03	1.68	0.005	7.82
F-Statistic	50.41		42.86		59.40	

A decision must be made as to what is the best method of dealing with the mullticolinearity problem. Given the robustness of the model as indicated by the similarity of regression results for other variables when binary variables are substituted with Net_Potevap, the most pragmatic solution would be to delete one of the variables which would solve the multicolinearity problem.

The crudeness of the potential evaporation model due to limited data (as explained earlier) and the similar regression results to the seasonal binary variables suggest that the explanatory power of the Net_Potevap equation is matched by the seasonal binary variables. In addition, the moisture variable is more inefficient due to the requirement of transformation which introduced a bias without adding significant information to the regression. Finally, the transformed moisture variable results are difficult to intuitively appreciate versus the results with the binary variables. Therefore the moisture variable is dropped from the estimating equation in favor of the binary variables.

PDIF Variable

This variable also had negative values that required a positive constant to over come the negative values. The "~" designation in front of the variable indicates it was transformed with a positive constant. While this knowingly introduced a bias, the magnitude of the bias is dependant upon the size of the constant and its effects can be evaluated for the PDIF variable and conditional values for the PDIF coefficient.

With the ability to measure the bias it was felt that it was worth running the model. As it turned out the correct price specification is the average price for this aggregated municipal level data set. Hewiit and Hanemann (1995) suggest a marginal price variable may be suitable in a discrete/continuos choice model that utilizes household level data.

Appendix B

Municipal Water Rates

						Water Rates $ / m3								
					Blk of	Basic		Unit	Block 1		Block 2		Block 3	
Year	Location	Prov.	Period	Quarter	Avg use	$	vol m3	$ / m3	$	vol m3	$	vol m3	$	vol m3
1991	Beausejour	MB	Q	Q1	1st blk	20.15	13.64		0.737	13 - 95.5	0.321	95.5 - 913		
1991	Beausejour	MB	Q	Q2	1st blk	20.15	13.64		0.737	13 - 95.5	0.321	95.5 - 913		
1991	Beausejour	MB	Q	Q3	1st blk	20.15	13.64		0.737	13 - 95.5	0.321	95.5 - 913		
1991	Beausejour	MB	Q	Q4	1st blk	20.15	13.64		0.737	13 - 95.5	0.321	95.5 - 913		
1989	Biggar	SK	B	Q1	1st blk	12.20	9.091		0.286	over 9.091				
1989	Biggar	SK	B	Q2	1st blk	12.20	9.091		0.286	over 9.091				
1989	Biggar	SK	B	Q3	1st blk	12.20	9.091		0.286	over 9.091				
1989	Biggar	SK	B	Q4	1st blk	12.20	9.091		0.286	over 9.091				
1991	Biggar	SK	B	Q1	1st blk	14.20	9.091		0.286	over 9.091				
1991	Biggar	SK	B	Q2	1st blk	14.20	9.091		0.286	over 9.091				
1991	Biggar	SK	B	Q3	1st blk	14.20	9.091		0.286	over 9.091				
1991	Biggar	SK	B	Q4	1st blk	14.20	9.091		0.286	over 9.091				
1992	Biggar	SK	B	Q1	1st blk	14.20	9.091		0.286	over 9.091				
1992	Biggar	SK	B	Q2	1st blk	14.20	9.091		0.286	over 9.091				
1992	Biggar	SK	B	Q3	1st blk	15.20	9.091		0.352	over 9.091				
1992	Biggar	SK	B	Q4	1st blk	15.20	9.091		0.352	over 9.091				
1989	Blackfalds	AB	M	Q1	Unit	23.68	18.181	1.295						
1989	Blackfalds	AB	M	Q2	Unit	23.68	18.181	1.295						
1989	Blackfalds	AB	M	Q3	Unit	23.68	18.181	1.295						
1989	Blackfalds	AB	M	Q4	Unit	23.68	18.181	1.295						
1991	Blackfalds	AB	M	Q1	Unit	23.68	18.181	1.295						
1991	Blackfalds	AB	M	Q2	Unit	23.68	18.181	1.295						
1991	Blackfalds	AB	M	Q3	Unit	23.68	18.181	1.295						
1991	Blackfalds	AB	M	Q4	Unit	23.68	18.181	1.295						
1992	Blackfalds	AB	M	Q1	Unit	23.68	18.181	1.295						
1992	Blackfalds	AB	M	Q2	Unit	23.68	18.181	1.295						
1992	Blackfalds	AB	M	Q3	Unit	23.68	18.181	1.295						
1992	Blackfalds	AB	M	Q4	Unit	23.68	18.181	1.295						
1991	Cochrane	AB	B	Q1	Unit	38.5	27.25	1.4						
1991	Cochrane	AB	B	Q2	Unit	40.42	27.25	1.48						

						Water Rates $ / m3								
					Blk of	Basic		Unit	Block 1		Block 2		Block 3	
Year	Location	Prov.	Period	Quarter	Avg use	$	vol m3	$ / m3	$	vol m3	$	vol m3	$	vol m3
1991	Cochrane	AB	B	Q3	Unit	40.42	27.25	1.48						
1991	Cochrane	AB	B	Q4	Unit	40.42	27.25	1.48						
1992	Cochrane	AB	B	Q1	Unit	40.42	27.25	1.48						
1992	Cochrane	AB	B	Q2	Unit	40.42	27.25	1.48						
1992	Cochrane	AB	B	Q3	Unit	40.42	27.25	1.48						
1992	Cochrane	AB	B	Q4	Unit	40.42	27.25	1.48						
1991	Dauphin	MB	Q	Q1	2nd blk	18.4	14.2		0.511	14.2 - 18.2	0.37	18.2 - 291		
1991	Dauphin	MB	Q	Q2	2nd blk	18.4	14.2		0.511	14.2 - 18.2	0.37	18.2 - 291		
1991	Dauphin	MB	Q	Q3	2nd blk	18.4	14.2		0.511	14.2 - 18.2	0.37	18.2 - 291		
1991	Dauphin	MB	Q	Q4	2nd blk	18.4	14.2		0.511	14.2 - 18.2	0.37	18.2 - 291		
1991	Drayton Valley	AB	M	Q1	2nd blk	9	0		1.36	0 - 40	0.92	40 - over		
1991	Drayton Valley	AB	M	Q2	2nd blk	9	0		1.36	0 - 40	0.92	40 - over		
1991	Drayton Valley	AB	M	Q3	2nd blk	9	0		1.36	0 - 40	0.92	40 - over		
1991	Drayton Valley	AB	M	Q4	2nd blk	9	0		1.36	0 - 40	0.92	40 - over		
1992	Drayton Valley	AB	M	Q1	2nd blk	12	0		1.43	0 - 40	0.98	40 - over		
1992	Drayton Valley	AB	M	Q2	2nd blk	12	0		1.43	0 - 40	0.98	40 - over		
1992	Drayton Valley	AB	M	Q3	2nd blk	12	0		1.43	0 - 40	0.98	40 - over		
1992	Drayton Valley	AB	M	Q4	2nd blk	12	0		1.43	0 - 40	0.98	40 - over		
1989	Estevan	SK	Q	Q1	1st blk	39.75	36.364		0.627	36 - 218	0.517	218 - 491	0.495	over 491
1989	Estevan	SK	Q	Q2	1st blk	39.75	36.364		0.627	36 - 218	0.517	218 - 491	0.495	over 491
1989	Estevan	SK	Q	Q3	1st blk	39.75	36.364		0.627	36 - 218	0.517	218 - 491	0.495	over 491
1989	Estevan	SK	Q	Q4	1st blk	39.75	36.364		0.627	36 - 218	0.517	218 - 491	0.495	over 491
1991	Estevan	SK	Q	Q1	1st blk	43.75	36.364		0.693	36 - 218	0.572	218 - 491	0.55	over 491
1991	Estevan	SK	Q	Q2	1st blk	43.75	36.364		0.693	36 - 218	0.572	218 - 491	0.55	over 491
1991	Estevan	SK	Q	Q3	1st blk	43.75	36.364		0.693	36 - 218	0.572	218 - 491	0.55	over 491
1991	Estevan	SK	Q	Q4	1st blk	43.75	36.364		0.693	36 - 218	0.572	218 - 491	0.55	over 491
1992	Estevan	SK	Q	Q1	1st blk	51.5	36.364		0.814	36 - 218	0.671	218 - 491	0.649	over 491
1992	Estevan	SK	Q	Q2	1st blk	51.5	36.364		0.814	36 - 218	0.671	218 - 491	0.649	over 491
1992	Estevan	SK	Q	Q3	1st blk	51.5	36.364		0.814	36 - 218	0.671	218 - 491	0.649	over 491
1992	Estevan	SK	Q	Q4	1st blk	51.5	36.364		0.814	36 - 218	0.671	218 - 491	0.649	over 491

						Water Rates $ / m3								
					Blk of	Basic		Unit	Block 1		Block 2		Block 3	
Year	Location	Prov.	Period	Quarter	Avg use	$	vol m3	$ / m3	$	vol m3	$	vol m3	$	vol m3
1991	Fort McMurray	AB	B	Q1	3rd Blk	21.18	0		0.736	1 - 23	0.9796	24 - 45	1.0055	45 - over
1991	Fort McMurray	AB	B	Q2	3rd Blk	21.18	0		0.736	1 - 23	0.9796	24 - 45	1.0055	45 - over
1991	Fort McMurray	AB	B	Q3	3rd Blk	21.18	0		0.736	1 - 23	0.9796	24 - 45	1.0055	45 - over
1991	Fort McMurray	AB	B	Q4	3rd Blk	21.18	0		0.736	1 - 23	0.9796	24 - 45	1.0055	45 - over
1989	Grimshaw	AB	M	Q1	Basic	26.5	18	1.47	0.352	18 - over				
1989	Grimshaw	AB	M	Q2	Basic	26.5	27.3	0.971	0.352	27.3 - over				
1989	Grimshaw	AB	M	Q3	Basic	26.5	27.3	0.971	0.352	27.3 - over				
1989	Grimshaw	AB	M	Q4	Basic	26.5	18	1.47	0.352	18 - over				
1991	Grimshaw	AB	M	Q1	1st Blk	26.5	18	1.47	0.352	18 - over				
1991	Grimshaw	AB	M	Q2	Basic	26.5	27.3	0.971	0.352	27.3 - over				
1991	Grimshaw	AB	M	Q3	Unit	17.1	0	0.667						
1991	Grimshaw	AB	M	Q4	Unit	17.1	0	0.667						
1992	Grimshaw	AB	M	Q1	Unit	17.1	0	0.667						
1992	Grimshaw	AB	M	Q2	Unit	17.1	0	0.667						
1992	Grimshaw	AB	M	Q3	Unit	17.1	0	0.667						
1992	Grimshaw	AB	M	Q4	Unit	17.1	0	0.667						
1991	Innisfail	AB	B	Q1	Unit	8.4	11.345	0.74						
1991	Innisfail	AB	B	Q2	Unit	8.4	11.345	0.74						
1991	Innisfail	AB	B	Q3	Unit	8.4	11.345	0.74						
1991	Innisfail	AB	B	Q4	Unit	8.4	11.345	0.74						
1992	Innisfail	AB	B	Q1	Unit	9.37	11.345	0.824						
1992	Innisfail	AB	B	Q2	Unit	9.37	11.345	0.824						
1992	Innisfail	AB	B	Q3	Unit	9.37	11.345	0.824						
1992	Innisfail	AB	B	Q4	Unit	9.37	11.345	0.824						
1992	Kamsack	SK	B	Q1	3rd blk	13	17	0.765	0.495	17 - 22.65	0.706	22.65 - 35.4	0.777	35.4 - over
1992	Kamsack	SK	B	Q2	3rd blk	13	17	0.765	0.495	17 - 22.65	0.706	22.65 - 35.4	0.777	35.4 - over
1992	Kamsack	SK	B	Q3	3rd blk	13	17	0.765	0.495	17 - 22.65	0.706	22.65 - 35.4	0.777	35.4 - over
1992	Kamsack	SK	B	Q4	3rd blk	13	17	0.765	0.495	17 - 22.65	0.706	22.65 - 35.4	0.777	35.4 - over
1991	Lethbridge	AB	M	Q1	Unit	11.76	0	0.294						
1991	Lethbridge	AB	M	Q2	Unit	11.76	0	0.294						

						Water Rates $ / m3								
					Blk of	Basic		Unit	Block 1		Block 2		Block 3	
Year	Location	Prov.	Period	Quarter	Avg use	$	vol m3	$ / m3	$	vol m3	$	vol m3	$	vol m3
1991	Lethbridge	AB	M	Q3	Unit	11.76	0	0.294						
1991	Lethbridge	AB	M	Q4	Unit	11.76	0	0.294						
1992	Lethbridge	AB	M	Q1	Unit	12.71	0	0.318						
1992	Lethbridge	AB	M	Q2	Unit	12.71	0	0.318						
1992	Lethbridge	AB	M	Q3	Unit	12.71	0	0.318						
1992	Lethbridge	AB	M	Q4	Unit	12.71	0	0.318						
1986	Morden	MB	Q	Q1	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1986	Morden	MB	Q	Q2	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1986	Morden	MB	Q	Q3	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1986	Morden	MB	Q	Q4	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1989	Morden	MB	Q	Q1	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1989	Morden	MB	Q	Q2	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1989	Morden	MB	Q	Q3	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1989	Morden	MB	Q	Q4	1st blk	16.45	13.64		0.583	13.6 - 90.9	0.528	90.9 - 454.5		
1991	Morden	MB	Q	Q1	1st blk	19.5	13.64		0.77	13.6 - 90.9	0.66	90.9 - 454.5		
1991	Morden	MB	Q	Q2	1st blk	19.5	13.64		0.77	13.6 - 90.9	0.66	90.9 - 454.5		
1991	Morden	MB	Q	Q3	1st blk	19.5	13.64		0.77	13.6 - 90.9	0.66	90.9 - 454.5		
1991	Morden	MB	Q	Q4	1st blk	19.5	13.64		0.77	13.6 - 90.9	0.66	90.9 - 454.5		
1991	Nipawin	SK	Q	Q1	Unit	16	13.64	0.924						
1991	Nipawin	SK	Q	Q2	Unit	16	13.64	0.924						
1991	Nipawin	SK	Q	Q3	Unit	16	13.64	0.924						
1991	Nipawin	SK	Q	Q4	Unit	16	13.64	0.924						
1992	Nipawin	SK	Q	Q1	Unit	16	13.64	0.924						
1992	Nipawin	SK	Q	Q2	Unit	16	13.64	0.924						
1992	Nipawin	SK	Q	Q3	Unit	16	13.64	0.924						
1992	Nipawin	SK	Q	Q4	Unit	16	13.64	0.924						
1991	North Battleford	SK	Q	Q1	1st blk	10.65	15		0.71	0 - 100	0.6	100 - 500		
1991	North Battleford	SK	Q	Q2	3rd blk	10.65	15		0.71	0 - 30	0.38	30 - 50	0.71	50 - 100
1991	North Battleford	SK	Q	Q3	3rd blk	10.65	15		0.71	0 - 30	0.38	30 - 50	0.71	50 - 100
1991	North Battleford	SK	Q	Q4	1st blk	10.8	15		0.72	0 - 100	0.61	100 - 500		

						Water Rates $ / m3								
					Blk of	Basic		Unit	Block 1		Block 2		Block 3	
Year	Location	Prov.	Period	Quarter	Avg use	$	vol m3	$ / m3	$	vol m3	$	vol m3	$	vol m3
1992	North Battleford	SK	Q	Q1	1st blk	10.8	15		0.72	0 - 100	0.61	100 - 500		
1992	North Battleford	SK	Q	Q2	3rd blk	10.8	15		0.72	0 - 30	0.39	30 - 50	0.72	50 - 100
1992	North Battleford	SK	Q	Q3	3rd blk	10.8	15		0.72	0 - 30	0.39	30 - 50	0.72	50 - 100
1992	North Battleford	SK	Q	Q4	1st blk	10.8	15		0.72	0 - 100	0.61	100 - 500		
1989	Oyen	AB	M	Q1	Basic	23	27.273		1.43	over 27				
1989	Oyen	AB	M	Q2	Basic	23	27.273		1.43	over 27				
1989	Oyen	AB	M	Q3	1st blk	23	27.273		1.43	over 27				
1989	Oyen	AB	M	Q4	Basic	23	27.273		1.43	over 27				
1991	Oyen	AB	M	Q1	Basic	30	27.273		1.859	over 27				
1991	Oyen	AB	M	Q2	Basic	30	27.273		1.859	over 27				
1991	Oyen	AB	M	Q3	1st blk	30	27.273		1.859	over 27				
1991	Oyen	AB	M	Q4	Basic	30	27.273		1.859	over 27				
1992	Oyen	AB	M	Q1	Basic	30	27.273		1.859	over 27				
1992	Oyen	AB	M	Q2	Basic	30	27.273		1.859	over 27				
1992	Oyen	AB	M	Q3	Basic	30	27.273		1.859	over 27				
1992	Oyen	AB	M	Q4	Basic	30	27.273		1.859	over 27				
1991	Ponoka	AB	M	Q1	Unit	16.97	0	0.44						
1991	Ponoka	AB	M	Q2	Unit	16.97	0	0.44						
1991	Ponoka	AB	M	Q3	Unit	16.97	0	0.44						
1991	Ponoka	AB	M	Q4	Unit	16.97	0	0.44						
1992	Ponoka	AB	M	Q1	Unit	16.97	0	0.44						
1992	Ponoka	AB	M	Q2	Unit	16.97	0	0.44						
1992	Ponoka	AB	M	Q3	Unit	16.97	0	0.44						
1992	Ponoka	AB	M	Q4	Unit	16.97	0	0.44						
1989	Portage	MB	Q	Q1	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		
1989	Portage	MB	Q	Q2	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		
1989	Portage	MB	Q	Q3	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		
1989	Portage	MB	Q	Q4	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		
1991	Portage	MB	Q	Q1	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		
1991	Portage	MB	Q	Q2	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		

						Water Rates $ / m3								
					Blk of	Basic		Unit	Block 1		Block 2		Block 3	
Year	Location	Prov.	Period	Quarter	Avg use	$	vol m3	$ / m3	$	vol m3	$	vol m3	$	vol m3
1991	Portage	MB	Q	Q3	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		
1991	Portage	MB	Q	Q4	1st blk	33.15	13.64		1.595	13.64 - 227	0.889	227 - 2273		
1989	Roblin	MB	Q	Q1	1st blk	20.88	14		1.07	14 - 114	0.191	114 - 1135		
1989	Roblin	MB	Q	Q2	1st blk	20.88	14		1.07	14 - 114	0.191	114 - 1135		
1989	Roblin	MB	Q	Q3	1st blk	20.88	14		1.07	14 - 114	0.191	114 - 1135		
1989	Roblin	MB	Q	Q4	1st blk	20.88	14		1.07	14 - 114	0.191	114 - 1135		
1991	Roblin	MB	Q	Q1	1st blk	29.8	15		1.42	15 - 115	0.249	115 - 1115		
1991	Roblin	MB	Q	Q2	1st blk	29.8	15		1.42	15 - 115	0.249	115 - 1115		
1991	Roblin	MB	Q	Q3	1st blk	29.8	15		1.42	15 - 115	0.249	115 - 1115		
1991	Roblin	MB	Q	Q4	1st blk	29.8	15		1.42	15 - 115	0.249	115 - 1115		
1991	Selkirk	MB	Q	Q1	1st blk	19.6	13.64		0.825	14 - 114	0.748	114 - 477	0.506	477 - 2136
1991	Selkirk	MB	Q	Q2	1st blk	19.6	13.64		0.825	14 - 114	0.748	114 - 477	0.506	477 - 2136
1991	Selkirk	MB	Q	Q3	1st blk	19.6	13.64		0.825	14 - 114	0.748	114 - 477	0.506	477 - 2136
1991	Selkirk	MB	Q	Q4	1st blk	19.6	13.64		0.825	14 - 114	0.748	114 - 477	0.506	477 - 2136
1992	Selkirk	MB	Q	Q1	1st blk	27.45	13.64		1.023	14 - 227	0.825	227 - 2045		
1992	Selkirk	MB	Q	Q2	1st blk	27.45	13.64		1.023	14 - 227	0.825	227 - 2045		
1992	Selkirk	MB	Q	Q3	1st blk	27.45	13.64		1.023	14 - 227	0.825	227 - 2045		
1992	Selkirk	MB	Q	Q4	1st blk	27.45	13.64		1.023	14 - 227	0.825	227 - 2045		
1986	Steinbach	MB	Q	Q1	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1986	Steinbach	MB	Q	Q2	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1986	Steinbach	MB	Q	Q3	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1986	Steinbach	MB	Q	Q4	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1989	Steinbach	MB	Q	Q1	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1989	Steinbach	MB	Q	Q2	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1989	Steinbach	MB	Q	Q3	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1989	Steinbach	MB	Q	Q4	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1991	Steinbach	MB	Q	Q1	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1991	Steinbach	MB	Q	Q2	1st blk	16.3	13.64		0.462	13.6 - 227.5	0.363	227.5 - 1137.5		
1991	Steinbach	MB	Q	Q3	1st blk	19.8	13.64	0.352						
1991	Steinbach	MB	Q	Q4	1st blk	19.8	13.64	0.352						

						Water Rates $ / m3								
					Blk of	Basic		Unit	Block 1		Block 2		Block 3	
Year	Location	Prov.	Period	Quarter	Avg use	$	vol m3	$ / m3	$	vol m3	$	vol m3	$	vol m3
1989	Swan River	MB	Q	Q1	1st blk	22.55	13.64	1.067						
1989	Swan River	MB	Q	Q2	1st blk	22.55	13.64	1.067						
1989	Swan River	MB	Q	Q3	1st blk	22.55	13.64	1.067						
1989	Swan River	MB	Q	Q4	1st blk	22.55	13.64	1.067						
1991	Swan River	MB	Q	Q1	1st blk	25.55	13.64	1.287						
1991	Swan River	MB	Q	Q2	1st blk	25.55	13.64	1.287						
1991	Swan River	MB	Q	Q3	1st blk	25.55	13.64	1.287						
1991	Swan River	MB	Q	Q4	1st blk	25.55	13.64	1.287						
1992	Swift Current	SK	M	Q1	Unit	6.25	12	0.759						
1992	Swift Current	SK	M	Q2	Unit	6.25	12	0.759						
1992	Swift Current	SK	M	Q3	Unit	6.25	12	0.759						
1992	Swift Current	SK	M	Q4	Unit	6.25	12	0.759						
1991	Tisdale	SK	Q	Q1	Unit	11.5	13.64	0.805						
1991	Tisdale	SK	Q	Q2	Unit	11.5	13.64	0.805						
1991	Tisdale	SK	Q	Q3	Unit	11.5	13.64	0.805						
1991	Tisdale	SK	Q	Q4	Unit	11.5	13.64	0.805						
1989	Weyburn	SK	B	Q1	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1989	Weyburn	SK	B	Q2	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1989	Weyburn	SK	B	Q3	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1989	Weyburn	SK	B	Q4	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1991	Weyburn	SK	B	Q1	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1991	Weyburn	SK	B	Q2	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1991	Weyburn	SK	B	Q3	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1991	Weyburn	SK	B	Q4	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1992	Weyburn	SK	B	Q1	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1992	Weyburn	SK	B	Q2	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1992	Weyburn	SK	B	Q3	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550
1992	Weyburn	SK	B	Q4	2nd blk	5.25	0		0.58	0 - 9	0.56	9 - 270	0.54	270 - 2550

Appendix C

Survey Forms

Location: ________________
Name: ________________
Position: ________________

If you have any questions regarding this survey please contact:
Rick Dzisiak at (204) 474-9309 or fax (204) 261-7251.

Billing Period: expected to be monthly, bi-monthly, or quarterly.

- number of hookups per Domestic account should be for that specific billing period.

- please enclose photocopies of water rate schedules for corresponding years.

Domestic Accounts only.

Year
1986

Billing period	Total Volume		Total Revenues		# of hookups per	% ~ Domestic
Date	gallons	cubic meters	gallons	cubic meters	Domestic account	vs Total Output

Number of Domestic hookups per meter size.

	gallons	metric
5/8"		
3/4"		
1"		
1 1/2"		
2", etc.		

Please answer; are there any extra policies to the rate schedule ? (example: in summer months 1000 gallons/quarter maybe included free in the minimum rate).
If so, please specify ____

____

Have there been any water consumption restricitions for 1986, 1989, and 1991? (example: due to drought or system breakdowns.)
If so, please specify ____

____

Lastly, has your organization undertaken any activities to promote water conservation (i.e. pamphlets with water bills, radio messages, etc.) over the survey period?
If so, please specify ____

____

General Survey Questions:

If you have any questions regarding this survey please contact: Rick Dzisiak at (204) 474-9309 or fax (204) 261-7251.

1 If your water meters are in gallons, are they Imperial or U.S.?

____

2 User group definitions; fill in information for these three water account types (categories), circle the corresponding groupings for your organization (please note any changes over the survey period):

Domestic: - single family, duplex, apartments, personal care-homes. Other ____________________

Commercial: - apartments, restaurants, small offices, car washes, light manufac Other ____________________

Institutional: - personal care-homes, jails, hospitals, schools. Other ____________________

Percentage of Pumpage	1986	1989	1991
Dom.			
Com.			
Inst.			
	100%	100%	100%

3 If the groupings in question two do not apply to your situation, list your account types and the groups that fall into each category.

____

____

____

____

____

When the forms are completed, they may be sent by fax to the number appearing at the top of the page.
Or if more convenient, sent by mail to:

Rick Dzisiak, Agriculture Building, Room 46
Agricultural Economics and Farm Management
University of Manitoba
Winnipeg, Manitoba R3T 2N2

Location: ____________
Name: ____________
Position: ____________

If you have any questions regarding this survey please contact:
Rick Dzisiak at (204) 261-7251 or fax (204) 261-7251.

Billing Period: expected to be monthly, bi-monthly, or quarterly.

- number of hookups per Domestic account should be for that specific billing period.

- please enclose photocopies of water rate schedules for corresponding years.

Domestic Accounts only.

Year
1992

Billing period	Total Volume		Total Revenues		# of hookups per	% ~ Domestic
Date	gallons	cubic meters	gallons	cubic meters	Domestic account	vs Total Output

Number of Domestic hookups per meter size.

	gallons	metric
5/8"		
3/4"		
1"		
1 1/2"		
2", etc.		

Please answer; are there any extra policies to the rate schedule ? (example: in summer months 1000 gallons/quarter maybe included free in the minimum rat
If so, please specify ____________

Have there been any water consumption restricitions for 1986, 1989, and 1991? (example: due to drought or system breakdowns.)
If so, please specify ____________

Lastly, has your organization undertaken any activities to promote water conservation (i.e. pamphlets with water bills, radio messages, etc.) over the survey per
If so, please specify ____________

General Survey Questions:

If you have any questions regarding this survey please contact: Rick Dzisiak at (204) 231-5121 or fax (204) 261-7251.

1 If your water meters are in gallons, are they Imperial or U.S.?

____

2 User group definitions; please fill in any missing information for this water account category circle the (circle the corresponding groupings for your organization), please note any changes over the survey period:
Domestic: - single family, duplex, apartments, personal care-homes.
Other ______________________________________

3 If the grouping in question two do not apply to your situation, list your Domestic account groups that fall into each category.

____
____
____

	Percentage of Pumpage 1986	1989	1991
Domestic			
Commercial			
Industrial			
	========	========	========
	100%	100%	100%

When the forms are completed, they may be sent by fax to the number appearing at the top of the page.
Or if more convenient, sent by mail to:

Rick Dzisiak, Agriculture Building, Room 403
Agricultural Economics and Farm Management
University of Manitoba
Winnipeg, Manitoba R3T 2N2

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