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Domestic Water Use: The Relevance of Rurality in Quantity Used and Perceived Quality

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Highlights

- **One-third of rural and small town residents rely on private wells for their drinking water.**
- **Rural residents connected to a municipal water system have a higher per capita use of water than urban residents.**
- **Water use appears to have a stronger association with economic incentives than with location characteristics. Households in areas with a higher proportion of water meters use less water than households in areas with a lower proportion of water metering.**
- **For households using tap water for drinking, rural households are less likely to treat their water than urban households.**
- **Locational characteristics are significant factors in determining perception of water quality as measured by the choice of treating tap water for domestic consumption. Water source (municipal systems or private wells) does not seem to affect water quality perception.**

Introduction

Water supply and management is a growing concern for residents of rural and urban municipalities in Canada. Over the past few years, several cases of water contamination and an intensified debate on environmental problems have increased the attention of the general public to water issues. In decision-making, as well as in the public debate, there are two major dimensions that come into play: growing water demand and ensuring good water quality. With the expansion of urban agglomerations, the management of this natural resource is also becoming a new area of potential tension and/or collaboration between municipalities that typically have different patterns of water utilization and management systems, such as rural and urban municipalities.

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Symbols

The following standard symbols are used in Statistics Canada publications:

.	not available for any reference period
..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published

Concerns about water scarcity have global and long-term implications. However, in a local perspective, as water is normally supplied by municipal governments, "scarcity" assumes a specific connotation. The constraint on water supply is typically determined by the conditions and capacity of municipal infrastructures. The status of these infrastructures has become, or is expected to become in the near future, a limiting factor to further growth for some municipalities. It is a dilemma that municipal governments have noticed, and they have begun to take action to manage water demand (Kingston Whig-Standard, 2006; Munro, 2004).

There is often a heated debate about which policy focus, or which combination of measures, a municipality should implement. The options range from costly investment in new infrastructures that often source water from neighbouring jurisdictions, to improved maintenance of existing infrastructure and water saving practices, to various economic incentives to reduce water use, such as metering and fees based on amount used.

This growth in water demand has been paralleled by growing concern about the quality of domestic water supply. In the 1990s, several cases of municipal water contamination received extensive media coverage and raised public awareness about the importance of water quality control. As a result of these cases, some provincial governments adopted specific legislation that set minimum standards and testing procedures for municipal water (Brennan, 2005). However, the understanding of the relationship between household perception and household practices regarding water quality is not well documented.

This analysis focuses on the effect of "rurality" in determining:

1. per capita water use at the municipal level; and
2. water quality perception of a household, as proxied by the water treatment choice of a household.

The baseline data presented in this bulletin indicate that, on average, water used for domestic purposes is higher in rural municipalities than in urban ones, but that rural households who drink tap water[1] are less likely to treat the water than urban households. Both the amount used and the perception of quality perception might be affected by location characteristics. On the one hand, the sparse settlement patterns of rural areas offer more opportunities for recreational uses of water (pools, gardens, etc), which in turn could explain the higher amounts used. On the other hand, a relatively high reliance on private sources of water (in particular wells) or different socio-economic characteristics of rural households could be a key factor in explaining higher confidence in the quality of water used at home.

Two data sources are used in the analysis: the Municipal Water and Wastewater Survey (MWWS) database 2004 of Environment Canada (Environment Canada, 2007b) and the Households and the Environment Survey, 2006 of Statistics Canada (Statistics Canada, 2006) (Box 1).

1. "Tap water" is literally water from a tap in the house, regardless of the source of the water (municipal system, private well, etc.)

Box 1 Data source

This analysis is based on two data sources: the Municipal Water and Wastewater Survey (MWWS), 2004 (Environment Canada, 2007b) and the Households and the Environment Survey, 2006 (Statistics Canada, 2006).

Municipal Water and Wastewater Survey (MWWS) 2004, produced by Environment Canada, was based on the previous Municipal Water Use (MUD) survey. Compared to its predecessor survey, MWWS 2004 introduced several changes in the questionnaire and, for the first time, included returns from 660 rural municipalities and small incorporated towns with less than 1,000 residents (Environment Canada, 2007a). As indicated by Environment Canada (2007a), the total usable survey base for 2004 includes 1,418 municipalities, representing about 28.9 million Canadians (or about 90% of the estimated Canadian population for that year). However, almost half of these municipalities were included in the database only after imputation and adjustment of previous MUD data. The response rates of MWWS 2004 varied substantially by question (Environment Canada, 2007a).

The database used for the computations in this paper retained 1,009 municipalities, for which data on the variables of interest were available. Appendix Table A.1 shows the count and population distribution of these municipalities by type of region. Some additional observations with invalid responses on specific variables were further excluded from the multivariate analysis. The MWWS 2004 variables were weighted by the population served by the municipal system to obtain summary statistics.

The Households and the Environment Survey (HES) 2006, conducted by Statistics Canada, was based on the sample frame of the Labour Force Survey and had a sample size of 28,334 households. Households were categorized into Census Metropolitan Areas (CMAs), Census Agglomerations (CAs), and non-CMA/CA areas (Box 2). Rural households were defined as any household that is not within a CMA or CA. All HES 2006 variables used in this analysis were weighted using survey weights, both for summary statistics and for regressions analysis. Given the complex sampling design of the HES 2006, standard errors and levels of significance for the estimates were calculated using a bootstrap method of re-sampling (Box 3).

For further details on these data sources see Environment Canada (2007a and 2007b) and Statistics Canada (2006).

Box 2 Definitions: geography and regional types

This analysis uses the Rural and Small Town (RST) definition for rural areas, which distinguishes between Census Metropolitan Areas, Census Agglomerations and Rural and Small Town areas; this is complemented by a classification of rural areas into Metropolitan Influenced Zones (MIZ) (du Plessis *et al.*, 2002). Incorporated towns and municipalities (Census Subdivisions or CSDs) are the building blocks for the delineation of CMAs, CAs and the MIZ zones. Hence, we applied this regional typology to the CSDs in the MWWS 2004 database.

It should be noted that MWWS 2004 extended the survey to rural municipalities with population of less than 1,000 individuals (the previous MUD included only municipalities with a population of over 1,000). However, in the database used for this analysis, these CSDs represent only about 5% the sample. In consequence, the statistics for rural should be interpreted primarily as Rural and Small Town municipalities with 1,000 or more residents and which are not part of a CMA or a CA. Appendix Table A.1 provides further details on the distribution of municipalities in the database by type of region.

A **Census Metropolitan Area (CMA)** has an urban core population of 100,000 and over. In this paper, CMAs have been divided into three groups based on population size: (1) **Larger CMA**, with population greater than 1.5 million (these are Toronto, Montreal and Vancouver); (2) **Medium CMA**, with population of 0.5 to 1.5 million people; and (3) **Smaller CMA**, with a population of less than 0.5 million people. A **Census Agglomeration (CA)** has an urban core population of 10,000 to less than 100,000. Both CMAs and CAs include all neighbouring municipalities where 50% or more of the workforce commutes to the urban core.

Rural and Small Town (RST) areas are towns or municipalities outside the commuting zone of CMAs and CAs. RST areas are disaggregated into four **Metropolitan Influenced Zones** (MIZ) based on the size of commuting flows of the workforce to any CMA or CA. The **strong MIZ** category comprises areas with a commuting flow of 30% or more. The **moderate MIZ** category comprises areas with a commuting flow between 5% and less than 30%. The **weak MIZ** category comprises areas with a commuting flow of more than 0% and less than 5%. The **no MIZ** category comprises those areas where no individuals commute to a CMA/CA; this category is collapsed with the weak MIZ group due to the small number of observations in the database.

To maintain consistency in the reporting of our results, we also present the results of the Households and the Environment Survey in terms of CMAs, CAs and MIZ zones.

We recognize that there are census urban residents (in settlements of 1,000 or more) and census rural residents (in the countryside and in settlements smaller than 1,000) within each CMA, CA and MIZ (du Plessis *et al.*, 2002). Consequently, our use of the CSD as the geographic unit of analysis will sometimes include residents of a town with a municipal water provider plus nearby countryside residents who would obtain their water from a private source.

Box 2 Definitions (continued): water consumption and measurement

The key definitions concerning water use are indicated below. For more details see also Environment Canada (1999 and 2007b) and Statistics Canada (2006).

Water destination. Three destinations or "sectors" are shown in the MWWS database: **domestic** (i.e. all household users); **commercial/industrial** (i.e. all manufacturing and businesses uses); and **other** which includes system losses and unaccounted uses (which, according to Environment Canada (1999), is believed to be under-reported). The total water use is the sum of these three destinations.

Measure of water used. Average daily total water use per capita (also referred to as total water use per day, per capita) is calculated by dividing the total daily water flow in each area (for example, CMA or strong MIZ) by the population served. **Average daily domestic water use per capita** (also referred to as domestic water use per day, per capita) is the water flowing through municipal water systems that is consumed by domestic or household users. These estimates are generated by dividing the domestic water flow of each municipal system by the population served.

Source of domestic water consumption. Municipal systems are water distribution centers that are run by municipalities and distribute water to residents who are connected to the system. **Private wells** are individual systems (usually paid for by the owner of the property) used by the private owner to obtain water.

Water metering. The **degree of metering** refers to the percent of total water flow that is metered for purposes of monitoring water use (used to determine the water use fee). It is estimated by municipal managers. Areas classified as "**high metering**" are municipal systems with more than 90% of serviced households being metered. Areas classified as "**some metering**" reported metering for 10% to 90% of serviced households. Areas classified as "**low metering"** reported less than 10% of serviced households being metered.

Water treatment. the HES 2006 considers any activity undertaken by a household to treat their water supply to be **water treatment**. A **filter or purifier** on a household water tap is a device that attaches to a water tap for the purpose of treating water. A **stand alone filter** is any device that is not connected to a water system (municipal system or private well) that has the purpose of treating water. This can range from an ordinary simple charcoal filter to a more complex osmosis filtration system.

Water uses, flows and source

There are substantial differences among types of regions, in terms of municipal water uses, the quantity used, and the source of the water that is used by households. Generally, the share of domestic water use relative to the total use and the amount used per capita are both higher in rural areas. Although water from a municipal system is the main source in each type of region, about one third of rural households rely on private sources of water (i.e. wells) for domestic use.

The geographic classification used in this analysis compares urban centers (CMA/CA) and rural and small town (RST) areas (Box 2). In some tabulations, a distinction is also made between towns and municipalities classified within larger agglomerations, namely Toronto, Montreal and Vancouver, and towns and municipalities classified within medium and smaller agglomerations (Box 2).

It should be recalled, however, that the database generated from MWWS 2004 for the purpose of this analysis includes only 5% of municipalities with less than 1,000 residents (Box 2). Moreover, relatively few non-farm households in the countryside (and even fewer farms) are connected to a municipal water provider. These households rely primarily on private wells and, as a result, the MWWS database does not provide statistics on water used by them.

The MWWS 2004 classifies municipal water use by three main destinations: domestic or household use, industrial and commercial use, and water loss or leakage from the municipal water system (Box 2). Overall the patterns of use in larger urban centers and rural and small towns are similar. However, the share of water devoted to domestic use is generally higher in rural and small town areas (Figure 1). The share of water used for commercial and industrial uses is the lowest in strong MIZ and highest in the smaller CMAs. The share of other uses, which includes water loss from the system, is slightly lower in rural areas (less than 10%) compared to larger urban centers (generally over 10%).

When water use is disaggregated by type of area with the MWWS 2004 dataset, the results indicate that per capita water use is higher in municipalities that are more rural (Figure 2). This pattern is true for total water used and water used for domestic purposes. Total water use per capita is lower (below 500 litres) in larger urban centers (larger CMA and medium CMA); it grows to about 600 litres in smaller CMA, CA and strong MIZ; and it is higher in zones that are more rural – over 800 litres per day per person in moderate and weak/no MIZ.

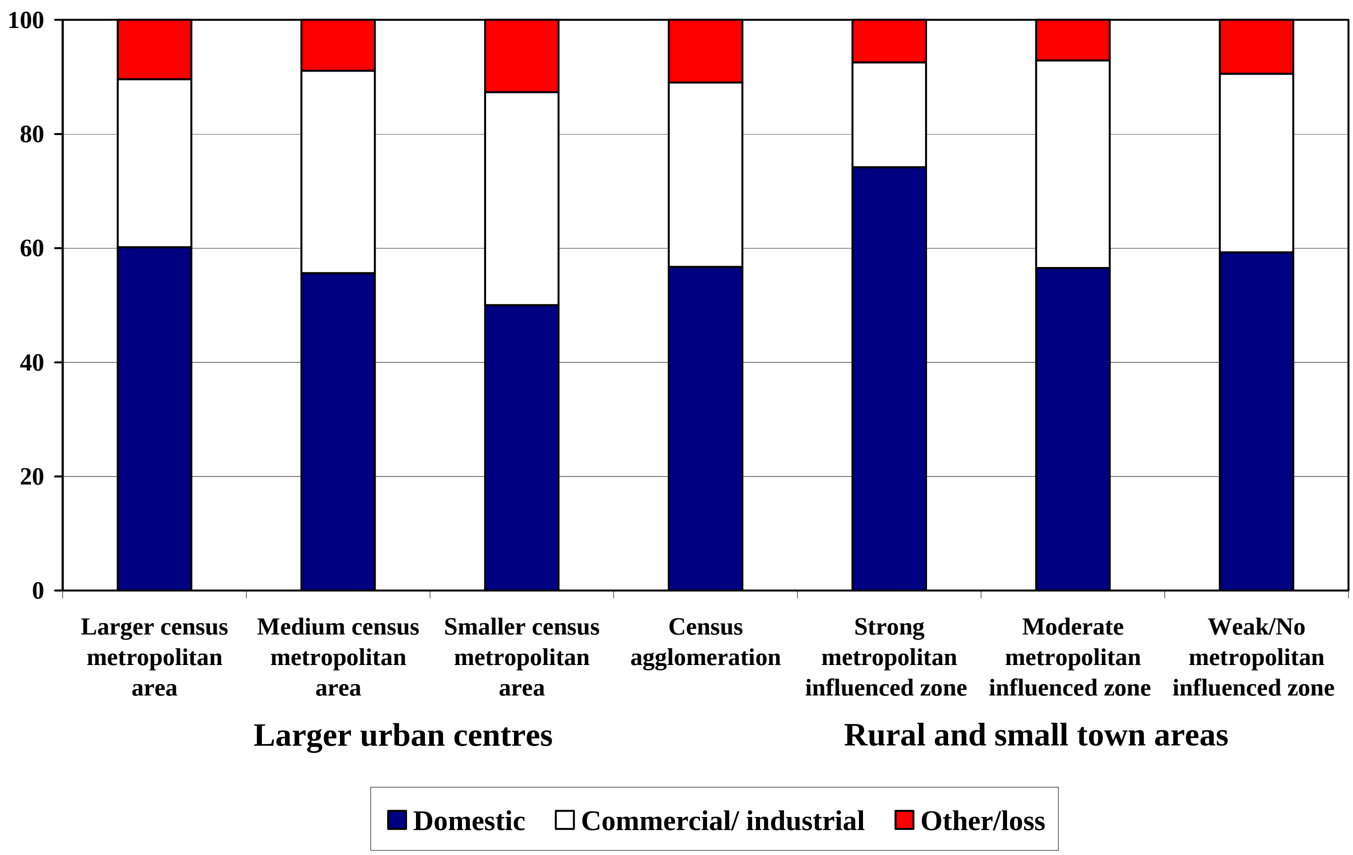
Domestic water use per capita shows a pattern similar to total water use per capita. The daily use is estimated at about 300 litres per capita for residents of all types of urban areas (Figure 3). However, medium CMAs are appreciably below that average (about 250 litres).

Among the ten provinces, in 2004 Manitoba showed the lowest domestic daily use of water at 219 litres per capita, while Newfoundland and Labrador showed the highest domestic daily use at 501 litres per capita (Environment Canada, 2007a). Provincial patterns across the urban-to-rural gradient tended to be similar to the national pattern (data not shown), but in some provinces the number of observations by regional type is not large enough to provide for a robust sample at the sub-provincial level.

The sources of water for domestic use are typically municipal supply, private wells, and surface water. Although the municipal water supply is prevalent in all regional types, there are still large differences between the residents of rural and urban municipalities. In rural areas, about one-third of households relied on water from a private well in 2006 (Figure 4). Rural households cannot always access a municipal water system and need to drill their own private well or seek alternative water sources. Comparatively, just over 14% of households within CAs obtain their water from a private well, and fewer than 4% of households in CMAs use a private well. However, two-thirds of rural households obtain their water from a municipal system, making municipal systems the main source of drinking water across Canada.

Figure 1 Municipal water systems in rural and small town areas report a higher share of water being used for domestic use

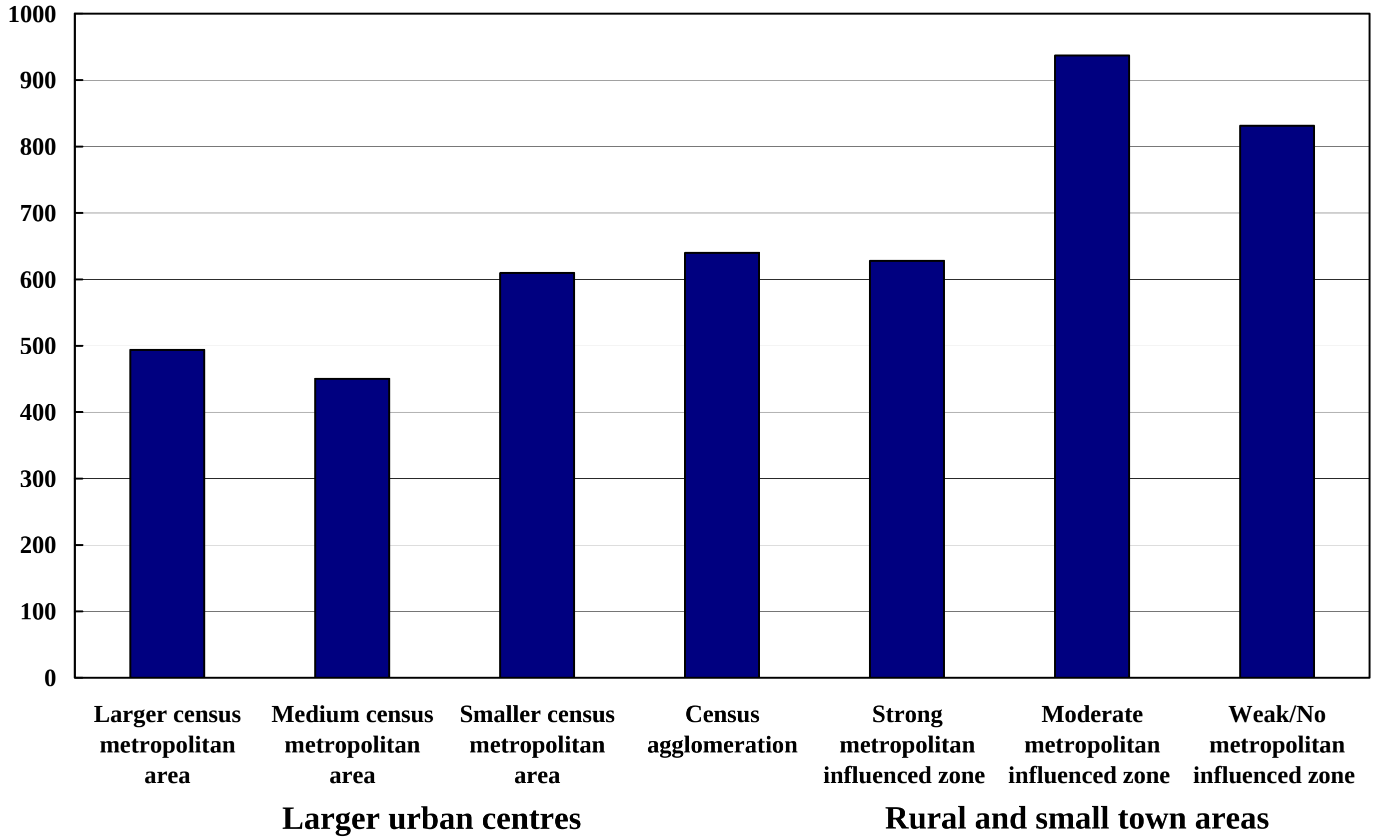
percent distribution of municipal water flow by type of destination, Canada, 2004



Note: Figures are for a sample of 1,009 municipalities used in this analysis. Shares are weighted by total flow.
Source: Environment Canada, Municipal Water and Wastewater Survey (MWWS), 2004.

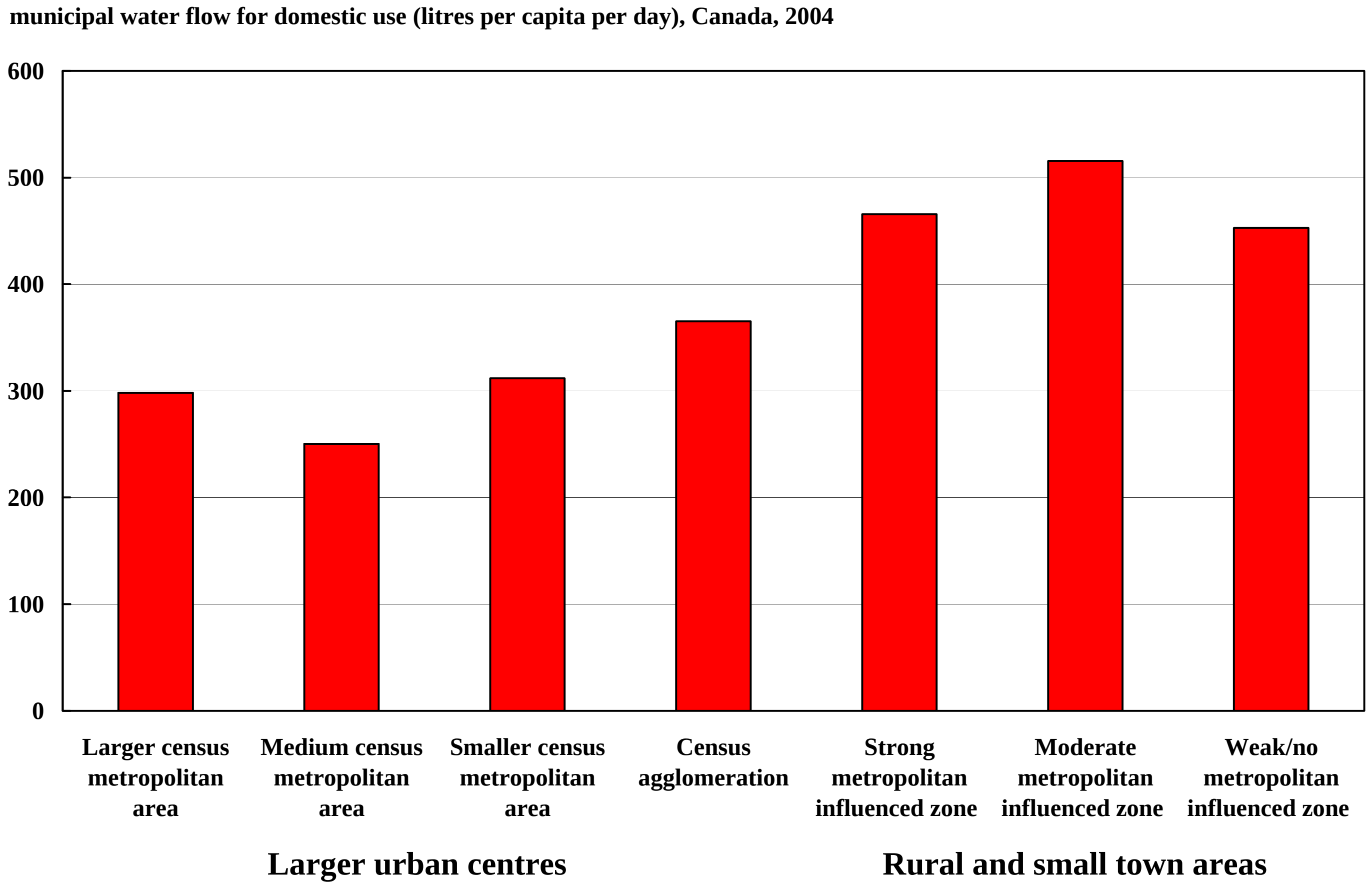
Figure 2 Municipal water use for all purposes, on a per capita basis, is highest in weak/no metropolitan influenced zone

municipal water flow for all uses (litres per capita per day), Canada, 2004



Note: Figures are for a sample of 1,009 municipalities used in this analysis. Averages are weighted by municipal population served. The sample average is 564 litres perr capita per day, compared to the 609 litres per capita per day for the entire Municipal Water and Wastewater Survey database (Environment Canada, 2007a).
Source: Environment Canada, Municipal Water and Wastewater Survey (MWWS), 2004.

Figure 3 Domestic water use of municipal water systems is highest in moderate metropolitan influenced zone

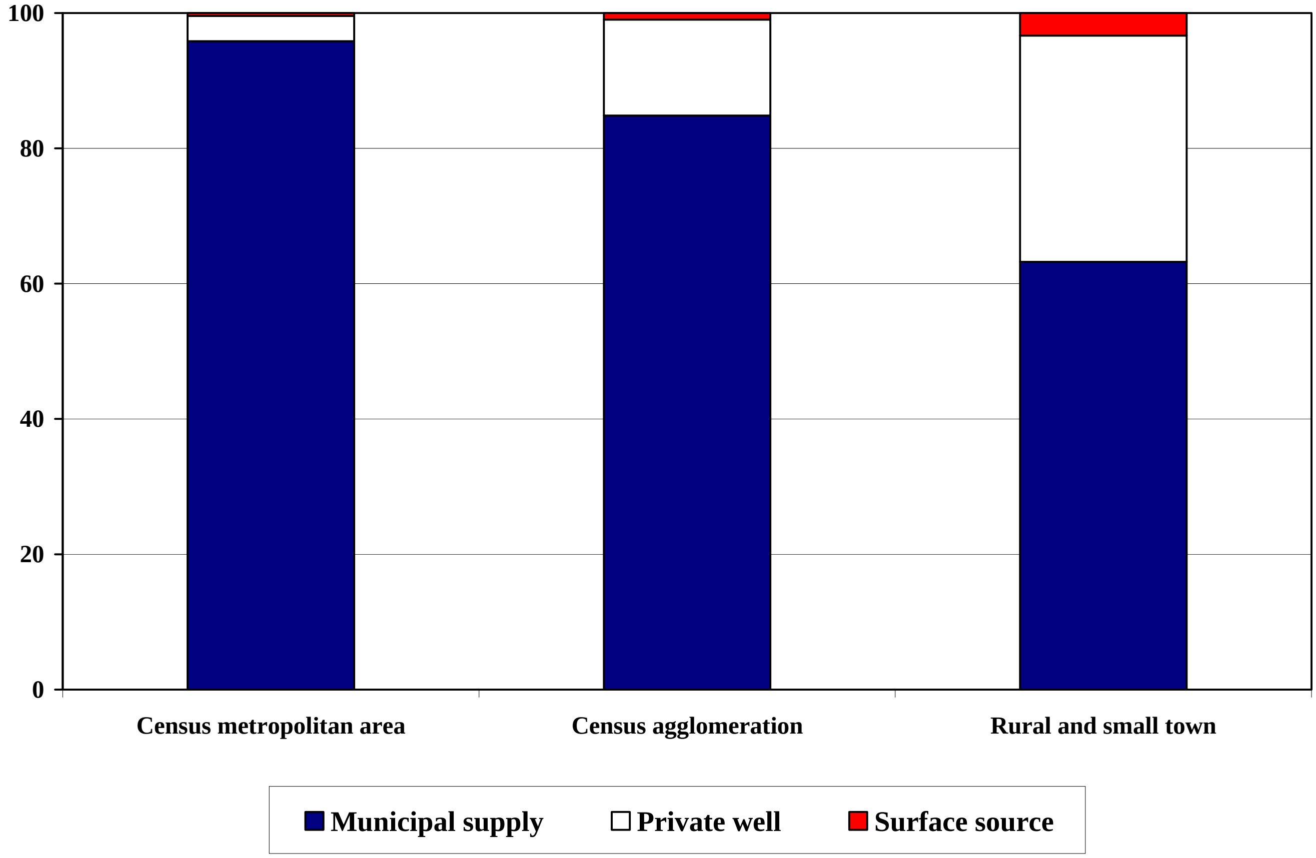


Note: Figures are for a sample of 1,009 municipalities used in this analysis. Averages are weighted by municipal population served. The sample average is 320 litres per capita per day, compared to the 329 litres per capita per day for the entire Municipal Water and Wastewater Survey database (Environment Canada, 2007a).

Source: Environment Canada, Municipal Water and Wastewater Survey (MWWS), 2004.

Figure 4 One-third of rural households obtain their water from a private well

percent distribution of households by source of household water, Canada, 2006



Note: “Other sources” are not included as their incidence is marginal.
Source: Statistics Canada, Households and the Environment Survey (HES), 2006.

Explaining differentials in water use

Various hypotheses could be formulated about the determinants of the amount of water used for domestic purposes, as presented in the previous section (for a review see Arbués *et al.*, 2003 and Dalhuisen et al., 2003). The existing literature has pointed in particular to two sets of explanatory factors: locational characteristics and economic incentives. Rural municipalities are characterized by low population density which may offer more opportunities for domestic water use (Troy and Randolph, 2006). Rural properties are commonly larger than urban properties and lawn and garden watering that nourish greenery is a typical water-consuming amenity in this environment. Hence, it would be expected that increasing rurality would be associated with higher use of water.

In terms of economic incentives, evidence on the consumption response to water pricing is presented by Dandy *et al.* (1997), Dalhuisen *et al.* (2003) and Reynaud *et al.* (2005). In the Canadian context, it has been suggested that users pay too little for their water. As argued by Environment Canada (2001), one of the key factors determining high water use is the absence of appropriate price signals. Environment Canada (2007a) indicates that, in 2004, approximately 63% of Canadians served by municipal water systems were metered. (It is 70% for the sample used in this analysis.) For the sample of municipalities used in this analysis, the share of the population in rural areas that is metered is less than 60% (Figure 5). This may be an important factor in the higher average water use in rural areas and this finding is consistent with the existing literature.

Also, water metering policies differ across provinces. Specifically, less than 8% of municipal water users in Newfoundland and Labrador, Prince Edward Island and the Yukon are metered. Also, 16% of municipal water users in Quebec are metered and 30% of municipal water users in British Columbia are metered (Environment Canada, 2007a). Although there is a wide variation in the rate of water metering among municipalities in Quebec, Ontario and British Columbia, Canada's three largest cities broadly reflect that of their respective provinces. Households in the Montreal CMA have essentially the same incidence of water metering as the other residents throughout Quebec (about 16%). In the Toronto CMA, about 98% of households have water meters while the figure is 92% for Ontario as a whole. Meanwhile, about 15% of households in the Vancouver CMA have a water meter compared to 30% throughout British Columbia, where other large municipalities have high metering rates[2].

To assess the effect of locational and economic factors in determining the per capita domestic use of water at the municipal level, a regression model is applied (Box 3). Location factors include the municipal population density in 2001 (inhabitants per square kilometre), and the type of region (Box 2). The effect of economic incentives is captured by three dummy variables indicating the extent of municipal water metering: "high metering" indicates that more than 90% of the population served is subject to metering, "low metering" indicates that less than 10% of the population relying on municipal water supply is subject to metering and "some metering" covers the range between the high and low cases. The low metering category was used as the reference group and therefore dropped from the model. Appendix Table A.3 shows descriptive statistics and Appendix Table A.4 shows the results of the regression models.

The dataset used in this analysis includes a total of 963 municipalities for which the indicators used in the model were available. Two alternative specifications of the model were used. The first

2. Note that each CMA and CA typically has many municipalities included within their boundaries (Box 2) and many of these municipalities would have their own water service. In 2001, there were 50 census subdivisions (i.e. incorporated towns and municipalities) within the Montreal CMA, 17 within the Toronto CMA and 18 within the Vancouver CMA.

included only population density as a location variable while the second included the regional indicator variables as well. Both specifications were also estimated with a sub-sample of 865 observations which excluded outliers that had extreme high and low values of water use. The estimated relationship that excluded the highest and lowest values tested whether the results were sensitive to a few municipalities whose water use was either considerably higher or considerably lower than the average.

The regression results suggest that economic incentives, as measured by the degree of municipal metering, are generally more important than locational factors in affecting average domestic use of water[3]. Once the location characteristics of the municipality are controlled for, municipalities with high degree of water metering are associated with an average daily water use of about 170 litres less than a similar municipality with low metering (for the sub-sample with the high and low outliers removed), or about 200 litres less when the full sample is used. Shifting from low metering to some metering is associated with a lower average domestic water use of about 70 litres per person per day or approximately 20% of 2004 average water use.

As mentioned above, the existing literature and economic theory suggest that the higher the price of the water the less a household will use of it. It is therefore not surprising that the presence of a water meter tends to reduce domestic water use.

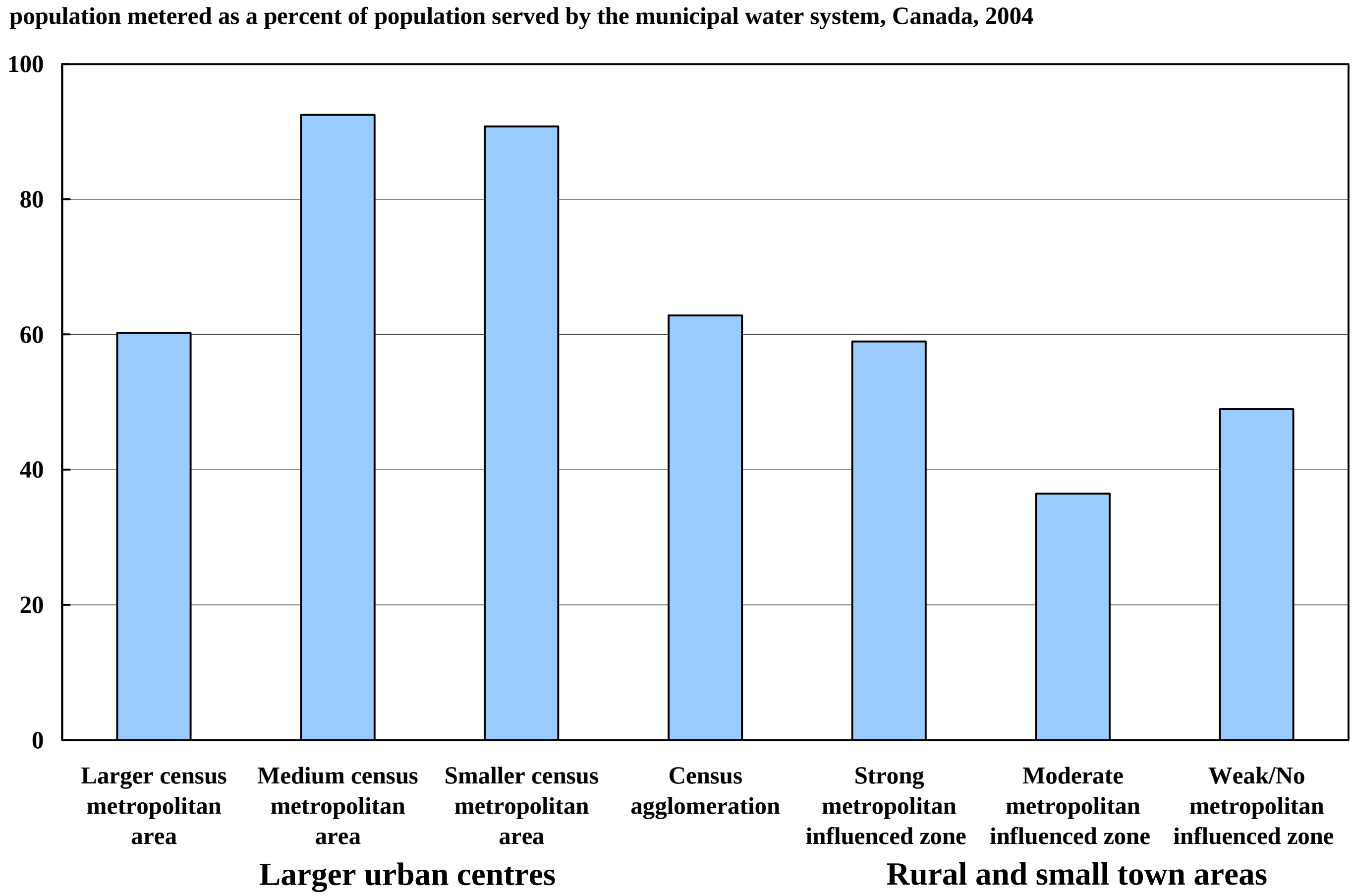
Population density also has a statistically significant association with water use levels, as expected. For each additional 100 inhabitants per square kilometre, water use is lower by about 50 to 90 litres (depending on the specification). In contrast, locational characteristics of the municipality, as captured by the type of area, appear to have a low association with water use. A statistically significant effect is found only for weak/no MIZ (in the full model and at the 10% statistical significance level). The daily per capita water use in this type of area is higher than in CMAs (which is the reference group). The magnitude of the increase is approximately 60 litres per capita per day.

Again, given that the existing literature shows that there are greater opportunities for domestic water use on rural properties, these results would be expected.

In summarizing to this point, the results indicate that average daily domestic water flow is lower in municipalities that meter their water flow – that is, economic incentives are clearly associated with level of water use. The population density of the settlement is also associated with the level of water use. In contrast, the type of area has a more limited association with water use. However, when significant, the results are still consistent with the expectation of higher water use in rural areas.

3. Reynaud *et al.* (2005) performed an analysis of 899 municipalities which pooled data from the 1993, 1995 and 1998 versions of the MUD database. They determined that the estimated change in the quantity of water consumed in response to a different price is somewhat over-estimated if one does not first take into account that the decision to introduce a water pricing structure is influenced by the characteristics of the municipality. Thus, our results may overstate (somewhat) the estimated lower level of water consumption due to the presence of water metering.

Figure 5 In rural and small town areas, less than 60% of the population serviced by a municipal water system has water meters



Note: Figures are for a sample of 1,009 municipalities used in this analysis. Averages are weighted by municipal population served. The average percentage of population metered for this sample is 71%, compared to the entire Municipal Water and Wastewater Survey database where 63% of residential clients and 83% of business clients were metered (Environment Canada, 2007a).

Source: Environment Canada, Municipal Water and Wastewater Survey (MWWS), 2004.

Water treatment as a possible indicator of water quality perceptions

There is evidence that suggests that water quality is a growing concern for many Canadians (Adamowicz *et al.,* 2007). Yet, there is limited understanding of the relationship between water quality concerns and water consumption decisions taken by Canadian households. In this part of the analysis we look at the choice of a household to treat its tap water. Although this does not address the issue of water quality perception directly, consumption choice remains a plausible, albeit indirect, indicator of water quality perceptions.

The results of the Households and the Environment Survey (HES) 2006 show that between 23% and 31% of households primarily drink bottled water, depending on location (Appendix Table A.2). For these households, the HES 2006 does not collect information on water treatment and therefore these households are not included in the analysis (see Box 2 for definitions of water treatment). When we excluded households that primarily drink bottled water, only about 40% of rural households use some form of water treatment, compared to over 50% in urban areas (Figure 6). This figure includes both rural households that are connected to municipal water systems as well as those which rely on private wells. Rural households using private wells are not notably different from rural households that are using municipal systems when it comes to the decision of whether or not to treat their drinking water.

In this analysis we focus on the factors associated with water treatment choices by households that drink primarily tap water or that drink both tap water and bottled water (that is, households that drink primarily bottled water are excluded from the analysis). The results are based on a logit model (Box 3). Using four sets of variables, this model shows the association of each variable with the probability that households are treating their drinking water. The four sets of explanatory variables are: (1) demographic variables, which included family size and age cohorts of the household members; (2) socio-economic variables, which include educational attainment and income level; (3) type of water source; and (4) locational characteristics of the households, defined as rural and major type of urban agglomerations (Box 2). Descriptive statistics for these explanatory variables are presented in Appendix Table A.5. The survey sample includes 15,504 households representing about 6.8 million Canadian households.

The detailed results of the logit model, including bootstrapped standard errors are reported in Appendix Table A.6. These results indicate that location plays a large role in the household decision to treat drinking water. The odds of observing water treatment are higher by a factor of 1.7 for households located in Toronto (compared to the medium and smaller CMA reference group), while households in rural areas are only 0.7 times as likely to treat their drinking water compared to the reference group.

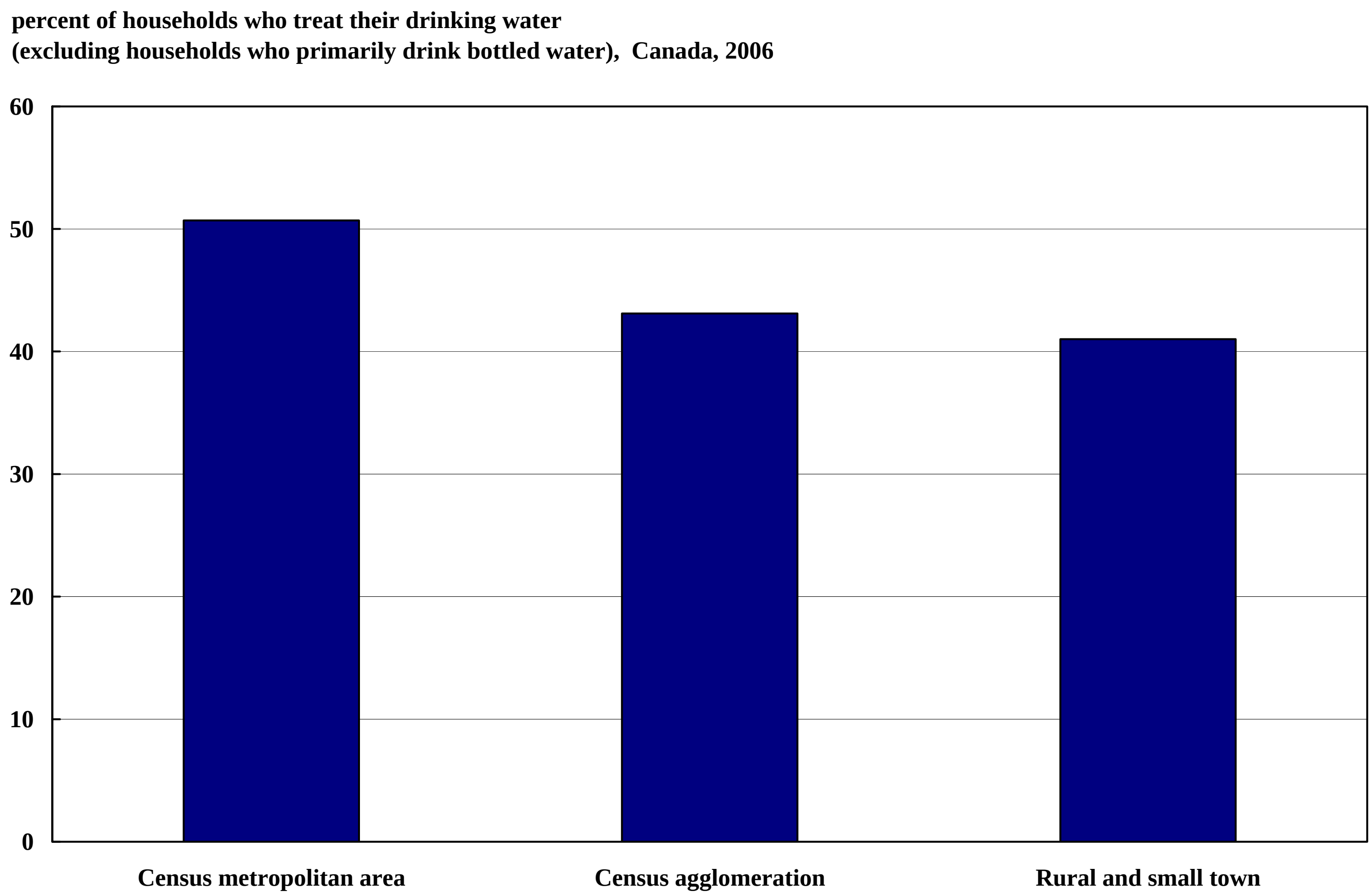
Socio-economic characteristics of the household also have a significant role, although this is only for specific categories. Households with any member with a high level of educational attainment (university degree level) and households with a higher income level (specifically between $80,000 and $99,999) are more likely to treat their water (in both cases the odds of water treatment are higher by a factor of 1.3).

Demographic factors have some effect but their patterns appear more difficult to interpret. The presence of an individual age 16 to 24 or the presence of an individual 55 years and over increases the likelihood of water treatment, while the number of individuals in other age groups has no significant effect. Finally, the source of water (municipal or private) does not have a significant effect on treatment choices of the households. In other words, the household that relies on a private source of water is not different in its water treatment decisions from those that rely on municipal water supply systems.

The results of the model allow the prediction of the probability of observing water treatment for typical household profiles. For the purpose of this analysis and for benchmarking purposes, the typical household is defined as a household with three members, two aged 45 to 54 and one aged 16 to 24, high school graduation (but no post-secondary) as the highest level of education attained by any household member, average household income between $50,000 and $59,999, using municipal water and drinking only tap water Figure 7 shows the predicted probability of water treatment for this typical Canadian household in different locations in Canada (See Appendix Table A.7 for details).

The geographic location of this typical household had a large impact on the likelihood of treating water. A household with this typical profile that is located in the large CMAs of Vancouver and Toronto has about a 55% chance of treating water (Figure 7). Montreal is a notable exception to the urban-rural gradient – the chance of treating water was below 30%, following the overall Quebec pattern of a lower likelihood of treating tap water (Statistics Canada, 2007). Note the strong urban-to-rural gradient of a lower probability of water treatment as one compares CMAs to CAs and as one compares CAs to rural areas.

Figure 6 In rural areas, 40% of households treat their drinking water



Source: Statistics Canada, Households and the Environment Survey (HES), 2006.

The predicted probabilities of this typical household are used as a benchmark for other types of household profiles. In particular, four additional household profiles are identified. These profiles emphasize household differences in the variables of the logit model that were statistically significant. Details on the specification of each profile and the resulting predicted probability by area of residence are reported in Appendix Table A.7.

The pattern in predicted probabilities for these four household profiles follows that observed for the base case – there is a clear urban-to-rural gradient for each profile. (Montreal, again, is an exception, following the lower likelihood of households in Quebec to treat their tap water.) Other household characteristics being the same, rural households were less likely to treat their water than urban households. Compared to the typical household, the single household (Case 2) has only one household member, has some post-secondary education, earns between $30,000 and $39,999 per year, and obtains drinking water from a private source. When this household is located in Toronto the probability of water treatment is 54%, whereas the same type of household located in rural areas has a 33% probability of treating water (Appendix Table A.7). The elderly couple household (Case 3) emphasizes the age variable within the household with an above average household income. Again, the urban areas of Toronto and Vancouver have a greater likelihood of treating their water than rural areas. This trend is also present in the other two cases: the mixed age, high education household (Case 4), which captures a higher household education attainment; and the young professional household (Case 5), which emphasizes the effect of high income.

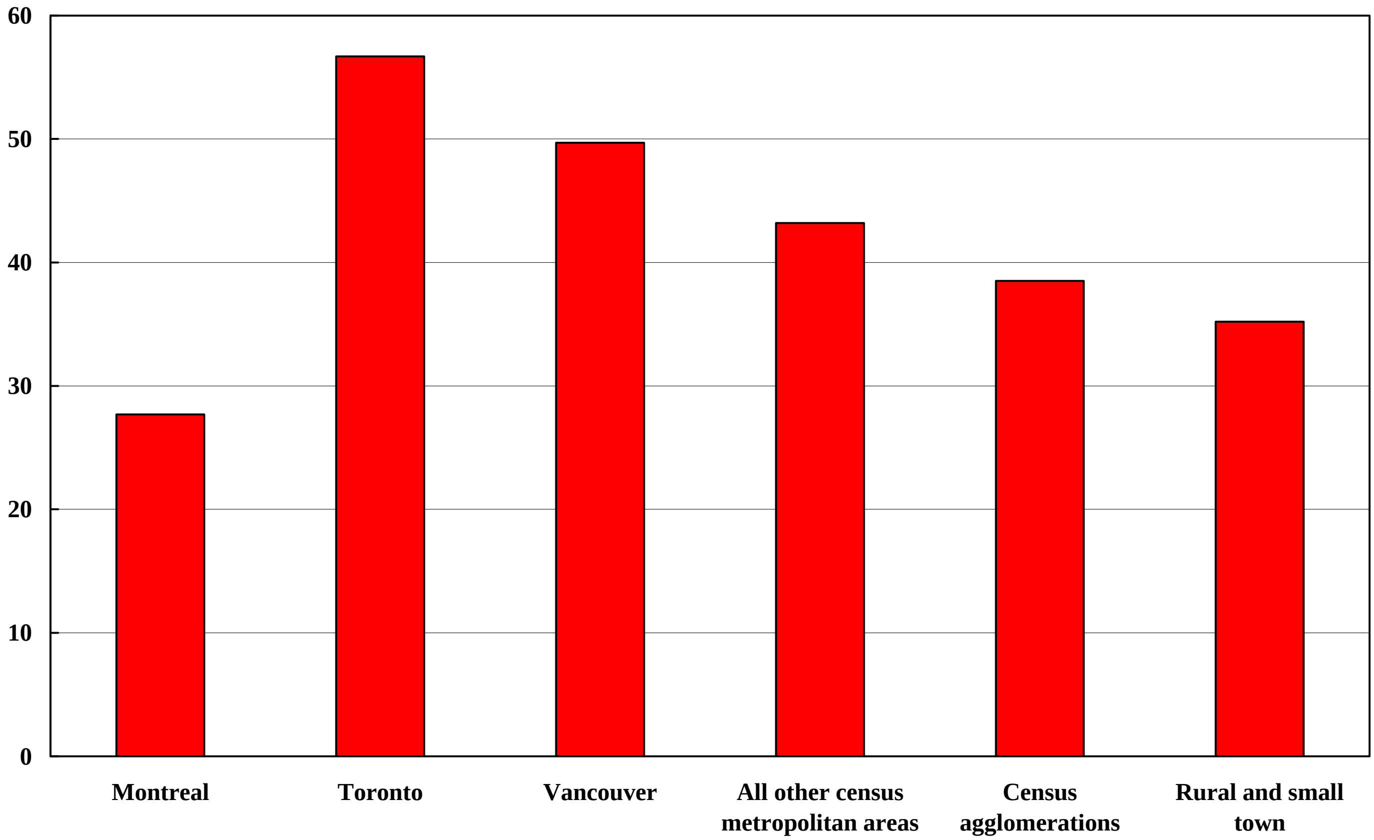
The differences in predicted probability of water treatment between the typical household and other household profiles are further detailed in Figure 8. This chart is evidence of the role of other variables, in addition to geographic location, in determining the probability of water treatment. For instance, compared to the typical household, the single household has a 1.8 to 2.3 percentage point lower probability of treating water within each area. For each case, the difference in estimated probabilities (compared to the typical household) is consistent across the geographic areas. A consistent difference compared with the typical case means that each case has an urban-to-rural gradient that is just as strong as the gradient in the typical case (Figure 7).

A household with the mixed family, higher education profile (Case 4) has a 13 to 14 percentage point higher probability of treating drinking water. Hence, differences in demographic and socio-economic characteristics of the households have a large and significant effect on the probability of water treatment.

Importantly, the difference in the share of households treating drinking water is flat across the urban-to-rural gradient (Figure 8). That is, for any given case, the percent of households treating drinking water shows the same strong urban-to-rural gradient as in Case 1 (the gradient is essentially the same because the difference with Case 1 is essentially the same).

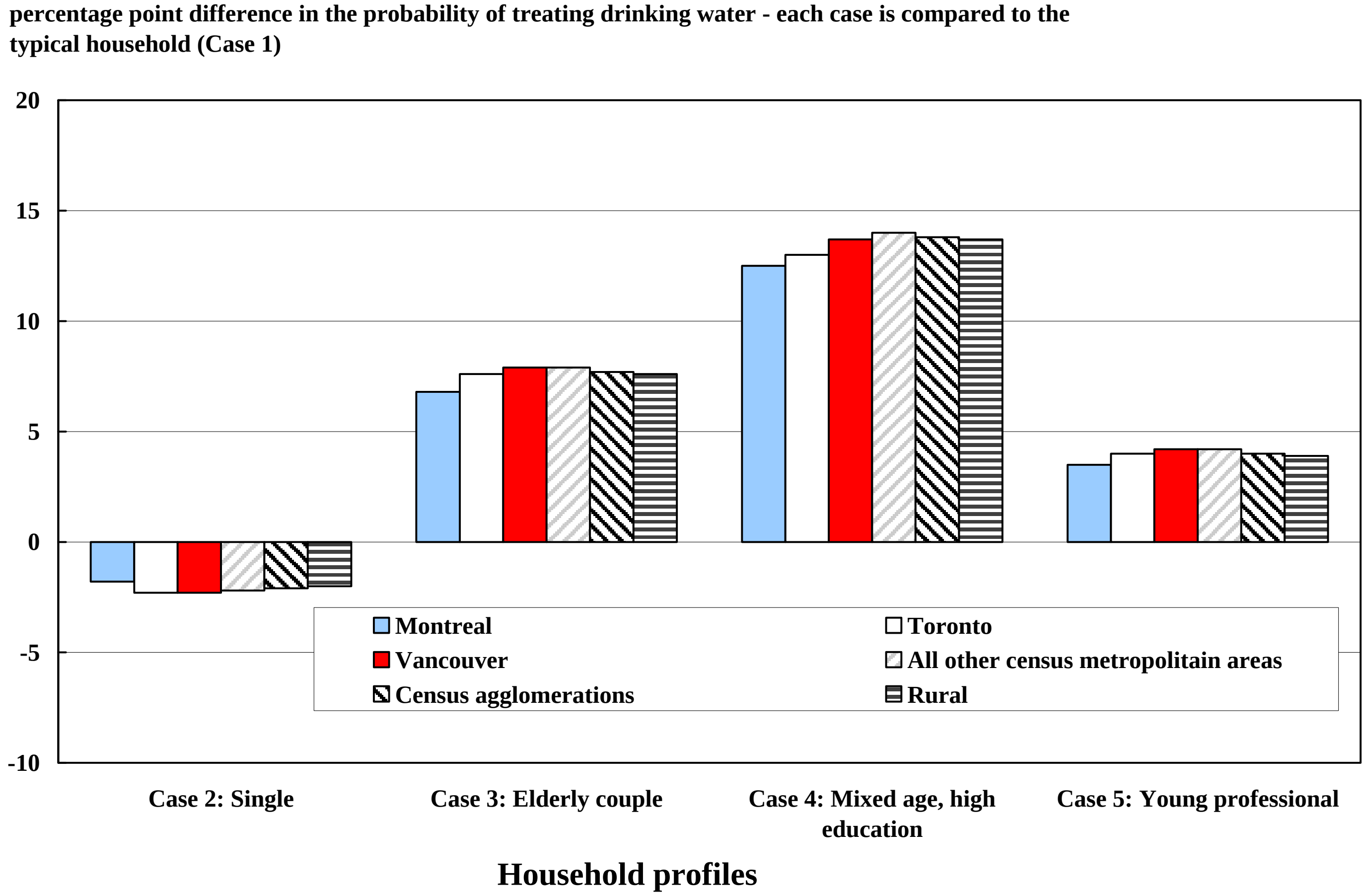
Figure 7 For a typical household, there is a strong urban to rural gradient in the probability of households treating their drinking water

probability of a typical household (Case 1 in Appendix Table A7) treating its drinking water (excluding households who primarily drink bottled water), Canada, 2006



Note: See Box 3 for methods used to derive figures. See Appendix Table A.7 for a description of each case.
Source: Estimated results based on Statistics Canada, Households and the Environment Survey (HES), 2006.

Figure 8 Each selected household profile has the same strong urban to rural gradient as the typical household



Note: See Box 3 for methods used to derive these figures. See Appendix Table A.7 for a description of each case.
Source: Estimated results based on Statistics Canada, Households and the Environment Survey (HES), 2006.

Conclusions

This bulletin focuses on the effect of "rurality" in determining the quantity of water used, at the municipal level, and on water quality perception of households, as measured by a household's water treatment choices. The baseline data presented in this bulletin indicates that, on average, water used for domestic purposes is higher in rural municipalities than in urban ones, but that rural households who drink tap water are less likely to treat their water than urban households. Urban households are also more reliant on municipal water systems than rural households. Though municipal water systems are the main source of water for the majority of rural households, private wells remain an important source of water as well.

The results of this analysis suggest that economic incentives are more relevant than location characteristics in determining average water use. Areas with higher shares of water metering use less water than areas with lower shares of water metering. The effect of population density and regional type are less clear, although they are to some extent consistent with the expectation that areas that are more rural would have higher water use compared to urban residents because of the tendency to have larger gardens that need summer watering.

In contrast, locational characteristics are significant determinants of the choice of treating tap water for domestic consumption while the source of water (municipal or private) is not. The location effect on treatment choices remains strong even after controlling for socio-economic characteristics of the household. However, some socio-economic characteristics also have a significant impact on the likelihood of a household treating its water.

Rural households appear more confident in the quality of their water supply, compared to their urban counterparts. Almost 60% of rural households do not treat their water, whereas fewer than 50% of CMA households do not treat their water. Finally, the type of water consumed (primarily tap or a combination of tap and bottle water) does not appear to be a factor in the treatment decision.

There are several implications for municipal water strategies. First, the results suggest that economic incentives might play a significant role for municipal water management. Even though the introduction of water metering systems cannot be viewed as a substitute for infrastructure policies, this could remain an important measure in containing the quantity of water used.

Second, assuming that the choice of water treatment reflects quality perception, municipal water sources are not perceived to have higher quality as compared to private sources. Household characteristics, such as higher education and income level, explain in part the choice of treating the water, but there appears to be a location specific factor that should be further investigated. With the notable exception of Montreal, urban households are more sensitive to water quality issues, as reflected by the decision to treat tap water for domestic consumption.

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Appendix Table A.1 Population and communities included in the Municipal Water and Wastewater Survey

Type of region	Population			Communities		
	Canada	Municipal Water and Wastewater Survey 2004 analysis	Municipal Water and Wastewater Survey 2004 analysis	Canada	Municipal Water and Wastewater Survey 2004 analysis	Municipal Water and Wastewater Survey 2004 analysis
	individuals		percent	communities		percent
Larger urban centres	**23,839,086**	**16,971,853**	**71.2**	**990**	**356**	**36.0**
Census metropolitan area	19,296,926	13,483,090	69.9	468	188	40.2
Census agglomeration	4,542,160	3,488,763	76.8	522	168	32.2
Rural and small town areas	**6,168,008**	**2,624,730**	**42.6**	**4,580**	**653**	**14.3**
Strongly influenced	1,524,579	625,833	41.0	566	96	17.0
Moderately influenced	2,285,538	924,103	40.4	1388	238	17.1
Weakly influenced	1,969,211	1,009,939	51.3	1014	272	26.8
Not influenced/Territories	388,680	64,855	16.7	1612	47	2.90
All regions	30,007,094	19,596,583	65.3	5,570	1,009	18.1

Note: The columns “Municipal Water and Wastewater Survey 2004 analysis” report the population and community figures for the municipalities of the Municipal Water and Wastewater Survey 2004 included in our analysis; that is, for the municipalities for which data were available for the variables of interest. All population figures are for the year 2001.

Source: Authors’ elaboration based on Environment Canada, Municipal Water and Wastewater Survey (MWWS), 2004 and Statistics Canada, Census of Population, 2001.

Appendix Table A.2 Primary type of drinking water consumed by households, Canada, 2006

Type of drinking water	Census metropolitan area				Census agglomeration	Rural
	Vancouver	Toronto	Montreal	Other		
	percent distribution of households					
Primarily tap water	66.3	53.4	58.7	58.0	55.3	57.1
Combination drinking water[1]	10.2	18.8	10.2	12.4	12.2	10.6
Primarily bottled water	23.0	26.8	30.3	28.4	31.0	29.4
Missing[2]	0.3	0.1	0.2	0.1	0.2	0.1

1. “Combination drinking water” refers to households which consume tap and bottled water, including “other” responses.

2. “Missing” includes Refused or Don't Know responses.

Note: All figures are weighted figures. The weighted sample, used for this computation, corresponds to 12,568,539 households. Households which responded “Primarily bottled water” were not included in the logistic regression analysis. This is because with the Households and the Environment Survey 2006, if a household primarily drank bottled water, the questionnaire did not request whether the tap water was treated.

Source: Statistics Canada, Households and the Environment Survey (HES), 2006.

Appendix Table A.3 Descriptive statistics: Factors associated with domestic water use from municipal water systems, Canada, 2004

Variable (mean)	Mean	Standard deviation
Dependent		
Average daily domestic water use in the municipality, unweighted (litres per capita)	468.30	310.90
Independent		
Metering indicators		
High metering (dichotomous)	0.49	0.50
Some metering (dichotomous)	0.07	0.26
Low metering (dichotomous)	0.44	0.50
Location indicators		
Population density (inhabitants per km^2)	339.00	482.00
Census metropolitan area (dichotomous)	0.19	0.39
Census agglomeration (dichotomous)	0.17	0.37
Strong metropolitan influenced zone (dichotomous)	0.10	0.29
Moderate metropolitan influenced zone (dichotomous)	0.24	0.42
Weak/no metropolitan influenced zone (dichotomous)	0.32	0.47
Number of observations (municipalities)	1,009	…

Note: Figures are computed from a sample of 1,009 municipalities of the Municipal Water and Wastewater Survey 2004 that reported information on water metering, total yearly water outflows, and destination flows. Municipalities with water systems outside Whitehorse and Yellowknife in the Territories are classified as weak/no metropolitan influenced zone municipalities. See Box 2 for variable definitions. All variables, except average daily domestic use in the municipality and population density, are in dichotomous form, meaning that the variable takes the value of 1 if the attribute is observed and 0 otherwise. Regional type variables take the value of 1 if the municipality is located in that regional type (see Box 2 for variable descriptions and definition of types of area).

Source: Environment Canada, Municipal Water and Wastewater Survey (MWWS), 2004.

Appendix Table A.4 Regression results: Variables in regression of factors associated with domestic water use[1] across municipal water systems

Variable	Model 1				Model 2			
	Full sample		Omitted outliers		Full sample		Omitted outliers	
	β	t-stat	*β*	t-stat	*β*	t-stat	*β*	t-stat
Constant	**590.07**	**38.54**	**535.42**	**49.73**	**623.25**	**18.86**	**520.16**	**27.82**
Metering indicators								
Some metering	**-76.03**	**-1.63**	**-106.51**	**-3.57**	**-75.84**	**-1.64**	**-105.47**	**-3.47**
High metering	**-200.70**	**-10.48**	**-168.67**	**-12.93**	**-199.25**	**-10.23**	**-167.68**	**-12.61**
Location indicators								
Population density	**-0.08**	**-5.83**	**-0.05**	**-5.80**	**-0.09**	**-5.51**	**-0.05**	**-4.68**
Census agglomeration	…	…	…	…	-20.32	-0.59	16.29	0.78
Strong metropolitan influenced zone	…	…	…	…	-35.50	-0.86	21.05	0.75
Moderate metropolitan influenced zone	…	…	…	…	-20.14	-0.57	18.06	0.85
Weak/no metropolitan influenced zone	…	…	…	…	**-57.18**	**-1.78**	13.03	0.69
R^2	0.13	…	0.19	…	0.13	…	0.19	…
Number of observations	963	…	865	…	963	…	865	…

1. Litres per capita per day.

Note: The full sample estimation includes 963 municipalities reporting information on water metering, total yearly water outflows and destination flows. The omitted outliers sample excludes the highest 5% and the lowest 5% of municipalities in terms of domestic water use per capita. Municipalities with water systems outside Whitehorse and Yellowknife in the Territories are included with weak/no metropolitan influenced zone municipalities. See Box 2 for variable definitions.

Source: Estimation based on Environment Canada, Municipal Water and Wastewater Survey (MWWS), 2004.

Appendix Table A.5 Descriptive statistics: Variables in logistic regression of factors associated with households which treat drinking water[1]

Variable name	Mean	Standard deviation
Dependent variables		
Treatment indicator (=1 if household treats drinking water)	0.473	0.500
Independent variables		
Family size	2.380	1.378
Age of household members (=1 if there is one or more household members present in the age class)		
Aged 0-15	0.278	0.448
Aged 16-24	0.200	0.400
Aged 25-44	0.479	0.500
Aged 45-54	0.294	0.456
Aged 55+	0.378	0.485
Education		
Some secondary (reference group)	0.112	0.315
High school graduate (no post-secondary)	0.123	0.334
Some post-secondary	0.397	0.489
University degree	0.363	0.481
Income bracket ($)		
0 to 19,999 (reference group)	0.138	0.345
20,000 - 29,999	0.112	0.316
30,000 - 39,999	0.124	0.330
40,000 - 49,999	0.096	0.295
50,000 - 59,999	0.090	0.287
60,000 - 79,999	0.155	0.362
80,000 - 99,999	0.010	0.300
100,000 and over	0.184	0.387
Type of water source		
Municipal (reference group)	0.868	0.338
Private	0.132	0.338
Type of household drinking water		
Primarily tap water (reference group)	0.811	0.391
Combination	0.189	0.391
Location		
Medium and smaller census metropolitan areas (reference group)	0.317	0.465
Census agglomeration	0.098	0.297
Rural	0.237	0.425
Vancouver	0.070	0.256
Toronto	0.156	0.363
Montreal	0.120	0.325
Weighted observations	6,779,154	…
Sample observations	15,504	…

1. Excludes households who primarily drink bottled water.

Note: The descriptive statistics are computed using survey weights. Invalid responses are not included. All variables, except family size, are in dichotomous form, meaning that the variable takes a value of 1 if the attribute is observed and 0 otherwise. “Reference group” indicates the category that is omitted in the logistic regression and thus the estimated odds ratios are to be compared to the status of the reference group. Family size is the number of family members at the time of the survey. The dummy variables for age of household members indicate the presence of one or more household members in that age class – thus, the variables are not a set of mutually exclusive dummies and no reference group is indicated.

Source: Statistics Canada, Households and the Environment Survey (HES), 2006.

Appendix Table A.6 Logistic regression results: Variables in logistic regression of factors associated with households which treat drinking water[1]

Variable	Coefficient	Boot-strapped standard error	P-value	Odds ratio
Constant	**-0.381**	0.107	0.00	**0.68**
Family size	0.026	0.031	0.40	1.03
Age of household members				
Aged 0-15	-0.004	0.082	0.96	1.00
Aged 16-24	**0.134**	0.072	0.06	**1.14**
Aged 25-44	0.084	0.071	0.24	1.09
Aged 45-54	-0.080	0.066	0.22	0.92
Aged 55+	**0.194**	0.074	0.01	**1.21**
Education				
High school graduate (no post-secondary)	-0.132	0.100	0.19	0.88
Some post-secondary	0.081	0.079	0.31	1.08
University degree	**0.236**	0.088	0.01	**1.27**
Income bracket ($)				
20,000 - 29,999	-0.011	0.099	0.91	0.99
30,000 - 39,999	-0.078	0.101	0.44	0.93
40,000 - 49,999	-0.041	0.107	0.70	0.96
50,000 - 59,999	0.111	0.110	0.31	1.12
60,000 - 79,999	0.168	0.104	0.11	1.18
80,000 - 99,999	**0.250**	0.106	0.02	**1.28**
100,000 and over	0.152	0.098	0.12	1.16
Type of water source				
Private	0.069	0.056	0.22	1.07
Type of drinking water				
Combination	-0.065	0.059	0.27	0.94
Location				
Census agglomeration	**-0.196**	0.064	0.00	**0.82**
Rural	**-0.336**	0.051	0.00	**0.71**
Vancouver	**0.260**	0.096	0.01	**1.30**
Toronto	**0.542**	0.090	0.00	**1.72**
Montreal	**-0.686**	0.151	0.00	**0.50**

1. Excludes households who primarily drink bottled water.
Note: Coefficients that are bold are statistically significant at the 10% level of significance. See Box 3 for methodology.
Source: Statistics Canada, Households and the Environment Survey (HES), 2006.

Appendix Table A.7 Predicted percent of households which treat their drinking water[1], showing results for selected case households

	Census metropolitan area				Census agglomeration	Rural
	Vancouver	Toronto	Montreal	Other		
Case 1: Typical household (2 persons aged 45-54; 1 person age 16-24; the household member with the highest educational attainment is a high school graduate (no post-secondary); income $50K-59K; water from a municipal source; only tap water)	49.7	56.7	27.7	43.2	38.5	35.2
Case 2: Single (1 person age 45-54, some post-secondary education; income $30K-39K; water from a private source; only tap water)	47.4	54.4	25.9	41.0	36.4	33.2
Case 3: Elderly couple (2 persons age 55+; the household member with the highest educational attainment has some post – secondary education; income $60K-79K; water from a municipal source; combination tap and other drinking water)	57.6	64.3	34.5	51.1	46.2	42.8
Case 4: Mixed age, high education (1 person age 16-24; 1 person age 45-54; 1 person age 55+; the household member with highest educational attainment has a university degree; income $50K-59K; water from a municipal source; tap water only)	63.4	69.7	40.2	57.2	52.3	48.9
Case 5: Young professional (1 person age 25-44; university degree; income $100K+; water from a municipal source; combination tap and other drinking water)	55.8	51.4	32.9	49.3	44.4	41.0

1. Excludes households who primarily drink bottled water.
Note: See Box 3 for an explanation of the computation of predicted probability.
Source: Statistics Canada, Households and the Environment Survey (HES), 2006.

Box 3 Methodology

A standard linear regression model was used to investigate the effect of water metering on total water use (see Appendix A.3 and Appendix A.4). The model is based on Municipal Water and Wastewater Survey (MWWS) 2004 data. The dependent variable is the average daily domestic flow. The explanatory variables include metering and location variables. Metering is measured by three dummy variables: high metering; some metering; and low metering. The "low metering" category was used as the reference group and therefore dropped from the model. The results were shown as relative to this reference group. Location variables include population density, Census Metropolitan Area (CMA), Census Agglomeration (CA), strong Metropolitan Influenced Zone (MIZ), moderate MIZ, and weak/no MIZ. As the reference group, "CMA" was dropped from the model and the results were presented as relative to this group. All variables were dummy variables except for population density (for definitions, please see Box 2).

Two alternative specifications were used. In the first specification, the average daily domestic flow is determined by metering variables and population density only. In the second specification, we add also the regional dummies. Each specification was estimated with two samples. The first was the full sample of 963 observations, for which data was available, and the second was an "omitted outliers" sample that excluded the top and bottom 5% of observations. A severe cut-off (removing the bottom 5% and top 5% of observations) was employed in order to assess the sensitivity of the results to unusually high and low water use per capita in the MWWS 2004 dataset.

It should be noted that the analysis conducted with the MWWS 2004 was also replicated with Municipal Water Use (MUD) survey data for 1998 and 2001, for the municipalities for which the same data was available. The results for these previous years are similar to those obtained for 2004, with the main difference being that locational factors (and particularly population density) were even less important in explaining water use levels when 1998 or 2001 data are used. In part, these differences can be explained by the inclusion of some rural communities in the 2004 database and a 2004 usable sample with lower average population density. Results for the MUD 1998 and MUD 2001 estimations are available from the authors upon request.

A **logistic regression** model was used to explain the household decision to treat drinking water. The dependent variable of this model is the dichotomous choice "treat/do not treat" drinking water, coded as 1 and 0 respectively. The explanatory variables included in the model are family size, age cohorts of household members, highest level of education achieved by any household member, total household income, household's type of water system (municipal or private; private includes surface sources), type of water primarily drunk in the household, municipality type (Box 2), and large urban indicators for Vancouver, Toronto, and Montreal. Each variable is classified as a dummy variable (1 for true, 0 for false) except for family size, where we recorded the number of family members in each of 5 age groups.

The dichotomous nature of treatment choices makes the analysis suitable for qualitative dependent variable modeling (Long and Freese, 2001). Generally, this specification postulates the existence of a latent model, which is continuous in its dependent variable (for instance, willingness to treat the water) but which is not observable in reality. The model for the observable dichotomous outcome is derived from this latent process (see Long and Freese, 2001). Hence, for the logistic regression, which is one form of qualitative dependent variable modeling, the resulting specification is as follows,

$$\Pr(y=1\,|\,\mathbf{x}) = \frac{\exp\left(\beta_0+\beta_1 x_1+\ldots+\beta_n x_n\right)}{1+\exp\left(\beta_0+\beta_1 x_1+\ldots+\beta_n x_n\right)} = \frac{1}{1+\exp^{\,x\beta}} = \Lambda(x\beta)$$

Box 3 Methodology (continued)

This implies that the probability of observing a positive outcome (y=1), that is, the presence of water treatment, is a function of a set of explanatory variables (x) defined by the logistic cumulative distribution function and Λ(.). In this equation, the β's represent the parameters to be estimated. Thus, using a more explicit notation for the set of explanatory variables included in the model (demographic, socio-economic, source, and location) we can write the model as,

$$\Pr(Treat = 1 \mid \mathbf{x}) = \Lambda(\beta_1 Demo + \beta_2 SocioEco + \beta_3 Source + \beta_4 Loc)$$

This equation represents the logistic regression model used in this study, which is estimated by maximum likelihood methods and using the bootstrapping procedure in SPSS.

Bootstrapping. The sampling designs for Statistics Canada's surveys are generally complex. As a result, the variance of an indicator cannot be estimated with simple formulas. Therefore, re-sampling methods are often used to estimate the variance. For the HES 2006 data, we use bootstrapping methods to estimate the variance of a variable and to derive coefficients of variation as quality indicators of the estimates. Similarly we use bootstrapping methods to make inferences in the logistic model. The bootstrap method consists of sub-sampling the initial sample and then estimating the variance using the sub-sample results. For this computation we used bootstrap weights, generated in the survey process. All these estimates were conducted using the BOOTVARE_V30.SPS program (see Estimation of the Variance Using Bootstrap Weights User's Guide for the BOOTVARE_V30.SPS Program (Version 3.0), Statistics Canada, unpublished document).

Interpreting odds ratios. The odds ratio measures the effect of a unit change in the explanatory variable on the odds of observing a positive outcome (water treatment, in our case). The Odds Ratio is calculated as: $OR = e^{\beta_k}$, where e is the base of the natural log and β_k is the estimated coefficient for the kth variable. The exponential of the coefficient is interpreted as: for a unit change in x_k, the *odds* of observing a positive outcome (treatment) is expected to change by a factor of "exp(β_k)", holding all other variables constant. An odds ratio of 1 indicates the explanatory variable has no effect on the treatment choice. For dummy variables, the odds ratio indicates the change in odds as compared to the omitted category. For example, a household income of $80,000 to 90,000 increases the odds of treating water by a factor of 1.28, as compared to households with income less than $20,000 (Appendix Table A.6).

Predicted probabilities. Generally, the information provided by the logit coefficient on the relationship between explanatory variables and outcomes is limited to the sign and statistical significance. A more meaningful interpretation of this relationship comes from the computation of predicted probabilities (Long and Freese, 2001). The predicted probability is the probability computed using the coefficient estimated by the model for any specific value of the explanatory variables. They are computed as:

$$\widehat{P}(Treat = 1 \mid \mathbf{x}) = \Lambda(\widehat{\beta}_1 Demo + \widehat{\beta}_2 SocioEco + \widehat{\beta}_3 Source + \widehat{\beta}_4 Loc)$$

where the β-hat coefficients are those estimated with the logit model and the value of the explanatory variables (*Demo, SocioEco, Source and Loc*) defines a specific household profile.

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Rural overview	Volume 1 No. 6; Volume 3 No. 3; Volume 4 No. 7; Volume 5 No. 2; Volume 6 No. 7
Demographics and migration	Volume 1 No. 1; Volume 2 No. 2; Volume 2 No. 3; Volume 3 No. 6; Volume 4 No. 2; Volume 5 No. 4; Volume 6 No. 3
Education and skills	Volume 4 No. 5; Volume 5 No. 6; Volume 6 No. 2; Volume 7 No. 1
Agriculture	Volume 3 No. 2; Volume 4 No. 8; Volume 6 No. 1
Workforce and employment	Volume 1 No. 2; Volume 2 No. 1; Volume 2 No. 6; Volume 2 No. 7; Volume 2 No. 8; Volume 3 No. 1; Volume 3 No. 4; Volume 3 No. 8; Volume 4 No. 1; Volume 4 No. 3; Volume 4 No. 7; Volume 5 No. 5; Volume 6 No. 8
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Tourism	Volume 5 No. 8; Volume 6 No. 5
Income and expenditure	Volume 1 No. 4; Volume 2 No. 5; Volume 3 No. 7; Volume 4 No. 4; Volume 5 No. 7; Volume 7 No. 4
Housing	Volume 2 No. 4
Health	Volume 1 No. 5; Volume 4 No. 6; Volume 5 No. 3
Internet and computer use	Volume 1 No. 7; Volume 3 No. 5; Volume 5 No. 1; Volume 7 No. 3
Social trends	Volume 6 No. 4; Volume 7 No. 1
Environment	Volume 6 No. 6; Volume 7 No. 2
Aboriginal and the north	Volume 1 No. 8