The Economics of Climate Change: The Economics of a Water Adaptation Strategy
by Ray Rivers, Linda Mortsch and Ian Burton
Environment Canada, Ontario Region.

Abstract

Global climate change may seem inevitable since the planet’s population has been unable to effectively reduce its emissions of greenhouse gases. Negotiations for an international agreement on targets and schedules for emissions reductions have proceeded slowly and the scientific consensus is that climate change is already underway. Much of the research into the effects of climate change has been focused on the potential environmental and economic damages and benefits that may result from the warming effects of the phenomena. Avoidance of the damages through anticipatory adaptive strategies has been relatively neglected partly from the concern that drawing attention to the potential efficacy of adaptation might reduce the resolve of parties to reach international agreement on greenhouse gas reductions and give encouragement to those who deny the existence or urgency of the climate change problem. Nevertheless adaptation cannot be ignored and programs to adapt to changing climate are an inevitable consequence of living on this planet. Further, the development of strategies to adapt will be crucial to survival while society ponders and ultimately delivers effective mitigation. This paper explores the economic consequences of an adaptive strategy for water demand and supply management for Ontario. It further discusses a vehicle that might be used to effectively deliver such a water adaptation strategy.

Introduction - Climate Change and Adaptation

This is really happening - we are doing this by ourselves to ourselves

Human activities such as combustion of fossil fuels and land use practices are emitting carbon dioxide, nitrous oxide, methane and other gases into the atmosphere. There is growing concern that humankind may be unintentionally altering the chemistry of the atmosphere, thereby enhancing the greenhouse effect and changing the climate system of the Earth. The temperature of the Earth is expected to increase and other climatic elements such as precipitation, evapotranspiration, and cloudiness will also be altered. Tangible evidence for the change has yet to be clearly isolated from natural variation in temperature yet the international scientific community, represented in the work of the Intergovernmental Panel on Climate Change (IPCC), has reached a consensus that global warming can now be detected. They have concluded that the balance of evidence suggests a discernable human influence on global climate and that hyrologic implications are quite serious with ramifications on water resources management. (1)

For example, the double carbon dioxide (2XCO2) General Circulation Model (GCM) scenarios suggest higher air temperatures for most of Canada and increases in both evaporation and evapotranspiration. Although many areas of Canada can expect increased precipitation,
ironically, in most cases climate change leads to less water availability (2). Even when precipitation remains constant, higher air temperatures, longer ice-free and freeze-free seasons, and a longer growing season contribute to an extended period of evaporation and transpiration. Declines of lake levels, streamflows, wetland levels, soil moisture, and groundwater levels are likely (3). Climate change impacts on runoff and streamflow include alterations in the magnitude of the mean, minimum, and extreme flows as well as their temporal distribution and duration. Also, there will be regional changes in water supply.

The Great Lakes Basin is predicted to be affected by global climate change as annual average temperatures warm and substantial decreases in total precipitation are felt in all but the northeastern areas of the Basin. (3) The Great Lakes Environmental Research Laboratory (GLERL), used four likely climate transposition scenarios and noted that higher temperatures and changes in precipitation resulted in Great Lakes net basin supply reductions of between 1% and 54% (4). These results are all the more significant given that climate changes are expected to take place rather dramatically with great variability and extreme events dotting the pathway towards higher average levels of temperature and reduced levels of water availability. It is not possible to say that this process will stabilize at some higher level of equilibrium as long as anthropogenic greenhouse gas emissions continue to increase the atmosphere. Further, climate change may manifest itself in ways that cannot be predicted and the global response is expected to be volatile.

Table 1 below summarizes the impacts on the Great Lakes of four GCM climate change scenarios linked to hydrologic models of the Great Lakes. All scenarios project a decrease in annual runoff for all the Great Lakes. Similarly, mean annual outflows and mean annual water levels decline under climate change scenarios. In general, climate change scenarios project long-term lake levels to decline to or below historic low levels in the Great Lakes.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>General Circulation Model Impacts on the Great Lakes by Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Change in Annual Runoff</td>
<td>CCC</td>
</tr>
<tr>
<td>Superior</td>
<td>-21</td>
</tr>
<tr>
<td>Michigan</td>
<td>-38</td>
</tr>
<tr>
<td>Huron</td>
<td>-36</td>
</tr>
<tr>
<td>Erie</td>
<td>-54</td>
</tr>
<tr>
<td>Ontario</td>
<td>-34</td>
</tr>
<tr>
<td>% Mean Annual Outflow Changes</td>
<td>CCC</td>
</tr>
<tr>
<td>Superior</td>
<td>-13</td>
</tr>
<tr>
<td>Michigan-Huron</td>
<td>-33</td>
</tr>
<tr>
<td>Erie</td>
<td>-40</td>
</tr>
<tr>
<td>Ontario</td>
<td>-39</td>
</tr>
<tr>
<td>St. Lawrence at Montreal</td>
<td>-40</td>
</tr>
<tr>
<td>Annual Change in Mean Water Levels (Metres)</td>
<td>CCC</td>
</tr>
<tr>
<td>Superior</td>
<td>-0.23</td>
</tr>
<tr>
<td>Michigan-Huron</td>
<td>-1.62</td>
</tr>
<tr>
<td>Erie</td>
<td>-1.30</td>
</tr>
<tr>
<td>Ontario</td>
<td>-</td>
</tr>
<tr>
<td>St. Lawrence at Montreal</td>
<td>-1.30</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Increases in Mean Annual Water Temperature (Celsius)</td>
<td>CCC</td>
</tr>
<tr>
<td>Superior</td>
<td>5.1</td>
</tr>
<tr>
<td>Michigan</td>
<td>5.6</td>
</tr>
<tr>
<td>Huron</td>
<td>5.0</td>
</tr>
<tr>
<td>Erie</td>
<td>4.9</td>
</tr>
<tr>
<td>Ontario</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Adapted from Mortsch and Quinn, 1996, 904 (5)

The fact that we know climate will change and that we expect that change to be volatile without end has prompted discussion of mitigation strategies to curb the increasing global greenhouse gas emissions. The uncertainty of the consequences of global climate change driven by continued rates of increase in the levels of greenhouse gas emissions from all nations can only be adequately addressed by strategies that lead to reductions in the rate of increase of those emissions. Society’s confidence in the science of climate and the atmosphere has been strengthened by the role that science has played in predicting and developing mitigative actions for destruction of the earth’s ozone layer. In the same way that the world community has acted to ban ozone destroying chemicals, it must act to limit the creation and emission of greenhouse gases.

However, global climate change is a continuous process, has already started and will likely result in effects regardless of the most dramatic mitigative action the world community could possibly undertake today. Thus, there is a need to consider adaptation strategies to prepare for the consequences of climate change. This paper examines an adaptive strategy for water supply management for Ontario in the Great Lakes Basin. An adaptation strategy for the Great Lakes/St.Lawrence Basin was described by Mortsch et. al as including the following components:

- a process of change (behaviour, action, attitude, policy, decision-making);
- leading to actions (passive, reactive, or anticipatory); and
- resulting in desired outcomes and an anticipated duration (6).

Adapting to possible impacts of climate change is important given the significance of the impacts in the Great Lakes Basin including increased precipitation, lower lake levels, reduced streamflow, decreased water quality, decreased lake ice cover, and an increased incidence of extreme events. Simple, easy to implement adaptation strategies can be classified as ‘no regrets’ measures. ‘No regrets’ options have been gaining favour because they address known environmental problems in addition to climate change. They continue to be valuable from a benefit/cost perspective irrespective of the magnitude of climate change. However, for significant impacts, such as a potential decline in streamflow of 50%, very specific dramatic strategies will be required. Burton in 1995 suggested six reasons why we must adapt to climate variability and change now:

1] Climate change cannot be totally avoided. We are already committed to some change.
2] Anticipatory and precautionary adaptation is more effective and less costly than forced, last minute emergency adaptation.
3] Climate change may be more rapid and more pronounced than current estimates suggest. There is a possibility of nasty surprises.

4] There are immediate benefits to be gained from better adaptation to climate variability and extreme atmospheric events.

5] There are immediate benefits to be gained by the removal of maladaptive policies and practices.

6] Climate change brings opportunities as well as threats. There are future benefits to be gained from climate change.(7)

Water Supply Adaptation for Ontario

*Canada continues as one of the most water intensive/water inefficient nations on Earth*

Schaefer and Hurst reviewed the latest information on water use and noted that 4.4 billion cubic metres of water were supplied in 1994 to Ontario industrial, commercial, institutional and residential users with just over half of that going to households (8). This represents a slight decline in total volume supplied from a decade earlier. Nevertheless, water supplied to residential properties, estimated at 260 litres per capita per day in 1994, increased at a faster rate (24%) than population growth (20%) over the period 1983 to 1994. Industrial water use, on the other hand declined sharply in response to higher prices and changes in demand. The great Ontario recession of the 1990’s and industrial restructuring following the implementation of free trade in Canada has no doubt contributed to this drop in industrial water use.

Wastewater flows, on the other hand, have increased steadily and actually exceeded the volume of water supplied in 1994 by almost a billion cubic metres, (5.3 cu m) almost 20% greater than the flow levels of a decade earlier. This may be partly attributed to high infiltration and inflow as a result of inadequate maintenance of the high cost water and sewer infrastructure required to support Ontario’s urban sprawl communities. The Ontario Ministry of the Environment and Energy in 1990 had estimated outstanding municipal infrastructure restoration financial requirements of between $6 billion and $12 billion (9). These estimates are likely low since they were prepared before the discontinuation of the Municipal Assistance Program that has provided grants to municipalities for the maintenance and upgrading of water and wastewater works. Studies by Rivers and others have demonstrated that reducing the hydraulic loading to municipal sewage plants could lead to commensurate reductions in the discharge of conventional wastewater contaminants such as bio-chemical oxygen demand and suspended solids. This work concluded that water conservation would permit the postponement of expenditures for expansions of wastewater facilities to accommodate growth. Perhaps even more important was the conclusion that water conservation may be the most cost effective pollution prevention strategy for dealing with wastewater pollution (10).

Almost 80% of Ontario’s population is served by municipal water systems as opposed to wells and septic systems. Yet, only two thirds of those using municipal water are equipped with water meters to pay for the actual amount of water used, a number that has been increasing over the last five years. Among all municipalities 17% still offer their customers ‘declining block rates’ that discourage water conservation since the marginal cost of water is less than the average cost. One
third of all water users were charged a constant price per unit for all the water they used and only 4% of all municipalities utilized environmentally conserving 'increasing block rates' (11).

Climate change studies are forthcoming that will further refine the effects of decreased net water supply for both surface and groundwater resources in the Great Lakes Basin. However, based on GCM and climate change transposition scenarios, a consensus on climate change impacts in the Great Lakes Basin is emerging indicating that net water supply will fall throughout the basin and that future lake levels will drop significantly. This will lead to two consequences in the absence of adaptation - water shortages for surface as well as groundwater users and increased pollution. Warmer temperatures combined with higher evapotranspiration rates will lead to an increase in the demand for water for irrigation and other purposes and thus greater use of both surface and groundwater supplies by household residents as well as farmers seeking to compensate for the drying effects of climate change. At the same time there will be less soil moisture and reduced streamflow and groundwater levels.

Further, since surface water volumes in both the tributaries and the Great Lakes are expected to decline over time the practice of utilizing dilution (assimilation) for wastewater treatment will become less effective. Thus the concentration of pollutants will increase in these wastewater discharge bodies reversing the trend of the last two decades of progressive improvement in ambient water quality. Ontario residents will either have to suffer the consequences of this increased water pollution or undertake significant new expenditures for wastewater treatment enhancements and adopt a strategy for water conservation.

While it is clear that adaptation for reduced water supply will be required, it is far less certain how extensive this adaptation need be. Since global climate change is likely to be erratic, volatile and dis-continuous specification of the exact degree of adaptation would be seen as a spurious and academic exercise. Sceptics already abound since the apparent trend, over the last few years, has been towards increasing rather than decreasing water levels and water supply in the Great Lakes basin. On the other hand, there is a consensus among climate scientists that the long run trend will be towards a dryer - not a wetter future. An additional consideration, in this regard, may be the need to respond to renewed pressure from US jurisdictions facing even greater predicted water supply reductions than Ontario. Action by states bordering the Great Lakes to divert water towards water scarce portions of the USA would greatly accelerate both the timing and the degree of adaptive actions required in Ontario.

Given that predictions based on climate modeling have exceeded a 50% reduction in water supply for some portions of the Great Lakes Basin, it might be appropriate to consider minimum conservation adaptation strategies for Ontario of between 20% and 40%. Additional population growth would require even greater reductions making the 40% level perhaps a more realistic goal. The purpose of this paper is to examine how 20% to 40% reductions in water use could be undertaken and at what cost to society. Clearly adaptation strategies for water use in Ontario should address the demand as well as the supply side of water use. Options, thus must have regard for strategies that include water pricing and population growth management to control the
demand for water and improved maintenance and technological adoption to stretch and permit greater use of existing supplies and infrastructure.

**Water Demand Management**

*Too much effort has made trying to expand supply and too little thought given to demand*

The price elasticities of demand for water vary between industrial and residential users and between the short and the longer run. An analysis by Tate and Rivers (12) indicated that an across the board increase in industrial water charges in Ontario by less than 2 cents per cubic metre would lead to a 30% decrease in industrial water intake and a 25% reduction in consumption. Other work by Shaw indicated that a one dollar per cubic metre increase in water charges for municipal water users would be necessary in order to achieve a 21% decline in municipal water use in Ontario. (13). A review of water use in Ontario between 1983 and 1994 by Schaefer and Hurst demonstrated this difference in price elasticities noting that while industrial and residential water rates rose respectively 35% and 31% industrial water use fell dramatically while residential water use actually increased (14).

Work by Econometric Research Limited indicated that a ten cent real average price increase for the four municipalities in the Regional Municipality of Halton would amount to a monthly pooled reduction for the four municipalities of 0.175 cubic metres per capita. (15) For Halton Region, with average water prices totaling about one dollar per cubic metre, this would imply that an approximate ten percent increase in the price of water would lead to a two and a half percent reduction in municipal water use, roughly the same relationship by as estimated by Shaw.

Water pricing can be a very effective tool for reducing demand particularly if technological options exist to complement behavioral adjustment to more expensive water. Further, the mere implementation of water meters, without any change in average water charges, has been shown to reduce water use by 30% or more. (16). Yet municipalities, as progressive as Toronto and Hamilton, still have thousands of water customers that continue to be supplied water for a flat monthly rate regardless of how much they use. Different pricing schedules can be expected to lead to different levels of water use. Pricing water not only serves to accumulate revenue for the supplying municipality, it also communicates a price signal that influences consumer behaviour.

If the long run supply of water is declining and the long run demand increasing, efficient allocation would argue for a rate structure where marginal units are priced higher than preceding ones - increasing block rates. Yet, in 1994 less than 5% of the Ontario water using population was made to pay for their water use through increasing block rates (17). The majority of those using water meters paid on the basis of constant block rates or a two part tariff (including constant block rates) and 17% of municipalities charged for water using declining block rates where the marginal price of water falls with increased volumes used.

Another variable associated with the exogenous demand for water is population growth. Although natural rates of population growth have been declining and are perhaps insignificant from this perspective, immigration continues to increase the human footprint of Ontario.
Ontario's population grew by 20% over the eleven years from 1983 to 1994. Indeed, it is not just the growth itself that serves to increase the demand for water - it is the nature of human settlement. Work by Rivers and Tate (18) demonstrated that per capita water use in highly concentrated urban centers, such as the City of Toronto, was significantly less than that of the sprawled out suburbs.

The efficiency of high density urban development over traditional urban sprawl development in Ontario was underlined by Pamela Blais in her ground breaking work for the Golden Commission (19). Further research by Thorp, Rivers and Pebbles for the State of the Lakes Ecosystem Conference (SOLEC 96) demonstrated that land use is the most significant stressor on the nearshore ecosystem of the Great Lakes and that urban sprawl development is the greatest stressor among land uses (20). Yet human settlement in the Great Lakes basin and Ontario continues to take the form of urban sprawl. Clearly, putting an end to inefficient urban sprawl has to be part of a water conservation adaptation strategy. Given the high correlation between use of the private automobile and urban sprawl, ending sprawl would also be a leading edge mitigation measure in the fight against ever increasing greenhouse gases, that are causing climate change.

**Towards an Adaptation Strategy**

*The existence of a strategy is of little value unless some body is prepared to implement it.*

Canada stands as one of the top water consuming nations in the world and thus has great potential for water efficiency. Relatively low water prices have served to undermine attempts at water efficiency over the years throughout Canada, and especially in Ontario. The federal government conducted a major inquiry in the 1980's that formed the basis of federal water use policy and called for full cost user pay for water (21). The Ontario Ministry of Natural Resources had encouraged efforts at water efficiency in the early 1990's with very limited success notwithstanding the growing body of evidence that shows that reducing water use may be the single most cost effective solution to the preventing water pollution.

Clearly, the point of departure for a water reduction strategy involves universal water metering and a third of Ontario households on municipal water still do not have a water meter. Even worse some municipalities such as Hamilton appear to have actually lost interest and de-emphasized or terminated universal metering programs over the last few years. Second, if water conservation is to become a goal, the only water rate structure that promotes conservation is the increasing block rate. With less than 5% of Ontario's water users paying for water on the basis of increasing marginal rates the task of putting together an effective pro-active and anticipatory water conservation adaptation strategy is defeated before it can start. Third, the degree of subsidization among water users is still estimated at 25% of the full costs of water infrastructure systems (22). Since the costs of enhancements to water/wastewater infrastructure are pooled and cross subsidized through property taxes, water users consume more than they would were these costs placed directly on the water bill.
The federal and provincial governments have seen their roles in water management reduced. Even as municipalities have grown in size and mandate, environment ministries at the senior levels of government have downsized. As a consequence these agencies are no longer in a position to exercise influence to convince municipalities to undertake water conservation programs. Municipalities operating even more independently of each other than in the past now have difficulty placing the priority for a water conservation strategy ahead of so many other priorities, unless they themselves were to face imminent water shortages. On the one hand, while the Province of Ontario may have the constitutional authority to force water conservation policies on municipalities in the Province, no such policies appear to be in the works.

As Ontario’s municipalities evolve through forced amalgamations to become virtual ‘city-states’, with the added responsibility of social and other activities downloaded from the Province, they will be less inclined to pursue activities with a perceived longer term payback, such as water conservation programs with higher water prices, than they were in the past. An added factor is that all provincial water and wastewater treatment facilities are being turned over to municipalities thus further reducing provincial responsibility for these facilities and provincial influence in municipal water use policy. The bottom line is that municipalities lack the incentives necessary for them to undertake costly water conservation programs or to alter existing water prices. A logical consequence of the above is that municipalities lack the incentives to undertake conservation and would not likely be interested in participating in an Ontario water conservation adaptation strategy unless and until they actually experience water shortages themselves.

Thus the best hope for actualization of a water conservation strategy in Ontario, short of there being a major water shortage crisis, is for the senior levels of government to impose one. The Province of Ontario would need to mandate a water conservation policy through changes in legislation and, possibly, with support from the federal government. Ideally it could do so through a new water agency to administer Ontario water based policies and legislation. Such an agency could be charged with implementing all water taking and discharge permits; setting appropriate water and wastewater rates for municipal, industrial, farm and other users; settling disputes among water users; monitoring and conducting scientific research on water ecosystem issues in the Basin; implementing international water agreements and programs, such as the Great Lakes Remedial Action Plans, and mandated to develop and implement policies and programs to ensure that environmental goals, such as a climate change water adaptation strategy.

A water resource conservation agency would use economic instruments as a first priority, through its ability to levy charges for water withdrawn from surface and ground sources, to ensure that environmental goals are met. It would sanction water based emissions trading and apply water use tariffs to water supplied and returned to municipal water and wastewater systems such that conservation becomes a priority and water based ecosystems are protected. It could establish utilities where they do not exist for the development of sustainable municipal water, wastewater and stormwater systems. Given the ability to surcharge for water services the agency would have an influence over municipal water rates and pricing schedules and thus would be in a position to effect water demand management uniformly and fairly across the province. For example, were the agency to surcharge all water users a flat ten percent charge (about 10 cents
per cubic metre) it would retrieve over 400 million dollars in revenue - more than the annual budget for the Ministry of Environment and Energy.

However, ten cents would not be sufficient to induce the kinds of behavioural change needed to effect a 20-40% reduction in water use. To achieve that level of total water use reduction might require a one dollar surcharge - effectively doubling the water rates in Ontario but bringing in revenues of over three billion dollars a year after adjustment for income and price effects on demand. Such a substantial amount of money could be redirected, for example towards funding the $6-12 billion of estimated current water and wastewater infrastructure improvements needed in Ontario. A doubling of average water rates would, of course have four consequent effects. First, given the much higher price elasticities of demand for industrial water users, it would force these users to continue to seek out less water intensive and more water efficient technologies, thereby inducing additional water pollution prevention.

Second, it might would force water users, especially those in rural areas, to seek out alternatives to municipal systems putting pressure on private ground water supplies that are already stretched to the limit in some cases possibly provoking the need for even greater regulation. Third, it would improve the market allocation of the water resource by encourage municipalities to finally provide universal water metering services to all residents and to implement water rates that reflected the long run marginal cost for a dwindling water supply for a growing population. The market for water conserving appliances would be stimulated and new development would include measures to ensure water conservation through progressive landscape and appliance features in new homes and businesses and thus serve to as a restraint to continued urban sprawl in Ontario. Finally, there would be an income effect but with current household water use averaging 260 litres a day the monthly household effect would be the equivalent of the price of a case of beer.
References


