Freshwater Supply and Demand in Canada: Statistics and Accounts

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Introduction

Statistics Canada (StatCan) has been working on the development of its water statistics program since the turn of the century. This water statistics program is comprised of several components, which all essentially serve one need: to increase knowledge of the interaction between water and human activity, over time and across the country. Such a system for water statistics has been identified by StatCan (StatCan) as one missing component of the Canadian System of Environmental and Resource Accounts (Statistics Canada, 1997).

This article is divided in two parts: The first part provides an overview of institutional arrangement that have allowed for the development of the water statistics program, while the second part presents some of the water statistics and accounts that result from these recent developments.

Institutional Arrangements for Water Statistics

StatCan Environment Accounts and Statistics Division (EASD) has a mandate to collect, develop, compile, analyze and disseminate environmental data, emphasizing their integration with socio-economic data. The division delivers its mandate mainly through four program elements: (1) environmental accounts, (2) environmental surveys, (3) spatial analysis and reporting, and (4) national and international collaboration on environmental indicators.

EASD has grown and developed mainly as the result of internal and joint federal initiatives. While this growth has been largely opportunistic, EASD has a clear vision of what a complete and comprehensive environment statistics program should comprise. Inspiration for this is taken from Statistics Canada's vision of a national statistical agency, which provides quality guidelines and principles of comprehensiveness and objectivity; the System of National Accounts which provides a comprehensive framework for economic statistics; the UN System of Integrated Environmental and Economic Accounts (SEEA), which defines several environmental accounts linked to the SNA (including water accounts); data users including other government departments, NGOs and universities, who provide input on the nature of statistics that they require to reach their objectives; and international agencies such as the UN-ECE and OECD, which provide a forum to discuss longer-term development objectives for environmental statistics.

Inter-Departmental Arrangements

EASD's ongoing federal government support confirms the need for a national source of environment statistics and for a national focal point for developing environmental statistical standards to ensure national and international coherence. For example, in 2004, a five year Memorandum of Understanding was signed by Statistics Canada, EC (EC) and Health Canada, launching the Canadian Environmental Sustainability Indicators (CESI) program. CESI has since then provided data and information helping to track Canada's performance with regards to water quality, air quality and greenhouse gas emissions. This was mainly achieved by the development of database, annual indicators, reports and environmental surveys, and largely the result of interdepartmental collaboration. Three water-specific environmental surveys were developed: the the Industrial Water Survey (IWS), the Survey of Drinking Water Plants (SDWP), and the Agricultural Water Survey (AWS).

Since 2010/2011, the CESI survey program has been permanently funded through a joint Treasury Board Submission with EC. The data produced by these surveys are used in EC's reporting of activities related to both the CESI initiative and the Federal Sustainable Development Strategy (FSDS), which has a legislated requirement to report to parliament.

Another important institutional arrangement is that of the Policy Research Data Group (PRDG) initiative. This initiative has provided funds to EASD to conduct its other surveys (e.g. Waste Management, Environmental Protection Expenditures Survey), as well as helping support the development of the environmental accounts, including Canada's Water Accounts. This funding confirms that EASD's surveys and accounts fulfill horizontal policy needs.

In 2009, Infrastructure Canada also sponsored EASD to inventory drinking water plants and wastewater treatment plants as part of their overall infrastructure inventory to support a large national funding initiative. This inventory included the provision of basic tombstone information gathered through the SDWP and follow-up calls.

Finally, in 2010, EASD partnered with Agriculture and Agrifood Canada (AAFC) to assume responsibility for conducting the 2012 Farm Environmental Management Survey (FEMS). This survey covers the farm environmental practices that affect, among others, water quality; the survey measures, for example, pesticides, nutrients and manure management plans, tillage practices, etc.

Institutional arrangements based on partnerships

EASD's development has been driven by partnerships and by specific long-term user data needs. These partnerships and needs include those of national and international bodies as well as those required to meet internal quality standards and interdepartmental guidelines. As such, EASD's partners and users have been varied.

Among external partnerships, meeting the statistical needs of EC has been a top priority for the program since its inception. Working within the context of differing time frames and mandates of a statistical agency and a policy department, StatCan and EC have nonetheless built a strong partnership that has resulted in, for example:

- As mentioned previously, StatCan's commitment to surveys supporting the CESI initiative and the FSDS;
- Several other project teams in EASD maintain close working relationships with their counterparts in EC and other federal departments. For example, the water accounting work is a collaborative effort with EC's Water Survey of Canada, Natural Resources Canada's (NRCan) National Atlas of Canada and AAFC; the development of the Survey of Industrial Processes focussed on data gaps expressed by EC's Pollution Data Branch; The Materials and Energy Flows Accounts group work with EC's Greenhouse Gas Division to ensure comparability of emissions estimates;
- Statistics Canada is supporting the review of EC's Reference Hydrometric Basin Network and Water Quality Network, with contribution with regards to the geo-statistical aspect of the network and drainage areas (station location and distribution, basin land cover, land use, etc.);
- In 2009, StatCan established a trilateral Assistant Deputy Minister-level committee with EC and NRCan to facilitate the publication of data related to the impacts of climate change, including glacial mass balance, temperature, precipitation, snow cover and sea ice cover statistics. This has been an invaluable forum to discuss other horizontal priorities such as energy, ecosystems, biodiversity and statistical methodologies.

The institutional arrangements described above have supported the development of a comprehensive water statistics program. The coverage of this program includes such components as a physical stock account for water, renewable water trends, water use, and virtual water. These components are described below.

Physical stock account for water

Canada is often presented as a water-rich nation, and this notion is easy to understand: we do have one of the largest renewable water supplies in the world and have access to a considerable portion, perhaps as much as 20%, of the world's stock of surface freshwater. Perhaps because of this, little has ever been done to measure the assets comprehensively, spatially and temporally. (Statistics Canada, 2010)

EASD developed and published a model to estimate the renewable portion of Canada's physical water assets in 2009 (Bemrose *et al.*, 2009). This model, the Water Yield, provides estimates that are derived from the monthly amounts of unregulated flows of water in Canada's rivers and streams. Measuring this part of the hydrological cycle over time provides insight into the status and trends of water resources in Canada, including monthly supplies and inter-annual changes.

The model involved the development of a data framework for Canada, which required the assembly of a database for unregulated streamflow gauging stations data, and the compilation of contributing basin shape and areas for each station. The runoff depth data points when then used to generate a spatial distribution of monthly runoff over the extent of Canada for each of the thirty years, using ordinary kriging as the interpolation method for optimum surface prediction. Finally, the monthly runoff surfaces were scaled to produce water yield estimates that were summed to generate annual values, which were then averaged to produce the thirty-year surface and scaled back to a volume based on the resolution (100 km^2) of the surfaces, producing the water yield estimate of 3472 cubic kilometer. The results were then validated with an assessment of the stability of the Water Yield model estimates conducted by repetitively removing input data and observing how the interpolation performed, and by assessing differences between the observed and predicted values.

Renewable water trends

Knowing the long term average amount of renewable water and its spatial and monthly distributions proved interesting and useful, but also raised the questions about temporal trends. EASD, in collaboration with the Statcan's Business Survey Methodology Division (BSMD), developed and applied a method to measure these hydrologic trends (Bemrose *et al*., 2010).

Research on the magnitudes of present and historical components of the hydrological cycle is a mainstay of hydrometeorological science. Numerous studies have been conducted which use nonparametric rank-based techniques to determine the magnitude and significance of a trend found between time and streamflow. The Mann-Kendall test, one of the main methods used for trend estimation, provides a global robust estimate of the slope of the underlying trend in the series of annual water yield estimates. The method presented by StatCan offered a complement to this global estimate where the time series is deconstructed into several components separating the underlying trend-cycle from the irregularities in the series. This was achieved by first estimating a trend and it's cyclical component for the water yield time series, and by secondly describing the global trend over the span of the series by fitting a linear model to the trend-cycle estimate. This allowed to conclude that, from 1971 to 2004, water yield in Southern Canada decreased an average of 3.5 cubic kilometre per year, which is equivalent to an overall loss of 8.5% of the water yield over this time period.

<u>Water use</u>

Statistics on water use in Canada are now more complete than never, in large part because of EASD's new water surveys. These biennial surveys are briefly described in turn:

Industrial water survey

StatCan conducted the Industrial Water Use survey, on behalf of EC, from 1976 to 1996, at which point EC funds were cut. The StatCan CESI proposal included the revival of this survey.

The survey process was entirely revised and conducted in 2006 for reference year 2005 (Statistics Canada, 2008). The survey questionnaires (one for each of the three components; manufacturing, mining, and thermal-electric power generation) were designed in consultation with specialists in StatCan and EC. The information collected includes the sources of water used, what purposes industry used the water for, whether or not water was re-circulated or re-used, where the water was discharged and what treatments were used for water brought into the facility and discharged from the facility. Also, water acquisition costs and operating and maintenance expenses related to water intake and discharge is collected.

The frame used for sampling purposes is the StatCan Business Register with the observed population of all manufacturing, selected mining and all thermal-electric locations as defined by the North American Industry Classification System (NAICS) 2007. The target population consists of locations primarily engaged in manufacturing, coal mining, metal ore mining, non-metallic mineral mining (excluding sand and gravel quarrying), nuclear electric power generation and fossil fuel electric power generation. There is an independent sampling strategy for each of the three sectors, where a census is taken of the thermal-electric power generating stations component of the survey. A stratified simple random design is used for sample selection in the manufacturing and mineral extraction sectors. The manufacturing component of the survey is divided into four sampling groups, from a “must-take” group to “low-rate” group. In all cases, locations are stratified by industry (3 and 5 digit NAICS) and by geography, i.e. provinces and drainage regions (Statistics Canada, SDAC). The 2007 response rate for the manufacturing component of the Industrial Water Survey was 72%. For the mining component of the survey, it was 79%. The response rate was 92% for the thermal-electric component. Edits and imputation were done using StatCan’s Generalised Edits and Imputation System (GEIS). Five methods of imputations were used: Deterministic imputation (only one possible value for the field to impute), historical imputation, imputation by ratio, donor imputation (using a "nearest neighbor" approach to find a valid record that is most similar to the record requiring imputation) and manual imputation.

Survey of Drinking Water Plants

The Survey of Drinking Water Plants (SDWP) is conducted to provide Canadians with national and regional information related to the production of drinking water. The survey questionnaire is designed in consultation with specialists at StatCan, HC, EC and provincial agencies that regulate drinking water facilities. The information collected included the sources of raw water, the volumes of raw and treated water processed by the drinking water plants, the classification of the drinking water plants, the treatment processes used, and the quality of the raw and treated water. Capital expenditures and operation and maintenance costs related to drinking water treatment were also collected. The SDWP was conducted in part to fulfill the data requirements for the development of a national indicator of source and treated water quality. It is also intended to provide other statistical measures of the links between human activity and environmental quality.

The target population was composed of drinking water facilities licensed and regulated by provincial/territorial agencies that draw and process raw/source water from the environment and convey treated/potable water for consumption. The survey does not include information on the distribution of treated water. The target population is derived from a survey frame that was built in 2007 when StatCan requested the inventories of drinking water plants held by the provinces and territories. Excluding systems that supply water to communities with less than 300 people and other regulated systems that service schools, camp grounds, commercial establishments, provincial parks, etc., a survey frame of approximately 2,600 drinking water facilities serving communities of 300 or more people was compiled, the majority being publicly-owned (municipal) systems. This survey is a census with a cross-sectional design. The response rate for the survey was 56% in reference year 2007. This survey also relied on the GEIS, and six methods of imputation were used: deterministic imputation, imputation by linear regression, trend imputation, imputation by ratio, donor imputation and manual imputation. The criteria for ratio and donor imputation were various combinations of water treatment type, source water type and geographical location (province, drainage region, or Canada). No imputation was conducted on water quality variables.

Agricultural Water Use Survey

The Agricultural Water Survey (AWS) is conducted to gather information on water use, irrigation methods and practices, and sources and quality of water used for agricultural purposes on Canadian farms. The data collected is used in CESI's reporting activities. The information will also be used by AAFC to inform water use policy and development of programs for Canadian irrigators. StatCan will also use the survey results to improve the modeling of irrigation volumes by type of crops and as part of the water accounts.

The target population for this survey is composed of the Canadian farm operations that do irrigation. The surveyed population includes agricultural operations with sales meeting a certain threshold and that reported irrigating or owning irrigation equipment on the 2006 Census of Agriculture. The AWS questionnaire was designed by a project team made up of StatCan's Agriculture Division and EASD, AAFC, EC employees and provincial experts. Questionnaire design specialists from Statistics Canada's Questionnaire Design Resource Centre (QDRC) were consulted.

A stratified sample design was used. Geographic strata were defined at the DR level or, when there were small populations within an individual DR, groups of DRs. This resulted in fourteen geographic strata. Within each of these strata, the population was divided into four sub-strata based on their predicted water use for irrigation. This predicted value was derived from a model which used data from the 2006 Census of Agriculture and the 2007 Agriculture Water Use Survey. Units were categorized into one of four sub-strata of zero, low, medium and high predicted water use. The thresholds for these sub-strata varied from one geographic stratum to the next. In order to reduce the response burden on those farmers who had been selected for recent StatCan surveys, a sample coordination method known as the “microstratum” approach was used. Within a geographic/size stratum, the units which had recently been least burdened by other StatCan agriculture surveys were more likely to be selected for the AWS. The sample was allocated to minimize coefficient of variation targets at the geographic stratum (DR group) level while at the same time not exceeding a maximum sample size of 2000 units. The targets were not consistent from one DR group to the next. In those DR groups where greater irrigation was anticipated, the targets were lower than those used in other areas. The total sample size was 1981 units.

For those fields related to irrigated area or irrigation volume, the missing or inconsistent data was imputed in an automated manner using a nearest neighbor imputation approach. The imputation was done in such a way to minimize the number of changes to the original data. For all other fields, the response was set to the “don’t know” value. After performing the editing and imputation steps, a total of 1322 units were used for estimation purposes. This results in a response rate of 66.7%.

Discussion

EASD’s research and development in the field of water statistics and accounts has led to the compilation of the most thorough set of water statistics in Canada ever. The funds provided by CESI and PRDG, among others, have supported the development of water surveys and models, the compilation of statistics and the publication of results and analysis that, arguably, leave few data gaps of national importance, and that allow further analytical output. For example, the survey data has allowed for the development of the water flow account, which in turn informed us with regards to virtual water; we now know that Canadian exports account for 66% of water intake through the goods and services it exports (when rain-fed agriculture is included, Statistics Canada, 2010, op. cit.). This points to the importance of agricultural exports in explaining water use in Canada. Multiple other examples demonstrate the importance and interest of having quality water asset and water use data.

Several issues were faced when developing this program. For example, environmental surveys generally focus on physical data in units of measure never or not typically used in other StatCan surveys (e.g. water quality). Also, it is not unusual for one or two respondents to dominate in one geographic area or in one industry sector. The use of environmental geographies (e.g. DRs) alongside administrative boundaries also creates a risk of residual disclosure. Another issue faced by the survey program relates to business surveys where the revenues dominate the need for confidentiality, resulting in quantitative data (e.g. water intake) being suppressed although it may not be as sensitive. EASD and BSMD are working together to find ways to address the problems that sometimes arise when standard suppression rules are applied to non-standard variables.

Other issues include the perception of intrusion from the national statistical organization in non-traditional sphere of inquiry, the complexity of environmental subject matter, the availability of venture capital, and the willingness and availability to participate in inter-divisional and inter-departmental research initiatives. As a result, and despite the generally good relations with other federal departments and agencies, the integration of our products directly into their policy development processes and operational activities remains relatively low. The surveys, publications and accounts are being used but more often as an adjunct to analytical or research work. There are few instances of another department using our statistics to fulfill a legislated requirement.

These challenges are nonetheless worth facing: Since its first edition in 1978, Human Activity and the Environment has been popular as a teaching tool and a source of data for public servants, academics and consultants. The most recent edition, focusing on the Freshwater Supply and Demand in Canada, has ignited a lengthy public debate on water use.

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