Environment Canada Environnement Canada

Audit of the National Hydrometric Program

Final
March 19, 2010

Canada

Audit Key Steps

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List of Acronyms

ADM	Assistant Deputy Minister
ARWR	Total Actual Renewable Water Resources
EC	Environment Canada
GNI	Gross National Income
HYDAT	Hydrometric Database
INAC	Indian and Northern Affairs Canada
MSC	Meteorological Service of Canada
NAT	National Administrators Table
NHPCC	National Hydrometric Program Coordinators Committee
QMS	Quality Management Systems
RHBN	Reference Hydrometric Basin Network
WEM	Weather and Environmental Monitoring
WEO	Weather and Environmental Operations

Prepared by the Audit and Evaluation Team

Acknowledgements

The audit team responsible for this project was led by Sophie Boisvert, CIA, and included Stephanie Brossard, Lalit Golani, Yue Yan and Harjit Singh Saini, under the direction of Jean Leclerc, CIA. C. David Sellars, P. Eng., from Schlumberger Water Services (Canada) Inc., led the assessment of the network configuration.

The audit team would like to thank those individuals who contributed to this project and, particularly, employees and managers of the National Hydrometric Program, along with provincial and territorial members of the National Administrators Table and the National Hydrometric Program Coordinators Committee, who provided insights and comments as part of this audit.

Original signed by

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Chief Audit Executive

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EXECUTIVE SUMMARY

The audit of the National Hydrometric Program was included in the departmental Audit and Evaluation Plan 2009–2012 as approved by the Deputy Minister, upon recommendation of the External Audit Advisory Committee. The rationale for this audit is explained by the complexity of the program in terms of its management structure, network size, capacity and sustainability. The objective of the audit is to provide assurance on the adequacy of:

1. the internal and external governance of the hydrometric network, looking in particular at the committee architecture, decision-making process, reporting structure, and the centre of control; and
2. the current hydrometric network configuration and delivery approaches, compared to its size, capacity and sustainability.

The scope is Department-wide and focuses on Environment Canada's governance and configuration of the National Hydrometric Program as it existed at the time of the audit. The scope does not cover the management performed by the other jurisdictions (provinces, territories or municipalities) or the National Water Quality Monitoring Program.

To assess the governance of the program, the audit team used recognized governance models, frameworks and indicators from national and international institutions in order to derive the audit criteria. The assessment of the network configuration was performed by a reputable expert advisor in the water management field. Interviews with federal, provincial and territorial managers from the National Hydrometric Program and other water specialists were performed, along with an extensive documentation review to validate all findings.

Statement of Assurance

This audit has been conducted in accordance with the *International Standards for the Professional Practice of Internal Auditing* and the *Policy on Internal Audit* of the Treasury Board of Canada.

In our professional judgement, sufficient and appropriate audit procedures have been conducted and evidence gathered to support the accuracy of the conclusions reached and contained in this report. The conclusions were based on a comparison of the situations, as they existed at the time, against the audit criteria.

Summary of Findings and Recommendations

Reliable data and information concerning the levels and flows of Canada's lakes and rivers are critically important to continued economic prosperity, the sustainable management of the environment, and the health and safety of Canadians. Hydrometric information is also required to effectively support policy development and implementation with respect to water availability for economic development in different regions. It has been estimated (Environment Canada 2004) that water's measurable contribution to the Canadian economy ranges from \$7.5–\$23 billion annually, and the amount invested in water monitoring should reflect this economic value. It is clear that the best method for collecting and archiving hydrometric data, and establishing national standards, is via a nationally coordinated program.

Overall, the governance of the National Hydrometric Program is functioning well. The framework exists for participation and delegation of responsibilities among the federal, provincial and territorial Parties. Authorities and responsibilities are reasonably clear and consistent. An accountability regime is in place and operational risks are well assessed. Decision making is open, transparent and based on consensus. By definition, a decision-making process based on consensus brings coherence, but takes time and may impact negatively on efficiency. All Parties accept this as a normal cost to manage a federal-provincial/territorial program. In addition, the National Hydrometric Program is compliant with the International Organization for Standardization (ISO) ISO 9001:2000 standards and is being managed from a continuous-improvement perspective.

The governance of the National Hydrometric Program would benefit from continuous improvements to: the program's authorities and responsibilities within Environment Canada and between Environment Canada and Indian and Northern Affairs Canada; the assessment of strategic risks, the performance of the program in general, and clients' satisfaction; the establishment of priorities on the basis of clients' needs; and communication, exchange of information, learning and innovation (the term "clients" is defined in section 1.2 of the report).

On the aspect of network sustainability, a detailed comparison of the effectiveness of the hydrometric programs in different countries was performed with the use of station densities. It is notable that Canada is a country with one of the largest land spaces, greatest renewable water resources, and one of the lowest abilities to fund the program. More interestingly, compared with other countries, the hydrometric network densities in Canada are among the highest compared to its capacity to fund programs.

While the capacity to fund programs is of interest in comparing the National Hydrometric Program to other countries, the overriding issue is that the importance of our water monitoring programs is undervalued. The size and structure of the hydrometric network is considered insufficient for the overall characterization of water resources in Canada. The needs of other clients for water resources planning, environmental assessment, project approvals, climate change analysis and other scientific requirements are not generally met by the current network configuration, particularly in northern Canada. It was noted that it is not just a question of the total number of stations, as some stations are located for specific needs and are not always in the best locations for research and hydrological analysis. Particular concern was expressed regarding the loss of key long-term stations in reference to the Hydrometric Basin Network. The loss of stations in the 1990s due to budget cuts was a loss to hydrologic records in Canada.

The National Hydrometric Program has been making great strides in the past several years with respect to improving service delivery to clients. This has been achieved in a context of resource restraints and a decrease in the number of hydrometric stations. As a result, it is necessary for the program to continue looking for service and technological improvements through innovative, cost-effective solutions.

The National Hydrometric Program would also benefit from carrying out the following through strategic planning: assessing the current network risks and vulnerabilities; evaluating the demands and establishing priorities to ensure the network provides the largest benefits for the financial resources available, and that resources are optimized to address the areas of greatest concerns; and continued efforts at service and technological improvements through innovative, cost-effective solutions, especially in remote locations.

Recommendations regarding the Network Governance are that:

1. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the National Administrators Table (NAT) and the National Hydrometric Program Coordinators Committee (NHPCC), pursue efforts in the development and implementation of a new approach to strategic planning based on a regular assessment of strategic risks, clients and stakeholders' needs, and that includes strategies for learning, innovation and external communication.

2. The Assistant Deputy Minister, Meteorological Service of Canada, explore with the Assistant Deputy Minister, Science and Technology Branch, a single-window approach to the management of water quantity and quality falling under the purview of Environment Canada, that would benefit provinces and territories.

3. The Assistant Deputy Minister, Meteorological Service of Canada, meet with his counterpart in Indian and Northern Affairs Canada (INAC) to try to clarify roles and responsibilities between the two departments in the management of the National Hydrometric Program (water quantity management).

4. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, further develop the framework to assess the overall performance of the program (ultimate outcomes) and the satisfaction of clients.

5. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, ensure the National Hydrometric Program meets its legal obligation regarding the *Canada Water Act*, section 38, which requires that a report on the operations under the Act be laid before Parliament after the end of each fiscal year.

Recommendations regarding Network Sustainability are:

6. As part of the strategic planning referred to in recommendation #1, the Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, assess the current network risks and vulnerabilities, evaluate the demands and establish priorities to ensure the network provides the largest benefits for the financial resources available and that resources are optimized to address the areas of greatest concerns.

7. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, consider the integration of the hydrometric network with the climate data network, both for network design and data reporting, to improve the scientific value of the hydrometric and climate networks.

8. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, continue looking for service and technological improvements through innovative, cost-effective solutions, especially in remote locations, through the NAT strategic planning exercise.

Management Response

Management concurs with all of the recommendations contained in the Audit of the National Hydrometric Program. Specific actions designed to address the recommendations have been undertaken and will be completed by March 31, 2011.

1 INTRODUCTION

The audit of the National Hydrometric Program was included in the departmental Audit and Evaluation Plan 2009–2012 as approved by the Deputy Minister, upon recommendation of the External Audit Advisory Committee. The rationale for this audit is explained by the complexity of the program with respect to its management structure, network size, capacity and sustainability. The content of this report reflects the document review and interviews performed during the audit. This report presents the audit observations validated during exit briefings with management, along with an audit opinion and recommendations.

1.1 Background

The National Hydrometric Program provides for the collection, interpretation and dissemination of real-time and historical surface-water level and flow data to Canadians—information that is vital to meet water management needs and environmental needs across the country and that is required as a basis for economic and social development.

The National Hydrometric Program is part of the Meteorological Service of Canada, and is ISO 19001 compliant. It is managed through a national partnership between the federal, provincial and territorial governments. Since 1975, the program has been carried out under formal cost-shared agreements signed between Environment Canada and each of the provinces, and between Environment Canada and INAC (representing the territories), as per the *Canada Water Act*. It utilizes a centralized, standardized approach to data collection, processing and distribution, with costs shared according to specific interests and needs. The federal component of the collective partnership is commonly known as the Water Survey of Canada. The program has been continuously operated, in general, by the federal government (i.e., Water Survey of Canada) since 1908, except in Quebec, where the province took over the responsibility in 1963.

The *Constitution Act, 1867* does not specifically assign jurisdiction over water or the environment to the provinces or the federal government. As such, the provinces and the federal government share jurisdiction over such matters through their respective powers. The federal government's authority for participating in water resources management is specifically reflected in the following: the *International Boundary Waters Treaty Act* (Canada–United States); the *International River Improvements Act*; the *Fisheries Act*; the *Navigable Waters Protection Act*; the *Canada Water Act*; and certain aspects of the *Canadian Environmental Protection Act, 1999*.

Under the 1975 agreements, Environment Canada has taken a leadership role in the National Hydrometric Program, which has resulted in a national network generating accessible and reliable water quantity data and information for Canadians. This partnership has been of benefit not only to the country but also to the provinces and territories. As a result, efforts have been made by all jurisdictions to renew and modernize the 1975 agreements to reflect current and emerging roles and needs.

Almost every sector of a nation's economy has a requirement for water information. Further explanation about these major user communities is provided in section 1.2 of this report.

The co-operative nature of the National Hydrometric Program has allowed flexibility to adapt to the changing needs of water management in each part of the country. It has also advanced the commitment of the Parties to maintain national standards, develop hydrologic expertise, implement efficient, modern technology, and provide water-resource data and information to all those who need it. Co-operation also helps to address the emerging needs for environmental conservation and protection.

Currently, there are 2865 water level and stream flow stations being operated under the federal-provincial/territorial cost-sharing agreements. Data for 1456 of the 2865 active stations are transmitted in near real-time. Data from an additional 5577 hydrometric stations no longer active are stored with the active-station data in the national hydrometric database (HYDAT). Most of the stations are located in the southern half of the country, where the population and economic pressures are greatest. As a result, the adequacy of the network in describing hydrologic characteristics, both spatially and temporally, decreases significantly to the north.

1.2 Why the National Hydrometric Program is Important

Reliable data and information concerning the levels and flows of Canada's lakes and rivers are critically important to continued economic prosperity, the sustainable management of the environment, and the health and safety of Canadians. The National Hydrometric Program provides Canadians with timely, easily accessible water-quantity data relevant to the economic prosperity and quality of life of all Canadians. This information is utilized by all Canadians 24 hours a day, every day, and continues to be an important factor in reducing the impacts on society resulting from hazardous weather and environmental conditions. Hydrometric information is also required to effectively support policy issues such as: water availability for economic development in different regions; industrial and municipal water use and future development; flood and drought warning and situation management; infrastructure development (bridges, dams, culverts, sewage treatment facilities, etc.); green energy production; water export; and understanding the impact of climate change.

Additionally, Canada's international commitments as a member of the World Meteorological Organization require the sharing and exchange of meteorological and hydrometric data. There are also legal obligations under the International Joint Commission to exchange water data from stations along the Canada–U.S. border. Canada has also committed to provide data for inter-jurisdictional bodies, such as the Prairie Provinces Water Board and Ottawa River Regulation Board.

As previously explained, the water information is important for many sectors of the economy. The four major user communities that need the most hydrometric data and information are as follows:

- Structural designers who use hydrometric data to optimize the design of various types of hydraulic structures such as bridges, culverts, pipeline crossings, dams, reservoirs, dykes and other flood-protection works, irrigation and drainage schemes, and other various water-related industrial structures.

- Those responsible for emergency management in the area of flood prediction and avoidance, whose goal is to reduce flood damage through flood warnings or to avoid flood damage completely.
- The resource-use community, which needs hydrometric data for day-to-day operations. Examples of such sectors include: water supply and sewage disposal, agriculture, forestry, transportation, hydroelectric generation, mining, oil and gas, fishing, trapping, and eco-tourism.
- Government and/or resource and environmental management communities who require water quantity information for biodiversity and habitat assessment and stewardship, water quality research and development, treaty obligations regarding apportionment, and integrated environmental prediction activities generally, such as climate change. International commitments include the World Meteorological Organization standards for network density and the Global Climate Observing System.

Throughout this report the term “client” is used to represent the above groups of users.

The hydrometric information has serious and far-reaching financial and social implications, and should be based on the best possible data.

1.3 Risk Assessment

A preliminary risk assessment of the National Hydrometric Program was carried out to identify the possible areas and levels of risks. The Risk Assessment Tool developed by the Office of the Comptroller General of Canada for the guidebook *Internal Audit Planning for Departments and Agencies, 2008* was used to assess the risks.

Each major area of the program was looked at through the following risk domains and categories:

- Strategic Risks: organizational change; strategic oversight and direction; and stakeholder engagement.
- Operational Risks: human resources; third party; knowledge capital; capital infrastructure; information technology infrastructure; legal and compliance; internal fraud; external fraud; business processes.
- Hazard Risks: natural hazards; human actions–intentional; human actions–unintentional.

In addition, each major area of the program was looked at through the following risk factors: degree of change and how recent the change is; complexity; legislative and other compliance requirements; knowledge required; and degree of dependencies.

Related documentation was reviewed, such as the *Canada Water Act* and the Agreements on Hydrometric Monitoring between different levels of government and Environment Canada, as well as policies and directives. Further, interviews were conducted with management from the National Hydrometric Program to gain an understanding of the legislative requirements, objectives, priorities and governance of the program, and to identify the possible risks and controls in place. In that context, the following persons were interviewed: the Assistant Deputy Minister, Meteorological Service of Canada; the General Director, Weather and Environmental Monitoring; and the Acting Director, Hydrometric Monitoring.

Two primary risks were identified for the purpose of this audit: the governance of the program, and the network configuration and alternative program-delivery methods.

The internal and external governance of the program is complex, due to the number and diversity of the stakeholders involved: federal, provincial and territorial governments, other government departments, municipalities, and the private sector. As a result, the decision-making process among these stakeholders regarding setting directions, establishing priorities and deciding on investments is multi-faceted and not fully clear. Also, the audit team was informed that the multiple reporting structures require a high level of coordination, which is not satisfying all Parties. Coordination is required between the following:

- Weather and Environmental Operations in Environment Canada, responsible for budgeting and delivering the program with the regions, and Weather and Environmental Monitoring, which sets functional direction.
- Two components of water management in Environment Canada: the water quality component of the Science and Technology Branch, which reports to the Ecosystem Sustainability Board, and the water quantity component of the Meteorological Service of Canada, which reports to the Weather and Environmental Services Board.
- Environment Canada and INAC.

As a consequence, there are two sets of agreements between the federal, provincial and territorial governments, one for water quality and one for water quantity.

From the sustainability perspective, program managers are concerned that the current size and structure of the hydrometric network is insufficient to meet Canada's needs and that the ability to maintain a coordinated water monitoring program may be in serious jeopardy, more precisely the ability to:

- maintain a coordinated National Hydrometric Program;
- meet the challenges identified in the face of a changing climate and increased human impacts on water resources; and
- satisfy the needs of watershed managers in small-to-medium-size basins, and address the development and ecological pressures in the north and other remote regions of Canada.

For instance, there are only two active stations in the northern arctic ecozone, and one in the arctic cordillera, and these are operated as federal or federal/provincial stations. It is recognized by program specialists that the freshwater contributions to the Arctic Ocean are not currently well defined, and calculations have not been adequately assessed with the level of monitoring in place.

Program managers also believe that global hydrometric needs have not been optimally met through alternative program-delivery methods. There is considerable documentation describing the data and information deficiencies required to meet the broad range of demands on the National Hydrometric Program, such as:

- the Canadian Water Resources Association's numerous workshops and conferences;
- two comprehensive national assessments, *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada* (2001) and *Threats to Water Availability in Canada* (2004);
- numerous hydrometric network analyses completed by the provinces and federal government (Kangasniemi and Miles 2003; Pyrce 2004; AMEC 2005; Terripan Consultants 2006) (Annex 4, reference number 5).

The business case presented on June 15, 2006, and accepted by Environment Canada's Weather and Environmental Services Board, also concluded that user needs have not been optimally met. It is now considered an unfunded pressure within Environment Canada. At this point, the National Hydrometric Program does not operate according to the principles outlined in the business case, but rather under the principles outlined in the Agreements on Hydrometric Monitoring and the ISO architecture.

The overall concern is that the current decision making and management configuration of the program is not as well designed as required to address many of the challenges identified in the face of a changing climate and increased human impacts on water resources. It is evident that social, economic and public policy considerations have played a large part in the development of the hydrometric network in Canada. The current network is not a scientifically designed network but rather a network of opportunity driven primarily by the needs of water managers and Parties, and has evolved based on information available at the time. Access costs have also influenced the network configuration, with stations located in more populated areas where there is road access. Many stations are located for specific needs rather than meeting a scientific or overall water resources planning purpose. The number of hydrometric stations in Canada that can meet science and planning needs, particularly for climate variability and change analysis, is therefore much less than the total number of stations in the national network.

Further, it may not satisfy the needs of watershed managers in small-to-medium-size basins, or address the development and ecological pressures in the north and other remote regions of Canada. The question is being asked: Is there a need to consider other methods of service delivery, including more uses of modelling as opposed to measuring real data?

1.4 Objectives and Scope

Based on the conclusions drawn from the risk analysis, the objective of the audit is to provide assurance on the adequacy of the following:

1. The internal and external governance of the hydrometric network, looking in particular at the committee architecture, decision-making process, reporting structure and the centre of control.

2. The current hydrometric network configuration and delivery approaches, compared to its size, capacity and sustainability. This includes:
    a. looking at the business case submitted to the Weather and Environmental Services Board in 2006, though it is now considered an unfunded pressure within Environment Canada;
    b. assessing the complexity of the National Hydrometric Program, its sustainability, and the capacity of the current configuration to meet Canada's needs and international obligations;
    c. exploring an optimum hydrometric network, through the comparison of the National Hydrometric Program with those of other countries, and consideration of service delivery methods, such as more uses of modelling as opposed to measuring real data.

The scope is Department-wide and focuses on the Environment Canada governance and configuration of the National Hydrometric Program as it existed at the time of the audit. It does not cover the management performed by the other jurisdictions (provinces, territories or municipalities) or the National Water Quality Monitoring Program.

1.5 Methodology

The audit was conducted in accordance with the Treasury Board Policy on Internal Audit and included the following phases: planning; conduct; debrief to the National Hydrometric Program management and key Parties; and reporting. The planning phase consisted of interviews and consultation with program managers; in-depth analysis of background information; conduct of the preliminary risk assessment; and development of an audit program and associated tools. To assess the governance of the program, the audit team used recognized governance models, frameworks and indicators from national and international institutions in order to derive the audit criteria. The governance models used are shown in Table 1.

Table 1: Governance models used in the audit

Institutions	Governance Models	
Governance International	❑	The Good Governance Model (2008)
World Bank	❑	A Decade of Measuring the Quality of Governance (2007)
	❑	Worldwide Governance Indicators (1996–2007)
	❑	Assessing Governance: Diagnostic Tools and Applied Methods (2002)
Institute of Internal Auditors	❑	Organizational Governance, Professional Guidance (2008)
Canadian Institute of Chartered Accountants	❑	CoCo Model: **Guidance on Control, which presents a control model referred to as** Criteria of Control **(CoCo)** (1995). Used for this audit: the Effectiveness and Efficiency of Operations **aspect.**
Office of the Auditor General	❑	Governance Framework and excerpts from various Auditor General's reports
Treasury Board Secretariat	❑	Management and Accountability Framework

Based on these models, the audit team selected the criteria to assess governance as shown in Table 2, along with their correspondence with the appropriate seven of the ten elements of the Management and Accountability Framework, which sets out the Treasury Board's expectations for good public service management.

Table 2: Criteria used to assess governance

Dimensions of Governance	Criteria	Correspondence with the Management and Accountability Framework
1. Program's Objectives and Strategies	❑ Clear and understood	Policy and programs
	❑ In line with mandate	
2. Authority & Responsibility	❑ Participation and delegation	Governance and strategic Directions
	❑ Clear	
	❑ Consistent	
3. Decision Making	❑ Open and transparent	Governance and strategic directions
	❑ Efficient	
	❑ Coherent	
	❑ Based on effective, efficient and negotiated rules	
4. Performance and Accountability	❑ Accountability regime	Accountability
	❑ Performance assessment	Results and performance
	❑ Clients' satisfaction assessment	Citizen-focused service
5. Internal and External Risks	❑ Identified, monitored and managed	Risk management
6. Exchange of Information	❑ Sufficient, complete, timely, accurate	Governance and strategic directions
7. Learning and Innovation	❑ Continuous improvement strategy	Learning, innovation and change management

The assessment of governance involved extensive and in-depth analysis of program documentation, as listed in Annex 3, along with interviews in June 2009 with 20 senior managers and representatives from the National Hydrometric Program, the NAT and the NHPCC. The sample selected for the interviews covered all Parties of the program as shown in Table 3. A list of those interviewed is provided in Annex 5.

From interviews, each observation has been recorded in relation to the relevant criteria and analyzed accordingly. During the summer and fall, the audit team corroborated and validated each observation with written evidences from the documentation listed in Annex 3, which represents more than 170 documents. The documentation reviewed included annual reports, minutes of meetings spanning five years and covered by 88 documents, business plans, business cases, public surveys, briefing notes, federal-provincial Agreements on Hydrometric Monitoring, the Office of the Auditor General reports, the Handbook/Guideline: Implementing the Weather and Environmental

Services Quality Management System (Annex 3, reference number 24), stakeholder reports, and certain Acts such as the *Canadian Environmental Assessment Act*, *Dominion Water Power Act*, *Northwest Territories Waters Act*, and *Canada Water Act*.

The assessment of the network configuration/sustainability was performed by a reputable expert advisor in the water management field. The work performed included extensive technical and scientific document review, as listed in Annex 4; consultations with stakeholders and Parties of the National Hydrometric Program; benchmarking and comparison with the hydrometric programs of other countries, especially the G9 countries; and expert advice and assessment. Consultations were carried out between the end of July and end of September 2009, with a selection of 27 stakeholders representing provincial and territorial government Parties, program managers from Environment Canada, hydropower utilities, university researchers, private developers and water resources consultants, as shown in Table 3. A list of those interviewed is provided in Annex 6.

Table 3: Sample for audit objectives I & II

Coverage	Representatives										
	Provincial and Territorial Governments		Environment Canada National Headquarters		Environment Canada Regional Offices		Others		Total Sampling		Total NAT & NHPCC Population
	I	II	I	II	I	II	I	II	I	II	
National Administrators Table	6	5	2	-	2	1	-	-	10	6	18
National Hydrometric Program Coordinators Committee	5	5	2	-	3	3	-	-	10	8	18
Others: Government, University, Hydro Utility, Consultant, and Developer	-	2	-	1	-	2	-	8	-	13	-
TOTAL	11	12	4	1	5	6	-	8	20	27	36

Preliminary observations on governance were submitted to the program management, NAT and NHPCC at their annual meeting in September 2009, and on the network configuration to program management later in the fall, for factual review and comments.

1.6 Statement of Assurance

This audit has been conducted in accordance with the *International Standards for the Professional Practice of Internal Auditing* and the *Policy on Internal Audit* of the Treasury Board of Canada.

In our professional judgement, sufficient and appropriate audit procedures have been conducted and evidence gathered to support the accuracy of the conclusions reached and contained in this report. The conclusions were based on a comparison of the situations, as they existed at the time, against the audit criteria.

2 FINDINGS AND RECOMMENDATIONS – NETWORK GOVERNANCE

This section presents audit findings and recommendations on the governance of the national hydrometric network as per the dimension of governance that was looked at.

2.1 Program's Objectives, Strategies and Risks Assessments

The following four criteria were used to assess governance of the program's objectives, strategies and risks:

1. Public officials on all levels are aware of, and can identify with, the program's objectives and strategies.
2. The program's objectives, priorities and strategies are in line with Environment Canada's mandate.
3. Internal and external risks faced by the program are identified, monitored and managed.
4. Program managers consider best practices currently available within and outside of their organization.

As part of the Meteorological Service of Canada, the Hydrometric Monitoring Program is included in the Quality Management System registered to the ISO 9001:2000 standard, which provides a framework to manage the program from a continuous improvement perspective. The Quality Management System registered to the ISO 9001:2000 provides a high level of assurance about the management framework in place to help managers focus on performance, clients and quality in delivering the program.

The National Hydrometric Program is well understood within the National Hydrometric Program community (the water resource community at large, including federal, provincial and territorial Parties and clients as defined in section 1.2). However, the importance of the program is not well known outside this community. The impacts of the program on public safety, infrastructure protection and scientific knowledge are not sufficiently known by other programs, departments, central agencies and the public in general. The risk is that the program may not be positioned in a way that reflects its true value when being assessed through government-wide prioritization and budgetary exercises.

The program is aligned with the departmental mandate. In the past, priorities were derived from funding opportunities rather than brought into line with overall client needs. Currently, the National Hydrometric Program is conceptually working at shifting its strategic planning approach based on a clients-driven model. This model is being developed and piloted.

Operational risks are well assessed by program managers, especially in the area of human resources in general and more specifically occupational health and safety, succession planning, and training. On the other hand, improvements are required in assessing strategic risks for the program, especially in the area of economic, public policy, program development and technological risks. Continuous improvements, learning and innovation are being carried out on an ad-hoc basis by all. Respondents believe that not enough is being done to keep up with technology.

Assessing strategic risks is essential for the strategic planning and future directions of the program. Without a strategic risk assessment, the program may not be best positioned, priorities may not be best aligned, and contingency plans may not be well established.

Recommendation

1. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and the NHPCC, pursue efforts in the development and implementation of a new approach to strategic planning based on a regular assessment of strategic risks, clients and stakeholders' needs, and that includes strategies for learning, innovation and external communication.

2.2 Authority, Responsibility and Accountability

The following three criteria were used to assess the governance around the program's authority, responsibility and accountability:

1. The decision-making approach enables delegation of authority and participation of key stakeholders.
2. Authority and responsibility are clearly defined and consistent with the achievement of the program's objectives.
3. There is a well-established, agreed-upon accountability framework among Parties, strictly enforced and balanced with capabilities.

One hundred percent of interviewees said that the decision-making approach adopted by the National Hydrometric Program managers provides the framework for delegating authority and allowing participation of key stakeholders.

Responsibilities and authorities for delivering the National Hydrometric Program are clear and consistent among the federal, provincial and territorial Parties. They are well defined in the Agreements on Hydrometric Monitoring.

Responsibilities and authorities within the Meteorological Service of Canada are clear and work well through new collaboration and communication, between Weather and Environmental Operations, which is responsible for budgeting and delivering the program, and Weather and Environmental Monitoring, which is responsible for developing the functional directions of the program.

For Parties and clients outside of Environment Canada, it is more difficult to understand the contribution made by the various branches of the Department and by Indian and Northern Affairs Canada in the delivery of the Program. Results from documentation review and interviews indicate that responsibilities and authorities are less clear:

- This is evident within the Department, between the Science and Technology Branch (responsible for water quality monitoring and reporting to the Ecosystem Sustainability Board) and the Meteorological Service of Canada (responsible for the hydrometric or water quantity monitoring and reporting to the Weather and Environmental Services Board). The two branches do not work as a single window, resulting in two water agreements—one for water quality and one for water quantity—for the provincial and territorial Parties.
- This is also evident between Environment Canada and INAC, resulting in confusion about setting directions and delivering the program.

There is an accountability regime in place for the program. However, for outside of Environment Canada, the accountability regime is not well known, not well communicated, and perceived as ambiguous. This perception is made worse by the backlog affecting the production of the annual report required under section 38 of the *Canada Water Act*.

While the audit team did not conduct any audit work in the National Water Quality Monitoring Program or outside of the Department, evidence gathered as part of this audit is sufficient to present the following recommendations.

Recommendations

2. The Assistant Deputy Minister, Meteorological Service of Canada, explore with the Assistant Deputy Minister, Science and Technology Branch, a single-window approach to the management of water quantity and quality falling under the purview of Environment Canada, that would benefit provinces and territories.
3. The Assistant Deputy Minister, Meteorological Service of Canada, meet with his counterpart in INAC to try to clarify roles and responsibilities between the two departments in the management of the National Hydrometric Program (water quantity management).

2.3 Exchange of Information and Decision Making

The following five criteria were used to assess the effectiveness and efficiency of exchange of information and decision making within the National Hydrometric Program:

1. The decision-making approach is open for suggestions from clients, and transparent to insiders, stakeholders and the public.
2. Decisions are made based on effective and efficient rules, either formal (constitution, legislation, regulation) or informal (code of ethics, customs, traditions), and assume negotiations with stakeholders on the importance of those rules.
3. The decision-making approach is efficient.
4. The decision-making approach results in coherent and coordinated actions.
5. The exchange of information among Parties is sufficient, complete, timely and accurate.

The governance provided by the NAT and the NHPCC structure is working well. It provides an excellent tool for all Parties (territorial, provincial and federal) to work together at developing the program, deciding priorities and delivering its components. It is critical to keep this tool, which promotes co-operation and ownership among all Parties.

Decision making is open and transparent. Decisions are made based on consensus. All Parties interviewed believe that consensus is the only suitable mechanism to make decisions in the context of a federal-provincial/territorial partnership program. Decisions made are coherent, because, by definition, consensus brings coherence. However, consensus may affect the length of the decision process and its efficiency. All Parties accept this as a normal cost to manage a federal-provincial/territorial program.

While working well, additional efficiencies in the mechanics of the two committees can be looked at, such as the exchange of information; updates to the program’s Internet site so as to be kept current as a central venue for exchange of information; and improving participation by all Parties during meetings.

2.4 Performance and Client Satisfaction Assessment

The following two criteria were used to assess the governance related to the performance and client satisfaction assessment of the program:

1. There is a well-established, agreed-upon performance assessment framework, which is balanced with capabilities.
2. There is a framework to assess if services provided are of high quality, cost efficient and satisfy the demands of clients.

The quality of hydrometric data is constantly being assessed. The program has a positive working relationship and governance with its Parties. However more attention is required in assessing the overall performance of the program, i.e. the ultimate outcomes, and in ensuring consistency of reporting across the board.

More attention is also required in assessing the satisfaction of clients. Their satisfaction is currently assessed on an ad-hoc basis, when clients fill a WEB-based comment-form; and via the conduct of Stakeholders Workshops. The implementation of these workshops has been slower than expected.

There is a backlog in producing the annual report for the program, which covers client satisfaction assessment. The *Canada Water Act*, section 38, requires that a report on the operations under the Act be laid before Parliament after the end of each fiscal year. This legal requirement is also reflected in the Agreements on Hydrometric Monitoring with the territories and provinces.

Sufficient performance assessment and client satisfaction surveying has a positive impact on the internal and external decision making and prioritization, and ultimately the ISO certification. It is important for public safety, infrastructure, and scientific knowledge.

Recommendations

4. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, further develop the framework to assess the overall performance of the program (ultimate outcomes) and the satisfaction of clients.
5. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, ensure the National Hydrometric Program meets its legal obligation regarding the *Canada Water Act*, section 38, which requires that a report on the operations under the Act be laid before Parliament after the end of each fiscal year.

3 FINDINGS AND RECOMMENDATIONS – NETWORK SUSTAINABILITY AND CONFIGURATION

3.1 Comparison of Hydrometric Programs

A detailed comparison of the effectiveness of the hydrometric programs in different countries would require a level of study that was beyond the scope of this assessment. However, it is possible to use a few measures that, although far from being perfect, give some comparative information about the hydrometric program in selected countries.

The first simple measure used is the geographical hydrometric station density. The World Meteorological Organization recommendations for hydrometric station density range from a minimum of 1 station per 1000 km^2 to 3.3 stations per 1000 km^2 (World Meteorological Organization 1981). This comparison measure is simplistic and does not take into account other parameters. For example, countries with spatially variable climate, complex terrain and varying land use would require a higher station density than a country with more uniform climate, topography and land use.

A second simple measure used is the station density per volume of water in a given country. This measure recognizes that the more water a country has, the more hydrometric stations are needed. To assess the volume of water, the audit team used the Total Actual Renewable Water Resource (ARWR), which "gives the maximum theoretical amount of water annually available for each country in cubic kilometres" (World Resources Institute). However, again, this measure does not take into consideration other parameters such as those mentioned above.

A third measure used is related to the capacity of various countries to fund their hydrometric network. For this measure, the audit team used the Gross National Income (GNI) adjusted by Purchasing Power Parity (PPP), which is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output, plus net receipts of primary income (compensation of employees and property income) from abroad. In other words, GNI measures the total income of all people who are citizens of a particular country.

Table 4 provides a comparison of those three measures for seven countries, including Canada.

The analysis of Table 4 indicates that four of the seven countries surveyed have station densities in the range (1 to 1.33) recommended by the World Meteorological Organization. It is notable that these four countries are the smallest in terms of land and have the highest population densities. The three largest countries in terms of land (United States, Canada and Australia) have low station densities combined with the lowest population densities. The reasons for this pattern are likely to be the following:

- the high costs of maintaining stations in unpopulated areas;
- the lower population density, which provides a lower tax revenue per unit area to support government inventory programs.

Table 4: Comparison of hydrometric network

Country	Population Density Per km²	Number of Hydrometric Stations	Station Density Per 1000 km²	Area km²	Total ARWR - (km³) 2008[1]	Station Density Per Total ARWR - (km³) 2008[2]	GNI - (PPP in Billions, Current International Dollars) 2008[3]	Station Density Per GNI in Billions of Current International Dollars
England And Wales	390	1396	9.23	151 174	147	9.50	2218.21	0.63
Germany	230	3000	8.40	357 021	154	19.48	2952.42	1.02
Japan	874	1444	3.82	377 873	430	3.36	4497.72	0.32
France	115	1500	2.22	674 843	204	7.35	2134.44	0.70
United States	31	7000	0.71	9 826 630	2071	3.38	14 282.67	0.49
Canada	**3.2**	**2931**	**0.29**	**9 984 670**	**2902**	**1.01**	**1206.46**	**2.43**
Australia	2.8	2100	0.27	7 686 850	492	4.27	727.49	2.89

The station densities for provinces and territories in Canada follow a similar pattern. Only Prince Edward Island, the smallest province, has a station density within the range recommended by the World Meteorological Organization.

As well, Table 4 shows that Canada has the highest total ARWR to cover, by a significant difference margin, and the lowest station density per volume of water (total ARWR), which means that the Canadian National Hydrometric Program is small compared to its responsibilities.

Finally, the station density per GNI indicates that Canada and Australia are two countries investing more in their hydrometric network when the capacity to fund programs is taken into consideration. Of course, from a hydrologic perspective, GNI is irrelevant when the objective is to properly characterize water resources over a large and hydrologically complex area such as Canada.

Furthermore, the overriding issue with the size of the hydrometric network is that the importance of our water monitoring programs is undervalued. It has been estimated (Environment Canada 2004) that water's measurable contribution to the Canadian economy ranges from $7.5–$23 billion annually and the amount invested in water monitoring should reflect this economic value.

[1] Food and Water, World Resources Institute (Annex 3, #79)
[2] Food and Water, World Resources Institute (Annex 3, #79)
[3] World Development Indicators 2009, The World Bank Group (Annex 3, #80)

3.2 Network Size and Configuration

Based on documentation reviewed and interview results, the size and structure of the hydrometric network is considered insufficient for the overall characterization of water resources in Canada. The needs of specific clients are met where a gauge is established for a particular purpose. It is axiomatic that where data are collected for a specific purpose, those data needs are likely to be met. The needs of other clients for water resources planning, environmental assessment, project approvals, climate change analysis and other scientific requirements are not generally met by the current network configuration, particularly in northern Canada. It was noted that it is not just a question of the total number of stations, as some stations are located for specific needs and are not always in the best locations for research and hydrological analysis. Particular concern was expressed regarding the loss of key long-term stations in the Hydrometric Basin Network. The loss of stations in the 1990s due to budget cuts was a loss to hydrologic records in Canada.

The network was originally developed for water resources engineering purposes (flood plain management, hydropower), and new issues of greatest concern are not well addressed by the current network configuration. Climate change also results in data becoming outdated where there are significant shifts in the hydrologic signal. All these needs require consideration of climate variability and change, and it is this issue that underpins the most pressing need for improved data collection in Canada.

The changing climate in Canada can be observed through reductions in glacier mass and trends in temperatures in the Arctic. The influence of the changing climate on water resources is much less evident. The annual, seasonal and daily variability observed at water monitoring stations is much greater than any underlying long-term trends in the data, and therefore the long-term trends are difficult to detect. This is made even more complex by the existence of short-term trends, some lasting several decades that reflect climate oscillations resulting from, among other things, periodic changes in ocean currents. Thus, a trend in stream flow may be detected over the past 30 years but it does not necessarily mean that the trend will continue, as it may be caused by a climate oscillation. The complexity is further compounded by land-use changes and possible water use upstream of a flow gauge that would affect the flow records.

Detection of climate change is difficult given that the time aspect of trends is not consistent because of climate oscillations, land use changes and water use. Furthermore, the spatial distribution of trends is also not consistent. Recent research by Ehsanzadeh and Adamowski (2007) found that water monitoring stations in northern Canada have experienced an upward significant trend in seven-day low flows while a significant downward trend dominated the Atlantic provinces and southern British Columbia. In other parts of the country, no significant trends were found. The shifts in the annual timing of seven-day low flows also varied across the country.

Predictions of the impacts of climate change on water resources have primarily been carried out with the use of atmospheric and ocean Global Coupled Models (GCMs), to provide future climate scenarios in order to drive hydrologic models that predict changes in rivers, lakes and streams. However, GCMs are not effective for predictions of extremes (both wet and dry), which are the most important issues in water resources planning. The models are considered reasonable for prediction of average climate conditions, but averages do not tell the complete story. For example, at a specific location, the average rainfall may be projected to increase with climate change, but high-intensity rainfalls may decrease and periodic drought conditions may be more prevalent.

Given the current inadequacy of prediction tools for making specific forecasts of the impacts of climate change on water resources, it is imperative that robust water monitoring networks be maintained and enhanced. However, even with the most comprehensive water monitoring system in place, it is still extremely difficult to detect whether the predictions of the impacts of climate change are valid. The projected changes are gradual and are masked by the “noise” of the natural variability and climate oscillations. Rigorous statistical and scientific tools have to be applied to a relatively long data set to determine with any confidence whether a trend exists. In addition, hydrologic models can be improved with comprehensive spatial data in pristine areas, collected over a shorter time period. Therefore, a monitoring strategy should focus on maintaining long-term stations in pristine areas not affected by land use changes and water use, and on establishing new stations in pristine areas not currently represented. Stations located in small- and medium-sized basins provide these kinds of opportunities. Larger basins are more likely to be influenced by storage, abstractions and land use changes.

In the absence of definitive trends in water resources data, engineers and planners are continuing to primarily rely on analysis of historical data for decision making. At some point, engineers, water resource planners and policy makers who depend on professional advice will have to adopt climate change trends as part of project design. The magnitude and nature of those trends can only be definitively determined from analysis of data from a robust water monitoring network. Alternative approaches could be used, such as adding arbitrary safety factors to account for climate change. However, these arbitrary factors are not scientifically defensible and could lead to over-designed structures and other costly decisions. At a specific location in Canada, it is not known with certainty whether the magnitude of floods will increase or decrease or whether droughts will be more or less severe.

Collection and organization of data are the absolute basis of the scientific method. Without data, Mariotte would never have discovered in 1684 that rainfall was the origin of flow in the River Seine. Prior to his findings it was thought that river flow originated in underground springs. It could be argued that much of our current understanding of the effects of climate change is as primitive as the idea that all flow in the River Seine originates in springs. We require extensive data networks to support rigorous scientific analysis, so that we will be able to make well-informed decisions regarding the impacts of climate variability and change on water resources in Canada.

A business review of the hydrometric network in British Columbia (Azar et al. 2004) investigated the economic benefits of the hydrometric network. It was found that sectors such as water supply, agriculture and sewage disposal are reasonably well-served by the hydrometric network. The major economic sectors of forestry, transportation, small hydro, mining, and oil and gas are the least well-served. These sectors require short- and long-term regional data, often on small streams throughout the province.

The benefits of the hydrometric network for all sectors primarily relate to cost savings in design and construction and reduced operating costs. Where data are inadequate, there is increased uncertainty in the design process, and there are increased risks of project failure and/or environmental impacts. Sometimes, conservative decisions are made to compensate for the risk, which leads to increased costs and can affect project feasibility. These decisions are made not only by project designers and operators but also by regulators. This sometimes leads to less water being allocated for the project than is available; in other instances, approvals may be delayed or, in the extreme, not provided due to this uncertainty.

In the case of the small hydro and mining sectors, investors require low risk regarding available water supplies for power generation, mill operation and waste disposal. Stream flow records are key to demonstrating project feasibility, and the absence of adequate data can lead to reduced investment.

The estimated benefit/cost ratio of the current hydrometric network in British Columbia was estimated to be 19.1 (Azar et al. 2004). Every dollar spent continuing to support the present network returns more than nineteen dollars in benefits. It was also concluded that expansion of the network, including integrating other data in addition to the data recorded under the National Hydrometric Program, is in the best economic interests of the province, and would promote provincial goals of economic growth and sustainable resource development.

Recommendations

6. As part of the strategic planning referred to in recommendation #1, the Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, assess the current network risks and vulnerabilities, evaluate the demands and establish priorities to ensure the network provides the largest benefits for the financial resources available and that resources are optimized to address the areas of greatest concerns.
7. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, consider the integration of the hydrometric network with the climate data network, both for network design and data reporting, to improve the scientific value of the hydrometric and climate networks.

3.3 Sustainability of a Coordinated Monitoring Program

The Water Survey of Canada is a well-respected organization among water resources professionals in Canada. A nationally coordinated program is the best method of hydrometric data collection, particularly for data archiving and access and for establishing national standards. It was noted that signed Agreements on Hydrometric Monitoring with the Parties assist the continuity of the program.

There are concerns about the decrease in the number of Water Survey of Canada stations since 1980, and the apparent lack of commitment to overall long-term funding for the network. Specifically, the national hydrometric network is inadequate for small- and medium-sized basins. This deficiency is partly a result of the historical development of the network, and partly because it is more challenging and costly to monitor flows on small basins and maintain the same data quality.

The national hydrometric network in northern Canada is also inadequate. Part of the problem is that stations are costly to maintain in remote locations. While the network in the north is generally regarded as the weakest part of the network in Canada, it is also under the most threat for a number of reasons:

- INAC has been reducing its contribution: only 10 percent of stations are now funded by INAC compared with 40 percent previously.
- When budgets are cut, there is pressure to close stations that are the highest cost to maintain.
- A number of stations are tied to specific research projects. When those projects end, there is often no funding to continue with monitoring.
- While the network in the north is sparse, the needs are also sparse.

The National Hydrometric Program has also not been totally able to effectively respond to the increasing needs for hydrologic data. As a result, many organizations collect their own data, which is thereby "lost" for the overall benefit of Canada. Pressures exist to provide increased services to meet the needs of additional Parties and to respond to other data collection requirements. It is important to meet both site-specific needs and broader scientific requirements.

All this poses a risk to the sustainability of a coordinated monitoring program.

Historically, the funding for the National Hydrometric Program was primarily from the federal government. That proportion has gradually declined and the federal government is now contributing less than 50 percent to the program. At the same time, the Parties and clients would like more influence on the overall program management, which is, to an extent, justified by their funding contributions.

In addition to the risks mentioned above, there is a risk caused by the funding mechanism of the program. As per the Agreement on Hydrometric Monitoring, either Party has the authority to modify or terminate their agreements on March 31 of any year, when a 12-month written notice is provided. A reduction in funding might cause the National Hydrometric Program to reduce its workforce.

A number of different ideas were proposed by respondents to make the partnerships more effective and provide more opportunities to tailor the program to clients needs. These ideas include the following:

- *<u>Incorporating other data in the national database</u>*: The National Hydrometric Program may consider taking the lead in integrating other data into the national database so that the national database becomes a "network of networks." The risk of not enabling this is an increased "balkanization" of hydrologic data in Canada, and a less relevant national database. While the other data may not meet the same quality standards as the program's data, it would still be of considerable value to hydrologists. If all hydrometric stations operating in Canada (operated by municipalities, environmental agencies, consultants, private developers and hydropower utilities) were included, it is estimated that the network could increase in size between 10–30 percent.

- *Integrating the hydrometric network with the climate data network*: This integration could also be implemented both for network design and data reporting. As a simple example: for improving hydrological models and understanding the relationship between climate and water, climate stations could be maintained in watersheds where there is a stream gauge.

- *Providing value-added services online*: The National Hydrometric Program may consider providing value-added services online, such as basic data analyses and station information—for instance, rating curves and survey benchmarks. Environment Canada developed the Consolidated Frequency Analysis Program to analyze Water Survey of Canada data for flood frequency. This program is widely used in Canada but needs to be updated with a Windows interface.

- *Reducing the cost of operating stations in remote locations*: The National Hydrometric Program may consider examining some of its operations, to reduce costs by lowering data standards for a number of stations in remote locations. Seasonal operation of gauges would be an example where the winter flows would not be measured. Furthermore, in northern Canada, there are many potential stream gauging locations in bedrock sections where the rating curve would be stable and fewer visits to the gauge would be required. An improved operational method of program delivery should also review operational procedures to respond to different types of data needs while also focusing on cost reductions.

- *Continuing to explore modelling:* Modelling is currently not accurate enough to replace data collection, and requires good data for model calibration. With changes in watersheds over time, particularly land-cover changes, the collection of continuous data will always be required. However, models can be useful as a complement to a data collection program. For example, they can be used to fill missing gaps in data and generating-flow estimates on a catchment nearby to a stream gauge. Nevertheless, it is also possible that scientific advances could result in model improvements such that, combined with remote sensing, flow estimates from models in ungauged areas could be improved even without nearby data. It could, however, take many years to obtain that level of modelling capability.

It is clear that the best method for collecting and archiving hydrometric data, and establishing national standards, is via a nationally coordinated program. The National Hydrometric Program has been making great strides in the past several years in improving service delivery to clients. Hydrometric data are available for download with an effective web interface that is efficient for the user community. The number of real-time stations, which are of particular value for flood forecasting and water management, has been increased. This has been achieved in a context of resources restraints and a decrease in the overall number of hydrometric stations. As a result, it is necessary for the program to continue looking for service and technological improvements through innovative, cost-effective solutions.

Recommendations

8. The Assistant Deputy Minister, Meteorological Service of Canada, with the collaboration of the NAT and NHPCC, continue looking for service and technological improvements through innovative, cost-effective solutions, especially in remote locations, through the NAT strategic planning exercise.

4 MANAGEMENT RESPONSE

Management concurs with all of the recommendations contained in the Audit of the National Hydrometric Program. Specific actions designed to address the recommendations have been undertaken and will be completed by March 31, 2011.

5 CONCLUSION

Reliable data and information concerning the levels and flows of Canada's lakes and rivers are critically important to continued economic prosperity, the sustainable management of the environment, and the health and safety of Canadians. This information is utilized by all Canadians 24 hours a day, every day, and continues to be an important factor in reducing the impacts on society resulting from hazardous weather and environmental conditions. This information is also required to effectively support policy issues related to water availability and economic development in different regions. It has been estimated (Environment Canada 2004) that water's measurable contribution to the Canadian economy ranges from $7.5–$23 billion annually, and the amount invested in water monitoring should reflect this economic value.

It is clear that the best method for collecting and archiving hydrometric data, and establishing national standards, is via a nationally coordinated program. Overall, the governance of the National Hydrometric Program is functioning well. The framework exists for participation and delegation of responsibilities among the federal, provincial and territorial Parties. Authorities and responsibilities are reasonably clear and consistent. An accountability regime is in place and operational risks are well assessed. The quality of hydrometric data is constantly being assessed. Decision making is open, transparent and based on consensus.

The National Hydrometric Program has been making great strides in the past several years in improving service delivery to clients. This has been achieved in a context of resource restraints and decreases in the overall number of hydrometric stations. As a result, it is necessary for the program to continue looking for service and technological improvements through innovative, cost-effective solutions.

The governance of the National Hydrometric Program would benefit from continuous improvements to: the program's authorities and responsibilities within Environment Canada and between Environment Canada and INAC; the assessment of strategic risks, the performance of the program in general, and clients' satisfaction; the establishment of priorities on a client-need basis; and communication, exchange of information, learning and innovation.

Halliday (2008) provided a succinct summary of the risks of an inadequate monitoring system, in his history of the Water Survey of Canada:

> We cannot begin to address the challenges to the quality of our water and the integrity of our aquatic ecosystems without a fundamental understanding of the natural hydrologic system. It has been said that if we are not measuring it, we are not managing it. Today when water data acquisition, including stream flow monitoring, receives little attention, one can certainly say, "We are not measuring it." This lack of attention damages Canadian productivity and leaves Canadian citizens vulnerable to both natural and anthropogenic threats to our waters.

The National Hydrometric Program would also benefit from assessing the current network risks and vulnerabilities; evaluating the demands and establishing priorities to ensure the network provides the largest benefits for the financial resources available, and that resources are optimized to address the areas of greatest concerns; and from continuing to look for service and technological improvements through innovative, cost effective solutions, especially in remote locations, through strategic planning.

Annex 1
Network Configuration

History of Water Monitoring in Canada

To understand the current configuration of the hydrometric network in Canada, it is useful to review the history of the development of the network. A comprehensive history of the Water Survey of Canada was prepared by Halliday (2008) marking the one hundredth anniversary of the first parliamentary appropriation for stream gauging. This section of the report draws primarily from that history.

The federal government took a major role in the establishment of the hydrometric network for a number of reasons. The early water-level observations in the Great Lakes-St. Lawrence system were related to navigation, a constitutional responsibility of the federal government and the Colonial Government prior to Confederation. The development of the hydrometric network in Alberta and Saskatchewan originated with the needs of irrigated agriculture, a shared constitutional responsibility. The hydrometric network in British Columbia started with monitoring in the federally administered Railway Belt, and expanded to the rest of the province. In response to interest in hydroelectric power development, Ontario started systematic stream gauging in 1912 and Quebec in 1913, and they assigned the task to the federal government in 1919 and 1922, respectively.

In the early days of the Survey, hydrometric work was carried out in two separate branches of the Interior Department: the Irrigation Branch in Alberta and Saskatchewan, and the Dominion Water Power Branch elsewhere. (The initial Railway Belt Survey in 1911 was carried out by the Railway Lands Division, Dominion Lands Branch.) The operation was identified by names such as the Manitoba Hydrographic Survey (the word "hydrographic" was replaced by "hydrometric" in 1917). On July 1, 1920, all hydrometric surveys conducted by the Department of the Interior were centralized in the Dominion Water Power Branch.

In 1908 there were 110 stations operated by various entities. By 1915, the hydrometric network had grown to more than 816 stations, and by 1922 there was an active hydrometric survey in every province. In 1929 the network reached 1024 stations. The Great Depression then intruded on the hydrometric program. The economic conditions and changed social priorities led to severe cutbacks in federal government programs. (The transfer of the responsibility for natural resources administration to the three prairie provinces in 1930, while welcome at the time, was a federal cost-saving measure.) The Minister of the Interior advised the provinces on March 31, 1932, that the agreements on hydrometric surveys would be terminated on March 31, 1933. The measurements required by the *Boundary Waters Treaty* continued as a federal expense. Some other work continued to be carried out under letter agreements with some provinces. The result was a network decline to 708 stations. All hydrometric surveys were discontinued in Prince Edward Island; they were not resumed until 1961. It would take until the 1940s before the hydrometric network reached the same level of development as it had in the

1920s. The network reductions in the 1930s had other consequences. In western Canada, the 1930s included several drought years. The entire decade is often described as a drought. The hydrometric network reductions therefore coincided with hydrologically important conditions. The loss of data during this period continues to haunt Canadian hydrological understanding.

The post-war boom of the 1950s resulted in increased government spending. The 1950s was a time of “nation building,” with engineering projects like the construction of the St. Lawrence Seaway. The hydrometric network was expanded under ad hoc arrangements with the provinces. By the end of the 1950s the network consisted of 1582 stations, a 50-percent increase from 1945.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) International Hydrological Decade, 1965–1974, led to an international effort to increase global understanding of hydrological processes and provided an impetus to improve water monitoring. By the end of the decade, the hydrometric network in Canada had grown to more than 3000 stations.

Network expansion continued until the mid-1980s, then remained stable at about 3500 stations until the early 1990s. The decline beginning in the 1990s was, in part, a consequence of constrained resources at the federal and provincial level, as governments came to grips with major budget deficits. It was also the result of decisions made within Environment Canada that specifically targeted spending on water programs, including monitoring. After a precipitous drop in 2002, the largest numerical network decline in the history of Canadian stream gauging, the hydrometric network stabilized at about 60 percent of its size in the 1980s. The drop in network size is made up almost entirely of decreases in the number of federal and federal-provincial stations. In 1975, the first year of the Agreements on Hydrometric Monitoring, the federal government funded 60 percent of the cost of the network; the percentage is now less than 40 percent.

Current Network

Most provinces and territories in Canada have operating Agreements on Hydrometric Monitoring with the federal government for operation of their hydrometric networks. The Water Survey of Canada operates approximately 2100 hydrometric sites within the federal-provincial/territorial Agreements on Hydrometric Monitoring framework. And additional 800 or so stations are operated by the provinces, territories and “contributors” under the Agreements on Hydrometric Monitoring, for a current total of 2931.

Most stations in the National Hydrometric Program are in the higher-populated areas in southern Canada. The history of network development shows that the network has evolved primarily in response to water management needs rather than scientific requirements.

The Reference Hydrometric Basin Network (RHBN) is an evolving sub-network of about 230 stations in the overall national hydrometric network, which complements Canada’s Reference Climate Station network of 300 long-term climate observing stations identified for use in addressing climate change and variability (Environment Canada 1996) in, predominantly, temperature and precipitation. These networks help to meet Canada-wide and regional needs. They also represent a major step forward in addressing the need for Canadian data in support of hemispheric and global-scale scientific studies of climate change.

The National Hydrometric Program has a well-established partnership system. There are agreements between the federal government and most provinces/territories for the operation of the federal and provincial networks, and the data for all stations are reported under the National Hydrometric Program. Partnerships under the program have also been established between provinces and organizations such as hydropower utilities and municipalities.

The hydrometric stations funded by the federal government have not increased in number in recent years. It is recognized that the RHBN needs to be reviewed and stations added as record lengths increase for stations that are currently not in the RHBN. If all ecoregions in Canada are to be included in the RHBN, a significant number of additional stations would be required. The additional stations could also serve other purposes.

The partnership programs have been successful at establishing new stations and stabilizing funding for parts of the network. However, there is a downside to the partnership system, as it introduces a bias in the network toward stations required for water management and away from regional stations in unregulated pristine watersheds, which could be used for climate change detection and other scientific and regional hydrology applications. With the partial exception of the RHBN, the hydrometric network in Canada has evolved without priority given to stations with long-term records in pristine areas that would be of scientific value, particularly for detecting climate change. Factors mitigating against these types of stations include the following:

- The partnership programs used to solidify the network tend to focus on stations for water management.
- Monitoring stations are often implemented for scientific purposes as part of a special program. However, the stations are often discontinued after a few years because the funding for the special program is terminated.
- It is more costly to maintain stations in remote, pristine areas, so network managers are less likely to install stations in those areas when they have limited budgets.
- The variability of network budget allocations in most jurisdictions results in stations being closed for a period of years and then reopened later, which creates a gap in the long-term record.

Proposed Network Improvements To Date

For the past 20 years there has been interest in Canada to improve water monitoring networks, particularly to detect climate change. A workshop was held in 1992 by the National Hydrology Research Institute, called Using Hydrometric Data to Detect and Monitor Climatic Change. The primary objective of the workshop was to provide directions to Environment Canada toward evolving a network that could be used to detect and monitor climate change. The recommendations on monitoring were as follows:

> A greater effort is warranted to evaluate the existing network for its potential use in addressing the climatic change issue. Criteria should be refined for a national hydrometric reference network. Long-term stations need to be maintained and coverage of the North and small basins should be improved.

Although the hydrometric network in Canada declined in the 1990s, stations that formed the RHBN were designated following the workshop, as a result of that initiative.

In 2001, Environment Canada hosted a National Science Workshop, Trends in Canadian Hydrological Time Series. It was one of the final deliverables of an 18-month Climate Change Action Fund project entitled Monitoring the Impacts of Climate Change on Canada's Water Resources, which involved several experts from the Meteorological Service of Canada, the National Water Research Institute, three Canadian universities and the private sector.

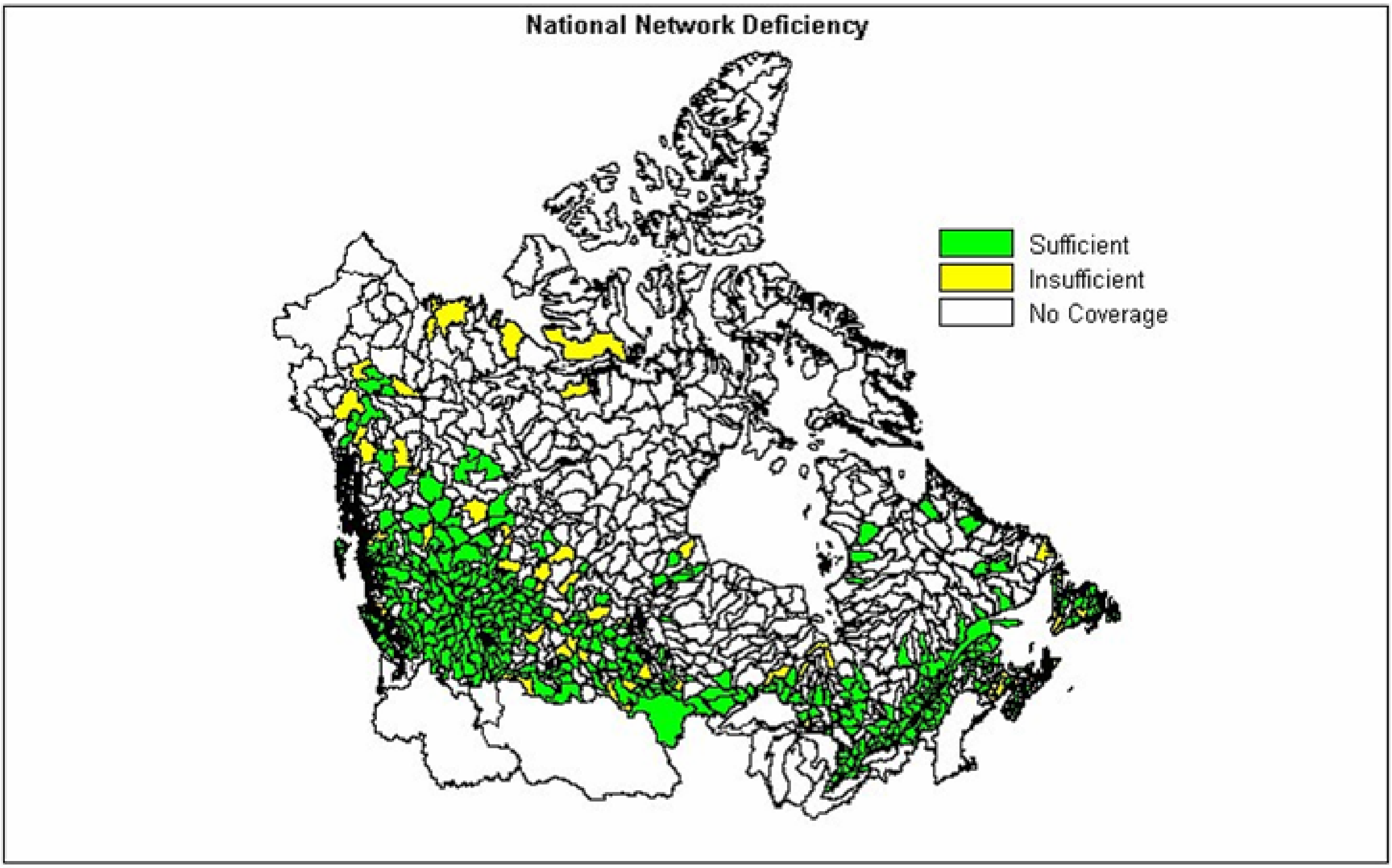
The workshop participants concluded that there are general trends toward decreasing flows and earlier spring runoff in southern Canada, which is consistent with precipitation and temperature trends. Specific results varied, however, due to different statistical methods and assumptions, and due to data limitations resulting from the poor spatial distribution and short record length of much of the hydrometric network, especially in central and northern Canada.

The participants recommended improved long-term integrated climate and hydrometric monitoring, better linkages with scientists engaged in climate modelling and adaptation strategies, and the development of a long-term strategy.

In 2004, in response to Canada-wide concerns about the impacts of climate change and about other water-related issues, a national science assessment was published by Environment Canada, entitled *Threats to Water Availability in Canada.* The document was intended to serve water-science decision makers, resources managers and the research community, as an important reference for developing future research directions and priorities, and sound management policies and practices. The report concluded that there are deficiencies in the design, operation and coordination of Canada's surface water, groundwater and climate monitoring networks. Expansion of baseline monitoring of key components of the hydrologic cycle was recommended.

The *Threats to Water Availability in Canada* chapter Climate Variability and Change, Rivers and Streams (Whitfield et al. 2004) noted that the current Canadian approach of a data collection process driven by immediate needs is unlikely to result in an adequate network for providing basic data for evaluating impacts of climate variability and change on water resources. A thorough review and design of our observing networks was recommended, together with enhancing data collection in northern Canada where the changes in local climates are predicted to be larger than in the south. With this focus, it was noted that we are more likely to be able to verify that change is occurring as predicted. As far as can be ascertained, there has been negligible progress on implementation of the recommendations of the national science assessment *Threats to Water Availability in Canada*.

To overcome the current network deficiencies, the Hydrometric Monitoring Business Case (Environment Canada 2006) proposed an enhanced monitoring network for Canada. The document provided details on the network improvements that would be required to meet the needs of clients. Figure 1 integrates Environment Canada's two key frameworks, the National Drainage Area Framework (970 sub-sub drainage areas) and the National Terrestrial Ecological Framework (1020 eco-districts), to identify network deficiencies. In order to have sufficient information, there needs to be at least one active hydrometric station measuring natural flow in each corresponding eco-district within a sub-sub drainage area. This strategy ensures that there will be sufficient information to understand the hydrological processes and the interrelationships with the



landscape. This information is essential for research and for enhancing predictive capabilities and data transfer.

As the map shows, areas of sufficiency are concentrated in the southern, more populated regions of the country. Network sufficiency declines to the north and northeast, with great extents of northern Canada having no coverage at all.

Figure 1: Deficiencies in National Hydrometric Network

Source: Hydrometric Monitoring Business Case (Environment Canada 2006)

Based on the above strategy, Canada would need an additional 928 new hydrometric stations to optimize the proposed enhanced network and to more adequately characterize Canada's diverse hydrology.

Hamilton and Whitfield (2008) addressed the extent to which water monitoring networks meet science needs, in a commentary entitled "Coupling Science and Monitoring to Meet Future Information Needs" in the *Canadian Water Resources Journal*. They comment as follows:

> Complex, interactive, environmental issues are a cause for concern about the future of our environment and our economy. Our existing scientific understanding of these issues is insufficient to even fully comprehend, let alone effectively manage, the risks of decisions that are being made in the face of unknown uncertainty. Developing improved process understanding, change-detection and prediction capabilities to respond to this challenge will require a fresh approach to how we connect science and monitoring. Addressing this challenge requires developing a strategy in which monitoring is considered as an integral part of a science-based solution complete with clearly stated questions, methodologies and analytical frameworks. Such a strategy must be robust to changing opportunities and challenges while preserving core values of the existing data legacy.

Annex 2
Network Configuration Benchmarking

The hydrometric network in Canada was compared with networks in other countries, particularly those in the G8. Information on network configuration in other countries was obtained from Internet sources where available, reference material, and direct contact with agencies in other countries. Some countries include stations that have water level monitoring without flow measurements as part of their hydrometric network. These stations were excluded from the benchmarking comparison, as water level stations are less costly to operate than stream flow gauges. The gauging stations that are not currently active were not included in this assessment; only operating stream gauges were counted with the exception of Russia as described below.

The total number of active hydrometric stations in Canada under the National Hydrometric Program is 2931. These are stations that are maintained by the Water Survey of Canada or by contributors, and the data is published in HYDAT. Data collected by the Water Survey of Canada for some hydro utilities, such as BC Hydro, are included in the national database, while data collected by Ontario Hydro and Hydro Quebec are not in the national database.

England and Wales

The surface monitoring network in England and Wales includes 1396 flow gauges and 2040 water level gauges (Stewart 2008). The network expanded between 1995 and 2005 due to the need for flood warning.

Few stations in the United Kingdom are “natural,” i.e. unaffected by flow regulation and land use changes. Probably as a result of the extent of water use in the country and the lack of pristine areas, there is no specific strategy for monitoring climate change. A small number of stations (15) are designated as part of the Environmental Change Network.

Australia

Australia has about 2100 hydrometric stations, which are managed at the state level. This information is based on discussions with the hydrometric program staff in each state. Most of the state networks are expanding. A National Water Initiative Work Plan has been developed to improve the coordination of data collection and management. Apart from this initiative, there are no plans to specifically monitor for climate change. This is probably because water resources in Australia are heavily exploited and there are few natural areas where the effects of climate change could be monitored.

United States

The United States Geological Survey (USGS) maintains about 7000 active stream gauges (USGS 2005). To evaluate stream flow variability and change in a climatic context, the USGS identified more than 1600 stream gauges where the discharge was primarily influenced by climatic variations. These stations form the USGS Hydro-Climatic Data Network, monitoring watersheds where the data are appropriate to the study of federal-interest problems and issues such as flood frequency, drought severity, and long-term climatic change (Slack and Landwehr 1992).

The USGS has developed a science strategy (USGS 2007) that addresses natural science research and applications. A key part of the plan is expanded and modernized USGS observing networks for land, water and biological resources, to enable rigorous analyses of future responses to climate change.

Germany

Information from the hydrometric network in Germany is available on the following websites:

List of federal gauges: www.pegelonline.wsv.de/gast/pegelinformationen
Map with gauges: www.pegelonline.wsv.de/gast/karte/standard
List of state gauges: www.pegelonline.wsv.de/gast/links

The number of hydrometric stations in Germany is 3000, an estimate provided by i. A. R. Fritsch of the German Federal Institute of Hydrology in Koblenz (Bundesanstalt für Gewässerkunde (BfG)).

Japan

Information on the hydrometric network in Japan is available only in Japanese. The network is operated by the River Bureau of the Ministry of Land, Infrastructure and Transport and Tourism. Information on the network is available at www1.river.go.jp.

There are 5632 water level gauges in Japan, primarily reflecting the need for real-time flood forecasting on small streams. According to Atsushi Hattori, Head, River Division, River Department, NILIM, there were 1444 stream flow gauges in Japan in 2007.

Russia

Complete information on the current hydrometric network in Russia was not available. Information on the network in the former Soviet Union was found in Shahgedanova (2003) and Sokolov (1964). In 1960 the hydrometric network in the former Soviet Union consisted of 5866 sites.

France

According to Wittwer (2009), there are 1200 real-time water level stations and 1500 hydrometric stations in France, as part of the flood forecasting system.

Annex 3
Documentation References – Network Governance

#	Reference	Document Name	Author	Date
1.	A2.1	Hydrometric Agreement Renewal: Presentation to the Weather and Environmental Services Board	National Hydrometric Program, Environment Canada	**January 23, 2007**
2.	A2.2 and A2.3	Outcome Project Plan: Hydrometric (Water Quantity) Monitoring Network – c1a3	Atmospheric Monitoring and Water Survey Directorate, Environment Canada	**2005–06**
3.	A2.4	An Analysis of Canadian and Other Water Conservation Practices and Initiatives: Issues, Opportunities and Suggested Directions for the Water Conservation and Economics Task Group, Canadian Council of Ministers of the Environment	J. Kinkead Consulting, A. Boardley and M. Kinkead	**2006**
4.	A2.5	National Administrators Table (NAT), Briefing Note: Kelowna Meeting	National Hydrometric Program, Environment Canada	**October 10–11, 2007**
5.	A2.6	Business Impact Analysis: Data Capture Worksheets; Service/Activity Analysis Worksheet; Critical Services Analysis Worksheet; Downtime, Staff Requirements and Minimum Service Levels Worksheet; Dependencies Analysis Worksheet; Recovery Strategies and Resource Requirement Analysis Worksheet	Environment Canada	**Not Available**
6.	A2.7	Fact Sheet: Canada–Ontario Cost Share Agreement for Water Quantity Surveys	Ontario Ministry of Natural Resources Science and Technology Strategies, Environment Canada	**Not Available**
7.	A2.8	Summary of Hydrometric Network	*Canada Water Act* reports, Environment Canada	**Not Available**
8.	A2.9	Program Assessment: Key Questions for Guidance of Template Completion: 2.1.1.3	Environment Canada	**May 9, 2008**

#	Reference	Document Name	Author	Date
		Inland Water Monitoring (2A1C)		
9.	A2.11	*Canada Water Act*	Department of Justice Canada	**June 25, 2008**
10.	A2.12	The *Canada Water Act* Annual Report 2005–2006	Environment Canada	**2005–06**
11.	A2.13	Alberta's Water Resources Summary	Alberta Environment	**April 28, 2003**
12.	A2.14	Hydrometric Program: A National Partnership	Indian and Northern Affairs Canada	**Not Available**
13.	A2.16	Hydrometric Program: Pacific and Yukon Hydrometrics	Pacific and Yukon Region, Environment Canada	**Not Available**
14.	A2.17	Summary of Provincial/ Federal Agreement Status	Not Available	**January 23, 2007**
15.	A2.19 and A2.21	2008–2009 Planning and Financial Strategies– Outcome Project Group 2A1 Weather and Environmental Monitoring	Environment Canada	**March 17, 2008 and April 8, 2008**
16.	A2.22	An Optimal Hydrometric Program for Canada	The Hydrometric Monitoring Business Case Team, Weather and Environmental Services Board, Environment Canada	**June 8, 2006**
17.	A2.23	Weather and Environmental Monitoring Networks: Hydrometric Monitoring	Environment Canada	**May 30, 2007**
18.	A2.24	Outcome Project Group Summary: 2A1 Monitoring and Reporting–Environmental Monitoring Allows EC to Identify, Analyze and Predict Weather, Air, Water and Climate Conditions	Monitoring and Reporting, Weather and Environmental Services Board, Environment Canada	**June 10, 2005**
19.	A2.25	Outcome Project Summary: 2A1c–Inland Water Levels and Flows are Monitored (C1a3)	Weather and Environmental Services Board, Environment Canada	**August 8, 2005**
20.	A2.26	Outcome Project Plan Template: Inland Water Levels and Flows are Monitored / Environmental Monitoring Allows EC to Identify, Analyze and Predict	Tim Goos, 2A1 monitoring team lead, outcome project leads, and sub-component managers	**May 17, 2005**

#	Reference	Document Name	Author	Date
		Weather, Air, Water and Climate Conditions		
21.	A2.27	About the Water Survey of Canada Hydrometric Program Hydrometric Monitoring – A Brief Overview	Water Survey of Canada, Environment Canada Manager, Water Survey of Canada, Atlantic Region, Environment Canada	**June 16, 2004** **January 8, 2007**
22.	A2.28	Hydrometric Main Estimates: - Table 10: Details on Project Spending - Table 5.3: Details on Major Capital Project Spending - Table 7: Capital Projects by Business Line - Details on Project Spending for Environment Canada - B.2.7 Projects by Business Line	Treasury Board of Canada Secretariat; Environment Canada	**Not Available**
23.	A2.30	2007–2008 Recorded “Hydrometric” Revenues	Rapport Disco (in house), Audit and Evaluation Branch, Environment Canada	**November 4, 2008**
24.	A2.31	Handbook/Guideline: Implementing the WES Quality Management System – 2A1c Hydrometric Monitoring (WSC), Version 2Dv01	Water Survey of Canada, Environment Canada 2A1c Core Team: Pat McCurry – team leader Annette Verley, Guy Morin, Stuart Hamilton, Rene Savoie, Chris Thomson, Mark Maslen	**July 10, 2008**
25.	A2.32	Memorandum – Note de Service – Letter of Agreement between Water Survey of Canada (WSC) and Baffinland Iron Mines Corp. – Amendment to Letter of Agreement between Qulliq Energy and Water Survey of Canada (WSC)	Manager, Water Survey of Canada, Environment Canada	**December 8, 2008**
26.	A2.33	The *Canada Water Act* Annual Report, 2005–2006	Environment Canada	**2005–06**
27.	A2.34	Canada – Alberta Agreement on Hydrometric Monitoring	Alberta Environment	**November 29, 2006**
28.	A2.35	The Northern Hydrometric Network: 100th Anniversary of the Water Survey of Canada,	Weather and Environmental Services Board Meeting – A/Manager, Hydrologic Applications and Services,	

#	Reference	Document Name	Author	Date
		2A1 Weather and Environmental Monitoring	Water Survey of Canada; and Manager, Prairie and Northern Region, Water Survey of Canada, Outcome Project Group 2A1 Environment Canada	**August 5, 2008**
29.	A2.36	Hydrometric Monitoring Business Case – Financial Priority	Ted R.Yuzyk, Weather and Environmental Services Board, Environment Canada	**August 29, 2006**
30.	A2.37	Memorandum of Understanding between Department of Indian Affairs and Northern Development and Department of the Environment for Northwest Territories / Nunavut Water Quantity Surveys	Water Survey of Canada, Environment Canada	**August 2008**
31.	A2.38	Canada – Manitoba Memorandum of Agreement for Water Quantity Surveys	Manitoba Hydro; Manitoba Water Stewardship; Environment Canada	**2001–04**
32.	A2.39	Changing the Flow: A Blueprint for Federal Action on Freshwater Water Quantity Monitoring in British Columbia: A Business Review of the BC Hydrometric Programs	Gordon Water Group of Concerned Scientists and Citizens Resource Information Department, Ministry of Sustainable Resource Management, British Columbia	**Not Available** **April 2003**
33.	A2.40	Hydrometric Monitoring Program	Not Available	**June 15, 2006**
34.	A2.41	Corporate Governance Maturity Model	Open Compliance and Ethics Group and the National Association of Corporate Directors	**2006–07**
35.	A2.42	Policy Research Working Paper 4370 – Governance Indicators: Where Are We, Where Should We Be Going?	The World Bank: World Bank Institute, Global Governance Group, Development Research Group, and Macroeconomics and Growth Team	**October 1, 2007**
36.	A2.43	Governance Matters 2008: Worldwide Governance 1996–2007	The World Bank Group	**2008**
37.	A2.44	Confidential Study: Public Sector	The World Bank Group	**2006**

#	Refe-rence	Document Name	Author	Date
38.	A2.46	Assessing Governance: Diagnostic Tools and Applied Methods for Capacity Building and Action Learning	Daniel Kaufmann, Francesca Recanatini and Serge Biletsky, the World Bank	**June 2002**
39.	A2.47	Public Officials – Survey Diagnostic: Questionnaire Overview	The World Bank Group	**2007**
40.	A2.48	Report of the Auditor General of Canada to the House of Commons: Chapter 1: Placing the Public's Money Beyond Parliament's Reach	Office of the Auditor General of Canada	**April 2002**
	A2.49	Chapter 10: Exhibit 10.5 – Governance Solutions to Identified Problems		**October 1, 1995**
	A2.50	Chapter 2: Governance of Small Federal Entities		**December 2008**
	A2.51	Chapter 7: Governance of Crown Corporations		**February 2005**
	A2.52	Chapter 1: Natural Resources Canada – Governance and Strategic Management		**April 2005**
41.	A2.53	Special Examinations Manual: 5. Understanding the Business and Corporate Governance	Office of the Auditor General of Canada	**November 15, 2007**
42.	A2.54	The Governance Self-Assessment Test	Governance International	**Not Available**
	A2.55	Good Governance Model		
43.	A2.56	Audit of Governance and Performance	Western Economic Diversification Canada	**April 8, 2008**
44.	A2.57	Organizational Governance: Embracing Internal Audit's Role	The Institute of Internal Auditors	**Not Available**
45.	A2.58	Hydrometric Monitoring Business Case: Financial Priority (v4.0)	Weather and Environmental Services, Environment Canada	**August 29, 2006**
46.	A2.59	Memorandum of Understanding between Department of Indian Affairs		

#	Refe-rence	Document Name	Author	Date
		and Northern Development and Department of the Environment for Northwest Territories / Nunavut Water Quantity Surveys – Annual Report 2007/2008	Water Survey of Canada, Environment Canada	**August 2008**
47.	A2.60	The *Canada Water Act* – Annual Report 2005–2006	Environment Canada	**2007**
48.	A2.61	Priority Management and Enabling Boards Submission Template	A/Manager, Hydrologic Applications and Services, Water Survey of Canada; and Manager, Prairie and Northern Region Water Survey – Outcome Project Group 2A1, Environment Canada	**August 5, 2008**
49.	A2.62	The Northern Hydrometric Network: 100th Anniversary of the Water Survey of Canada	Manager, Prairie and Northern Region; and A/Manager, Hydrologic Applications and Services, Water Survey of Canada, Environment Canada	**August 5, 2008**
50.	A2.63	Climate and Atmospheric Research Directorate Councils: Capabilities Assessment Instrument and Guide	Office of the Auditor General of Canada	**March 31, 1999**
51.	A2.64	Tableau de bord des Ressources Humaines, et Sciences et Technologie	Environment Canada	**Not Available**
	A2.65	Our Workforce Human Resources Dashboard, and Science and Technology		
	A2.66	Our Workforce Human Resources Dashboard 2, and Science and Technology		
52.	A2.68	Schedule C of Memorandum of Agreement between Government of Canada and Government of Alberta 2008–2009 (Version 1)	Alberta Environment; Water Survey of Canada, Alberta District; Environment Canada	**February 7, 2008**
53.	A2.71	Quality Management System Overview Process Map	Weather and Environmental Services – Water Survey of Canada Handbook, Outcome Project Lead – 2A1c, Environment Canada	**July 10, 2008**

#	Refe-rence	Document Name	Author	Date
54.	A2.73	ISO 9001:2000 Quality Management System Readiness Training, 2A1c Hydrometric Monitoring	Weather and Environmental Services, Environment Canada	**July 10, 2008**
55.	A2.83	Hydrodynamic and Environmental Modelling of the St. Lawrence River	Meteorological Service of Canada and Water Survey of Canada Centennial Workshop, Environment Canada	**October 20–23, 2008**
56.	A2.85	Internal Control Systems	Encyclopedia of Business and Finance	**2009**
57.	A2.88 and A2.89	Customer Need or Product Requirement V6 and V7	Alberta Environment	**Not Available**
58.	A2.90	Hydrometric Network Standards: A Systematic Approach to Problem-Solving	Alberta Environment	**September 4, 2008**
59.	A2.91	National Hydrometric Program: Comments on Customer Requirements and Products Exercise	Alberta Environment	**October 6, 2008**
60.	A2.92	A Strategic Plan for Environment Canada's Weather and Environmental Monitoring Program	Director, Network Strategies and Design, Meteorological Service of Canada, Environment Canada	**March 2007**
61.	A2.94	Draft Minutes of the NAT Face-to-Face	Whitehorse, Yukon	**September 16–17, 2009**
62.	C9.2 to C9.9	Compendium of Practices, Interpretations and Administrative Procedures for the Water Quantity Survey Agreements	Water Quantity Surveys; Federal-Provincial Cost Sharing Agreements; Environment Canada	**July 1985**
63.	C9.10	Canada – Alberta Agreement on Hydrometric Monitoring	Alberta Environment and Environment Canada	**November 29, 2006**
	C9.11	Canada – British Columbia Agreement on Hydrometric Monitoring	British Columbia Environment and Environment Canada	**July 2008**
	C9.12	Canada – Saskatchewan Memorandum of Understanding on Hydrometric Monitoring	Administrator for Saskatchewan, Saskatchewan Watershed Authority; Environment Canada	**April 25, 2005**
	C9.13	Canada – Yukon Memorandum of Agreement on the Hydrometric Monitoring	Minister of the Environment, Government of Yukon; Environment Canada	**January 25, 2008**

#	Reference	Document Name	Author	Date
		Program for the Yukon		
	C9.14	Memorandum of Understanding on Hydrometric Monitoring for the Northwest Territories and Nunavut	Department of Indian Affairs and Northern Development; Environment Canada	**November 30, 2006**
	C9.15	Memorandum of Understanding between the Government of Canada and the Government of Quebec concerning Hydrometric Monitoring in Quebec	Administrator for Quebec, Government of Quebec; Environment Canada	**December 11, 2006**
	C9.16	Canada – Ontario Agreement on Hydrometric Monitoring	Ontario Minister of Natural Resources; Environment Canada	**January 11, 2007**
	C9.17	Canada – Manitoba Agreement on Hydrometric Monitoring	Minister of Water Stewardship, Manitoba	**November 29, 2006**
64.	C9.18	Comparison of Bilateral Agreements	Audit and Evaluation Branch, Environment Canada	**Fall 2009**
65.	C9.19	Hydrometric Program: Budget Comparison	Audit and Evaluation Branch, Environment Canada	**Fall 2009**
66.	C9.21	Water Quantity Monitoring: Networks and Information Needs Workshop	Water Survey Division, Environment Canada; Manitoba Water Stewardship; Manitoba Hydro	**January 17–18, 2007**
67.	C9.22	Monitoring Committee–Water Survey, Terms of Reference	Water Survey of Canada, Environment Canada	**June 14, 1999**
68.	C9.23	6th Teleconference of the National WSC Federal-Provincial Web Task Group – Minutes	Environment Canada	**June 27, 2001**
69.	C9.24	Water Quantity Monitoring: Networks and Information Needs Workshop – Seminar Report	Terriplan Consultants	**January 17–18, 2006**
70.	C9.25	Water Survey of Canada (2A1c) National Management Committees – Water Survey of Canada Centennial Workshop	Operational Management Committee–Hydrometric; Subcommittee on Field Operations; Data Control Subcommittee; Subcommittee on Field Safety–Hydrometric; National Hydrometric Program Coordinators Committee	**October 2008**

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71.	C9.26 C9.27 C9.28	*Canadian Environmental Assessment Act* *Department of Indian Affairs and Northern Development Act*, Chapter I-6 *Dominion Water Power Act*, Chapter W-4	Department of Justice Canada	**June 17, 2009**
72.	C9.29	Water Monitoring Business Plan – Northwest Territories and Nunavut: Northern Affairs Program Water Management	Indian and Northern Affairs Canada	**2006**
73.	C9.30	*Mackenzie Valley Resource Management Act*	Department of Justice Canada	**June 18, 1998**
74.	C9.31	*Northwest Territories Waters Act*	Department of Justice Canada	**June 23, 1992**
75.	C9.32	Terms of Reference – Federal-Provincial Agreement on Water Quantity Surveys	Water Quantity Surveys National Program Working Group	**August 15, 2001**
76.	C9.33	National Hydrometric Program – Quality Policy Manual (Version: 1.0)	Environment Canada	**October 15, 2004**
77.	C9.34	Strategic Plan Framework – National Administrators Table: Canada/Territorial/Provincial Hydrometric Program	Administrator, Province of Ontario; Administrator, Environment Canada Quebec Region	**May 7, 2009**
78.	C9.35 to C9.46	National Administrators' Teleconference, Operational Management Committee and Face-to-Face Meetings – Minutes (88 documents)	National Hydrometric Program, Environment Canada	**2004–2009**
79.	A2.94	Food and Water	EarthTrends – Environmental Information, World Resources Institute	**2008**
80.	 A2.95	World Development Indicators 2009 – Key Development Data and Statistics, Country Profiles: – Australia		

#	Refe-rence	Document Name	Author	Date
	A2.96	– Canada	World Development Indicators database, The World Bank Group	**September 2009**
	A2.97	– France		
	A2.98	– Germany		
	A2.99	– Japan		
	A2.100	– United Kingdom		
	A2.101	– United States		
81.	**A2.102**	**Economic Indicators – Canada**	**EarthTrends – Economics, Business, and the Environment, World Resources Institute**	**2003**

Annex 4
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Annex 5
Interviews – Network Governance

Title	Province	Organization	Category
Acting Director	Saskatchewan	Hydrometric Monitoring, Environment Canada	Federal government
Director General	Ontario	Weather and Environmental Monitoring, Environment Canada	Federal government
Director, Water Resources Management Division	Newfoundland and Labrador	Environment and Conservation, Water Resources Management Division, Government of Newfoundland and Labrador	Provincial government
Engineer	New Brunswick	Water Quality and Quantity, New Brunswick Department of Environment	Provincial government
Flood Warning System Program Leader, Water Resources Section	Ontario	Natural Resource Management Division, Lands and Waters Branch, Ontario Ministry of Natural Resources	Provincial government
Director, Basin Operations	Saskatchewan	Operations Division, Saskatchewan Watershed Authority, Government of Saskatchewan	Provincial government
Director, Science and Information Branch	British Columbia	Ministry of Environment, Government of British Columbia	Provincial government
Head, Water Management and Planning	Northwest Territories	Indian and Northern Affairs Canada	Federal government – Indian and Northern Affairs Canada for the Northwest Territories
Manager, Water Resources Division	Northwest Territories	Indian and Northern Affairs Canada	Federal government – Indian and Northern Affairs Canada for the Northwest Territories
National Manager, Hydrometric Operations	Ontario	Environment Canada	Federal government
Standards and Procedures Officer, Hydrometric Operations	Ontario	Environment Canada	Federal government
Water Survey Manager, Atlantic Water Survey Section	Nova Scotia	Environment Canada	Federal government
A/Manager, Water Survey	Ontario	Meteorological Service of Canada – Operations, Ontario Region, Environment Canada	Federal government

Title	Province	Organization	Category
Manager, Water Survey Division	British Columbia and Yukon	Meteorological Service of Canada – Operations, Pacific and Yukon Region, Environment Canada	Federal government
Managers, Water and Wastewater Management Branch	Nova Scotia	Nova Scotia Environment, Government of Nova Scotia	Provincial government
Director, Direction de la surveillance des barrages et l'hydrométrie	Quebec	Centre d'expertise hydrometrique du Québec, Government of Quebec	Provincial government
Executive Director, Regulatory and Operational Services Manager, Surface Water Management, Water Science and Management Branch	Manitoba	Manitoba Water Stewardship, Government of Manitoba	Provincial government
Manager, Monitoring Programs and Quality Management	Alberta	Environmental Assurance Division, Ministry of the Environment, Government of Alberta	Provincial government
Director, Water Resources	Yukon	Water Resources Branch, Environment Yukon, Government of Yukon	Territorial government
Director General	National	Weather and Environmental Operations, Meteorological Service of Canada, Environment Canada	Federal government
A/Regional Director	Alberta	Meteorological Service of Canada, Weather and Environmental Operations, Environment Canada	Federal government
Assistant Deputy Minister	Ontario	Meteorological Service of Canada, Environment Canada	Federal government

Annex 6
Interviews – Network Configuration

Title	Province	Organization	Category
Manager, Water and Wastewater Management Branch	Nova Scotia	Nova Scotia Environment, Government of Nova Scotia	Provincial government
Head, Water Management and Planning	Northwest Territories	Indian and Northern Affairs Canada	Federal government – Indian and Northern Affairs Canada for the Northwest Territories
Director, Water Resources Management Division	Newfoundland and Labrador	Department of Environment, Government of Newfoundland and Labrador	Provincial government
District Manager, Water Survey	Northwest Territories	Meteorological Service of Canada – Operations, Prairie and Northern Region, Environment Canada	Federal government
Research Scientist, Hydrological Process and Modelling Research, National Hydrology Research Centre	Saskatchewan	Aquatic Ecosystem Impacts Research Division, Water Science and Technology, Science and Technology Branch, Environment Canada	Federal government
Professor, Department of Geography and Department of Forest Resources Management	British Columbia	University of British Columbia	University
Director, Science and Information Branch	British Columbia	Ministry of Environment, Government of British Columbia	Provincial government
Manager, Forecasting and Information, Water Stewardship Division	British Columbia	Ministry of Environment, Government of British Columbia	Provincial government
Executive Director, Regulatory and Operational Services	Manitoba	Manitoba Water Stewardship, Government of Manitoba	Provincial government
Director, Flood Forecasting Coordination	Manitoba	Manitoba Water Stewardship, Government of Manitoba	Provincial government
Manager, Surface Water Management, Water Science and Management Branch	Manitoba	Manitoba Water Stewardship, Government of Manitoba	Provincial government
Head, Hydrometric Section, Hydraulic Engineering and Operations	Manitoba	Power Supply, Manitoba Hydro	Hydro utility
Manager, Monitoring Programs and Quality Management	Alberta	Environmental Assurance Division, Ministry of the Environment, Government of	Provincial government

Title	Province	Organization	Category
		Alberta	
President	Saskatchewan	Halliday and Associates	Consultant
President	Alberta	Canadian Projects Ltd.	Developer
Professor	Ontario	University of Waterloo	University
Chercheur-professeur	Quebec	University of Laval	University
Manager, Water Survey Division	British Columbia and Yukon	Meteorological Service of Canada – Operations, Pacific and Yukon Region, Environment Canada	Federal government
Director, Direction de la surveillance des barrages et l'hydrométrie	Quebec	Centre d'expertise hydrométrique du Québec, Government of Quebec	Provincial government
A/Manager, Water Survey	Ontario	Meteorological Service of Canada – Operations, Ontario Region, Environment Canada	Federal government
Hydrologist, Water Resources Section	Ontario	Natural Resource Management Division, Lands and Waters Branch, Ministry of Natural Resources, Government of Ontario	Provincial government
President	Ontario	Lorant Consulting	Consultant
Manager, Hydrology Section, Water Resources Branch	Yukon	Department of Environment, Government of Yukon	Territorial government
Director	British Columbia	Meteorological Service of Canada – Operations, Pacific and Yukon Region, Environment Canada	Federal government
A/Director	Alberta	Strategic Integration, Prairie and Northern Region, Environment Canada	Federal government
Director General	National	Weather and Environmental Operations, Meteorological Service of Canada, Environment Canada	Federal government
President	British Columbia	Hayco	Consultant