

A Canada-wide Framework for Water Quality Monitoring

**Submitted by
Water Quality Task Group**

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Executive Summary

A Canada-wide Framework for Water Quality Monitoring is a follow-up to the Canadian Council of Ministers of the Environment (CCME) Experts Workshop on Water Quality Monitoring hosted in October 2002 by the CCME Sub-Group on Water Quality Monitoring. This initiative also responds to the direction set by the Canadian Council of Ministers of the Environment to enhance water quality monitoring in Canada. The purpose of the Framework is to enhance water resource management by serving as a guide to jurisdictions in the development and implementation of water quality monitoring programs in Canada. By using the Framework, improved coordination can be achieved through more consistent approaches and by identifying specific areas for inter-jurisdictional cooperation. These approaches would promote the development of credible, comparable data and information on water quality that could be more effectively shared and utilized nation-wide.

The Framework recommends high level, nationally-consistent guidance in establishing the purpose of monitoring, program design, site selection, data management, interpretation and reporting. The Framework also calls for greater coordination among jurisdictions in developing tools that could support a Canada-wide network of monitoring sites of national, regional and local interest. At the sites of national interest, opportunities exist for cooperation on core sets of variables and/or criteria for selecting key variables of most relevance to the site, water use and issue, and making the resulting data available to all interested parties.

Acknowledgements

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1. Introduction

In May 2001, CCME Ministers agreed to link existing water quality monitoring networks to ensure that Canadians have access to comprehensive information on the quality and safety of water. In response, a Monitoring Sub-Group was formed under the CCME Water Quality Task Group (WQTG) to develop a plan of action.

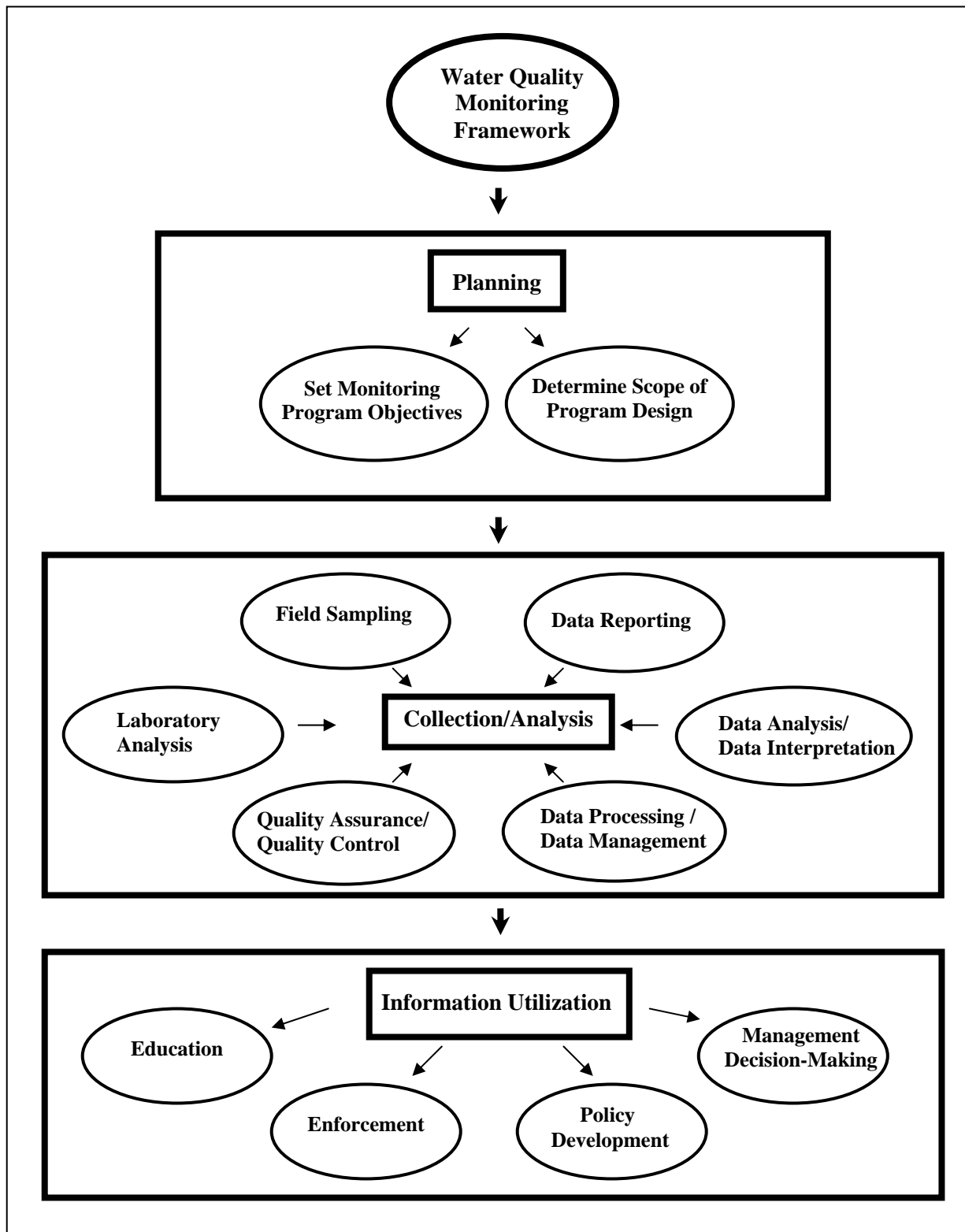
As part of the action plan, the CCME Monitoring Sub-Group held an Experts Workshop on Water Quality Monitoring¹ to facilitate a national dialogue on Canadian water quality monitoring and to share information on the current state of the science, technology and best practices in this area.

The aim of the workshop was to identify opportunities for enhancing linkages among existing Canadian water quality monitoring networks and to build on the strengths of our collective water quality monitoring capacities. The workshop participants reached an agreement that collaboration and coordination among jurisdictions will increase the efficiency, affordability, currency and credibility of water programs with regard to water quality monitoring, database management, data interpretation (e.g., guidelines) and reporting. To further efforts in this regard, there was a consensus among workshop participants to pursue the development of a *Canada-wide Framework for Water Quality Monitoring*.

This report outlines a proposed Framework for water quality monitoring. The Framework has been developed in consultation with members of the Sub-Group, as well as water quality monitoring experts from each Canadian jurisdiction and international sources. In addition, input was received from national workshops on the implementation of the CCME Water Quality Index. The Framework is intended to provide a Canada-wide approach, including a set of guiding principles. It is expected that this guidance will lead to greater consistency in how water quality monitoring is conducted in Canada. A schematic that provides an overview of the Framework for Water Quality Monitoring is provided in Figure 1.

¹ The proceedings of the Experts Workshop on Water Quality Monitoring are available at http://www.ccme.ca/assets/pdf/monitoring_workshop_current_state_eng.pdf

Figure 1. Schematic of a Canada-wide Framework for Water Quality Monitoring



2. Method for Developing the Framework

The CCME Canada-wide Framework for Water Quality Monitoring was developed under the guidance of the CCME Monitoring Sub-Group, using interview responses obtained from water quality experts in each jurisdiction across Canada. Important additional information was taken from the United States, Australia, and other foreign sources.

3. Review of Existing Monitoring in Canada

It is useful to briefly review current water quality monitoring activities in Canada. A national review was conducted in 2002 and was reported at the Experts Workshop in October 2002. More details from the review are attached in Appendix 1. Generally, the review showed that monitoring networks vary widely across the country, but have many common strengths, challenges and gaps. The key strengths identified were the high level of water quality expertise, a strong laboratory capacity and field methodology, the potential of watershed and multi-barrier approaches to improve the overall quality and safety of water in Canada, and the growing use of web-based and GIS technologies for improving access to and use of water quality data. Challenges identified in existing monitoring networks included gaps in monitoring programs for some key threats to water quality, the need for federal-provincial-territorial water quality monitoring agreements with some jurisdictions and a lack of policy requirements for trend monitoring in most jurisdictions. There is also a lack of common terminology among databases intended for linkage, and weaknesses in the linkage between monitoring program results and policy/decision-making.

Canadian jurisdictions have a great deal of experience developing and implementing monitoring programs. However, better coordination of approaches, techniques, methods and results would help strengthen all programs. As well, monitoring results such as improved water protection following monitoring-based evaluations need to be more visible to senior management. Additionally, the relevance and usefulness of monitoring information needs to be more fully explained to the Canadian public. Improved dialogue and sharing of data and experience will improve monitoring programs across Canada.

4. Purpose of a Canada-wide Framework

This Framework is a guide for jurisdictions in the planning and implementation of water quality monitoring programs. While each jurisdiction has substantial expertise in doing this, it was agreed that some degree of national guidance was needed. Additional guidance would help to:

- promote the linkage of distributed monitoring networks where desirable,
- increase sharing of data and information, and
- support a collective effort to achieve water quality objectives.

This document has been designed primarily as a tool for practitioners and is not intended to be prescriptive.

The Framework is also an important national initiative to help monitoring program managers to better position their programs with other priorities within their departments. The Framework will help affirm the collective commitment to strengthen water quality monitoring capacities

nationally as the requisite foundation for understanding and managing water resources in Canada. Finally, the Framework may spark other coordination and cooperative measures, such as broader data sharing initiatives through, for example, a national on-line portal. This portal could allow users to discover, access and use information on the design and development of monitoring programs, including guidance, technical reports, access to provincial and federal web sites, etc. In summary, the Framework is intended to promote the transfer of *data* into *information* and ultimately to *knowledge* for the benefit of Canadians and policy makers.

5. Guiding Principles

Canadians want and need to have access to comprehensive information about the quality, safety and availability of their water, both groundwater and surface water resources. To achieve this, CCME elaborated a set of principles² to guide cooperative arrangements for all environmental monitoring and reporting.

1. **Communication of information:** There will be open, transparent and timely reporting of information from monitoring programs, sufficient to meet the needs of jurisdictions and their obligation to communicate to the public.
2. **Mandates respected:** Cooperative arrangements will respect the mandates of jurisdictions and other parties.
3. **Shared responsibility:** Providing resources and implementing monitoring and reporting activities is a shared responsibility among federal, provincial, territorial and local governments, and between governments, industry, academic institutions and other partners. Identifying these responsibilities is an integral component of cooperative arrangements.
4. **Effectiveness and Efficiency:** Parties will plan and deliver monitoring and reporting activities in a way that makes the best use of public and private resources.
5. **Timely sharing of data between parties:** Parties will share their data with each other in a timely fashion to support their activities and to meet their legal, program and/or international obligations.
6. **Third party access to data:** Third parties may have access to data for research and/or analysis other than that for which it was originally collected, subject to the applicable government legislation, policies and contractual obligations. Third party discovery and access to these data could be facilitated through distributed and interoperable data standards and websites.
7. **Proprietary information:** Parties will protect proprietary information included in data in accordance with applicable policies and legislation.
8. **Cost recovery:** Where appropriate, parties may make data, analysis and reports available on a cost-recovery basis, consistent with applicable government policies.
9. **Scientific standards:** Parties will respect commitments to national and international monitoring and reporting protocols, and will work cooperatively to develop new protocols as appropriate, to allow for the meaningful analysis and comparison of data and results.
10. **Standardized data and data management:** Parties agree that data should be standardized and to respect data management protocols and develop new protocols

² The Principles are available at http://www.ccme.ca/assets/pdf/m_r_stmnt_of_prncpls_e.pdf

as appropriate, to ensure compatibility and facilitate the effective sharing of data, support data integrity, permit comprehensive data analysis, and protect historical records.

11. **Accountability and transparency:** Parties will make information about cooperative arrangements available to stakeholders and the public, and will consult, as appropriate, in developing these arrangements.
12. **Flexibility:** Cooperative arrangements should provide the flexibility to adapt to changes in technology, priorities, and organizational structures and mandates.
13. **Reciprocal notice:** Parties will provide appropriate prior notice in the event of terminating or changing cooperative arrangements.

6. Water Quality Defined

In Canada, “water quality” is a term most identified by society to describe the physical, chemical, and biological characteristics and conditions of water and aquatic ecosystems, which influence the ability of water to support the uses designated for it.

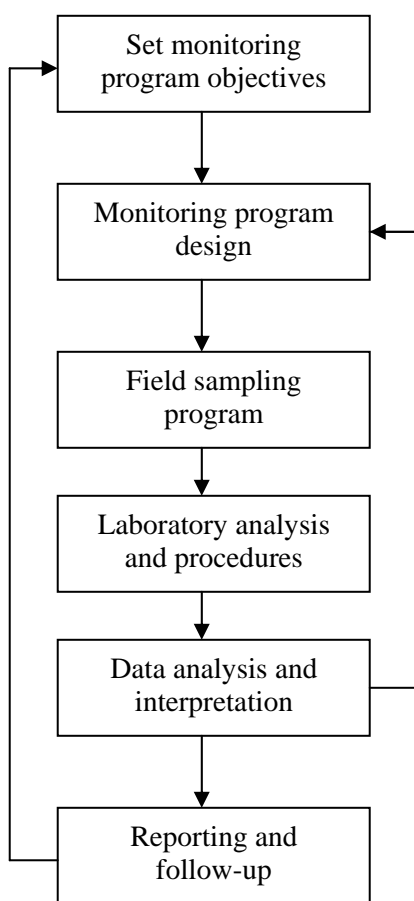
Water quality is measured with a wide range of physical, chemical and biological variables, parameters, indicators and measurements. The chemical and physical characteristics of water and sediment influence aquatic biota and the ecosystems in which they reside. Biological measures are viewed as more integrative, while the typical physical-chemical results from water samples show a “snapshot” of conditions at the moment of sampling.

7. Monitoring Program Design Considerations

Every monitoring program should have a clear underlying purpose and supporting rationale (i.e., question or questions being posed and why?), and the intended end use of the resulting data should be identified. Monitoring is often the most resource-intensive component in any aquatic resource assessment and management regime. It is imperative that data not be collected for its own sake; there must be a purpose for every variable or parameter measured.

For generalized guidance, the following diagram shows the kind of factors that need to be considered in the design and implementation of water quality monitoring programs.

Figure 2. Generic Water Quality Monitoring Program Design Considerations



Define and state the objectives of the monitoring program. If reviewing an existing program, determine if the original objectives are still relevant. Ensure that the right questions are being asked.

Use up-to-date methods and locally-relevant considerations to determine variables, monitoring frequency and site selection, to enable the program to answer the question.

Make sure field procedures and techniques will generate reliable and credible data. Develop, document and use Standard Operating Procedures and include these in metadata records. Utilize technical innovations wherever feasible. In the event that data sharing among monitoring networks is envisioned, consistent methods will yield the most comparable data.

Use a certified laboratory and develop a field sampling program in consultation with the lab; ensure sample container preparation, shipping, sample handling and analysis are satisfactory. Implement QA/QC program for field sampling and laboratory analysis and ensure the laboratory utilizes standard analytical methodologies (when possible) and reports in standard units of measure. Use defensible benchmarks (e.g., guidelines or objectives) and locally-relevant scientific knowledge when interpreting data.

Determine if the objectives have been answered, or could be answered with more data. If not, re-check program design elements. Include consideration of QA/QC of data.

8. Monitoring Program Objectives

Setting objectives is a critical initial step in establishing a monitoring program. In a country as diverse as Canada, there are a multitude of possible specific monitoring program objectives. It is as important to periodically review the current relevancy of objectives for existing monitoring programs as it is to set new objectives.

The overall objective of water quality monitoring programs is to inform Canadians about the suitability of water for various beneficial uses in both the spatial and temporal domains. The key concern in setting specific objectives for monitoring programs is to ensure that the right questions are being asked about the water quality issue of interest. Canadians want to know if their water is clean and safe to use (i.e., is it swimmable, fishable?), and if water quality is getting better or worse (i.e., trends). Monitoring programs generate new scientific information about the condition of water and should be seen as an integral part of an overall water management program within jurisdictions.

In general, monitoring program objectives can be effectively characterized by addressing a suite of simple questions:

- What is the program attempting to monitor? What are the issues?
- How much is already known about water quality as it relates to a given issue?
- What degree of change or impact do we want to be able to detect?
- What level of confidence do we want to have in the results?
- Is a study, investigation or impact assessment necessary?
- Is a short-term picture of water quality (i.e., synoptic surveillance study) adequate or do the underlying questions require systematic measurements over a long-term?
- Who is the monitoring program for? Who will be receiving and using the results of the monitoring program?

8.1 Examples of Monitoring Program Objectives

There is a wide variety of monitoring program types and objectives in Canada, including:

- To provide assurance that surface and groundwater meet the site-specific water quality objectives set for its use;
- To investigate the reasons why water in a specific location does not meet the objectives set for it;
- To establish a record of water quality to use as a basis for developing site-specific water quality objectives;
- To determine long-term trends or track changes in water quality over time. These can be due to changes in land or water use;
- To determine the effect of discharges on water quality compared with conditions prior to the discharges;
- To describe the habitat and/or physical conditions in the water, and its associated biota and sediment, for use as a baseline, in impact assessment, in state of environment reporting, and for setting in-stream flow needs;

- To evaluate non-point sources that may affect water quality; and,
- To determine the effectiveness of efforts to improve water quality (e.g., changes in land or water use, or effluent controls).

Within these general objectives, there can be more specific goals. Monitoring program objectives need to be clear, measurable and precise to properly design the program. For example, a program established to track changes over time may specifically state that a pre-determined degree of change should be detectable from the data. This specific objective will drive decisions on sampling frequency and duration of the program. For nutrient studies, a specific objective may be that loadings from a specific watershed need to be understood. This specific objective will drive the variables to be measured and the need for flow data. Further illustrations of specific objectives could be made available through monitoring program designs posted on a web site established as a recommended implementation step in this Framework.

9. Monitoring Program Design

Once the monitoring program objectives are established, the next step is to determine the scope of the program and the specific steps and considerations needed in developing a detailed design. Moving through distinct steps will assist in developing a program that will generate the kind of data needed to answer the questions posed, meet the program objectives, and do so as cost effectively as possible.

Despite the multiplicity of possible objectives for water quality monitoring programs, there are often two broad sub-sets of monitoring program designs:

- Long-term studies designed to monitor for status and trends; and
- Shorter-term studies, such as for survey or compliance monitoring, designed to support site-specific studies, investigations, impact assessments or in-stream flow needs assessments.

9.1 Specific Design Considerations

The following design considerations may be important when establishing long- or short- term studies (Table 1):

Long-term status and trends monitoring

- Determine the definition of long-term for each program and what constitutes a status and a trend. Monitoring programs for trends require a duration and sampling frequency that will reveal a statistically valid trend.
- Decide how much change should be detectable in the data, and at what level of statistical confidence. Tools such as statistical power should be used to determine both the duration and frequency of sampling. It is possible, however, that there will be no change even over long periods of record. A Canada-wide guidance document on statistical methods that is user friendly and scientifically sound would be helpful in assisting jurisdictions in making program assessments and decisions.

- Water quality is often influenced by flow effects and seasonality. Monitoring sites on streams and rivers should be established at or near flow gauging stations, if possible, to take advantage of hydrological data that can directly influence water quality results. Alternatively, the study design may require that a flow gauging station be established at the monitoring site or that the samples be flow-weighted (e.g., Equal Discharge Increments or Equal Width Increments).
- Implementation of *in situ* technologies for automated and continuous monitoring should be considered. Sites with this state-of-the-art technology are able to collect, store, and remotely transmit real-time water quality data.
- In a network of status and trend sites within a province or territory, establishment and use of a spatial framework (e.g., ecozones, biogeoclimatic zones, watersheds, etc.) can assist with site selection and defining network “representativeness”. Reporting of results could also be done on an ecozone or watershed basis.
- For existing sites, assess existing data. It may be determined that after a certain number of data points, conclusions can be drawn about the degree of variation in some program variables and adjustments can be made, as necessary. Adjustments could include dropping or adding variables, or adjusting the number of samples seasonally.
- For long-term programs, careful consideration should be given to a balanced set of physical, chemical and biological components that will best respond to the objectives and questions posed. Frequently, long-term sites include only chemical variables with field observations (temperature, etc.), and no biological or sediment data. The nature of biological and sediment data is that these may only have to be collected during one time period each year, even in a long-term study.
- The “polluter pays” principle should be considered in monitoring design. When new sites are established, or old ones threatened by budget cuts, it may be prudent to engage the industries or municipalities in the drainage basin that affect the water quality, or benefit from the data, and seek their support. Some excellent examples of this exist in Canada, such as the Columbia River Integrated Environmental Monitoring Program (CRIEMP) that has numerous industrial, government and local stakeholders contributing to one agreed-upon program on the lower Columbia River.

Shorter-term survey or compliance monitoring

- For specific sector-based industries (e.g., mining, pulp and paper), national guidance on appropriate program components exists through the Environmental Effects Monitoring (EEM) program. These can be used as guidance in designing monitoring studies in other sectors.
- Consider statistical approaches in program design. The right sampling frequency is often tied to the inherent variation in the data. Unfortunately, sampling frequency often falls back to “monthly” or “quarterly” without the benefit of an assessment of the actual frequency that might show important information (e.g., poor water quality during precipitation events). Evaluate the data to determine if enough has been collected to allow confident statistical interpretation. There is a need to make good judgments about sampling frequency. Such an evaluation would tend to make monitoring programs more effective.
- Review the need for one or more “control” or “reference” sites against which comparisons can be made with impact sites. These would normally be locations where

the influence being measured is not present. This may mean a site located upstream, or in a different part of a lake or estuary, separated by as much distance as possible.

- Review the need to focus on a specific timeframe for monitoring as it relates to the issues of interest. For example, the best monitoring time may be during late winter low flow conditions in a river, or spring or fall overturn in a lake. Monitoring during the spring freshet, when the majority of dissolved and suspended matter is present, may be the key consideration in Canadian river monitoring. If agricultural pesticide contamination is the issue, design of the sampling program around times of application and potential runoff may be most appropriate. The season may create an opportunity to collect data that are highly revealing, and reduce the need to repeat at other times of the year. Increased sampling frequencies during these key periods of time may provide greater understanding of water quality conditions.
- If monitoring for attainment of water quality objectives, ensure that the correct specific and supporting variables (e.g., temperature, hardness, pH, etc.) are monitored, and the monitoring frequency is appropriate to each objective (e.g., five samples in a 30-day period, etc.).

Table 1. Summary of Considerations in Designing Monitoring Programs

	Existing Monitoring Programs	New Monitoring Programs
Longer-term Status and Trends Monitoring	<ul style="list-style-type: none"> • Review the original questions that the program was established to answer. • Review previous objectives for current relevance. • Will variables and sampling frequency address the objectives? • Are any trends detectable now? 	<ul style="list-style-type: none"> • Ensure the question being asked of the program is clear. • How much change in trend do you want to be able to detect? • At what level of confidence? Select appropriate statistical treatment. • Select variables, frequency and technology appropriate to answer the question.
Shorter-term Survey or Compliance Monitoring	<ul style="list-style-type: none"> • Identify control site or sites. • Is an impact already detectable? • If no, consider program design changes, or draw appropriate conclusions. • If yes, what management actions are required? • What follow-up monitoring is required to verify the effectiveness of management actions? 	<ul style="list-style-type: none"> • Ensure the question being asked of the program is clear. • Are control or reference sites available? • How will you detect an impact? • What sampling intensity is needed to detect the impact? • Select variables and frequency appropriate to answer the question.

9.2 Monitoring Site Selection and Classification

The selection of sampling locations is another key component of the program design and also allows some degree of integration of programs across the country. In addition to the requirements of the program and its objectives, sampling site locations will often be dictated by a range of site-specific factors. Practical sampling considerations, such as accessibility and safety concerns, also play a major role in site selection. Assuming that each jurisdiction may have several active monitoring networks along with a host of dormant or discontinued sites, the relative importance of each site within the overall monitoring programs of each jurisdiction can be ranked by priority. For example, each jurisdiction highly values its long-term trend sites as they tend to provide the most consistent and reliable historical record. However, even some long-term trend sites can be abandoned for periods of time and then re-sampled after a period of dormancy once sufficient initial information (usually at least ten years) has been collected. The following ranking can be used in these cases:

9.2.1 Sites of National Interest

These would include status and trend stations that are highly valued within each jurisdiction, and which have long periods of recorded, reliable data. These sites could be ranked as the priority for national monitoring and reporting. Additional sites of national interest may be in National or provincial parks, at heritage river sites, at jurisdictional boundaries, or in significant ecozones or watersheds, or be valuable for informing on influences of climate change. Some criteria could be

established for formal recognition of these sites within this Framework. In addition to variables currently being measured, a core set of variables could be agreed upon.

9.2.2 Sites of Regional Interest

These are trend or shorter-term impact sites not included in the national list, but which generate data of interest to multiple jurisdictions or users. These may include sites monitored by industry or lay-samplers, such as volunteers and community groups. These data may not necessarily be considered a priority for national treatment, but data would be made available as provided by the guiding principles cited in section 5 above.

9.2.3 Sites of Local Interest

These may include short-term surveillance, impact or baseline sites used in survey or compliance monitoring to confirm the existence of a problem or that a problem has been solved. These data would normally be of interest only to the jurisdiction or user that collected them, but could be shared under the same guiding principles.

The following table describes these three ranks along with the level of national consistency or coordination that could be attached to each.

Table 2. Recommended Characteristics of Monitoring Sites Arranged by Interest

	National Interest	Regional Interest	Local Interest
Long-term trend sites	Yes	Optional	Optional
At or near hydrometric station	Yes	Yes	Optional
Use of Canada-wide core set of variables	Yes	Optional	Optional
Use for WQ Index	Yes	Optional	Optional
Inclusion of data in a distributed and interoperable information system for timely access and use	Yes	Optional	Optional
Site-specific water quality objectives established	Optional*	Optional	Optional
Consistent criteria for field and laboratory methods and sampler training	Yes	Optional	Optional
Basis for federal – provincial – territorial water quality agreement	Yes	Optional	No

*In many cases, CCME or provincial guidelines are the most appropriate benchmark against which to compare water quality data, but in some cases, site-specific objectives may be more relevant.

10. Field Sampling Program

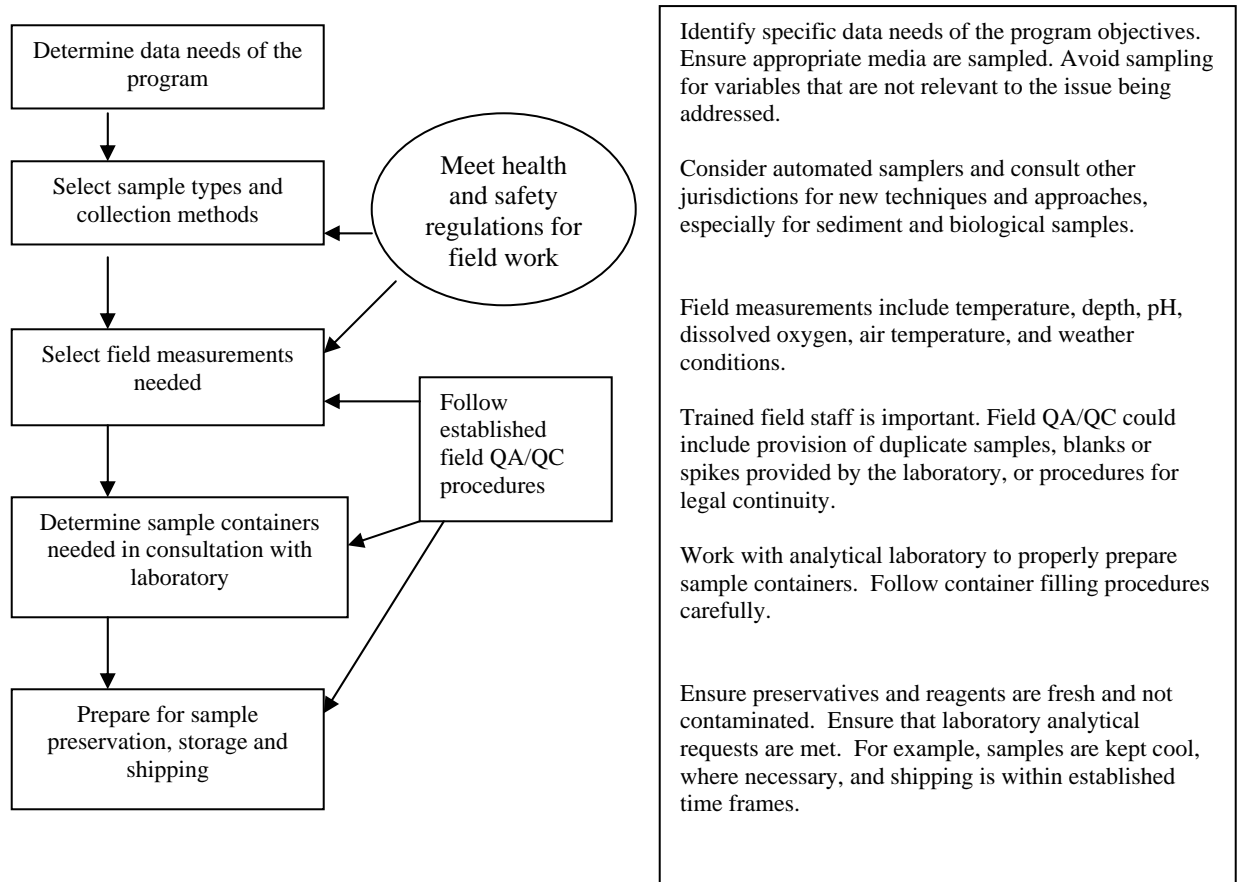
Field sampling is done by all jurisdictions and there may be a wide variation in approaches and techniques used to collect data. Variations can be identified and differences noted and shared through the implementation of this Framework. Differences are important considerations when comparable data are sought and shared across distributed networks. In some situations (e.g., remote, inaccessible and high-risk locations), the field sampling component of the program can be as or more costly than the laboratory analysis of the samples. It is important for all staff collecting samples to be well trained to ensure that the samples are not compromised. Field quality assurance and quality control protocols are important factors in retaining scientifically-valid samples. Recent advances in *in-situ* technologies for automated and continuous monitoring and telemetry should be considered as part of a modern integrated monitoring program.

Given the potential variability in field sampling techniques, promotion and adoption of consistent Canada-wide approaches, although desirable from a network linkage and data sharing perspective, remains a challenge. A national inventory and assessment of techniques, methods and approaches is needed to characterize the nature and extent of this variability in Canadian monitoring programs. Standard Operating Procedures for field sampling should be developed, documented and used, and included in metadata records. Metadata records, which should be completed for every monitoring site, are vital for providing context and assisting with data interpretation and data comparability.

Consequently, it is crucial to take a measured, skilled and organized approach to field sampling. This Framework offers general guidance when developing a field sampling program. Figure 3 highlights several key considerations (adapted from Australian Guidelines, 2000³).

³ Australia and New Zealand Environment and Conservation Council, 2000. *Australian Guidelines for Water Quality Monitoring and Reporting – Summary*.

Figure 3. Steps in Developing a Field Sampling Program



Additional considerations in developing the field sampling program include:

- Sampling site description (site number, geo-reference coordinates, and factors such as access, representativeness, proximity to a gauging station where applicable, and location of the control site, etc.). A standard format for site descriptions could be developed and adopted nationally;
- Sampling frequency (monthly, 30-day average, increased intensity with flow, spring overturn, etc.);
- Sampling methods for water (surface grab, integrated depth, discrete depth, vertical haul, dredge type, etc.);
- The numerous sampling methods for plant and animal tissues or sediments (methods could be available on the web);
- Containers and field preparations required (use of field filtration equipment, field chemical tests and electrical gear, pre-acidified containers, rinse or not rinse, etc.); and
- Sample preservation and shipment (field DO, use of freezer packs, travel time limits, etc.).

Since field sampling may, in some cases, be undertaken by technical personnel or lay samplers with limited scientific training and experience, a separate guidance document on national field sampling guidelines would be a helpful component of this Framework, and could be made available on-line through a national water quality monitoring portal. Until then, several jurisdictions have field sampling manuals or documents (Alberta, Saskatchewan, British Columbia, Quebec, Canada) that could be made available through links to the CCME web site. Recent interest in expanding aquatic bio-monitoring programs and networks has raised the importance of field training, which is a key requirement in assuring that credible, comparable data are acquired for use. Similarly, increasing interest in the deployment of automated water quality sensors, which result in data rich projects, has underlined the need for clear operational protocols and adequate training of users.

11. Selection of Variables (Parameters)

In general, the selection of variables to be measured is based on local site considerations and the objectives of the program, including the water quality issues and water uses of interest. For example, if the objective is to develop a network for assessing the status and trends of water quality for the support of aquatic life, one would select parameters having the most significant influence over the health of aquatic life at that specific site or location.

Even though the reasons for doing shorter-term studies vary widely, the basic designated water uses are few and consistently recognized across the country. These are water for aquatic life; source water for drinking water; water for agricultural uses (irrigation and livestock watering), water for recreation and water for industrial uses. These five basic water uses support the concept of a common, or core set of water quality variables that are typically used as good indicators for each. However, the exact set of variables would need to be tailored to land use inputs. In addition, there may be supplementary variables that apply on a site-specific, case-by-case basis. Canada's principal water quality monitoring interpretive benchmarks – the CCME Canadian Environmental Quality Guidelines for water – are developed according to designated water uses. Provincial guidelines also complement the suite of benchmarks available. Water quality data can therefore be interpreted to determine if water uses are being protected.

The following table provides a list of recommended core and supplementary variables for consideration in monitoring programs based on the water use being protected. This approach is already well established in many monitoring programs in Canada. It must be stressed that this table represents guidance only and should be seen as a starting point for selection of variables for any given program. In all cases, site-specific conditions need to be considered in selecting the full slate of variables to include in a monitoring program. One reason for this is that some variables are naturally high in certain geographic regions of Canada and, though they may exceed CCME or provincial guidelines for the protection of aquatic life, they have healthy ecosystems that are adapted to the ambient conditions.

Table 3. Proposed Core and Supplementary Variables for Consideration in the Protection of Priority Water Uses

	Protection of Aquatic Life	Industrial Uses	Agricultural Uses	Suitability of Source Water for Drinking Water Supply¹	Recreational Uses
Core Variables	Dissolved Oxygen Temperature pH Turbidity Conductivity Nutrients Flow (where applicable) Condition of biological communities (at least two communities) For lakes: Total P Chlorophyll, Secchi disk transparency Others as specified in site-specific objectives	Differs depending on the industry (e.g., mining, pulp & paper); see CCREM (1988) Others as specified in site-specific objectives	Differs if water is used for livestock watering or irrigation; see CCME (1999) Others as specified in site-specific objectives	E. coli Total coliform Nitrate/Nitrite Colour Odour Taste Chloride Ammonia Temperature Total dissolved solids Dissolved organic carbon pH Flow (where applicable) Others as specified in site-specific objectives	Fecal indicator organisms (e.g., E. coli) Nuisance plant growth Nutrients Chlorophyll Turbidity Secchi disk transparency Others as specified in site-specific objectives
Supplementary Variables	Toxicity testing Other parameters of concern (on a site-specific basis) Organism health (tissue residue, condition index, EROD, etc.)	Other parameters of concern (on a site-specific basis)	Pesticides Blue-green algae or algal toxins Other chemicals of concern (on a site-specific basis)	Other parameters of concern (on a site specific basis) e.g., iron, manganese, bromide	Other parameters of concern (on a site-specific basis)

¹Treatment of all surface water used for potable purposes is recommended, and is required by some jurisdictions.

It may be possible to achieve a consensus on a core set or sets of variables so that an assessment of water quality for a designated use is consistent across Canada. Variations would be expected, but this would allow the sharing of information more comprehensively on a core set of variables measured in a similar way across the country. At a minimum, sites of national interest could be coordinated in this way.

Questions that may also be helpful to consider in selecting variables include:

- Does the variable directly measure the issues of concern?
- Do changes in the variable explain measured changes in the environment?
- Can the variable be measured reliably, repeatedly and consistently?
- Is the variable appropriate given the time frame or scope of the study?
- Is the variable a key determinant for supporting or impairing the water use at the site in question?

12. Laboratory Analyses

There are often many specific analytical techniques to choose from for the same variable. Appropriate methods can be found by referring to reference materials on standard methods. Choices need to be made on the basis of what method will reveal the best information to answer the question posed by the monitoring program. Cooperation with laboratory staff should be sought when working out the details of best analytical procedures for any given circumstance.

As a general rule, analytical results from laboratories, especially if they support regulatory, assessment and management activities, should be able to meet the following basic principles:

- The investigator must be confident that all analytical data generated by or received from the laboratory are reliable as well as scientifically and technically defensible;
- The laboratory can ensure that procedures are documented so that any anomalies, deficiencies or sources of error can be identified and addressed;
- The investigator can be confident that full value is obtained when purchasing analytical services;
- The laboratory can show resulting data are consistent with national and international standards; and
- Results from the laboratory are comparable with those of other laboratories, or at least, the method details are identified so as to assess the nature and extent of differences among laboratories.

To achieve these principles, all jurisdictions should only use analytical laboratories accredited for specific analytical tests under the Standards Council of Canada, the Canadian Association of Environmental Analytical Laboratories (CAEAL) or an equivalent. Where SCC/CAEAL or an equivalent accreditation does not exist, the laboratory should maintain full documentation on QA/QC, be prepared to undergo proficiency testing for the variables in question, and make these test results available to the investigator. Like field methods, a national inventory and assessment of laboratory analytical methods is required, and the results should be made available to CCME member jurisdictions. There are opportunities to identify and share preferred analytical techniques and protocols for the set of monitoring sites that are of national interest.

The following is a typical sequence of steps in preparing to use a laboratory and receive data:

Identify the analysis required:

- Normally this is driven by the question being posed by the monitoring program.

Select analytical methods and detection limits:

- Include laboratory staff in deciding upon appropriate methods. For example, determine detection limits in light of precision required and associated costs.
- For most environmental samples, more sensitive analytical techniques should be selected unless data indicate that a less sensitive method is appropriate.
- Make sure the detection limit specified is low enough to meet the needs of the study requirements.

Consider holding times and sample stability:

- Samples must be shipped to the laboratory within specified times.
- Variables such as pH, alkalinity, and organic and inorganic carbon in water can vary significantly over a 24-hour period and should be analyzed in the field or as a first priority in the laboratory.

The laboratory performs the analysis:

- Understand the quality control procedures; request a QA/QC report from the laboratory.

Receive data:

- Review analytical results from the laboratory immediately.
- Correct typos or other apparent mistakes.
- Check for the need to re-analyze anomalous samples.
- Analytical results should be downloaded directly from the laboratory to the data storage and retrieval system to minimize human intervention and ensuing errors.

13. Data Management

Data management is a key component of any monitoring program. Data management in water quality monitoring programs is often complex due to the large number of records generated, the wide variety of monitoring and reporting objectives, and the wide differences in data management approaches and IT/IM architectures available and employed throughout Canada. The complexity of the dataset increases with the broad range of laboratory methods employed. Data management systems used by various jurisdictions differ considerably with respect to the manner in which data are received, stored and retrieved. Considerable financial and human resources are often invested in the development and maintenance of these data systems. The situational analysis in 2002 pointed out that there was inconsistency in data management systems, even within the same department.

A good example of a consistent data management tool for monitoring data is the federal ENVIRODAT, which includes maintenance records for laboratory methods codes. There is currently an exercise underway to modernize Environment Canada's water quality data holdings (ENVIRODAT) and provide a reliable central service for managing and distributing ENVIRODAT codes. This exercise includes the adoption of standards to more effectively improve the credibility, comparability, accessibility and delivery of these databases. These standards include collection level and station level metadata, using CSDGM (Content Standard for Digital Geospatial Metadata) and SensorML, respectively. The other facet of this modernization includes a comparability assessment of laboratory methods used in water quality.

The guiding principles in section 5 call for good reporting and coordination, and recognize that data are to be shared with other parties in a timely fashion as appropriate to program needs and restrictions. Data should be managed in a way that promotes data interoperability and comparability so that, where required, data/databases from distributed networks and programs (inter-jurisdictional) can be used together for a common purpose.

14. Interpretation of Results

When interpreting the results of field sampling, there must be a linkage back to the original intent of the monitoring program. The intent is to provide an approach that will serve as guidance through various steps in the data interpretation process. Each investigator must also use their experience and understanding of water quality to aid in the interpretation of results.

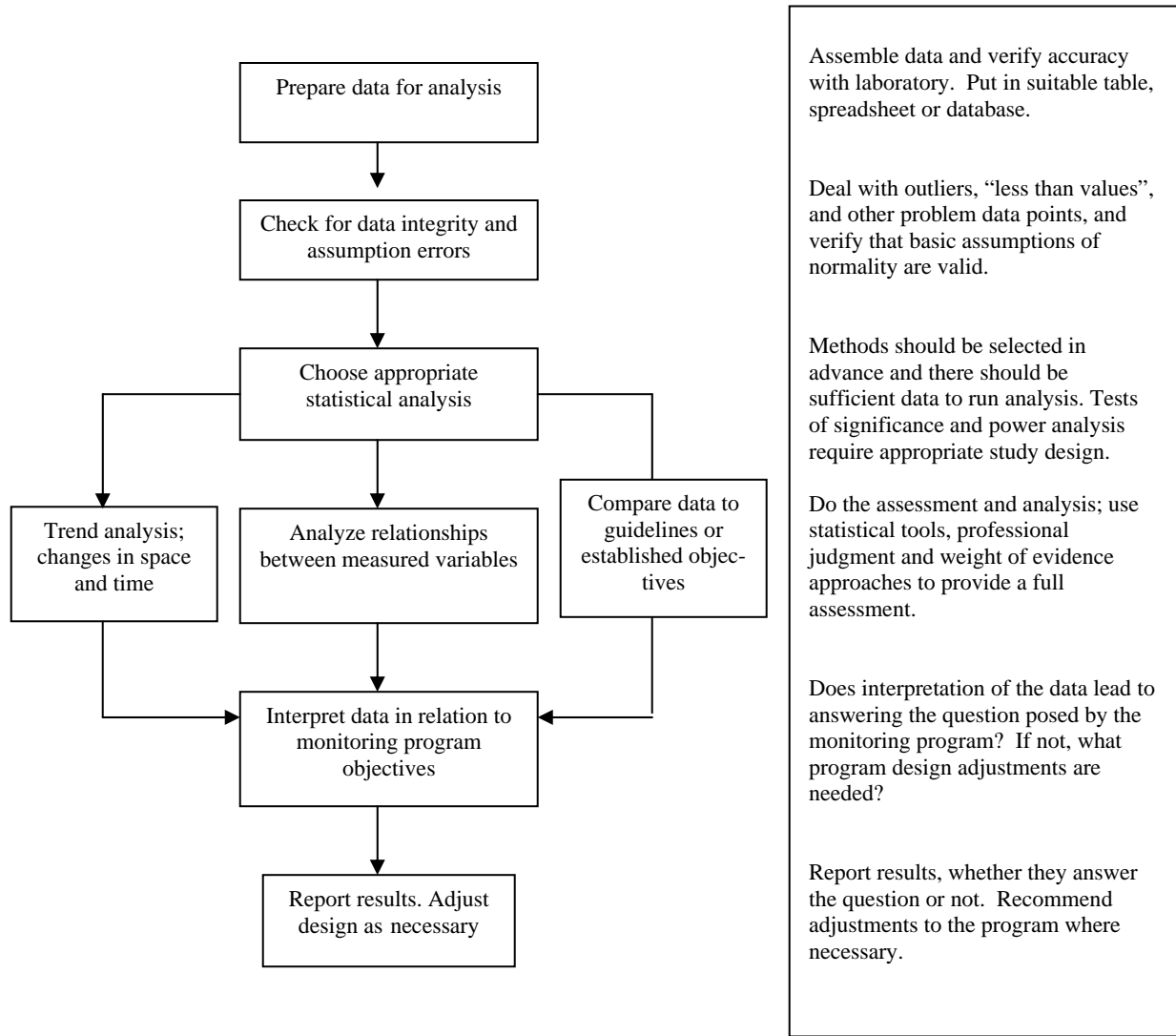
There are three basic approaches for data assessment:

1. Assessment over long periods of record for the purpose of determining trends and changes over time (e.g., for trend monitoring);
2. Analyzing the relationships between measured values for variables in the monitoring program to determine differences and the significance of the differences (e.g., for survey or compliance monitoring). This may include upstream vs. downstream or control site comparisons, or other spatial or temporal differences; and
3. Assessment of the extent to which measured water quality meets published guidelines, criteria or objectives (e.g., for survey or compliance monitoring, or objectives established within a water quality index).

Prior to conducting the interpretation, data should be prepared and examined in a structured manner and the appropriate statistical treatments employed. Preferably, these treatments would have been selected in advance and the program designed to allow the use of the selected treatment. The steps in data interpretation can be represented in the following diagram (adapted from the Australian Guidelines, 2000)⁴.

⁴ See footnote 3.

Figure 4. Steps in Interpretation of Results



15. Reporting

Reporting on monitoring program results is a critical part of an overall monitoring program and, in most cases, the integrative component that allows one to measure the overall performance of the program. The report should reflect how well the questions posed by the program have been answered. Within government agencies, there can be day-to-day pressures that result in delays in data interpretation and reporting. It may be helpful to commit time to the reporting as part of the monitoring program so that this important component is retained.

There are many options for a reporting format. A report should contain many of the elements described in this Framework: statement of objectives, program design, variables measured, field techniques, laboratory QA/QC, data management and interpretation, conclusions and

recommendations. The use of web-based and GIS technologies have added a new dimension to traditional reporting options.

As a Canada-wide Framework, it is important to focus on what is reported and how this could be done nationally. Based on the interviews conducted across the country, there is not yet a consensus on the extent to which jurisdictions should report on a Canada-wide basis. However, the guiding principles and instructions from Ministers lend support to the need for organizing some form of Canada-wide reporting, particularly on trends.

A reporting mechanism could be an on-line portal established through the CCME web site and linked to each jurisdiction's web site. Interpretive and assessment reports from each jurisdiction could be linked to the on-line portal with instruction on how to obtain copies of reports that are not available electronically. In addition, depending on the level of comfort and technical capabilities of each jurisdiction, links to specific monitoring stations could be established and data could be made available to an outside user. It is recognized that there are restrictions placed on the use and sharing of some types of monitoring data such as those associated with regulatory approvals, where data are considered proprietary information and subject to freedom of information and protection of privacy requirements.

The kind of interpretive and assessment reports that would be posted and available through the portal could include:

- Descriptions of federal, provincial and territorial water quality monitoring programs and strategies, and any revisions or annual operational plans;
- Impact assessment reports;
- Short-term baseline studies intended to describe the water quality at specific locations;
- Environmental Effects Monitoring (EEM) Program study reports;
- State-of-Environment (SOE) reports by jurisdictions;
- Reports on long-term trend analysis;
- Reports on the Water Quality Index (e.g., the Freshwater Indicator of the Canadian Environmental Sustainability Indicators annual report);
- Case studies for existing municipal, forestry, mining, agriculture, and non-point source monitoring programs;
- Operational manuals such as field sampling protocols, special analytical techniques, and new field techniques (e.g., the use of *in-situ* mesocosm apparatus or continuous monitoring equipment);
- A forum for posting questions and exchanging more detailed technical information; and
- Web-based and GIS tools providing interactive and dynamic reporting capabilities.

In Table 2 of this Framework, monitoring sites of national, regional and local interest are described. The priority for Canada-wide reporting would be the sites of national interest. This would include reporting results from a common set of variables, methodologies, and calculated water quality indices for the agreed trend sites across Canada.

16. Path Forward

As documented earlier in this report, a review of the existing water quality monitoring networks in Canada demonstrated many strengths, challenges and gaps. The purpose of the Canada-wide Framework for Water Quality Monitoring was to provide a guide for jurisdictions in the planning and implementation of water quality monitoring programs. As with all collaborative work, it is essential to evaluate the importance of the product produced and to determine how this product can be best utilized to achieve its primary objectives. Development of this high-level guidance document is a substantial step towards introducing concepts within water quality monitoring that can lead to national consistency. More specifically, it provides essential information that can be used to ensure all aspects of water quality monitoring are carried out with the utmost accuracy and efficiency.

The following are some important steps that will help advance this Framework and at the same time address some of the challenges and gaps identified within water quality monitoring networks across the country:

- The Water Quality Monitoring Sub-group under the CCME Water Quality Task Group should be designated to act as a lead resource group to:
 - Develop numerous technical documents detailing each element of water quality monitoring to act as companion documents to the Framework. In light of limited resources and time, it will be important to identify key gaps and priority needs of jurisdictions, and to evaluate existing documents prepared by federal or other jurisdictions that could be used or built upon in the Canada-wide context. Jurisdictions should be encouraged to use these documents to decrease the sources of errors that can occur in water quality monitoring programs and to improve national consistency. Topics of interest may include:
 - water quality monitoring program design
 - field sampling
 - automated sampling
 - laboratory analysis
 - quality assurance/quality control
 - data analysis and interpretation
 - statistical methods
 - data processing and management
 - data reporting
 - new/innovative techniques and equipment for water quality monitoring, analysis (e.g., neural networks for QA of automated data) and reporting.
 - Define criteria for the selection of national water quality monitoring sites. The establishment of a national water quality monitoring network(s) should be multifaceted to include a variety of water body types (estuary; small, medium and large lakes; streams and rivers; groundwater); representative sampling locations across the country (e.g., wet coastal areas; dry plains; the mountains and the Precambrian

Shield; the north and the south); and representative samples of sites impacted and not impacted by varying degrees of human activities.

- A link or portal on the CCME web site should be established where a user can access various products produced under this initiative along with existing interpretive reports, guidance documents, training manuals, field sampling protocol documents, analytical methods, etc. The portal would also provide links to the web sites of individual jurisdictions and to other groups or agencies where the user can pursue additional information.

Appendix 1. Review of Existing Water Quality Monitoring in Canada

It is useful to review the current situation in Canada on water quality monitoring. A review was conducted and was reported at the CCME Experts Workshop on Water Quality Monitoring in October 2002.

The conclusions of the review showed that:

- Monitoring networks vary widely, and have many common strengths, challenges and gaps.
- Monitoring results need to be more visible to senior management within the generating agency, and to the public, and the relevancy and usefulness of monitoring information needs to be more fully explained.
- Better coordination among jurisdictions is a challenge, but also coordination within jurisdictions needs to improve, and may need to be done as a first step.
- Better linkages among jurisdictions will spread techniques and innovations, even if specific program details do not change. Improved dialogue and sharing of data and experience will improve monitoring programs across Canada.

Common elements to build on:

- All jurisdictions have monitoring networks, for long-term and shorter term studies.
- The basic rationale for the long-term trend sites is similar across the country.
- Many common elements and variables are measured in each jurisdiction, with local differences and field techniques.
- Adoption of a watershed approach to managing water quality is a growing trend.
- There is a recent focus on improving drinking water safety, with accompanying regulatory and institutional strengthening.
- Monitoring networks are vulnerable to funding reductions due to many factors.
- All jurisdictions have had their programs reduced and otherwise affected by cut backs.
- There is a common use of lay and/or contract samplers to collect samples in the field.
- All jurisdictions report not having full capacity to achieve their water quality goals.
- Some jurisdictions do not want to have their water quality compared to that of others.

Strengths of existing monitoring systems:

- Watershed and multi-barrier approaches have a strong potential to improve the overall quality and safety of water across the country.
- Procedural improvements have been made to alert communities if bacteriological findings warrant.
- A high level of expertise in water quality exists across the country.
- Canada has good laboratory capacity and field methods, even if these vary among jurisdictions.
- The use of Water Quality Index for assessment and public reporting is expanding.
- The use of site-specific objectives and associated monitoring and public reporting is a growing trend.

- Some jurisdictions are using an overall water strategy and policy with monitoring as an element.
- There is a growing use of web-based and GIS techniques.

Gaps in existing monitoring systems:

- Networks of trend stations are not required as a matter of policy in most jurisdictions, but persist through the efforts of professional staff.
- Although coordination mechanisms are available through CCME, they are not being used as a forum for coordinating approaches or sharing stories.
- A common terminology (i.e., parameter vs. variable) is not used among data bases intended for linkage.
- Long-term data tend not to be written up and reported, creating a problem with the visibility and value of long-term monitoring.
- Some threats to water quality, as identified in recent reports, are not monitored adequately.
- Federal-Provincial-Territorial water quality agreements are not in place in all provinces or territories.
- Coordination between drinking and non-drinking water staff is lacking in some jurisdictions.
- Linkages can be poor between databases within the same jurisdiction.
- Monitoring program designs may not achieve the desired results.
- Linkages between monitoring program results and policy making can be weak.