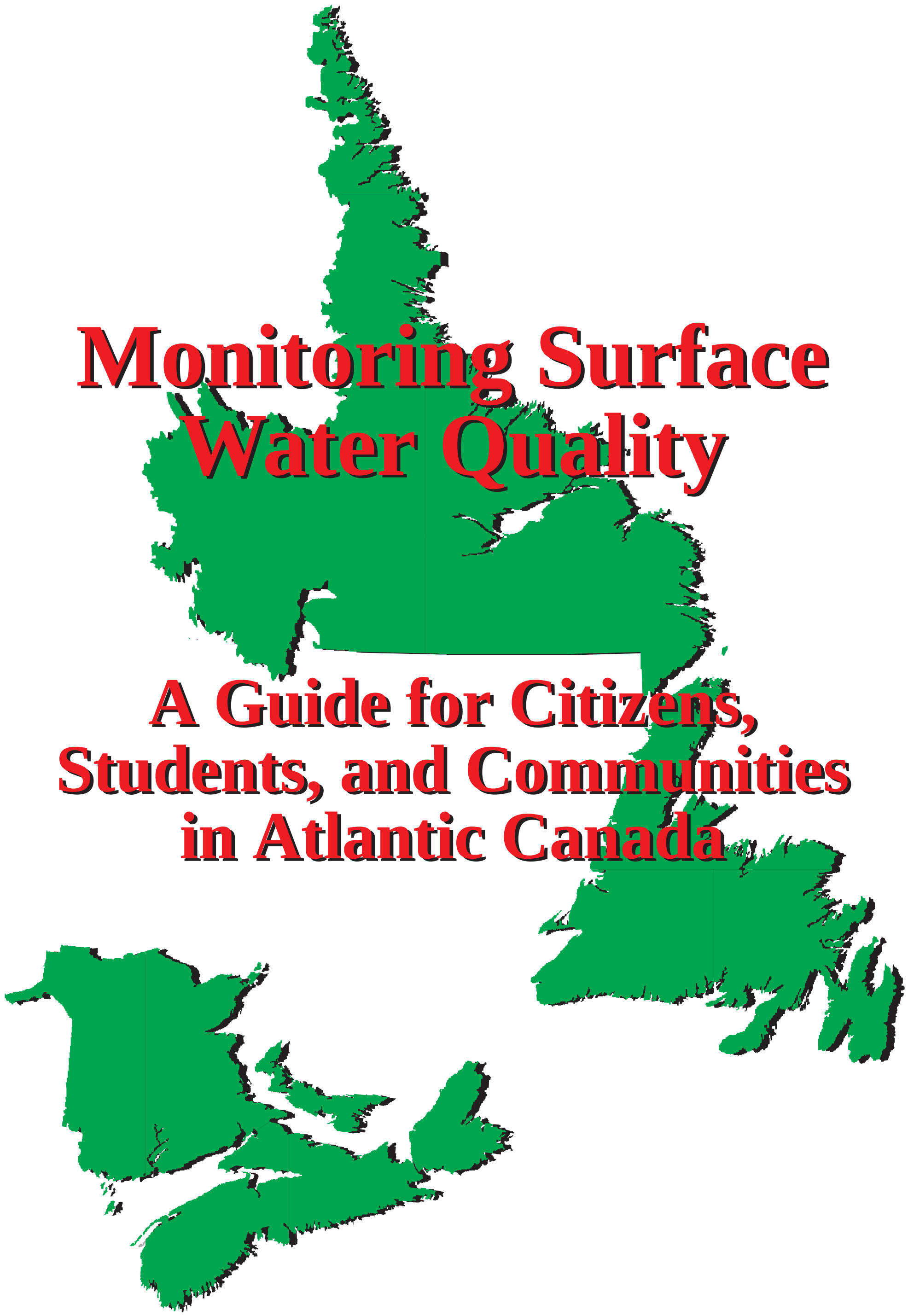
Canada - New Brunswick Water/Economy Agreement

Monitoring Surface Water Quality



A Guide for Citizens, Students, and Communities in Atlantic Canada

Environment Canada · Environnement Canada

Monitoring Surface Water Quality:

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Esperanza Stancioff's "Clean Water: A Guide to Water Quality Monitoring" is one of the more recent and comprehensive manuals for volunteer monitoring of coastal waters. Stancioff's steps for organizing a monitoring program provided an organizational framework, and were modified to reflect a Canadian approach in our section entitled "Organizing a Community Based Monitoring Program".

The freshwater biological content of this document comes from Dr. Mike Dickman's "Waterways Walkabouts". Dr. Dickman effectively illustrates how aquatic plants can be used as indicators of water quality.

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The Editors

PREFACE

The scientific study of water quality is a fairly recent phenomenon which arose from human health concerns. One of the first major works was in the 1840s where the drinking waters of large English cities were studied to try to understand the causes of the typhoid and cholera epidemics which raged periodically. This work provided the initial impetus for ensuring safer drinking waters and sewage disposal.

By the early 1910s, investigators began examining the relationships between industrial effluents and human health and fisheries resources. It wasn't until the 1950s that legislators in North America and Europe began to establish laws protecting aquatic habitats.

The history of water quality monitoring in Canada is relatively short. Apart from a small number of university and fisheries studies, health concerns were the driving force behind most water quality studies in the early to mid part of the 20th century. In the 1950s, large scale data collection began by the Federal Department of Energy, Mines and Resources, the Department of Fisheries, and their provincial counterparts. Only since the mid-1960's has full documentation of results in data banks and reports become the practice.

The work of Environment Canada and of environmental agencies in provincial governments is to provide environmental monitoring (including water quality) data amenable to scientific interpretation. Depending on the situation, the data should allow the determination of the severity of pollution problems, to assess trends in water quality in impacted areas, to provide background information on poorly studied basins, to study seasonal changes to be expected in undisturbed situations or in gathering data for areas where developments are expected to bring further changes. These data can be compared to water quality objectives, so that an estimation of overall quality can be made in relation to the various uses planned or being made of basin waters.

In recent years, interest in community-based water quality monitoring using volunteers has increased. Regional success stories on the Miramichi River (Miramichi Swim Watch) and Annapolis River (Clean Annapolis River Project) suggest great potential in community-based programs. Through the Atlantic Coastal Action Program (ACAP), multi-stakeholder groups are bringing citizens, industry and government together to work towards a shared goal, a sustainable economy within healthy local environments. ACAP groups are building a sense of community ownership in their local watersheds, rivers, estuaries and coastal areas. At almost every ACAP site there has been enthusiasm for some form of community-based environmental monitoring, in general, and water quality monitoring in particular.

Unfortunately, little information exists on community-based water quality monitoring programs in Canada. Success stories in the United States such as the Massachusetts Water Watch Partnership have provided inspiration for Canadian efforts. The United States Environmental Protection Agency as well as numerous community groups have produced documentation on community-based water quality monitoring.

This document is not an all-encompassing manual, but rather a guide and compilation of relevant Canadian and American information on community-based water quality monitoring. There can be no set prescription for a program as each community will be different with respect to land-use, stream and coastal characteristics, industry, population and issues. It is intended that sufficient information be presented so that a volunteer group can make an organized and well-prepared start on a monitoring project. To do this, appendices have been included that describe five regional case studies, a list of vendors of monitoring equipment, and a list of funding agencies. A generic glossary and list of reference material have been compiled. While the focus of this document is on water quality monitoring, the principles outlined are general enough so that groups interested in habitat inventory, wildlife monitoring, land-use inventories and other environmental monitoring projects will find sections relevant.

1.0 INTRODUCTION

Canadians generally take for granted what appears to be an almost unlimited amount of clean water. In reality, most of us live close to our southern border while most of our fresh water flows north. Atlantic Canadians are dependent upon the fresh water in our wells, rivers, and lakes. As a coastal region, we have numerous estuaries and near shore areas of importance.

Water plays an intimate role in our living environment. Water of suitable quality and quantity is essential to all life forms. It shapes and beautifies the landscape, controls our climate, determines the nature of the surrounding environment and is a vital requirement in agriculture, industry, power generation, recreation and tourism. The basic problem we face is that human's uses of water can interfere with others. While water of good quality is needed for drinking, swimming, fishing, farming, and manufacturing, water can also be used for the disposal of industrial waste, sewage, and waste heat. Its quality can deteriorate and limit its future use.

Increasing population and industrial activity have focussed public attention on water quality and the need to monitor and protect the resource. This has prompted changes in legislation to control water pollution, and environmental agencies have been created to manage the resource. Water quality monitoring has traditionally been carried out by provincial and federal government agencies, municipalities, industry, and researchers at academic institutions. In recent years, citizens and environmental interest groups have become more active in water quality monitoring. In the United States, for example, numerous volunteer groups routinely carry out water quality monitoring.

Water quality monitoring provides an avenue for meaningful participation by the public in environmental stewardship. Such approaches serve to educate individuals as to the simplicities, complexities, and costs of monitoring; provide information on environmental resources that can be of value to a large group of data users; and can influence decision making. Educational functions include removing barriers presented by scientific terminology, increasing knowledge of key environmental issues, providing experience with simple but relevant monitoring techniques, and developing an understanding of the expense and value associated with monitoring. Using this information, a monitoring group can inform the public of the environmental health of their local ecosystem, monitor changes in environmental quality due to pollution and pollution control measures, and provide information to both the regulators and the regulated. Identifying locations that most urgently require remediation, identifying the need for in-depth studies or research to fill important information gaps, and identifying the priority of contaminants and pollution sources will ensure that the data collected will influence decision making.

It is hoped that this manual will spark the participant's interest in water quality work and encourage greater community participation in watershed management and environmental stewardship.

2.0 WATER AND HOW HUMANS INTERACT WITH IT

Before discussing water quality monitoring, it is important to step back and quickly review the hydrological cycle (water cycle) and how we as humans impact upon water quality. A community-based group must consider all potential sources of contaminants within a watershed, or study area. What happens upstream in a watershed has direct influence on a study area.

The Hydrologic Cycle

The hydrologic cycle is a world-wide natural circulation system in which water evaporates from the earth's surface (from oceans, from other bodies of water and from land areas), condenses to form clouds and is returned to the earth as precipitation.

Evaporation is a continuous process, particularly from the ocean surface. A large part of the evaporated moisture condenses and is returned directly to the ocean as precipitation. A considerable portion, however, is carried over land areas by wind where it is precipitated as rain, sleet or snow. A relatively small amount may condense as dew or frost. Nearly all of this dew or frost evaporates directly or is absorbed by plants and returned to the atmosphere by transpiration.

The moisture which falls over the land as precipitation may follow any number of courses. Some re-evaporates before reaching the ground. Some is intercepted by vegetation, buildings or pavement and evaporates. That which reaches the ground infiltrates or runs off into stream channels, to be carried to the ocean. In its passage back to the ocean, some water evaporates from the surface of streams and lakes and some seeps into the ground.

Of the water which enters the ground, either by direct infiltration or through the banks or beds of streams, part is stored near the surface where it evaporates or is used by vegetation and returned to the atmosphere by transpiration. Another portion joins the ground water and may find its way to streams, appear at the surface in springs, or travel through the ground to the ocean. On the way to the ocean, there may be an interchange, in either direction, between streams and ground water.

Although the basic cycle is simple in concept--ocean to cloud, to land, to river, to ocean--it is obvious that, with the many alternative routes water may follow in every phase of the cycle, the analysis of the hydrologic cycle is an extremely complex task.

Throughout the cycle, the composition of water changes. Atmospheric water can be thought of being fairly pure under natural circumstances, but on contact with soils and bedrock, becomes a dilute solution of sodium, potassium, calcium, bicarbonate, sulphate and chloride. Moreover, a number of minor inorganic and organic compounds can also appear. Other factors influencing the composition of water, include sea-spray, and human activity.

Point and Non-Point Sources of Pollution

One of the main reasons for water quality monitoring, is to assess human influence on aquatic ecosystems. The sources of ecosystem disturbance, however, are not necessarily as simple as effluent pipes.

Human influence on water quality is often thought of in simple terms, such as discharging wastes from sewage collection systems or industrial outfalls. Without doubt, these "point sources" can have major impacts on receiving waters. Generally, related problems are correctable once the sources are identified and remedial technology is applied.

More difficult to deal with are problems emanating from diffuse, "non-point" sources. Examples of non-point sources include acid precipitation being generated often thousands of kilometres away, siltation of streams caused by logging, woods roads and agriculture, the input of nutrients from agricultural fertilization of fields, and urban runoff.

The changes in water quality which are caused by these activities are often cumulative in effect and difficult to remedy because of the widely scattered sources.

Special Characteristics of Atlantic Canada

Water quality conditions are somewhat different in Atlantic Canada than in other parts of Canada for a number of reasons. Firstly, most of the region, due to its coastal setting, receives higher rain and snowfall amounts than much of Canada. Secondly, because of past glacial activity in large portions of our region, soils and glacial tills which act as reservoirs for ground water are much thinner than in Central Canada. These two factors combine to make our lakes and rivers more hydrologically dynamic than in most parts of the country.

Coupled with the flow characteristics of our rivers, is an abundance of bogs and other wetlands which can contribute high levels of naturally produced dissolved organic carbon. In some cases, this gives the waters a brownish colour and potentially complicates the interpretation of water quality information.

Another characteristic of our region is the generally low number of highly industrialized areas. Most pollution sources in our region are relatively small-scale or diffuse compared to situations elsewhere in North America, and so often produce more subtle effects which require careful collection and analysis of data. However, in the heavily industrialized areas of Saint John, Halifax and Sydney, there are large industries whose effluent can have a significant influence on environmental quality. Little River in Saint John, N.B. for example, receives discharges from a paper plant, oil refinery, municipal sewers, as well as urban runoff. Various contaminants could be present in each effluent type but any environmental effect in the river could be difficult to attribute to a specific source.

All the above factors support the need for careful evaluation of all aspects of sample collection, analysis and interpretation regardless of where samples are collected to ensure meaningful results.

3.0 THE CHEMISTRY OF SURFACE WATERS

What do we find in our waters

Precipitation itself is not pure water. In much of Atlantic Canada, sodium chloride (salt) is an important component of precipitation due to the influence of sea-spray on local atmospheric conditions. Other ions carried by sea-spray are calcium, magnesium, potassium and sulphate. Other potential influences on precipitation chemistry are dust from soils, a phenomenon more important in western Canada, and the inputs of acid forming substances, which result in acid rain. Precipitation that reaches the earth, is subject to ion exchange reactions with soils, bedrock and lake sediments, which considerably alter its original composition. Table 1 illustrates differences in major ions between precipitation and surface waters at a site in central Nova Scotia. Some parameters increased in concentration due to geologic input and contributions from soils while others decreased due to uptake by plants and micro-organisms.

Table 1

Average ion concentrations of rain and streamwater in central Nova Scotia. Data are in mg/L. (Freedman and Clair 1987)

Constituents	Precipitation	Roger's Brook
pH	4.6	5.1
Calcium	0.09	0.93
Magnesium	0.07	0.61
Sodium	0.600	3.16
Potassium	0.04	0.27
Iron	-	0.4
Aluminum	-	0.11
Manganese	-	0.04
Ammonium	0.06	-
Sulphate	1.32	3.10
Chloride	1.05	4.8
Nitrate	0.6	0.014
Alkalinity	-	0.90
Dissolved Organic Carbon	-	7.3

- indicates not detected

Seasonal changes influence the concentration of a number of parameters in water. Snowmelt periods, for example, will increase parameters such as sulphate and nitrate which are deposited with the snow, and decrease dissolved organic carbon (DOC) which is generated by soils especially in summer. Dry summer periods will increase the importance of ground water to streams and lakes and thus ions generated there, such as calcium and magnesium, will be at higher concentrations.

Mineral ions, metals and dissolved organic matter are not the only substances found in water. Gases are also present. For example, oxygen is produced through photosynthesis by aquatic primary producers, and is also exchanged with the atmosphere. It is used in most respiration activities of aquatic biota, with the exception of anaerobic degradation in sediments and pollution situations. A major by-product of aerobic respiration is carbon dioxide (CO_2) which is then used by plants. In natural waters, respiration aside, CO_2 is usually formed by the breakdown of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$). Both oxygen and CO_2 are slightly soluble in water and can be exchanged with the atmosphere, though CO_2 solubility is much greater. The amount of each gas in water is dependent on biological activity, water temperature, and on mixing and turbulance. Dissolved oxygen concentrations at sea level in pure water has been calculated for a range of temperatures (Table 2). Deviations from these values can indicate high biological uptake if measured values are lower than those estimated in the table, or high photosynthesis activity or vigorous turbulence in the water body, should measured values be higher. Decomposition of industrial wastes that contain organic matter can consume oxygen resulting in less being available for aquatic animals.

Other substances, such as waste discharges from towns and industries, as well as pesticides from a number of sources can also be found in waters of the region.

Pesticides, for example, are used in silviculture operations, agricultural areas, and in urban areas for home and garden/turf management. Where these chemicals are found, however, depends greatly upon the chemical properties of the substance. Some may remain in the water while other contaminants absorb to sediment particles and are deposited in the bottom sediments.

Table 2

Solubility of oxygen, from a wet atmosphere at a pressure of 760 mm Hg, in mg per litre, at temperatures from 0° to 35°C.

Temp	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	14.16	14.12	14.08	14.04	14.00	13.97	13.93	13.89	13.85	13.81
1	13.77	13.74	13.70	13.66	13.63	13.59	13.55	13.51	13.48	13.44
2	13.40	13.37	13.33	13.30	13.26	13.22	13.19	13.15	13.12	13.08
3	13.05	13.01	12.94	12.94	12.91	12.87	12.84	12.81	12.77	12.74
4	12.70	12.67	12.60	12.60	12.57	12.54	12.51	12.47	12.44	12.41
5	12.37	12.34	12.28	12.28	12.25	12.22	12.18	12.15	12.12	12.09
6	12.06	12.03	12.00	11.97	11.94	11.91	11.88	11.85	11.82	11.79
7	11.76	11.73	11.70	11.67	11.64	11.61	11.58	11.55	11.52	11.50
8	11.47	11.44	11.41	11.38	11.36	11.33	11.30	11.27	11.25	11.22
9	11.19	11.16	11.14	11.11	11.08	11.06	11.03	11.00	10.98	10.95
10	10.92	10.90	10.87	10.85	10.82	10.80	10.77	10.75	10.72	10.70
11	10.67	10.65	10.62	10.60	10.57	10.55	10.53	10.50	10.48	10.45
12	10.43	10.40	10.38	10.36	10.34	10.31	10.29	10.27	10.24	10.22
13	10.20	10.17	10.15	10.13	10.11	10.09	10.06	10.04	10.02	10.00
14	9.98	9.95	9.93	9.91	9.89	9.87	9.85	9.83	9.81	9.78
15	9.76	9.74	9.72	9.70	9.68	9.66	9.64	9.62	9.60	9.58
16	9.56	9.54	9.52	9.50	9.48	9.46	9.45	9.43	9.41	9.39
17	9.37	9.35	9.33	9.31	9.30	9.28	9.26	9.24	9.22	9.20
18	9.18	9.17	9.15	9.13	9.12	9.10	9.08	9.06	9.04	9.03
19	9.01	8.99	8.98	9.96	8.94	8.93	8.91	8.89	8.88	8.86
20	8.84	8.83	8.81	8.79	8.78	8.76	8.75	8.73	8.71	8.70
21	8.68	8.67	8.65	8.64	8.62	8.61	8.59	8.58	8.56	8.55
22	8.53	8.52	8.50	8.49	8.47	8.46	8.44	8.43	8.41	8.40
23	8.38	8.37	8.36	8.34	8.33	8.32	8.30	8.29	8.27	8.26
24	8.25	8.23	8.22	8.21	8.19	8.18	8.17	8.15	8.14	8.13
25	8.11	8.10	8.09	8.07	8.06	8.05	8.04	8.02	8.01	8.00
26	7.99	7.97	7.96	7.95	7.94	7.92	7.91	7.90	7.89	7.88
27	7.86	7.85	7.84	7.83	7.82	7.81	7.79	7.78	7.77	7.76
28	7.75	7.74	7.72	7.71	7.70	7.69	7.68	7.67	7.66	7.65
29	7.64	7.62	7.61	7.60	7.59	7.58	7.57	7.56	7.55	7.54
30	7.53	7.52	7.51	7.50	7.48	7.47	7.46	7.45	7.44	7.43
31	7.42	7.41	7.40	7.39	7.38	7.37	7.36	7.35	7.34	7.33
32	7.32	7.31	7.30	7.29	7.28	7.27	7.26	7.25	7.24	7.23
33	7.22	7.21	7.20	7.20	7.19	7.18	7.17	7.16	7.15	7.14
34	7.13	7.12	7.11	7.10	7.09	7.08	7.07	7.06	7.05	7.05
35	7.04	7.03	7.02	7.01	7.00	6.99	6.98	6.97	6.96	6.95

* From Hutchinson (1957)

Water Quality Parameters

The following sections describe some of the water quality parameters that are used to gain basic insights into water quality. Some are applicable to both freshwater and estuarine waters. Much of this material has been extracted from the "Water Quality Sourcebook" (Environment Canada, 1979).

Colour

Two measures of colour are possible; *true colour* is a measure of the dissolved colouring compounds, whereas *apparent colour* is influenced by the suspended material in the sample. The colour of water is attributable to the presence of organic and inorganic materials; different materials absorb various light frequencies. Colour is measured according to the platinum-cobalt scale, which compares the colour of the water sample with that of a series of standard chemical solutions. Water with low turbidity exhibits virtually identical values for apparent and true colour. Water with a turbidity level greater than 3 Jackson Turbidity Units (JTU) usually has a yellow, red, or brown tinge.

Environmental Range

Water whose colour is less than 10 platinum-cobalt (Pt-Co) units passes unnoticed to visual inspection; water with a value of 100 resembles black tea and may be encountered in waters draining peat deposits. Water from swamps and bogs may exhibit values in the 200 to 300 Pt-Co unit range.

Sources

A water's colour may be derived from natural mineral components such as iron and manganese, and from organic sources. Common organic sources include algae, protozoa, and natural products from decaying vegetation such as humic substances, tannins, and lignins. The leaching of organic soils can also produce other less common organic acids. Since humic substances, tannins, and lignins are complex natural organic compounds that are resistant to microbial decay, they are ubiquitous in the environment and are a common source of natural water colour.

Organic and inorganic compounds from industrial or agricultural uses may add colour to a water. For example, steel works, refineries, chemical plants, pulp and paper plants, and a number of other industries may alter the colour of their discharge waters. Colouration may also result from irrigation.

Water Quality Guidelines

Colour is not normally considered a serious pollution problem, although colour may be detrimental in that it interferes with the passage of light, thereby impeding the photosynthesis of aquatic plants. Guidelines suggest that no undue increase in the colour of natural waters be allowed through waste disposal or other activities.

Domestic, industrial and recreational uses of a water may be affected by its colour. For aesthetic considerations and to prevent possible staining of clothes, food, and fixtures the acceptable limit for true colour in public drinking waters is 15 Pt-Co units. For waters used for direct recreational contact such as swimming the maximum permissible limit for colour is 100, although the objective is the same as the drinking water limit.

Effects on Use

Any perceptible colour in raw waters is objectionable from a purely aesthetic viewpoint. Although coloured water often has some absorptive and coagulative action that prevents scaling in industrial boilers, it is undesirable for many industrial processes. The production of fine papers, white textiles and pharmaceuticals, as well as steam generation, ice manufacture, beverage and photographic industries, and domestic uses may also be adversely affected by the colour of a water.

Dissolved Oxygen

Oxygen is one of the gases that is found dissolved in natural surface waters. It is slightly soluble in water. The amount of dissolved oxygen in natural water varies since it is dependent upon temperature, salinity, turbulence (mixing) of the water, and atmospheric pressure (decreasing with altitude). The concentration of dissolved oxygen is subject to diurnal and seasonal fluctuations that are due, in part, to variations in temperature, photosynthetic activity and river discharge. Respiration by organisms and re-aeration processes control dissolved oxygen concentrations. The decomposition of organic wastes by micro-organisms and oxidation of inorganic wastes may reduce dissolved oxygen to concentrations approaching zero.

Environmental Range

Typically the concentration of dissolved oxygen in natural surface water is less than 10 mg/L. The maximum solubility of atmospheric oxygen (i.e. saturation) in freshwater ranges from approximately 15 mg/L at 0°C to 8 mg/L at 25°C at sea level (see Table 2). Seawater saturation ranges from 11 mg/L at 0°C to 7 mg/L at 25°C.

Sources

The oxygen dissolved in water may be derived from either the atmosphere or from photosynthesis by aquatic plants including phytoplankton.

Water Quality Guidelines

Dissolved oxygen concentrations produce no adverse physiological effect on humans, however, adequate amounts of dissolved oxygen must be available for fish and other aquatic animals.

Many aerobic organisms cannot survive below certain levels of dissolved oxygen. The dissolved oxygen requirement is dependent on temperature and varies greatly from organism to organism, therefore, the recommendation of a single arbitrary oxygen concentration for all organisms in all types of waters is not very useful. Fluctuations in the concentration of dissolved oxygen to extremely low concentrations are particularly harmful to the organisms in an aquatic environment. Although minimum acceptable values of dissolved oxygen are not appropriate, it has been shown that concentrations of less than 4 mg/L produce detrimental effects on most aquatic organisms.

Drinking water criteria do not specify any guidelines for dissolved oxygen. However, waters saturated with dissolved oxygen are preferable for drinking as improved palatability results form dissolved oxygen's ability to precipitate substances such as iron and manganese, which produce undesirable tastes.

Effects on Use

Waters highly saturated with dissolved oxygen are acceptable for all uses except for industrial applications, since the presence of dissolved oxygen increases the corrosiveness of a water. Thus, the absence of dissolved oxygen is preferable for many industrial applications.

pH

pH indicates the balance between the acids and bases in water and is a measure of the hydrogen ion concentration in solution. pH values reflect the solvent power of water, thereby indicating its possible chemical reactions on rocks, minerals, and soils.

Environmental Range

As an index of the hydrogen ion concentration, pH is measured on a scale from 0 to 14. A value of 7 indicates a neutral condition; values less than 7 indicate acid conditions, and values greater than 7 indicate alkaline conditions in a water. Natural fresh waters range from pH 4 to 9 as controlled by the bicarbonate-carbonate system. The range of pH is broader in fresh water than in seawater; seawater ranges from 8.0 to 8.3 pH units. The theoretical pH for rain water is actually slightly acidic with a level of 5.6.

Sources

The presence of carbonates, hydroxides, and bicarbonates increases the basicity of water, while the presence of free mineral acids and carbonic acid increase its acidity. Acid mine drainage and industrial wastes that have not been neutralized may significantly lower the pH of the water.

Water Quality Guidelines

A pH range from 6.5 to 8.5 pH units is acceptable in drinking water. If the pH is outside this range, an evaluation of the cause and its effects must be ascertained. A pH greater than 8.5 interferes with the disinfection process of drinking water while a pH below 6.5 can result in premature corrosion.

The pH of the water may influence the species composition of an aquatic environment and affect the availability of nutrients and the relative toxicity of many trace elements. For the protection of the aquatic environment, the pH should be within the range of 6.5 to 9 units; also, discharges should not alter the ambient pH by more than 0.5 pH units in mixing zones. An identical range has been suggested for aesthetic and recreational uses. A pH value above 9 may lower the solubility of calcium carbonate, causing a precipitate and thus a milky appearance of the water.

Effects on Use

The pH of drinking water supplies is adjusted to control corrosion in the distribution system. Industries such as bleaching, brewing, photography, electro-plating, ore dressing, and photo-engraving are also affected by the pH of their water supplies. Thus, pH is important in determining the treatment of water supplies.

Specific Conductance

Specific conductance (conductivity) is a numerical expression of a water's ability to conduct an electrical current. It is measured in microsiemens per centimetre (µS/cm) corrected to a standard temperature, usually 25°C. The conductivity of water is dependent on the concentration of dissolved salts and temperature.

Specific conductance provides a good indication of the changes in a water's composition, especially in its mineral concentration. It is particularly sensitive to variations of dissolved solids, but provides no indication of the relative quantities of the various components. As more dissolved solids are added, the water's specific conductivity increases. An empirical relationship exists between specific conductance and total dissolved solids; specific conductance multiplied by 0.65 closely approximates total dissolved solids, although this relationship should be derived empirically for each site.

Environmental Range

Specific conductance in natural surface waters has been found to range from 50 to 150 µS/cm. Ground water and water in arid regions usually have elevated specific conductance. The conductivity of arid waters is typically 1000 µS/cm. The specific conductance of seawater is usually expressed in terms of salinity. Specific conductance in surface water is usually highest when ground water infiltration provides a significant portion of the streamflow and is lowest in spring when waters from melting snow provide dilution.

Industrial wastes can elevate the specific conductance of receiving waters to 10,000 µS/cm.

Water Quality Guidelines

No guidelines have been established to regulate specific conductance since the high values are found to correlate with total dissolved solids; which have outlined objectives.

Effects on Use

Values of high specific conductance reflect the presence of high concentrations of total dissolved solids. The effects of these are discussed in the section "Total Dissolved Solids".

Temperature

Temperature may be defined as the condition of a body which determines the transfer of heat to, or from, other bodies. Temperature is usually measured by either a thermometer or thermistor and is expressed on a relative scale such as the Celsius scale (°C). Physical, biological and chemical processes in the aquatic environment are affected by temperature. For example, increasing water temperature decreases the solubility of oxygen in water while increasing the oxygen demand of fish. Higher temperature increases the solubility of many chemical compounds.

Temperature variations are part of the natural climatic regime. Natural bodies of water may exhibit seasonal and diurnal variations, as well as vertical stratification in temperature. Aquatic organisms have both an upper and lower temperature limit for optimal growth, spawning, egg incubation and migration. These limits vary from species to species. Changes in temperature regimes may, therefore, alter the distribution and species composition of aquatic communities.

Environmental Range

The temperature of surface water is a function of latitude, elevation, season, time of day, rate of flow, depth, and other factors. Surface water varies from 0°C under ice cover to 40°C in hot springs. Ground water tends to exhibit more uniform temperatures than surface water. Seawater rarely varies by more than 25°C, either in a given location or from place to place.

Sources

The temperature of a water is primarily a reflection of the climatic regime: however, humans can modify water temperatures. Waters used for cooling in power plants transfer waste heat into receiving waters. The discharge of many industrial wastes may also elevate water temperatures above ambient levels. The release of bottom waters from impoundments (dams) in summer may introduce cooler water to rivers receiving such discharges.

Water Quality Guidelines

Temperature is a pervasive parameter, yet it is difficult to prescribe guidelines. No single temperature requirement can be applied uniformly to large areas.

Public drinking waters should be of a temperature that is refreshing to the consumer. Temperatures of 15° C have been viewed acceptable, with an objective of less than 15°C. Water temperatures may also affect the efficiency of standard water treatment processes. Low temperatures reduce biological growth in distribution lines.

Although water-related recreational activities are generally pursued during the warmer months, water temperatures may affect recreational uses of water. The degree of hazard depends on the immersion time, the metabolic rate of a swimmer, and the water temperature. Swimmers who are in contact with waters below 15°C for periods longer than one hour and who do not take special precautions risk hypothermia. The immersion of the human body in water with a temperature above 35°C for an extended time period is also hazardous. However, the temperature that individuals can withstand without decreasing or increasing their deep body (core) temperature varies considerably.

The temperature of irrigation water whether it be high or low temperature may affect plant growth either by direct contact or by altering the soil temperature. However, no specific temperature guidelines have been proposed.

Changes in the natural freezing patterns and freeze-up dates should be avoided so that wildlife is not encouraged to remain past normal migration times and then be forced to over-winter in an environmentally unsuitable region.

It is difficult to specify a temperature objective for the protection of aquatic life and still account for diurnal and seasonal fluctuations. Table 3 (Environment Canada, 1979) presents four general levels of protection. Level I dictates no change from the pristine natural state; level II permits some temperature modification but still a high level of protection for aquatic life; level III allows further modification of natural values; and level IV offers minimal protection to the aquatic environment and permits increases that may result in damage.

Table 3

Temperature Guidelines for Fish and Other Aquatic Organisms

(Environment Canada, 1979)

Level of Protection	Temperature Criteria
I	No change beyond natural minimum and maximum temperatures.
II	No change greater than 0.5 Celsius degrees beyond natural minimum and maximum temperatures.
III	No change greater than 1.0 Celsius degree beyond natural minimum and maximum temperatures.
IV	No change greater than 2.0 Celsius degrees beyond natural minimum and maximum temperatures.

Additional Requirements: The natural pattern of daily temperature fluctuation must be maintained (normally maximum temperature occurs in daytime, minimum at night).

Effects on Use

Temperature affects the palatability and desirability of water for public consumption. High water temperatures are the concern of many industries that use water for cooling or condensing purposes.

Total Dissolved Solids

Total Dissolved Solids (TDS) is an index of the amount of dissolved substances in a water. The presence of such solutes alters the physical and chemical properties of water.

The range of dissolved solids is variable (Table 4).

Table 4

Total Dissolved Solids - Salinity Relationships

(Environment Canada, 1979)

Total Dissolved Solids mg/L	**Degree of Salinity**
0 - 1,000	Fresh: non-saline
1,001 - 3,000	Slightly saline -> Brackish
3,001 - 10,000	Moderately saline-> Brackish
10,001 - 100,000	Saline
>100,001	Brine

Sources

The base flow of a waterway acquires mineral constituents in the form of dissolved salts in solution, such as sodium, chloride, magnesium, sulphate, etc. In periods of high surface runoff, overland flow contributes dissolved materials to waters. In addition, significant contributions to the TDS load are anthropogenic in the form of municipal and industrial effluents, agricultural runoff, and aerosol fallout.

Water Quality Guidelines

Basic guidelines on the concentration of TDS which have been established relate to taste and palatability rather than to detrimental health effects on human and aquatic biota. TDS concentrations of 500 mg/L or less have been designated as an objective level for drinking water providing none of the individual dissolved constituents exceed their particular guidelines. If the TDS concentration exceeds 2000 mg/L laxative effects have been observed in humans.

A similar laxative effect has been shown in livestock. For animals, concentrations less than 2500 mg/L have proven to be satisfactory in most circumstances. Industrial users of waters usually prescribe TDS concentrations to be less than 1000 mg/L, but this is quite variable among individual users and their particular requirements.

Effects on Use

High concentrations of TDS limit the suitability of a water as a drinking source. Industries are sensitive to boiler scaling or to accelerated corrosion associated with substantial amounts of TDS in water. High TDS waters may interfere with the clarity, colour, and taste of manufactured products.

Turbidity

Turbidity is a measure of the suspended particles such as silt, clay, organic matter, plankton, and microscopic organisms in water which are usually held in suspension by turbulent flow and Brownian movement. Turbidity is measured by comparing the optical interferences of suspended particles to the transmission of light in water in an instrument previously standardized with samples of standard turbidity units. Turbidity is reported in Jackson Turbidity Units (JTU) or in Nephelometric Turbidity Units (N.T.U.). Both units are equivalent.

Environmental Range

It is impractical to assign a range of values to turbidity, however, non-detectable turbidity may be approximated by pure distilled water (zero Jackson Turbidity Units (JTU)). Values exceeding 1000 JTU may be observed in wastewaters; waters with very high natural turbidity may be in the range of several hundred JTU.

Sources

The amount of solid materials in suspension in water may result from natural erosion, runoff, and algal blooms, although humans may contribute to the presence of such materials. The concentration and particle size of these suspended materials may cause significant variation of turbidity values. Turbidity is high during spring runoff.

Water Quality Guidelines

High turbidity reduces photosynthesis by submerged, rooted aquatic vegetation and algae; this reduced plant growth may in turn suppress fish growth and reproductivity. Turbidity, therefore, can affect aquatic biological communities. Water quality guidelines suggest that discharges resulting from human activity should not alter ambient turbidity levels.

Turbidity, unless attributable to asbestos-based minerals, does not affect the safety of a drinking water, but does alter its consumer acceptability. Although water with a turbidity of 5 JTU or less is acceptable for drinking, a value of less than 1 JTU is the recommended level. Turbidity also affects recreational uses of water and recommendations for water with direct recreational contact range from 5 to 50 JTU.

Effects on Use

High turbidity adversely affects domestic, industrial, and recreational uses of a water. Often some of this suspended matter has to be removed prior to industrial use, since highly turbid waters are abrasive to pumps, pipes, and turbine blades. Turbidity puts an excess load on water treatment plants by interfering with disinfection and generating extra sludge.

Water Clarity

Material that becomes mixed and suspended in water will reduce its clarity and make the water turbid. Materials contributing to this turbidity are varied. In the summer, an important constituent is plankton. These organisms grow and multiply rapidly in warm, sunlit, nutrient rich water. During periods of heavy run-off, silt-laden surface water can be observed. In shallow areas, wind-generated waves and boat wakes interact with the bottom to stir up sediments. Wind and boat generated waves breaking on shore also contribute to turbidity.

The Secchi disk provides a convenient method for measuring light penetration below the water surface. One can determine the transparency or limit of visibility of the water. The Secchi disk is a black and white disk attached in the centre to a measured and marked rope. The weighted disk is lowered slowly straight down into the water and the exact depth that the disk disappears from view is observed. This depth is averaged with the depth that the disk reappears to give what is known as the "Secchi disk transparency". The less algae and silt in the water, the deeper the Secchi disk will be visible. Alternately, shallow readings will occur in water with significant amounts of suspended algae, silt, or colour.

Salinity

Salinity is a key factor affecting the physical make-up of an estuary. It is the concentration of dissolved salts in the water, usually expressed in parts of salts per 1000 parts of water (parts per thousand, ppt). Freshwater contains few salts (drinking water usually has a salinity of less than 0.5 ppt), while seawater averages 35 ppt.

The salinity levels within an estuary vary, depending on the volume of freshwater that flows in. Salinity declines in the spring when rainfall, ground water and melting snow cause large increases in freshwater inflows. In the fall, when freshwater inflows are greatly reduced, high levels of salinity can extend further up an estuary.

Salinity levels are graduated on a horizontal plane from one end of the estuary to the other. They are also graduated vertically from top to bottom. Since the presence of salts increases density, the lighter freshwater tends to remain at the surface, while salinity increases with depth. However, the relationship between depth and salinity is not constant. Winds and tidal action can cause mixing of bottom and surface waters, particularly in shallow areas.

Perhaps the most important aspect of graduated salinity levels is their effect on the distribution and well-being of the various biological populations living in an estuary. Some species of finfish spawn in fresh water and live part of their lives at sea; others do the opposite. Bottom dwelling species (oysters) are tolerant of salinity variations but salinity will affect growth and spawning.

Other Parameters

In addition to the aforementioned water quality parameters, there are others which volunteer groups can monitor. These additional parameters will require access to specialized equipment or partnership with an agency that can perform the analyses.

Chlorophyll-a

Chlorophyll-a is a green pigment contained in algae and other organisms and is essential for photosynthesis. Its abundance is directly proportional to the amount of algae in a body of water. Algal growth increases and decreases throughout the summer months. As the amount of algae increases, water clarity decreases, and a water body can assume a greenish, brown, or red coloration depending on algae type. As algal growth increases, the corresponding increase in chlorophyll-a can be used as a measure of the amount of algae.

Faecal Coliform Bacteria

Faecal coliforms originate in the digestive tract of warm-blooded animals and are discharged to the environment with faecal wastes. Faecal coliform bacteria may indicate sewage pollution entering water bodies. Faecal coliform measurements indicate human health risks associated with drinking contaminated water, contact recreation (swimming), and from harvesting and ingesting contaminated shellfish. Another parameter indicative of faecal coliform presence is the bacteria *E. coli* which is also used as an indicator of water quality.

Analysis of both faecal coliforms and *E. coli* requires special laboratory equipment such as incubators and microscopes, and as a consequence can be beyond the capability of some volunteer groups unless specially trained and equipped.

4. ORGANIZING A COMMUNITY-BASED WATER QUALITY MONITORING PROGRAM

Material from the University of Maine Cooperative Extension (Stancioff 1992) and the United States Environmental Protection Agency (1990(a), 1990(b), 1993) formed the basis of this section. Chapter 8 of the USEPA (1993) document entitled "Guidance Specifying Management Measures for Sources of Non-Point Pollution in Coastal Waters" provides some good technical background on water quality monitoring.

Types of Monitoring

Community-based water quality monitoring programs differ depending on their purpose and funding. The objective of a program and the level of funding required to meet the objectives are closely connected. For example, if the primary purpose is public education, participants may focus on documenting pollution sources in a watershed, an activity which does not require a high level of expertise or much equipment. If another group wishes to collect scientifically defensible water quality data, however, considerable expertise in terms of equipment, training, sample analysis and quality control is needed, thus requiring greater funding.

A monitoring program may include the following activities:

- gathering **baseline data** by consistent monitoring of the same sites over time;
- conducting **investigative sampling** to locate sources of pollution by sampling impact areas;
- conducting **shoreline or watershed surveys** to document potential and actual, direct and indirect sources of pollution;
- conducting **resource inventories** to survey flora and fauna of the area as possible indicators of environmental quality;
- conducting **land use inventories** to identify types and locations of particular land-use activities which influence water quality.

The basic principles of a monitoring program include: understanding the system you want to monitor, designing the monitoring program to meet set objectives, paying attention to details early, monitoring source activities, and building in ongoing program evaluation processes (USEPA, 1993).

Getting Started

Organizing is a dynamic process for each group, and an integral part of a group's learning process. We recommend an approach where all groups who have an interest (stakeholders) are invited to participate from the onset. This approach is the backbone of the Atlantic Coastal Action Program (ACAP). The following are some tips for getting started. Though in a general sequential order, many of the activities should occur concurrently (eg. planning and budgeting).

1. **Gather the troops**

- Have an initial planning meeting with a few very interested people and define your purpose.
  - education, public awareness
  - background water quality data
  - watershed management
  - investigative monitoring
- Consider youth in your early meeting and throughout the program. High and junior high school environment clubs are often looking for student projects. Other constituencies include fishermen, recreational boaters, and anyone who spends time on the water. These stakeholders often have essential local knowledge and may be very willing to participate.

2. **Gather information**

- Other groups. What's being done elsewhere?
- Local knowledge. The local community has a valuable knowledge base that must be used.
- Consult with local, provincial and federal government agencies as to their activities in your area of interest. Consult with industries to find out what water quality monitoring they do. Invite their participation.
- Is there a university, community college, research or other academic institution in the area that might have information or have carried out research?

3. **Identify the data uses and data users**

It is an important aspect of study design to understand who currently collects and uses data in the study area. It is equally important to know who will use the data produced in a water quality monitoring project.

- Uses
  - baseline conditions
  - determine patterns, trends
  - identify emerging issues
  - monitor changes

- Users
  - public
  - local, provincial, federal government
  - environmental groups
  - industry
  - academia

4. **Structure and moderate an open public meeting**

- At or before the meeting present an agenda and follow it.
- Review basic steps and time requirements to create a monitoring group.
- Invite representatives from industry and government to attend. They are important data users (and sources of data) and can provide considerable technical knowledge.
- Ask what people want to know about the watershed.
- What areas should be studied?
- List known concerns and problems.
- Identify local people with skills to offer.
- Discuss the formation of a technical committee to provide advice on designing studies. Seek out local people with technical skills as well as representatives from major stakeholders.
- Record (minutes) that first meeting for your archives.
- Gather names, addresses, and phone numbers. This is your starting core of volunteers.

5. **Form a technical advisory committee**

A technical advisory committee (TAC) may in fact be your basic organizational or parent committee. However, it is recommended that a TAC be formed especially from the perspective of data quality and peer review.

- Should represent major stakeholders and data users
- Provides advice and technical/scientific expertise on sample collection and quality control
- Provides "peer review" of interpretation products
- Technical liaison to stakeholders
- Can provide "translation" of technical jargon
- Sounding board for study design and objectives so that project expectations can be met.

6. **Plan**

A monitoring project should have a narrowly and clearly defined objective at an appropriate level of detail. Streams, rivers, lakes, wetlands, all present different monitoring considerations. For example, upstream-downstream monitoring can work well in a river but not in all lakes. Estuaries are challenging due to tidal factors and changing salinity.

- Decide which watershed or estuary issue you want to address.
- Identify your monitoring goals.
- Identify which variables (parameters) are most appropriate to your study plan.
- Identify sample sites that are safe and easy to access.
- Decide in advance how you will handle and interpret the data that is gathered. Develop a strategy for communicating information to the public and media.
- Determine appropriate quality assurance and quality control (QA/QC) procedures to meet your objectives.
- Consult with your technical advisory committee to ensure your plan is technically sound and can be accomplished.

7. **Operate a pilot project for the first year**

Murphy's Law jokingly says that "If anything can go wrong, it will!" It is therefore prudent to start small and learn by doing through a pilot study.

- Keep the project to a manageable size
- Select a location
- If private property must be crossed, seek permission in advance
- Determine parameters, equipment needs, sampling schedules, personnel requirements
- Design a data collection form to record field observations

- Determine costs including equipment, supplies, travel (mileage), communication and coordination
- Establish quality control procedures and express them in a written document
- Evaluate materials, methods, and training
- Refine pilot project as technical, logistical and financial hurdles are encountered
- Expand program based on knowledge from pilot.
- Budget for full project

8. Budget

As mentioned previously, study objectives and costs are directly related, and must be thoroughly thought out and examined.

- Determine what equipment is needed to attain the study goals. What can be bought, donated or borrowed?
- Determine how many people will be needed to collect samples. Determine a value for donated support.
- Determine what stakeholders can contribute to the project.

- Identify means of raising money to acquire equipment or support associated costs. Appendix II lists some potential sources of funding, while Appendix III lists vendors of water quality monitoring equipment.

9. Train and Retrain the Volunteers

- Recruit volunteers for monitoring.
- Develop and conduct training sessions specific to your study needs.
- Emphasize proper sampling and handling techniques (Quality Control).
- Emphasize proper observational note taking and record keeping.
- Document your procedures in a handbook for ready access to volunteers.

10. Maintain volunteer interest

- Recognition (hats, t-shirts, group photo certificates) for efforts
- Newsletter

- Communicate results of monitoring
- Special guests
- Local media to promote group activities
- Social event around a specific monitoring activity.

11. **Compile data in a data base** (eg. dBase, Quattro Pro)

Data are of limited value if left sitting on pieces of paper in a file cabinet. By using electronic storage, a group can handle large amounts of data and use presentation software to interpret and communicate results. Some American groups have customized software programs such as Maine's VolWat and the Chesapeake Bays' CitMon.

- Graphics capability
- Location information (description and latitude/longitude from record sheet)
- In situ measurements
- "Lab" measurements
- Field observations (high flow, wind, rain, tidal stage if applicable, etc.)
- Dates
- Time of sampling

12. **Data reduction and interpretation**

In the interpretation of data, the use of graphics tools can be invaluable in reducing large amounts of data to simple graphics. Software products range from simple graphs to complex geographic informations systems. Appendix V has examples of outputs used to present water quality information.

- Graphics: bar charts, time series plots, scatter plot, maps, pie charts
- Statistical summaries: minimum, maximum, mean, median, ranges, box plots
- Comparison to standards, criteria or objectives
- Use technical advisory committee for advice during interpretation to ensure that study objectives were met. A peer review process is essential to good interpretation, building program credibility, and producing quality information.

13. **Communicate**

- ❍ Keep volunteers informed of findings
- ❍ Consult with your technical committee as to interpretation of results
- ❍ Communicate results to the stakeholders, public, government, industry, and media

14. **Continually Evaluate the Project and Modify as Needed**

- ❍ Seek input from volunteers on how to make it better
- ❍ Are the objectives being attained?
- ❍ Is the program evolving with the community?

SIX KEY ELEMENTS FOR A SUCCESSFUL AND CREDIBLE PROJECT

1. **Co-ordination**

At least one person should be recognized as having a strong coordinating role within the water quality monitoring project, to ensure that all elements of the project flow together. Depending on the size of the project, paid personnel (eg. co-ordinator, technical director) may be required. Do not necessarily expect volunteers to be able to manage a very involved project.

2. **Budget**

Developing a budget will help a group design a monitoring project that can be realistically achieved. The least expensive part of any program is collecting the sample. Costs associated with analysis, data management, and project administration can easily be overlooked, and will result in frustration, loss of motivation, and disenchantment. In the end, the ability to work within the program budget will affect the quality of the program and the information produced.

3. **Training**

Training is absolutely critical. Even the most well-explained plans and procedures will be interpreted differently by different individuals. A periodic step-by-step demonstration, with ample opportunity for questions and answers, must be built into any training program. Follow-up checks of how well volunteers are adhering to laboratory and field procedures must be conducted by qualified trainers. A handbook or field manual is an ideal quick reference for new volunteers, a reminder for the more experienced, and a useful training tool.

4. **Reporting**

Reporting is very important in a monitoring program. Data stored in a file drawer have little value, but data synthesized into a report can be used to meet the objectives of the monitoring project. Reports need not always be in written form. Consider making visual or oral presentations, or using a mixture of media like maps, tables, charts, etc. Always consider the target audience and match the presentation and language to that audience. The important thing is to convert the data into useful, understandable information.

5. **Peer Review**

As the group decides how to present their information, and before the information is released to the public, it is highly recommended that the data be reviewed by a "peer" review team such as the technical advisory committee. This review team should objectively assess and assure the quality of the conclusions drawn from the data. The makeup of the team will depend on the project's objectives, but the team members should be invited early in the project to provide oversight and guidance as the project develops. Major stakeholders and data users often have insights that can contribute significantly to a review process.

6. **Documentation**

Detailed documentation of procedures, including quality assurance, will enable others to evaluate the quality of the data. There are many books written on the subject of quality assurance, and space in this document is insufficient to cover the topic thoroughly. Quality assurance is a consideration in all aspects of a water quality monitoring project including study design, field sampling, sample analysis, field measurements, data interpretation and report writing. There are examples where volunteer groups collect data used by government agencies. Such confidence in a program can only come from early stakeholder involvement through documentation, sound quality assurance practices, and trust. Some common quality assurance practices will be discussed in the next section.

5. WATER SAMPLING

General Water Sampling Considerations

The collection of water samples may seem a relatively simple task. However, more than the simple dipping of a container into water is required to obtain representative water samples and to preserve their integrity until analysed. Representative samples can be easily obtained from well mixed rivers and lakes, but collection of a representative sample from waters with significant spatial and temporal (space and time) variations becomes more complex.

The sections on water sampling practices are not intended to be all-inclusive but rather to introduce common sampling procedures. Furthermore, instructions for operating sampling and field measurement equipment are not intended to replace those of the manufacturer but are to be considered as supplementary information. The sampling procedures described in this manual reflect those most widely used for physical, chemical and microbiological analyses by Environment Canada. Safety measures are also outlined. For more details, the reader should consult "Sampling for Water Quality" (Environment Canada, 1983).

There can be various approaches to collecting data and sampling. Some groups who must cover a wide area may wish to equip several volunteer teams with inexpensive monitoring equipment to take stream side "field measurements". On the other hand, an urban group may want to establish a central "laboratory" where samples could be delivered for measurement. Both approaches are appropriate as long as quality assurance procedures are established, documented, followed, and appropriate technical and scientific advice is sought. A Technical Advisory Committee can be especially valuable in providing expert advice on sampling protocols and quality control.

Station Location

Sampling stations (locations) and the frequency of sampling must be outlined in the project design. They are determined by the project objectives, and the spatial and temporal variability of the system. It is the responsibility of the field investigator to locate all sampling stations accurately, and to take the sample at exactly the same location each time. Only if the same location is consistently sampled can water quality changes over time be interpreted with confidence. Therefore, accurate station location descriptions including latitude and longitude must be prepared on the first visit to every sampling site. An example of a station location form is provided in Appendix IV.

Observation-Based Samples

In addition to locating sampling stations, volunteers should observe and record any unusual conditions which may indicate a need for additional water samples or notification of regulatory agencies. For example, the illustration shows old pesticide containers that were near a monitoring site. Their presence was documented on field sheets and photographed.

Upon observing an unusual condition, such as an unusual colour or odour of the water, excessive algal growth, indications that foreign substances have entered the system (oil slicks, surface films, etc.) or fish kills, the field investigator should take samples in addition to those required by the project design. If additional samples are collected but not exactly at an established station, a new station location description should be accurately recorded. If a fishkill is observed, provincial and federal authorities should be informed immediately. Examples of field observation sheets from various community groups are also provided in Appendix IV.

Preparation for Field Trips

Prior to going out to conduct water sampling, the volunteer should go through a checklist to make sure that everything is in order.

General Preparation

(a) Obtain specific instructions on sampling procedures.
(b) Prepare an itinerary according to the sampling schedule.
(c) Prepare list of required equipment and materials.
(d) Ensure that all sample bottles have been cleaned in accordance with established procedures.
(e) Ensure that the laboratory has prepared the chemical reagents and standards needed for the trip.
(f) Ensure permission has been granted where crossing private property is required.

Checklist Prior to Field Trip

(a) Check and calibrate field meters, if used (pH, specific conductance, dissolved oxygen, turbidity) and thermometers.

(b) Replenish supplies of reagents for dissolved oxygen determinations as well as reagents for chemical preservation.

(c) Obtain fresh buffer solutions; pH values for the buffers should be close to the values expected in the field.

(d) Obtain KCl solution for pH probes if required in field.

(e) Obtain road maps, station location descriptions, field sampling sheets, sampling bottles, labels, samplers, preservation reagents, pipettes, equipment manuals, etc.

(f) Obtain writing materials and extra rope.

(g) Obtain charging cords if the equipment has in-field charging capabilities.

(h) Obtain distilled water for pH, blanks and buffer measurements.

(i) If field filtering is required, obtain filtering apparatus.

(j) If microbiological sampling is to be done, obtain sterile bottles and ice chests. All samples should be stored on ice.

Collecting Surface Water Samples

It is recommended that the design of the field sampling program be tested and assessed by a pilot project or in the initial rounds of sampling to ensure both its efficiency and effectiveness with respect to the objectives of the study. For example, assumptions about mixing of a river or lake can be tested by cross-sectional and vertical sampling. Other elements of the sampling program, such as ensuring that an adequate volume of water is collected or that the handling of samples is adequate, can also be checked during the pilot project.

For water quality sampling sites located on a homogeneous (well mixed) reach of a river or stream, the collection of depth-integrated samples in a single vertical may be adequate. For small streams a grab sample taken at a point where the water is well mixed and flowing at an average rate is usually adequate.

For each sampling site located on a non-homogeneous reach of a river or stream, it is necessary to sample the channel cross-section at a specified number of points and depths. Generally, the more points that are sampled along the cross-section, the more representative the results will be. Three to five sites along the cross-section are usually sufficient, and fewer are necessary for narrow and shallow streams.

The following general guidelines apply to the collection of a water sample:

(a) Do not include large particles, such as leaves and detritus, in the sample, and avoid disturbing sediments as much as possible during wading.

(b) All sample bottles and caps should be triple-rinsed at the sampling site before filling with the sample.

(c) Face the sampling apparatus or bottle upstream to avoid contamination. Sampling from the upstream side of a bridge enables the collector to see whether any floating material is coming downstream and aids in the prevention of contamination of the sample from paint chips or dirt from the road.

(d) Collect a sufficient volume to permit analysis of all the parameters of interest by the laboratory.

(e) An integrated sample can only be collected using specialized equipment and methods, while a specialized sampler must also be used for collecting water from pre-determined depths in a lake or river.

Field Quality Assurance

The Field Quality Assurance program is a systematic process which, together with the laboratory and data storage quality assurance programs, ensures a specified degree of confidence in the data collected. The Field Quality Assurance program involves a series of steps, procedures and practices as described in the following sections:

General Measures

(a) All equipment, apparatus and instruments should be kept clean and in good working condition in accordance with manufacturers' instructions.

(b) Records should be kept of all repairs to the instruments and apparatus, and of any irregular incidents or experiences which may affect the accuracy of results.

(c) Conditions in the working area should be such that they encourage and maintain a completely safe environment.

(d) It is essential that consistent methodologies be used by volunteers, and that the methodologies have been reviewed by a Technical Advisory Committee.

Prevention of Sample Contamination

The quality of data generated in a laboratory depends primarily on the integrity of the samples that arrive at the laboratory. Consequently, the field investigator must take the necessary precautions to protect samples from contamination and deterioration.

There are many sources of contamination; the following are some basic precautions:

(a) Field measurements should always be made in-situ or on a separate sub-sample, which is then discarded. They should never be done on the water sample which is being submitted to the analytical laboratory.

(b) Sample bottles, new or used, must be cleaned according to the recommended methods.

(c) Only the recommended type of sample bottle for each parameter should be used.

(d) Water sample bottles should be employed for water samples only. Bottles that have been used in the laboratory to store concentrated reagents should never be used as sample containers.

(e) Before being used in the field, any preservatives should be freshly prepared and dispensed with clean glassware.

(f) Recommended preservation methods must be followed.

(g) When preserving samples, the possibility of adding the wrong preservative to a sample or cross-contaminating the preservative stocks should be minimized by preserving, in one operation, all the samples for a particular parameter.

(h) The inside portion of sample bottles and caps should not be touched with bare hands, gloves, mitts, etc. Do not put anything in the sample bottle except the water sample.

(i) Sample bottles must be kept in a clean location, away from dust, dirt, fumes and grime. Vehicle cleanliness is an important factor in eliminating contamination problems.

(j) Petroleum products (gasoline, oil, exhaust fumes) are prime sources of contamination. As such, spills or drippings (which are apt to occur in boats), exhaust fumes, cigarette smoke, and over-board spillage must be avoided.

(k) Bottles which have been sterilized for microbiological sampling must remain sterile until the sample is collected. If the sterile heavy-duty paper or aluminum foil has been lost or if the top seal has been broken, don't use the bottle.

(l) All foreign, and especially metal, objects must be kept out of contact with preservatives and water samples.

(m) Specific conductance should never be measured in sample water that was first used for pH measurements. Potassium chloride diffusing from the pH probe alters the conductivity of the sample.

(n) Samples must never be permitted to stand in the sun; they should be stored in a cool, dark place; ice chests are recommended. Keep the empty bottles in the coolers for additional cleanliness.

(o) Samples must be submitted to the laboratory promptly.

(p) Persons must refrain from smoking while collecting samples.

Field Quality Control

Quality control is an essential element of a field quality assurance program. In addition to standardized field procedures, field quality control requires the submission of blank and duplicate samples to test the purity of chemical preservatives; to check for contamination of sample containers, filter papers, filtering equipment or any other equipment that is used in sample collection or handling; and to detect other systematic and random errors occurring from the time of the sampling to the time of analysis. Replicate samples must also be collected to check the reproducibility of the sampling. The timing and the frequency of blank, duplicate and replicate samples are established in the project design.

Bottle Blanks

Prior to a field sampling trip, one sample bottle for every ten of each type being used during the sampling trip should be selected at random, filled with distilled water, preserved in the same manner as field samples, and set aside for submission with the field samples for chemical analysis for the parameters of interest as "bottle blanks". This should detect any widespread contamination caused by the bottle washing process. A similar process can be carried out in the field to account for field contamination.

Filter Blanks

Field filtering of samples is a complicated procedure that depends upon the analyses being conducted (eg. dissolved metals, dissolved phosphorus, chlorophyll-a). In these cases, professional advice should be sought.

Spiked Samples

A spiked sample is one where a known amount of a substance has been added to a water sample to ensure that there are no systematic errors or bias in the analytical methodology. It also verifies the field handling and transport of the sample. Spiking is very much parameter specific and cannot be applied to each and every parameter.

Field Measured Parameters

A number of parameters including pH, conductivity, dissolved oxygen, temperature and turbidity, can be measured at the sampling site. Where possible, these measurements are taken *in situ*. In all other cases, their values should be determined as soon as possible after sample collection. When using equipment, either in the field or in the laboratory, it is always best to follow the manufacturer's directions for operation, calibration, and maintenance. Any modification should be documented by the volunteer group.

Dissolved Oxygen Measurement

Dissolved oxygen (DO) concentrations may be determined directly with a DO meter or by a chemical method such as Winkler analysis. The method chosen will depend on a number of factors including the accuracy and precision required, convenience, equipment and personnel available and expected interferences. Dissolved oxygen (DO) should be measured *in situ*, as concentrations may show a large change in a short time if the sample is not adequately preserved. Even when the sample is preserved, as in a Winkler analysis (a chemical titration method of determining DO), it is advisable to run the titrations within 3 to 6 hrs from the time the sample was taken. Numerous DO meters are manufactured and in all cases, the manufacturers' instructions must be followed to ensure proper calibration and sample measurements.

Reagents in the Hach and LaMotte test kits are contained in individual premeasured "powder pillows". These kits are less costly than DO meters, but are generally not as accurate. The manufacturer's directions must be closely followed.

Temperature Measurement

Temperature measurements may be taken with alcohol-toluene, or electronic thermometers. Some meters, such as those used to measure dissolved oxygen and specific conductance, have temperature measuring capabilities. Temperature values at specified depths can be measured *in situ* if adequate cables and probes are available. Otherwise, temperatures must be measured immediately in the field after the water sample has been taken from the required location and depth.

In-field Procedure

If a thermometer is used:

(a) Rinse the thermometer by pouring a portion of the water sample over it.

(b) Immerse the thermometer in the sample for approximately 3-5 min. or until the reading stabilizes. Do not place the thermometer in any of the sample bottles being submitted to the laboratory.

(c) Record the value to the nearest 0.5 in degrees Celsius on the field sheet.

Conductivity Measurement

In situ measurements for conductivity are preferable; if this is not possible, a sample is collected and measurement should be made as soon as possible, since the conductivity of a water sample may change with time. Conductivity is temperature dependent. If the conductivity measurement is not automatically temperature corrected, then the temperature at the time of measurement should also be recorded.

There are various conductivity meters available which may also have temperature and salinity determining capabilities. Since probes vary and cable lengths are optional, the group must select the equipment to meet the requirements of the sampling program and as always follow the manufacturer's specifications.

pH Measurement

pH is a measure of the acidity or basicity of a solution. Neutral solutions have a pH of 7; acid solutions, a pH of less than 7; and alkaline solutions, a pH greater than 7. Optimally, pH is determined *in situ*, but if this cannot be done it can be determined by taking a water sample and measuring the pH as soon as possible.

There are many portable pH meters on the market today; the group should select the one that best suits project needs. Digital meters are preferable, since analog meters are sometimes difficult to read while taking *in situ* measurements.

Turbidity Measurement

Turbidity is measured by instrumental methods and is a measure of the suspended sediment such as clay, silt, organic matter, plankton and microscopic organisms in a water sample as indicated by optical interference. Whenever possible, turbidity should be measured in the field. Otherwise, the turbidity is measured at the laboratory. The field measurement is preferable, since some of the particulate matter will settle or adhere to the container wall during transportation. Furthermore, changes in the pH of the sample may cause the precipitation of carbonates and humic acids, affecting the turbidity of the sample. When the analysis cannot be done immediately, the sample should be stored in the dark and analyzed within 24 hr.

Secchi Depth: Water Clarity Measurement

The Secchi disk is a 20 centimetre (8 inch) diameter disk, with black and white quadrants. A line measured and marked in decimeters (10 cm) and metres is attached to the center. The limit of visibility is the deepest point at which you can still see the Secchi disk.

Take the reading without sunglasses and with the sun to your back. (If in a boat, move well forward, clear of the stern propellers and take reading on shaded side.) Lower the disk into the water until the disk barely disappears from sight. Note the depth reading, in meters, based on the length of suspension line that is submerged. Slowly raise the disk and record the depth at which it reappears (barely perceptible).

Average the two depth readings obtained above. The average of the two readings is considered to be the limit of visibility, or index of transparency.

Salinity Measurement

Salinity can be determined by measuring the specific gravity of a sample using a hydrometer, correcting the reading for temperature, and converting the specific gravity to salinity at 15°C. This is done by using a table of corresponding densities and salinities (Ellett 1991). A hand-held salinity refractometer may also be used. Alternatively, some digital conductivity meters have the capability of determining salinity and conductivity with automatic temperature correction. As with other parameters, the selection and use of a particular apparatus will be determined by the study design and to a certain extent budgets. Manufacturer's directions should be followed regardless of method used.

Recording of Field Data

The sampling location, sampling date, time, parameter measured and value must be recorded. The interpretataion of water quality data cannot be accomplished without all supporting information.

Station Location Description

The importance of an accurate written description of each station location and the conditions under which the samples are collected cannot be overemphasized. In fact, interpretation of water quality data may be limited by the accuracy of such descriptions. It is therefore recommended that a consistent format be used (examples may be found in Appendix IV).

An accurate description of the sampling location includes distances to specific reference points. It is important that these reference points be long-standing and clearly identified. For example, "5 m NW of the willow sapling" is a poor location designation for a long-term sampling program. An example of a better description would be "upstream of a south culvert where Little River passes under Champlain Drive, City of Saint John, and reaching out 2 m on the left hand side looking upstream".

The latitude and longitude values should be obtained from 1:50,000 topographical maps. If necessary and if available, navigational charts can be used to provide more accurate latitude and longitude values than the topographical maps.

The format for a good description should include:

Station Description **-** Enter descriptions of the water body above and below the sampling station, describe the banks on either side of the water body, and the bed material, if known. Description of the water body should include any irregularities in morphology affecting flow or water quality. These irregularities may include a bend in a river, widening or narrowing of the channel, presence of an island, rapids or falls, or the entry of a tributary near the sampling station. Description of the banks should mention slope, bank material and extent of vegetation. Bed or sediment material may be described as rocky, muddy, sandy, vegetation-covered, etc. Station location descriptions should mention seasonal changes that may interfere with year-round sampling.

Observations **-** Enter any additional information about conditions, either natural or anthropogenic, which may have a bearing on water quality. It is very important that events such as rainfall, cloud cover, stage of tide, wind direction, flow, etc. be recorded in the field. Observations of weather, dead fish, algal growth, slicks on the water surface and other phenomena may make a significant difference in explaining anomalies in data. Do not hesitate to record all observations, no matter how trivial they may initially seem.

Detailed Sketch of Station Location **-** Sketch the location of the sampling station (including distances expressed in suitable units) with respect to local landmarks and permanent reference points. Some groups photograph sample locations during different seasons to document location, changes, or unusual events.

Map **-** Include a map which locates the sampling station on a larger scale with respect to roads, highways and towns. The combination of the map and the sketch of the station location should provide complete location information. A volunteer travelling to the site for the first time will therefore have enough information to locate the sampling station confidently and accurately.

Field Sheets

The recording of observations, field measurements, sampling date, time and location on the field sheets must be standard practice. All field measurements and records must be completed before leaving a station. A standard field sheet should be designed to ensure that there is consistency in reading observations. Examples are illustrated in Appendix IV.

Sampling for Microbiological Analysis

All water samples submitted for microbiological analysis must be collected as aseptically as possible in order to accurately reflect microbiological conditions.

Sample Containers **-** Microbiological samples were traditionally collected in sterile 200-mL or 500-mL wide-mouthed glass or non-toxic plastic bottles with cork or screw caps. More recently, however, sterile "whirlpack" bags (disposable) have been used as they are safer, can be closed with the aid of sampling tongs, and they provide for less risk of sample contamination.

General Sampling Procedure

(a) Remove as one unit, the protective paper and stopper of the sample bottle.

(b) Do not rinse the sterile bottle.

(c) If the sample is to be collected in a hand-held fashion, hold the sample bottle near the base and plunge the bottle neck downward below the water surface 25-40 cm. Tilt bottle so that the neck points slightly upward and during filling push bottle horizontally forward in a direction away from the hand to avoid contamination. If a current is present, direct the mouth of the bottle against the current.

(d) If a bacteria sampling apparatus is used, fit the bottle into the spring clamp with the bottle mouth downward. The mechanism is designed so that the bottle is then rotated to the upright position under the water surface by the mechanical sampler.

(e) Remove bottle and decant sufficient water to leave a space of 3-4 cm between stopper and water line.

(f) Replace cap or stopper and paper covering, fasten cover and label bottle (if not pre-labelled) with a waterproof marking pencil.

(g) Place bottle in an ice chest.

(h) Record the time of sampling and depth of sample, water temperature and ambient temperature on the field sampling sheet. Description of the location can be obtained from the station location description sheet.

(i) Water samples should be collected in duplicate and submitted to the laboratory promptly. If immediate processing is impossible, samples should be stored in the dark in melting ice. Storage under these conditions minimizes multiplication and die-off problems up to 30 hr after collection. Samples should never be frozen.

Field Safety

Samples are collected during a wide range of weather extremes. Knowledge of the hazards that may be encountered and the means by which they can be minimized is a necessary consideration in any field project. Volunteers must ensure that they are adequately equipped before they embark on a sampling trip. As a precautionary measure, first aid kits are recommended. The collection of surface water samples may involve collection from bridges, or docks, or from shoreline. The ability to swim is essential. It is highly recommended that in community-based volunteer program, **sampling be carried out in teams of two or more** for additional safety. Some field safety procedures are given in the following sections.

Traffic may present serious problems when working from bridges. Bridges with sidewalks for pedestrian traffic provide a margin of safety. The volunteer must take special care when sampling from bridges over navigable water, as boat operators and water skiers may not be able to see apparatus suspension lines. Samples should be taken in the absence of water traffic, or special precautions such as the attachment of flags, etc. should be taken to make suspension line visible. Power lines strung close to bridges are also dangerous and should be avoided. A hazard warning should also be noted on the site location form.

Wading is one of the easiest methods to collect samples from many streams, but it may also be extremely dangerous. Wading permits the investigator to examine stream flow and decide where to sample. Rubber boots or even chest-high waders are standard equipment. A wading rod or similar probing instrument is often useful to estimate the current and to locate holes and unsafe footing. If the wader has any uncertainty about his ability to wade a stream, he or she should be attached by a rope to a rigid mooring and must wear an approved flotation device. An extra change of clothing is always advisable, and essential during the colder months. In volunteer programs, it is advisable to use shoreline sampling as much as possible. Even then, one must be conscious of footing and obstacles.

Winter Sampling

Winter sampling requires suitable clothing to maintain a comfortable working temperature and to prevent frostbite. A warm hat, woolen undergarments, extra socks, mitts, proper footwear, and in some cases glasses to prevent snow blindness, should be taken. The volunteer should also check the wind chill factor because reports of temperature alone may be deceiving. In volunteer programs, sampling through the ice should be avoided for obvious safety reasons.

Boat Safety

Though shoreline sampling is preferred, it may be necessary in some projects to use watercraft to collect samples. If so, all appropriate watercraft safety precautions and regulations must be followed.

Safety Precautions when Handling Chemicals

Corrosive compounds, including acids and bases are sometimes used for the preservation of water samples for special analysis. The best safety precaution is to preserve samples in the laboratory whenever possible to avoid possible spills in the field. Care must be exercised to avoid inhalation of vapours, powders and or direct contact with skin, eyes and clothing. Chemicals should never be pipetted orally. Spills should be cleaned up immediately by dilution with large quantities of water, neutralization or mopping up of the chemical followed by disposal of the contaminated material.

Skin which has been in contact with acids or bases should be washed immediately with plenty of water. After the skin has been washed, the contaminated area may be swabbed with a neutralizing solution. This procedure should be followed by a second washing with soap.

If any chemicals enter the eyes, they should be rinsed *immediately with plenty of water*. Rinse the outside of the eyes as well. It may be necessary to hold the eyelids open during the wash procedure. Continue rinsing for several minutes. After first aid, all eye injuries must be treated professionally. A squeeze bottle of distilled water should be included with the field sampling equipment.

Routine care should be taken to prevent bottle and other glassware breakage during sampling; for example, freezing, overtightening of tops, rough handling of pipettes, and improper packaging and storage of glass sampling bottles if called for may result in breakage during transport.

6. BIOLOGICAL MONITORING

Methods for monitoring chemical and physical properties of streams have been well recognized and implemented in numerous community-based monitoring programs. As expertise is gained, there is a natural progression to examine impacts upon biota and to use biota as indicators of water quality (Ely, 1991).

Dickman (1992) provided an example of how aquatic plants can be used by volunteer groups to monitor freshwater quality in the Great Lakes area of Ontario. His approach was used identify the location of inputs of toxic substances to the aquatic ecosystem. The following has been extracted from his publication "Waterways Walkabout". This approach was developed for southwestern Ontario, and would have to be modified to be applicable to Atlantic Canada. Nevertheless it is worthy of discussion. As with all monitoring activities, a training component is essential.

Freshwater Stream Surveys

Aquatic plants can easily be used as monitors to indicate the health of our waterways, and it is not necessary to be an aquatic plant specialist to do so. Simple ways and means to recognize the impact of pollutants on aquatic plants.

A Waterways Walkabout is an effective method to recognize, identify and document sources of water pollution. The method consists of noting changes in the dominant aquatic plants growing along streams or lakes. Water pollution problems are identified by observing aquatic vegetation and recording any changes. Volunteers should emerge with a healthy appreciation of the value of natural aquatic vegetation to indicate water pollution problems.

Large macrophytes (aquatic plants) are easily recognized as there are usually less than 20 common species at most sites, and their absence is easily detected. Most are rooted and therefore reflect soil, sediment and water quality conditions. Once the ecological principles determining river vegetation are understood, indices for assessing the controlling factors can be devised. Many of these indices are presented in standard textbooks of limnology.

Each aquatic plant species has a particular range of tolerance and therefore, in each habitat, there will be a range in which each particular plant type can grow well, a peripheral range in which it will grow less well (i.e. a range in which it occurs less frequently), and there will also be conditions which it cannot tolerate and, therefore, areas from which it is excluded.

Aquatic plants provide the informed observer with a great deal of information about the water quality conditions to which plants have been exposed. Where natural organic-rich substrates abound in unshaded reaches of the water, aquatic plants can be used to indicate some rather basic biological information about the amount and severity of pollution. The observation of these aquatic plants is especially important where the pollution source or sources continuously discharge into the waterway.

If, for example, a toxic discharge occurs only once a month during the summer, the aquatic plants living there will be affected by it and therefore, the plants can be said to represent a kind of continuous water quality monitoring system. *Before a walkabout, basic knowledge of aquatic plant life and how various types of plants are affected by toxic discharges will have to be obtained*. The method of recognizing sources of water pollution presented, relies on a simple classification system of four basic plant types, as follows:

Plant Types

Each of the **five** basic plant types you will be looking for on a walkabout have been assigned a key or code, as follows:

1. (T) Tall stemmed emergents (plants taller than 1 m), e.g. cattails

2. (S) Short stemmed emergents (shorter than 1 m), e.g. sedges, arrowheads, grasses, etc.

3. (F) Floating leaved aquatics (e.g. water lilies)

4. (U) Submersed aquatics or taxa (found underwater), e.g. water milfoil).

5. (FP) Floating plants (e.g. Duckweeds - rare except in stagnant ponds)

It is extremely important to be able to recognize these five plant types as they form 5 strata or levels from the floating leaf and floating plant level to the tall stemmed emergent level. By observing changes in the distribution of these strata of aquatic plants, one should be able to locate toxic discharge points (i.e. point sources). For example, along a gradient of increasing toxicity, there will be a decrease in stratal and species diversity. This means that as one moves toward increasingly unfavorable conditions (i.e. increasing toxicity), there will be a reduction in stratal types. This simply means that fewer and fewer different species of aquatic plant life will be found living together in a biotic community as their environment becomes polluted.

In an unpolluted aquatic environment, some examples of the five strata or plant types will often be found living together. But in general, as one draws closer and closer to a toxic discharge point, this natural stratal diversity will be reduced to only one or two pollution tolerant plant types. Sometimes no aquatic plants are found near a discharge sources. One possibility is that at least at one point in time, over the last few months, what is known as a "shock-load" occurred. This means that at some point in time, a toxic discharge occurred which exceeded the tolerance limits of the aquatic plants that were growing there. Such infrequent discharges are referred to as "shock-loads". Toxic "shock-loads" can eliminate one or even all of the aquatic plant species near the pollution discharge point (pipe, ditch, etc.).

To classify the impact of a toxic input point source zones or zonation is used to describe the present aquatic plant life.

Zonation Patterns - Major Zones:

There are four major zones in an aquatic plant zonation pattern:

Zone 1 **Impact Zone/Dead Zone:**

As one draws closer and closer to a toxic discharge, it becomes increasingly apparent that the less pollution tolerant species are being replaced by more tolerant forms until, if the toxin is powerful enough, even the most tolerant species cannot survive and all that is left is a Dead Zone or Impact Zone, where no plants are found. Before concluding that you have found evidence of a toxic discharge source, read the comments on the *Cautionary Comments about Applying Zonation Patterns* which are provided on the following page.

Zone 2 **Primary Recovery Zone:**

This zone is dominated by the most pollution tolerant plants. Typically, the tall stemmed emergents such as bulrushes, cane grass (*Phragmites*) and cattails (*Typha)* dominate this zone. These tall stemmed emergents are able to live on the shorelines or stream banks. The water which they receive via their extensive subterranean root and rhizome system has passed through the soil and sediment where much of the initial toxic load is filtered out.

Zone 3 **Secondary Recovery Zone:**

This zone is characterized by the presence of short stemmed emergents, such as sedges, arrowheads and grasses. These plants frequently form a fringe in front of the tall stemmed emergents. The short stemmed emergents and the floating leaved aquatics (water lilies (*Nuphar*) and pond weeds (*Potamogeton*), etc.), unlike the tall stemmed emergents, have the majority of their stems' surface exposed directly to the toxins in the water column.

Zone 4 **Tertiary Recovery Zone:**

This zone is characterized by the presence of submersed aquatics such as water milfoil (*Myriophyllum*). These plants are completely immersed in the water and probably for this reason they are the most sensitive to any toxins present in the water. Thus, when these submersed aquatics are abundant in the water, the level of toxic substances in the water can be assumed to be below the plants threshold.

Cautionary Comments about Applying Zonation Patterns

The survival of plants and other organisms in a river or stream is affected by many factors. The type of bottom, strength of current, extent of spring flooding, amount of overhanging vegetation, and other factors are all important. Thus, conditions for growth of aquatic plants change from place to place along most waterways. Many streams have places with little or no vegetation, even when there is no human interference. A bare spot may be a clue to the presence of a toxic effluent, but other supporting information will have to be obtained. As many factors as possible must be considered before reaching a conclusion about the impact of a point source. Occasionally, the volume of discharge from a pipe is so great that the natural substrate (sediments) are washed away, making it impossible for plants to get a footing. You can differentiate between the two because a rocky substrate will always be found in the second case.

Eutrophication

Nutrient-rich effluents entering a stream or lake can cause either algal blooms or the excessive growth of higher aquatic plants (aquatic weeds). These aquatic weeds can clog waterways and cause severe night time oxygen depletion and, ultimately, anoxia (i.e. deficiency of oxygen in the tissues), which limits the natural distribution and movements of fish and invertebrates.

The luxurious, excessive growth of the higher aquatic plants in a stream or other waterway is called eutrophication. Typically, eutrophic conditions result in a reduction of species richness and species diversity and an increase in aquatic plant density, height, biomass and productivity. For this reason, whenever higher aquatic plants grow excessively, to the detriment of other species of both plant and other forms of aquatic life, a pollution source of nutrient-rich effluents should be suspected.

Data Sheets and Data Entries

Collecting data properly will help summarize findings for a report to describe the waterway's condition. This will be needed even if there are no pollution problems found, since this is useful information for future reference to determine any changes in the waterway. The relevant data, to be observed and recorded, include the various plant types, sources of discharge, diameter and type of pipe (or ditch) from which the discharge is emitted, type of discharge, and so on. Data must be recorded on a data sheet.

The minimum items to include on a data sheet are:

- Name of participants
- Waterway being surveyed and segment
- Date
- Time
- Site discharge points or non-point sources
    - outfall material
    - pipe diameter
    - discharge flow
    - type of discharge
    - stream conditions

    - damage indicators (smell, surface coating, aquatic plants, colour, solids, algal growth)
    - source of discharge
    - stream blockages (erosion, log jam, storm sewer, dumping, construction)

As with all programs, accurate recording of field observations is extremely important.

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9.0 GENERAL GLOSSARY OF COMMONLY USED ENVIRONMENTAL TERMS

Accuracy	Refers to the agreement between the measured value and the accepted or "true" value. It is expressed as the difference between these two values.
Acid mine drainage	Low pH drainage water from certain mines. The low pH is usually caused by the oxidation of sulphides to sulphuric acid. Mine drainage can also contain high concentrations of metal ions.
Acute toxicity	Mortality that is produced in a short period of time-exposure, usually 24 to 96 hours.
Aerobic	That which is dependent upon oxygen, or in the presence of oxygen.
Algae	Simple one-celled or many-celled organisms, usually free-flowing, capable of carrying on photosynthesis in aquatic ecosystems.
Algal blooms	Excessive growths of algae that form unsightly scums and layers of turbid water, impairing the water for recreation, domestic, aesthetic, and aquatic life uses.
Aliquot	A representative sample of a larger quantity.
Ambient temperature	The temperature of the surrounding medium, such as ambient, air, which comes into contact with the apparatus.
Anerobic	That which is not dependent upon oxygen, or in the absence of oxygen.
Anthropogenic	Human based or human sourced.
Anoxia	The failure of oxygen to gain access to or be utilized by the body tissues of an organism. Absence of oxygen. (*anoxic* adj.)
Aseptic sampling	Maintaining the sterile nature of sampling equipment and apparatus so as to avoid microbiological contamination.
Assimilative capacity	The ability to transform and/or incorporate substances (e.g. nutrients) into an ecosystem, without undue impairment to the functioning ecosystem.
Baseline information	Data generated by consistent monitoring of the same sample sites over time.
Bed material	The sediment mixture of which the bed of a water body is composed.
Benthic	Of or living on or in the bottom material of a water body.
Bioaccumulation	Uptake and retention of environmental substances by an organism from both its environment (i.e. directly from the water) and its food.
Bioconcentration	The ability of an organism to accumulate substances within its body to concentrations greater than in its surrounding environment or food.
Biodegradability	The characteristic of a substance that can be broken down by microorganisms.
Biodegradation	The process of destruction or mineralization of either natural or synthetic materials by the microorganisms in soils, waters or wastewater treatment systems.
Biomagnification	The increasing concentration of a substance up the food chain.
Biota	All the plants and animals occurring within a certain area.
Blank	A sample of distilled water.
Bottom sediment	Those sediments which make up the bed of a body of running or still water.
Carcinogen	Cancer-causing chemicals or substances.
Centroid of flow	Midpoint of a channel of uniform flow.
Chlorophyll-a	The photosynthetic green pigment present in most plants or algae.
Chronic toxicity	Toxicity marked by a long duration, that produces an adverse effect on organisms. The end result of chronic toxicity can be death although the usual effects are sublethal (e.g. inhibits reproduction or growth). These effects are reflected in the productivity and population structure of the community of organisms that are affected.
Composite sample	A sample obtained by mixing several discrete samples, or representative portions thereof, into one bottle.
Concentration	Amount of a substance in a mixture. Typically, expressed as parts per million (ppm), parts per billion (ppb).
Contaminant	A substance foreign to a natural system or present at unnatural concentrations in air, water, soil or food.
Contamination	The introduction of a foreign substance to air, water, soil or food.
Conventional pollutants	A term which includes nutrients, substances which decompose using oxygen in the process, material which produce an oily sludge deposit, and bacteria. Conventional pollutants include phosphorus, nitrogen, chemical oxygen demand, biochemical oxygen demand, oil and grease, volatile solids, total and faecal coliform bacteria, and chlorides.
Cross section	A plane perpendicular to the direction of flow.
Depth-integrated sample	A sample which represents the water-suspended sediment mixture throughout the water column so that the contribution to the sample from each point is proportional to the stream velocity at that point.
Detection limit	The smallest concentration of a substance which can be measured with a specified degree of precision and accuracy by a specific analytical method.
Detritus	Decaying plant and animal matter.
Discharge	The thaw rate of water at a given time expressed as a volume per unit of time.

Dissolved oxygen concentration	The amount of oxygen dissolved in a given volume of water (usually expressed as mg/L).
Diurnal	Processes that have daily cycles or vary with the amount of sunlight.
Ecology	The study of the relationships of organisms to their environment.
Ecosystem	The interacting complex of living organisms including humans and their non-living environment; the biotic community and its abiotic environment.
Effluent	Contaminated waters discharged from facilities to either wastewater sewers or surface waters.
Environment	All biotic and abiotic factors that actually affect an individual organism at any point in life cycle.
Erosion	The wearing away and transportation of soils, rocks and dissolved minerals from land surface shorelines or river bottoms by rainfall, running water, wave, wind or current actions.
Estuary	A water body that forms a transition zone between fresh water and full-strength salt water.
Eutrophication	Having abundant nutrients which leads to excessive productivity of plant and animal matter, frequently resulting in oxygen depletion in the lower layers of a body of water.
Faecal Coliform bacteria	A group of organisms associated with the intestine of warm-blooded animals, used commonly as an indicator of the presence of fecal material and the presence of organisms potentially capable of causing disease in humans.
Filtration	The process of passing a liquid through a filter to remove suspended matter.
Grab sample	A sample taken at a selected location, depth and time.
Groundwater	All subsurface water in the land portion of a watershed.
Heavy metals	Generic term for polluting metals such as lead, cadmium, mercury, zinc, etc.
Homogeneous	Uniform in composition.
In situ	In place (e.g.: a measurement made in the river).
Inorganic	Compounds that do not contain carbon in their molecules.
Invertebrate	Animals without a vertebral column.
Leachate	A solution that derives its content by dissolving or carrying particles from the soil, wastes or rock layers through which it moves.
Littoral zone	A shallow area along the shore of a body of water with light penetration to the bottom, usually with emergent subaquatic plants.
Loadings	Total mass of a substance to a water body over a specified time (e.g. tonnes per year of phosphorus).
Macrophytes	A member of the macroscopic plant life (i.e. larger than algae) especially of a body of water (i.e. water weeds or marsh vegetation).
Marshland or salt marsh	A protected intertidal wetland where freshwater and salt water meet, characterized by salt march cordgrass, salt hay, and black ruth.
Non-point source	Source of pollution in which pollutants are discharged over a widespread area or from a number of small inputs rather than from distinct identifiable sources.
Nutrient	A chemical that is an essential raw material for growth and development of organisms.
Organic	Compounds that contain carbon in their molecules.
Organochlorines	An organic compound which includes chemically bound chlorine. Many organochlorines are formed in industrial processes whenever chlorine or chlorine-based compounds are used. Thousands of chlorinated organic compounds exist, but only a small portion of those in industrial processes have been identified. Organochlorines include compounds such as PCBs and pesticides.
Pesticides	Any substances used to kill plants, insects, fungi or other organisms - includes germicides, insecticides, algicides and fungicides.

Photosynthesis	A process occurring in the cells of green plants and some micro-organisms in which solar energy is transformed into stored chemical energy.
Phytoplankton	Minute, microscopic aquatic vegetative life; plant portion of the plankton; the plant community in marine and freshwater situations which floats free in the water and contains many species of algae and diatoms. They form the base of the natural food chain.
Point source	Any discernible, confined and discrete conveyance such as any pipe, ditch, channel, tunnel or conduit from which pollutants are discharged.
Pollution (water)	Anything causing or inducing objectionable conditions in the watercourses and adversely affecting the environment and use or uses to which the water thereof may be put.
Primary treatment	Mechanical removal of floating screenable, rackable or settleable solids from wastewater.
Quality assurance	The total integrated program for assuring reliability of monitoring and measurement data. This program includes quality control measures.
Quality assurance project plan	A written and observed plan detailing the following: Monitoring objectives, program scope, methods, field and lab procedures, and the quality assurance and control activities necessary to meet stated objectives of data quality.
Quality control	This is defined as the routine application and procedures for obtaining prescribed standards of performance and for controlling the measurement process.
Representative sample	A sample of a universe or population whose composition is expected to exhibit their average properties.
Sample sites or stations	The location where a sample is taken and/or where measurements/tests are conducted. This location should be documented on a map and described in writing. The same location should be used each time a test is performed.
Sampling vertical	A vertical line from the water surface to the bottom along which one or more samples are collected to determine various properties of the water body, such as the concentration of suspended sediment, nutrients and metals.
Secondary treatment	Primary treatment plus bacterial action to remove organic parts of the waste.
Sewer (sanitary)	A municipal sewer for the collection and transmission of domestic, commercial and industrial waste not including land drainage or stormwater runoff.
Sewer (storm)	A municipal sewer for the collection and transmission of stormwater runoff, land surface water and water from soil drainage not including any industrial wastes other than unpolluted cooling waters.
Sludge	Solid removed from waste treatment facilities.
Solubility	The ability of a substance to form a solution with another substance.
Spatial	Varying over a geographic area or space; eg: upstream versus downstream.
Stakeholder Group	A group comprising delegates from agencies, organizations, institutions, government departments, industries, and private citizen groups, all of which have an interest in a specific area or issue.
Stratification	The arrangement of a body of water, such as a lake, into two or more horizontal layers of differing characteristics.
Substrate	The base on which an organism lives and grows.
Surface water	Natural water bodies, such as rivers, streams, brooks and lakes as well as artificial water courses, such as irrigation, industrial and navigational canals in direct contact with the atmosphere.
Suspended solids	Particulate matter suspended in water.
Sustainable development	Development which meets the needs of the present generation without compromising the ability of future generations to met their own needs.
Temporal	Varying over time; eg: monthly or weekly sampling.
Toxicity	Quality, state or degree of the harmful effect resulting from alteration of an environmental factor.
Trace contaminants	Toxic and other deleterious substances found in trace concentrations in the environment.
Trace element	A chemical element found naturally or required by living organisms in extremely small quantities.
Water Quality Objectives	Goals set by the Government of Canada for protection of the uses of water as in allowable concentrations of individual chemicals.
Water Quality Standards	A criterion or objective for a specific water use standard that is incorporated into enforceable regulations.
Watershed	The region draining into a river, river system, or body of water.
Watershed survey	A qualitative and quantitative process of determining the extent of pollution in a watershed by identifying existing non-point sources of pollution and inspecting the point sources of pollution.

Wetlands	Naturally vegetated lowlands, such as marshes or swamps, located between mean high water and the yearly normal maximum flood water level.
Winkler analysis	A wet chemistry method involving titration to determine dissolved oxygen.
Zooplankton	The animal portion of the community of small organisms that live suspended in the water column of a lake.

APPENDIX I
CASE STUDIES

Clean Annapolis River Project (CARP)
P.O. Box 118, Clementsport, N.S., B0S 1E0
Phone: (902) 532-7533; FAX (902) 532-7036

The CARP River Guardian Project was initiated in September of 1992 to monitor the quality of the Annapolis River and some of its tributaries. Initial funding support was through the Environment Canada, Environmental Partners Fund which provided support for the first two years of this project. By March 1994 alternate sources of funding must be found for the project to continue.

The key to the project are the 31 Annapolis Valley citizens who have been trained as River Guardians. The project was designed and supported by organizations and individuals with technical and scientific credibility. Government and academic inputs and in-kind support, from numerous groups and individuals, resulted in the ability to conduct coliform sampling and in the loaning of equipment. The College of Geographic Sciences provided the design of a database and the Acadia Centre for Estuarine Research, ACER, contributed monitoring design, sampling protocol, training, and technical support.

After initial recruitment and training, eight sites were chosen as initial sampling sites. Due to volunteer interest, this was expanded to 16 sites that span 75 km of the River from Aylesford to Annapolis Royal. Bridges were used for several sampling sites due to their regular spacing along the river.

The following parameters were measured weekly: water level, secchi depth, suspended particulate matter, chlorophyll, temperature, pH, conductivity, dissolved oxygen, air temperature, percent cloud cover, wind speed and direction. Fecal coliform samples were taken on the first Sunday of each month and were analysed by the Valley Regional Hospital Laboratory with the N.S. Dept. of Health assuming the cost. ACER provided the analysis for salinity, chlorophyll, and suspended particulate matter.

All measurements made by River Guardians are recorded on either a Field Data Sheet or a Laboratory Data Sheet and subsequently entered into a database file. A procedures manual was developed for the River Guardians by Dr. Michael Brykinsky of ACER to ensure data quality.

The Annapolis River Guardian Project has had a very successful start. Due to the hard work of many volunteers, a picture of the water quality of the waterway is starting to emerge.

Société d'aménagement de la rivière Madawaska et du lac Temiscouata Inc.
P. O. Box 1070, St. Jacques, N.B., E0L 1K0
Phone: (506) 739-1992; FAX 739-1988

The Madawaska group was, in 1993, in the process of planning a water quality monitoring project. This site is unique as part of the ACAP area borders the United States, and a large portion of the watershed lies in the Province of Quebec. Their group goal was to have over thirty volunteer participants who would conduct monitoring using various kits for the parameters dissolved oxygen, pH, and temperature. Qualitative descriptions of the river would also be determined. One of the major thrusts was to educate the public as to the changes in water quality that occur as a result of pollution. The support of the Canada-New Brunswick Water Economy Agreement was used to acquire monitoring equipment, train volunteers, and produce a project report and brochure.

In total 20 volunteers participated in the community-based water quality monitoring project. In addition to the aforementioned parameters, faecal coliforms were also measured. Six samplings occurred between August 20 and September 20, 1993. At one site, elevated faecal coliform counts were traced to the malfunctioning pump on a sewage treatment system which resulted in direct discharge to the Madawaska River. Dissolved oxygen, temperature, and pH were generally within the ranges required to sustain aquatic life. There were a few anomalous values, the cause of which could not be determined.

The group prepared a public summary report and a brochure on water quality, pollutants, and what could be done by individuals to minimize pollution. This met the group's principal goal of public education and awareness.

Miramichi River Environmental Assessment Committee
15 Jone Street, Newcastle, N.B., E1V 2S6
Phone (506) 622-6499, FAX (506) 622-3204

The Miramichi River Environmental Assessment Committee MREAC had previously decided to operate in 1993, a Swim Watch program where volunteers would collect samples for bacteriological analyses by the N.B. Department of Health. Samples were collected from popular recreation areas in the Miramichi River system and estuary. Monitoring results were published in the local newspaper.

Support was provided to the existing Swim Watch project so that costs associated with sample collection could be met. The remainder of the financial support went to the purchase of equipment so that the Swim Watch volunteers would be in a position to augment their existing monitoring program in 1994 with water quality field measurements.

One of the strengths of MREAC is a strong parent committee and an active technical committee. The MREAC monitoring activities are well planned so as to ensure a high degree of success.

St. Croix Estuary Project Inc.
237 Water Street, St. Andrews, N.B., E0G 2X0
Phone (506) 529-4868; FAX (506) 529-4878

The St. Croix Estuary Project (SCEP) is a community-based environmental planning organization concerned with the St. Croix Estuary (part of an international waterway shared by Canada and the United States) and Chamcook Harbour. As part of the process to assess the environmental quality of these waters, SCEP initiated a pilot program in 1993 to monitor faecal coliform bacteria and three ambient water quality parameters. Faecal coliforms was selected to be the priority parameter for sampling because of historically high levels of coliform counts in the area and the related closure of major shellfish growing areas to harvesting.

The planning and management of the pilot program was the responsibility of SCEP's Water Quality Monitoring Committee. Input to the program was received by representatives of government agencies on both sides of the border. Forty people including SCEP staff, citizen volunteers, and senior high school students were involved directly in field activities.

Thirty-nine sites were sampled with most sites being sampled at least six times. Temperature, dissolved oxygen, and salinity were measured in situ, while laboratory analyses of coliform samples were performed by either SCEP technicians or personnel at the Maine Department of Marine Resources water quality laboratory in Ellsworth, Maine. Results of bacterial analyses showed consistently very high counts in several locations around the project area. The information confirmed the need to keep shellfish growing areas closed to harvesting in the near future.

The goal of developing the operational basis for planning and implementing an expanded water quality monitoring program was met in 1993. In 1994 SCEP is planning to monitor eight major point source discharges on a regular basis, continue with monitoring at priority stream and estuarine sites, conduct sediment monitoring for heavy metals, and engage in various other monitoring and public awareness/education activities.

ACAP Saint John Inc.
P.O. Box 6878, Station A, Saint John, N.B., E2L 4S3
Phone: (506) 652-2227; FAX (506) 658-2879

Community-based water quality monitoring was identified as the vehicle to fill a need for monitoring in the Saint John Harbour area. ACAP Saint John established a Community Environmental Monitoring Committee in 1992, and this group designed and carried out the pilot water quality program in 1993.

Six Harbour and estuary locations were identified for monitoring through a stakeholder survey. The locations were: Little River, Marsh Creek, the Inner Harbour, South Bay, Duck Cove, and Saints Rest Marsh. Each location was adopted by a community group. Twenty-two volunteers received training at a one-day session held at the Saint John campus of the New Brunswick Community College. Training was provided by NBCC staff and Environment Canada personnel.

During the months of July and August, the volunteers sampled weekly at low tide from two stations for each location. Volunteers measured and recorded the water and air temperatures at each station, made several site observations, collected a water sample, and collected and "fixed" a sample for dissolved oxygen. The samples were analysed for pH, turbidity, salinity, and dissolved oxygen at the NBCC by a Chemical Technology Co-op student. Results of analyses, including quality control samples, were recorded on laboratory data sheets and entered into a spreadsheet.

The following conclusions were made from the data collected:

1. Triplicate sampling demonstrated that volunteers could collect reproducible samples and that laboratory analysis were consistent.

2. The lower portion of Little River was grossly degraded as indicated by severe oxygen depletion, high turbidity, and significant thermal pollution.

3. The dissolved oxygen depletion and the increased turbidity of Marsh Creek indicated that the possible uses of this water body were compromised.

4. Locations within the Harbour and estuary with high water flows and exchanges (South Bay, Harbour, Duck Cove, Saints Rest) had acceptable water quality for the parameters monitored.

During an evening session to present the results and to recognize the volunteers, a round table discussion was held concerning the positive and negative aspects of the pilot study. Positive aspects included: community involvement and participation, that good background data had been gathered, that there was a better understanding of the effort and cost of environmental monitoring, that the data were independent of government or industry, and that the information could be used as a basis to monitor changes in stream quality. The negative comments appeared to be more along the lines of constructive criticisms: include bacteriological monitoring, include industry specific parameters, find better thermometers, explore sediment banking, sample through a tidal cycle at some sites, and make sure the tide tables are accurate for each site.

The strengths of the Saint John pilot were that:

1. there was planning, design, and budgeting
2. a field procedures handbook for the volunteers was produced (Hoben etal. 1993)
3. a training session was held
4. a technical report was prepared and printed after peer review by the ACAP Saint John Technical Advisory Committee
5. a newsletter for public distribution was prepared based on the technical report
6. a volunteer night was held to recognize the efforts of the volunteers and to present the final results
7. the results were incorporated into a mall display unit
8. existing community groups were recruited to adopt sampling sites

APPENDIX II

POTENTIAL SOURCES OF FUNDING

As part of the Atlantic Coastal Action Program, ACAP, a document was prepared to help community groups solicit financial support for projects (ACAP, 1993). Included in the document are tips for fund raising, project proposal writing, and a list of potential funding bodies. This document is an excellent starting point for funding efforts.

Some examples of funding bodies identified include:

Program	Agency
Environmental Partners Fund	Environment Canada
Nova Scotia Environmental Trust Fund	N.S. Department of the Environment
New Brunswick Environmental Trust Fund	N.B. Department of the Environment
Environment and Development Support Program	CIDA/Canadian Environmental Network
Healthy Environment Program	Health and Welfare
SEED	Employment and Immigration Canada
P.E.I. Young Environmentalists	P.E.I. Department of the Environment
Newfoundland and Labrador Conservation Corps	Nfld. Department of the Environment
Volunteer Support Fund	Environment Canada
Youth Action Fund	Environment Canada

There is also a list of private non-profit foundations and corporations that provide support to worthy projects within their mandates.

APPENDIX III

VENDORS OF WATER QUALITY MONITORING EQUIPMENT

There are numerous suppliers of water quality monitoring equipment in Canada and the United States. The following list represents the major vendors of scientific equipment. The list is not intended to be all inclusive.

Atlantic Purification Systems
10 Ferguson Road
Dartmouth, N.S.
B3A 4M1 Ph: (902) 469-2806

Campbell Scientific (Canada) Corp.
192 St. Clair St.
Chatham, Ontario
N7L 3J6 Ph: (519) 354-7356

Canadawide Scientific
1230 Old Innes Road
Unit 414
Ottawa, Ontario
K1B 3V3 Ph: (800) 267-2362

Canlab Division
Baxter Diagnostic Corporation
2390 Argentia Road
Mississauga, Ontario
L5N 3P1 Ph: (800) 323-4340

Cole Parmer Instrument Company
7425 North Oak Park Avenue
Niles, Illinois
U.S.A. 60714 Ph: (800) 323-4340

Fisher Scientific
8505 Devonshire Road
Montreal, Quebec
H4P 2L4 Ph: (800) 361-5423

LaMotte Chemical Products
P. O. Box 329
Chestertown, MD
21620, U.S.A. Ph: (800) 344-3100

Millipore (Canada) Ltd.
3688 Nashua Drive
Mississauga, Ontario
L4V 1M5 Ph: (800) 268-4881

YSI Incorporated
1725 Brannum Lane
Yellow Springs, OH
45387, U.S.A. Ph: (800-765-4974