Testing The Forest Water Quality Index (FWQI)
A Case Study

An Interim Report Prepared by the Aquatic Centre for Research and Education (ACRE)

For The Western Newfoundland Model Forest (WNMF)
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Introduction

During the past six years, the Aquatic Centre for Research and Education (ACRE) has carried out a physical, chemical and biological inventory of the Hughes Brook watershed. In addition to the inventory, ACRE is carrying out an in-depth study of the water quality of Hughes Brook. Water quality data collected in the past have indicated fluctuation in pH and dissolved oxygen along sections of Hughes Brook. Preliminary bacteriological studies have indicated that the water samples taken from several different sites along the river system are 'contaminated' and unsatisfactory for recreational use (e.g., swimming). It is important to note that one of ACRE's primary goals is to engage and mentor postsecondary students in field research, data collection techniques and report writing.

This project report contains a description of a test of the Forest Water Quality Index (FWQI) done over five months - i.e., a case study of water quality samples done on the Hughes Brook, Bay of Islands, Western Newfoundland, system using the Forest Water Quality Index (FWQI). The intent of the study was to test the FWQI model on a data set with respect to the impact of a farm on the natural habitat of Hughes Brook. The report is considered interim since it utilizes only five months of water quality research data collected at three stations located on the Hughes Brook system and analyzed by the Water Resources Division of the Department of Environment. To determine seasonal variations of water quality and possible impacts on the ecosystem, an additional seven months of water quality data will be collected and analyzed. A final report will be produced at the end of the study.

In The Water Quality Index (WQI), that forms the basis of the FWQI has been applied by the Water Resources Management Division of the Department of Environment in the Newfoundland and Labrador in (approximately) 1994. The water quality indices are calculated for the following three different uses:

- Drinking Water Quality Index: drinking, recreational, irrigation, and livestock uses.
- Aquatic Water Quality Index: aquatic life and wildlife protection uses,
- Overall Water Quality Index: all uses including the protection of human health, aquatic ecosystems, and wildlife.

Department of Environment, 1994

The environmental standards used to compare the attainment of water quality objectives for each of the above cases are listed in Table 1. The most stringent environmental regulations are used to determine overall quality indices followed by aquatic and then drinking water uses. The determination of the water quality index is based on the following three major factors: 1. the number of objectives that are met, 2. the frequency with which the objectives are not met, and 3. the magnitude by which the objectives are not met.

Since the fiasco of Walkerton, Ontario, in June of 2000, water, and increasingly water quality, has become a burning issue for all Canadians - indeed, for people around the world.

> THE TROUBLE WITH WATER – and there *is* trouble with water – is that they're not making any more of it. They're not making any less, mind, but no more either – there is the same amount of water on the planet now as there was in prehistoric times. People, however, they're making more, far more than is ecologically sensible – and all those people are utterly dependent on water for their lives (humans consist mostly of water), for their livelihoods, their food, and, increasingly, their industry.
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> p. 15, ***Water***, 1999, Marq de Villiers

Marq de Villiers, a Canadian, has done the world a great service with the publication of his book, ***Water.*** A former editor and publisher of Toronto Life, de Villiers traveled from the flood plains of China to the rainforests of Brazil in researching the book. His prognosis on the state of the world's water is not good. Marq now lives just across the water from Newfoundland at Lunenberg, Nova Scotia.

Water is perhaps our most valuable resource. Water is vital for life; without water life would not exist.

> Water is the lifeblood of the environment; it is essential for the survival of all living things and we must do everything possible to maintain its quality for today and the future. Almost all life forms depend on water. Water is of such importance in so many ways; it is no wonder that in many cultures it is regarded with spiritual reverence. Water is a natural resource, but it differs in many ways from our other natural resources. Firstly, it moves. Secondly, its total quantity on the earth is fixed. Thirdly, water is essential for human survival.

p. 95, Carla Griffin, Student Independent Projects, Environmental Studies, Sir Wilfred Grenfell College, May 2001.

We depend upon our water bodies to provide clean, healthy and top quality water for recreational uses, municipal water supply, fish and wildlife and invertebrate habitats, irrigation of croplands, aesthetic purposes or for sheer enjoyment, and a variety of industrial purposes including forestry and paper making (Mitchell and Strapp, 1997). In short, top quality water is a top priority for all sectors of society today.

> Considering the relative scarcity of fresh water on the one hand, and its irreplaceable role on the other, one might expect that mankind would be rather careful with it. Nothing could be further from the truth. We waste it, pollute it, deplete aquifers at high rate, while the demand for clean fresh water is huge. For example, the production of one kilogramme of grain requires some 200 litres of water, while a kilogramme of meat even requires 2000 litres of water.

p. 1. Stortenbeker, C.W., 1993.

While the development of watershed monitoring programs in Canada is still in its infancy, such programs are under development in most provinces and in many of the states of the United States. The province of Prince Edward Island, for example, has deemed soil erosion from extensive farming a main issue in watershed management programs. Nova Scotia instigated the Tyndal Water Supply Protection Strategy in Cumberland County in 1998. New Brunswick has introduced a number of programs including in 2002 the Sustainable Development Program of Bathurst and the Water Classification Program of the New Brunswick Department of Environment and Local Governments.

Ontario, particularly since the Walkerton and O'Connor inquiries, has instigated strict legislation and regulations to protect the quality of drinking water. The Ontario government, for example, in 2002 passed the Nutrient Management Act that deals with a nutrient management plan to ensure that farms are managed in an environmentally friendly way to prevent contamination of lakes, streams and groundwater with nutrient contaminants (Water – Ontario Ministry of the Environment, http://www.ene.on.ca/water.htm).

This report describes a project in which personnel with the Aquatic Centre for Research and Education (ACRE) conducted a case study test of the Forestry Water Quality Index (FWQI) by water sampling of the Hughes Brook system located in the Bay of Islands, Western Newfoundland. Data were collected over five months and analyzed by provincial Water Resources of the Department of Environment.

In recent years, water quality issues within forest harvesting areas have become a major issue for both the forestry industry and environmental sectors. The development of a water quality planning and communication tool sensitive to forest harvesting activities was the result of this concern. The model that has evolved is the Forestry Water Quality Index (FWQI), to be referred to simply in this report as the FWQI.

The FWQI is an adaptation of the Water Quality Index developed by the Canadian Council for Ministers of the Environment (CCME). The parameters used in the index are those typically affected by forestry activities; those parameters were focused on to analyze water quality data with respect to forestry activities.

Streams and rivers provide excellent ecosystems for monitoring the impacts of all anthropogenic effects on the environment. The whole river includes the watershed which in turn includes all land that provides rain and snowmelt drainage into the river (Mitchell and Strapp, 1997). Biomonitoring, or the monitoring of living organisms within an ecosystem, can be used to determine the possible deleterious effects of forestry activities (Chiasson and Williams, 1999); but, the monitoring of physical and chemical parameters of ecosystems can also be used. It is the latter form of monitoring that has been used in this case study test.

The Ellsworths currently run a beef cattle farm but for many years it was a dairy farm located on the bank of Hatchery Brook, a productive tributary of Hughes Brook just upstream from the town of Hughes Brook (Fig. 1) on the Northshore of the Bay of Islands. In this test of the FWQI model, samples were taken from three stations established on Hatchery Brook at, above and below the location of Ellsworth's Farm (Fig. 2.). Samples were taken over a five-month period January to May 2005. While the data analyzed for this interim report were taken over five months, data sampling has continued and a final report will be submitted when the sampling period ends on December 31, 2005. The data sampling in the final analysis, therefore, will have been taken over a twelve month period and all four seasons to test the impact of changing seasons on the water quality data.

All water samples were analyzed via Aquatest Laboratories as a service to ACRE by the Water Resources Division of the Department of the Environment and with the full cooperation and assistance of Paula Dawe, regional officer and Haseen Khan, Director. ACRE is grateful for this significant contribution and with Annette Tobin who did much of the initial work on the FWQI model.

Literature Review

The water quality parameters most commonly affected by forestry activities include turbidity (NTU), dissolved organic carbon (DOC, mg/L), dissolved oxygen (DO) and temperature; and, the nutrients potassium (mg/L), phosphorus (mg/L) and nitrogen (mg/L) (Department of Forest Resources and Agrifoods et al, Forestry Water Quality Index, 2004). While other parameters are often sampled and their impacts analyzed, those seven parameters are most commonly used.

Turbidity describes the degree of light penetration into the water. While fish can tolerate high levels of turbidity for a short period of time, problems result when high levels continue for extended periods. Clearly, forestry activities such as road building, stream crossings, harvesting near streams and site preparation can affect the turbidity of the water and the severity is affected by the extent of the operation and the length of the time the operation is carried out. As well, turbidity is also usually a visual manifestation of high levels of silting or sedimentation in the water body – a problem that can have devastating effects on the eggs of resident fish populations and on invertebrate populations within the ecosystem that provide a food supply for larger organisms since oxygen deprivation is the result. Stress of organisms causing disease susceptibility and reduced growth are other ill effects of this problem. Undisturbed forests maintain soil erosion at a minimum.

High levels of dissolved organic content (DOC) can have deleterious effects on organisms within an ecosystem. Organic materials come from branches, logs and tree tops that fall into water bodies. As decay takes place, these dissolved organic materials can cause reduced dissolved oxygen (DO) levels in the short term to the extent that organisms cannot live. Once the decay process is complete, the DOC levels return to normal. Under normal conditions a small amount of DOC will eventually find its way into water bodies and will ultimately decay but the impact is negligible.

If soil is disturbed during forestry activities, severe nutrient losses from the soil into the adjoining water bodies can result. While these nutrients are essential in small quantities for organism survival, in large amounts they can cause severe problems in the ecosystem. Typical nutrients include nitrogen, phosphorus and potassium but the two main nutrients are nitrogen and phosphorus. An imbalance of nutrient levels, eutrophication or over-fertilization (p. xii, Environment Canada, 2001), causes rapid plant growth which in turn causes changes in the natural seasonal variations in the water body. Other deleterious effects of an imbalance of nutrient levels include decreased levels of dissolved oxygen (DO), fish kills from high levels of nitrogen, changes or loss of invertebrate populations, poor larval growth, reduced body size of organisms and reduced swimming abilities. Other undesirable changes include imbalances of carbon dioxide and pH from such disturbances as well as other general changes in habitat and in biodiversity. While these are speculated impacts of disturbances caused by forestry activities, insufficient scientific data collection and monitoring of ecosystems exist in most regions to unequivocally pinpoint poor forestry practices as the root cause.

Temperature changes from poor tree harvesting practices near water bodies involving mainly removal of overhanging trees and branches that provide shade and thus a cooling effect on the water and a loss of protection from predation for fish is another negative that can result from poor forestry practices. While wide buffer zones can largely ameliorate these negative effects, situations where tree removal close to water bodies still occurs can have these negative impacts. Fluctuating temperatures that result in a change in dissolved oxygen (DO) levels is another negative effect.

Only a few studies have included analyses of water quality in Newfoundland and Labrador. One such study was undertaken in Gros Morne National Park in 1994 (Pomeroy, Komidina and O'Callaghan, 1994). In addition to visual inspections of selected water bodies within the Park, surface water samples and sediment samples were taken. Samples were analyzed for conductance; apparent color; nitrate/ nitrogen concentrations and pH; concentrations of trace elements such as sodium, chloride, arsenic, cadmium, copper, mercury and the like; and, PAH (polynucular aromatic hydrocarbons). The study was undertaken to provide baseline data on the impact of anthropogenic activity and impacts on water quality.

A limited study was conducted in 2003 at Hughes Brook by Todd Turner (2003) in which he measured conductivity, dissolved oxygen, hardness, temperature and salinity at two sites in Hughes Brook. Samples were collected on May 29, 2003, July 30, 2003 and

August 19, 2003; the intent was to measure any differences between the spring run-off period and the summer period. Results showed that conductivity and temperature increased significantly from May to August, hardness and pH were fairly consistent throughout and salinity remained consistently low throughout the sampling period.

It is worth noting that in the Turner study, although pH was consistent throughout, at a low reading of 8.2 on July 30, 2003 and a high of 8.3 on August 19, 2003, pH readings were consistently high in the alkaline range. Previous studies carried out at Hughes Brook by Burridge et al. (2002) for the summer period between June to August showed a pH range of 7.1 to 8.3 and that this is consistent with other data analyzed from students during the years between 1999 and 2001 and again for 2003 to 2004 for the general summer periods. These pH values are no doubt influenced by the fact that the Hughes Brook system is underlain by rock of the Ordovician formation consisting of mainly limestone, siltstone, sandstone, dolomite (dolostone) and shales with the limestone and dolomite predominating (p. 7) (Appendix XX).

Yetman (1998) studied the impacts of logging operations on the invertebrates of Green Woods Brook, Central Newfoundland. Samples were taken above and below the logging operation and several physical and chemical parameters of the stream were monitored between July 12 and August 7, 1997. Parameters included pH, water velocity, water depth, turbidity and aerial particulates. Samples of invertebrates were also taken at the stream during this period. Statistical analysis of 39 invertebrate species showed no significant difference between the invertebrate density above or below the logging activity although there appeared to be a favoring of sediment preferring organisms, such as Chironomids, in areas of increased sediment below the logging operation; i.e., there appeared to be a reduction in species diversity and abundance below the logging activity sites as opposed to above the sites.

A study of water quality in the Richbuckto River drainage basin of New Brunswick measured specific conductivity, dissolved oxygen, carbon, phosphorus and nitrogen at 36 stations over five years between 1996 and 2001. Each station was sampled between 1 and 26 times (mean = 7.5, standard deviation = 6.0) during the ice free seasons. Principal component analysis (PCA) was used to identify the processes explaining the observed variance in water quality. As well, stations were first grouped into freshwater and estuarine or brackish water subsets. One recommendation from the study was that the water quality parameters that explained most of the variance by PCA should be monitored more closely since they are the key elements in understanding variability in water quality in the Richbucto drainage basin. Cluster analysis showed that high phosphorus and nitrate concentrations were found mostly in areas of peat runoff, tributaries receiving treated municipal effluent, and lentic zones upstream of culverts. Peat runoff was also shown to be acidic whether it was runoff from a harvested area or from a natural bog.

Alberta has produced the Alberta River Water Quality Index (RWQI) which was developed specifically as a way to summarize complex physical, chemical, and biological data into a simple composite descriptor of water quality (River Water Quality: What's Available – Index – Alberta Environment. http://ww3.gov.ab.ca/env/water/SWQ/resources01.cfm). The index provides a simple snap-shot of the annual water quality conditions at many rivers in the province; it is not meant to replace the conventional scientific process of analyzing and interpreting technical data. The Alberta River Quality Index is based on the average of four sub-indices calculated from each of the four variable groups: metals and ions, nutrients, bacteria and pesticides. A rating system ranging from excellent to poor is used to rate relative water quality at sites located on major provincial rivers.

Since the Walkerton and O'Connor Inquiries, after the Walkerton disaster of June 2000, Ontario has enacted tough legislation to combat pollutants entering their source water for drinking purposes. The Provincial Groundwater Monitoring Information System (PGMIS) is a web-driven application that assists the Ministry of the Environment and its partners to monitor the state of the province's groundwater resources. They consider that source water protection is the first barrier in a multi-barrier approach to protecting the water in Ontario's lakes, rivers and underground aquifers. They believe that watershed-based planning takes the natural boundaries of surface and groundwater into consideration. Their 2002 enacted Nutrient Management Act also requires that farms must develop nutrient management plans to deal with animal waste and other substances that are spread on fields. It is fair to say that Ontario during the past five years has done more to protect water quality on a variety of fronts than any other jurisdiction in Canada (Water – Ontario Ministry of the Environment, http://www.ene.gov.on.ca/water.htm).

Consistency with respect to the actual water quality constituents measured varied somewhat from study to study; this fact makes any significant comparisons between and among studies difficult. For example, Vecchia (   ) of the US Geological Survey measured the following parameters in water quality data analysis comparisons in the Souris River near Westhope, North Dakota, and in the Souris River near Coulter, Manatoba: dissolved oxygen, dissolved calcium, dissolved sodium, dissolved sulfate, dissolved chloride, dissolved solids, total ammonia, total nitrogen, total phosphorus, dissolved arsenic, dissolved boron, dissolved iron and dissolved manganese. 10-day sampling intervals were used in data collection from the two sites.

A sampling of the variables used in the Alberta River Water Quality Index includes: metals and ions – e.g., aluminum, arsenic, beryllium, lead, mercury, nickel, silver, zinc and fluoride of a list of 22 (River Water Quality: What's Available – Index – Alberta Environment, 2005, pp. 1,2, 4). Pesticides included in the Index are represented by the following examples from a list of 17: 2,4-D, MCPP, diazinon, atrazine, malathion and diuron. Nutrients and related variables included dissolved oxygen, pH, total phosphorus, total nitrogen, nitrite-nitrogen (NO2-N) and ammonium nitrogen. Bacteria testing included fecal coliform and Esccherichia coli. The variables that most commonly do not meet the guidelines are fecal coliform bacteria, phosphorus and nitrogen.

Baldigo, Murdock and Burns (2005) conducted a study in the Catskill Mountain watersheds, New York that examined the combined effects of clear-cut harvest and acid deposition on water quality of small streams to produce severe stream acidification. These conditions were shown to be acutely toxic to juvenile brook trout. In general, it was concluded that clear-cutting can adversely affect the chemistry of circumneutral and acidified streams in the Catskill region. It was also concluded from the study that the type, extent and intensity of timber harvests in some watersheds may warrant consideration of the status of soil acidity, the susceptibility of stream waters to acidification, and the sensitivity of resident biota to acidity. Additional research was recommended.

In a similar study conducted at approximately the same time, the Virginia Association of Soil and Water Conservation Districts indicated that the quality or condition of water determines its ability to support life and it affects the human use of the resource (Virginia Association of Soil and Water Conservation Districts Water Quality Factors, ___). As water quality declines, the aquatic communities change from pollution sensitive to pollution tolerant organisms. Water with very poor quality will support few, if any, organisms. The important parameters used to measure water quality included pH, dissolved oxygen, alkalinity, salinity (of seawater - the most important of 70 elements and minerals present being sodium chloride), nitrate and phosphate. Some aquatic organisms can support a wide range of water conditions while others require pollution-free water.

Forsyth County Environmental Affairs Department in Winston-Salem, North Carolina (2005) listed the following factors monitored at 12 monitoring sites in Forsyth County: pH, ammonia nitrogen, nitrate-nitrogen, total phosphorus, total suspended solids (TSS), conductivity, turbidity and the metals copper, zinc, lead, aluminum, cadmium, and chromium. The deleterious effects of imbalances in streams of each factor are discussed individually.

As early as the mid-1980s, Fisheries and Oceans Canada included in their publications guidelines the kinds of impacts they felt at the time needed to be addressed with respect to fish habitat and activities such as dredging and mining activities in Canada. The following excerpts capture the thinking at the time:

> Fish habitat means spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes... No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.
>
> Fisheries Act, Section 31, 1985

In a later version of the Act, the following disconcerting addition was made to the Fisheries Act:

> ...unless authorized by the Minister of Fisheries and Oceans.
>
> Fisheries Act, Sections 34 and 35, 1988.

These words seem to give a means whereby the Minister could support destruction of habitat of the type described provided the reason were serious enough.

Methodology

From January to May 2005 water samples were collected monthly at three areas of Hughes Brook: Site 1 – upstream from a beef cattle farm/ agricultural area, Site 2 – adjacent to the farm, Site 3 – downstream from the farm (Figure XXX). To be more specific, Site 1 was located approximately 100 meters upstream from the first bridge on Goose Arm Road, Site 2 was located adjacent to the Ellsworth's Cattle Farm, approximately 50 meters from the cattle farm grazing field and Site 3 was located downstream from the farm, beyond the community of Hughes Brook, approximately 200 meters from where Hughes Brook intersects with the Northshore Highway.
At each site water samples were collected at the middle of the river approximately 30 centimeters below the surface of the water. As per the Provincial Department of Environment and Conservation, Water Resources Division protocol.

The water samples were analyzed based on *Canadian Environmental Quality* criteria by ACCUTEST Laboratories Ltd., a nationally certified and accredited laboratory based in Ottawa. The data will then be averaged per section and incorporated into the Canadian Water Quality Index Model (Version II). The goal of this model is to summarize large amounts of water quality data into simple terms based on particular water uses (drinking water, aquatic life, recreational use). The overall goal of this portion of the project is to determine if agricultural practices have an effect on the water quality of Hughes Brook and if possible attempt to quantify those effects.

The second goal of this project is to use select water quality collected from Hughes Brook and apply these data to the Forest Water Quality Index (FWQI). The FWQI is a new planning tool currently on water quality and ecosystem health. Since Hughes Brook serves as an important spawning habitat for both Atlantic salmon (*Salmo salar*) and Eastern brook trout (*Salvelinus fontinalis*), it is of utmost importance to gauge the effects of any potential activity in the Hughes Brook watershed. It is also of interest to explore the potential effects of various levels of forestry activity coupled with agricultural activities.

Results

Appendix X gives the FWQI water quality data for five months from January to May 2005. Water sampling will continue until December 31 2005.

Appendix XX gives the series of charts presenting the data for five months from January to May 2005.

Discussion/ Preliminary Conclusions

Nineteen of the 37 parameters that could yield data under the FWQI model actually yielded relevant data in this study. The other eighteen parameters yielded 0 or negligible results. This means that just over half of the possible data sets yielded data from which any conclusions could be drawn with respect to impacts of the farm on the Hughes Brook ecosystem.

Dissolved oxygen (DO) and temperature were time dependent parameters that did not yield data in this study. This means that other data sources must be sought if these two parameters are to enter into the discussion as to their possible impacts of the presence of Ellsworth's farm on the adjacent habitat. Since the seven parameters mentioned earlier (p.) include those two, it is important that data be obtained. The primary purpose of this case study was to determine the possible impacts on various aspects of the river ecosystem of the presence of the farm on the Hughes Brook system and the effluent from it.

In the following specific discussion, results with respect to the nineteen parameters actually measured and yielding results will be discussed. Each of the parameters considered relevant to forestry activity will be discussed first.

Turbidity (NTU) demonstrated upward spikes during the April spring runoff period for upstream of the farm and at the farm as would be expected; results from downstream samples were not as clearly attributable to natural spring runoff, a seasonal occurrence (Fig.). There were no discernable differences between and among the three sites sampled. Dissolved organic carbon (DOC) demonstrated a progressive increase from January to May (Fig.) - as might be expected, with thawing and increased biological activity within the ecosystem at the onset of spring. There were no differences detected between and among the three sites.

Among the nutrients tested, potassium yielded 0 data. Total phosphate yielded several 0 readings throughout the five-month data set (Fig.); no conclusions could be drawn from the data presented. With respect to KeldahNitrogen, there were no significant differences detected among the three sites. Low values were recorded throughout the period for the upstream site and two unexplained spikes were recorded – one in January at the farm and one in April downstream. These could be attributable to manure effluent entering the ecosystem during thaw periods but this would be a tenuous impact conclusion at best. The owners would have to be closely questioned to establish this as fact.

Additional parameters measured under the FWQI model included color. As for dissolved organic carbon in the system, color also demonstrated progressive increases through the January to May period for all three sites (Fig.). Spikes in the data during May can be attributable to increased spring runoff. No differences were observed among the three sites with respect to color and, therefore, no impacts with respect to the presence of the farm were detected.

Hardness as $CaCO_3$ progressively decreased upstream throughout the sampling period with one unexplained upward spike in the data for May. No significant changes in hardness of the water quality were detected for the farm or downstream sites.

The data for pH for this study were recorded in the high range, hovering near 8 throughout the study period for all three sites (Fig.). In all previous measurements done by ACRE, pH has always been recorded as high for the Hughes Brook system – no doubt attributable to the high alkaline content of west coast Newfoundland rivers caused by a predominance of limestone bedrock. This is in keeping with other studies (Turner, 2003).

Ammonia showed no significant pattern of differences - trends from month to month or from one sample site to the other (Fig.). One spike during February at the farm could perhaps be attributable to manure effluent being released into the river system during a winter thaw but more data would be necessary to draw any definitive conclusions. The range was from 0.02 to 0.04 mg/L for all samples analysed. Similar comments can be made for nitrate, aluminum, and iron since no discernable trends from month to month or from one site to the other could be detected.

Calcium, sulphate, chloride and sodium (with some anomalies) demonstrated progressive decreases through January to May for all three sites but no evident differences from one site to the other (Fig.). Magnesium demonstrated no evident trends but there were consistently higher values at the upstream site Fig.), which would lead one to conclude effluents are entering the system at this site from some unknown source. More data are needed to establish this.

While higher values were recorded for total dissolved solids (TDS) at the upstream site, there were no evident trends established either within sites over five months or from one site to the other (Fig.).

With respect to conductivity, there were progressive decreases recorded from January to May for the three sites sampled but no discernable differences were shown between the three sites (Fig.). Since many of the elements measured in this study demonstrated progressive decreases through the winter and into the spring season, these differences are considered to be entirely attributable to natural changes with respect to decreasing levels of ions in the system from winter to spring and not to any human activities occurring in and around the ecosystem. In conclusion, it can be said that no evident impacts were recorded from the adjacency of the farm on the Hughes Brook system.

The following conclusions can be reached from this case study:

1. The FWQI model failed to record any evident impact upon the Hughes Brook aquatic ecosystem from the adjacency of the Ellsworth cattle farm as measured at three sites: above, at and below the farm.
2. The FWQI model demonstrated several natural and seasonal changes in the recorded parameters measured during the five month period of this study.
3. Parameters such as dissolved oxygen (DO) and temperature, as two of the important parameters in measuring anthropogenic impacts on aquatic ecosystems,

must and should be measured by means other than the FWQI model as it is used in this study.

4. Since only nineteen of the 37 possible parameters of the FWQI model yielded something other than 0 or negligible results in this study, the number and type of physical factors measured in river systems such as Hughes Brook is quite adequate for the purposes of this study.
5. While there is little real evidence that trends from one site to the other in this study will yield any different results in the longer term, it is advisable and recommended that FWQI water quality measurements and analyses continue until the end of December 2005.

Water quality testing such as this has not been without its critics. A group of experts who attended a conference in 2001 in Quebec City, as part of the 10^{th} International Symposium on Toxicity Assessment organized by Environment Canada's St. Lawrence Centre and Canada's International Development Research Centre (IDRC). These experts from Latin America, all members of WaterTox, a network of scientists supported by IDRC, said that it is impossible to verify the presence of certain contaminants within waterways and there are many contaminants that form and reform once chemicals enter the water system. Their major premise was that conditions change after a contaminant enters a waterway and that these new conditions may or may not affect organisms in the ecosystem. A program officer with Canada's International Development Research Centre (IDRC) in Ottawa said that "Certain chemical contaminants slip through the 'testing net' and are not picked up." The WaterTox network was created and has been supported by the IDRC to field test simple, inexpensive analysis technologies to better control the quality of water in countries of the South (Simple Inexpensive Water Quality Tests Point to Weaknesses in Routine Chemical Analysis Testing, Quebec City, 2001).

Nevertheless, it is felt that this form of monitoring as manifested in the factors measured within the FWQI model, while not perfect, certainly has its merits. It is likely that the index can provide valuable scientific information that can be used for improvement of farm and forestry practices and other possible anthropogenic impacts on waterways. Parameters measured, however, should be compared with the Canadian water quality guidelines for the protection of aquatic life as a standard for possible deleterious effects (Appendix X Canadian Water Quality Guidelines for the Protection of Aquatic Life) and to determine whether or not these levels pose any threat to aquatic life in water bodies where the FWQI is to be used.

With the completion of a full year data set at the end of January 2005, ACRE should be in a more favorable position to make definitive statements with respect to the use of the FWQI model to monitor impacts of farm or forestry practices on aquatic ecosystems. With expansion of ACRE's research interests into the Humber River Basin study as part of the Centre of Environmental Excellence (CEE) research efforts in the region, the FWQI model should assume greater importance in monitoring possible deleterious impacts of anthropogenic activities.

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