Use of the Ecoregion Approach to Setting Water Quality Objectives in the Vancouver Island Region, British Columbia Ministry of Environment

Prepared for the B.C. Ministry of Environment
Vancouver Island Region

May 2009

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Executive Summary

The British Columbia (B.C.) Ministry of Environment began establishing generic provincial water quality guidelines in the early 1980's. These are used to do a preliminary evaluation of the water quality data, and to establish site specific ambient water quality objectives. Water quality objectives and the associated monitoring and assessment are key components of the adaptive management cycle, guiding management decisions and actions. The development of water quality objectives is a resource intensive process, requiring three years of monitoring and assessment on individual watersheds.

In 1985, an ecoregion classification system was adopted by the Wildlife Branch of the Ministry of Environment as a framework for managing the diverse nature of B.C.'s topography, climate and ecosystems. Within this system, areas with similar features can be grouped into discrete geographical units at five different levels. The ecoregion classification system was established to help in area-based planning, one of the core reasons for water quality objectives development. Using this classification system as a model, the Vancouver Island Region (VIR) has initiated an ecoregion-based approach to water quality objectives development. Rather than developing water quality objectives for each individual watershed, VIR has been working towards the long term goal of developing objectives for each ecoregion as a whole. Within each ecoregion, representative watersheds have been chosen and three year monitoring and assessment programs have been established with local partners. The data are used to develop ecoregion-based water quality objectives for all lakes and streams in that ecoregion.

A number of studies have shown that land classification systems can be useful for identifying areas of relative homogeneity for water quality. Several studies discussed in this report support the premise that fundamental water quality is

similar between watersheds, within ecological regions. One example found that un-impacted watersheds can be used to establish background levels and subsequent site specific water quality objectives for adjacent impacted watersheds. To further verify the validity of the ecoregion approach as it applies to VIR, this report compares water quality objectives for two Vancouver Island streams in the same ecoregion. The objectives were found to be interchangeable and applicable to either watershed. Applying the ecoregion approach system to water quality is seen as a reasonable, cost effective, and scientifically defensible means to develop water quality objectives.

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Acknowledgements

This report outlines and confirms the vision of staff from Vancouver Island Region of the B.C. Ministry of Environment who support the use of Water Quality Objectives in an Adaptive Management process while engaging partners to enhance effectiveness and efficiency. Jason Winchester of the Integrated Land Management Bureau provided the maps presented in the report. Danielle Prpich assisted with final editing of the report.

1. Introduction

Site-specific water quality objectives have been established in British Columbia (B.C.) since the mid-1980's. The objectives were developed in response to the 1981 Auditor General's report (Auditor General of B.C. 1982) which found that although the Ministry of Environment (MoE) had a good system of authorizing discharges to the environment, further work was needed to determine whether the Ministry was also protecting the environment. As a result, the Ministry developed generic water quality guidelines to be used across the province, and set site-specific objectives for specific water bodies that would take local conditions into account (BC Ministry of Environment, Lands and Parks, 1986).

1.1 The Adaptive Management Cycle

In general, an adaptive management cycle (Figure 1) is the process whereby the goals of an organization are fed into a policy development framework. In the context of water quality objectives, monitoring is carried out to see if the policies are being implemented effectively, and that the results of the monitoring are interpreted and reported out, so that management actions are taken as necessary.

MoE's Environmental Protection Division cites adaptive management as a key strategy that will be used to achieve the goal of "*continuous improvement in air, land and water quality*" (B.C. MoE 2008). The Ministry's commitment to adaptive management is highlighted in this quote from the Strategic Plan:

> *"This work depends on an adaptive management framework, which includes setting and implementing standards and guidelines, checking for their attainment, and adjusting the requirements and guidelines as needed. The "checking" function includes monitoring and assessment of ambient environment conditions, as well as compliance, verification and assessment to ensure that regulatory requirements are being met. When non-compliance is found, division staff engages with the Conservation Officer Service to conduct*

enforcement. Both types of checking inform pollution control and prevention decision-making" (B.C. MoE 2008).

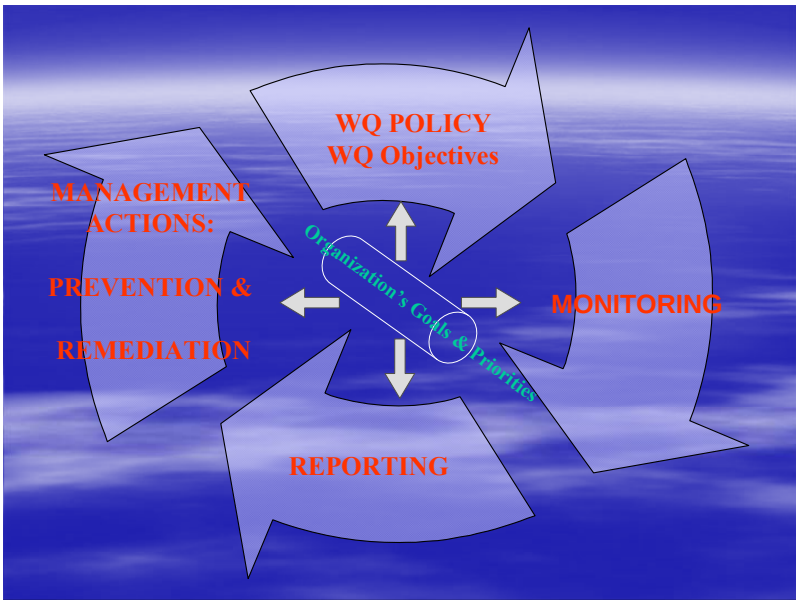


Figure 1: The Adaptive Management Cycle

1.2 Developing Water Quality Objectives

MoE develops generic province wide ambient water quality guidelines for key variables in B.C. surface waters. These are used for: a) the evaluation of data on water, sediment and biota; and b) the establishment of site specific ambient water quality objectives. Site specific water quality objectives use the guidelines as a starting point, taking into account background water quality, hydrology/limnology/ oceanography, as well as present and future uses of the water body. Once established in a given water body, site specific objectives take precedence over the generic provincial guidelines in guiding management decisions.

To develop water quality objectives for a given water body, an extensive three year monitoring program is developed and carried out in order to understand year-to-year variability and seasonal changes while building a strong, reliable dataset. The dataset is used to develop the objectives while providing an assessment of existing water

quality and baseline data for future trend analysis. Once objectives have been established, follow-up monitoring occurs once every three to five years, unless site specific circumstances warrant increased frequency. This is referred to as water quality objectives attainment monitoring, as the intent is to determine whether the established objectives are in fact being attained (met).

Within B.C., water quality objectives have traditionally been developed for most variables using what is referred to as the Background Concentration Approach. Using this approach, ambient water quality data are compared to the generic water quality guidelines. If the background values are less than the guideline, the guideline is used as the site-specific objective. If the background concentration exceeds the guideline, then the background concentration becomes the site-specific objective (Figure 2).

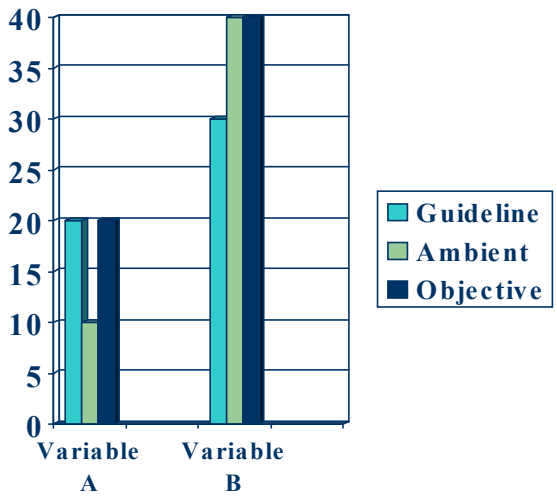


Figure 2: Examples of Developing a Water Quality Objective Using the Background Concentration Approach

Determining background concentration can be a challenge due to a number of factors including natural variability, storm events, and lack of historical data. Researchers have not reached consensus on whether it should be the 90th percentile, the 95th percentile, or the maximum concentration of the historic data set. In B.C., when the data have not been deemed satisfactory, the site-specific objective has been

established as being no allowable increase when going from upstream to downstream from an operation. To account for analytical precision and accuracy, the definition of no increase has been set at a maximum increase of 20%.

In other situations, when background data is unavailable due to impacts from human activities, it has been suggested that one could examine the water quality in nearby un-impacted watersheds to determine the background concentrations. Using the principle behind this concept, the Vancouver Island Region (VIR) began to expand this “paired watershed” approach to include all water bodies in an ecoregion. Since there are only eleven ecoregions in the VIR (see Figure 3) with over 60 individual community watersheds, this was deemed to be a manageable task.

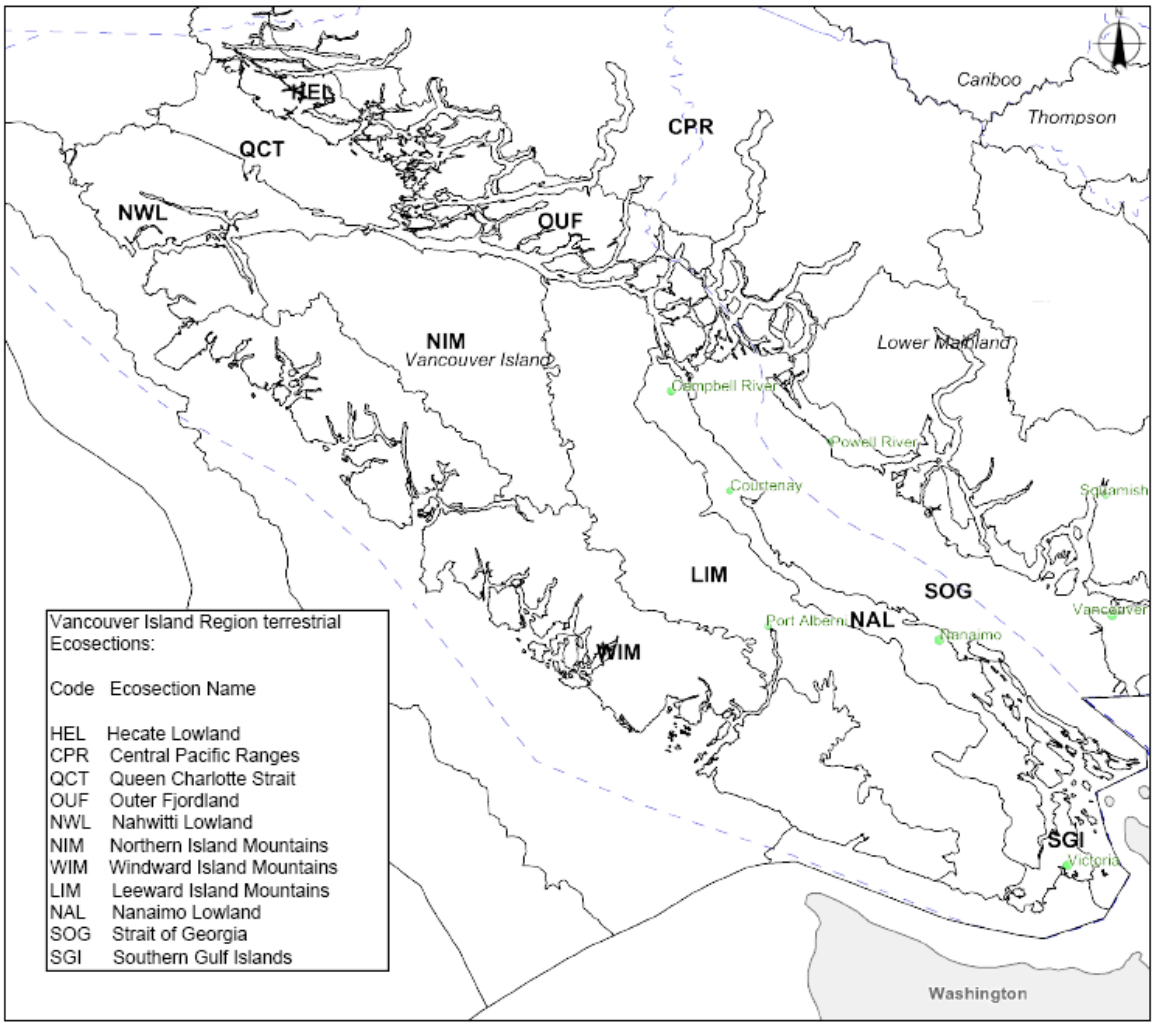


Figure 3: Vancouver Island Region Terrestrial Ecosections

2. Ecoregions– Definition and a Brief History

The Ecoregion Classification System was first adopted by the Wildlife Branch of B.C. MoE in 1985 in order to provide a systematic view of the small scale ecological relationships in B.C. (see several papers in References for Demarchi).

The Ecoregion Classification helps one understand and depict the great habitat diversity of the province. DeMarchi (1995) explains that B.C. has many ecosystems due to its varied physiography, climates, climatic history, and complex topography. The province's plants and animals are affected by that environment, as well as by historic factors such as the position of glaciers or other barriers to dispersal and

migration. The Ecoregion Classification is based on climatic processes and topography, and it brings into focus the extent of critical habitats and their relationship with adjacent areas. Within the Ecoregion Classification system areas with similar fundamental features can be grouped to simplify B.C.'s terrestrial and aquatic ecosystem complexity into discrete geographical units at five different levels (Table 1) (Demarchi 1996).

Each ecosystem is ultimately identified by sampling individual sites. At the lowest level in an ecosystem classification, attention is divided among specific parameters. For terrestrial sites, topography, surficial materials, soil development, moisture regime, microclimate, floristics, succession, productivity, and animal use are considered. For aquatic environments, parameters considered include water chemistry, geology, climate, bathymetry, substrate, morphology, and currents.

Table 1. Ecoregion Classification System (Demarchi 1996)

Ecodomain	Ecodivision	Ecoprovince	Ecoregion	Ecosection
				
An area of broad climatic uniformity for use in global environmental strategies	An area of broad climatic and physiographic uniformity for use in national state of the environment reporting.	An area with consistent climatic or oceanography, relief and regional landforms for use in provincial state of the environment reporting.	An area with major physiographic and minor macroclimatic variation for use in regional strategic planning.	Areas with minor physiographic and macroclimatic or oceanographic variations for resource emphasis and area planning.
——————————>				
Increasingly more detail				

2.1 Ecoregions in the Vancouver Island Region

Building on the Ecoregion Classification system and the principle that fundamental water quality in adjacent watersheds are very similar, the VIR has initiated an ecoregion approach to the development of water quality objectives. The ecoregion areas utilized by the VIR are in fact based on the ecosections developed by Demarchi (1995); however, for ease of communication with a wide range of stakeholders the term ecoregion, rather than ecosection, was adopted by Vancouver Island regional staff. Using this approach, VIR has been split into eleven terrestrial ecoregions, based on similar climate, geology, soils, hydrology etc. (see Figure 3). Due to a number of factors including accessibility and logistics, this work is initially limited to six ecoregions on Vancouver Island. (Figure 4)

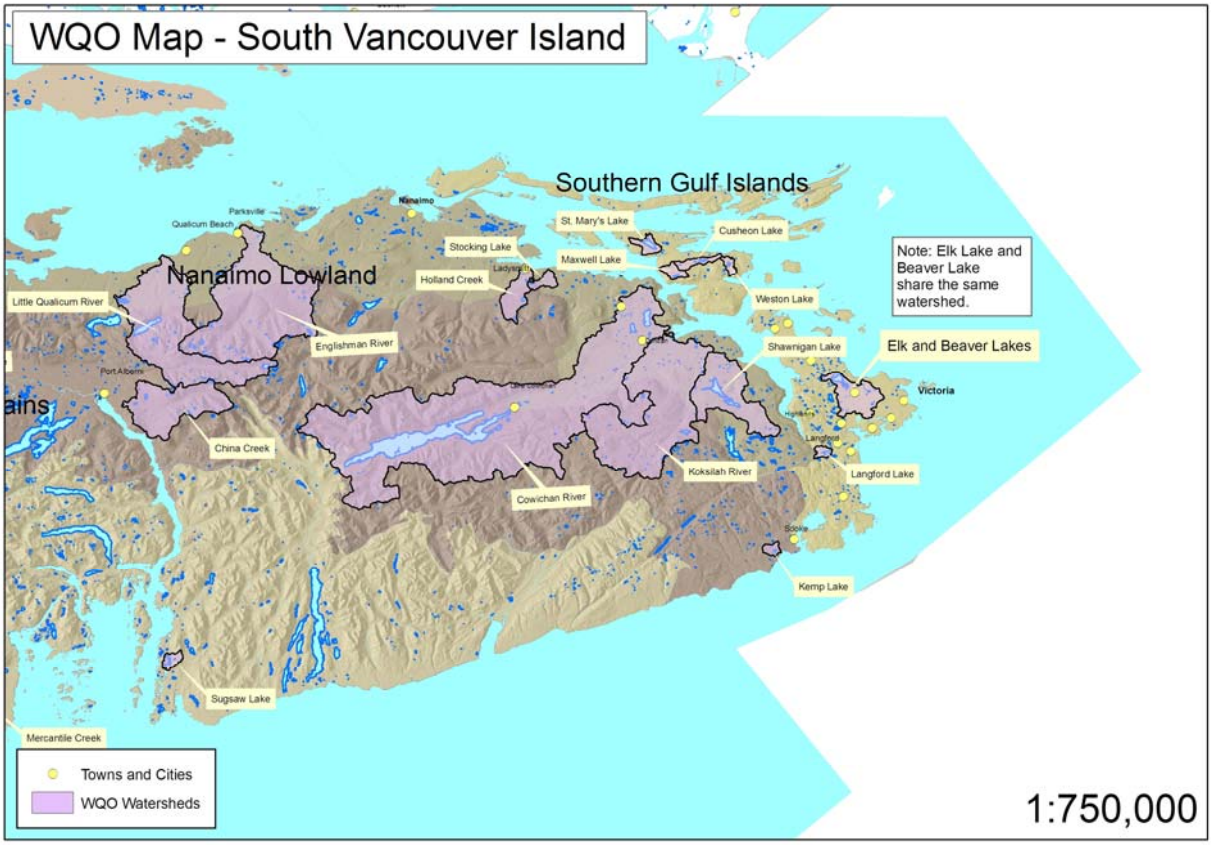
Figure 4. Overview of Vancouver Island terrestrial ecoregions (based on ecosection divisions in Demarchi (1996)).

Rather than developing water quality objectives for each individual waterbody, VIR has been working towards the long term goal of developing objectives for each ecoregion as a whole. Within each ecoregion, representative watersheds have been chosen and three year monitoring and assessment programs have been established with local partners. The program includes the collection of water quality (chemical and physical) and quantity data, as well as biological data. The data from the watersheds studied thus far (Figures 5-7) has been used to develop and verify the ecoregion based water quality objectives for all lakes and streams in that ecoregion. Over time, other priority watersheds within each ecoregion will be monitored for one year to verify the validity of the objectives developed for each ecoregion and to determine whether the objectives are being met for individual watersheds.

Figure 5: Northern Vancouver Island ecoregions and watersheds studied

Figure 6: Central Vancouver Island ecoregions and watersheds studied

Figure 7: Southern Vancouver Island ecoregions and watersheds studied



3. Theory for Using the Ecoregion Approach to Define Natural Background

The idea that water quality in nearby adjacent watersheds should be similar, assuming that all the factors cited for developing ecoregions apply, has been tested in several applications. To explore this further, three cases from the literature are examined in this section. A case study is also discussed, where this premise was used as a means to estimate the background concentration of a metal as a preliminary step to establishing site-specific water quality objectives.

A number of studies have shown that land-classification systems can be useful for identifying areas of relative homogeneity for water quality that varies according to predominant land type and present use. Larsen *et al.* (1988) delineated five ecological regions in Ohio to evaluate a framework for assessing attainable water quality in small streams. Variables measured by the researchers were total phosphorus, Kjeldahl nitrogen, nitrate, nitrite, ammonia, total organic carbon, specific conductivity, alkalinity, calcium, and magnesium. Multivariate classification of the streams based on their major ion chemistry and nutrient richness was performed. The authors found a correspondence between spatial patterns in water-quality variables and the delineated regions. This supported the hypothesis that regional differences in surface-water quality occur and that a land-classification system was useful for characterizing fundamental water-quality goals.

Rohm *et al.* (1987) studied fish, physical habitat and water quality in 22 streams in Arkansas. Ordination analysis of the data showed greater similarity in streams within the same ecological region than in streams from different ecological regions, again supporting the concept that fundamental water quality is similar within ecological regions. Water quality variables measured were ammonia, nitrate, nitrite, suspended solids, turbidity, ortho phosphate, total phosphorus, dissolved solids, chloride,

hardness, sulphate, specific conductivity, alkalinity, biochemical oxygen demand, dissolved oxygen and temperature.

Newsom (1993) tested the water quality of relatively un-impacted rivers and streams in three ecoregions in the Southern Interior Ecoprovince of B.C. Data for dissolved solids, alkalinity, hardness, ammonia and total phosphorus from September and October 1973 and 1974 were used in the evaluation. It was determined that mean concentrations were fairly similar among ecoregions, although the greatest variation in mean concentrations was for total phosphorus and dissolved solids. The use of the Kruskal-Wallis test identified that one of the variables was significantly related at the 95% confidence level while the other four variables had significant relationship at the 85% confidence level. Finally, potential sources of error in this analysis were suggested to be the use of a limited number of sites due to the use of an existing data set, sites potentially impacted by logging or farming, frequency of some sample collections, and finally, the age of the data and the fact that better analytical detection limits have been developed.

MacDonald (1997) provided evidence of how the natural background concentration approach can be used for adjacent and nearby water bodies when discussing the desire to establish site-specific water quality objectives for a contaminated watershed in Montana. In this case, the Upper Fork River, a tributary to the Columbia River, has had a great deal of historic mining activity. As a result, copper concentrations were deemed to be higher than background. It was not possible to establish a monitoring station upstream on the river to determine background copper levels. In an attempt to estimate background concentrations, a nearby reference site was established in an area with similar mineralogy. Data from this site indicated that background dissolved copper concentrations were in fact considerably lower than those in the Upper Fork River.

These studies illustrate that there is evidence that water quality in water bodies of similar mineralogy also can be similar. Incorporation of this scientific finding into existing methodologies may be a useful and efficient means to develop site-specific water quality objectives in relatively un-impacted water bodies on Vancouver Island, and in B.C.

4. Examples of Using the Ecoregion Approach

To further verify the validity of the ecoregion approach as it applies to VIR and other areas of B.C., this section compares water quality objectives of two different streams within the same ecoregion in each of the VIR and the Okanagan Region.

4.1 Vancouver Island Region

McKelvie Creek is located on Vancouver Island west from Campbell River. It is a second-order stream, 10.2 km in length, draining into the Tahsis River just north from the Village of Tahsis, B.C. on the west coast of Vancouver Island. McKelvie Creek falls within the Windward Island Mountains (WIM) eco-region.

McKelvie Creek has significant fisheries values, with steelhead present in the creek and likely a number of other species as well. The McKelvie Creek watershed consists of Crown Land located within TFL 19, which is managed by Pacific Forest Products. The watershed has the potential to support timber harvesting in the future and a hydroelectric producing dam. These activities, as well as natural erosion and the presence of wildlife, all potentially affect water quality in McKelvie Creek.

Water quality objectives have been developed for the community watershed portion of the creek using the background concentration approach. These are included in Table 2 below.

Table 2. Water Quality Objectives for McKelvie Creek

Variable	Objective Value
Fecal Coliform Bacteria	≤60 CFU/100 mL (90th percentile) [(1)]
Escherichia coli	≤60 CFU/100 mL (90th percentile) [(1]
Turbidity	2 NTU average [(1)]; 5 NTU maximum
Temperature	≤15^{o}C (long-term) with hourly rate of change ≤ 1^{o}C
True Colour	15 TCU maximum
Total Organic Carbon	4.0 mg/L maximum
Total Suspended Solids	25 mg/L maximum in a 24-hour period; 5 mg/L average [(1)]

[(1)] based on a minimum of five weekly samples collected over a 30-day period

To test that the use of an ecoregion approach is valid, we compared the water quality objectives developed for McKelvie Creek to monitoring data for Mercantile Creek, a nearby creek in the same ecoregion. Temperature values were not available for Mercantile Creek. For microbiological variables fecal coliforms and *E. coli*, there were four periods when five samples had been collected in a 30-day period. Three of the four sampling periods on Mercantile Creek would have achieved both the fecal coliform and *E. coli* objectives developed for McKelvie Creek.

For the suspended solids and turbidity, the five samples in 30 days requirement were not met in Mercantile Creek so that only maximum concentrations could be assessed. This sampling frequency is not needed to assess colour or total organic carbon concentrations relative to objectives. The following were the results:

Table 3. Maximum Concentrations in Mercantile Creek: 2002 – 2006

Variable	Number of Values	Maximum Concentration
True colour	1	10 TCU
Total Organic Carbon	2	3.3 mg/L
Suspended Solids	54	5 mg/L
Turbidity	36	2.6 NTU

This indicates that the objectives for McKelvie Creek appear to be appropriate for use in Mercantile Creek. All six of the tested variables met objectives, with the exception of one sampling period for fecal coliforms and *E. coli*; however, the assessment for McKelvie Creek indicated a similar problem with these two microbiological variables. .

4.2 Okanagan Region

There are a number of watersheds on the west shore of Okanagan Lake that have had extensive monitoring performed. Two of these watersheds, Powers and Lambly creeks, are adjacent to each other and are subject to minimal human activity. These two water bodies are in the Thompson-Okanagan Plateau Ecoregion and are in the Northern Okanagan Basin Ecosection. A preliminary report on Lambly Creek (Draft report, Mould Engineering, 2000) outlined some possible water quality objectives for that creek. To simplify discussion, minor modifications have been made to these (e.g. changed suggested objectives for turbid flow periods for turbidity from an average of 4.57 NTU to 5 NTU). The resulting possible objectives are in Table 4. In Table 5, we have then compared the possible Lambly Creek objectives to the data for two stations on Powers Creek.

Table 4. Possible Objectives for Lambly Creek

Variable	Objective Value
Fecal Coliform Bacteria	≤10 CFU/100 mL (90th percentile) (1)
Escherichia coli	≤10 CFU/100 mL (90th percentile) (1)
Turbidity	5NTU average (1) 25 NTU maximum during turbid flow periods; maximum of 3 NTU during clear flow periods
Temperature	rate of change not exceeding 1^{o}C
Total Suspended Solids	20 mg/L maximum in a 24-hour period during clear flows and 130 mg/L maximum during turbid flow periods; 5 mg/L average (1) during clear flow periods and 15 mg/L average during turbid flow periods

(1) based on a minimum of five weekly samples collected over a 30-day period

For microbiological variables fecal coliforms and *E. coli* at the Powers Creek downstream site, there were three periods when five samples had been collected in a 30-day period. For two of those three periods, the possible 90th percentile objective was met.

As is evident from Table 5, for the turbidity and suspended solids objectives, the possible Lambly Creek objectives (5 NTU mean turbidity and 130 mg/L maximum suspended solids) might be achieved at both stations in Powers Creek.

Table 5. Maximum Concentrations in Powers Creek: 1996 – 2001

Variable	Upstream Site		Downstream Site	
	Number of Values	**Maximum**	**Number of Values**	**Maximum**
Turbidity (NTU)	25	1.8	149	20
			Average	1.86
Suspended Solids (mg/L)	21	5	105	107
			Average	5

5. Discussion

5.1 Setting the Stage

The use of an ecoregion approach in watersheds with minimal human impact seems to be a reasonable, efficient and cost-effective means to developing site-specific water quality objectives. The province of B.C. is not alone in using this type of area-based planning approach for characterizing attainable water quality goals, as was illustrated by the four studies from the literature presented in this report. They show that water quality in water bodies of similar mineralogy also can be similar. The fundamental reasoning behind the ecoregion approach is that baseline water quality (physical, chemical and biological) will be similar in all watersheds within each ecoregion. The studies provide evidence that this principle can likely also be applied successfully in developing site-specific water quality objectives in relatively un-impacted water bodies on Vancouver Island, and potentially on a broader scale throughout B.C.

5.2 Examining Two B.C. Examples

Examination of both sets of the paired B.C. watersheds validated the principle that water quality objectives established for one of the watersheds could be applied to the other watershed in the pair with a fair degree of confidence. This has important cost implications for the future and is a good means of providing information in a planning context for Vancouver Island water bodies. It also provides further evidence that the concept could be effectively applied to ecoregions across all of B.C.

In the paired watershed comparison, using microbiological variables, it was shown that there was good correlation between the two pairs of adjacent water bodies when the Background Concentration Approach was used. This illustrates the applicability of the Background Concentration Approach for developing a water quality objective within the ecoregion approach.

5.3 Added Benefits to the Approach

Using the ecoregion approach, where only one watershed in an ecoregion is monitored for three years and only one water quality objectives report is developed, is a significant improvement over the traditional process of developing water quality objectives for individual water bodies. It means that once objectives exist in a given ecoregion, water bodies can be monitored on a rotational basis to determine attainment of objectives. This then allows for adaptive management by the region to take place (see Section 1). Thus, use of the ecoregion approach is one extremely important component of the business model used by the Vancouver Island Region.

The cost-effectiveness of the ecoregion approach is a significant improvement over traditional methods of developing water quality objectives. A longstanding challenge in developing site specific water quality objectives in B.C. is the intensive level of effort required to collect the data over three years, evaluate the data and to develop the water quality objectives. In summary, this effort could be in the order of $50,000 for the continuous measurement devices (installation costs and maintenance costs for personnel time, travel expenses, etc. being in addition). Laboratory costs over the three-year period are in the order of $5,000 to $10,000 per year, and finally there is a cost of up to $15,000 to $20,000 to prepare the actual assessment and objectives documents. Developing one set of water quality objectives that can be applied to other water bodies within the same ecoregion will significantly reduce the resources required for water quality objectives development.

The VIR has made the process more efficient and effective by developing monitoring and assessment partnerships with local stakeholders and groups. This links to Goal #3 in the Strategic Plan for the Environmental Protection Division (B.C. MoE 2008). The Region has been able to engage partners in specific routine monitoring

components within the water quality objectives development and attainment program, i.e., collection of discrete samples at regular frequencies. Regional staff train partners and conduct routine technical and safety audits to ensure high quality data. Regional staff continues to conduct specialized monitoring including continuous monitoring instrumentation, biomonitoring and sediment sampling.

The Region has further increased effectiveness by establishing core fundamental monitoring programs in all waterbodies sampled. This ensures that all water bodies are sampled at the same sampling frequency, on similar timing, and for the same core set of variables. This applies to both monitoring to develop objectives and to determine attainment of objectives, and allows for maximum comparability and consistency when comparing data from year-to-year, watershed-to-watershed or ecoregion-to-ecoregion. Over the long term, this will contribute to the use of the data in other work:

- For data analyses that may be needed such as identifying the impacts from widespread concerns such as climate change;
- For data collection on additional variables such as metals, DOC, nutrients that are also monitored to complete a more thorough water quality assessment. (Development of objectives for these parameters are deferred unless warranted by activities within a given water body);
- To examine the effects of ultra violet light (UV sensitivity Index) in a number of water bodies;
- To develop a map to indicate areas of potential concern regarding disinfection by-products formation in drinking water due to chlorination;
- To allow for more power and leverage in trend detection and impact assessment interpretation; and
- For incorporating biological objectives into water quality objectives. Vancouver Island Region has targeted the year 2010 for the integration of

biological monitoring into this work. This is seen as an ideal companion piece to the ecoregion approach.

Looking ahead, the Vancouver Island Region will examine whether several ecoregions may be combined based on fundamental water quality, so that several water bodies in different ecoregions can be managed using one common set of water quality objectives. Such a finding could be important due to accessibility logistics in some of the remaining ecoregions on Vancouver Island, an issue common to much of B.C.

Finally, it must be acknowledged that, where large human developments such as mines are proposed or are present, other more expensive but site-relevant procedures may need to be undertaken by proponents to develop defensible water quality objectives. Even in those situations, it may be possible to use more detailed results from one watershed to others in the same ecoregion. For many areas of B.C., including Vancouver Island, the dominant issue is often urban development and population growth (i.e. with associated non-point source pollution). In such cases, the background concentration approach to developing water quality objectives in combination with the ecoregion approach may be an ideal method for assessing the cumulative effects from urbanization, agriculture, logging, and other issues. This has long been acknowledged in the scientific community and in no way detracts from the use of the ecoregion approach as a defensible first-estimate of a site-specific objective that can be broadly applied.

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