Coast Region

Environmental Protection Division

Environmental Sustainability and
Strategic Policy Division

Ministry of Environment

Phosphorous Management in Vancouver Island Streams

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Executive Summary

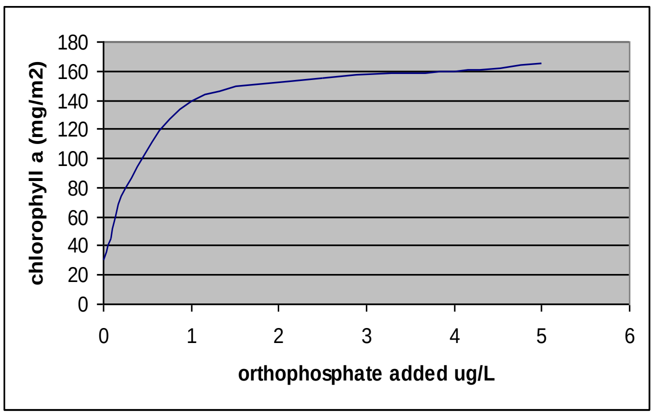
This document gives guidance on management of in-stream phosphorous on Vancouver Island, with the intent of limiting and preventing excessive nutrient input and subsequent environmental impact. It is intended for local governments, developers, consultants and other Ministry staff. Phosphorous is essential to primary productivity in streams, but at levels even slightly higher than background can cause excessive algal growth and a number of associated impacts to the health of streams and their resources. Rainwater runoff and groundwater inflow from land development, agriculture, failing septic fields and treated sewage effluent discharges are leading sources of phosphorous in urban and rural residentially developed areas. With a high rate of population growth on Vancouver Island, where the very low stream flows in the summer make streams extremely sensitive to phosphorous pollution, it is vital to manage phosphorous inputs into streams. To address this challenge, a Vancouver Island phosphorous objective was developed to protect Vancouver Island streams using area specific data: **May to September total phosphorous average, with samples collected monthly, should not exceed 5 µg/L, and maximum total phosphorous should not exceed 10 µg/L in any one sample.** This objective should be used in proactive area-based planning by stakeholders in watersheds to ensure phosphorous is managed at all possible sources. A professionally derived phosphorous loading estimate, that ensures the objective is met, should be included on a site specific basis. Specifications around a phosphorous objective can be incorporated into development of Liquid Waste Management Plans and Environmental Impact Studies. Best management practices should be developed for a given land use in conjunction with water quality monitoring and education and awareness programs. Wider assessments of ecological health such as stream benthic invertebrate monitoring should be incorporated into stream monitoring.

Introduction

Phosphorous is an essential nutrient supporting primary productivity (algal growth) in streams. Algal growth in turn determines stream insect abundance and ultimately the fisheries resources. Coastal ecosystems in British Columbia (BC) are naturally low in nutrients and are typically phosphorous limited. This is exemplified on Vancouver Island, where thin unproductive soils and high precipitation result in very low nutrient levels in streams. Background stream nutrient concentrations on Vancouver Island confirm, with few exceptions, that phosphorus is the critical limiting nutrient.

Algae in phosphorous-limited west coast streams have evolved to be very efficient in using phosphorous. Small amounts of phosphorus from natural or manmade sources are quickly utilized and can result in significant increases in algal growth. At relatively low levels, this is actually of benefit to the stream ecosystem and the fisheries resource. However, at only slightly higher levels of phosphorus, the rapid response and accumulation of algal biomass (Figure 1) can rapidly lead to negative impacts. Excessive algae in streams can irritate fish gills, consume oxygen in the streams, smother spawning gravels, alter insect abundance and diversity, and limit recreational use of streams, while leading to taste and odour issues that can adversely affect potable water quality. Thus, maintenance of relatively low phosphorous conditions is important to maintaining the healthy condition of streams for all users of the resource.

Figure 1 – Impacts of decreased phosphorous loading based on data from Bothwell *et al.* (1992).



Phosphorous uptake and release by biological organisms is complex and dependant on the interaction of factors such as stream temperature, depth, width, current, substrate and light exposure. It can be difficult to determine what level of nutrient enrichment impacts will result from a measureable level of available phosphorous. Defining safe or acceptable levels of phosphorous in streams requires an understanding of regionally specific stream characteristics that affect the response of nutrient loading in streams.

BC is geographically diverse, with many different ecoregions and stream types, making it extremely difficult to develop provincial guidelines for phosphorous in streams. As a result, no BC Water Quality Guideline has been developed for phosphorous in streams, despite its role in determining stream productivity and potential negative impact on stream health. Rather, chlorophyll "*a*", a photosynthetic pigment in algae, has been used as a measure of algal biomass to determine nutrient enrichment impacts in streams.

As a measure of algal biomass, chlorophyll "*a*" addresses the symptom, rather than the cause, of the enrichment. By measuring the symptom or response it is difficult to establish a preventative approach to nutrient enrichment. Using phosphorous (the cause) as a measure is possible if regionally specific information is available for areas with similar stream characteristics. Incorporating such an objective into area-based (focusing on the whole watershed) plans or local bylaws can help limit phosphorous levels in streams, while protecting fundamental ecosystem health.

This document explains how the phosphorous objective for Vancouver Island was derived and gives guidance on management of in-stream phosphorous on Vancouver Island, with the intent of limiting and preventing excessive nutrient input and environmental impact. It is intended for use by local governments (e.g. Regional Districts), developers, consultants and Ministry staff for use in Environmental Impact Studies and area-based planning. This document explains the need for phosphorous management in Vancouver Island streams and provides the following information to assist in phosphorous management:

- Summary of the drivers behind the need for regionally specific phosphorous objective;
- Summary of the development of a phosphorous objective for Vancouver Island streams;
- Direction on monitoring for phosphorous and sampling program design;
- Direction on how such an objective can be implemented by local governments;
- Direction on management programs for phosphorous; and,
- Resources/links to assist in phosphorous management.

Drivers

Regionally Specific

On Vancouver Island, streams tend to be shorter and shallower than those on mainland BC. Summer stream conditions on Vancouver Island are typically warm, clear, relatively shallow, slow moving, with low flow and with stable substrate. Natural or baseline total phosphorous levels are virtually undetectable through the summer, typically at or less than 2 µg/L. These streams are so phosphorous limited that, with reduced salmon returns providing less natural sourced phosphorous to streams, there is an ongoing program of controlled, low level stream fertilization in many Vancouver Island streams as a fisheries restoration tool.

Ecoregions

For efficiency in water quality management, Vancouver Island has been divided into smaller regions (termed *ecoregions*) with similar soil, geology, vegetative cover, precipitation, slope …etc. These and other terrestrial features greatly influence water chemistry. It is recognized that different phosphorous limits may be recommended on a site specific basis. This document considers all ecoregions on Vancouver Island, though the focus is on what are called the

Nanaimo Lowlands and Southern Gulf Islands ecoregions, areas that, when combined, cover the south and east coast of Vancouver Island from Port Renfrew south to Victoria and north to Campbell River. This is where most development pressure presents risk to stream water quality.

Phosphorous Management

Traditional or historical phosphorous management focused on older municipal sewage treatment plant discharges, the "big pipes". These discharges to streams generally had secondary treatment, no nutrient removal and, with population growth, received larger volumes of effluent. As a result, phosphorous became a significant issue in a number of east coast Vancouver Island streams, resulting in BC Water Quality Guideline exceedences for chlorophyll "*a*". Various site specific solutions to these problems have been adopted by different local governments, mainly involving changes to effluent treatment, in some cases specifying phosphorous loading limits for effluent receiving water bodies, and working to ensure limited increases in phosphorous at the edge of the initial dilution zone (as defined in the Municipal Wastewater Regulation (MWR)). Impacts from the majority of these sources have been reduced or eliminated, while others are progressing towards long term solutions.

Seasonality

Phosphorous is generally only of concern during the summer months from approximately May through the end of September. This is the time of year when streams are at their lowest flows, resulting in higher phosphorous concentrations and higher water clarity. Combined with high summer temperatures and more hours of daylight, these influences make this the period that streams are at the highest risk for degradation of salmonid habitat, ecological disruption and aesthetic impacts due to algal growth.

Today's Challenges

While sources such as agricultural activities and aging septic systems need to be addressed in some areas, population growth and urban development have become the dominant source of nutrient enrichment in many Vancouver Island streams. Much of the south and east coast of Vancouver Island is under significant development pressure. Many recent development proposals are relatively large, potentially housing in excess of 5000 people and include semi rural developments outside of municipal boundaries.

Stream Augmentation

In many new developments, proponents are faced with the challenge of a limited water supply to meet water consumption demands, which leads to water storage for summer use. This further causes difficulties in managing wastewater disposal in small, but highly sensitive, fish bearing streams, particularly during the summer months. With low stream flows in the summer, stream augmentation using treated wastewater can appear to be a solution to wastewater disposal. While Vancouver Island streams do need more water (see Vancouver Island watershed allocation plans at http://www.env.gov.bc.ca/wsd/water_rights/wap/) during the summer months, it must be extremely low in nutrients given the typical lack of dilution water. Solving wastewater disposal challenges can be a difficult fit under existing regulations like the MWR which sets minimum standards for discharges.

Non Point Source Pollution

Another consideration in both new and existing developments is phosphorous inputs from non point source pollution, including storm water runoff, land disturbance and riparian removal/change. In agricultural areas, non point source pollution includes runoff from fertilized fields or livestock areas. Non point source pollution is defined as pollution which cannot be traced back to a single origin or source. As a result, this type of pollution is not easily regulated in BC, despite the fact that many regulations, policies, programs and guidelines regarding non point source pollution exist.

Cumulative Effects

Cumulative effects are defined as changes to the environment that are caused by an action in combination with other past, present or future human actions. While each action alone may seem to have a negligible impact, combined they can reach the carrying capacity of the environment to assimilate contaminants. As they are subtle, gradual and come from many small sources, changes from cumulative effects are elusive and not easily regulated.

Increasing pressure on water resources necessitates a preventative rather than a reactive approach to nutrient enrichment in streams. Cumulative effects of various impacts to water quality, including wastewater discharges, non point source pollution and changes in hydrology associated with development, need to be managed at the source before downstream water quality is affected. Addressing the cause (upstream) rather than measuring the response (downstream) is a more efficient and effective approach, and should allow us to reach our goal of having high quality streams for all users (including aquatic life, recreational use, drinking water and irrigation). In streams with excessive nutrient supply the goal is to reduce nutrients to levels that support the food chain without causing excessive algal growth or stream impairment.

Public and Government Expectations

The public has very high expectations that stream health will be protected and maintained on Vancouver Island. The geography and relatively high population of Vancouver Island is such that the public has a strong connection to our streams. In response to concerns about deterioration of stream water quality on Vancouver Island due to nutrient inputs, the West Coast Region of the Ministry of Environment (MOE) did an analysis of the issue with the goal of proposing a water quality objective for phosphorous.

A phosphorous objective for streams on Vancouver Island provides a regionally specific, measureable target for Ministry staff and stakeholders. MOE can work with stakeholders to develop proactive, area-based plans from an ecosystem perspective. This addresses problems at the source and, through limiting phosphorous, ideally minimizes nutrient enrichment effects downstream. A phosphorous objective harmonizes with development of site specific water quality objectives and biological monitoring. With this harmonized approach regional MOE staff can be more effective and efficient when working with cumulative effects from land use issues, existing discharges, Liquid Waste Management Plan guidance and new proposals under the MWR, while ensuring a consistent regional approach.

Vancouver Island Phosphorous Objective

Approach

MOE's approach to developing a phosphorous objective for Vancouver Island involved three components: a review of existing scientific literature, a summary and interpretation of existing water quality data (up to and including 2008) for streams on Vancouver Island, and a workshop convened in January 2009 where technical aspects of guidelines and options for establishing objectives were discussed by a panel of experts. This work was lead by Rick Nordin and an internal report "*A phosphorus guideline for Vancouver Island Streams*" (Nordin, 2009) was produced summarizing theory behind nutrient/algal relationships, methodologies used for developing phosphorous objectives/guidelines in other jurisdictions, existing Vancouver Island data and the conclusions of the workshop panel.

Phosphorous

Existing Vancouver Island data showed an inconsistent relationship between phosphorous and chlorophyll "*a*", suggesting that chlorophyll "*a*" should not be used to help define an acceptable limit of phosphorous. Phosphorus comes in several forms, including total phosphorous, dissolved phosphorous and soluble reactive phosphorous or orthophosphate. Several factors were considered to determine what form of phosphorous to use. Key factors were that soluble reactive phosphorous values were more often below minimum detection limits (due to the high metabolic demand for it by biological organisms), that it is harder to get an accurate measure of low levels of soluble reactive phosphorous as it is almost instantaneously taken up by biological organisms (thus its presence nearly always indicates excess amount or limitation of growth by some other factor), and that total dissolved phosphorous and total phosphorous were virtually the same for all Vancouver Island streams. For these reasons, and because MOE had more above detection limit total phosphorus data available for review, total phosphorus was considered to be the parameter most appropriate for use as an objective.

Literature

Methods for development of phosphorous guidelines for other jurisdictions were evaluated for comparison and for applicability in the Vancouver Island scenario. Percentile calculations most commonly used by most jurisdictions were considered, for example:

- United States Environmental Protection Agency (USEPA) – reference condition approach 3 possible methods: 1) characterize reference reaches and use professional judgement, 2) 75th percentile of reference condition streams, or 3) 5th to 25th percentile of all sites
- Canadian Council for Ministers of the Environment (CCME) – 25th percentile of a set of streams (test and reference) then add a safety factor
- New Zealand –75th percentile of a set of background sites (modified USEPA)
- Australia – 80th percentile of undisturbed reference sites

Vancouver Island Phosphorous Objective Development

The Vancouver Island existing data was comprised of data from MOE and data from the British Columbia Conservation Foundation (BCCF) stream fertilization program. From this, three main datasets were considered, using growing season data (May through September) only, and the various methodologies for guideline development from other jurisdictions were tested on these data. As the Vancouver Island data included abundant reference condition sites, the 75th percentile calculation was deemed most appropriate for determining a phosphorous limit. The calculation results are noted below.

- (Dataset 1) The MOE 2008 Index of Benthic Invertebrate (IBI) data set included data from 15 reference sites from across Vancouver Island. Late summer total phosphorous at these background sites ranged from <2-10 µg/L, and averaged 4.7 µg/L, with a 75th percentile value of 5.5 µg/L.

- (Dataset 2) Other MOE water quality data from 86 reference and 93 test (impacted) sites were also analyzed. The 75th percentile for the entire reference site data set was 5.0 µg/L.

- (Dataset 3) The BCCF data set included 73 sites as part of their nutrient addition project (fisheries enhancement). The project recommended adding phosphorous to phosphorous limited (<1 µg/L total phosphorous) streams to bring levels up to a target of 2.5 µg/L based on flow rates and release time. The small phosphorous amounts added at these phosphorous limited streams were found to be very rapidly taken up by algae. The 75th percentile of the background phosphorous data was 4.0 µg/L.

- The 75th percentile of all of the above reference data was 5.0 µg/L. Calculations for individual reference sites were examined, and the 75th percentile of all of the reference site averages was 5.2 µg/L. It was concluded that an average collected during the growing season (May to September) was the most appropriate measure for determining phosphorous exceedences at individual sites. The 75th percentile of only the maximum values for each watershed was 10 µg/L.

While there is some natural variability through the summer growing season, it is generally of limited duration and magnitude. The data suggested that a reasonable approach would be to incorporate an average seasonal phosphorous concentration of 5 µg/L as an appropriate limit to protect water quality in Vancouver Island streams, further supported by a maximum seasonal objective of 10 µg/L to limit occasional short term increases in phosphorous. It was determined that a water quality objective for phosphorous should apply from May through September, the time period during which streams are most susceptible to degradation from excessive phosphorous inputs.

Thus, the recommended objective is that, on Vancouver Island, the growing season average of monthly total phosphorous samples collected between May and September (growing season) should not exceed 5 µg/L and the growing season maximum total phosphorous value should not exceed 10 µg/L.

Phosphorous Loading and Land Use

A phosphorous objective is only a starting point for management of phosphorus in streams. The use of a phosphorous objective necessitates that nutrient budgets be developed for Vancouver Island streams. Land use changes can cause nutrient loading and subsequent phosphorous increases in streams, and should be critically and thoroughly evaluated in planning and approval decisions. Though much of the background data for such protocols have not been collected on Vancouver Island, an effort should be made to do so with the following considerations:

Calculated (theoretical) Nutrient Budget

Nutrient budgets (relating land use and nutrient loading) should be prepared for streams on a site specific basis, taking into consideration all existing and proposed land uses both upstream and downstream of the site in question. Key components to a nutrient budget include watershed phosphorus export coefficients, soil retention calculations, topography and precipitation, including for the season during which the worst case impacts occur (summer). These and other factors are used to accurately estimate phosphorus concentration changes that would occur due to the land use changes proposed. From the nutrient budget, a watershed phosphorous loading estimate can be determined. Anthropogenic phosphorous sources in the watershed should be limited so as to not exceed the phosphorous loading estimate. Development of the nutrient budget and loading estimate must be completed by a licensed qualified professional and should include the participation of a soil scientist and a hydrogeologist to evaluate the generation, movement, absorption and transfer of nutrients through the soil to surface water streams.

Measured (field-checked) Nutrients

A calculated phosphorous concentration objective implemented with a phosphorous loading estimate is, in effect, a projection or model of what will occur in a given stream. Laboratory results from a grab sample taken from that stream to measure instantaneous phosphorous concentration should be considered relative to a number of unknowns, such as what the biological uptake by algae was in the stream.

A professionally derived watershed phosphorous loading estimate should be developed which will result in instantaneous stream phosphorus concentrations meeting the maximum (10 µg/L) and average (5 µg/L) May – September objective in Vancouver Island streams.

Biomonitoring

To strengthen the link between nutrients and biotic responses, biomonitoring tools need to be included in monitoring programs. Biomonitoring provides information on what is actually happening with the organisms living in the stream, can validate the results of other sampling parameters and provides a scientifically defensible and nationally accepted assessment protocol. **Thus, the phosphorous objective should also be complemented with wider assessments of ecological health such as benthic macro invertebrate community analysis (e.g. Canadian Aquatic Biomonitoring Network (CABIN)).**

Phosphorous Monitoring

Where there is a proposed discharge to the freshwater aquatic environment or potential for non-point source impacts to occur via runoff or groundwater inflow, the following should be considered as part of a basic phosphorous monitoring plan:

Background

Establishment of baseline phosphorous levels is an important component of a phosphorous monitoring program. In many cases true background does not exist because of long-present anthropogenic influences in the watershed. In these cases, upstream levels must be considered and comparisons made to nearby watersheds within the same ecoregion. Some professional judgment may have to be made regarding typical background values.

Associated Parameters

Total phosphorous is better understood when considered with other parameters with which it is typically associated or by which it may be influenced. Sampling could also include the following: nitrogen (ammonia, nitrate, nitrite,), other forms of phosphorous (orthophosphate, total dissolved phosphorous), chlorophyll "*a*", turbidity, total suspended solids, temperature and *Escherichia coli.*

Seasonal

As a minimum, mid monthly monitoring between May 1st and September 30th should be completed to ensure appropriate data for determining maximum and average total phosphorus concentrations.

Length of Study

Annual monitoring programs can assess water quality status and trends. A sampling program is an iterative process; for example, if the first several years of sampling indicate no trends or concerns, the sampling program may be minimized (as approved by the Ministry) or repeated periodically.

Implementation

Legislation

For the phosphorous objective to be most useful in protecting the environment it must be implemented such that there is a feedback loop with which to ensure maintenance or improvement to environmental health. For dischargers under the MWR, there are requirements to complete an Environmental Impact Study as part of the pre-registration process. For local governments developing Liquid Waste Management Plans under the Environmental Management Act, there are minimum standards set under the MWR to protect water quality that are used to ensure plans are consistent with the Ministry's long-term environmental management objectives. Liquid Waste Management Plans include commitments from parties involved, an implementation schedule and a plan monitoring component. This enables those affected by, or required to carry out, the provisions to determine their impact. **Specifications around phosphorous management and a phosphorous objective can be incorporated into MWR registrations and incorporated into Liquid Waste Management Planning.**

Public Education

Raising awareness of an issue can be an effective way to enhance public participation in activities to reduce the problem. Implementing measures to educate the public is recommended in any plan for reducing phosphorous inputs to the environment.

Management Programs

As phosphorous often comes from non point sources, managing phosphorous in a given watershed often requires an area-based approach. **Best management practices can be developed for a given land use in conjunction with water quality monitoring and an education and awareness program.** If considered background, upstream phosphorous levels can be used to determine what phosphorous levels may be feasible to reach within a given watershed; if there are upstream impacts then upstream levels can be a short-term goal for phosphorous reduction, with ecoregion background levels as a longer-term goal.

There are many resources available for best management practices guidelines around development. The most recent best management practices document produced by the BC MOE is called Develop with Care, and has a section specific to Vancouver Island. This is intended to assist people who are involved in planning, implementing and reviewing and/or approving land developments in British Columbia's urban and rural areas. Its primary purpose is to provide province-wide guidelines for the maintenance of environmental values during the development of urban and rural lands. It also provides information on ways that environmental protection and stewardship can benefit the community, the property owner and the developer, as well as the natural environment.

Resources/links

Develop with Care:
http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare2006/develop_with_care_intro.html
Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in BC
http://www.waterbucket.ca/rm/?sid=44&id=330&type=single
MOE Water Quality Protection documents:
http://www.env.gov.bc.ca/wat/wq/wq_protection.html
MOE Municipal Liquid Waste information
http://www2.gov.bc.ca/gov/theme.page?id=1D1E3C96BFEE11B9960E8FFEC5AF406A

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