Comox Lake Watershed Protection Plan

Comox Valley
REGIONAL DISTRICT

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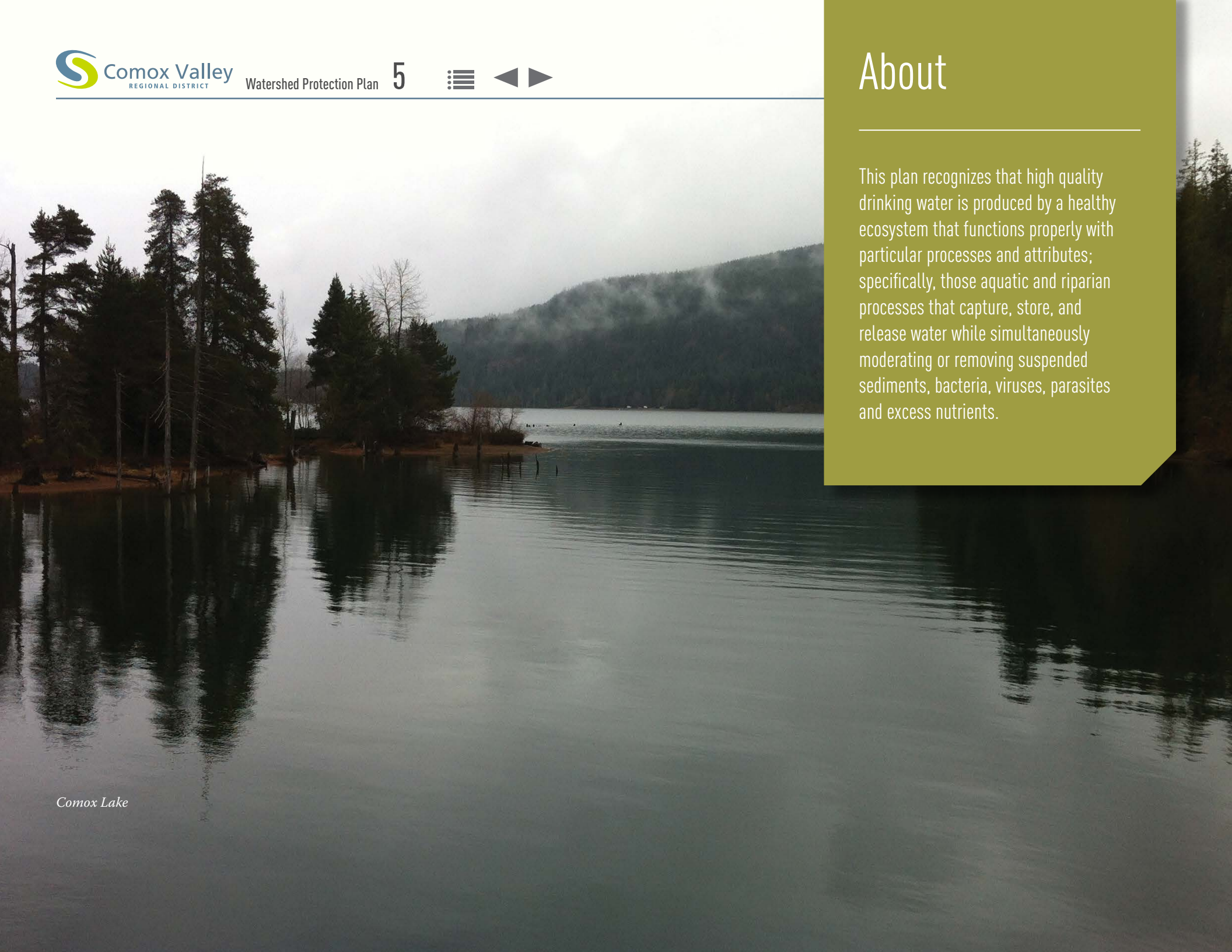
About

This plan recognizes that high quality drinking water is produced by a healthy ecosystem that functions properly with particular processes and attributes; specifically, those aquatic and riparian processes that capture, store, and release water while simultaneously moderating or removing suspended sediments, bacteria, viruses, parasites and excess nutrients.



Comox Lake

Executive Summary

Comox Lake supplies the Comox Valley Regional District with its main source of drinking water. The objective of this Watershed Protection Plan is to guide the management of the Comox Lake Watershed for the long-term protection of drinking water at the highest possible quality. The plan was developed in close consultation with the Comox Lake Watershed Advisory Group which is comprised of land-owners, regulators and technical advisors. A risk assessment was conducted to update both natural and human-caused risks in the context of a deep-water intake in Comox Lake. This assessment formed the basis of fifty-four recommendations that are intended to act as a road map to a comprehensive watershed management program.

After considering protective barriers already in place, the hazards that posed the greatest risks to water quality were:

Very High Risk Rating

- Camping in undesignated areas in the watershed, especially near the lakeshore or other riparian areas
- Augmentation/concentration of streamflows
- Wildfire
- Off Road Vehicle use (ATV's, side-by-sides, dirt bikes, snowmobiles) off of maintained roads
- Flooding on the order of a 100- to 200- year event

High Risk Rating

- Drought
- Intentional harm to the water source or watershed
- Earthquake resulting in the loss of the BC Hydro Dam
- Aircraft accident on Comox Lake
- Sewage management facilities
- Body contact recreation on Comox Lake (parasites and viruses)
- Trails and non-motorized trail use (hiking, mountain biking, horse riding, cross-country skiing and snowshoeing)
- Timber harvesting- cutblock location and extent
- Wildlife contamination of Comox Lake

Comox Lake

Key Recommendations:

- The CVRD should dedicate the resources required to support implementation of the Watershed Protection Plan. A full time watershed protection coordinator should be hired to oversee the implementation of the plan.
- A comprehensive water quality monitoring program should be developed and implemented which includes both the lake and major tributaries. A robust monitoring program to fill data and knowledge gaps, and allow for proper resource allocation to address any concerns, is a top priority.
- Should land be available for sale within the Comox Lake Watershed, the CVRD should purchase the land to gain additional control over its water supply. Priority should be given to those portions of land within the Village of Cumberland that are not within the CVRD's zoning jurisdiction and any properties that directly border Comox Lake.
- Additional disinfection should be installed to reduce the risk of pathogens from body contact recreation (*e.g.* swimming, watersports) and other human sources.
- All available information pertaining to the Comox Lake Watershed should be gathered, indexed and maintained by the CVRD.
- A trail management plan should be developed and enforced for all existing trails.
- The Watershed Advisory Group should meet at least semi-annually and continue to advise and support the implementation and adaptation of the Watershed Protection Plan.
- No new development, including highway development, should occur in the Comox Lake Watershed.
- Camping outside of designated campgrounds should not be permitted in the watershed. In addition to garbage and human waste posing a health risk, wildfire risk is a concern.
- ATV use should be limited to maintained logging roads and subject to code of conduct, enforcement and user agreements with landowners.
- Forestry companies should continue to provide annual updates to the CVRD on their proposed forestry plans, innovations and updates to practices.
- As recommended by the Regional Water Supply Strategy, the Village of Cumberland and Royston should join the Comox Valley Water System.
- An education and outreach program should be implemented for the local community and visitors relating to watershed health and drinking water source protection.

Introduction

A clean, safe and plentiful supply of drinking water is taken for granted by most people on Vancouver Island. In generations past, obtaining water was a matter of dipping a bucket into a nearby stream, or digging a well and installing a hand pump. Knowledge of water-borne disease was low, and running out of water would have been considered unthinkable. Today we rely upon bulk water delivery via reservoirs, pipes, valves, and pumps to service individual homes and businesses. As the population grows and more demands are placed on the land base, the chances of encountering disease-causing organisms increases. A changing climate has made rain and snowfall less predictable, and more people are placing a greater demand on the available water supply. Running out of clean water is now a very real possibility.

Comox Valley residents are fortunate to have Comox Lake as a drinking water source. It is fed by headwater streams and the Comox Glacier, and most of the watershed is undeveloped. While it may seem that the supply of drinking water offered by Comox Lake far exceeds the needs of the population, there are other important demands placed on the water supply including hydro-electric power generation and fisheries flows which must also be considered. As a changing climate makes rainfall and snow pack less predictable, the Comox Glacier continues to recede, and the population of the Comox Valley increases, water quantity will be an important consideration alongside water quality.

Fortunately, though our supply of water is finite, we are beginning to understand the precious nature of freshwater on Vancouver Island and learning to use it more wisely. At a technical level, our understanding of water-borne disease, microbial ecology, treatment and disinfection methods, and water safety planning has markedly improved in the last few decades. The value of landscape-scale watershed management is being recognized. We understand the risks of not managing our water and watersheds properly. The challenge is to help the general public understand the modern complexity of delivering enough safe water. It is no longer as simple as dipping a bucket into a stream.

Creeks and Communities workshop

Objective of the Plan

The objective of the Watershed Protection Plan is to guide the management of the Comox Lake Watershed for the long-term protection of drinking water at the highest possible quality.

Vision

"Working through the Watershed Advisory Group, the CVRD will ensure that water resources and ecosystem function within the Comox Lake Watershed are protected in order to provide a high quality, sustainable drinking water supply."

Underlying Principles

This Watershed Protection Plan is founded on several complementary underlying principles:

It is a plan focused specifically on drinking water. While there are many other values within the Comox Lake Watershed, drinking water quality is the priority of this plan.

This plan recognizes that high quality drinking water is produced by a healthy ecosystem that functions properly with particular processes and attributes; specifically, those aquatic and riparian processes that capture, store, and release water while simultaneously moderating or removing suspended sediments, bacteria, viruses, parasites and excess nutrients. (see Proper Functioning Condition)

This plan relies on current science, much of which has evolved substantially in the last decade, to inform the concept of "safe" and "healthy" water supplies. (see Drinking Water Safety Plans)

This plan acknowledges that people are a part of the Comox Lake Watershed and seeks to manage the risks associated with their activities.

The plan is intended to be a living document that is periodically amended and updated.

Awareness

A "source-to-tap" approach to managing drinking water starts with an understanding of the water supply area and its ecology, an identification of the hazards, and an assessment of risks to water quality.

Water quality monitoring

Proper Functioning Condition

Proper Functioning Condition (PFC)[1] is both an assessment method and a term used to describe a riparian-wetland area which possesses the ability to:

- Dissipate stream energy associated with high water flow, thereby reducing erosion and improving water quality;
- Filter sediment, capture bedload, and aid floodplain development;
- Improve flood-water retention and ground-water recharge;
- Develop root masses that stabilize streambanks against cutting action;
- Develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding and other uses;
- Support greater biodiversity.

These components are in order relative to how processes work on the ground. The underlying principle is that if the streams that provide water to Comox Lake are healthy, the lake will be healthy and the water quality will be high, provided other uses of the lake do not reduce water quality.

Drinking Water Safety Plans

The concept of drinking water safety has undergone significant change over the last several years. "Traditionally, the regulatory approach to maintaining the quality and safety of drinking water has largely been a prescriptive one, based on the ability of any given supply to meet standards set for a number of different chemical or biological parameters. In Canada this legislation is the Guidelines for Canadian Drinking Water Quality. Drinking Water Safety Plans (DWSPs) provide a proactive method of dealing with risk which better protects Public Health[2]."

DWSPs rely on four principal processes:

- Collecting and collating the best information possible about the water supply system;
- Analysing and understanding the risks that are present and that in certain circumstances will threaten the safety of water customers;
- Assessing correctly what needs to be done to reduce these risks to an acceptable level; and
- Determining how to obtain the resources necessary to do this, how to prioritise and audit the identified tasks and how to deliver the actions within the required timescale.

This Watershed Protection Plan addresses these four processes as they apply to the watershed and raw water supply (source water protection).

What is a Watershed?

A watershed is an area of land where all the water that is under it or drains off it, goes to the same place. Watersheds are sometimes referred to as catchment areas or drainage basins.

A watershed is typically made up of an interconnected network of streams, wetlands, lakes and ponds. Streams near the top of the watershed, called "headwater streams", have a smaller drainage area and therefore receive less water and are smaller than streams nearer the outlet of a watershed.

Large watersheds, such as the Comox Lake Watershed, are made up of a series of smaller watersheds or "sub-watersheds". The Cruickshank watershed, Perseverance Creek watershed, Upper Puntledge River watershed, Beech Creek watershed and Pearce Creek watershed are examples of sub-watersheds in the larger Comox Lake Watershed.

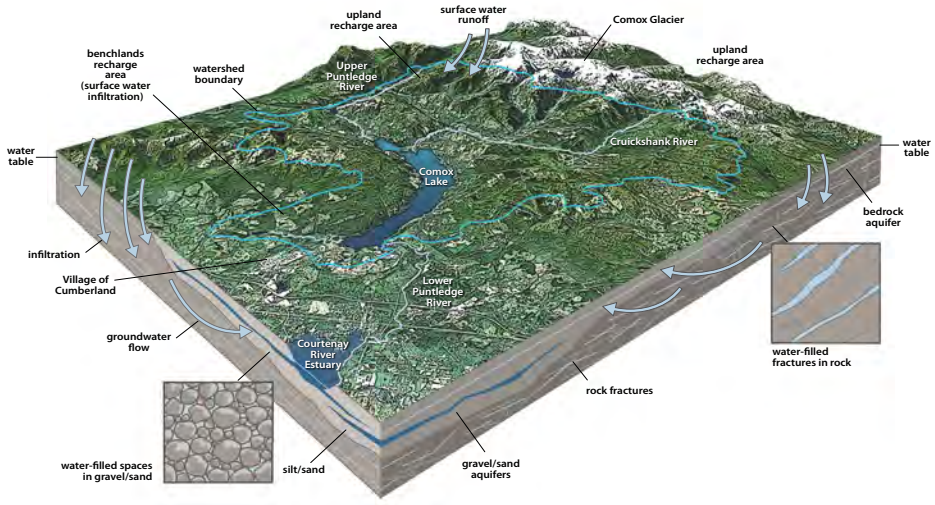


Figure 1 – Comox Lake watershed diagram

Since water can only flow downhill, the extent of a watershed is defined by topography. Watersheds can cross ownership and jurisdictional boundaries. The boundaries of watersheds are heights of land called watershed divides.

Riparian Areas

Riparian areas are the lands adjacent to streams, rivers, lakes and wetlands, where the vegetation and soils are strongly influenced by the presence of water. Although they make up only a small fraction of the land, they are among the most biologically productive and valuable of all landscape types. There are three key features that all riparian areas have in common:

- A lot of water is present, either seasonally or regularly, and that water is either on the surface or close to the surface;
- Vegetation is present that responds to, requires, and survives in abundant water;
- Soils have been modified by abundant water, stream or lake processes and by lush productive vegetation.

Riparian areas are formed as the result of water, soil and vegetation interacting with one another. Whether they are called floodplains, shorelines, green zones or riparian areas, their character begins with the fine wet soils developed in them.

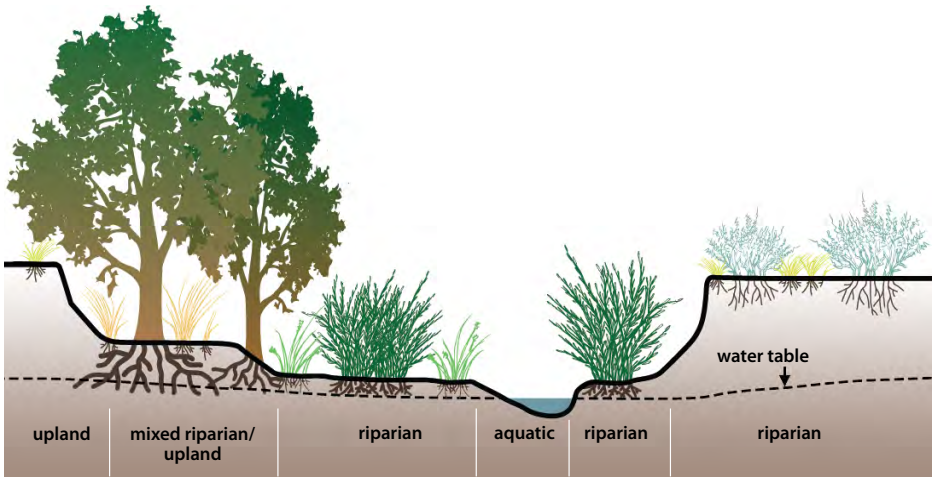


Figure 2 – Riparian area cross-section

Riparian areas provide similar functions for flowing water (streams and rivers) and standing water (lakes and wetlands)[3]:

Stream and Rivers	Lakes and Wetlands
trap sediment	trap and store sediments; prevent re-suspension of sediments
build and maintain banks	build and maintain shorelines and banks
reduce flood damage	reduce damage from high water levels and wave action
store water, especially flood water	store water, especially flood and spring runoff water; act as a surface reservoir
extend perennial flows or levels by recharging underground aquifers	extend seasonal or long-term levels by recharging underground aquifers
dissipate flow and ice energy	dissipate wave and ice energy
high primary production, including forage and shelter values	high primary production, including forage and shelter values
maintain or improve water quality	maintain or improve water quality
filter and buffer water, both from over-land flow (runoff) and water from within the channel	filter and buffer water, both from over-land flow (runoff) and water from within the basin
maintain biodiversity	maintain biodiversity
	trap nutrients and sediments to balance nutrient cycling, in-filling and primary production

Proper Functioning Condition of Streams and Wetlands

River systems and their associated riparian areas and wetlands provide many environmental values including fish, bird and wildlife habitat, as well as human economic values such as drinking water, timber harvest, livestock production and recreation. The exploitation of these landscapes for human use often causes ecological damage or disruption that can result in the loss of all or some of the values associated with streams and their riparian areas.

Proper Functioning Condition (PFC) is a qualitative method of assessing the physical state of a stream and its riparian margins or associated wetlands. PFC assessments examine the state of three critical components: hydrology (water), soil or landforms and the erosion or deposition of the resulting in-stream sediments, and the riparian/

wetland vegetation. PFC assessments are used to determine whether stream/riparian/wetland systems are functioning in a way that will allow the maintenance or recovery of the desired values (fisheries, drinking water, forage for livestock or wildlife, etc.). The assessment method was developed in the 1990's by the Forest Service and Natural Resource Conservation Service of the U.S. Department of Agriculture and the U.S. Bureau of Land Management and has led to the establishment of the National Riparian Service Team charged with training cadres of PFC assessment teams.

The assessment protocol relies on a checklist containing 17 questions about hydrology, vegetation and erosion/deposition of in-stream sediment. Most questions must be answered yes or no (some are not applicable in certain cases). All require extensive knowledge of streams and riparian areas to answer and are best performed, reach by reach, by a team of trained practitioners with a diversity of expertise.

The summary output of a PFC assessment is the determination that the stream reach is in proper functioning condition, functional-at risk or nonfunctional. For the functional-at risk result there is a further determination that the reach is trending upward or downward. If a stream is found to be non-functional or functional-at risk with a downward trend, restoration efforts may be wasted until the damage begins to stabilize through natural processes.

PFC provides an alternative to the all too common scenario where management decisions are forced out of the conflict between competing values (*e.g.*, drinking water versus recreation; fisheries versus timber harvest). The PFC process tables the apparent conflicting values while the ecological imperatives are addressed with the understanding that the greatest array of values will be attained from streams and their riparian/wetland areas that are as close to proper functioning as possible. This is accomplished by establishing a common science-based language that greatly facilitates cooperation among resource users in reaching a common goal and is described as cooperative riparian restoration.

What is a Pathogen?

There are many different types of micro-organisms in water including bacteria, viruses and protozoa, but only a few are disease-causing. These are known as pathogens and must be inactivated or removed from drinking water in sufficient number to prevent illness. Many micro-organisms are actually helpful and new research suggests that these "good" micro-organisms are essential to human health and help regulate everything from obesity to allergic reactions and auto-immune disorders[4].

Water is only one of many ways that people can be infected by a pathogen. Pathogens can be present in or on food, and many can be transmitted from person-to-person or from animals to people. For example, *E. coli* infections can be caused by eating undercooked beef, and *Salmonella* can be transmitted to people by handling infected reptiles or eating contaminated fruit[5].

Current research suggests that receiving a low dose of certain pathogens through the water supply provides protective immunity against the same pathogens when they are encountered in non-waterborne situations (*e.g. Cryptosporidium* encountered through food or human contact)[6]. The science of controlling human disease is therefore complex.

How do Pathogens Relate to Drinking Water?

Pathogens can enter the drinking water supply system directly from the source water (lakes, ponds, creeks) or through breaks in pipes or other entry points in the distribution system. Waste from humans, domestic animals and wildlife can all contaminate the water. The water supplies that are at the greatest risk are those that are downstream from concentrated sources of waste such as wastewater treatment plants or agriculture, neither of which are present in the Comox Lake Watershed.

Some of the most well-known pathogens related to water are *Cryptosporidium*, *Giardia* (which causes "beaver fever"), and *E. coli*. Not all pathogens respond the same way to disinfectants or can be killed by chlorine alone. *Cryptosporidium* can be inactivated by very high doses of chlorine, but these levels are not practical for drinking water disinfection. UV-light is the preferred method of inactivating *Cryptosporidium*. *Giardia* can be inactivated by chlorine[7], ozone or UV-light. *E. coli* is easily killed by chlorine or UV[8].

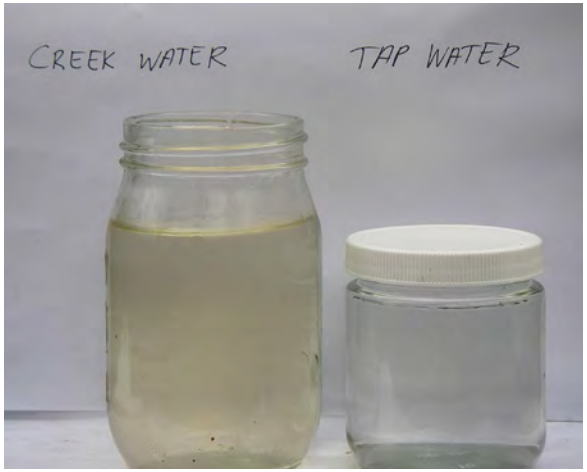
Pathogens are not evenly distributed in the environment and, since they are living organisms, their populations can change rapidly. Some pathogens, such as *Cryptosporidium* can form spores (oocysts) that can survive outside a warm-blooded host for a long time. They can therefore be difficult to track. The conventional approach is therefore to track "indicator organisms", such as total coliform bacteria, as a general indicator of the level of contamination.

All three of these organisms (*Crypto*, *Giardia* and *E. coli)* are associated with the presence of fecal matter and, when ingested in sufficient numbers and with sufficient infectivity, can cause gastrointestinal illness with symptoms such as nausea and diarrhea. These illnesses may become dangerous to people who are more susceptible to infection such as infants and young children, the elderly, and people with compromised immune systems.

The Comox Valley Regional District uses chlorination as part of their drinking water treatment program to deactivate these pathogens and is reviewing the addition of filtration and/or UV-disinfection.

Turbidity and Suspended Sediment

When water is contaminated with fine particulate matter and becomes cloudy or even muddy, the suspended sediment and loss of clarity can be quantified in two ways. Total suspended sediment (TSS) is a measure of the weight of sediment suspended in a specified volume of water. It is determined by filtering a known quantity of the water in question and accurately weighing the sediment retained on the filter. Results are normally expressed in milligrams per liter (mg/L). Total suspended sediment is usually comprised of eroded soil but may also include organic particles like detritus or algae.



Turbidity comparison

Turbidity is an optical measurement of water clarity which is reduced due to the presence of fine suspended matter, and some of these particles may be so fine that they will pass through the filters used to quantify the TSS. Turbidity is determined by directing a beam of infrared light through the test water to a sensor. Suspended matter or even colour caused by organic materials found in swamps, will scatter, refract, or absorb the light beam producing a proportional reading at the sensor. Turbidity is reported in nephelometric turbidity units (NTU) and when readings are greater than 5 NTU the cloudiness can be detected by the human eye. The correlation between TSS and turbidity is not universal and varies from site to site depending on the optical nature of the matter causing the cloudy or discoloured water.

Quantifying TSS requires a water sample to be analyzed in a laboratory and results may not be available for several days or weeks. Turbidity, however, can be measured by *in situ* (in-place) sensors connected to data loggers which record the output at pre-determined intervals of minutes or even seconds. Turbidity sensors located at remote sites can even be connected to transmitters so readings can be viewed at a central location in real-time, though the sensors must be routinely cleaned and serviced.

It is important to note that turbidity events may or may not be associated with elevated bacterial counts depending on the source of the particulate matter. If the turbidity is caused by inorganic soil erosion there may be no associated pathogenic bacteria, despite the high readings, and thus no direct threat to human health. Another risk posed by the sediment represented by elevated turbidity is that it may interfere with or disrupt the disinfection process allowing the survival of pathogens in the distributed water. This risk may be reduced if the sediment is largely inorganic in nature, which is the case in Comox Lake.


Perseverance Creek entering Comox Lake, December 11, 2014

Turbidity is of particular importance for municipal water supplies that do not filter the water. This is because of a recent decision by the BC Ministry of Health (BCMOH) to direct drinking water officers to issue Boil Water Notices (BWN) solely on the basis of elevated turbidity rather than on the presence of bacterial indicators like *E. coli.* In 2012 the BC Ministry of Health (BCMOH) released its *Drinking Water Objectives*

(Microbiological) for Surface Water Supplies in British Columbia. This document includes four conditions (see 4-3-2-1-0 Drinking Water Objective below) which must be met in order for water supply systems to be permitted to operate without filtration. One of these four conditions requires the average daily turbidity of the water supply just prior to disinfection (measured at least every four hours) to be "around 1 NTU, but do not exceed 5 NTU for more than two days in a 12-month period."

In 2013 the BCMOH released a *Decision Tree for Responding to a Turbidity Event in Unfiltered Drinking Water.* This document defines a "turbidity event", though not explicitly, as anytime the raw water turbidity exceeds 1 NTU. When this happens, a BWN is issued by the Drinking Water Officer (DWO) (as designated under the Drinking Water Protection Act) if the event is deemed to carry an "elevated risk". The default is for the DWO to assume that any turbidity greater than 1 NTU does represent an elevated risk unless the water system operator can provide compelling evidence to the contrary. The term "compelling evidence" is not defined but may include the absence of indicator organisms in the distribution system, despite elevated turbidity, or the continued maintenance of disinfection efficacy, *i.e.*, no loss of chlorine residual or UV transmittance through the water.

Disinfection

Disinfection is a process by which water is exposed to chemicals (usually chlorine, chloramine or ozone) or ultraviolet (UV) light to inactivate pathogens. Prior to being disinfected the water is referred to as "raw" water, to indicate that it has not been disinfected or filtered. A residual amount of chlorine is deliberately allowed to remain in the water to prevent regrowth of organisms as the water travels throughout the distribution system. Water is routinely tested throughout the distribution system to ensure there are no bacteria and to confirm that chlorine levels are neither too high nor too low.

UV light works as a disinfectant by damaging the genetic material (DNA and RNA) of microorganisms so that they cannot multiply[9]. They are therefore technically still alive, but cannot cause disease. UV disinfection does not significantly change the water quality and thus does not produce disinfection by-products, but it also does not leave any residual disinfection capacity. For this reason UV disinfection is usually followed by an application of chlorine or chloramine to provide a disinfectant residual.

Disinfection By-Products

While chlorine is very effective at decreasing the risk of illness from pathogens, it can also combine with organic materials in the water to form disinfection by-products (DBPs). Water that is very low in organic materials, such as the water in Comox Lake, will not generate significant DBPs.

One group of disinfection by-products is called tri-halomethanes (THMs). Over long-term exposure, THMs may have detrimental human health impacts such as increased risk of cancer. Water quality guidelines ensure that public drinking water is safe for human consumption. Water from Comox Lake has very low levels of organic matter in it; therefore, THMs are usually undetectable in the disinfected water.

The disinfection process can be made less effective when the water has high levels of turbidity or colour. For example, when UV light is used, water that is high in colour (caused by organic carbon) will absorb the light before it can reach the microorganisms. Turbidity can absorb or scatter light, but research has shown that turbidity does not adversely affect UV disinfection as long as turbidity is less than about 5 NTU[10]. Even at levels up to 10 NTU, research has shown that the effect of turbidity on the inactivation of *Cryptosporidium* and *Giardia* is insignificant[11] [12] [13].

4-3-2-1-0 Drinking Water Objective

Island Health has adopted the *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in BC*[14] (known as the 4-3-2-1-0 drinking water objective). This means that water suppliers will be required to provide long-term plans to reach the goals of:

- 4-log inactivation of viruses
- 3-log removal or inactivation of *Giardia* and *Cryptosporidium*
- 2 refers to two treatment processes for all surface drinking water systems
- 1 for less than 1 NTU of turbidity with a target of 0.1 NTU (for filtered supplies)
- 0 total and fecal coliforms and *E. coli*

as written in the document:

"**4 refers to a 4-log reduction in viruses:** For every 10,000 viruses in the water, a treatment system should be capable of inactivating 9,999 of them. Most viruses are easily inactivated by the use of chlorine.

3 refers to the 3-log removal or inactivation of parasites: For every 1,000 parasites in

the water, a treatment system should be capable of removing or inactivating 999 of them. Two common parasites are *Giardia* and *Cryptosporidium*. To remove parasites filtration is required. To inactivate parasites ultraviolet light or ozone or chlorine dioxide will need to be used. Health Canada has developed design guidelines to outline treatment methods which will provide the inactivation desired.

2 refers to two treatment processes for all surface water or unprotected groundwater: There is no single treatment technology that can assure drinking water safety on its own. A minimum of two treatment barriers is required for water that is at risk of containing pathogens and that includes all surface waters and some groundwater sources. Filtration and disinfection will generally be required for most surface water supplies to ensure a safe supply of water. For systems with very high quality sources and effective and ongoing watershed protection, 2 forms of disinfection may be permitted. This will generally be chlorination and UV light disinfection.

1 refers to maintaining a turbidity of less than 1 NTU: Turbidity of less than 1 NTU should be maintained. Raw surface water will need to be filtered if turbidity readings indicate poor results. Turbidity is caused by particulates in the water and can generally be described as cloudiness. The health risk increases as turbidity increases and the health risk will increase before cloudy water is noticed. Particles in water can include clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms. These can limit disinfection or treatment and protect disease-causing pathogens. For disinfection and treatment systems to be effective, the water must be less than 1 NTU.

0 refers to Bacterial Indicators: Most of the viral, bacterial and parasitic pathogens that contaminate drinking water are shed from the feces of humans and animals. It's not practical to test for each possible pathogen so an indicator organism (*E. coli*) is used to test for the possible presence of disease causing microbes. There should be "0" indicator organisms present in a treated water sample"[15].

Water Quality Monitoring

All watersheds are unique. They have distinctive ecological characteristics, climate regimes, land ownership, anthropogenic pressures and management priorities. Even two adjacent watersheds may function quite differently; therefore, it is challenging to use information from one watershed as a direct surrogate for another. The goal with water quality monitoring is to characterize the unique physical, chemical and biological processes of a particular watershed and their ranges of variability.

You cannot monitor what you cannot measure. Conducting regular measurement and monitoring of key parameters enables water managers to establish a baseline of normal conditions, measure changes to water quality over time, and provide information for science-based decision making. It is important to monitor both the raw water (water in the streams and lake before it is disinfected) and the water within the distribution system in order to understand how watershed processes affect stream and lake water quality and how it, in turn, is affected by treatment, storage and distribution.

Water quality monitoring is required to demonstrate that water supplies are meeting regulated water quality guidelines and objectives. Monitoring can identify and track emerging issues and threats and assess the effectiveness of remedial measures. Water quality monitoring enables direction of management resources in an efficient way to maximize effectiveness and then measure the success.

In the Comox Lake Watershed area, the CVRD monitors water quality for drinking water purposes, BC Hydro monitors water flows to inform their dam and diversion management, the Ministry of Environment monitors for compliance with lake water quality objectives, and the Department of Fisheries and Oceans monitors parameters such as water temperature for fisheries.

Equivalent Clearcut Area (ECA)

As rain and snow fall on a forested landscape, approximately 25-35% of the water is intercepted by the trees and evaporates before reaching the ground[16]. This slows the rate at which water reaches the streams and reduces the overall amount of runoff. When forests are harvested, more water reaches the streams at a faster rate, which has the potential to increase peak streamflow. Harvesting also leads to increased snow accumulation because snow is not captured by the tree canopy and sublimated into the atmosphere. Since the harvested site is exposed to direct sunlight and spring rainfall, the snow may also melt more quickly and therefore run off more quickly. Unless harvesting is carefully planned, significantly increased peak streamflow can lead to increased erosion in stream channels, increased turbidity and loss of riparian function.

With proper planning, the hydrological effects of forest harvesting can be minimized or almost eliminated. If only a small area of forest is harvested in any given sub-watershed, then the effect of harvest on the hydrology of the site is likely not detectable. As the size of harvested area increases, relative to the size of the remaining intact forest, the chances of a hydrological impact increase. Consideration must also be given to areas

which may have been harvested in the past but which have not fully re-grown. In order to determine the possible impact of a planned cutblock and associated roads, ditches etc., foresters use the concept of "equivalent clearcut area" or ECA. The threshold at which hydrological changes typically take place has been established by field research and continues to be refined as our ability to measure change improves.

The ECA is the area that is clearcut in a watershed but with a reduction factor to account for the regrowth of previously harvested areas or areas that are only selectively cut. It is often expressed as a percentage of watershed area. "In many cases, ECA may be a factor in limiting forest harvesting in watersheds that are sensitive to changes in peak streamflow (*e.g.* community watersheds or important fish streams)"[17]. It is also important to determine where in the watershed the harvested area is located, because lower elevation areas tend to melt earlier than those at higher elevation and contribute water to the stream during different periods. Aspect is also important- snow on sunny slopes melts earlier than snow on shaded slopes. Harvesting at elevations or aspects that cause melt to occur simultaneously (either with other harvested blocks or with lower elevation melt) can increase peak flow.

In large watersheds, ECA is usually calculated for individual sub-watersheds (*e.g.* Cruickshank River, Upper Puntledge River, Beech Creek) because a single number for the whole watershed would obscure the changes within individual sub-watersheds. For example, if a larger watershed consisted of three sub-watersheds of approximately the same size and one had an ECA of 30%, one had an ECA of 20% and one had an ECA of 10%, the overall ECA would be 20%, but one sub-watershed has three times as much harvesting as another.

ECA represents a best approximation of the effects of forest harvesting on streamflow. On Vancouver Island, variability in precipitation within a single watershed can exceed any variation between sub-watersheds due to forestry or other land use. Storm cells may develop over only a small part of the watershed and deliver high-intensity rainfall that overwhelms any potential changes in streamflow due to land use[18]. Peak flow often occurs as a result of very large high-intensity storms (*e.g.* "pineapple express" storms) during which changes in streamflow due to land use are indistinguishable from those in undeveloped watersheds. Streamflow monitoring on individual streams of concern (*e.g.* community watersheds), linked to precipitation data and ECA, is therefore the best way to detect change over time and prevent hydrological issues by adapting forest management based on local findings.

Wildfire

Wildfire is an integral part of a healthy ecosystem. Nearly all of the ecosystems in British Columbia have evolved with fire and have a capacity to respond to fire as an important disturbance event. Fire suppression efforts have been focused on significantly reducing the incidence of wildfire, while at the same time increased fire fuel loads, enhanced human access, and the effects of a changing climate increase the incidence, intensity and severity of wildfires.

Fire can have a significant impact on drinking water due to its dramatic physical and chemical effects on vegetation, soils, streams and lakes in a watershed. The effects of wildfire on source water quality can be widespread and long lasting, taking years or even decades for the ecosystem to regenerate.

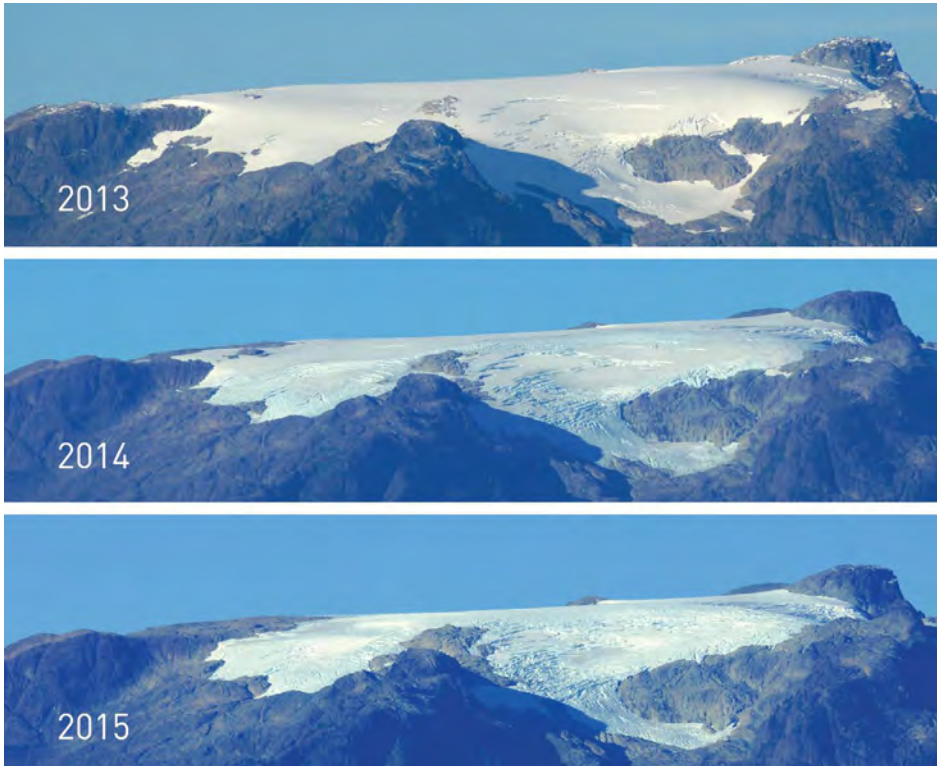
Wildfire can lead to soil erosion which may contribute nutrients and turbidity to a water supply.

Fire results in hydrological changes to watersheds that affect the timing, magnitude and duration of flood events and debris flows. High intensity rainfall events in steep watersheds that have been extensively burned are likely to move large amounts of debris

and suspended and dissolved materials into downstream reservoirs. Soil erosion results in increased turbidity and nutrient loading. Increased nutrient loading into streams and reservoirs may promote algal blooms and cyanobacteria. An increase in dissolved organic carbon can be a challenge for disinfection, as it may form undesirable by-products. Animals killed in the wildfire may result in increased bacterial loading.

The BC Wildfire Branch uses fire retardants to reduce the size and impact of wildfires (*i.e.* PhosCheck). Fire retardant use in the watershed could result in additional nutrients and contaminants potentially being introduced to the drinking water.

These various effects may necessitate changes to reservoir operation, disinfection protocols, and increased monitoring requirements for changes in water quality. If the water system is catastrophically compromised, an alternative water supply may be required.



Comox Glacier retreat – 2013-2015.

Glacier Retreat

A glacier is a large mass of ice that covers an area of land. Glaciers gain size when snow/ice accumulation is greater than the amount of snow/ice lost during warm months. When more ice is lost than gained over a given time period, the glacier is said to be retreating.

Why is this important to the CVRD drinking water supply system?

Comox Glacier sits in Strathcona Provincial Park and is a well-known feature of the Comox Valley. The Comox Glacier, along with the Moving and Cliffe glaciers, feed the Puntledge River, a major tributary stream supplying water to Comox Lake[19]. Researcher Dr. Dan Smith from the University of Victoria stated in May 2014 that based on tree ring analysis, he estimates that glaciers on Vancouver Island (including the Comox Glacier) will be gone within the next 25 years[20]. Recent repeat photographs show a smaller glacier in recent years[21]. This could potentially influence both the quantity and quality of the Comox Valley water supply. Flow monitoring would be required to determine the actual percentage of water supplied by the glacier; however, it is well-understood that wetlands, groundwater and glacier melt together supply most of the base flows to streams during the dry summer months.

In 2014-2015 the water levels in Comox Lake were the lowest on record. With changes in snowpack and glacial retreat, adopting water conservation measures will become increasingly important to ensure that there is enough, good quality water for human consumption (see Water Conservation).

Water Conservation

Despite the common conception that water is a renewable resource, it has finite limitations, especially when it comes to our drinking water supplies. Even though the majority of the earth is covered in water, only a tiny fraction of this is suitable for drinking water.

Comox Lake and the Puntledge River, which supply the CVRD with its drinking water, also have two other major water consumers that require water: BC Hydro and the Department of Fisheries and Oceans (DFO). BC Hydro manages and controls the Comox Lake Dam and the Puntledge River Diversion Dam for the provision of energy through its Puntledge Generating Station. DFO requires minimum water levels and flows in the Puntledge River for salmon populations. BC Hydro, the Department of Fisheries and Oceans, and the Comox Valley Regional District work together to ensure there is enough water being supplied to support energy production, meet fish habitat

requirements, and meet drinking water needs.

Increasing populations and a changing climate, which brings lower snowpack and more frequent droughts, increase pressures on both water supply and energy. If we use up water faster than it can be replaced, it could result in water shortages.

Water conservation measures can help reduce drinking water supply demand and help maintain lake and river water levels for ecological function while storing more water in the reservoir for use during times of drought. Water conservation is more than just using less water from the tap, it also includes conserving high quality water for high quality uses in a fit-for-purpose approach. Reclaiming and reusing cleaned wastewater, or capturing rainwater, can both augment local water supplies. For example, lower quality water can be used for non-potable uses, such as toilet flushing, irrigation, and many industrial purposes, allowing the higher quality water to be conserved for drinking.

Water conservation measures that are easy to implement include: replacing faucets, shower heads, and toilets with low flow products; decreasing shower time; washing cars less frequently; using dishwashers and washing machines only for full loads, and installing rain barrels to collect rainwater to use in gardens. A more in-depth water conservation method includes double-plumbing new buildings for reclaimed water use.

The Water Supply System

Watershed Ecology and History

History of Logging

The history of the Comox Lake Watershed is important because the land-use activities of the past continue to influence the ecological processes of today. Those processes, in turn, affect the quality and quantity of water and the resilience of the watershed to extreme weather events.

The Comox Lake Watershed is within the Coastal Western Hemlock (CWH) and Mountain Hemlock (MH) biogeoclimatic zones; specifically, the CWH very dry maritime east and west subzones (CWHxm1 and CWHxm2) and the CWH moist maritime submontane and montane subzones (CWHmm1 and mm2). Details of these zones are readily available[22]. Their key feature from a water quality perspective is that the CWH subzones are considered "summer-dry maritime" zones- areas where very little rain occurs in the summer months and where large wildfires occasionally occur. The trees in these CWH subzones are primarily Douglas-fir, western hemlock, and western redcedar. Historically, the trees in the watershed grew to be very large and had strong root masses capable of withstanding very high stream flows. These same roots were able to stabilize the steep slopes present in many areas of the watershed.

Not only were large fir, hemlock and cedar important to watershed ecology, their abundance and size made them a valuable export as timber. An excellent and detailed history of logging in the Comox Lake Watershed is contained in the book "Mountain Timber" by Richard Somerset Mackie. The first blocks of timber on Comox Lake (Blocks 31 and 32 Nelson Land District) were sold in 1888-89 and included the lower valleys of Toma Creek, the upper Puntledge and the Cruickshank Rivers where they entered the lake. Early experiments in floating timber to the east end of the lake and down the lower Puntledge failed because the river was too shallow and the logs were too big, so the timber blocks were resold in 1910. Comox Logging acquired these blocks and much of the timber around Comox Lake, and began setting up a floating logging operation and rail-line from the east end of the lake to Royston in 1927. There were no roads into the watershed at this time and everything came in and out via the lake.

Floating A-frame – Comox Lake

Between 1929 and 1934 the shores of Comox Lake were logged using a floating A-frame about 170 feet high. The A-frame was both harvester and camp. It was made of rafts of logs each 60 by 150 feet and accommodated 200 men in addition to a commissary, cookhouse, office, and blacksmith shop. The A-frame itself was made of timbers 220 feet long– massive individual Douglas-fir trees harvested from the watershed. It allowed the loggers to reach about 1500 feet up the slope from the lake, so only the lower slopes of the lake were initially logged. It was an economical logging method during the Depression when every dollar counted.

In the early 1930's rail lines were surveyed up the gentle lower slopes of the Toma Creek valley and up the Puntledge River to Willemar Lake (Block 32). The rail lines were in operation by 1933. In 1932/33 Lake Camp was built near the mouth of the upper Puntledge River and contained both land and water-based bunkhouses, a school, and a dance hall. Seventeen families occupied the camp by 1933 in addition to 110 single men. Skidders and high-lead techniques were used to get the logs to the rail line. By 1935 the "Cat and arch" system, pioneered by the Comox Logging Company near Lake Camp in 1933, was in use around Willemar Lake. The diesel tracked Caterpillars were used to yard the logs down to the edge of Willemar Lake where they were boomed to the rail line and hauled down to Comox Lake. The booms were first towed to the east end of the lake and later allowed to float on their own, blown down lake by the prevailing winds. The "Cat and arch" technique would later be exported to the Ladysmith operation, which employed 275 men by 1938, taking with it many of the Comox Lake logging crew.

A flood in February 1935 raised the water level of the lake by two feet, triggered by a heavy January snowfall and early February rain. The lakeside houses floated away and had to be towed back to land. The camp remained in use until 1937 and utilized "an excellent spring on the side of the hill not far from the camp" which was piped to the camp for drinking water.

In 1937 the floating portion of Lake Camp was towed over to the mouth of the Cruickshank River to log Block 31. The married quarters and dance hall were not moved and no families were allowed in the new camp. At the same time, Comox Logging bought several large valley-bottom blocks of timber from John D. Rockefeller of New York: Blocks 46, 748 and 749. Approximately 10 miles of valley bottom along the Cruickshank River and 8 miles along Comox Creek were logged between 1937 and 1950. This was the last of the railway and highlead skidder operations, which were, by then, old technology. This restricted logging to the valley bottom (along the rivers) and about 1000 feet up the mountain sides. By 1947, the railway tracks were torn up and converted to logging roads. Higher elevations would not be logged until the 1950s and 1960s after the road network was expanded.

Logging in the Comox Valley 1930's

Between 1911 and 1946 the Comox Logging Company's six skidders are said to have moved between 4 and 5 billion board feet of lumber from the flats north of Courtenay, the Bevan sidehill, the shore of Comox Lake, Toma Creek, the upper Puntledge River and the Cruickshank Valley.

As the subject of the early logging, the riparian areas along the lakeshore and the valley bottoms were subjected to an almost complete loss of large wood and the stability it provided. The trees that would have stabilized the stream banks, and the large fallen wood in the streams that would have trapped sediment and created complex stream habitat were lost. By the time the upper slopes were logged in the 1950's and 1960's, the trees regrowing in the valley bottom would not have been large enough to stabilize the soils.

Current Water Quality

In Canada, drinking water is regulated by the provincial governments. In BC, the Ministry of Health is responsible for drinking water which is regulated under the Drinking Water Protection Act (2001) and Drinking Water Protection Regulation (DWPR) (2003). The DWPR, Schedule A, sets out standards for potable (drinkable) water in the distribution system (not the raw water source). They are:

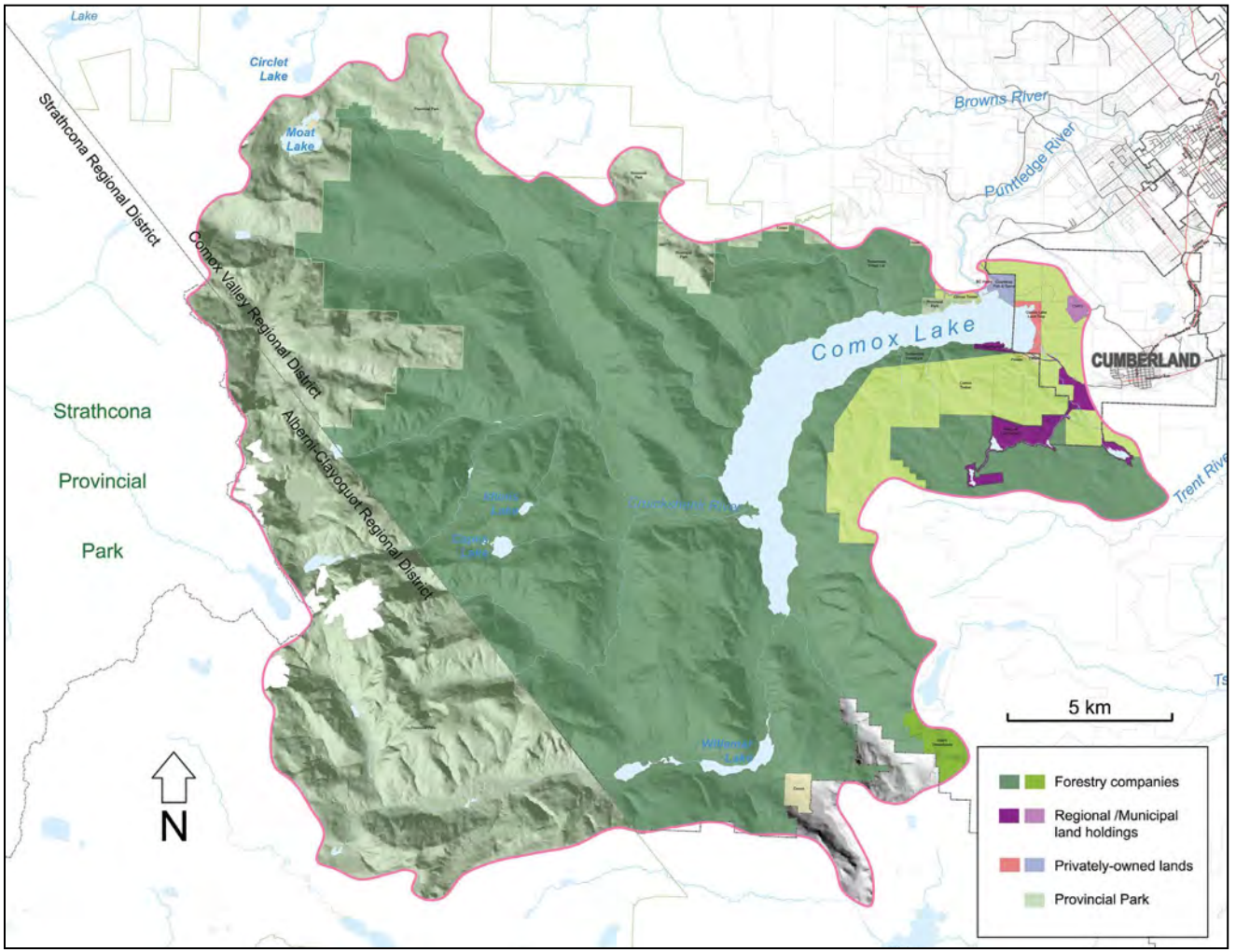
Micro-Organism	Potable Water Standard	
Fecal coliform bacteria	No detectable fecal coliform bacteria per 100 mL	
E. coli	No detectable *E. coli* bacteria per 100 mL	
Total coliform bacteria	(a) 1 sample in a 30 day period	No detectable total coliform bacteria per 100 mL
	(b) more that 1 sample in a 30 day period	At least 90% of samples have no detectable total coliform bacteria per 100 ml and no sample has more than 10 total coliform bacteria per 100 ml

The Guidelines for Canadian Drinking Water Quality are published by Health Canada. They include microbiological, chemical, physical and radiological parameters. The guideline for a specific parameter may be a maximum acceptable concentration (MAC) or it may be expressed as an aesthetic objective (AO) or operational guidance (OG). AOs and

OGs do not affect human health. These guidelines have not been adopted by the Province of BC and are not legally enforceable, though most jurisdictions try to comply.

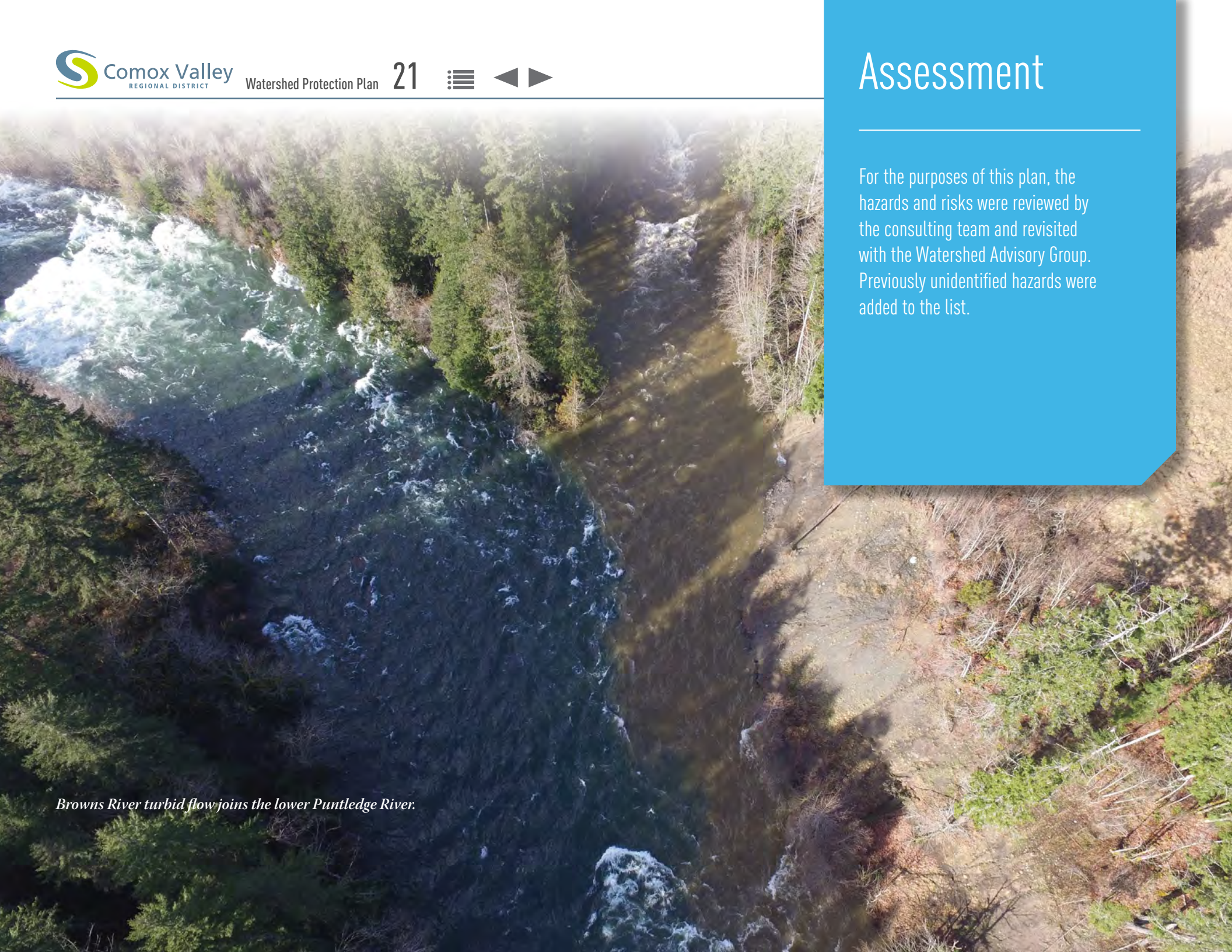
The quality of the water in Comox Lake is currently very good. The CVRD undertakes regular monitoring of the raw water in the lake itself and in the penstocks before it enters the chlorination plant. The CVRD also sends regular samples to the UVic Aquatic Sciences Lab where samples are tested for nutrients, bacteria, chlorophyll (a measure of algae in the water), and disinfection pre-cursors and by-products. Algae are important because they can contribute taste and odour compounds to the water and the algal cells are a source of organic matter that can react with chlorine to form disinfection by-products.

Comox Lake Watershed Map



Assessment

For the purposes of this plan, the hazards and risks were reviewed by the consulting team and revisited with the Watershed Advisory Group. Previously unidentified hazards were added to the list.



Browns River turbid flow joins the lower Puntledge River.

Analysing and Understanding Risks

Hazard Identification

A "source-to-tap" approach to managing drinking water starts with an understanding of the water supply area, an identification of the hazards, and an assessment of risks to water quality. The steps involved are outlined below[23]:

1. Understand the water supply system;
2. Identify hazards, hazardous events, and sources;
3. Estimate the level of risk for each identified hazard/event;
4. Identify and plan preventative measures for each hazard/event; and
5. Implement and monitor preventative measures.

The water supply system has been characterized previously[24]. This Watershed Protection Plan addresses the hazards and risks related to the Comox Lake Watershed and to the lake itself (reservoir) and is intended to be integrated with other risk assessments done for the distribution system. The hazard identification and risk assessment should be updated periodically since changing conditions may introduce new hazards or modify risks. Triggers for updating the assessment would include a significant change in public access or land ownership, wildfire that affects the larger sub-watersheds or lakeshore, major construction or alteration of roads, extreme weather events such as 100+ year storm events or prolonged drought, new development within the watershed especially on the lakeshore, significant changes in the operation of the hydro-electric dam, or large-scale changes to the water treatment process. Barring such major changes, the hazards list should be reviewed annually and the assessment updated every 4-5 years.

The key characteristics reviewed for hazards/ hazardous events were:

Watershed

- Geology and soils
- Topography and drainage patterns (hydrology)
- Streams and rivers
- Meteorology and weather patterns (climactic and seasonal variations)
- Riparian conditions
- Vegetative cover
- General watershed and stream health
- Wildlife
- Historical contaminated sites
- Competing water uses
- Nature and intensity of development/ land use activities:
  - Agriculture
  - Land clearing
  - Forestry
  - Mining
  - Industrial
  - Rural and urban development/ residential
  - Sewage treatment works and septic tanks
  - Recreational activity (land and water-based)
- Intermittent or seasonal use practices
- Future planning activities
- Development and planning restrictions

Source Water

- Surface water (stream, river, reservoir/lake, dam)
- Groundwater
- Flow and reliability of source water
- Seasonal and event changes (including infrequent events such as droughts or floods)
- Spatial variation
- General and unique constituents (physical, chemical, microbial)
- Major ions and pH
- Salinity, hardness
- Turbidity
- Bacteria, viruses and protozoa
- Naturally occurring organics
- Volatile and non-volatile synthetic organics
- Metals and radionuclides

Lake and Intakes

- Detention time
- Seasonal variations:

- Stratification
- Algal blooms

- Treatment efficiencies (microbial removal)
- Recreational/human activity
- Intake location and operation

The risk associated with each hazard was then assessed two ways:

1. The maximum risk in the absence of preventative measures (unabated risk or "worst case scenario"); and
2. The residual risk after consideration of existing preventative measures (abated risk).

Gaps in preventative measures were then used to develop watershed protection recommendations, and priorities for implementation were determined by the associated level of risk.

Context

Any discussion of hazards to drinking water quality or safety must be placed in context. Many of the sources of human waste and pollution that are common in other drinking water supplies are not present in the Comox Lake Watershed. For example, there is no agriculture, no active mining, no commercial or industrial facilities, very limited residential development (cabins), no sewage outfalls, limited recreational infrastructure (trails, docks, buildings), no major highways, no paved roads, no power transmission lines or pipelines. There is logging, a landfill (though the active portion is outside the watershed boundary), recreation (swimming, boating, windsurfing, hiking, mountain biking), camping at one public and one private campground, public access via logging roads, off-road vehicle use, hunting and fishing, limited trapping, power generation, and Department of National Defense exercises, all of which occur in the watershed or on the lake. There are wildlife present in the watershed including bear, deer, beaver, raccoons, cougar and waterfowl, that may carry disease-causing organisms, though their numbers are thought to be low relative to the size of the watershed. Domestic dogs often accompany their owners to campgrounds and during recreational activities. Fire presents a significant risk and operation of BC Hydro's dam may affect the ecology of the lake itself through alterations to flow patterns, exposure of lakeshore sediments to wind and wave action, and alteration to nutrient regimes.

It should be noted, that the CVRD currently draws water not from Comox Lake itself, but from the BC Hydro penstocks. The intake for the penstock is at the Puntledge Diversion Dam approximately 3.7 km downstream of the lake outlet. Between the lake and the penstock intake there are land-use activities, including limited agriculture and residential development, which may affect water quality. At certain times of the year, for example when the fish screens are being cleaned on the BC Hydro penstocks, the CVRD draws water from a third location even further downstream on the Puntledge River near the BC Hydro powerhouse. This site is also influenced by the Browns River which is subject to development. Since the CVRD has already made the decision to relocate the drinking water intake to the lake itself, no further efforts have been made in this plan to characterize or address the risks that are specific to the lower Puntledge River.

Risk Assessment

Hazards and risks to drinking water safety were previously assessed as part of earlier watershed protection planning efforts[25]. The assessments included source water

Figure 3 – Existing water supply from the Puntledge River and Puntledge Diversion Dam

characterization[26] and a contaminant source inventory[27]. This risk assessment assumes that a new deep-water intake is in place.

Hazards are biological, chemical, physical or radiological agents that have the potential to cause harm and/or can give rise to water quality that is unacceptable for consumers[23].

Hazardous events and **sources of hazards** are those incidents or situations that can contribute to the presence of a hazard (what can happen and how). This may include point sources of pollution such as a leaking fuel tank as well as diffuse (non-point) sources such as runoff from roads.

Risk is the probability (**likelihood**) of an identified hazard causing harm in exposed populations multiplied by the magnitude of that harm (**consequence**), *i.e.* the severity of the consequences or the effect. For example, the likelihood of *E. coli* being present in source waters and passing though the disinfection plant in sufficient numbers and infectivity to cause illness is the risk. Consequence may be established by considering factors such as the number of people who may get ill, degree of public outrage, size of the system contaminated, extent of boil water notices which would need to be issued, and any costs that may be incurred (*e.g.* fines, compensation, water treatment facilities upgrades, etc.).

For the purposes of this plan, the hazards and risks were reviewed by the consulting team and revisited with the Watershed Advisory Group. Previously unidentified hazards were added to the list. Many of the hazards identified in the 2006 report were specific to the location of the intake on the Puntledge River and were therefore eliminated. Each hazardous event/ source was then evaluated by asking the following questions:

- Is it still applicable to the new intake location? *i.e.* deep water intake
- Current monitoring – what existing monitoring is in place?
- Is there a data gap – are additional data needed to assess the risk?
- How is the risk currently controlled?
- Is control adequate – does the control mitigate the risk?
- Do any standard procedures cover this – are there any standard operating procedures that help control this risk?
- Likelihood & Consequence – what is the probability of the hazard/event occurring and its effects?
- Required Intervention to Prevent Failure – what needs to be done to mitigate the risk?
- What management tools are available, and who has them?

The hazards fell into four major categories:

1. Sediments

Sediment is the output of the natural weathering of rock. Wind, rain, snow and ice erode exposed rock and sediment is carried down hill by gravity and the action of water while being broken into smaller particles. This is known as inorganic sediment. Streams ultimately carry the sediment to the ocean. Sediment is also taken to mean the organic (carbon-based) material that results from the breakdown of plants, other organisms, and soil. Sediment generated on the landscape can result from both natural processes and human activities. Fire and blowdown can cause increased rates of sediment delivery to streams, and road construction, use, and maintenance can also generate increased sediment. Water has a huge capacity to move sediment and therefore the act of concentrating water, such as in ditch lines and culverts, can also cause increased erosion. In reservoirs, where the water level fluctuates, significant vegetation does not grow on the shoreline below the water. When the water level is drawn down, the soils are exposed, and, without plants to stabilize them, they are subject to erosion from wind and wave action.

When sediment is suspended in the water column, it is commonly measured either as "suspended solids" in milligrams of sediment per litre of water or as "turbidity" (cloudiness). Turbidity is a measure of how much light is prevented from passing through a known column of water. It is not a direct measure of suspended particles, but rather a general measure of the scattering and absorbing effects that suspended particles have on light. It is measured in Nephelometric Turbidity Units (NTU). Neither of these measures distinguishes between inorganic sediment and organic sediment. When organic sediment in the water column is exposed to the chlorine used to disinfect water, it can react and create undesirable by-products, some of which can be harmful to human health. The organic particles also bind the chlorine and may reduce its disinfection capability. Bacteria and other pathogens are also thought to "hide" from the effects of chlorine by attaching themselves to the microscopic crevices of inorganic and organic particles.

The Canadian Drinking Water Guidelines set a limit of 1 NTU for drinking water at the point of intake, but this measure does not reflect the different effects of 1 NTU of organic sediment *vs.* 1 NTU of inorganic sediment such as clay. "No single source indicator, for source water or unfiltered treated water, is by itself a reliable criterion for issuing a water quality notice, unless there is an empirically demonstrated relationship between turbidity or microbial load for the specific system in question."[28]

2. Nutrients

Comox Lake is considered "nutrient poor", that is, it has very low levels of nitrogen, phosphorus and other elements that are required for plant growth. Nutrients can enter the lake through natural or accelerated erosion of soils, decomposition of organic matter both in the upslope area of the watershed and in the lakes and streams (such as from the trees flooded by the creation of the reservoir), spraying of fertilizers to enhance tree growth, spraying of pesticides (*e.g.* Vision or Roundup) to reduce weeds, and use of fire retardants (*e.g.* PhosCheck) in the event of a wildfire. Excess nutrients are not a direct hazard to the safety of the drinking water except in very high quantities (*e.g.* nitrate can cause blue-baby syndrome (methemoglobinemia)), which are extremely unlikely in the Comox Lake Watershed given the watershed size and the lake volume. If the nutrient profile of the lake were to change, it could result in excess algal growth (phytoplankton) which may introduce undesirable tastes and odours to the water and could then react with chlorine to form disinfection by-products. Data to-date indicate that disinfection by-products in chlorinated water from Comox Lake are extremely low.

3. Pathogens

Waterborne human pathogens include parasites such as *Cryptosporidium* and *Giardia*, bacteria including *E. coli,* and viruses such as hepatovirus, which causes hepatitis. They are considered some of the most significant risks to the quality of drinking water given their ability to directly affect human health. Human beings are the primary source of many of the waterborne pathogens, but infected domestic animals and wildlife can also introduce pathogens into a watershed. Some wildlife species can bioamplify and/or disperse these pathogens within the watershed, and thereby increase the risk of human disease. However, the cross-transmissibility of disease organisms between humans and animals is largely unknown.

The ability of a given pathogen to contaminate a water supply is generally a function of sewage disposal into the water supply, uncontrolled human activity in the watershed, or the proximity of certain wildlife habitat to the water supply. Pathogens can cause severe illness and even death for people with weakened immune systems. For this reason, the water supply is disinfected to kill or inactivate pathogens before the water is distributed to homes and businesses.

If pathogens get into the distribution system in sufficient number, either due to inadequate disinfection or, for example, a break in the pipes, this can result in boil-water advisories or the need for additional disinfection or filtration.

The concentration of pathogens is expressed as the number of *Giardia* cysts and *Cryptosporidium* oocysts per 100 L of water or the number of bacteria per 100 mL. Research into waterborne viruses is limited, and identification is difficult and expensive. Viruses tend to have better survival at low temperatures, but are inactivated by Ultra-Violet (UV) light from the sun or an artificial light source. Preventative measures, such as UV disinfection, are used to kill viruses in drinking water that cannot be easily counted or identified.

Exposure to UV at the surface of the lake can help to reduce pathogens. As residence time in the lake increases, so does potential for UV exposure and pathogen reduction. Survival is also dependent on temperature, dissolved oxygen and pH and optimal conditions for pathogen reduction depends upon the type of pathogen.

4. Contaminants

Contaminants that might typically be found in the Comox Lake Watershed are gasoline, diesel fuel, oil, pesticides including herbicides, and wood preservatives. These are generally easily controlled and best management practices of forest companies strictly regulate the use of wood preservatives and pesticides as well as the storage of fuel and refueling practices. The greatest risk is therefore from accidents involving boats, passenger vehicles, logging trucks, off-road vehicles and aircraft. A spill of a significant quantity, or a smaller spill close to the intake, could render the drinking water unpalatable and coat the pipes and reservoirs of the distribution system. This would require temporary use of an alternate water source and costly decontamination of the water supply system. It is unlikely that a spill could occur that would be large enough to pose a risk to human health from drinking the water, since dilution would reduce the concentration of contaminants.

More significant contaminants, whose presence and effects are not well-understood in this watershed, are potential leachate from the regional landfill, and weathering of coal mine waste near White's Bay and lesser-known areas of the watershed.

Other Factors That Affect Risk

Comox Lake is very large with a surface area of 2100 ha, a maximum depth of 110 m in the central basin and a mean depth of 61 m. The east basin is approximately 35 m deep at its deepest point. The lake normally stratifies in the summer – that is, the upper layers of water warm up and are kept separate from the lower layers due to a difference in density. The depth of stratification varies by year with the thermocline generally between 10 and 30 meters. The lake therefore provides some measure of settling and some measure of UV disinfection for the upper water layers; however, recent bacterial monitoring done by UVic shows bacteria, including human-source bacteria, in the deep waters near the point where the new intake is proposed.

Due to the size of the lake and the snow and glacial melt waters that supply summer flows, the water temperatures in the deep water are generally cold (5 – 6 °C). The upper layers (epilimnion) can get very warm (20.9°C)[19]. This can increase bacterial and parasite survival.

Likelihood and Consequence

The likelihood of and consequence of each identified risk was reviewed using the following Table 1 and Table 2 as guidelines. The results of these assessments were then categorized according to the risk matrix presented in Table 3. All three tables are adapted from module 7 of the BC Source to Tap Assessment Guidelines[29] which in turn were adapted from an earlier Australian risk assessment guide[23]. We further adapted the tables to include numerical scores, similar to the Alberta process for drinking water safety plans[2]. The actual scores have no direct meaning; rather, they have a relative value that allows for the ranking of one risk against another and prioritizing mitigation. The aim is to distinguish between very high and low risks.

Table 1. Qualitative Measures of Likelihood

Level	Descriptor	Description	Probability of Occurrence in Next 10 years
1	Rare	May only occur in exceptional circumstances	<10%
2	Unlikely	Could occur at some time	10-30%
4	Possible	Will probably occur at some time	31-70%
8	Likely	Will probably occur in most circumstances	71-90%
16	Almost certain	Is expected to occur in most circumstances	>90%

Table 2. Qualitative Measures of Consequence or Impact

Level	Descriptor	Description
1	Insignificant	Insignificant impact, no illness, little disruption to normal operation, little or no increase in normal operating costs
2	Minor	Minor impact for small population, mild illness moderately likely, some manageable operation disruption, small increase in operating costs
4	Moderate	Minor impact for large population, mild to moderate illness probable, significant modification to normal operation but manageable, operating costs increase, increased monitoring
8	Major	Major impact for small population, severe illness probable, systems significantly compromised and abnormal operation if at all, high level monitoring required
16	Catastrophic	Major impact for large population, severe illness probable, complete failure of systems

Table 3. Qualitative Risk Analysis Matrix- Level of Consequences.

	Consequence	Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood		1	2	4	8	16
Rare	1	1	2	4	8	16
Unlikely	2	2	4	8	16	32
Possible	4	4	8	16	32	64
Likely	8	8	16	32	64	128
Almost Certain	16	16	32	64	128	256

	Consequence	Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood		1	2	4	8	16
Rare	1	Low	Low	Moderate	High	High
Unlikely	2	Low	Low	Moderate	High	Very High
Possible	4	Low	Moderate	High	Very High	Very High
Likely	8	Moderate	High	High	Very High	Very High
Almost Certain	16	Moderate	High	Very High	Very High	Very High

The identified risks were tabulated (Table 4) and categorized according to the four categories above. The details of the rationale for each hazard and risk rating are in Appendix 1.

Table 4. Likelihood and consequence scores of hazard sources in Comox Lake Watershed, ranked from highest abated risk to lowest.

Hazardous Event/ Source of Hazard	Unabated Risk- Worst Case Scenario				Abated Risk- Residual Risk with Current Barriers			
	Likelihood	Consequence	Risk Score	Risk Rating	Likelihood	Consequence	Risk Score	Risk Rating
1 Camping in undesignated areas in the watershed, especially near the lakeshore or other riparian areas	16	16	256	Very High	4	16	64	Very High
2 Augmentation/concentration of streamflows	16	4	64	Very High	16	4	64	Very High
3 Wildfire	8	16	128	Very High	2	16	32	Very High
4 Off Road Vehicle (ORV) use off maintained road networks	8	16	128	Very High	2	16	32	Very High
5 Flooding on the order of 100 to 200-year event	2	16	32	Very High	2	16	32	Very High
6 Drought	16	4	64	Very High	16	2	32	High
7 Intentional harm to the water source or watershed	1	16	16	High	1	16	16	High
8 Earthquake resulting in loss of the BC Hydro dam	1	16	16	High	1	16	16	High
9 Aircraft accident on Comox Lake	2	8	16	High	2	8	16	High
10 Sewage management facilities	16	4	64	Very High	4	4	16	High
11 Body contact recreation on Comox Lake (parasites and viruses)	8	4	32	High	4	4	16	High
Body contact recreation on Comox Lake (bacteria)	16	4	64	Very High	1	4	4	Moderate
12 Trails and non-motorized trail use (hiking, mountain biking, horse riding, cross-country skiing and snowshoeing)	8	4	32	High	4	4	16	High
13 Timber Harvesting- cutblock location & extent	8	4	32	High	4	4	16	High
14 Wildlife contamination of Comox Lake	16	2	32	High	8	2	16	High

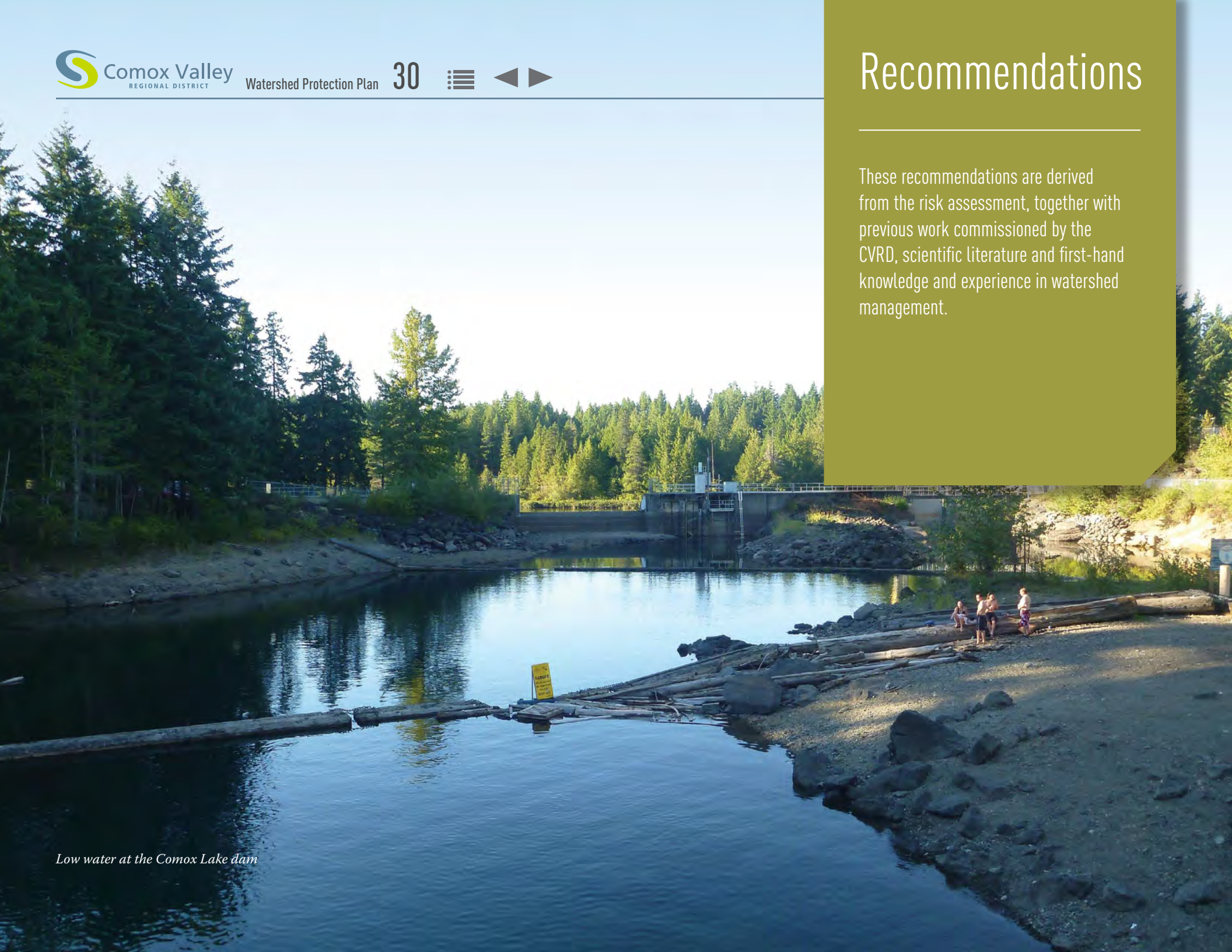
Hazardous Event/ Source of Hazard	Unabated Risk- Worst Case Scenario				Abated Risk- Residual Risk with Current Barriers			
	Likelihood	Consequence	Risk Score	Risk Rating	Likelihood	Consequence	Risk Score	Risk Rating
15 Lakeshore cabins, camping at designated campsites and Fish and Game Club on Comox Lake								
	8	4	32	Very High	2	4	8	Moderate
16 Road network								
	8	4	32	High	2	4	8	Moderate
17 Legacy forestry activities								
	4	4	16	High	2	4	8	Moderate
18 Transportation on roads adjacent to watercourses or Comox Lake								
	16	4	64	Very High	4	2	8	Moderate
19 Flooding on the order of >25 to <100 year event								
	4	4	16	High	4	2	8	Moderate
20 Timber harvesting operations								
	4	4	16	High	1	4	4	Moderate
21 Regional landfill operation								
	1	4	4	Moderate	1	4	4	Moderate
22 Underwater log salvage from Comox Lake								
	1	4	4	Moderate	1	4	4	Moderate
23 Timber harvesting- road construction & maintenance								
	2	4	8	Moderate	1	2	2	Low
24 Boating and fishing in Comox Lake including use of boat launches and docks								
	4	2	8	Moderate	2	2	4	Low
25 Mining spoils								
	4	1	4	Low	4	1	4	Low
26 Transportation over the Puntledge River Bridge (resulting in a spill or accident) near the Comox Lake outlet								
	2	4	8	Moderate	1	2	2	Low
27 Transportation on roads distant from watercourses or Comox Lake								
	1	2	2	Low	1	2	2	Low
28 Potential aircraft crash in other areas of the watershed								
	1	1	1	Low	1	1	1	Low
29 Silviculture & monitoring								
	1	1	1	Low	1	1	1	Low

Table 5. Hazard sources in Comox Lake Watershed, ranked from highest abated risk to lowest risk, and corresponding recommendations.

#	Hazardous Event/ Source of Hazard	Abated Risk Rating	Applicable Recommendations
1	Camping in undesignated areas in the watershed, especially near the lakeshore or other riparian areas	Very High	**2, 10, 11, 12, 19, 20, 28, 29, 48, 49, 53**
2	Augmentation/concentration of streamflows	Very High	**8, 12, 45, 49, 50**
3	Wildfire	Very High	**1, 11, 12, 20, 23, 24, 28, 29, 30, 48, 49**
4	Off Road Vehicle (ORV) use off maintained road networks	Very High	**10, 11, 12, 20, 30, 48, 49, 53**
5	Flooding on the order of 100 to 200-year event	Very High	**1, 12, 21, 23, 24, 42, 49, 51**
6	Drought	High	**1, 7, 9, 12, 21, 23, 25, 49**
7	Intentional harm to the water source or watershed	High	**11, 12, 23, 24, 48**
8	Earthquake resulting in loss of the BC Hydro dam	High	**12, 21, 23, 24**
9	Aircraft accident on Comox Lake	High	**12, 24, 46**
10	Sewage management facilities	High	**11, 12, 20, 32, 33, 37, 48, 49, 51, 53**
11	Body contact recreation on Comox Lake (parasites and viruses)	High	**9, 10, 11, 12, 20, 38, 48, 49, 53**
	Body contact recreation on Comox Lake (bacteria)	Moderate	**9, 10, 11, 12, 20, 38, 48, 49, 53**
12	Trails and non-motorized trail use (hiking, mountain biking, horse riding, cross-country skiing and snowshoeing)	High	**10, 11, 12, 19, 20, 26, 27, 30, 31, 41, 48, 49, 53**
13	Timber Harvesting- cutblock location & extent	High	**12, 18, 20, 43, 49, 53**
14	Wildlife contamination of Comox Lake	High	**9, 11, 12, 49**
15	Lakeshore cabins, camping at designated campsites and Fish and Game Club on Comox Lake	Moderate	**10, 11, 12, 16, 19, 20, 28, 31, 32, 33, 48, 49, 51, 53**
16	Road network	Moderate	**12, 20, 39, 49, 53**
17	Legacy forestry activities	Moderate	**12, 42, 49, 53**
18	Transportation on roads adjacent to watercourses or Comox Lake	Moderate	**3, 12, 23, 39, 40, 48, 49**
19	Flooding on the order of >25 to <100 year event	Moderate	**1, 12, 21, 23, 24, 42, 49, 51**
20	Timber harvesting- operations	Moderate	**10, 11, 12, 43, 49**
21	Regional landfill operation	Moderate	**12, 16, 17, 20, 49, 52**
22	Underwater log salvage from Comox Lake	Moderate	**12**
23	Timber harvesting- road construction & maintenance	Low	**12, 18, 39, 43, 49**
24	Boating and fishing in Comox Lake including use of boat launches and docks	Low	**10, 11, 12, 20, 24, 34, 35, 48, 49, 53**
25	Mining spoils	Low	**12, 47**
26	Transportation over the Puntledge River Bridge (resulting in a spill or accident) near the Comox Lake outlet	Low	**12, 48, 53**
27	Transportation on roads distant from watercourses or Comox Lake	Low	**12, 48**
28	Potential aircraft crash in other areas of the watershed	Low	**12, 24**
29	Post-harvest: silviculture & monitoring	Low	**1, 12, 20, 44**

Recommendations

These recommendations are derived from the risk assessment, together with previous work commissioned by the CVRD, scientific literature and first-hand knowledge and experience in watershed management.



Low water at the Comox Lake dam

Reducing Risk to an Acceptable Level

Recommendations

The Comox Lake Watershed is challenging to manage due to its sheer size, multiple land-owners, and multiple regulatory jurisdictions. As the water purveyor, the CVRD has the responsibility for providing safe drinking water, but has no direct ownership or control over the land base. It is for this reason that development of this Watershed Protection Plan (WPP) has taken a coordinated approach and sought the input of landowners and regulators through the Watershed Advisory Group, as well as technical advisors, in order to develop recommendations that are both scientifically defensible and technically feasible. This plan will only be effective if there is buy-in from affected land-owners, regulators, and users.

These recommendations are derived from previous work commissioned by the CVRD as well as scientific literature and first-hand knowledge and experience in watershed management. They reflect local knowledge provided by the WAG members and information gathered from other local governments and health agencies in BC and elsewhere.

While some of the recommendations can be implemented by individual land-owners, many of the recommendations are geared toward managing public access and behaviour in the watershed. Public acceptance of the WPP will require the CVRD and its partners to commit to public education. Many residents and visitors use the watershed for recreation, and changing habits and past practices takes time. Even the most advanced forms of treatment can fail and the cost of operation is directly linked to the quality of the water that is drawn from the watershed. "Prevention of contamination provides greater surety than the removal of contaminants by treatment"[30].

Many recommendations will take several years to implement.

Overarching Recommendations

Many of the recommendations apply to more than one risk. For each recommendation, the major risks to which that recommendation applies are listed in parentheses after the risk (*e.g.* recommendation #1 applies to risks 3, 5, 6, 19 and 29).

These recommendations do not apply to a specific hazard but are geared toward pro-active management of the watershed and overall reduction of risk.

1. Climate change adaptation must be considered in all water management decisions. (3)(5)(6)(19)(29)

2. Those lands that are currently within the boundaries of the drinking water catchment, but which are outside the drainage of Comox Lake, should be managed as buffer lands after a deep-water intake is commissioned.(1)

   After a deep-water intake is installed, there will be pressure to allow increased development and recreational activities on those lands that are currently part of the drinking water supply area, but which will be off-catchment lands once the intake is in place. Allowing greater density or a wider range of activities would encourage more users of the Comox Lake Watershed and therefore increase risk.

3. No highway development should occur in the Comox Lake Watershed, including a road to Port Alberni. (18)

   In 1981, the City of Port Alberni, Ministry of Highways and Regional District of Alberni-Clayquot proposed a connector highway between Port Alberni and the Comox Valley, through the Comox Lake Watershed[31] . This proposal is inactive, and the land-owner (TimberWest) would likely oppose such a plan; however, as populations increase, there may be renewed interest in developing this route.

4. No new development should occur in the Comox Lake Watershed.

   The CVRD is fortunate to draw its water from a headwater system with minimal residential or recreational development, no commercial or industrial facilities, and no point-source upstream discharges. This has prevented pollution and the need to remove contaminants from the water supply. Increased development would increase the number of users of the watershed and could contribute contaminants to the water supply. Degradation of ecological systems is usually a result of a series of small, incremental changes over time. Each one by itself may have minimal impact, and be difficult to quantify, but the cumulative effects of the changes cause degradation.

   The OCP Resource Area policy 62.3 states "Consider temporary use permits on lands designated resource area where the use will not compromise the drinking water quality or quantity." The challenge with assessing water quality and quantity impacts is that they are cumulative and it is difficult to determine at what threshold a development or series of developments could cause harm. As a precaution, this plan recommends no new development within the watershed.

This plan recognizes that the Village of Cumberland is partially within the boundaries of the Comox Lake Watershed, and that the CVRD does not have jurisdiction over zoning and development within the Village. A new deep-water intake will exclude a significant portion of land within Cumberland from draining into the drinking water supply. The Village core is outside the new watershed boundary, and those lands within the catchment and closest to the lake are zoned Industrial, Working Forest, Greenway Lands, and Recreation and Tourism 1. This should therefore not materially affect Cumberland's ability to renew the Village core and upgrade existing infrastructure. Comments related to zoning are contained in Recommendation 19.

5. Land within the Comox Lake Watershed should not be re-zoned to permit further residential, commercial, recreational, agricultural or industrial development.

6. Should land be available for sale within the Comox Lake Watershed, the CVRD should purchase the land to gain additional control over its water supply.

   Direct ownership of land provides the best control over the activities that occur on that land. Water is an increasingly precious and scarce resource and the Comox Valley Regional District is one of the fastest growing regions of the Province.

   Priority should be given to those portions of land within the Village of Cumberland that are not within the CVRD's zoning jurisdiction and any properties that directly border Comox Lake.

   In 2007, the Capital Regional District purchased 8700 hectares of land in the Leech Watershed as a future water supply source (projected for 2050). The cost was $59 million. This equated to a cost of approximately $21 per year per household. The intent is to allow the health of the land to regenerate in order to supply naturally clean water. By comparison, the cost of constructing a filtration plant is estimated at $150 million + $3M per year operating costs[32].

   Other land protection options include dedication of lands and nominal cost; conservation easements; covenants on title; landowner agreements that limit uses and sale; and dedication to a land trust[33]. Land trust options must be carefully researched, as several significant issues with the long-term viability of trusts in BC has arisen in recent years.

7. Water conservation should be encouraged throughout the Comox Valley Regional District. (6)

   The CVRD currently holds a water license on the Puntledge River with a maximum annual diversion amount of 9,092,180 m^3 per year. The CVRD exceeded its licensed withdrawal amount in 2003, 2004 and 2006 prior to implementation of water conservation measures. Annual demand in 2012 was 8,979,000 m^3 and 2016 usage is projected at 9,636,000 m^3; once again in excess of the water license allocation. The CVRD has applied for a Section 34 order with BC Hydro to access an additional 5.0 million m^3 per year of water originally allocated to power generation.

   The population of the CVRD is increasing rapidly and may increase by almost 50% in the next 20 years[34]. At the same time, low snowpack or drought years are predicted to become more common[35]. The CVRD submitted a new water license application to the Ministry of Forests, Lands and Natural Resource Operations on June 4, 2013 to provide additional water to meet growing demand. The application was rejected based on the rationale that there was insufficient water in the Puntledge River to accommodate the license[36].

   Water conservation is supported in the Regional Growth Strategy which has a goal to "provide affordable, effective and efficient services and infrastructure that conserves land, water and energy resources"[38].

8. As recommended by the Regional Water Supply Strategy, the Village of Cumberland and Royston should join the Comox Valley Water System. (2)

   The Regional Water Supply Strategy (RWSS) identified supply from Comox Lake as the least cost option for Cumberland and Royston. If Cumberland and Royston joined the Comox Lake system, it would allow the Cumberland water system of holding ponds, diversions and dams to be decommissioned. This would allow the restoration of natural drainage patterns into Comox Lake and help address the on-going Perseverance Creek erosion issue. The restoration of natural drainage patterns must also be taken into consideration for the siting of the deep water intake, as drainage patterns may in turn influence circulation in the shallow end of Comox Lake.

   A single system would promote harmonization of land-use regulations and bylaws pertaining to the Comox Lake Watershed. At present, the Village of Cumberland's bylaws focus on protecting the Village's water supply (which we acknowledge is part of the Comox Lake system) but do not specifically protect the Comox Lake system. If Village residents were on the Comox Lake system, it would make protection of the Comox Lake Watershed a higher priority for the Village and make public education easier. It would not alter the volume of water withdrawn from

the Comox Lake Watershed, because the Cumberland system is within a subdrainage of the Comox Lake Watershed. The Village of Cumberland is currently undertaking a review of their Long Range Water Supply Strategy to determine the best solution for the Village.

9. The intake depth and location of a drinking water intake on Comox Lake should be carefully considered. (6)(11)(14)

The Comox Lake Intake Conceptual Design report (2008) proposed an intake 800 m upstream of the lake outlet near the north shore of the lake. The preliminary siting study acknowledged that "there is little available data on water quality in and around the lake to help select the optimum location and depth for a new intake. For now, it is suggested that the intake be installed at a depth of 20 to 30 m." While the CVRD now has several years of data from the proposed intake location, sampling should be undertaken at multiple depths over a range of seasons and weather events, in addition to the sampling that is currently underway.

Intake design should include the ability to draw water from multiple depths to ensure that only the highest quality water is drawn into the intakes. This is not the approach suggested by the April 2015 Associated Engineering Report "Water Intake and Treatment Facility Feasibility Study and Concept" which stated "the precise location of the deep lake intake will be determined in the next phase of engineering work. With implementation of filtration, selecting an intake location that has the very best water quality with respect to turbidity is no longer the highest priority. This may provide an opportunity to reduce the capital cost for the intake and raw water pipeline on the lake floor"[39]. The first step in providing safe drinking water is to use high quality source water as a means of reducing the potential load of drinking water contaminants and thus reducing health risk and treatment costs.

While the current test location may turn out to be the best place, it may be that moving the intake even further up the lake (to the west) would provide higher quality water, due to the stronger influence of Perseverance Creek and more intense recreational use of the east end of the lake. The intake itself should be designed to prevent roosting by birds, especially gulls, and the accumulation of bird feces near the intake.

10. All activities, current and proposed, must recognize the need for toilet facilities that are properly maintained to avoid contamination of Comox Lake. (1)(4)(11)(12)(15)(20)(24)

Activities include: forestry activities, recreation, fire supression, and military exercises. Hauling of septage from all temporary and permanent facilities should be conducted only by qualified personnel who have been briefed on safe handling procedures and emergency response measures. If a vehicle hauling septage were to have an accident in the watershed, untreated human waste could enter roadside ditches, streams and the drinking water supply.

11. As part of its on-going options study, the CVRD should continue to consider UV disinfection as a key component of drinking water treatment. (1)(3)(4)(7)(10)(11)(12)(14)(15)(20)(24)

The CVRD's permit to operate was amended in 2015 to require the installation of filtration. The CVRD has awarded the "Comox Lake Water Treatment Options Study" to OPUS. This study will determine the final treatment solution. UV disinfection, alone or in combination with filtration, has been demonstrated to be effective at inactivating chlorine-resistant pathogens including *Giardia* and *Cryptosporidium*.

Administrative Recommendations

12. The CVRD should dedicate the resources required to support implementation of the Watershed Protection Plan. (all risks)

Source water protection requires constant monitoring and adaptation to changing watershed conditions. Without the required resources, this plan will be ineffective.

The CVRD should hire a full time watershed protection coordinator to oversee the implementation of the plan. This position could be supported by senior co-op students or summer students, but cannot be replaced by them. The required level of effort is beyond what can be done by existing staff.

13. The Watershed Advisory Group should meet at least semi-annually and continue to advise and support the implementation and adaptation of the Watershed Protection Plan.

The Comox Lake Watershed is owned by multiple entities and managed under a wide variety of legislation. It is therefore important to build and maintain good relationships with these stakeholders to ensure timely responses to issues of concern and proactive management of the watershed. The whole committee should meet at least twice per year to maintain good communication, while smaller sub-committees may need to meet more frequently.

The value of the Watershed Protection plan lies not only in the document, but in the process that occurred to develop the document. The discussions around the WAG table brought forth new information, reflections on differing perspectives, and new understanding amongst all participants. Communication amongst different agencies was improved and group members began to work toward implementing draft recommendations before the document was even complete. This momentum and these relationships must be maintained in order for the plan to be successful, because the watershed is too large and too diverse for any single agency to manage alone.

Many other communities have similar Watershed Advisory Groups, though they may be called something different. For example, nearby Campbell River has a 'Technical Watershed Committee' that meets on a semi-annual to quarterly basis to review current issues and development plans within the watershed. "The Committee's mandate is derived entirely from a voluntary, mutual interest by member organizations in the protection of source water quality, and knowledge that, although the Committee's activities do not currently emerge from a formalized regulatory process, the mechanisms to designate an area for drinking water protection and compel planning processes exist within the Drinking Water Protection Act if no other mechanism exists to prevent risks to source supplies"[40].

The value of watershed advisory committees has long been recognized by the Province. In 1999, the Auditor General of BC conducted a review called "Protecting Drinking Water Sources". In this report one of the key findings was that the Province lacked "an effective, integrated approach to land-use management" but noted that Community Watershed Roundtables were one mechanism for issues to be addressed in single watersheds. The BC's 2008 water plan "Living Water Smart" committed that "government will support communities to do watershed management planning in priority areas". This commitment is reflected in the 2014 Water Sustainability Act which paves the way for a "local government authority" to have more direct input into decisions affecting water. The details will be made public in the Water Sustainability Act Regulations which are in development.

14. Member agencies of the WAG should commit to abiding by the objective, vision and principles of the WPP.

15. A formal process should be established to ensure all WAG members, especially landowners, are aware of special events and activities planned for the Comox Lake Watershed and that the concerns of the WAG are addressed prior to permitting such events (*e.g.* sporting events on the lake, bike races, fishing derbys etc.).

    This will enable better cooperation and allow policies and practices to be put in place to protect drinking water and reduce risk. One option would be to develop a set of best management practices and integrate these into all event applications so that event owners are responsible for ensuring minimal impact on the lake and surrounding watershed. Certain activities whose risks cannot be adequately managed or are determined to be contrary to source water protection should not be permitted (*e.g.* ORV events).

16. The CVRD, and by extension the WAG as appropriate, should be included in the review process for all permit applications and land tenure applications in the Comox Lake Watershed. (15)(21)

    There is a very limited amount of Crown land in the Comox Lake Watershed. Almost all of it is downstream of the proposed deep-water intake (*e.g.* "off-catchment") but activities on this land could put significant pressure on those lands that do drain into the lake ("on-catchment"). Land in Strathcona Provincial Park is designated Provincial Park, but still belongs to the Crown and activities can still be authorized in the Park by the Province. The Water Supply Association of BC[41] and other local governments in BC[42] have identified provincial land-use proposals as a barrier to source water protection.

    Any proposed permits or land tenure authorizations should be referred to the CVRD. In addition, any Development Permit, subdivision or similar land use applications within the jurisdiction of the Village of Cumberland or CVRD that are within, or in close proximity to, the Comox Lake Watershed should be reviewed with specific reference to drinking water source protection and referred to the WAG as appropriate. In this context, the WAG could be established as an advisory committee to the CVRD Board in the same manner as the advisory planning commission.

17. The CVRD and the Village of Cumberland should ensure that their bylaws prohibit wastes or contaminated soils from being processed, deposited or stored in the Comox Lake Watershed. (21)

    The recent Environmental Appeal Board decision to allow a contaminated waste facility in the Shawnigan Lake watershed highlights the need for strong local bylaws. The local residents' association and the Cowichan Valley Regional District spent hundreds of thousands of dollars appealing the permit that allowed the contaminated waste site to proceed, but the permit was upheld. The Shawnigan

permit was issued by the Ministry of Environment to infill an existing quarry. While unlikely, there are several old mine sites and quarries in the Comox Lake Watershed for which similar permits could be requested. Both the CVRD and the Village must have bylaws to inhibit such permits from being granted.

The Rural Comox Valley Official Community Plan Section 64(3) states: "Consider adopting a soil removal and deposit bylaw under [sic] that prohibits deposits of materials that pose an environmental or health risk"[43]. Such a bylaw should be adopted as a proactive measure. Without such a bylaw, soil (whether contaminated or not) could be dumped on private land, as is occurring throughout the south Shawnigan Lake watershed, and create fill piles that erode into nearby streams and contribute sediment and unknown contaminants to the water supply.

18. Forestry companies should continue to provide annual updates to the CVRD on their proposed forestry plans. (13)(23)

19. The Village of Cumberland's OCP should include a watershed protection zone that encompasses all the Comox Lake Watershed lands within the Village of Cumberland. (1)(12)(15)

The Village's current OCP (2014) does not include the Comox Lake Watershed boundary on its maps. The land within the Village that is also within the Comox Lake Watershed is currently designated for a mix of uses including Recreation, Greenway, Working Forest, Industrial and Park (Map A).

Those lands designated "Recreation" include private land along the east end of Comox Lake. The OCP states that "the intent of this designation is to encourage low impact recreation uses that serve the local and regional area". Under the Tourism policy in section 6.2.3., the OCP states that "Low impact destination resort development will be directed to Comox Lake in accordance with Map A."

Similarly, the "Working Forest" designation states that "Land to the southwest of Comox Lake Road is intended to accommodate low impact recreational uses. Subdivision of land will only be permitted in this area for environmental conservation and appropriate recreational purposes". "Low-impact recreation" is not defined, but does not appear compatible with "destination resort development" on the shores of Comox Lake.

The "Industrial Zone" is further subdivided into "Industrial Reserve" and "Industrial-1,-2,-3" in the proposed Zoning Bylaw No. 1027, 2016[44] (currently under review). Industrial Reserve zoning (which covers the bulk of industrial land within the Comox Lake Watershed) permits lots of 1.0 ha in size and its uses include medical marijuana facilities and silviculture, along with accessory buildings. These lands, in the northeast corner of the Village, are less than 150 m from the lakeshore at their closest point. The small portion of land within the watershed that is zoned "Industrial" includes lots as small as 0.4 ha and uses up to and including heavy industrial uses such as automobile salvage and wrecking, sawmill and "industrial-heavy", however the latter term is not defined.

An overarching watershed protection zone on those lands that would be within the catchment of a new deep water intake should be used to direct incompatible development to those lands with appropriate zoning that are outside the drinking water supply area.

Lakeshore and riparian lands require an Environmental Development Permit from the Village of Cumberland, with the exception of an existing "disturbed area" on the south side of Perseverance Creek.

In section 5.5.1.4 Water Supply, the OCP states: "In order to maintain long term water quality that is protective of public health, recreational activities and forestry activities within the Village watershed will be closely evaluated and monitored to minimize potential impacts on water quality." This statement applies to protection of the Village's water supply system, but does not acknowledge the risks to the Comox Lake drinking water supply.

20. The CVRD Rural Official Community Plan (OCP) should include a watershed protection zone that encompasses all the Comox Lake Watershed lands within the CVRD. (1)(3)(4)(10)(11)(12)(13)(15)(16)(21)(24)(29)

Eroding shoreline at Cumberland Lake Park Campground.

21. The CVRD is currently undertaking a comprehensive zoning review which will result in amendments to bylaws 120 (CVRD Regional Growth Strategy Bylaw) and 337 (Rural Comox Valley OCP). If land use restrictions, due to changes in zoning, cause loss of value, consideration should be given to compensating land-owners. The CVRD should work with BC Hydro to ensure that a renewed Water Use Plan is consistent with the Watershed Protection Plan. (5)(6)(8)(19)

    BC Hydro is very sensitive to the multiple users of Comox Lake and takes great care to balance the need for power generation with drinking water supply, fisheries flows and downstream flooding. Extreme weather events in 2014-2015 (a drought-flood-drought cycle) caused significant rapid changes in the water level of the reservoir. Erosion has been noted along the shoreline, particularly in the Cumberland Lake Park Campground, which may be a direct result of the fluctuations in water level. While localized erosion may not impact water quality, erosion along significant areas of the shoreline may contribute significant quantities of sediment to the lake.

    It may be the case that no practical alterations can be made to the operation of the dam; however, the effect of rapid water level changes on shoreline erosion should be addressed in the next iteration of the water use plan to determine if there are strategies that could minimize rapid water level change.

    The CVRD should work with BC Hydro to assess the condition of the shoreline of the lake and assess whether erosion protection works for isolated areas are required or possible.

22. The Watershed Protection Plan should be updated every 2-3 years with addenda and formally reviewed and revised every 5-10 years. The implementation of the plan should be tracked and reported upon annually to assess progress.

Emergency Planning

Emergency planning is an essential component of watershed protection planning and drinking water safety plans. Furthermore, the GCDWQ recommend "a well-developed site-specific response plan for episodes of elevated source water turbidity brought about by extreme weather or other unforeseen changes in source water quality that may challenge the drinking water treatment in place."

23. Ensure that an emergency back up source is available for drinking water. (3)(5)(6)(7)(8)(18)(19)

    Maintain the option of using the Puntledge penstocks and Lower Browns River as a backup drinking water supply in the event of drought or contamination of the surface water of Comox Lake.

    CFB Comox has indicated that their wells could be accessed as an emergency drinking water supply for the community. Details of this option should be confirmed. Include backup water supply options in an updated Emergency Management Plan (EMP).

24. The Emergency Management Plan should be expanded to include watershed emergencies. It should be reviewed annually and updated periodically. (3)(5)(7)(8)(9)(19)(24)(28)

    Partners in the EMP should include at a minimum: CVRD, Village of Cumberland, TimberWest, Island Timberlands, Hancock Timber, DND, BC Hydro, Fish and Game Club, CLLC and the Coastal Fire Centre.

    The Emergency contact list should be reviewed and updated every six months. Watershed signage and contact information, and spill kit contents, should be checked at the same time. Secondary spill response kits and signage should also be placed at the Cumberland campground and at the west end of the lake.

    The Emergency Management Plan should include, but not be limited to, the following topics:

    - Fire suppression including large wildfire;
    - Vehicle accident adjacent to a watercourse or Comox Lake;
    - Aircraft accident on the lake and in other areas of the watershed;
    - Spill of a hazardous substance including fuel or septage;
    - Dam failure;
    - Total Chance Access plan;
    - Determine who is in charge of which emergencies and pre-determine command and communication structure;
    - Emergency shut-off to drinking water intake;
    - Hazard control points;
    - List of laboratories that can do water quality analysis in emergency situations (as close to real-time as possible);

- A common emergency telephone number to report emergencies;
- Wording for signage;
- Information on locations of good cell phone coverage and installation of signs at those locations;
- Radio frequencies used by forestry companies, police, fire, ambulance, Coastal Fire Centre and DND- designate a common emergency frequency;
- Location of spill containers and spill response materials and ensure partners have keys;
- The need for additional spill containers to be located at major tributaries;
- The value of pre-installing anchors for spill booms for easy deployment in the event of a spill;
- Ensure Comox Lake is listed as a community water supply with the Coastal Fire Centre; and
- The fire suppression plan should document current procedures and responsibilities and addresses any gaps.

Fire-scarred stumps

The Forestry companies operating in the watershed have historically taken on the responsibility of fire suppression. While it is appropriate that they do so given their expertise and resources, there are areas of the watershed that are not private forestry land. This could result in confusion as to roles and responsibilities, or even reporting of a fire. Drought conditions will elevate fire risk. While the majority of the plan is likely already in place, it should be documented, updated and coordinated so that all parties involved (Timber-West, Hancock Forestry, Island Timberlands, CVRD, Village of Cumberland, Fish and Game, and CLLC) have a clear understanding of the lines of communication and protocols.

Use fire retardants as a last resort and avoid direct application to water bodies.

Implement an annual "fire drill" for the watershed with all partners.

Regularly update and share the fire equipment registry.

25. A pre-determined multi-stage water conservation protocol should be implemented throughout the CVRD. Conservation should be automatic, based on reservoir levels and water supply forecasts. (6)

Recreation Management

Perhaps the most comprehensive and thorough review of the effects of recreation on drinking water watersheds was prepared by a team of experts in Australia in 2006[30].

This document sets out eleven principles for recreational access management in watersheds:

1. A risk assessment should be undertaken that considers the likelihood, consequence and certainty of any application and/or grouped activity and this should recognise the contribution of that activity to the cumulative impacts and the indirect impacts.
2. The precautionary principle should be applied in decision-making.
3. A preventive approach should be adopted.
4. The multiple barrier approach should be supported.
5. It should be possible to make decisions on a case-by-case basis but within a consistent policy framework.
6. Public health should be the primary consideration in water supply catchments.
7. Environmental, community, social and economic considerations are also important.
8. Lack of protection in one area should not be used as a reason for decreasing protection in other areas.
9. Water quality should not be degraded to the point where it just complies with the guidelines; the best possible quality of water should be supplied.
10. Direct and indirect costs of access should be borne by users, not the water consumers as a whole.
11. Social acceptance of decisions is necessary, this may require community education on risk and their participation in identifying what is acceptable.

Land-Based Recreation

Recreational access has been conclusively shown to have negative impacts on drinking water quality[30]. "It is now recognized that water treatment does not 'remove' contaminants even when working properly. Rather treatment barriers 'reduce' contaminant concentrations"[30]. "Public health practitioners and water catchment managers have differing views about what level of recreational access is appropriate in water catchments. However, one area of almost universal common ground is that a precautionary approach is warranted, with current levels of access not being increased until further analysis indicates that such changes will not have a negative impact on water quality. Additionally, in some areas with extensive approved recreation, there is a strong desire to reduce current levels of access. However, there is consensus that justification and evidence is required before access regimes are changed"[30].

26. A trail management plan should be developed for all existing trails. (12)

A co-operative agreement should be developed between the CVRD, Village of Cumberland and private land-owners. A trail champion group (*e.g.* UROC) should take responsibility for the day-to-day management of the trails. A condition of allowing trails to remain in use in the watershed should be the ability of the champion group to monitor and prevent the building of unauthorized trails in the watershed, together with the proper maintenance and monitoring of existing trails. No new trails should be added until this ability is demonstrated. A funding mechanism for decommissioning of the trails, should the need arise, must be built in to all agreements from the outset.

It is important that the trail network within the Comox Lake Watershed be managed to a common standard such as IMBA[49] or Whistler Trail standards[50]. This may require starting with a core agreement between key landowners and a trail champion, and then expanding the agreement to include other landowners and trails. For example, a land access agreement between the Village of Cumberland, UROC, Hancock Forest Management and TimberWest has been prepared which would designate UROC as the manager of trail network on the Cumberland side of the watershed. The management plan is currently under development.

Trails should be constructed in designated areas only. Unless otherwise covered by existing regulation, the CVRD should enact a bylaw to ensure that trails do not become permanent rights-of-way that would preclude watershed protection activities and measures.

Toilet facilities and signage should be installed at all major trail heads/gathering places and include code of conduct and emergency contact information

27. Trail agreements should be subject to monitoring and maintenance. (12)

All trails should be subject to a fixed time period, with an agreement that their tenure will be renewed based upon meeting a pre-determined performance standard. If they no longer meet the standard, or cannot be maintained, they must be properly decommissioned.

Trail counters should be installed (motorized and non-motorized) to assess the patterns and intensity of trail use. The Village of Cumberland has established some trail counters and plans to add more in 2016.

28. Camping outside of designated campgrounds should not be permitted in the watershed. In addition to garbage and human waste posing a health risk, wildfire risk is a concern. (1)(3)(15)

Current research shows that bacterial contamination in streams follows a seasonal and weekly trend that can be traced directly to camping in areas without proper waste disposal facilities[45]. In order to enable enforcement, a new CVRD bylaw may be required.

Current camping areas should not be expanded. A buffer should be established between the lake and all existing campsites. A minimum 30 m is recommended as a starting point.

29. Campfires outside of designated campgrounds should not be permitted in the watershed. (1)(3)

"One critical issue for many utilities is the increased risk of wildfire caused by recreational access. Picnicking and camping increase the risk of accidental wildfire, while recreational access in general poses a risk from malicious and deliberate fire lighting. Wildfire can destroy large tracks of land in catchments, resulting in an increased risk of turbid runoff in storm events which, in turn, can affect water treatment processes. In a catastrophic case of wildfire, the impact on turbidity can cause the catchment to become a net contributor of contamination, instead of a barrier, and affect yield negatively"[30].

30. ATV use should be limited to maintained logging roads and subject to code of conduct, enforcement and user agreements with landowners. (3)(4)(12)

- Designate areas outside the watershed for off-road hill-climbing and dirt biking.

- ORV events should not be permitted in the watershed.
- All ORV's must have spark arrestors.
- Signage should be installed at all major trail heads/gathering places and include code of conduct and emergency contact information.
- User groups should be engaged to assist in education and compliance through peer pressure.
- Provincial assistance should be requested to ensure that all ORV's comply with the Off-Road Vehicle Act (2014) which requires the display of a vehicle identification number and prohibits use on private land without owner permission.
- Enforcement of code of conduct and access restrictions may be required if voluntary codes of practice do not work.

31. Dog waste stations and wildlife-proof garbage cans should be installed and maintained at high use sites (trail heads, campgrounds). (12)(15)

    A new wildlife-proof garbage can was installed at Lake Park Campground in 2015 and there are plans for additional installations. Additional garbage cans and dog waste stations are required in high use areas outside the campground.

32. TimberWest should require proof that sewerage and septic facilities for all licensed cabins on its private lands in the Comox Lake Watershed are properly located, constructed and annually inspected as a requirement for renewing each licence. (10)(15)

    Almost all of the licensed cabins are between 50 and 75 years old and have only pit toilets[19]. If a site is poorly designed, untreated human waste can be washed or leach into the lake. Any sewage management facilities in the floodplain should be relocated immediately.

    The cabins are rarely used in winter, and summer use is intermittent. The volume of waste is therefore expected to be low. It may be reasonable to lower inspection frequency after the first two years if use does not warrant annual inspection.

33. TimberWest should consider phasing out cabin licences on Comox Lake. (10)(15)

    Where they have not already done so, TimberWest should shorten licences to 1 or 2 year cycles to permit better monitoring and enforcement of waste management on these properties.

Water-Based Recreation

34. Designated boat cleaning stations should be developed away from the lake to prevent the spread of invasive species. (24)

Purple loosestrife is known to be present on Comox Lake at the BC Parks ecological reserve. This riparian invasive plant is not native to the watershed and is therefore evidence of an introduced invasive species. The most likely source is boats. Invasive animals, such as zebra and quagga mussels are becoming problematic elsewhere in BC. In 2015 the Province launched a watercraft inspection program to control invasives[46].

35. All motorized boats must be fuelled at designated stations away from the lakeshore. Offenders and spills should be reported to the CVRD. (24)
36. The CVRD should ensure its bylaws regulate the size/type of boat allowed on the lake (*e.g.* no houseboats). Bylaw enforcement is also required.
37. Designated sani-dump facilities for bilge and holding tanks should be established outside the watershed; boat users and campers should be directed to these stations. (10)
38. Additional disinfection should be installed to reduce the risk of pathogens from body contact recreation (*e.g.* swimming, watersports) and other human sources[47]. (11)

    Unpublished data from UVic show that between June 2013 and July 2015, there were 103 occurrences of *E. coli* bacteria at depths of 9 m or greater at the proposed deep-water intake site. Of these, 45 contained bacteria from a human source. The highest levels were in the fall (Sept-Nov.). Current research shows that human-infective *Cryptosporidium* is more prevalent in watersheds with recreational access[48].

Land Management

39. A complete assessment of all roads, culverts and bridges in the watershed, including abandoned roads, should be undertaken (or data collated where it has already been done) including road density and stream crossing by subwatershed. This information should be mapped in a GIS database held by the CVRD. (16)(18)(23)

    Historic landslides should be documented along with probable cause.

    Current road design and maintenance practices should be documented and recorded with the Watershed Protection Plan.

    Roads should not be built in riparian areas.

    Roads should be planned to minimize road density and number of stream crossings. Targets for road densities and number of stream crossings should be set based on best available science.

    Ensure that drainage structures and stream crossings are sized for increased intensity and frequency of storms as predicted by climate models. Ensure that drainage structures do not concentrate flows beyond the capacity of receiving streams.

    Exposed soils, including ditchlines, with sediment delivery potential should be grass-seeded to prevent erosion immediately following road/ditch construction.

    A threshold should be established which automatically triggers post-storm field inspections of roads and stream crossings for erosion and landslide events.

40. An access management plan should be developed and implemented for the watershed. All unnecessary roads should be deactivated and roads in sensitive areas should be de-built and recontoured where possible. Hazard and access control points should be established. (18)

    A "fall-back" plan should be designed for potential years when forestry activity may be reduced in the watershed to ensure that road maintenance and access control is still available. TimberWest has such a plan but one is needed for the entire watershed.

    Traffic counters should be installed on major roads (including Comox Main) to assess timing and intensity of use by industrial users and the public.

    Access control on Comox Main should be maintained outside TimberWest working hours.

    All drivers of industrial vehicles should be trained on spill response and road control protocols.

    Vehicles carrying large volumes of potential contaminants (septage, fuel, pesticide) should be radio-equipped and/or escorted in and out of the watershed to reduce accident risk.

    Vehicle accidents or near-misses should be documented and recorded in the CVRD database.

41. All MTB trails in the watershed should be mapped and assessed for their condition against an agreed-upon standard such as IMBA[49] or the Whistler Trail Standard[50], regardless of the land ownership. A no net increase in trails within the watershed should be accepted as a precautionary starting point until an assessment is completed. (12)

    The Village of Cumberland is currently mapping trails in its area and has replaced some bridges. Mapping of other trails in the watershed is needed and all trails require condition assessment.

    Trails in riparian areas should be rerouted or decommissioned. Stream crossings should be perpendicular to the channel and adequate to protect floodplain areas. All trails deemed to be deficient (*e.g.* poorly sited or unsafe) should be recontoured and permanently decommissioned. Trails that are to remain should be repaired or realigned to correct minor deficiencies.

42. A PFC and risk assessment of all major streams and wetlands should be conducted with an emphasis on major tributaries first to assess stream condition including, but not exclusively, channel stability and riparian condition. (5)(17)(19)

43. Best practices and standards of each forestry company, in all of their operating areas, should be shared with one another to enable continual improvement and adaptation. (13)(20)(23)

    All private forest lands in the Comox Lake Watershed should be registered with the Managed Forest Council (MFC) as "Managed Forest Lands" to trigger and ensure compliance with, the Private Managed Forest Land Act and Regulations and trigger monitoring by the MFC.

    The Private Managed Forest Land Act, Section 13(1) states that "the forest management objective for private managed forest land with respect to water quality

is to protect human drinking water, both during and after harvesting." The Act further states that the objective for fish habitat is "to retain sufficient streamside mature trees and understory vegetation to protect all of the following:

a. a natural variation in water temperatures;
b. sufficient cover for fish;
c. a continual source of large woody debris for stream channel stability purposes;
d. a vigorous mass of roots capable of controlling stream bank erosion;
e. a filter to prevent the transport of sediment into stream channels;
f. woody debris sufficient for in-stream habitat;
g. a source of nutrients to the stream through litter fall."

As noted in the section Proper Functioning Condition, the fish habitat protection measures listed above also pertain to protection of ecological function and drinking water quality. Comparing practices throughout all the community watersheds in which these companies operate will accelerate sharing of information and promote a common high standard for drinking water protection that has already been tried and tested elsewhere on Vancouver Island.

Ensure logging plans are submitted to the CVRD at the planning stage to allow for input and potential amendment/ coordination of the plans.

Ensure that adequate riparian buffers are maintained to protect and stabilize stream banks during expected extreme weather events, including more frequent intense rainstorms, regardless of fish status or size and including headwater streams.

- Riparian buffers should be determined based on stream slope, entrenchment, width/depth ratio, sinuosity and dominant bed material with consideration of floodplain areas requiring stability and current riparian condition.
- No harvesting should occur in the riparian buffer to permit regeneration of trees, especially in legacy harvesting areas.

The equivalent clearcut area (ECA) should be calculated and documented on a subbasin basis and where two or more forestry companies are operating in the subbasin, data should be pooled and analysed. Harvesting plans should be co-coordinated in sub-basins where two or more companies are operating. Hydrologically sound ECA thresholds should be established and monitored for each sub-basin.

Each forestry company in the Comox Lake Watershed calculates the ECA for the sub-basins in which they operate. The challenge is that a few basins have more than one company operating in them and therefore the calculations may not be accurate unless data are shared between operators. While there is no immediate cause for concern, it is good practice to ensure that the entire basin is correctly assessed using all available data. While this may happen on an informal level between companies, this plan recommends ensuring that this practice is formalized and reported.

44. Pesticide and herbicide use should be eliminated wherever possible. All pesticides or herbicides intended for use in the watershed should be reviewed for safety in and around aquatic habitat and for potential human health impacts. Pesticides should not be stored in the watershed. (29)

Pesticides and herbicide application is controlled by the Pesticide Management Act. Pesticides may be periodically required to target invasive species. The least toxic option should be chosen. An application plan (chemical, timing, application method, personnel etc.) should be submitted to the CVRD and, by extension, the WAG prior to use. This will allow site-specific monitoring plans to be implemented. Aerial spraying should be avoided wherever possible. In order to minimize the reporting and review burden, best management practices should be agreed to by members of the WAG and any alterations from these protocols justified.

Fertilizer applications should avoid watercourses; however, the value of careful application of fertilizer within riparian zones should be reviewed for potential benefits to enhanced riparian growth *vs.* risks to water quality.

45. The Village of Cumberland should provide information on their water system including maps, an assessment of the system and how it is operated, location and capacity of dams, reservoirs and water diversions. (2)

The operation of the Cumberland water supply can affect the function and operation of the Comox Lake water supply, particularly through water diversions. Any plans to upgrade or modify the operation of the water supply system should be reviewed with the WAG to help mitigate risks and provide opportunities for monitoring. Any data collected by the Village of Cumberland on their water supply system should be included in the CVRD database for the Comox Lake Watershed.

46. The CVRD should work with DND to determine if SAR training over Comox Lake can be eliminated or reduced. (9)

47. The location of coal mine spoil piles should be mapped and they should be assessed for their potential to generate leachate that could enter Comox Lake. (25)

Education and Outreach

Few of the following recommendations pertain to a specific risk. Risk reduction can only be accomplished by educating watershed users and changing behaviour.

48. Develop an education and outreach program for the local community and visitors relating to watershed health, current forestry practices and drinking water source protection. (1)(3)(4)(7)(10)(11)(12)(15)(18)(24)(26)(27)

    This program should consider the following items:

- An education and awareness program for staff and elected officials served by the CVWS should be developed. Such a program would enable more informed decision-making and enable new councillors and staff to quickly understand the essential elements of watershed management, rationale and operation of the CVWS. Most importantly, it would allow them to more fully integrate their decisions within and amongst departments and communities, and help ensure that drinking water quality protection is given high regional priority.
- A series of educational Creeks and Communities workshops should be hosted for interested stakeholders, including CVRD board members and staff of member municipalities.
- Annual educational watershed tours should be held for local politicians, the WAG and the public and include tours of forestry operations. The WAG should revisit specific sites annually to track progress and expand their knowledge of ecology, forestry practices and effects.
- A separate website should be created as a stand-alone location for all public information pertaining to the Comox Lake Watershed. It should be linked to the digital library.
- A universal code of conduct and BMPs should be developed for all users and land-owners within the Comox Lake Watershed.
- Consistent language should be used for signage throughout the watershed and include emergency contact information.
- An on-going public education program should be developed to inform cabin owners/ users, campers and members of the CDFGPA of the issues around sewage disposal in the Comox Lake Watershed.
- A code of conduct brochure should be created for campground users, trail users and other watershed users.
- A social media campaign targeting behavioural change, as opposed to educational messaging, should be implemented where specific actions are desirable. Messaging aimed at behaviour change is typically focused on what is "fun, easy and popular" to create peer pressure and drive change.
- A display should be created that is suitable for presentation at festivals and events regarding watershed function and drinking water protection.
- All websites that reference Comox Lake Watershed (*e.g.* websites on MTB trails, access to Comox Glacier) should be contacted to request that information be added to the site noting that Comox Lake Watershed is a drinking water supply and link to Code of Conduct documents.
- Contact Chamber of Commerce and provide Code of Conduct information for distribution to visitors.
- Curriculum should be developed for schools. Good examples are available from other municipalities.

Measuring Progress

49. The CVRD should develop a comprehensive water quality monitoring program for all major tributaries to Comox Lake as well as a more comprehensive and long-term monitoring program for the lake itself. This is a high priority. (1)(2)(3)(4)(5)(6)(10)(11)(12)(13)(14)(15)(16)(17)(18)(19)(20)(21)(23)(24)

    A robust monitoring program is essential to determine trends, assess the efficacy of management actions, and pro-actively address new issues before they become problematic. At present, there is very limited information on the quality of the water entering the lake from tributary streams. A thorough monitoring plan, including adequate quality assurance protocols, would enable the CVRD to fill data and knowledge gaps and ensure that resources are properly allocated to address necessary management actions on a priority basis. It would also help characterize the natural range of variability and vulnerabilities inherent in this system. The data should be reviewed and interpreted annually by qualified water quality professionals and compared to current regulatory standards and guidelines. The results should be presented as part of the CVRD's annual water quality report.

    This monitoring program should be developed by knowledgeable professionals, and involve watershed managers, including forestry professionals with a detailed knowledge of the watershed. The CVRD should consider creating a

sub-committee of the Watershed Advisory Group for this purpose, with expert guidance. The plan should include the installation of continuous monitoring equipment in major tributary streams, which measures, at a minimum, turbidity, temperature, specific conductance, total suspended solids, and (where not already monitored) water level (stage). Trail cameras that are triggered by water level or other criteria could be mounted on bridges and would provide information on stream behavior during low flow and storm events. These could be tied to pump samplers that take simultaneous water samples matched to the photographs. Grab sampling on smaller tributaries should be conducted at least seasonally to provide a baseline against which to measure change. The CVRD should conduct parasite (*Cryptosporidium* and *Giardia*) monitoring on raw water at the lake intake, and at the outlet of major tributary streams. These data can then be used to determine the need for additional disinfection or filtration, based on health risk.

The microbial source tracking analysis done by UVic has been very informative and should be continued, though perhaps at a lower frequency, in the lake. The focus could be shifted towards a better understanding of tributary streams and beaches, while maintaining background level testing on the lake.

Water level monitoring equipment

The CVRD should establish a relationship with Mt. Washington to gather and report real-time snowpack data.

As noted in a recent Australian study "Risk is not managed merely by apparent achievement of water quality guideline or standard numbers. In general, monitoring programs which emphasize only treated drinking water quality monitoring will not effectively guarantee the safety of drinking water. Not only does end-point monitoring rationale make missing the opportunity to be preventive and identify contamination episodes as they are occurring more likely, it also frequently misses the opportunity to collect data that would provide improved insights on hazards and treatment performance, and the overall vulnerability of the system."

This program will require that all existing information be gathered and data gaps assessed before a program can be developed. Some of these components are:

- All documents related to the Comox Lake Watershed should be compiled into a single CVRD library and digitized as time and funds allow.
- All current and historical water quality and quantity data for the Comox Lake Watershed should be assembled into a single CVRD database.
- Historical air photos should be collected for the Comox Lake Watershed and an updated aerial photo library should be maintained. This is useful for tracking large-scale changes over time. Obtain historical information from WWII since training runs may have captured aerial photos of the watershed.
- CVRD should obtain and host available GIS data for the watershed within its GIS system.

Monitoring should be coordinated with all other agencies/ groups gathering data in the watershed/lake to reduce overlap, ensure a common data standard and obtain maximum information from the data:

- The CVRD should work with BC Hydro to ensure that watershed monitoring is integrated with existing hydrometric and rainfall data collection for consistency, data quality and sharing of data.
- The CVRD should coordinate the water quality monitoring program with the MOE water quality objectives attainment monitoring program.

50. The CVRD should partner with the Village of Cumberland to engage a geotechnical professional and a QEP to determine if the operation of the Cumberland Water Supply System affects Perseverance Creek and determine the scope and cost of stabilizing the eroding slope. (2)

Overflow from Cumberland Creek No. 2 Dam spillway flows into Perseverance Creek via a "spillway channel". This has increased flow in the channel and is causing erosion at the base of the slope and constant erosion of the slope during high rainfall events. This is contributing significant turbidity to Comox Lake. Perseverance Creek continues to contribute significant turbidity to Comox Lake in 2016. Since this recommendation was drafted, a hazard abatement report was completed by TetraTech EBA in 2015[51]. The report presented several options for reducing flow into the eroding channel, but most options would require significant alteration to the Cumberland Water Supply System.

Remedial work will require the co-operation of TimberWest to permit this work on their private lands.

51. The CVRD should work with Island Health to inventory, develop a database and conduct an annual inspection of all septic and sewerage facilities in the Comox Lake Watershed. (5)(10)(15)(19)

The annual inspection should include properties within the Village of Cumberland, the Cumberland Lake Campground, Comox Lake Land Corporation lands, the Courtenay Fish and Game Wildlife Protection Association and private Timber-West cabins. Deficient systems should be upgraded immediately. All systems must be protected from flooding, even if this is not a legal requirement of the Municipal Sewerage Regulation or the Island Health Authority.

A watershed-wide septic maintenance program would provide simpler administration and economies of scale. Consider a local service/ micro-utility to manage sewage facilities in the watershed.

Bank erosion in Perseverance Creek, January 28, 2016.

All pit toilets should be converted to self-contained units (vault). All pit or vault toilets should be pumped out at the end of the summer season before large storm events occur. (note: Two new vault toilets were installed at Cumberland Lake Park in 2015).

Consider a funding/loan program or micro-utility to help alleviate up-front costs of sewage improvements for privately-owned cabins (*e.g.* CLLC). CVRD should work with the Village of Cumberland to facilitate approvals for these upgrades. These upgrades should not be used to justify increased development density.

Review opportunities for greater control over sewage management through CVRD zoning and policies.

52. A hydrogeologist should be retained to review the ground water data and test wells (piezometers) at Comox Valley Waste Management Centre to provide long-term assurance no contaminants from the landfill are travelling toward the reservoir. This should be done in conjunction with landfill upgrades. Test wells should be installed between the landfill and Comox Lake to monitor groundwater quality including heavy metals, nutrients, pesticides and persistent pollutants over the long-term. (21)

In conjunction with the review, options for leachate discharge (*i.e.* offsite *vs.* onsite) should be examined.

53. The CVRD, in partnership with WAG members, should collect baseline data on watershed characteristics and usage. This information should be maintained in a simple database that summarizes key watershed characteristics and usage and be reported annually. Some of this information has already been gathered during the development of this Watershed Protection Plan and will be provided to the CVRD to begin building the database. (1)(4)(10)(11)(12)(13)(15)(16)(17)(24)(26)

The characteristics should include (but not be limited to):

- length of road network,
- location and condition of legacy roads and stream crossings,
- ECA by subdrainage and watershed total,
- length of trails,
- annual precipitation by month,
- number of boats using public and CDFGPA docks (and private docks if possible)
- number of visitor nights in the CDFGPA and Cumberland Lake Park Campgrounds,

- number of users on Comox Lake Main via TimberWest checkpoint, number of users seeking access to Comox Glacier via Strathcona Park,
- number of DND training exercises on or near the lake or in the watershed,
- number of members of CDFGPA,
- number of members in UROC,
- number of hunters in the watershed,
- license numbers of ATV's in watershed,
- number of TimberWest cabins which are occupied and for how long,
- number of trail users and pattern of trail use,
- number and type of sewage management facilities.

The summary should also track watershed incidents such as vehicle accidents, culvert failures, landslides or fire. These data should be used to understand trends over time that can help guide the management of the watershed.

54. The CVRD should publish, as part of its annual public water quality report, a summary of raw water quality and watershed events (see Recommendation 49).

The summary should include streamflow, rainfall, snowpack, extent of glacier retreat, fire incidence, and other relevant data from the annual monitoring program and discuss how, or if, watershed events are related to water quality events in the distribution system. It should include a comparison to Water Quality Objectives as set by the Ministry of Environment and to the Canadian Guidelines for Drinking Water Quality.

Fish and Game Club on Comox Lake

Implementation

Implementation is a roadmap for achieving the goal of producing high quality drinking water from a healthy watershed; putting this plan to work.

Monitoring provides a baseline of water quality and watershed health and allows the community to track trends over time. It also tracks progress toward full implementation of the plan and provides feedback that enables continual improvement and refinement of the plan.

Mouth of the Cruikshank River

Implementation and Monitoring

If the watershed protection plan is to be successful, it will require a commitment of resources, primarily from the CVRD, and stakeholders committed to a common vision. The plan is meant to be a living document that is amended and adapted based on monitoring data, including water quality data, watershed usage and condition, and an understanding of what strategies are most effective in the local community.

The watershed protection plan is comprehensive and will require a full-time coordinator to oversee the many tasks that need to be done. This person should have a good science and resource management background and be able to ensure that data are collected to a high standard to ensure credibility. This person will also need to be sensitive to the diversity of stakeholders in the watershed. Knowledge of the local community and issues is essential. This position could be supported by additional junior staff, for example co-op or summer students, who could take on some of the simpler tasks under the coordinator's supervision.

A priority task is the review of existing data and the development of a water quality monitoring program for the watershed. This will require outside expertise. The plan should be developed with the support of members of the WAG who have detailed knowledge about the watershed, including access issues/timing, sensitive areas, and practical field experience. A common data standard is needed so that data can be coordinated with other agencies that collect data on this system. This monitoring plan should be designed to be year-round and include both grab sampling and continuous water quality monitoring.

The WAG should serve as the implementation committee, led by the CVRD and the watershed coordinator. Sub-committees may be required to address water quality monitoring, emergency planning, and perhaps education and outreach. The WAG should report back to the Water Committee.

Objective

The objective of the Watershed Protection Plan is to guide the management of the Comox Lake Watershed for the long-term protection of drinking water at the highest possible quality.

Vision

"Working through the Watershed Advisory Group, the CVRD will ensure that water resources and ecosystem function within the Comox Lake Watershed are protected in order to provide a high quality, sustainable drinking water supply."

Recommendations have been loosely grouped by activity:

1. Overarching
2. Administrative
3. Emergency Planning
4. Recreation Management
5. Land Management
6. Education and Outreach
7. Measuring Progress

and fit within one of five goals. These goals were not specifically articulated by the WAG, but evolved from the conversations and recommendations.

Goals

1. Improve understanding of watershed function, integrity and resilience. Fill knowledge gaps through data collection, on-going monitoring and expert guidance. (Measuring Progress)
2. Protect the quality of water in Comox Lake and tributary streams by minimizing the input of sediment, nutrients, contaminants and pathogens. (Recreation Management and Land Management)
3. Protect and improve the reliability and security of the Comox Lake water supply by developing and implementing water conservation, flood and drought management and emergency plans. (Emergency Planning)
4. Build public and institutional support for protection of the Comox Lake Watershed and the understanding that the ecosystem services the watershed provides are part of the municipal infrastructure. (Administrative; Education and Outreach)
5. Track and measure the effectiveness of the Watershed Protection Plan and progress towards its full implementation. Ensure the plan remains effective over the long-term through continual feedback and adaptation. (Measuring Progress)

Not all recommendations have specific action items, for example, recommendation 1, which is to consider climate change in decision-making, is not associated with a specific task. Those recommendations that are specific are grouped under one

of the five goals, and labelled with their original recommendation number. Sub-recommendations are listed with the recommendation number followed by "a", *e.g.* 26a is a sub-recommendation of recommendation 26. For each recommendation, the lead agency, supporting agencies, timing, and rough cost have been provided. Listing of a supporting agency does not necessarily imply financial support, rather it is meant to suggest co-operation or in-kind support to accomplish the task. In order to spread the cost over multiple years, less critical tasks have been scheduled later in the 5-year timeline. The watershed protection plan has no fixed end point, because watershed management is an on-going process that is never "complete".

This timing is presented as a guideline. It should be the responsibility of the watershed coordinator to assess each task, break it down into tasks and determine the final schedule. That said, certain tasks such as implementing the water quality monitoring program, managing recreational access, and managing waste must not be delayed. Other tasks such as land acquisition may not be predictable, but the CVRD should be prepared to take advantage of opportunities when they arise. Outreach and education and monitoring will be required throughout the five years and beyond.

Monitoring is not an "event" that occurs at a fixed time, but rather is an on-going process that will help the CVRD to better understand the effectiveness of the plan. An effective monitoring and evaluation programme requires collecting and analyzing important data on a periodic basis. This process will involve collecting baseline data on existing conditions, reporting on progress toward improvements, making connections between actions and intended outcomes, and adapting the plan as new information is acquired. This process should involve the stakeholders on the WAG and be reported as part of an annual report.

Goal 1. Improve understanding of watershed function, integrity and resilience. Fill knowledge gaps through data collection, on-going monitoring and expert guidance. (Measuring Progress)

9. The intake depth and location of a drinking water intake on Comox Lake should be carefully considered. Collect additional water quality and lake circulation data and conduct hydrodynamic modelling to confirm intake location. (6)(11)(14)

   Lead Agency: CVRD
   Support Agencies: Consultant
   Timing: Jun. 2016- Jul. 2017
   Resources: $100,000

49. The CVRD should develop and implement a comprehensive water quality monitoring program for all major tributaries to Comox Lake as well as a more comprehensive and long-term monitoring program for the lake itself. This is a high priority. (1)(2)(3)(4)(5)(6)(10)(11)(12)(13)(14)(15)(16)(17)(18)(19)(20)(21)(23)(24)

    Lead Agency: CVRD
    Support Agencies: BC Hydro, DFO, MOE, TimberWest, Island Timberlands, Hancock, UVic, WAG, consultant
    Timing: develop monitoring plan Apr.–Jul. 2016, install monitoring equipment Sept. 2016
    Resources: Yr. 1 $330,000, Yr. 2 -5 $200,000 annually

50. The CVRD should partner with the Village of Cumberland to engage a geotechnical professional and a QEP to determine if the operation of the Cumberland Water Supply System affects Perseverance Creek and determine the scope and cost of stabilizing the eroding slope. (2)

    Lead Agency: CVRD
    Support Agencies: Village of Cumberland, TimberWest
    Timing: Sept. 2015
    Resources: $10,000

51. The CVRD should work with Island Health to inventory, develop a database and conduct an annual inspection of all septic and sewerage facilities in the Comox Lake Watershed. (5)(10)(15)(19)

    Lead Agency: CVRD
    Support Agencies: Island Health, CLLC, TimberWest, CDFGPA
    Timing: Jan-Mar 2017, annual inspection
    Resources: staff time

52. A hydrogeologist should be retained to review the ground water data and test wells (piezometers) at Comox Valley Waste Management Centre to provide long-term assurance no contaminants from the landfill are travelling toward the reservoir. This should be done in conjunction with landfill upgrades. Test wells should be installed between the landfill and Comox Lake to monitor groundwater quality including heavy metals, nutrients, pesticides and persistent pollutants over the long-term. (21)

    Lead Agency: CVRD
    Support Agencies: Consultant
    Timing: Jan. 2018- Dec. 2019
    Resources: $50,000

53. The CVRD, in partnership with WAG members, should collect baseline data on watershed characteristics and usage. This information should be maintained in a simple database that summarizes key watershed characteristics and usage and be reported annually. Some of this information has already been gathered during the development of this Watershed Protection Plan and will be provided to the CVRD to begin building the database. (1)(4)(10)(11)(12)(13)(15)(16)(17)(24)(26)

    Lead Agency: CVRD
    Support Agencies: WAG
    Timing: Develop database, April -Dec. 2016; Population of database, on-going
    Resources: staff time

Goal 2. Protect the quality of water in Comox Lake and tributary streams by minimizing the input of sediment, nutrients, contaminants and pathogens. (Recreation Management and Land Management)

6. The CVRD should purchase available watershed land to gain additional control over its water supply.

    Lead Agency: CVRD
    Support Agencies: None
    Timing: open
    Resources: $1M+, dependent on parcel size and location

26. A trail management plan should be developed for all existing trails. (12)

    Lead Agency: CVRD
    Support Agencies: TimberWest, Hancock, Island Timberlands, Village of Cumberland, UROC, CDFGPA
    Timing: complete by Mar. 2018
    Resources: staff time

26a. Toilet facilities and signage should be installed at all major trail heads/gathering places and include code of conduct and emergency contact information. (12)

    Lead Agency: CVRD
    Support Agencies: Village of Cumberland, TimberWest, Hancock
    Timing: Apr.-June 2016, Apr.-June 2017
    Resources: Yr. 1 $8500, Yr. 2 $8500, Yr. 3-5 $500 annually

27a. Trail counters should be installed (motorized and non-motorized) to assess the patterns and intensity of trail use. (12)

    Lead Agency: CVRD
    Support Agencies: None
    Timing: May 2016-Mar. 2021
    Resources: Yr. 1 $3200, Yr. 2-4 $700 annually

28. Camping outside of designated campgrounds should not be permitted in the watershed. In addition to garbage and human waste posing a health risk, wildfire risk is a concern. Restrict camping to designated campgrounds through bylaw implementation, education and enforcement. (1)(3)(15)

    Lead Agency: CVRD
    Support Agencies: TimberWest, Hancock, Island Timberlands, CDFGPA, Village of Cumberland, UROC, BC Parks
    Timing: Education immediately, bylaw and enforcement Apr. 2017- Mar. 2019
    Resources: staff time

29. Campfires outside of designated campgrounds should not be permitted in the watershed. Restrict campfires to campgrounds through bylaw implementation, education and enforcement. (1)(3)

    Lead Agency: CVRD
    Support Agencies: TimberWest, Hancock, Island Timberlands, CDFGPA, Village of Cumberland, UROC, BC Parks, BC Hydro
    Timing: Education immediately, bylaw and enforcement Apr. 2017- Mar. 2019
    Resources: staff time, consultant $15,000 (with Recommendation 28 above)

30. ATV use should be limited to maintained logging roads and subject to code of conduct, enforcement and user agreements with landowners. Develop an ORV code of conduct and user agreements with land-owners. (3)(4)(12)

    Lead Agency: TimberWest
    Support Agencies: Hancock Timber, CDFGPA, CVRD, other user groups
    Timing: May 2016 – Sept. 2017
    Resources: staff time, Pacific Salmon Foundation

30a. Designate areas outside the watershed for off-road hill-climbing and dirt biking. (3)(4)(12)

    Lead Agency: Landowners including TimberWest, Hancock, Island Timberlands
    Support Agencies: CVRD, MFLNRO
    Timing: May 2016 – Sept. 2017
    Resources: staff time, Pacific Salmon Foundation

31. Dog waste stations and wildlife-proof garbage cans should be installed and maintained at high use sites (trail heads, campgrounds). (12)(15)

    Lead Agency: CVRD, Village of Cumberland
    Support Agencies: UROC, CDFGPA, BC Hydro
    Timing: May 2016-Mar. 2017 and Apr. 2019-Mar. 2020
    Resources: Yr. 1 $7500, Yr. 4 $2500

32. TimberWest should require proof that sewerage and septic facilities for all licensed cabins on its private lands in the Comox Lake Watershed are properly located, constructed and annually inspected as a requirement for renewing each licence. (10)(15)

    Lead Agency: TimberWest
    Support Agencies: Island Health
    Timing: May 2016- Mar. 2017
    Resources: staff time

34. Designated boat cleaning stations should be developed away from the lake to prevent the spread of invasive species. (24)

    Lead Agency: CDFGPA, Village of Cumberland
    Support Agencies: CVRD, CLLC, Province of BC
    Timing: May. 2016-Sept. 2016 access provincial program
    Resources: Provincial check point program, future TBD

35. Ensure all motorized boats are fuelled at designated stations away from the lakeshore. Offenders and spills should be reported to the CVRD. (24)

    Lead Agency: CDFGPA, CLLC, Village of Cumberland
    Support Agencies: CVRD
    Timing: May. 2016-Sept. 2016, on-going
    Resources: staff time (student)

36. The CVRD should ensure its bylaws regulate the size/type of boat allowed on the lake (*e.g.* no houseboats). Bylaw enforcement is also required.

    Lead Agency: CVRD
    Support Agencies: Village of Cumberland
    Timing: Apr. 2020-Mar. 2021
    Resources: staff time

37. Designated sani-dump facilities for bilge and holding tanks should be established outside the watershed; boat users and campers should be directed to these stations. (10)

    Lead Agency: CDFGPA, Village of Cumberland
    Support Agencies: CVRD, DFO
    Timing: Apr. 2017- Sept. 2017
    Resources: staff time, ~$10,000

38. Additional disinfection should be installed to reduce the risk of pathogens from body contact recreation (*e.g.* swimming, watersports) and other human sources.[52] (11)

    Lead Agency: CVRD
    Support Agencies: consultant
    Timing: concurrent with deep water intake
    Resources: ~ $4M+

39. A complete assessment of all roads, culverts and bridges in the watershed, including abandoned roads, should be undertaken (or data collated where it has already been done) including road density and stream crossing by subwatershed. This information should be mapped in a GIS database held by the CVRD. (16)(18)(23)

    Lead Agency: TimberWest, Hancock Timber, Island Timberlands, Village of Cumberland
    Support Agencies: CVRD
    Timing: May 2016-Mar. 2017
    Resources: additional GIS staff time

40. An access management plan should be developed for the watershed. All unnecessary roads should be deactivated and roads in sensitive areas should be de-built and recontoured where possible. Hazard and access control points should be established. (18)

    Lead Agency: TimberWest, Hancock Timber, Island Timberlands, Village of Cumberland
    Support Agencies: CVRD
    Timing: Apr. 2017- Mar. 2019 access plan, on-going road management
    Resources: TBD

40a. Traffic counters should be installed on major roads (including Comox Main) to assess timing and intensity of use by industrial users and the public. (18)

    Lead Agency: TimberWest, Hancock Timber, Island Timberlands, CVRD
    Support Agencies: CDFGPA, Village of Cumberland
    Timing: May 2016-Aug. 2017 initial installation; on-going monitoring
    Resources: equipment loan, staff time

41. All MTB trails in the watershed should be mapped and assessed for their condition against an agreed-upon standard such as IMBA[53] or the Whistler Trail Standard[54], regardless of the land ownership. A no net increase in trails within the watershed should be accepted as a precautionary starting point until an assessment is completed. (12)

    Lead Agency: CVRD, Village of Cumberland
    Support Agencies: UROC, TimberWest, Hancock
    Timing: Apr. 2017- Mar. 2018
    Resources: mapping $15,000, Vancouver Island University (VIU) student intern, assessment $60,000

42. A PFC and risk assessment of all major streams and wetlands should be conducted with an emphasis on major tributaries first to assess stream condition including, not but not exclusively, channel stability and riparian condition. (5)(17)(19)

    Lead Agency: CVRD
    Support Agencies: Consultant, TimberWest, Hancock, Island Timberlands
    Timing: Jun. 2017-Mar. 2021
    Resources: $50,000 annually Yr. 2- Yr. 5, GIS in-kind/ VIU student

43. Best practices and standards of each forestry company, in all of their operating areas, should be shared with one another to enable continual improvement and adaptation. (13)(20)(23)

    Lead Agency: TimberWest, Hancock, Island Timberlands
    Support Agencies: CVRD, WAG
    Timing: on-going
    Resources: staff time

44. Pesticide and herbicide use should be eliminated wherever possible. All pesticides or herbicides intended for use in the watershed should be reviewed for safety in and around aquatic habitat and for potential human health impacts. Pesticides should not be stored in the watershed. (29)

    Lead Agency: TimberWest, Hancock, Island Timberlands, Village of Cumberland
    Support Agencies: CVRD
    Timing: May 2016-Jun. 2016, on-going
    Resources: staff time

45. The Village of Cumberland should provide information on their water system including maps, an assessment of the system and how it is operated, location and capacity of dams, reservoirs and water diversions. (2)

    Lead Agency: Village of Cumberland
    Support Agencies: CVRD
    Timing: Jul. 2016-Dec. 2016
    Resources: staff time

46. The CVRD should work with DND to determine if SAR training over Comox Lake can be eliminated or reduced. (9)

    Lead Agency: CVRD, DND
    Support Agencies: None
    Timing: May 2016-Jun. 2016
    Resources: staff time

47. The location of coal mine spoil piles should be mapped and they should be assessed for their potential to generate leachate that could enter Comox Lake. (25)
    Lead Agency: CVRD
    Support Agencies: TimberWest, Hancock, Island Timberlands, Village of Cumberland
    Timing: Apr. 2019-Mar. 2020
    Resources: $5000

Goal 3. Protect and improve the reliability and security of the Comox Lake water supply by developing and implementing water conservation, flood and drought management and emergency plans. (Emergency Planning)

23. Ensure that an emergency back up source is available for drinking water. (3)(5)(6)(7)(8)(18)(19)

    Lead Agency: CVRD
    Support Agencies: DND
    Timing: initial discussion May 2016, on-going
    Resources: staff time

24. The Emergency Management Plan should be expanded to include watershed emergencies. It should be reviewed annually and updated periodically. (3)(5)(7)(8)(9)(19)(24)(28)

    Lead Agency: CVRD
    Support Agencies: Village of Cumberland, City of Courtenay, Town of Comox, TimberWest, Island Timberlands, Hancock Timber, BC Hydro, CLLC, DND, CDFGPA, Coastal Fire Centre, Provincial Emergency Program.
    Timing: May 2016- March 2017, annual review
    Resources: staff time

24a. Ensure Comox Lake is listed as a community water supply with the Coastal Fire Centre.

    Lead Agency: TimberWest
    Support Agencies: Hancock Timber
    Timing: immediately
    Resources: staff time

25. A pre-determined multi-stage water conservation protocol should be implemented throughout the CVRD. Conservation should be automatic, based on reservoir levels and water supply forecasts. (6)

    Lead Agency: CVRD
    Support Agencies: City of Courtenay, Town of Comox
    Timing: immediate pre- summer 2016
    Resources: staff time

Goal 4. Build public and institutional support for protection of the Comox Lake Watershed and the understanding that the ecosystem services the watershed provides are part of the municipal infrastructure. (Administrative; Education and Outreach)

8. As recommended by the Regional Water Supply Strategy, the Village of Cumberland and Royston should join the Comox Valley Water System. (2)

    Lead Agency: CVRD, Village of Cumberland
    Support Agencies: Regional Water Committee, Water Advisory Committee
    Timing: TBD
    Resources: TBD

12. The CVRD should dedicate the resources required to support implementation of the Watershed Protection Plan. (all risks)

    Lead Agency: CVRD
    Support Agencies: None
    Timing: Mar. 2016
    Resources: as noted in each recommendation, total approx. $400,000-$700,000 annually

12a. The CVRD should hire a full time watershed protection coordinator to oversee the implementation of the plan. This position could be supported by senior co-op students or summer students. (all risks)

    Lead Agency: CVRD
    Support Agencies: None
    Timing: Apr. 2016
    Resources: $80,000 coordinator, $35,000 student(s) with grant support

13. The Watershed Advisory Group should meet at least semi-annually and continue to advise and support the implementation and adaptation of the Watershed Protection Plan.

    Lead Agency: CVRD
    Support Agencies: WAG
    Timing: April 2016, on-going
    Resources: Yr. 1 $14,500, Yr. 2 $14,500 (facilitation/expert advice), $7,500 annually on-going, volunteer time (WAG)

14. Member agencies of the WAG should commit to abiding by the objective, vision and principles of the WPP.

    Lead Agency: CVRD
    Support Agencies: WAG
    Timing: April 2016
    Resources: staff time, volunteer time (WAG)

15. A formal process should be established to ensure all WAG members (including landowners) are aware of special events and activities planned for the Comox Lake Watershed and that the concerns of the WAG are addressed prior to permitting such events (*e.g.* sporting events on the lake, bike races, fishing derbies etc.).

    Lead Agency: CVRD, TimberWest, Hancock
    Support Agencies: WAG
    Timing: Sept. 2016-Dec. 2016
    Resources: staff time, volunteer time (WAG)

15a. Develop a set of event best management practices and integrate these into all event applications so that event owners are responsible for ensuring minimal impact on the lake and surrounding watershed.

    Lead Agency: CVRD
    Support Agencies: WAG
    Timing: Sept. 2016-Mar. 2017
    Resources: staff time, volunteer time (WAG)

16. The CVRD, and by extension the WAG as appropriate, should be included in the review process for all permit applications and land tenure applications in the Comox Lake Watershed. Request that the Province and Village of Cumberland refer land use applications to the CVRD for comment (*not approval*). (15)(21)

    Lead Agency: CVRD
    Support Agencies: WAG
    Timing: Request Jun. 2016, on-going
    Resources: staff time, volunteer time (WAG)

17. The CVRD and the Village of Cumberland should ensure that their bylaws prohibit wastes or contaminated soils from being processed, deposited or stored in the Comox Lake Watershed. (21)

    Lead Agency: CVRD, Village of Cumberland
    Support Agencies: Ministry of Environment
    Timing: Apr. 2019-Mar. 2020
    Resources: staff time

18. Forestry companies should continue to provide annual updates to the CVRD on their proposed forestry plans. (13)(23)

    Lead Agency: TimberWest, Hancock, Island Timberlands
    Support Agencies: CVRD
    Timing: annual
    Resources: staff time

19. The Village of Cumberland's OCP should include a watershed protection zone that encompasses all the Comox Lake Watershed lands within the Village of Cumberland. (1)(12)(15)

    Lead Agency: Village of Cumberland
    Support Agencies: CVRD
    Timing: Apr. 2019-Mar. 2020
    Resources: staff time

20. The CVRD Rural Official Community Plan (OCP) should include a watershed protection zone that encompasses all the Comox Lake Watershed lands within the CVRD. (1)(3)(4)(10)(11)(12)(13)(15)(16)(21)(24)(29)

    Lead Agency: CVRD
    Support Agencies: WAG
    Timing: Apr. 2019-Mar. 2020
    Resources: staff time, volunteer time (WAG)

21. The CVRD should work with BC Hydro to ensure that a renewed Water Use Plan is consistent with the Watershed Protection Plan. (5)(6)(8)(19)

    Lead Agency: CVRD, BC Hydro
    Support Agencies: WAG
    Timing: Apr. 2018-Mar. 2019
    Resources: staff time, volunteer time (WAG)

21a. The CVRD should work with BC Hydro to assess the condition of the shoreline of the lake and assess whether erosion protection works for isolated areas are required or possible. (5)(6)(8)(19)

    Lead Agency: CVRD, BC Hydro
    Support Agencies: TimberWest, Village of Cumberland, CDFGPA
    Timing: Aug. 2017- Sep. 2017 (minimum lake level), in advance of Water Use Plan
    Resources: staff time + $10,000 equipment, volunteer time

48. Develop an education and outreach program for the local community and visitors relating to watershed health, current forestry practices and drinking water source protection. (1)(3)(4)(7)(10)(11)(12)(15)(18)(24)(26)(27)

    Lead Agency: CVRD
    Support Agencies: WAG, Village of Cumberland, City of Comox, City of Courtenay, Chambers of Commerce
    Timing: adapt outreach materials Jun. 2016- Mar. 2017, website Apr.-Jun. 2017, on-going
    Resources: Yr. 1 $110,000, Yr. 2 $80,000, $50,000 annually on-going, staff time, volunteer time (WAG)

Goal 5. Track and measure the effectiveness of the Watershed Protection Plan and progress towards its full implementation. Ensure the plan remains effective over the long-term through continual feedback and adaptation. (Measuring Progress)

22. The Watershed Protection Plan should be updated every 2-3 years with addenda and formally reviewed and revised every 5-10 years. The implementation of the plan should be tracked and reported upon annually to assess progress.

    Lead Agency: CVRD
    Support Agencies: WAG, consultant
    Timing: Apr. 2019- Mar. 2020
    Resources: staff time, $30,000, volunteer time (WAG)

54. The CVRD should publish, as part of its annual public water quality report, a summary of raw water quality and watershed events.

    Lead Agency: CVRD
    Support Agencies: WAG
    Timing: Mar. 2017, on-going at year end
    Resources: staff, volunteer time (WAG)

Performance Indicators

In order to assess whether the watershed protection plan is effective, and the progress made toward plan implementation, suggested performance indicators are listed below each goal.

Goal 1. Improve understanding of watershed function, integrity and resilience. Fill knowledge gaps through data collection, on-going monitoring and expert guidance. (Measuring Progress)

- Forested area by age class
- Road density by subbasin
- Length of road network and condition
- Length of trail network and condition
- Number of stream crossings (roads + trails)
- Water quality trends by tributary
- ECA by subbasin
- Length of stream, wetland, and lake shoreline in functional, functional at-risk and non-functional condition
- Number, type and condition of septic systems
- Number of intense rainstorms greater than 25 mm in 24 hours
- Number of days annually when fire danger rating is high or extreme
- Annual snowpack

Goal 2. Protect the quality of water in Comox Lake and tributary streams by minimizing the input of sediment, nutrients, contaminants and pathogens. (Recreation Management and Land Management)

- Water quality trends by tributary stream (compare to Cdn. Water Quality Guidelines for the Protection of Aquatic Life)
- Water quality trends at the lake intake (improving, unchanged, declining)
- Number of days that turbidity at the lake intake is greater than 5 NTU
- Number of bacterial breakthroughs in the distribution system

Goal 3. Protect and improve the reliability and security of the Comox Lake water supply by developing and implementing water conservation, flood and drought management and emergency plans. (Emergency Planning)

- Number of human-caused fire starts
- Number of vehicle incidents (near misses, accidents)
- Number of days of water restrictions by level (1, 2, 3, 4)
- Per capita water consumption

Goal 4. Build public and institutional support for protection of the Comox Lake Watershed and the understanding that the ecosystem services the watershed provides are part of the municipal infrastructure. (Administrative; Education and Outreach)

- Dollars spent on watershed protection, including education (by all WAG partners) *vs.* dollars spent on water treatment
- Number of bylaws within the CVWS service area referencing watershed protection

- Number of positive *vs*. negative public comments on social media, newspaper, or direct contact with local government
- Number of participants in educational events/ contacts with watershed ambassadors
- Number of reported/ documented instances of code of conduct violations (*e.g.* boat fuelling on lake, campfires outside campgrounds, ORV's off-road)
- Number of instances of vandalism in the watershed (*e.g.* BC Hydro property, CDFGPA, forestry equipment)

Goal 5. Track and measure the effectiveness of the Watershed Protection Plan and progress towards its full implementation. Ensure the plan remains effective over the long-term through continual feedback and adaptation. (Measuring Progress)

- Percentage of recommendations started
- Percentage of recommendations completed
- Percent complete of each recommendation
- Effectiveness should be summarized by performance indicators from Goals 1-4

Resources

Since the CVRD is the water purveyor, the majority of resources directed toward this plan will need to be provided by the CVRD. The estimated budget is:

Year 1:	$629,700
Year 2:	$562,200
Year 3:	$562,200
Year 4:	$444,700
Year 5:	$406,500
Total:	$2,605,300

This estimate does not include costs associated with capital upgrades such as a lake circulation study for the deep-water intake location or additional treatment. Over five years, based on a population of 41,000 users, the cost of watershed protection is approximately $0.03 per person per day.

There are resources, both financial and other, that are available to assist in implementation. These include:

- Co-operation with stakeholders on the WAG who may already be gathering data and making observations that simply need to be tracked in a central database;
- Adapting education and outreach materials already developed by other agencies including Metro Vancouver and the Regional District of Nanaimo (see Appendix 3);
- Working with local stewardship groups to extend educational messages regarding watershed stewardship to include the Comox Lake Watershed (*e.g.* Project Watershed);
- Hiring co-op students with expertise specific to a task, *e.g.* a social marketing student to assist with the development of a social media campaign;
- Partnership with small business to access programs that fund science and technology interns such as ECO Canada which provides up to 50% of an intern's salary up to $15,000 per year. This can be a win-win-win for the business, the CVRD, and the student who needs to gain experience;
- Engage interns requiring a final project applicable to the watershed *e.g.* students at VIU who require a GIS practicum;
- Partnering with university research programs *e.g.* the partnership already formed with UVic to gather additional water quality data;
- Partnering with landowners to engage in research specific to Comox Lake Watershed;
- Working with local user groups (*e.g.* UROC, CDFGPA) to manage or assist with selected aspects of the plan (*e.g.* trails management, spill response);
- Partnering with DND to support emergency planning; and
- Project-specific grants from agencies such as the Real Estate Foundation of BC and the Pacific Salmon Foundation, and Eco-Action.

Financial Implications

Supplying drinking water is a complex and expensive process. The current annual operating budget for CVRD water services is on the order of $3M per year using chlorine disinfection, plus an additional $2M per year as a sinking fund for capital upgrades.[55] Since many of the major risks of using the Puntledge River intake can be mitigated by moving to a deep-water intake in Comox Lake, the CVRD plans to relocate the intake in the near future. The estimated cost of this work is $15.8M for a new intake and pump station and $12.7M for new transmission mains[56](class C estimate: -15% to +20%). If UV disinfection is added, the additional cost will be approximately $4.5M[57], bringing the estimate for moving the intake and adding UV to between $28.5M and $40M.

If filtration of drinking water is added, the estimated additional cost is approximately $29M to build the plant. A pilot program to determine the best type of filtration is estimated at $8.6 M. The additional direct capital cost for filtration is therefore approximately $37.6M. It should be noted that all estimates are class 'C' estimates (-15% to +20%) therefore the additional cost of filtration could be in the range of $32 to $45M. The total budget for all upgrades would therefore be between $60 and $85M, plus inflation, borrowing costs and land acquisition (approx. $6.5M) (total direct plus indirect costs of $66.5M to $91.5M). The CVRD is currently undertaking a study to determine treatment options.

The cost of operating a water filtration plant is variable, but a 2011 study by Stats Canada determined an average cost of $161 per megaliter (1000 m^3) per year[58]. Using this calculation, the estimated annual cost of filtering the full volume allowed by the CVRD's water license would be approximately $1.46M per year. Cost of filtration is directly dependent on the quality of the water entering the plant. If the water quality is high, then filters do not need to be changed/backwashed as frequently, the useful life of the plant is extended and operating costs are lower. If the incoming water is of poor quality, physically, chemically or biologically, then the operating costs of the plant increases. A review of treatment costs and watershed characteristics for 27 US drinking water utilities found that for every 10% increase in forest cover of the source water area, chemical and treatment costs decreased by 20%[59]. Not enough data were available for supplies with more than 65% forest cover, but it was suggested that treatment costs level off when forest cover is between 70 and 100%. A growing body of information supports compensating land-owners for the protection of forested and riparian areas, in order to reduce drinking water treatment costs[60].

Ecological Benefit

The ecological benefits of watershed protection are considerable. While this plan is focused on drinking water quality, the ecological processes and attributes that give rise to clean water also benefit the terrestrial and aquatic species of the watershed. They provide resiliency against a changing climate and help to secure the quantity of water available for human and ecosystem needs. For example, healthy forests improve air quality, absorb carbon emissions, filter air pollution, improve water quality and soil, moderate snowmelt and runoff, provide wildlife habitat and block winds.

Riparian zones are particularly rich habitats because they are transitional zones (ecotones) between aquatic and terrestrial environments. They are areas through which surface water and subsurface hydrology connect waterbodies with their adjacent uplands. They store surface water and sediment, which reduces downstream damage from floods. They also remove pollutants from overland flow and shallow groundwater.

Riparian areas control stream temperature, stream structure (primarily through the introduction of large wood), and sedimentation. Water availability within riparian areas promotes the growth of trees and other plants whose roots act to stabilize streambanks and prevent erosion. This in turn protects water quality for aquatic species and prevents smothering of fish habitat. Protection of riparian areas for drinking water quality also protects the habitat of amphibians and reptiles, small mammals and birds, and provides connectivity corridors for larger mammals including deer and bears. Aquatic invertebrates, which play a critical role in the food web of streams, can be significantly affected by the loss or alteration of the riparian canopy, which then affects nutrient dynamics within the stream.

Good land use planning and management protects soils from compaction and limits hydrological changes. Water is retained on the land and downstream flooding is moderated. Groundwater, which is recharged through the infiltration of rain and snowmelt, provides baseflow to streams, and to Comox Lake, during dry summer months. Retention of forest soils also limits nutrient export into the lake and downstream to the marine foreshore. Loss of excess nutrients from the land into marine foreshore areas creates ocean "dead zones."

Deep Water Intake

A new deep-water intake will be at a higher elevation than the existing Puntledge River intake. This may mean that it will be possible to eliminate four and possibly five of the existing pump stations in the Comox Valley Water System and save the energy used to run them. Excess water pressure generated by the greater hydraulic head may also be used to generate energy via turbines (micro-hydro) elsewhere in the distribution system[53].

Water filtration would require additional energy demand. An energy balance study would be required to determine if energy savings created by the new intake configuration would be consumed by the filtration plant or whether a net energy benefit would remain.

Appendices

Appendix 1 – Rationale for Each Risk Rating

Risk assessment is a difficult process to do objectively, particularly in the absence of data. "Generally risk assessment will often include subjective judgements based on experience and will at best be qualitative or semi-quantitative. Rarely will enough knowledge be available to complete a detailed quantitative risk assessment. Although numerical rankings can be assigned, these rankings provide a relative indication of the likelihood, consequences (severity) and risk and should not be assumed in subsequent analyses to have accuracy in absolute terms. The aim should be to distinguish between very high and low risks."[23]

This risk assessment attempts to capture comments from the Watershed Advisory Group and is intended to be as transparent as possible. Where uncertainty exists, we have erred on the side of caution. Where there is supporting science, it is noted in the recommendations that arise out of each risk and the references are (will be) contained in endnotes in the Recommendations section of the plan.

"If this community watershed was undisturbed, which activities would my community be willing to allow into the watershed and what conditions would it insist on before the activity was permitted to occur?"

In reading the risk assessment and associated recommendations, it is important to try to look at the watershed objectively, from a functional point of view, and not to allow value judgements or personal wants and needs to creep in. One way to try and "stand back" is to ask yourself the following question: "If this community watershed was undisturbed, which activities would my community be willing to allow into the watershed and what conditions would it insist on before the activity was permitted to occur?"

Once that question is answered, then the associated costs and benefits can be tallied and objectively examined. Beyond that, it becomes the community's decision, through its elected representatives, as to what it is willing to pay for (either financially, in terms of health risk, or socially) and what it is not willing to risk.

The following hazards are ranked from greatest risk to least risk, based on abated risk (*e.g.* with existing barriers in place). Risks are based on current levels of use/ extent. If the usage rates increase (for example public use of roads) the risk may also increase. Some risks have the same rating and are not prioritized within that rating group.

1	Source/ Hazardous Event	Camping in undesignated areas in the watershed, especially near the lakeshore or other riparian areas
Hazard	Sediment	See Wildfire; trampling of riparian area;
	Nutrients	
	Pathogens	Microbial contamination from litter and human waste; Microbial contamination from dogs
	Contaminants	Fuel, personal care products
General Comments: Camping tends to be short-term i.e. long weekends; Potential shampoo and soap input during short-term camping; No camper/ trailers can access White's Bay since there is no vehicle access; Willemar Lake sees some camping activity; Strathcona Park receives back-country use; There is a lot of backcountry use away from lake; The east portion of lake also receives unregulated public use in White's Bay, and the Boston Creek area (undesignated areas); Two human-induced fires occurred at the Ecological reserve and Hydro dam in 2014; Drought increases fire risk and 2014 and 2015 were both drought years; Consequence rating due to fire and parasites;		
Unabated Risk	Likelihood	16
	Consequence	16
	Level of Risk	256
	Risk Rating	**Very High**
Existing Preventative Measures	The lakeshore is generally very steep and the geography discourages widespread lakeshore use; Chlorination of water supply.	
	2006 Risk Ranking	None
Current Abated Risk	Likelihood	16
	Consequence	4
	Level of Risk	64
	Risk Rating	**Very High**
Data Gaps	Current inventory of how many people are camping in the watershed, for how long, and where; Little information available on bacterial counts at White's Bay; Need information on human-caused fires in the region; Number of fires extinguished in the watershed by forestry crews, F&G members etc.;	
Comments & Recommendations Install traffic counters to determine number of users accessing the watershed, timing and trends; Camping only in designated areas of the watershed; Risk rating could be lowered by watershed use permits and active management of campers; Public education required.		

2	Source/ Hazardous Event	Augmentation/concentration of stream flows
Hazard	Sediment	Turbidity due to erosion in receiving stream channel
	Nutrients	
	Pathogens	
	Contaminants	
General Comments	Perseverance Creek erosion is thought to be due to excess flows in an undersized channel resulting in stream bank failure; The augmented flows are the result of historical diversion of flows from other natural drainages to serve the Village of Cumberland water supply network; No correlation exists between turbidity and bacterial counts in the source water; Recent research shows disinfection is not compromised with turbidity < 10 NTU; 2014/2015 landslide in Perseverance Creek did not result in a loss of disinfection; Magnitude of consequence is related to regulatory response, not just health risk.	
Unabated Risk	Likelihood	16
	Consequence	4
	Level of Risk	64
	Risk Rating	**Very High**
Existing Preventative Measures	None	
	2006 Risk Ranking	None
Current Abated Risk	Likelihood	16
	Consequence	4
	Level of Risk	64
	Risk Rating	**Very High**
Data Gaps	Documentation of previous land slides or erosion related to diversion of flows from one sub-watershed to another;	
Comments & Recommendations: The CVRD should partner with the Village of Cumberland to engage a geotechnical professional and a QEP to determine if the operation of the Cumberland Water Supply System affects Perseverance Creek and determine the scope and cost of stabilizing the eroding slope; (COMPLETE) The Village of Cumberland should join the regional water supply; Ensure that road drainage structures do not concentrate flows beyond the capacity of the receiving stream;		

3	Source/ Hazardous Event	Wildfire
Hazard	Sediment	Turbidity from particulate fallout and erosion
	Nutrients	Nutrients from phosphate-based fire retardants or soil erosion
	Pathogens	Microbiological contamination from dead animals
	Contaminants	Chemical contamination from fire retardants
General Comments	Increasing drought risk is associated with a changing climate; Must consider the long-term natural fire cycle and weather; Risk of accidental/intentional human-caused fire; Most backcountry fires are human-caused; High risk from camping and campfires outside regulated campsites; High risk of fire from partiers near Hydro dam; Risk from remote cabin users accessing cabins during high fire-risk periods; High risk from ORV's sparking fires; Changing fuel load may result from forest pests (*e.g.* pine beetle in interior); Consider fire fighting methods and input of nutrients to lake; use of aircraft etc. Road network provides access for fire fighting.	
Unabated Risk	Likelihood	8
	Consequence	16
	Level of Risk	128
	Risk Rating	**Very High**
Existing preventative measures	Comox Lake would provide significant dilution of fire retardants; Forestry companies perform routine fire patrol and have response plans in place; Comox Lake is large enough to use an aerial fire-fighting water source; An extensive road network is available for firefighting access; Cutblocks may limit fire spread; Forestry companies implement forest closure based on local conditions; Campfires are not permitted anywhere in Strathcona Provincial Park.	
	2006 Risk Ranking	
Current Abated Risk	Likelihood	2
	Consequence	16
	Level of Risk	32
	Risk Rating	**Very High**
Data Gaps	Fire frequency data – TimberWest has some; Are remote cabins still accessible during fire closures? Fire fighting methods; Clear coordination and communication protocol between forest companies, CVRD and Village of Cumberland.	

Comments & Recommendations:
Install spill huts on major tributaries;
Develop a watershed-wide co-coordinated Total Chance Access Plan;
Document the Total Chance Access Plan;
Integrate existing fire management protocols and resources for all Forestry companies, DND, CVRD, Village of Cumberland and include in the Emergency Plan;
Determine who is in charge and pre-determine command and communication structure;
Implement an annual fire drill for the watershed;
Regularly update fire equipment registry;
Ensure firefighting participants all have access to a designated radio frequency;
Assess the need/ utility of creating deliberate fire breaks;
Ensure Comox Lake is listed as a community water supply with regional fire suppression teams;
Use fire retardants as a last resort and avoid direct application to waterbodies;
Restrict camping to designated campsites;
Ensure off-road vehicles have spark arrestors;

4	Source/ Hazardous Event	Off Road Vehicle (ORV) use off maintained road networks
Hazard	Sediment	Riparian trampling and damage; Erosion from off-road access including hill climbing; Increased fire risk; Invasive species spread
	Nutrients	
	Pathogens	Microbial contamination from litter and human waste
	Contaminants	Chemical contamination from fuel

General Comments:
ORV's include ATV's, dirt bikes, side-by-sides, snowmobiles;
Use is primarily in summer;
Off-road vehicles (ORV's) are used by hunters and fishermen;
4x4's are not a significant issue due to the terrain in most of the watershed;
Access for ORV's increases fire risk and erosion from hill climbing;
ORV's drive through fish habitat/wetlands and pose a potential sediment source;
More motorized users on Forbidden Plateau and Boston Creek;
ATV use is gaining in popularity;
Trails increase in size from mountain bike to dirt bike to ATV;
There is easy access to Comox Main - no highway, no trailering required;
Snowmobiles are in high alpine areas but use is rare;
Snowmobiles access snow line through the old ski lodge on Forbidden Plateau;

Unabated Risk	Likelihood	8
	Consequence	16
	Level of Risk	128
	Risk Rating	**Very High**

Existing Preventative Measures	TimberWest restricts access to the upper watershed and Comox Lake Main when forestry activity is occurring; Forestry companies perform routine fire patrol and have response plans in place; Chlorination of the water supply.	
	2006 Risk Ranking	None
Current Abated Risk	Likelihood	2
	Consequence	16
	Level of Risk	32
	Risk Rating	Very High
Data Gaps	Pattern, location and intensity of ORV use; Number of fire starts in the region due to humans and due to ORV's;	

Comments & Recommendations:
Develop designated areas outside the watershed for off-road hill-climbing and dirt biking;
ORV use should be limited to logging roads and subject to code of conduct and user agreements with landowners;
ORV events should not be permitted in the watershed;
All ORV's must have spark arrestors;
Signage should be installed at all major trail heads/gathering places and include code of conduct and emergency contact information;
Engage user groups to assist in education and compliance through peer pressure;
Enforcement of code of conduct and access restrictions may be required if voluntary codes of practice do not work;
Public education.

5	Source/ Hazardous Event	Flooding on the order of a 100 to 200-year event
Hazard	Sediment	Turbidity from erosion
	Nutrients	
	Pathogens	Pathogens washed into lake from flooded areas including inundated septic fields/pit toilets
	Contaminants	Potential contaminants from coal mine spoils

General Comments:
Climate models predict more frequent more intense storms;
Comox Lake is large and has some settling capacity;
Nutrients washed into the lake would also be heavily diluted;
NW hydraulics report noted 40% greater storm intensity on neighbouring Tsolum River in recent years;
There is a risk of flooding around the lake and cabins;
Shoreline erosion by wind and wave action would be accelerated by large storms;
Tributary streams are more at risk than the lakeshore which is generally rocky;
The east end of lake is shallow and sediment could be resuspended from the lake bottom;
The coal mine spoils White's Bay area are erodable;
The area behind the Fish and Game club is erodable;
Cumberland has limited turbidity data for their systems *e.g.* Perseverance Creek;
A very large flood could cause overtopping or failure of the BC Hydro dam.

Unabated Risk	Likelihood	2
	Consequence	16
	Level of Risk	32
	Risk Rating	Very High
Existing Preventative Measures	BC Hydro manages the water level in the reservoir to reduce flooding and prevent the dam from overtopping; Real-time rainfall and stream flow data are monitored by BC Hydro and shared with CVRD to aid in emergency preparedness; CVRD utilizes a turbidity management plan; Chlorination of the water supply.	
	2006 Risk Ranking	High
Current Abated Risk	Likelihood	2
	Consequence	16
	Level of Risk	32
	Risk Rating	Very High
Data Gaps	Data/reports to confirm/refute whether coal mine spoils and leachate are an issue (study done in 2001?); Meteorological projections; Design safety factor of BC Hydro dam;	
Comments & Recommendations: Implement a turbidity monitoring program on the tributaries to assess current input to the lake and identify areas at risk of erosion; Assess the channel stability of the tributaries as part of a larger PFC assessment of the watershed; Assess the current condition of the shoreline of the lake and assess whether erosion protection works are required or possible; Require septic maintenance and inspection; Investigate alternative water sources as emergency backup; Inventory and assess old mine sites for potential leachate and erodability; Ensure riparian areas are managed for maximum bank stability;		

6	Source/ Hazardous Event	Drought
Hazard	Sediment	Exposure of lakeshore due to increased drawdown; increased fire risk
	Nutrients	Concentration of nutrients
	Pathogens	Concentration of pathogens
	Contaminants	Potential changes in water chemistry

General Comments:
Low snowpack in last 2 of 2 years;
Increased frequency of drought predicted;
Comox Glacier is retreating and normally supplies summer flows;
Drought is often associated with higher than normal air temperatures which drives additional evaporation from the lake surface;
CVRD has exceeded licensed water extraction volumes in 2002, 2004 and 2006 and is expected to exceed again in 2016;
Water restriction bylaw may result in unintended consequences *e.g.* higher use as people ensure they water their lawns at specific times;
Comox Lake is so large that water would be available for drinking however this would likely require reallocation of water from BC Hydro power generation;
Capital grant applications to higher levels of government for water supply improvement may be contingent upon universal metering.

Unabated Risk	Likelihood	16
	Consequence	4
	Level of Risk	64
	Risk Rating	Very high
Existing Preventative Measures	Some water conservation programs in support of reduced household water use; Stage 1- 3 water restriction bylaw in effect; Chlorination of the drinking water supply;	
	2006 Risk Ranking	none
Current Abated Risk	Likelihood	16
	Consequence	2
	Level of Risk	32
	Risk Rating	High
Data Gaps	Flow data for tributaries to Comox Lake; Percentage of inflow to Comox Lake from rainfall vs. snow and glacier melt; Incidence of phytoplankton blooms and associated taste and odour events;	
Comments & Recommendations: Water conservation measures are essential; Universal water metering should be implemented throughout the CVRD; Consequence is mitigated (made less severe) through water conservation.		

7	Source/ Hazardous Event	Intentional harm to the water source or watershed
Hazard	Sediment	See Wildfire
	Nutrients	See Wildfire
	Pathogens	Microbial contamination
	Contaminants	Chemical contamination

General Comments:
The risk is small, but someone seeking to do intentional harm could cause significant health risk or long term interruption;
The proximity of CFB Comox may increase the risk of threats to the regional water supply;
There is potential for action against forestry company assets;
There is potential for wildfire caused by arson;
There is potential for harm to BC Hydro dam and power facilities;

Unabated Risk	Likelihood	1
	Consequence	16
	Level of Risk	16
	Risk Rating	High
Existing Preventative Measures	A new deep water intake would be below the water surface and less accessible to surface contaminants; Continuous water quality monitoring is undertaken 24/7 to identify changes in pH, temperature, turbidity, and chlorine residual and the system is alarmed; Forestry personnel, Hydro personnel, and Fish and Game Club caretaker are vigilant about unusual activity;	
	2006 Risk Ranking	VH
Current Abated Risk	Likelihood	1
	Consequence	16
	Level of Risk	16
	Risk Rating	High
Data Gaps	Would a new pump house be publicly accessible?	

Comments & Recommendations:
Install an automatic emergency pump/valve shut-off;
Identify an alternative temporary water source;
Integrate the Emergency Preparedness plan with the WPP;
Obtain a list of labs that can do analysis in emergency situations (as close to real-time as possible);
Obtain and review Vancouver 2010 security strategy for Vancouver water supply for additional protection measures;
Investigate whether CFB Comox water wells could be a partial emergency backup;
Update emergency response plan with current contact information.

8	Source/ Hazardous Event	Earthquake resulting in the loss of the BC Hydro dam
Hazard	Sediment	
	Nutrients	
	Pathogens	
	Contaminants	

General Comments:
Though there is little that can be done to mitigate the risk, dam failure should be included in Emergency Response planning

Unabated Risk	Likelihood	1
	Consequence	16
	Level of Risk	16
	Risk Rating	High
Existing Preventative Measures	Seismic standard of dam construction	
	2006 Risk Ranking	none
Current Abated Risk	Likelihood	1
	Consequence	16
	Level of Risk	16
	Risk Rating	High
Data Gaps	Estimated magnitude of earthquake which could destabilize the dam	

Comments & Recommendations:
Include dam failure in emergency response planning.

9	Source/ Hazardous Event	Aircraft accident on Comox Lake
Hazard	Sediment	
	Nutrients	
	Pathogens	
	Contaminants	Chemical contamination from fuel

General Comments:
DND conducts search and rescue (SAR) training on the lake with large CH-149 Cormorant helicopters (also regular boat training with access via Fish and Game ramp);
SAR training occurs in poor weather as well as good weather. This was historically discouraged. DND does not fly in weather below 3 miles visibility and 1500 foot ceilings;
SAR rationale for using Comox Lake- DND has indicated it is not necessary if training can be conducted elsewhere;
In the event that a helicopter goes down, it would be treated like any crash and a rescue response would be coordinated out of Victoria tasking Comox aircraft, vehicles and personnel;
DND can act as a limited resource in the event of a drinking water emergency: 19 Wing has it own water source and in emergency situation could be used as a limited water source;

General Comments: Large helicopters carry a large volume of fuel; If hydrocarbons enter the distribution system, it could interrupt water supply for an extended period; Entrainment of water could short-circuit directly to the intake at certain times of the year; There is a risk of aircraft crash if fighting a forest fire; The risk is very small, but if it occurred a faster response may reduce the length of water service interruption. Response time is not predictable, therefore consequence cannot be lowered without more information; Low levels of fuel in water supply is not a significant health risk. The concern is taste and odour;		
Unabated Risk	Likelihood	2
	Consequence	8
	Level of Risk	16
	Risk Rating	High
Existing Preventative Measures	Comox Lake would provide significant dilution of fuel releases; A spill kit is available at the Fish and Game Club; The deep water intake will lower the risk of drinking water contamination if hydrocarbons remain on the lake surface; Fuel would volatilize quickly; The CVRD has a boat available for spill response; If DND involved (*e.g.* training exercise) DND would be available to mitigate a spill	
	2006 Risk Ranking	H
Current Abated Risk	Likelihood	2
	Consequence	8
	Level of Risk	16
	Risk Rating	High
Data Gaps	Need a copy of spill response/crash response protocol for the Cumberland Fire Dept; How much fuel is on board fire fighting aircraft? The likelihood of a DND failure is extremely remote; aircrew would elect to crash land as opposed to ditching.	
Comments & Recommendations: Obtain a copy of DND's crash response protocol and Cumberland Fire Department protocols and integrate them into the Emergency Response Plan for the watershed; Ensure DND has access to the spill kit at the Fish and Game Club and is included on the emergency call out list; Determine whether SAR training over the lake can be reduced or eliminated or moved to south end of lake only. Local DND staff have agreed to relocate training however federal training exercises still utilize Comox Lake.		

10	**Source/ Hazardous Event**	**Sewage management facilities**
Hazard	Sediment	
	Nutrients	
	Pathogens	Microbial contamination from leaking septic facilities;
	Contaminants	Contaminants (pharmaceuticals and personal care products, cleaning agents) from greywater
General Comments: Facilities include up-to-date septic systems, pit toilets, self-contained toilets, and old unregulated discharge from remote cabins; There are 26 cabins on the east side of the lake owned by members of the Comox Lake Land Corp (CLLC). Six are used year round; It is difficult to get approvals for septic system upgrades; The cost of septic upgrades is expensive (market-driven barrier); Ten cabins have wastewater holding tanks, nine have septic systems and seven have pit toilets and seepage pits for greywater; There is a concern of flood inundation. The height of the BC Hydro dam is 135.3m; the highest recorded lake level at the dam was 136.3 m during 2010 flood event. The reservoir could go up to 2m higher than highest recorded (138.3m). The 2010 flood event went to the foot of some of the CLLC cabins; 11 cabins draw drinking water directly from the lake; CLLC cabins typically use wood and electric heat sources; 42 cabins are owned by TimberWest on the south & central portions of the lake; The status of the pit toilets or septic systems in the TimberWest cabins is unknown but believed to be poor; Flood inundation is a known risk on the Cruickshank peninsula The Fish & Game club has an up-to-date septic system; no dumping of grey or black water is allowed on club property. Holding tanks may only emptied in town; The Fish & Game club has vault toilets that are regularly pumped out; The Cumberland Lake Park campground installed a new septic system in 2005; The pit toilet at the Cumberland Lake Park Campground has been replaced with a vault toilet and moved away from the lake; Any development of the campground is through the CVRD since it is land within CVRD jurisdiction, but owned by the Village of Cumberland; No regular monitoring of septic systems occurs by IH until a failure occurs; Microbial source tracking shows presence of human-source bacteria at deep water intake; CVRD monitoring showed caffeine present in the lake which is a surrogate for septic discharge; Human-to-human transmission more likely than animal-to-human; Chlorination has a low to moderate effectiveness in killing parasites; Facilities are all in east basin nearest to the deep water intake; High use in summer months, especially long weekends;		
Unabated Risk	Likelihood	16
	Consequence	4
	Level of Risk	64
	Risk Rating	Very High

Existing Preventative Measures:
Comox Lake Land Corp (CLLC):
17 septic systems are higher than the high bank at the cabins;
Fields are located behind the cabins in the high bank area;
Most get water from wells;
CLLC has looked into a small treatment system for CLLC property (cost prohibitive);
CLLC has own garbage disposal program;
Patrol officer checks unattended beaches on east lake that the public does access;
Many cabins have upgraded their septic systems; owners required clean up after dogs;
CLLC have been in contact with the fire department to discuss process if fire occurred;
No boat refueling is permitted on dock;
Boats must be repaired away from the dock;

Septic system for Fish & Game buildings was professionally sized and installed 8-10 years ago. It is maintained regularly;
Cumberland Lake Park Campground installed a new septic system in 2005 which is pumped back up to the parking lot. It is maintained on a regular basis by the Village of Cumberland;
Campground upgrades are underway (2015) as outlined in the Cumberland Lake Park Plan;
Chlorination is highly effective against bacteria; no breakthroughs have occurred; no historical outbreaks of waterborne disease; no reported cases of swimmers becoming ill;
Chlorination has a low to moderate effectiveness in killing *Giardia*;

	2006 Risk Ranking	H
Current Abated Risk	Likelihood	4
	Consequence	4
	Level of Risk	16
	Risk Rating	High
Data Gaps	Current inventory of location, type, maintenance program and condition of septic/ sewage facilities; Testing and monitoring of septic fields and lakeshore is needed to determine if waste is entering the lake. The CVRD conducted some preliminary testing primarily of south and central lake and caffeine was shown to be present which is an indicator of sewage effluent; Power supply available for septic treatment; identify elevation of septic fields/pit toilets and susceptibility to flooding.	

Comments & Recommendations:
Conduct an inventory of location, type and condition of septic/sewage facilities; Zoning is required from Cumberland for DP process (note: CLLC indicates approval process is difficult);
Develop a funding/loan program or micro-utility to help alleviate up-front cost of sewage improvements for privately-owned (CLLC) cabins;
Develop a watershed-side septic maintenance program;
Install piezometers between septic fields and lake to monitor groundwater movement and septic leakage;
Conduct shoreline monitoring including coliforms, testing for optical brighteners present in laundry soaps, and a SCUBA survey of aquatic plant populations (indicators of nutrient input from disposal fields);
Ensure all pit toilets are pumped out at the end of the season before large storm events occur;
Convert existing pit toilets that discharge to ground into self-contained units;
Improve communication and education around waste management;

Comments & Recommendations:
Consider a local service area/micro-utility to manage sewage in the watershed;
Exert greater development control via CVRD zoning and policies
Ensure cabin leases are renewed only if septic systems are in compliance;
The CVRD should work with Island Health to develop a database and conduct an annual inspection of all septic and sewerage facilities in the Comox Lake Watershed;
TimberWest should consider phasing out cabin leases;
Immediately close or relocate any facilities in the floodplain/ inundation zone.

11	**Source/ Hazardous Event**	**Body contact recreation on Comox Lake**	
Hazard	Sediment		
	Nutrients		
	Pathogens	Microbial contamination from litter and human waste	
	Contaminants	Personal care products	

General Comments:
In 2014 coliform counts at the Cumberland Lake Campground beach were “moderate” (i.e. >200, <1000 CFU/100mL) indicating that a higher risk of illness was present;
In 2015, one sample on August 11 at the Cumberland Lake Campground beach was 4500 and swimming was not recommended; samples from May-early August were <5;
There are no restrictions on swimming areas or timing;
There are no restrictions on waterskiing or paddleboarding;
Body contact recreation occurs in summer months when water temperatures are elevated and microbial survival is greatest;
The database on parasite prevalence is short (began fall 2014), but most results are zero;
Human-to-human transmission is more likely than animal-to-human;
Chlorination is highly effective against bacteria; no breakthroughs have occurred; no historical outbreaks of waterborne disease; no reported cases of swimmers becoming ill;
Chlorination has a low to moderate effectiveness in killing *Giardia*;

Unabated Risk		Bacteria	Parasites & Viruses
	Likelihood	16	8
	Consequence	4	4
	Level of Risk	64	32
	Risk Rating	Very High	High
Existing Preventative Measures	Chlorination of the drinking water supply.		
	2006 Risk Ranking	None	

Current Abated Risk		Bacteria	Parasites & Viruses
	Likelihood	1	4
	Consequence	4	4
	Level of Risk	4	16
	Risk Rating	Moderate	High
Data Gaps	Microbial source tracking to confirm source of bacteria at beaches; Number of unique users for various body-contact recreation types (*e.g.* swimming, SUP, waterskiing); Records of gastrointestinal illness in the users of the Comox Lake water supply; Parasite sampling database over multiple years;		

Comments & Recommendations:
Additional disinfection is required to reduce pathogen risk (*e.g.* UV disinfection);
Continue the microbial source tracking program currently underway with UVic and extend the focus to summer beach areas to determine actual loading from body contact and associated health risk;
Obtain records of gastrointestinal illness in the users of the Comox Lake water supply;
Public education program;
Regular patrols;
Healthcare professionals to advise patients with GI illness not to swim in public facilities including lakes.

12	**Source/ Hazardous Event**	**Trails and non-motorized trail use (hiking, mountain biking, horse riding, cross-country skiing and snowshoeing)**
Hazard	Sediment	Turbidity from erosion of trails; Ground compaction; Increased runoff; Erosion of stream crossings and trampling of riparian area; Increased fire risk; Invasive species
	Nutrients	
Hazard	Pathogens	Microbial contamination from litter and human waste; Microbial contamination from dogs and horses
Hazard	Contaminants	

General Comments:
Unauthorized trail construction and use is extensive near the east basin of the lake closest to the intake;
Promotion of trail use to tourists introduces people to the watershed who may carry microbial pathogens that are not normally present in the watershed or the local population;
Trails near Forbidden Plateau are unmanaged;
Winter use includes cross-country skiing and snowshoeing on Forbidden Plateau;
Intensity of trail use is thought to be high in summer and low in winter;
Trail counter data collected by the Village of Cumberland estimates annual use at about 65,000 users on the Cumberland trail network;
Cumberland is promoting trail use as an economic development activity;
No toilet facilities are available;
Limited garbage facilities available;

General Comments:
Dog waste is common along trails;
Some stream crossings are poorly located;
Limited trail monitoring and maintenance occurs; Large special events must be managed so risk is not increased;
Trail-building camps constitute camping outside designated campsites;
Trails are extensive in Perseverance creek area which is an existing concern due to landslide and erosion and which increases access to Cumberland's water supply on Allen Lake;
Campfires are not permitted anywhere in Strathcona Provincial Park;
Chlorination does not protect against parasites;

Unabated Risk	Likelihood	8
	Consequence	4
	Level of Risk	32
	Risk Rating	High
Existing Preventative Measures	Forestry companies and Village of Cumberland are preparing user agreements that include trail condition assessment, management, and code of conduct on Cumberland side of watershed. (No such plan is available for the unregulated trails); Chlorination of the water supply;	
	2006 Risk Ranking	
Current Abated Risk	Likelihood	4
	Consequence	4
	Level of Risk	16
	Risk Rating	High
Data Gaps		Pattern and intensity of trail use; Inventory and mapping of all existing trails and their condition;

Comments & Recommendations:
Bylaw to prevent permanent rights of way;
Provision of toilet facilities;
A trail management plan should be developed for all existing trails;
Trail tenure should be subject to monitoring and maintenance;
Provide dog waste stations and wildlife-proof garbage bins;
Signage should be installed at all major trail heads and include code of conduct and emergency contact information;
Install trail counters to assess pattern and intensity of trail use;
No new trails should be constructed until a complete trail assessment is complete and all necessary decommissioning or upgrades have taken place;
A common trail standard should be adopted for consistent use in the watershed *e.g.* IMBA or Whistler Trail Standard;
Trails should be constructed in designated areas only;
Approach Recreation Sites and Trails BC to determine if planning or enforcement assistance is available;
Large special events *e.g.* Enduro races, must be managed carefully so risk is not increased;
Network with Mt. Washington resort to share best practices and promote a common code of conduct.

13	Source/ Hazardous Event	Timber Harvesting- cutblock location and extent
Hazard	Sediment	Sediment from erosion caused by unintended hydrological changes or riparian vegetation loss; Increased soil compaction from tree canopy removal;
	Nutrients	Nutrients from soil erosion
	Pathogens	Pathogens from wildlife due to increased forage
	Contaminants	

General Comments:
More frequent and intense storms, and higher streamflows, are expected due to a changing climate;
The PMFL Council Field Practices guide permits selective harvest of trees in the riparian buffer and limited buffers are required on streams less than 3 meters wide;
Headwater streams, most of which are less than 3 m wide, are very susceptible to disturbance and often provide moderation of flows to lower reaches in summer due to their higher elevation;
Certain sub-basins are managed by multiple land owners/operators;
Harvesting an area generally increases forage and may attract ungulates;
Cutblock design around rain-on-snow events, for certain elevations, is generally not applicable below 600m;
The impacts of changing climate, ocean currents (*e.g.* El Niño) and changes in storm intensity may be more significant than minor variations in mature tree cover over the landscape;

Unabated Risk	Likelihood	8
	Consequence	4
	Level of Risk	32
	Risk Rating	High
Existing Preventative Measures	Regulation of private land under the PMFL Act & Regulations; Regulation of Crown Land under Forest Practices Code; Forestry companies in the watershed all use the Best Management Practices for Private Forest Land in BC; Each riparian area adjacent to a harvest area is assessed by a Professional Forester and Biologists to assess the impact of partial or all tree removal on stream bank erosion, fish habitat, and drinking water quality; ECA thresholds are calculated and implemented by each land-owner; Cutblocks and roads are planned to avoid unstable and potentially unstable terrain; Planning includes how roads will be constructed and maintained to access each cutblock and deactivated following harvest and replanting; Cutblock plans include harvesting, reforestation and monitoring; Plans specify the type of equipment to be used, timing and condition of harvest to minimize ground disturbance, compaction and erosion which impedes newly planted tree growth; All harvested areas must be replanted per PMFLA Regulations and implemented and monitored by Registered Professional Foresters.	
	2006 Risk Ranking	M

Current Abated Risk	Likelihood	4
	Consequence	4
	Level of Risk	16
	Risk Rating	High
Data Gaps	Co-coordinated ECA thresholds for sub-basins with two or more land-owners; ECA not calculated the same way by all land-owners/ operators in the watershed;	

Comments & Recommendations:
Consequence primarily related to harvesting in riparian areas;
Riparian buffers should be determined based on stream slope, entrenchment, width/depth ratio, sinuosity and dominant bed material with consideration of floodplain areas requiring stability, and current riparian condition;
Ensure that adequate riparian buffers are maintained to protect and stabilize stream banks during expected extreme weather events, including more frequent intense rainstorms, regardless of fish status or size and including headwater streams;
No harvesting should occur in riparian buffers in order to permit regeneration of trees, especially in legacy harvesting areas;
Conduct a PFC assessment of all major streams and wetlands with an emphasis on major tributaries first to assess stream condition including, not but not exclusively, channel stability and riparian condition;
Hydrologically sound ECA thresholds should be established and monitored for each sub-basin especially where two or more land-owners/operators access timber in the same sub-basinHarvesting plans to manage ECA thresholds should be co-coordinated when two or land-owners/operators access timber in the same sub-basin;
Ensure harvesting plans are submitted to the WAG annually at the planning stage to allow for input and potential amendment/ coordination of the plans with other watershed activities/issues;
Best practices and standards of each forestry company, in all of their operating areas, should be shared with one another to enable continual improvement and adaptation;
Ensure that all private forest lands in the Comox Lake Watershed are registered with the Managed Forest Council as “Managed Forest Lands” to trigger, and ensure compliance with, the Private Managed Forest Land Act and Regulations and trigger monitoring by the MFC.
Public education on current forestry practices is required;
Conduct annual watershed tours, especially for members of the WAG and Water Committee, and include areas under active harvesting, post-harvest and post-planting (*i.e.* a range of conditions). Revisit specific areas each year to track progress.

14	Source/ Hazardous Event	Wildlife contamination of Comox Lake
Hazard	Sediment	
	Nutrients	Salmon carcasses contribute nutrients to inflow streams
	Pathogens	Microbial contamination, including bacteria, viruses and parasites, from droppings and dead animals
	Contaminants	

General Comments:
There is documented coliform contamination in the east basin from birds;
The waste management centre to the east is a refuge and food source for birds, especially gulls;
The deep water intake will be located in east basin;
Summer prevailing winds are northwest and blow toward the intake;
The east shore is likely within the deep water intake zone of influence;
Many seagulls are present at the boat launches;
DFO has a salmon carcass planting program for creeks that usually occurs in November;
Nitrogen and ammonia levels increase during the salmon run but this condition is not currently tracked;
High levels of bacteria are present during low flows in Aug-Sept and increase until the first major rainfall-potential causes may include increasing temperature/phytoplankton life cycle;
Spikes in levels in have been seen in the fall (Oct.) – Microbial source tracking (UVic) suggests the source is bears attracted to the salmon run;
Based on current data, no correlation has been shown between bacterial loads and turbidity events;
No correlation has been shown between high flows and bacterial counts;
The database on parasite prevalence is short (began fall 2014);
Only 38% of isolates from Comox Lake carried virulence genes as shown in a 2 year study and their infectivity is unknown;
Chlorination has a low to moderate effectiveness in killing *Giardia*;
Populations of large ungulates are generally small;

Unabated Risk	Likelihood	16
	Consequence	2
	Level of Risk	32
	Risk Rating	High
Existing Preventative Measures	The proposed deep water intake is not on the river where salmon runs/decay is concentrated or where bears and birds would be most attracted; Fish and Game Club code of conduct prohibits dumping fish entrails into the lake; Deep water intake monitoring shows lower levels of bacteria at deep water intake than at current penstock intake; Disinfection of the drinking water with chlorine. No coliform bacteria have been detected in the distribution system;	
	2006 Risk Ranking	H
Current Abated Risk	Likelihood	8
	Consequence	2
	Level of Risk	16
	Risk Rating	High

Data Gaps	Need a detailed understanding of lake circulation and stratification, particularly in the east basin; Need to understand the zone of influence on the proposed deep water intake; Need to understand the cause of increased bacterial counts in Aug/Sept and whether it is linked to water temperature or algal lifecycles; Need to document nitrogen levels during fish returns and carcass planting programs;
Data Gaps	No current understanding of viruses in Comox Lake (very challenging and expensive); Further study required to assess human health risk in terms virulence of bacteria from wildlife; Obtain records of gastrointestinal illness in the users of the Comox Lake water supply; **Bird Control:** Could bird control at the landfill be directed toward reducing numbers of birds rather than relocating them?

Comments & Recommendations:

Bird Control:
Ensure that fish entrails and food are not fed to seagulls by fishermen;
Ensure fish entrails are not dumped into the lake;
Bird control is required at the landfill – The CVRD has a 2-year contract in place, but the goal is to keep birds out of landfill, not protection of water quality. Determine if bird control program can be made more effective for protecting the water supply.

Install continuous temperature loggers at various depths near the proposed location of the deep water intake to assess stratification;
Ensure that the deep water intake is carefully sited and can draw water from multiple depths;
Design the deep water intake to prevent bird roosting;
Monitor algal (phytoplankton) species and densities in the east basin of the lake and correlate these data with bacterial data to determine if there are common trends or cause & effect linkages;
Monitor inflow streams for nitrogen levels during salmon spawning seasons to assess potential effect of increased salmon returns in the watershed on lake nutrient status;
Continue deep water intake monitoring;
Continue the microbial source tracking program currently underway with UVic;
Dual disinfection (chlorine + UV) should be installed to inactivate potential viruses and parasites;
Obtain records of wildlife numbers from the Fish and Game Club to determine wildlife population trends;
Educate hunters to ensure gut piles are not placed in riparian areas;
Obtain records of gastrointestinal illness in the users of the Comox Lake water supply;

15	Source/ Hazardous Event	Lakeshore cabins, camping at designated campsites and Fish and Game Club on Comox Lake (excluding Fire and Sewage Management)
Hazard	Sediment	Trampling of riparian zone; See Wildfire
	Nutrients	See Sewage Management Facilities
	Pathogens	See Sewage Management Facilities Microbial contamination from litter and human waste; Microbial contamination from dogs.
	Contaminants	Oil from heating systems, contaminants from household products and materials (*e.g.* pesticides, paint); Stormwater runoff from hard surfaces.

General Comments:
There are 26 cabins on the east side of the lake owned by members of the Comox Lake Land Corp (CLLC).
Six are used year round;
11 cabins draw drinking water directly from the lake;
CLLC cabins typically use wood and electric heat sources, not oil;
42 cabins are leased by TimberWest on the south & central portions of the lake;
Many of the cabins are old and have not been upgraded for many years. Several are in the Cruickshank floodplain.
Any development of the Cumberland campground is through the CVRD since it is land within CVRD jurisdiction, but owned by the Village of Cumberland;
Activities at the Fish and Game Club are subject to a code of conduct (see preventative measures below);
High use in summer months, especially long weekends;
Lower risk of fire than in undesignated camping areas due to containment and caretaker presence at campground, Fish and Game Club and CLLC cabins.

Unabated Risk	Likelihood	8
	Consequence	4
	Level of Risk	32
	Risk Rating	Very High
Existing Preventative Measures	Comox Lake Land Corp (CLLC): CLLC has own garbage disposal program; Patrol officer checks unattended beaches on east lake that the public does access; Many cabins have upgraded their septic systems; owners required clean up after dogs; CLLC have been in contact with the fire department to discuss process if fire occurred; No boat refueling is permitted on dock; Boats must be repaired away from the dock; Code of Conduct in place for Fish and Game Club which includes: no ATV use on property, pets on leash and droppings cleaned up, no dogs in swimming area, litter control, no release or grey or blackwater, regulations on boating and fuelling, no discharge from holding tanks. Campground upgrades are underway (2015) as outlined in the Cumberland Lake Park Plan; Chlorination is highly effective against bacteria; no breakthroughs have occurred; no historical outbreaks of waterborne disease; no reported cases of swimmers becoming ill; Chlorination has a low to moderate effectiveness in killing *Giardia*;	
	2006 Risk Ranking	H
Current Abated Risk	Likelihood	2
	Consequence	4
	Level of Risk	8
	Risk Rating	Moderate
Data Gaps	Usage rate of TimberWest cabins; (note- this information is currently being collated) Inventory of heating types in TimberWest cabins; Number of visitors/users of the Cumberland Campground and Fish & Game Club by season.	

Comments & Recommendations:
Ensure dog waste is managed at all camp sites and cabins;
Fence off and replant trampled shoreline areas;
Require a buffer from lake for designated campsites;
Collect and properly dispose of unneeded/unused household chemicals;
Ensure stormwater is infiltrated to ground before it reaches the lake;
Adopt a consistent code of conduct for all lakeshore users (cabins, campground and Fish & Game Club);
Do not expand existing camping areas;
Risk is also affected by rate of compliance with preventative measures;

16	Source/ Hazardous Event	Road network
Hazard	Sediment	Turbidity from erosion from road surface; Runoff from the road; Turbidity from failures of stream crossings;
	Nutrients	
	Pathogens	
	Contaminants	Spills of hazardous materials; runoff from the road

General Comments:
The main haul roads are stable and have been in place for a long time;
Geology is very stable in the majority of the watershed;
Most historic abandoned roads have been inventoried, especially on TimberWest lands. A LiDAR data set enables detailed inventory of roads, trails, and crossings;
The roads may have recovered but may have old log cribbing that is susceptible to failure;
Forestry companies likely have most of the required road assessment information, but information should be integrated for the whole watershed;
The road network provides access for increases human activity which increases risk;
Roads on non-timber land may be built to different standards and maintained at different frequencies;
All culverts on the main roads have been upgraded and replaced as part of TimberWest's on-going road inspection and maintenance program;
Washout of culverts is rare, even in recent extreme rain events (2015/16);
A severe rainstorm may overwhelm existing culverts and stream crossings on minor roads depending on the design storm that was used at the time they were built;

Unabated Risk	Likelihood	8
	Consequence	4
	Level of Risk	32
	Risk Rating	High
Existing Preventative Measures	Forestry companies have road maintenance and inspection programs for the majority of the roads in the watershed; There is only a minimal road network in Strathcona Provincial Park; Culverts and bridges are inspected and maintained; Current forest roads and crossings have been professionally designed; Village of Cumberland has routine road inspection during storm events; Forestry activity is shut down if road surfaces are too soft to support use; TimberWest has a "fall-back" plan for years when forestry activity may be reduced in the watershed to ensure that road maintenance and access control is still provided;	
	2006 Risk Ranking	None
Current Abated Risk	Likelihood	2
	Consequence	4
	Level of Risk	8
	Risk Rating	Moderate
Data Gaps	Road density and stream crossings by sub-watershed (a coarse measure of risk); Age and condition of roads and stream crossings; Number of landslides in the watershed;	

Comments & Recommendations:
CVRD should undertake a turbidity monitoring/source tracking program on tributary streams to Comox Lake;
A complete assessment of all roads in the watershed, including abandoned roads, should be undertaken (or data collated where it has already been done by landowners). This should consider analysis of road density (km/ha) and stream crossing (#/ha) by subwatershed;
Historic landslides should be documented along with probable cause;
Current road design and maintenance practices should be documented and recorded with the Watershed Protection Plan;
A threshold should be established which automatically triggers post-storm field inspections or roads, road crossings, for erosion and landslide events;

17	Source/ Hazardous Event	Legacy forestry activities
Hazard	Sediment	Channel erosion due to destabilized riparian areas; Erosion from failure of old stream crossings
	Nutrients	
	Pathogens	
	Contaminants	

General Comments:
The Comox Lake Watershed has been the focus of logging activity since the late 1800's;
Historical logging removed very large trees that stabilized steep slopes and riparian areas;
The shoreline of the lake and many of the riparian areas were logged first;
Rail lines ran along streams in the valley bottoms;
Forestry practices gave little or no consideration to watershed and stream health;
The trees in the riparian areas may not yet have regrown to a size where they can sufficiently stabilize the channel during very high streamflow events, and therefore the channels are at risk from erosion;
High elevation steep slopes and bedrock with shallow soil sites are less affected, but the lower valley bottom systems where flooding and erosion occurs from heavy rainfall is dramatically affected;
The steep bedrock-controlled terrain in the back of the watershed sheds rain water very quickly (time of flow concentration is very fast), causing erosion and bank failures in the bigger systems;
Second growth trees have been left during second pass harvesting but several decades are still needed to recruit trees large enough to stabilize stream banks;

Unabated Risk	Likelihood	4
	Consequence	4
	Level of Risk	16
	Risk Rating	High
Existing Preventative Measures	All of the major legacy terrain issues (other than riparian recruitment of large trees, which only time can address) around the major rivers and water bodies have been addressed (rehabilitation, road deactivation) and the ones that remain may cause small landslides in the back country and high elevation areas away from water supply areas; TimberWest has an on-going watershed inspection and monitoring program that records and assesses risk (hazard and consequence) at known legacy sites as well as any new sites found on a routine basis. If the risk is significant to the forest resource or water quality (or fish habitat in the back country) then consultants are hired to write rehab prescriptions and TimberWest executes the work to be completed to mitigate the risk; TimberWest has a full time staff member that continually inspects the watershed and writes assessments reports / updates.	
	2006 Risk Ranking	none
Current Abated Risk	Likelihood	2
	Consequence	4
	Level of Risk	8
	Risk Rating	Moderate
Data Gaps	Riparian condition of the streams in the watershed, with particularly reference to age class, size and health of riparian trees; Location and condition of legacy roads and stream crossings that have not been re-purposed for current use.	

Comments & Recommendations:
Conduct a PFC assessment of all major streams and wetlands with an emphasis on major tributaries first to assess stream condition including, not but not exclusively, channel stability and riparian condition;
Continue to map and review the condition of legacy roads including stream crossings, to identify potential areas of instability;
Identify at-risk riparian areas through a PFC assessment.

18	Source/ Hazardous Event	Transportation on roads adjacent to watercourses or Comox Lake
Hazard	Sediment	Turbidity from dust off road surface; Increased fire risk - fire reduces cover and increase soil erosion; Invasive species spread.
	Nutrients	
	Pathogens	Microbial contamination from litter and human waste; Microbial contamination from accident involving septic waste truck;
	Contaminants	Chemical contamination from fuel, pesticides or other chemicals;

General Comments:
Road management requires collaboration with private landowners;
Highest use in the watershed is with recreation in the summer months; Comox Lake Main is typically closed in the winter which limits access to the upper watershed reaches;
Comox Lake Main is narrow in places, steep and very close to the lake;
Comox Lake Main is radio-controlled, but casual users often do not have radios and could cause an accident;
Public access is restricted to weekends- no access during work days and strict no access enforced during high fire hazard by fire wardens and staff
The riparian zone of Comox Lake is steep and rocky and prevents direct access to most of the lake;
There have been several vehicle accidents on Comox Lake Main resulting in vehicles entering the lake;
There have been no water quality warnings associated with previous vehicle accidents;
There was a 1981 proposal to connect Courtenay and Port Alberni using Comox Lake Main- This would significantly increase the risk to the water supply if a road connector is to be completed at some future time through the watershed. TimberWest has indicated they would oppose such a proposal;
ORV's drive through fish habitat/wetlands and pose a potential sediment source;
There is easy access to Comox Main from local communities- no highway, no trailering required for ORV's;
During weekends there is no access control at gates etc.;
Damage to assets in the area is common (*e.g.* equipment vandalism); landowners recognize not all recreationalists are to blame for damage;
It is difficult to manage "free-for-all" recreation access;
There is concern about "other" rule breakers causing damage i.e. the majority of users follow rules but a minority still cause damage;
Comox Lake Main and other roads are used to transport fuel, septic waste, pesticides, possibly heating oil, hydraulic fluids and other potential contaminants;
Invasive plants do not appear to be spreading into the watershed from roads but can destabilize riparian areas;
Invasive plant distribution may change with a changing climate.

Unabated Risk	Likelihood	16
	Consequence	4
	Level of Risk	64
	Risk Rating	Very High

Existing Preventative Measures	Comox Lake Main is the primary access route to the majority of the watershed therefore is a control point; TimberWest restricts access to the upper watershed and Comox Lake Main when forestry activity is occurring; Gates are locked at high-risk times of the year (*e.g.* fire season) and security personnel are present; Comox Lake Main and other key roads are radio-controlled; Forestry companies perform routine fire patrol and have response plans in place; Chlorination of the water supply; Notification of consumers to avoid using water in the event of a spill; Ability to isolate balancing reservoirs.	
	2006 Risk Ranking	M
Current Abated Risk	Likelihood	4
	Consequence	2
	Level of Risk	8
	Risk Rating	Moderate
Data Gaps	Number, timing and type of vehicles using main access roads; Inventory of types and volumes of materials transported; Document known accidents and record any future incidents; Hazard and access control points; Spill response plan; How are outhouses managed- exchanged or pumped out?	

Comments & Recommendations:
Risk is based on current controlled road network use. An increase in use would result in a corresponding increase in likelihood and therefore risk;
Traffic counters should be installed on major roads to assess timing and intensity of use;
Coordinate gate access management outside of TimberWest working hours;
Ensure vehicles carrying larger volumes of potential contaminants (septage, fuel, pesticide) have radio access and are escorted in and out of the watershed to reduce accident risk;
Hazard control points and access control points should be identified as part of the whole-watershed road network assessment;
Include vehicle accident (including vehicles containing larger volumes of potential contaminants) in the Emergency Prevention and Response Plan;
Ensure all logging truck drivers are trained and follow road control protocols (*e.g.* radio call points) and spill response;
No highway development should occur in the Comox Lake Watershed including a road to Port Alberni;

19	Source/ Hazardous Event	Flooding on the order of >25 to <100 year event
Hazard	Sediment	Turbidity from erosion
	Nutrients	Nutrients washed into lake from flooded areas
	Pathogens	Pathogens washed into lake from flooded areas
	Contaminants	Potential contaminants from coal mine spoils
General Comments: Climate models predict more frequent more intense storms; Comox Lake is large and has some settling capacity; Nutrients washed into the lake would also be heavily diluted; NW Hydraulics report on Tsolum River noted 40% greater storm intensity in recent years; There is a risk of flooding around the lake and cabins (especially near the Cruickshank); Shoreline erosion by wind and wave action would be accelerated by large storms; Tributary streams are more at risk than the lakeshore which is generally rocky; The east end of lake is shallow and sediment could be resuspended from the lake bottom; The coal mine spoils White's Bay area are erodable; The area behind the Fish and Game club is erodable; Cumberland has some turbidity data for their systems *e.g.* Perseverance Creek; Magnitude of consequence is related to regulatory response, not just health risk		
Unabated Risk	Likelihood	4
	Consequence	4
	Level of Risk	16
	Risk Rating	High
Existing Preventative Measures	BC Hydro manages the water level in the reservoir to reduce flooding and prevent the dam from overtopping; Real-time rainfall and stream flow data are monitored by BC Hydro and shared with CVRD to aid in emergency preparedness; CVRD has implemented a turbidity management plan;	
	2006 Risk Ranking	None
Current Abated Risk	Likelihood	4
	Consequence	2
	Level of Risk	8
	Risk Rating	Moderate
Data Gaps	Data/reports to confirm/refute whether coal mine spoils and leachate are an issue (was a study done in 2001); Meteorological projections;	

Comments & Recommendations:
Implement a turbidity monitoring program on the tributaries to assess current input to the lake and identify areas at risk of erosion;
Assess the channel stability of the tributaries as part of a larger PFC assessment of the watershed;
Assess the current condition of the shoreline of the lake and assess whether erosion protection works are required or possible;
Require septic maintenance and inspection;
Investigate temporary alternative water sources as emergency backup;
Inventory and assess old mine sites for potential leachate and erodability;
Ensure riparian areas are managed for maximum bank stability;
Consequence mitigated by real-time data and turbidity management plan to allow water system to be temporarily isolated;

20	Source/ Hazardous Event	Timber harvesting- operations
Hazard	Sediment	Erosion of disturbed soils from machinery access on cutblocks; Increased risk of fire (see Wildfire)
	Nutrients	Nutrients from soil erosion
	Pathogens	Microbial risk from human waste
	Contaminants	Chemical contamination from fuel and hydraulic fluids
General Comments: Soil disturbance or chemical spills caused by harvesting operations anywhere in the watershed may contribute sediment or contaminants to tributary streams and, under high flow conditions, contaminants could reach the lake in under an hour from the furthest point on any stream; Harvesting activities increase fire risk; Increased human presence increases risk of microbial contamination; Geology of the watershed is generally very stable, with the exception of the area near Perseverance Creek.		
Unabated Risk	Likelihood	4
	Consequence	4
	Level of Risk	16
	Risk Rating	High
Existing Preventative Measures: Forestry companies go beyond the minimum standards set out in law; Forestry companies all supply (and require crews to use) outhouses; Fuel is not stored in the watershed; Some forestry companies use rain gauges and operate local weather stations to monitor rainfall and all companies avoid working on wet soils; All forestry companies shut down operations when fire risk is high or soils and roads are too soft or wet; Forestry companies have fire suppression equipment on site (*e.g.* fire extinguishers on equipment, water trucks, excavators); Forestry companies maintain a roster of equipment available for use in emergency response including fire suppression;		

Existing Preventative Measures: Watershed monitoring programs by trained personnel (*e.g.* road condition, stream crossing condition, forest pest outbreaks/trends) are on-going; Well-trained forestry personnel provide "eyes and ears" to manage forestry risks as well as risks associated with natural events (*e.g.* storms) and public activities; Operators and contractors are trained in fire response, spill response and shut down protocols.		
	2006 Risk Ranking	None
Current Abated Risk	Likelihood	1
	Consequence	4
	Level of Risk	4
	Risk Rating	Moderate
Data Gaps	Number of incidents related to forestry activities versus public access/ activities.	
Comments & Recommendations: Ensure all field personnel understand that a higher level of care is required in the Community Watershed, particularly around riparian areas; Utilize harvesting Best Management Practices which aim to prevent the delivery of sediment or chemicals into a watercourse (*e.g.* utilizing puncheon or brush mats, full suspension yarding, fall away/ yard away techniques, windthrow prevention techniques, machine fueling procedures, etc.); Divert runoff into vegetated areas to trap and filter sediment wherever possible; Share incident reports with the WAG including fires put out by forestry personnel (regardless of cause), vehicle incidents and spills, vandalism etc.		

21	**Source/ Hazardous Event**	**Regional landfill operation**
Hazard	Sediment	
	Nutrients	
	Pathogens	Microbial contamination of the lake from birds
	Contaminants	Leachate from landfill entering lake from groundwater
General Comments: Potential source of leachate; Source of food and refuge for birds that also land on lake and contribute fecal matter to the lake; Under management of CVRD; A solid waste management plan has been approved; Upgrades are scheduled to cover old landfill site and build a new lined landfill with water management so that none drains toward lake – 2016/2017 timeframe (similar to deep water intake); Groundwater plume modelling will be available for the new site; Piezometers on-site now – monitoring is underway; Bird management is on-going (see Wildlife).		

Unabated Risk	Likelihood	1
	Consequence	4
	Level of Risk	4
	Risk Rating	Moderate
Existing Preventative Measures	Upgrades to landfill containment and operation	
	2006 Risk Ranking	M
Current Abated Risk	Likelihood	1
	Consequence	4
	Level of Risk	4
	Risk Rating	Moderate
Data Gaps	Plume of existing landfill; Geology under the landfill; Chemical composition and quantity of leachate;	
Comments & Recommendations: Piezometers and monitoring wells should be installed between the landfill and the lake to monitor water quality including heavy metals, nutrients, fire retardants, salts, pesticides, persistent pollutants; No new landfills or waste, management facilities should be constructed in the Comox Lake Watershed; Review options for leachate discharge onsite vs. offsite;		

22	**Source/ Hazardous Event**	**Underwater log salvage from Comox Lake**
Hazard	Sediment	Turbidity from disturbance of lake bed
	Nutrients	Nutrients from disturbance of lake bed
	Pathogens	Potential disturbance on encysted parasites
	Contaminants	
General Comments	Underwater log salvage is not contemplated	
Unabated Risk	Likelihood	1
	Consequence	4
	Level of Risk	4
	Risk Rating	Moderate
Existing Preventative Measures	TimberWest owns the lakebed of Comox Lake and therefore would control these activities; TimberWest has no plans for underwater salvage at this time;	
	2006 Risk Ranking	M

Current Abated Risk	Likelihood	1
	Consequence	4
	Level of Risk	4
	Risk Rating	Moderate
Data Gaps	Value of salvage resource in Comox Lake to determine if salvage is ever likely;	

Comments & Recommendations:
If underwater log salvage is proposed in the future, this risk should be reassessed.

23	**Source/ Hazardous Event**	**Forestry- road construction and maintenance**
Hazard	Sediment	Sediment from newly- exposed soils during rain events
	Nutrients	
	Pathogens	
	Contaminants	Chemical contamination from fuel

General Comments:
Road construction during very wet periods (typically November to March, with intermittent dry periods) in sensitive areas or soils can be high risk due to sediment generation, but in the summer or dry periods can be very low risk;
Though the roads are steep, underlying geology provides good stability;
No evidence of significant erosion was seen during two field tours- summer and fall;

Unabated Risk	Likelihood	2
	Consequence	4
	Level of Risk	8
	Risk Rating	Moderate
Existing Preventative Measures	Road construction only during dry conditions; Terrain assessment prior to road layout; Road maintenance and deactivation on-going; Routine road and watershed inspections are on-going on a year-round basis, and main roads and known erosion-sensitive sites are inspected by pick-up or helicopter immediately after each major storm event.	
	2006 Risk Ranking	none
Current Abated Risk	Likelihood	1
	Consequence	2
	Level of Risk	2
	Risk Rating	Low
Data Gaps	Current road density and number of stream crossings;	

Comments & Recommendations:
Due to current road deactivation and management practices, road densities and the number of crossings in the Comox watershed have decreased over the last decade;
Utilize road construction and maintenance 'Best Management Practices' which consider, timing, runoff water management, erosion mitigation measures, chemical spill prevention, sensitive area avoidance, etc. during construction and maintenance activities;
Upon completion of harvesting and silviculture activities, deactivate unnecessary roads and recontour ones constructed in sensitive areas;
Avoid building roads in riparian areas;
Grass seed exposed soils and ditches with sediment delivery potential;
Plan roads to minimize the number of stream crossings and overall road density;
Ensure newly designed drainage and stream crossing structures sized for increased intensity and frequency of storms as predicted by climate models;
Periodically reassess and retrofit existing structures that are undersized;
Set targets for road densities and number of stream crossings based on best available science.

24	**Source/ Hazardous Event**	**Boating and fishing in Comox Lake including use of boat launches and docks**
Hazard	Sediment	Turbidity from shoreline disturbance and wave action
	Nutrients	
	Pathogens	Microbial risk from human and fishing waste
	Contaminants	Chemical contamination from fuel

General Comments:
There are only two boat launches: one at the Fish and Game Club and the Cumberland boat launch;
The Cumberland boat launch is public. There are no rules on fuelling and limited signage;
There is limited access to the spill kit at the Fish and Game Club and it is quite far from the Cumberland boat launch;
There have been complaints of fuelling occurring on the lake;
Smooth water is located in the east portion of lake so the majority of boating occurs there near the proposed deep water intake;
Fishing occurs further out toward the centre basin and Cruikshank delta but access is from east basin boat launches;
Most boats are day-use although a few boats are docked on CLLC properties for extended periods of time;
A houseboat was temporarily moored on the lake;
There are 13 docks at CLLC;
CVRD has a boat at the Fish and Game Club that could be used to deploy a spill boom;
Invasive species (plants and animals) could be spread by boats;

Unabated Risk	Likelihood	4
	Consequence	2
	Level of Risk	8
	Risk Rating	Moderate

Existing Preventative Measures	The presence of only two boat launches limits the activity and permits limited control over terms of use and educational messaging; Comox Lake would provide significant dilution of fuel releases; Fish and Game Club property regulations (code of conduct) must be signed by members. They include no fuelling on lake and no dumping of fish remains in lake; The boat launch can only be used by members and their guests. Members are responsible for their guests; A spill kit is available at the Fish and Game Club; The deep-water intake will lower the risk of drinking water contamination if hydrocarbons remain on the lake surface; Gasoline would volatilize quickly; The CVRD has a boat available for spill response.	
	2006 Risk Ranking	H
Current Abated Risk	Likelihood	2
	Consequence	2
	Level of Risk	4
	Risk Rating	Low
Data Gaps	Number of people, timing and type of boats using boat launches. Need to assess trends; Who enforces if bylaws are put in place? How many people are fuelling on the lake? How many incidents of fuel spills have been noted? To whom are spills reported? Who has access to spill kit at Fish and Game? Do people know it is there? What is the response time if a spill occurs? Is PEP aware of the spill kit? Have there been boating accidents that released fuel?	

Comments & Recommendations:
Universal no fueling on the lake/ dock policy;
Ensure fire departments or other emergency responders know of spill kit and are trained on its use;
Install a second spill kit at the Cumberland Lake Park Campground;
Boats should be cleaned before entering the lake to prevent spread of invasive species;
Utilize traffic counters to assess number and timing of boats using boat launches;
Regulate type of boat motor/type of boat allowed on lake through bylaw *e.g.* houseboat restriction;
Create consistent signage and codes of conduct for both boat launches;
Install signage at Cumberland launch and implement rules on fuelling;
Develop a program for local fuel spill reporting and provide spill response materials at the Cumberland Lake Campground. Incorporate this information into the Emergency Response Plan;
Pre-install anchors for spills booms so that they can be easily deployed in event of spill;
Identify and sign areas of good cell coverage to make emergency calls or notify required groups;

25	**Source/ Hazardous Event**	**Mining spoils**
Hazard	Sediment	
	Nutrients	
	Pathogens	
	Contaminants	Contaminants from leachate
General Comments	Parts of the Comox Lake Watershed, especially near Cumberland, have extensive areas of historical coal mining activity; The locations of these mines and spoil piles is not currently mapped; No leachate has been detected, but specific monitoring has not been undertaken; Spoil piles near Perseverance Creek and White's Bay could be inundated by a flood	
Unabated Risk	Likelihood	4
	Consequence	1
	Level of Risk	4
	Risk Rating	Low
Existing Preventative Measures	None	
	2006 Risk Ranking	H
Current Abated Risk	Likelihood	4
	Consequence	1
	Level of Risk	4
	Risk Rating	Low
Data Gaps	Location, size and elevation/proximity to watercourse of existing spoil piles in the watershed.	

Comments & Recommendations:
The location of all spoil piles should be mapped and assessed for the potential to generate leachate that could enter Comox Lake.

26	Source/ Hazardous Event	Transportation over the Puntledge River Bridge (resulting in a spill or accident) near the Comox Lake outlet
Hazard	Sediment	
	Nutrients	
	Pathogens	Microbial contamination (*e.g.* septage trucks)
	Contaminants	Chemical contamination (*e.g.* fuel)
General Comments: A deep water intake would almost certainly be isolated from this land use and the remaining risk is very small; The road is open to the public; Fuel and septic trucks access this bridge; No management or control occurs on weekends or after hours;		
Unabated Risk	Likelihood	2
	Consequence	4
	Level of Risk	8
	Risk Rating	Moderate
Existing Preventative Measures	A spill kit is located at Fish and Game Club; Forestry companies all have bridge inspection programs; The bridge approach has been improved; Other recent bridge improvements have occurred (side rails etc.); Net water flow is normally away from the deep water intake; Chlorination of water supply; Ability to isolate balancing reservoirs and prevent contamination from entering the distribution system; Notification of consumers in the event of a spill to prevent consumption;	
	2006 Risk Ranking	VH
Current Abated Risk	Likelihood	1
	Consequence	2
	Level of Risk	2
	Risk Rating	Low
Data Gaps	Record of number of accidents or near-misses.	
Comments & Recommendations: Identify everyone who has keys to the spill container; Establish a common emergency contact telephone number; Document accidents or near misses;		

27	Source/ Hazardous Event	Transportation on roads distant from watercourses or Comox Lake
Hazard	Sediment	Increased fire risk; Invasive species spread
	Nutrients	
	Pathogens	Microbial contamination from litter and human waste
	Contaminants	Fuel from vehicle accidents
General Comments: Road management requires collaboration with private landowners because there is almost no crown land in the watershed; Ditches concentrate water and carry it toward streams from long distances; Risks are related to the presence and maintenance of the roads, fire, to ORV use, recreation, and to increased human presence in the watershed.		
Unabated Risk	Likelihood	1
	Consequence	2
	Level of Risk	2
	Risk Rating	Low
Existing Preventative Measures	TimberWest restricts access to the upper watershed and Comox Lake Main when forestry activity is occurring; Forestry companies perform routine fire patrol and have response plans in place; Chlorination of the water supply.	
	2006 Risk Ranking	M
Current Abated Risk	Likelihood	1
	Consequence	2
	Level of Risk	2
	Risk Rating	Low
Data Gaps	Timing and intensity of road use, both for forestry and public use.	
Comments & Recommendations: Traffic counters should be installed on major roads to assess timing and intensity of use; See transportation on roads adjacent to watercourses.		

28	Source/ Hazardous Event	Potential aircraft crash in other areas of the watershed
Hazard	Sediment	See Wildfire
	Nutrients	
	Pathogens	
	Contaminants	Chemical contamination of tributaries with fuel

General Comments:
There was a heli-logging crash Oct 31, 1997 at south end of Comox Lake. It involved a Chinook helicopter and a limited post-accident fire, Jet A fuel type (source Transport Canada);
No recent record of wildfires caused by aircraft crashes in forested areas;
There was an anecdotal report of a small plane crash near small airport on Forbidden Plateau;

Unabated Risk	Likelihood	1
	Consequence	1
	Level of Risk	1
	Risk Rating	Low
Existing Preventative Measures		No heli-logging is proposed for the watershed
	2006 Risk Ranking	M
Current Abated Risk	Likelihood	1
	Consequence	1
	Level of Risk	1
	Risk Rating	Low
Data Gaps		

Comments & Recommendations:
Include aircraft crash in the Emergency Prevention and Response Plan.

29	Source/ Hazardous Event	Silviculture and Monitoring
Hazard	Sediment	
	Nutrients	
	Pathogens	
	Contaminants	Chemical contamination from pesticides;

General Comments:
Forest and watershed health is contingent on reforestation practices;
Monitoring provides feedback and information on which harvesting and silviculture practices are effective and which should be avoided;
Replanting programs often prescribe weed control through the use of pesticides and herbicides;
International Agency for Research on Cancer (IARC) (part of the World Health Organization) has recently classified glyphosate as a "probable human carcinogen";
Fertilizers are used to enhance growth of new trees.

Unabated Risk	Likelihood	1
	Consequence	1
	Level of Risk	1
	Risk Rating	Low
Existing Preventative Measures	Pesticide use near watercourses is carefully planned and controlled in accordance with the Integrated Pest Management Act, and applied by certified professionals; There is a "no-go" zone next to watercourses; Comox Lake has a very significant dilution capacity; Cutblocks are generally replanted within one to two years of harvest; Newly planted areas are regularly monitored for growth rate and successful establishment; Seed stock is sourced from geographically similar areas to maximize survival.	
	2006 Risk Ranking	none
Current Abated Risk	Likelihood	1
	Consequence	1
	Level of Risk	1
	Risk Rating	Low
Data Gaps	The carriers used in herbicides are proprietary; therefore the effects of the carriers on ecosystem and human health, not the active ingredient, are not well-understood; Water quality analysis to confirm whether pesticides are detectable in source water post-application; Types and application rate of fertilizers.	

Comments & Recommendations:
Pesticide and herbicide use should be eliminated wherever possible;
All pesticides or herbicides intended for use in the watershed should be reviewed for safety in and around aquatic habitat and for potential human health impacts;
Pesticides should not be stored in the watershed;
Aerial spraying of pesticides should be avoided wherever possible;
Explore reforestation with species or varieties that are suited to predicted climate conditions;
Fertilizer applications should avoid watercourses;
The value of careful application of fertilizer within riparian zones should be reviewed for potential benefits to enhanced riparian growth vs. risks to water quality;
Annual updates from each forest company should be presented to the WAG including any innovations and updates to practices as part of a program of continual improvement;

Appendix 2 – Emerging Trends in Drinking Water Treatment Technology

During the course of developing this Watershed Protection Plan, the CVRD's permit to operate was amended to require the installation of filtration, due to elevated source water turbidity. In and of itself, turbidity does not pose a health risk; it is monitored as an indicator of potential risk from pathogens (bacteria, protozoa and viruses). The general thinking is that the processes that wash soil particles into the water supply and cause elevated turbidity (*e.g.* snowmelt, high rainfall events) may also wash pathogens into the water. Furthermore pathogens may be shielded from disinfectants by particles suspended in the water column. In the case of systems disinfected with chlorine, the chlorine may bind to particles in the water and be consumed before inactivating the pathogens. When turbidity is caused by particles with a high organic content, the organics may react with chlorine and cause the formation of hazardous disinfection by-products.

Data from Comox Lake and elsewhere demonstrate that there is no correlation between turbidity and bacterial counts[62]; that is, the numbers of indicator bacteria present in the water in Comox Lake do not increase with increased turbidity. However, since there are very few data on parasites in Comox Lake and no data on viruses, the presence of these potential pathogens cannot be discounted whether or not turbidity is elevated. Monitoring of disinfection by-products within the CVRD system shows that disinfection by-products are not an issue of concern because the organic content of the water is very low.

For many years, the only technologies available to improve water safety were disinfection, usually with chlorine, and filtration. These have become the default processes for water systems in British Columbia. There are however, several other technologies that have been very successfully employed elsewhere and which are much less expensive to implement and operate. As stated in the 2008 report "Turbidity and Microbial Risk in Drinking Water" prepared for the BC Ministry of Health[28] "recent advances in water treatment technologies, particularly the demonstrated capabilities of UV disinfection, offer the potential to develop equally effective alternative means to conventional filtration for achieving the agreed upon public health protection goals." This is also acknowledged within the Guidelines for Canadian Drinking Water Quality.

The Guidelines for Canadian Drinking Water Quality (GCDWQ) outline considerations for exempting drinking water systems from filtration requirements. The main considerations include a vulnerabilities assessment, source water protection, inspection and verification, treatment, distribution and emergency response planning. "Whether or not filtration technology is in place, the drinking water treatment process must still achieve a minimum 3-log reduction of *Giardia lamblia* cysts and *Cryptosporidium* oocysts and a 4-log reduction of viruses. Utilities using surface water … that are considering not using filtration will need to treat source waters for all three types of organisms (protozoa, viruses and bacteria), using a multi-disinfectant strategy. A possible strategy includes (1) ultraviolet irradiation or ozone to inactivate cysts/oocysts (2) chlorine to inactivate viruses, and (3) chlorine or chloramines to maintain a residual in the distribution system."

There are several BC examples where a dual-disinfection strategy is in place without filtration and several other significant examples in the US:

The Capital Regional District (CRD) supplies unfiltered water from a protected watershed to approximately 350,000 people in the greater Victoria area. When the UV plant was constructed in 2004 it was the largest UV disinfection plant in Canada and the second largest in North America. It treats approximately 580ML/day and was built at a cost of $13.5 million in 2004[63]. Water is chlorinated prior to distribution.

The Coquitlam watershed supplies approximately one-third of the water for Greater Vancouver. A UV disinfection plant was opened in 2014 at a cost of $100 million[64]. It can supply 1200 ML/day of unfiltered water from its protected watershed[65]. Water is ozonated and receives soda ash before being disinfected with UV and then chlorinated for distribution. Extensive pre-engineering work determined that UV would be effective at turbidities to, or slightly above, 10 NTU[66].

Campbell River receives its drinking water from a watershed complex that includes John Hart, McIvor, Lower and Upper Campbell Lakes and Buttle Lake as well as numerous streams. Water from John Hart Lake passes through BC Hydro penstocks before entering the City's distribution system. The City also has a submerged lake intake in John Hart Lake. The John Hart Lake watershed is closed to camping and motorized recreation. The rest of the watersheds are open and have multiple uses including forestry, recreation, mining and hydro generation[67]. The City uses chlorine and UV without filtration to disinfect its drinking water[68].

The City of Kelowna draws its water from Okanagan Lake to supply just over 60,000 customers[69]. The lake is very large, but has pockets of intensive urban development and wastewater discharge within the catchment including the City of Kelowna, District of Peachland, Naramata and City of Penticton. The City of Kelowna does not filter its water and uses chlorination as the primary disinfection process. In 2005 UV disinfection was added to three pump stations (Poplar Point, Eldorado and Swick Road) and in 2014 UV disinfection was added to the Cedar Creek system.

New York opened the largest UV Disinfection facility in the world in 2013. It has the capacity to treat 2.02 billion US gallons (7636 ML) of unfiltered water per day[70] from the Catskill and Delaware watersheds and supplies 9 million residents of New York City and upstate New York[71]. It was built at a cost of $1.6 billion. The watersheds are open and contain extensive urban development. Water is chlorinated prior to distribution. New York is one of five major US cities that have a filtration waiver from the USEPA. The others are Seattle, Portland, San Francisco and Boston. Seattle and Portland have closed watersheds, while San Francisco and Boston's watersheds are open to multiple uses with only a few restrictions such as swimming and fires in the Boston system[72]. Seattle installed UV disinfection in 2004[73]. Portland uses only chloramination[74], San Franscisco uses both chlorination and UV[75] and the Metropolitan Boston Water System uses ozone and chloramination[76].

Appendix 3 – Example Education and Outreach Materials

Glossary & Guide to Acronyms

Bacteria are microscopic, single-celled organisms that are some of the most numerous organisms on earth. They can be spherical, spiral or rod-shaped and appear singly or in chains. They are found in almost every habitat on earth. Bacteria perform many beneficial services including production of vitamins in the human intestine. They are involved in fermentation, nitrogen fixation, and some can cause disease (referred to as pathogenic). Examples of bacteria include *E. coli* and *Salmonella*. The singular term is "bacterium."

Bankfull depth is the average vertical distance between the stream channel bed and the water surface elevation required to completely fill the channel to a point where water would spill onto the floodplain or intersect a terrace or hillslope. When applied to lakes, ponds or impoundments, bankfull width is the line of mean high water. When applied to tidal waters, bankfull width is the line of mean high tide.

Bankfull width is the lateral extent of the water surface elevation perpendicular to the channel at bankfull depth.

Bedload is the silt, sand and gravel, or soil and rock debris rolled along the bottom of a stream by moving water.

Best Management Practices (BMPs)

Biogeoclimatic zone is a geographic area having similar patterns of energy flow, vegetation, and soils as a result of a broadly homogeneous microclimate. Biogeoclimatic zones are used in British Columbia as a defining unit in the Biogeoclimatic Classification System that groups ecologically similar sites based on climate, soils, and vegetation; widely used as a framework for resource management and scientific research in British Columbia.

Body contact recreation means full water-body contact activities or immersion in the water *e.g.* swimming, waterskiing, stand-up paddle boarding and operation of personal watercraft (water/jet ski).

Breakthrough refers to a potential contaminant or pathogen passing through the water treatment process and into the water distribution system.

Canadian Forces Base (CFB)

Catchment is another word for watershed and is the term commonly used in Australia.

Chlorination refers to the addition of chlorine to water for the purpose of disinfection.

Coliforms are a type of non-pathogenic, naturally occurring bacteria monitored when testing water to indicate the possible presence of pathogenic (disease-causing) bacteria. While some coliform bacteria can be naturally found in soil, the types of coliform bacteria that live in the intestinal tract of warm-blooded animals and originate from animal and human waste are called fecal coliform bacteria.

Comox Lake Land Corporation (CLLC) is an association of owners that jointly own a block on land on which there are 26 cabins at the east end of Comox Lake.

Comox Valley Regional District (CVRD)

Comox Valley Water System (CVWS)

Contaminant is a substance that causes harm by contact or association.

Consequence is the magnitude of harm caused by an identified hazard.

Courtenay and District Fish and Game Protective Association (CDFGPA) also called the "Fish & Game Club" which has its headquarters on Comox Lake.

Crown land means land owned by the Province of British Columbia.

Data gap means missing data or information.

Department of Fisheries and Oceans (DFO) is the former and commonly used name for Fisheries and Oceans Canada.

Department of National Defense (DND)

Disinfection is the process of destroying microorganisms in water by the application of a disinfectant (*e.g.* chlorine, ozone or ultraviolet radiation) to kill or inactivate pathogens in water.

Escherichia coli (*E. coli*) is one subgroup of fecal coliform bacteria. Even within this species, there are numerous different strains, some of which can be harmful (pathogenic). The EPA has determined that *E. coli* are one of the best indicators for the presence of potentially pathogenic bacteria. One specific species of *E. coli* (*E. Coli* 0157:H7) caused illness in the Walkerton outbreak.

Emergency Management Plan (EMP)

Equivalent Clearcut Area (ECA) describes a second-growth block of timber in terms of its hydrological equivalent as a clearcut. As second growth develops, the hydrological impact on a site is reduced. The rate of reduction is expressed in proportion to the height of the second growth. The ECA is a measure of the site hazard for peak flows in a cutblock.

Filtration is the mechanical process which removes particulate matter by separating water from solid material, by passing it through a filter.

Fecal coliforms are naturally occurring bacteria which live in the intestinal track of warm-blooded animals and originates from animal and human waste. Fecal coliforms are commonly used as an indicator of fecal contamination.

Floodplain is a relatively flat landform adjacent to a stream that is composed of primarily unconsolidated depositional material derived from the stream and that is subject to periodic flooding.

Gastrointestinal Illness (GI illness) is caused by a variety of different disease-causing microbes or germs that can be acquired by consuming contaminated food or water, contact with contaminated recreational water, infected animals or their environments, or infected people. These pathogens can cause a variety of symptoms, such as diarrhea, nausea, vomiting, abdominal pain, abdominal cramps, fever and sometimes headaches, rash and paralysis.

Geographical Information System (GIS)

Guidelines for Canadian Drinking Water Quality (GCDWQ)

Hazard identification is the systematic evaluation of a water supply system to recognize existence of hazards and define their characteristics.

Hazardous events and **sources of hazards** are those incidents or situations that can contribute to the presence of a hazard (what can happen and how). This may include point sources of pollution such as human and industrial waste discharge as well as diffuse sources such as those arising from agricultural and animal husbandry activities. Other examples include continuous, intermittent or seasonal pollution patterns as well as extreme and infrequent events such as droughts or floods. Using *Cryptosporidium* as an example, failure at a water treatment plant leading to *C. parvum* passing into the distribution system is a hazardous event.

Hazards are biological, chemical, physical or radiological agents that have the potential to cause harm and/or can give rise to water quality which is unacceptable for consumers. An example of a hazard is the protozoan parasite *Cryptosporidium parvum* which, if present in sufficient numbers, can cause illness.[23]

Indicator organisms are microorganisms, such as **coliform bacteria**, that are not in themselves harmful but whose presence is indicative of possible **pollution** or the presence of other more harmful microorganisms which, through its population size or condition, mirrors environmental conditions within an ecosystem.

International Mountain Bicycling Association (IMBA)

Island Health (IH) is the regional health authority for Vancouver Island, formerly known as Vancouver Island Health Authority (VIHA).

Likelihood is the probability of an identified hazard causing harm.

Leachate is water containing contaminants which leaks from a disposal site such as a landfill or dump.

Ministry of Environment (MOE)

Mitigation includes measures designed to counteract environmental impacts or to make impacts less severe.

Mountain Bike Trails (MTB) trails

Montane means mountain.

Nephelometric Turbidity Units (NTU) are a unit of measure for the **turbidity** of water as measured by a nephelometer, based on the amount of light that is scattered by particles in the water.

Nutrients are substances, elements or compounds, necessary for the growth, development and reproduction of plants and animals, as a pollutant any element or compound, such as phosphorous or nitrogen that encourages abnormally high organic growth in ecosystems

Off-catchment lands are lands that are outside the Comox Lake Watershed boundary and therefore drain away from the drinking water supply.

Official Community Plan (OCP)

Off Road Vehicle (ORV) includes all terrain vehicles (ATVs), side-by-sides, dirt bikes and snowmobiles

On-catchment lands are lands that drain into the drinking water supply.

Parasites are organisms that are obliged to live on or in other organisms, often causing illness, disease or death *e.g. Cryptosporidium, Giardia* (beaver fever).

Pathogen is a microorganism such as a virus, bacterium, parasite, or fungus that causes disease in its human, animal or plant host.

pH is the concentration of hydrogen ions in water. The pH of water indicates how basic or neutral it is. A pH of 7 is neutral, above 7 is basic and below 7 is acidic. The pH also influences the toxicity of metals, especially aluminum and iron. At more acidic pH levels, these metals are significantly more toxic.

Potable water is water that is toxicologically and pathologically safe and aesthetically fit to drink.

Preventive measures are any planned actions, activities or processes used to prevent hazards from occurring or reduce them to acceptable levels. Preventive measures should be comprehensive from catchment to consumer for each identified hazard.

Private Managed Forest Lands (PMFL)

Private Managed Forest Lands Act (PMFLA)

Proper Functioning Condition (PFC) is a qualitative method for assessing the condition of riparian-wetland areas. The term PFC is used to describe both the assessment process, and a defined, on the-ground condition of a riparian-wetland area. The on-the-ground condition termed PFC refers to how well the physical processes are functioning.

Qualified Environmental Professional (QEP)

Qualitative means descriptions or distinctions based on some quality or characteristic that can be observed but not measured. *e.g.* type of plant species in riparian zone.

Quantitative means a description or distinction based on numerical values which can be measured or quantified *e.g.* number of plants in a riparian zone.

Riparian areas or **riparian zones** are the areas of land along a waterbody that contain vegetation, animals or ecosystem types that are dependent upon a regular supply of water. Riparian areas are characterized by moist soils and plants that grow in this area like "wet feet". Riparian zones are very productive areas and are essential for protecting water quality.

Riparian-wetland area is another term for riparian zone.

Risk assessment is the systematic process of using available information to predict how often identified hazards or specified events may occur (likelihood) and the magnitude of their consequences. Risk should be assessed at two levels: maximum risk in the absence of preventive measures, and residual risk after consideration of existing preventive measures.

Risk is the probability or likelihood of an identified hazard causing harm in exposed populations, including the magnitude of that harm, *i.e.* the severity of the consequences or the effect. For example, the likelihood of *C. parvum* being present in source waters and passing though the treatment plant in sufficient numbers and infectivity to cause illness is the risk. Consequence may be established by considering factors such as the number of people who may get ill, degree of public outrage, size of the system contaminated, extent of boil water notices which would need to be issued, and any costs that may be incurred (*e.g.* fines, compensation, water treatment facilities upgrades, etc.).

Risk management refers to the overall process of evaluating the water supply system, identifying hazards, sources and hazardous events, assessing and prioritizing risks, and developing and implementing effective preventive measures and strategies to manage the risks.

Search and Rescue (SAR)

Silviculture is the practice of controlling the establishment, growth, composition, health, and quality of forests to meet diverse needs and values.

Spatial variation means differences across a landscape.

Stand-Up Paddleboarding (SUP)

Subdrainage or **subbasin** or **subwatershed** is an area of land that drains to a common point, which is also part of a larger watershed *e.g.* the Boston Creek watershed is a subwatershed of the Comox Lake Watershed.

Submontane means situated in the foothills or lower slopes of a mountain range.

Thermocline a steep temperature gradient in a body of water such as a lake, marked by a layer above and below which the water is at different temperatures**.**

Total Suspended Sediment (TSS) is the amount of solids suspended in the water, or those large enough to be caught by a 0.45µm filter. A close relationship may be established between TSS and turbidity, since they both measure clay, silt and colloidal material suspended in the water.

Total Chance Access Plan An access plan that identifies known resource values, terrain stability, existing roads, future roads, stream crossings and access points. The plan guides the location of roads and crossings both for day-to-day operation and in the event of an emergency such as wildfire. These plans typically include information such as the location of spill kits, access points for emergency responders, pumping locations for filling fire suppression equipment, and locations where cellular telephone coverage is present.

Turbidity is an optical characteristic of water, in that it is a measurement of how much light passes through it. Turbidity is caused by the amount of suspended matter in the water, including clay, silt, fine particles of organic and inorganic matter and microscopic organisms. High turbidity levels can obscure light availability and reduce plant production as well as negatively affect some animal behaviors such as predator avoidance. Particles can also settle out on the stream or lake bottom and smother aquatic invertebrates, as well as developing fish embryos. Turbidity is a health concern for humans drinking chlorinated water due to the possible reaction of chlorine with organic materials to produce carcinogenic substances.

United Riders of Cumberland (UROC)

University of Victoria (UVic)

Vancouver Island University (VIU)

Viruses are microorganisms that are smaller than bacteria that cannot grow or reproduce apart from a living cell. A virus invades living cells and uses their chemical machinery to keep itself alive and to replicate itself.

Watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. The word watershed is sometimes used interchangeably with drainage basin or catchment. Ridges and hills that separate two watersheds are called the drainage divide. The watershed consists of surface water--lakes, streams, reservoirs, and wetlands--and all the underlying ground water. Larger watersheds contain many smaller watersheds. It all depends on the outflow point; all of the land that drains water to the outflow point is the watershed for that outflow location. Watersheds are important because the streamflow and the water quality of a river are affected by things, human-induced or not, happening in the land area "above" the river-outflow point.

Watershed Advisory Group (WAG)

Watershed Protection Plan (WPP)

Windthrow means areas where trees are uprooted, blown down, or broken off (windsnap) by winds.

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