VAN ANDA IMPROVEMENT DISTRICT

Drinking Water
Source Assessment Report

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Executive Summary

Community water supply systems are expected to provide safe drinking water in quantities sufficient to meet demand at all times including during unexpected and extreme events such as fighting fires and drought. Natural characteristics and human activities influencing drinking water sources determine the quality of the raw water and the amount that is available for use in a community water system.

Alluvia Environmental Services was retained by the Vancouver Coastal Health Authority to undertake drinking water source assessments for a small number of community water supplies in the Vancouver Coastal Health Region between April and June, 2004. The focus of these assessments was to characterize drinking water sources, identify potential hazards, and recommend ways to minimize risk to public health and improve the sustainability of the drinking water supply.

Priest Lake watershed is a multiple use watershed with a number of competing interests, of which drinking water protection is only one. Resource extraction has been occurring in the Priest Lake watershed continuously since the late 1800's. Cumulative impacts of forestry, mining, roads and human habitation over time and space are resulting in drinking water quality that is at the threshold of potability. Stakes are high for the Van Anda Improvement District because Priest Lake is their only nearby water supply. Groundwater has been ruled out as an alternative drinking water source because fractures and solution channels in limestone can transport water quickly without the filtration offered by sand and gravel aquifers, leaving it vulnerable to microbial and chemical contamination from land uses and human activities at the surface. For these reasons, it is critical that action be taken in the short term to improve overall drinking water quality in the watershed.

Based on the results of the source assessment in this report, the following recommendations are made to improve source water quality and minimize the risk of waterborne illness:

1. Install a chlorine residual analyzer.
2. Inspect septic systems on the north side of Priest Lake.
3. Apply water treatment capable of effectively inactivating *Giardia, Cryptosporidium,* and other pathogens.
4. Develop an emergency response plan that includes responses to emergencies associated with source water.
5. Initiate an integrated watershed management planning and protection process.
6. Continue source water quality monitoring program, adding tests for total organic carbon (TOC), and phosphorus.
7. Redraw Priest Lake community watershed boundary based on air photo interpretation.

Acknowledgements

I would like to extend appreciation and thanks to individuals who supplied information for this source water assessment:

- Van Anda Improvement District trustees: John Wood, Walter Gussman, Ron Arnold, and Glyn Isherwood
- Dan Glover, Drinking Water Officer, Vancouver Coastal Health Authority
- Karen Rothe, Ministry of Sustainable Resource Management
- Jordan Rosenfeld, Ministry of Water, Land and Air Protection
- Don Wallace, Terasen Gas

Special thanks go to Harold Diggon from Texada Quarrying Ltd. who volunteered to drive the Van Anda Improvement District trustees, Dan Glover and me on a tour of the watershed and the limestone mining operations.

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1. Introduction

1.1 Project Overview

Community water supply systems are expected to provide safe drinking water in quantities sufficient to meet demand at all times including during unexpected and extreme events such as fighting fires and drought. Natural characteristics and human activities influencing drinking water sources determine the quality of the raw water and the amount that is available for use in a community water system.

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1.2 Scope

This water source assessment covers the watershed area to and including the intake and considers how the natural aspects of the watershed and human activities within it affect water quality and availability. Integrity and location of the water intake were also evaluated to ensure that the best quality water from the source is being taken into the system.

Watershed characteristics such as topography and size, climate, geology, vegetation cover, wildlife, and human activity are all factors that collectively determine source water quality and availability. Figure 1 illustrates these factors and serves as a model for communicating the scope of this drinking water source assessment. Treatment, storage and distribution systems are represented in this figure for completeness and while they can influence drinking water quality, they are outside of the scope of this assessment. Where relevant, information about these and other aspects of the water supply system is conveyed to present a more complete picture of the water supply system, but this report is an assessment of the drinking water source only.

1.3 Water Source Assessment Methodology

Water source assessments have two components: 1) field investigation and, 2) office research, analysis and report writing. The field investigation took place on April 28, 2004 and involved visiting the drinking water source at the intake with representatives from Van Anda Improvement District; Dan Glover, Drinking Water Officer, Vancouver Coastal Health Authority; and Harold Diggon, from Texada Quarrying, making observations and interviewing those present. Following the field investigation, information about the water source was compiled and analyzed to establish a preliminary understanding of the natural features of the watershed and possible effects of human activities within it.

This report provides an overview of the water system, description of watershed characteristics, a summary of source water quality and quantity concerns, and identification of land uses and human activities occurring in the watershed. Any characteristic, event or circumstance that could cause harm by impairing source water quality or quantity is considered a hazard. In this assessment, hazards and their relative risk to drinking water are evaluated in Table 5. Risk characterization is performed for each hazard to help determine which hazards pose the greatest risks, and to prioritize source water protection efforts.

The final section of this report contains recommendations to improve public health protection and the sustainability of the drinking water source.

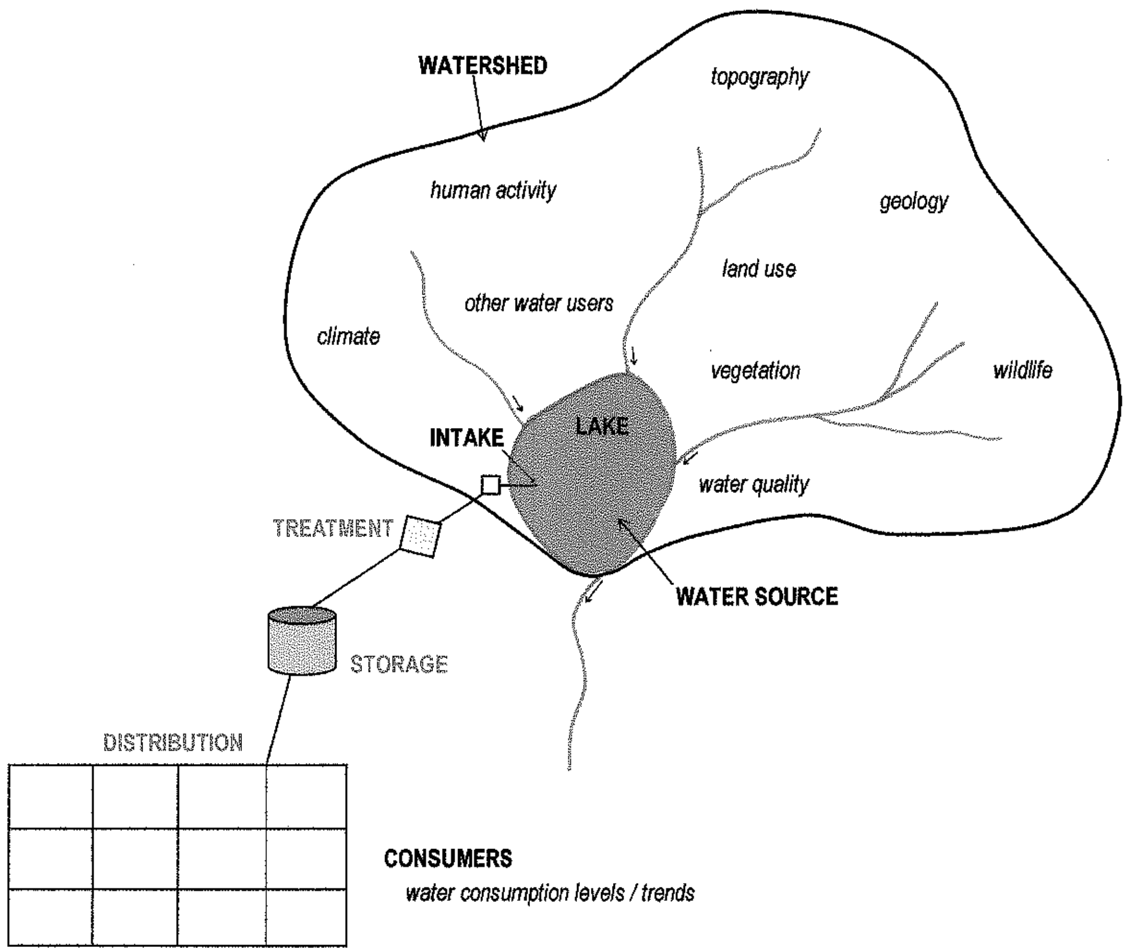

Figure 1. Factors influencing drinking water quality and availability in a watershed

2. Water System Overview

Van Anda is a community located on northeastern Texada Island in Georgia Strait between Vancouver Island and the Sunshine Coast. Van Anda Improvement District (VAID) supplies water to approximately 200 connections from their sole source, Priest Lake. Water from the lake is disinfected using 12% sodium hypochlorite and is pumped to a 45,000 imperial gallon wood stave tank which supplies water to consumers by gravity.

Twice within the past three years Van Anda Improvement District water system has been on a boil water advisory due to unacceptable bacteriological water quality in the system. The first boil water advisory was in place for less than one month in spring 2001. The second boil water advisory established in May, 2003 was lifted in March, 2004 after ten months.

Trustees for Van Anda Improvement District who were present for the field investigation showed enthusiasm and commitment to supplying safe drinking water. Their community is fortunate that knowledgeable, skilled trustees volunteer their time to maintaining the water system.

2.1 Integrity and Location of Intake

Water from Priest Lake is captured through an 8 inch intake pipe located near the eastern end of the lake. The pipe has a 3 mm mesh screen on the end which is cleaned annually. The location of the intake is not marked at the water surface. There are some signs identifying the drinking water source, and trustees for VAID indicated there are plans for more signs.

3. Priest Lake Watershed Characterization

3.1 Priest Lake

A physical survey of Priest Lake was performed in 1970 by the Fish and Wildlife Branch of the Department of Recreation and Conservation in which depth contours (bathymetry) of Priest Lake were surveyed and mapped (see Appendix I for the map). According to that survey, Priest Lake has a surface area of 42 hectares (104 acres) and volume of 2.28 million cubic metres (500 million imperial gallons). At the time of the survey, the mean depth of the lake was 5.3 metres (17.4 feet) and the maximum depth was 16.5 metres (54 feet). It is reasonable to assume that some lake infilling has occurred over the past 30 years making the lake shallower; however, the rate of infilling is unknown.

Riparian areas are the moist zones of vegetation between a water body and the upland area that function to stabilize the lakeshore and filter runoff. Based on the view of the lake visible from the intake, the riparian area around the lake appears to be mostly intact, though the riparian buffer to the north and east of the intake is thin to non-existent. There is no riparian buffer between Gillies Bay Road and the eastern tip of the lake to slow overland runoff and filter contaminants before they reach the water.

Basic administrative and location information for Priest Lake and its watershed are presented in Table 1 as a cross-referenced list to inform integrated watershed management.

Table 1. Administrative and georeferencing information for Priest Lake, drinking water source for Van Anda Improvement District

Water Supplier	Van Anda Improvement District
Water Source	Priest Lake
Watershed Code	905-126000-61600
Waterbody Identifier	00307JERV
FPC Community Watershed #	TEX.003
Watershed size	1131 hectares
Water licence #s	C047520, C023365, C017599
Water licence amount	73 million imperial gallons per year
Point of diversion #	PD45676
Latitude/Longitude at intake	49°44'48" N, 124°33' 55" W (approx.)

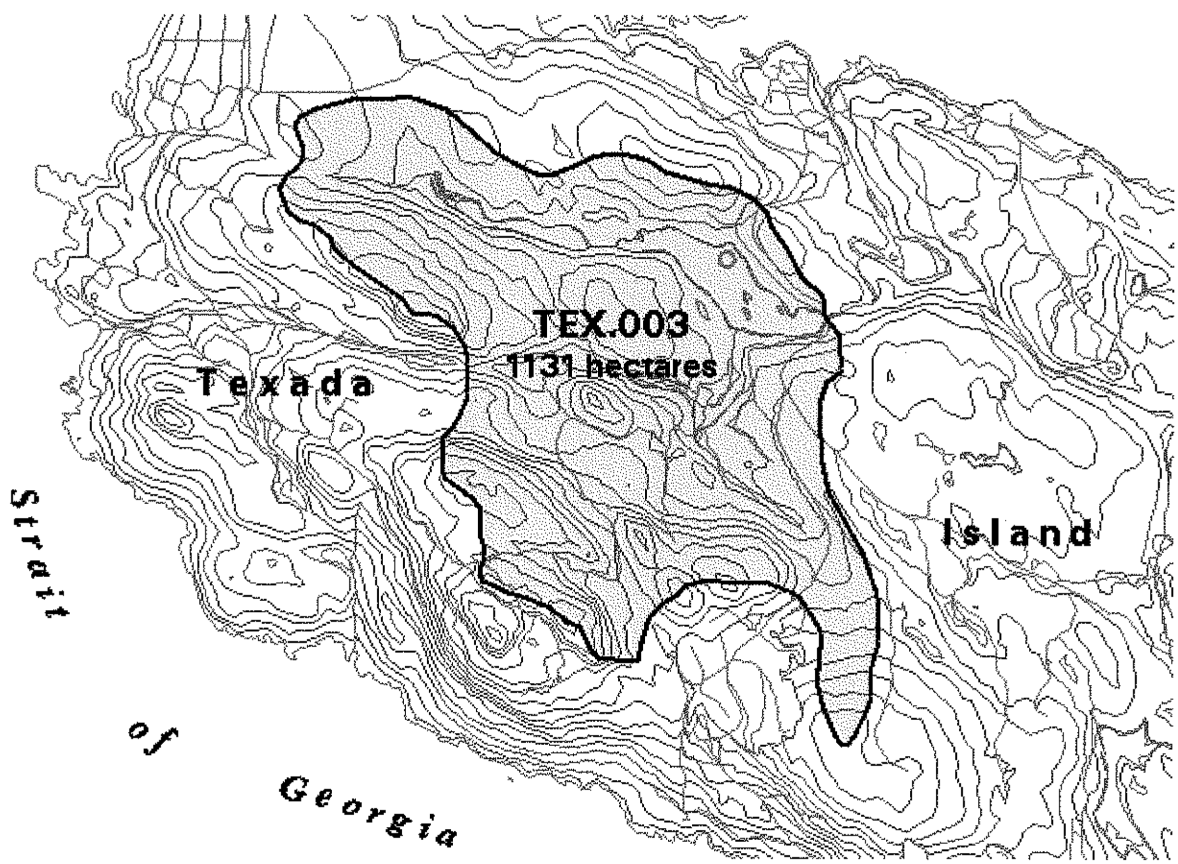

Figure 2. Priest Lake Community Watershed boundary established under the Forest Practices Code

3.2 Watershed Topography

Priest Lake watershed occupies 1131 hectares according to the community watershed boundary established under the Forest Practices Code (Figure 2), and lies in the north central part of Texada Island. Some concern was expressed by VAID trustees that the current community watershed boundary excludes a large open pit limestone mine that has altered the topography of the watershed. After reviewing available topographic information and aerial photographs taken in 1999[1], I have concluded that a significant portion of the quarry is within the catchment area of Priest Lake watershed.

At 80 metres elevation, Priest Lake is in the northern portion of the watershed receiving drainage primarily from the west and south, where the highest watershed elevation is 340 m near Surprise Mountain. A number of other lakes including Spectacle (Balkwill) Lake and Kirk Lake and small wetlands are present in the lower elevations of the watershed.

3.3 Climate

Climate on Texada Island is characterized by mild wet winters and warm dry summers, with average annual precipitation of 949 mm[2] - slightly drier than the 1113 mm at Powell River to the east on the mainland[3]. Average monthly precipitation on Texada Island ranges from 38.4 mm in the driest month (July) and 147.4 mm in the wettest month (November). Temperature data were unavailable for Texada Island, but average monthly temperatures at Powell River range from 4.0°C in January to 18.3°C in August[3].

These climate patterns indicate that in winter, water stores are replenished as rain increases and temperatures decrease. Heavy rains coincide with the dropping of fresh leaf litter from the alders. Winter can also be a time of high runoff, resulting in higher turbidity from sediment and organic matter. In summer warmer, drier weather accompanied by increased water use for gardening and recreation can deplete water supplies.

3.4 Geology

Priest Lake watershed is underlain by two types of bedrock. Volcanic basalt is present in the western portion of the watershed, whereas bedrock in the eastern and south parts of the watershed is composed of limestone (Energy and Mines, 2004) which is currently being mined in a quarry in the southern part of the watershed.

Surficial materials overlying bedrock include till, glaciofluvial and glaciomarine deposits composed of medium-textured fine sand with thin deposits of silt and clay over top (EBA, 2000). According to Contour Geoscience Ltd (cited in EBA, 2000), 7.2% of the watershed (81.8 hectares) has high surface erosion potential and two forest cutblocks were planned for

[1] Ministry of Sustainable Resource Management, Air Photo Library. Roll # 30BCB99004, Frame # 33-34, Scale: 1:15,000.

[2] Based on Climate Normals 1961-1990 at Environment Canada climate station no. 1048140.

[3] Based on Climate Normals 1961-1990 at Environment Canada climate station no. 1046390.

such areas between 2001 and 2005. To avoid or mitigate erosion associated with development in the watershed, they have recommended avoiding road building on highly erodible material and preventing water flow from concentrating in ditches and along roads.

3.5 Vegetation

Based on observations made during the field investigation of the drinking water source assessment, forests within the Priest Lake watershed are composed predominantly of Douglas fir, cedar and alder with some hemlock and pine. Much of the island was logged heavily in 1950's and 1960's, and now "13.4% of the watershed is occupied by stands with a significant component of alder"[4] due to past forestry practices and deer browsing on cedar and fir, dwarfing them compared to the fast-growing alder. Numerous heavily browsed "bonsai" cedars and firs were noted in the understory of the alder. The proportion of alder in the watershed is a concern for some VAID trustees because of the volume of organic matter these deciduous trees contribute annually to the watershed through leaf litter, possibly impacting drinking water quality by contributing humic substances that colour the water and can react with chlorine to produce harmful by-products such as trihalomethanes during disinfection.

Priest Lake watershed contains several small wetland areas vegetated primarily with sedges, Skunk Cabbage and cattails. These wetlands may be beneficial to water quality as they function to slow water flow to the lake and to filter sediment and contaminants out of the water. Wetlands can be a source of organic colour in drinking water (AWWA, 1999), but it is uncertain whether wetlands of the size observed in the Priest Lake watershed would be significant contributors of coloured water.

3.6 Wildlife

Texada Island is home to numerous wildlife species the most relevant of which to drinking water quality are beaver and black-tailed deer. Beaver have been known to be in the watershed in the past and it is unknown whether they still inhabit the watershed. Beaver are notorious hosts of *Giardia lamblia*, a microscopic protozoan pathogen responsible for Giardiasis, an illness otherwise known as "beaver fever". Numerous other common animals can be hosts to *Giardia* such as Canada geese, mallard ducks, black bears, weasels, as well as brown and rainbow trout (Dissmeyer, 2000).

A large population of black-tailed deer exists on Texada Island and there are no natural predators such as cougars to keep the population in check; however, hunting regulations recognize the abundant population of black-tailed deer on Texada Island allowing a hunter to take more deer per season than in other nearby management areas (Ministry of Water, Land and Air Protection, 2003). Deer are known hosts to *Cryptosporidium*, another type of waterborne protozoan pathogen responsible for outbreaks of gastrointestinal illness. Muskrat, elk, great blue heron, sparrows and dogs are other examples of *Cryptosporidium* hosts

[4] Brian Kukulies, Tenures Forester, Sunshine Coast Forest District. Letter to Eileen Lavergren, Secretary to the Van Anda Improvement District dated December 1, 2000. File: ORCS 19600-55/TSL_ALL.

(Dissmeyer, 2000). Domesticated animals and human sewage are sources of both *Giardia* and *Cryptosporidium* (British Columbia Provincial Health Officer, 2000).

3.7 Source Water Quality

The most recent physical and chemical source water quality tests for Priest Lake were performed in June 2000 and February 2004. Elevated water quality constituents of concern for this test include total coliforms and colour.

Van Anda Improvement District disinfects its surface water supply, but there have been recent spikes in total and fecal coliforms in water samples from near the water intake in Priest Lake. Total and fecal coliforms are not usually harmful themselves, but are used as indicators of the possible presence of disease-causing organisms in water. Normal levels of coliforms in the source water are less than 20 colony forming units (CFU)/100 mL total coliforms and less than 5 CFU/100 mL fecal coliforms. In October 2003, total coliforms jumped to 890 CFU/100 mL and fecal coliforms were estimated to be 440 CFU/100 mL. This spike was associated with heavy precipitation. While coliform levels did not remain this high, they did remain elevated through the winter of 2003/04. Source water samples taken on two occasions in late May, 2004 had high concentrations of total coliforms (1710 and 200 CFU/100 mL), but normal levels of fecal coliforms (1 and <1 CFU/100 mL). This spike of total coliforms was not associated with precipitation.

The aesthetic objective for colour, ≤ 15 true colour units (TCU) (Health Canada, 2003) was exceeded in both samples. In 2000, apparent colour was 15 TCU and in 2004, it was 26 TCU. Colour is a measure of the amount of dissolved organic and inorganic coloured compounds in water and is an aesthetic indicator. Organic colour sources include decaying vegetation and the most common inorganic sources are iron, manganese and copper. The organic component of colour can be a concern because it is a precursor to the formation of disinfection by-products such as trihalomethanes.

Van Anda Improvement District tested for hydrocarbons in Priest Lake, Kirk Creek and Quarry Creek in March 2004 due to concerns over possible contamination from fuel oil used to blast at the quarry. No hydrocarbons were detected in any of the samples.

3.8 Source Water Quantity

Source water volumes are affected by climate, amounts of water flowing into and out of the lake through streams and groundwater, and consumption rate of all source water users. Van Anda Improvement District holds a water licence as a waterworks for 73 million imperial gallons per year. One other domestic water user on the lake holds a licence for 365,000 imperial gallons per year.

Actual annual water use for Van Anda water district is estimated based on the pump hours. In 2001 and 2002, annual pump hours amounted to 3300 hours – equivalent to approximately 44 million imperial gallons[5]. In 2003, a total of 3100 pump hours were required to furnish water demand estimated to be approximately 41 million imperial gallons[5].

Based on anecdotal information provided by VAID trustees, water levels in the lake fluctuate approximately one metre between high and low water levels and this does not affect the intake. Priest Lake presently contains an adequate volume of water to meet the needs of the community of Van Anda, yet there are concerns over having adequate water flow in the event of a fire. This is an issue with storage and pumping capacity, not the source.

Although Priest Lake has an adequate supply for Van Anda Improvement District at the present time, climate change can impact the amount and timing of water flowing to Priest Lake. Climate scientists predict that coastal BC could experience warmer drier summers and wetter winters as climate changes (Environment Canada, 2004), threatening both the quality and quantity of water supplies. Water conservation plays a key role in mitigating the impacts of climate change.

[5] Total annual water volume estimated by recording the rate at which the wood stave storage tank filled after cleaning and translating that into a pumping rate.

4. Land Uses and Human Activity in the Priest Lake Watershed

Land uses and other human activity within a watershed can impact drinking water quality by changing the way water flows in the watershed and introducing contaminants to the water. The Priest Lake watershed sustains multiple uses including forestry, roads and residential areas close to the lake, recreation, and limestone mining. Small-scale iron and gold mining has taken place in the past and present, and as a result there are numerous small tailings piles and old mine shafts in the watershed. A natural gas pipeline traverses Texada Island passing Priest Lake at its eastern tip, and a graveyard is located near the northeast watershed boundary. The activities of the Stickleback Recovery Team could have a beneficial effect in the watershed as the team works to improve water quality for the endangered Stickleback species pair.

Each land use and human activity identified in the watershed is described briefly below and their relative risks are characterized in Table 5.

4.1 Forestry

Forestry activities can influence water quality by increasing runoff and peak flows in streams, increasing turbidity. Short-term increases in nutrient concentrations can also occur. Forest harvesting in the Priest Lake watershed takes place on Crown land and private land. Approximately 39% of land in the watershed (441 ha) is privately owned (EBA, 2000)[6] excluding the quarry which is presently not considered part of the watershed. Crown land forest harvest is regulated under the Forest Practices Code including special requirements for community watersheds such as Priest Lake. A Coastal Watershed Assessment was prepared by EBA Engineering in 2000 to assess impacts of past forestry and to provide recommendations for mitigating the effects of further development. Some concern has been expressed that Crown land forestry activities are not taking into account added impacts from harvesting on private land. Last year, one cutblock close to the lake was harvested causing some concern among water users.

4.2 Roads

Roads are sources of contaminants such as sediment, hydrocarbons, and metals, and can change the flow paths of water in a watershed causing increased runoff and peak flows in streams. As of 2000, road density in Priest Lake watershed was 2.0 km/km^2 (or 22.6 km total), and construction of another 2.9 km was planned for the time period between 2001 and 2005 (EBA, 2000), bringing total road density to 2.3 km/km^2. Gillies Bay Road runs directly beside the easternmost tip of Priest Lake, where there is no riparian vegetation to filter runoff.

[6] Based on 1991 forest inventory data.

4.3 Residential Areas

Residences can be sources of contaminants from septic systems, pesticides, fertilizers, oil, and household chemicals. An estimated 25 private residences exist throughout the Priest Lake watershed. Of primary concern to the drinking water source are the small cluster of residences located on the north shore of Priest Lake due to their proximity to the intake and use of septic systems. One or two of the septic fields may be within the 30-metre (100-foot) setback from sources of drinking water required by the *Health Act* Sewage Disposal Regulation.

4.4 Recreation

Recreation in a watershed can impact a drinking water source by introducing microbial pathogens from human and animal wastes, and increase the use of trails and roads accelerating erosion. Motorized recreation amplifies the risk of erosion and is a source of hydrocarbons and other chemical contaminants. Use of the Priest Lake watershed around or upstream of intake is not restricted except that swimming and motor boats are prohibited on the lake.

4.5 Limestone Mining

An open pit limestone mine or quarry, owned by Lafarge and operated by Texada Quarrying, is located at the southern edge of the Priest Lake watershed. Texada Island contains the only tidewater lime deposit on the BC coast, which extends down to approximately 1000 feet deep. Limestone is currently extracted at a rate of five million tonnes per year and the 30-year mine plan has plans to expand the quarry to the north, east, south and down. Drilling and blasting are used to extract limestone rock which is loaded into trucks for transport. Ammonium nitrate and oil are used as explosives and are reportedly consumed during blasting, presenting no harm to the environment. Ammonium nitrate is stored outside of the Priest Lake watershed[7].

As discussed previously, there have been questions about whether the quarry is in or out of the watershed. Mining has occurred up to the height of land, changing local topography and watershed boundaries. Air photography analysis reveals that a significant portion of the quarry drains to Priest Lake.

Van Anda Improvement District have raised concerns over the impacts of the mine on drinking water quality, sediments in particular. During the field investigation and watershed tour, light-coloured fine-grained sediment was visible on vegetation and woody debris in some streams in the watershed. Texada Quarrying and Lafarge appear to be responsive to those concerns. Recently, the quarry diverted drainage from the settling pond at the quarry

[7] Personal communication. Harold Diggon, Texada Quarrying Ltd. April 28, 2004.

away from a stream entering Priest Lake to minimize sediment loading. According to Mr. Diggon from Texada Quarrying, Lafarge has plans to increase water monitoring.

4.6 Small Scale Metal Mining

Mining of metals such as gold and copper is part of Texada Island's history and continues in the present. Active mining can contribute sediment to watercourses and mine shafts and tailings piles can be sources of acid rock drainage, which increases the acidity of water, mobilizing toxic metals in rock such as lead, zinc, cadmium and arsenic. An unknown number and size of old mine shafts and tailings piles exist in the Priest Lake watershed, so the degree of potential impact on the water source is difficult to assess.

4.7 Graveyard

A small active graveyard is situated near the northeast watershed boundary approximately 300 metres (1000 feet) from the shore of Priest Lake. Concerns have been raised about the graveyard primarily because of the underlying limestone bedrock that often contains fractures and solution channels in which water and contaminants can flow rapidly without filtration.

4.8 Natural Gas Pipeline

A ten-inch steel high-pressure natural gas pipeline owned by Terasen Gas traverses Texada Island from south to north, passing the eastern tip of Priest Lake. The pipeline, which is buried approximately one metre underground, transmits natural gas in gaseous form at pressures of approximately 2160 psi. Terasen Gas monitors the pipeline remotely using a SCADA system and performs periodic inspections to ensure safety.[8] Hypothetically, if the pipeline ruptured near Priest Lake, gas would be released and vapourize into the atmosphere, posing very little threat to the drinking water source unless an explosion occurred, in which case water quality could be seriously impaired.

4.9 Stickleback Recovery[9]

The Priest Lake Watershed is critical habitat to the unusual and endangered Stickleback species pairs (*Gasterosteus spp.*). Two species of Stickleback, one limnetic (living in the upper portion of the water column) and one benthic (dwelling near the lake bottom), have evolved together in the Van Anda Creek watershed inhabiting Priest, Balkwill and Emily Lakes. Paxton Lake, also on Texada Island, and Enos Lake near Nanaimo, are the only other

[8] Personal communication. Don Wallace. Terasen Gas. May 31, 2004.

[9] Personal communication. Jordan Rosenfeld, Co-Chair Stickleback Species Recovery Team, Ministry of Water, Land and Air Protection. June 2, 2004.

locations where extant Stickleback species pairs are currently known to exist in British Columbia; a species pair in Hadley Lake on Lasqueti Island was extirpated by introduced catfish.

Stickleback species pairs do not mate with each other as long as there is sufficient habitat of both types available and water quality is good. Most fish require fairly good water quality to survive, but Stickleback species pairs are especially sensitive to turbidity and colour in the water because they recognize their mates by sight. In cloudy water, limnetic and benthic species begin interbreeding because they can no longer perceive the appropriate cues for distinguishing mates of the same species, and the population becomes hybridized and the species pairs become extinct.

A Stickleback Recovery Team has been formed to develop an action plan to recover and protect Stickleback species pairs and, in fact, representatives from the Recovery Team toured the Priest Lake watershed in April, 2004. Because of the sensitivity of the species to water quality, one important goal of this group will be to ensure beneficial water quality for the Stickleback species pair. Reducing turbidity and colour in the water are common goals of the Van Anda Improvement District and the Stickleback Recovery Team. Both groups could benefit from collaboration to improve water quality in the watershed.

5. Hazard Identification and Risk Assessment

Throughout the drinking water source assessment potential threats to source water quality and quantity were examined. In this section, threats or hazards are identified and assessed for their risk to public health using a qualitative risk assessment approach (see Table 5). A hazard is an event, condition or situation with potential to cause harm. Risk assessment involves characterizing the significance of the risk to human health and the drinking water source posed by an identified hazard.

Risk can be determined by the product of two factors: likelihood and consequence.

- Likelihood is the chance that a hazard will actually compromise source water quality or quantity, posing a public health threat.
- Consequence is the combination of the severity, nature, and duration of an event, as well as the size of the population affected and type of health consequences.

In assessing risk of hazards associated with the drinking water source, five levels of likelihood and consequence were used to estimate a risk level of low, moderate, high, or very high. For each hazard, a level of likelihood is selected from Table 2, and a level of consequence is estimated from Table 3. The intersection of the likelihood row and the consequence column in Table 4 give a level of risk to the drinking water source for that hazard. Estimations of likelihood, consequence and risk are based on the professional judgement of the assessor in consultation with the environmental health officer.

Likelihood depends on 1) the probability of the potentially harmful event or condition happening in the next ten years, and 2) the probability that water quality contamination or reductions in water volume will result.

Table 2. Qualitative measures of likelihood[10]

Level	Descriptor	Description	Probability of Occurrence in Next 10 Years
A	Almost certain	Is expected to occur in most circumstances	>90%
B	Likely	Will probably occur in most circumstances	71-90%
C	Possible	Will probably occur at some time	31-70%
D	Unlikely	Could occur at some time	10-30%
E	Rare	May only occur in exceptional circumstances	<10%

[10] After:
NHMRC/ARMCANZ Co-ordinating Group. 2001. *Framework for Management of Drinking Water Quality: A Preventive Strategy from Catchment to Consumer.* National Health and Medical Research Council/Agriculture and Resource Management Council of Australia and New Zealand.
http://www.nhmrc.gov.au/advice/pdf/watergly.pdf.;

Berry, T and Failing, L. 2003. Source to Tap Assessment Risk Assessment Workshop Notes. Prepared for the Source to Tap Assessment Team, Ministry of Health Planning and Ministry of Water, Land and Air Protection. September, 23, 2003. Compass Resource Management.

Consequence refers to the degree of impact if a drinking water hazard created a harmful effect such as unacceptable water quality, health effects in consumers, significant reduction in water volume, or loss of source. Factors that influence consequence include the nature of the effect, severity of impact, duration of the effect, and the number and vulnerability of the population affected.

Table 3. Qualitative measures of consequence[11]

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

Table 4. Qualitative risk analysis matrix – How to determine risk level[9]

	Consequences				
Likelihood	**1 Insignificant**	**2 Minor**	**3 Moderate**	**4 Major**	**5 Catastrophic**
A (almost certain)	Moderate	High	Very High	Very High	Very High
B (likely)	Moderate	High	High	Very High	Very High
C (possible)	Low	Moderate	High	Very High	Very High
D (unlikely)	Low	Low	Moderate	High	Very High
E (rare)	Low	Low	Moderate	High	High

Table 5 consolidates hazard identification and risk characterization to understand the potential impacts a hazard could have on a drinking water source, preventive measures in place to prevent a hazard from causing harm, estimated likelihood, consequence and risk levels, and any assumptions made in characterizing the risk associated with a hazard.

A risk characterization approach was used in this drinking water source assessment to help identify the hazards that pose the greatest threat to the drinking water source and human health, and consequently, assists in prioritizing watershed management options. It is

[11] After NHMRC/ARMCANZ Co-ordinating Group. 2001. *Framework for Management of Drinking Water Quality: A Preventive Strategy from Catchment to Consumer.* National Health and Medical Research Council/Agriculture and Resource Management Council of Australia and New Zealand. http://www.nhmrc.gov.au/advice/pdf/waterqly.pdf.

important, however, that readers understand the limitations of the risk characterization presented here. Because a qualitative risk assessment approach was applied, risk was estimated based on professional judgement which can be influenced by uncertainty and the assessor's bias. Every effort was made to be as objective as possible when assigning likelihood and consequence values.

Table 5. Drinking Water Hazards in the Priest Lake Watershed – Identification and Risk Characterization

Drinking Water Hazards in Priest Lake Watershed	Possible Effects on Drinking Water	Existing Preventive Measures	Likelihood Level	Consequence Level	Risk Level	Assumptions/ Comments
1. Wildlife	• Source of microbial pathogens such as *E.coli*, *Giardia*, and *Cryptosporidium*.	• Disinfection with sodium hypochlorite	Almost Certain A	Major 4	Very High	• Lake is natural habitat for animals that carry *Giardia* and *Cryptosporidium*, including ducks and geese. A large population of black-tailed deer exists in the watershed. • Sodium hypochlorite is not generally considered to be effective at inactivating *Giardia* and *Cryptosporidium*.
2. Roads	• Source of contaminants such as hydrocarbons, sediments, and heavy metals • Accidental spills • Altered hydrology – increased runoff and peak flows	• Lake allows sediment to settle out before it reaches intake.	Possible C	Major 4	Very High	• Risk rating is very high due to the proximity of Gillies Bay Road to the eastern edge of the lake where there is no riparian buffer. A serious accident or spill near the lake could result in temporary or long-term loss of the drinking water source. • Relatively high road density in watershed: 2.3 km/km^2. • Unknown condition of roads in watersheds creates uncertainty in determining risk levels. • Increased sediment in the water reduces treatment effectiveness.
3. Residences with septic systems near lake	• Septic system effluent can be a source of nitrogen, pathogens, and chemicals.	• Sodium hypochlorite disinfection for microbial contaminants	Possible C	Moderate 3	High	• A couple of lake front residences northwest of the intake have septic systems on the lake side of their homes, within 30 metres of the lakeshore.

Drinking Water Hazards in Priest Lake Watershed	Possible Effects on Drinking Water	Existing Preventive Measures	Likelihood Level	Consequence Level	Risk Level	Assumptions/ Comments
4. Forest harvesting	• Altered hydrology – increased runoff and peak flows. • Increased erosion and sediment loading. • Short term increase in nitrogen concentrations.	• Forest harvesting on Crown land is regulated under the Forest Practices Code which is includes some measures to protect drinking water quality in designated community watersheds. • Lake allows sediment to settle out before it reaches intake.	Possible C	Moderate 3	High	• Forest harvesting is also carried out within the 39% private land of the watershed and management practices are not regulated under the Forest Practices Code. • Increased sediment in the water reduces treatment effectiveness.
5. Graveyard	• Decomposing remains can be a source of harmful viruses, bacteria, chemical preservatives used in embalming such as formaldehyde. • Pesticides and fertilizers are associated with maintenance of cemetery grounds.	• Sodium hypochlorite disinfection for microbial contaminants	Possible C	Moderate 3	High	• Fractures or solution channels in limestone and fractures in basalt bedrock could transport cemetery leachate directly to the lake. It is unknown whether such direct conduits between the cemetery and lake exist. This uncertainty makes an accurate estimate of likelihood difficult.

Drinking Water Hazards in Priest Lake Watershed	Possible Effects on Drinking Water	Existing Preventive Measures	Likelihood Level	Consequence Level	Risk Level	Assumptions/ Comments
6. Natural gas pipeline	• Impacts on drinking water unlikely if the pipeline ruptured (except in the event of an explosion near the lake)	• Pipeline is monitored remotely (SCADA).[12] • Terasen Gas performs inspections regularly[10]. • In the event of a pipeline rupture, a section of pipe is isolated to minimize release of natural gas.	Rare E	Major 4	High	• Natural gas in the pipeline is in a vapour form[10], thus in the event of a rupture, the gas would quickly vapourize in the atmosphere. Because natural gas has a lower density than air, it will rise rather than settle at the earth's surface. • Given the monitoring of the pipeline, an explosion is unlikely, but if it did occur it would have serious impacts on water quality.
7. Limestone quarry	• Sediment source • Ammonium nitrate and fuel oil used for blasting are potential water contaminants • Alteration of the topography of the watershed – changed water flows, increased runoff	• Lake allows sediment to settle out before it reaches intake.	Possible C	Minor 2	Moderate	• Fine dust and sediment were visible in on riparian vegetation next to streams in the watershed near the quarry. • Increased sediment in the water reduces treatment effectiveness. • While sediment may have an impact on water quality, the limestone itself may increase the buffering capacity of the water and in fact, limestone is commonly used to neutralize acid rock drainage.
8. Recreation	• Microbial contamination from human and animal (e.g., dog, horse) wastes • Increased use and erosion of trails and roads – sediment source	• Sodium hypochlorite disinfection for microbial contaminants	Possible C	Minor 2	Moderate	• Proximity of activity to lake is a significant risk factor. • Swimming in the lake, especially near the intake is a high risk activity for water quality. • Increased sediment in the water reduces treatment effectiveness.

[12] Personal communication. Don Wallace. Terasen Gas. May 31, 2004.

Drinking Water Hazards in Priest Lake Watershed	Possible Effects on Drinking Water	Existing Preventive Measures	Likelihood Level	Consequence Level	Risk Level	Assumptions/ Comments
9. Small-scale mining	• Tailings piles and mine shafts may be sources of acid rock drainage (ARD) (low pH water containing dissolved metals) • Sediment source	• None identified	Possible C	Insignificant 1	Low	• Some acid rock drainage is probably occurring within the watershed. • One tailings pile is located in the residential area approximately 100 metres from the lake. • Metals levels and pH levels are within normal range in water quality samples taken at the intake. • Uncertain number, location and size of tailings piles and abandoned mine shafts. • Dilution will be a mitigating factor, but this depends on location and density of ARD sources.

6. Recommendations

Priest Lake watershed is a multiple use watershed with a number of competing interests, of which drinking water protection is only one. Resource extraction has been occurring in the Priest Lake watershed continuously since the late 1800's. Cumulative impacts of forestry, mining, roads and human habitation over time and space are resulting in drinking water quality that is at the threshold of potability. Stakes are high for the Van Anda Improvement District because Priest Lake is their only nearby water supply. Groundwater has been ruled out as an alternative drinking water source because fractures and solution channels in limestone can transport water quickly without the filtration offered by sand and gravel aquifers, leaving it vulnerable to microbial and chemical contamination from land uses and human activities at the surface. For these reasons, it is critical that action be taken in the short term to improve overall drinking water quality in the watershed.

Recommendations from the drinking water source assessment are presented in Table 6 with their rationale, a listing of the hazards (from Table 5) addressed by the action, and identification of the person/group/agency with primary responsibility for implementing the action. Recommendations have been loosely categorized in the following groups by priority:

1. Actions to prevent waterborne disease outbreaks (Recommendations 1-3)
2. Actions to address regulatory issues (Recommendation 4)
3. Watershed planning actions (Recommendation 5)
4. Other (Recommendations 6-7)

Table 6. Priest Lake Drinking Water Source Assessment Recommendations

Recommendation	Rationale	Hazard(s) Addressed	Responsibility for Action
1. Install a chlorine residual analyzer.	A combination of high surface runoff areas in the watershed (e.g., roads, new cutblocks, quarry), sediment sources, abundant wildlife and heavy winter rains mean that suspended sediments and pathogens can be flushed into the lake simultaneously. Sediment is problematic for disinfection because a) chlorine can react with particles increasing chlorine demand and reducing chlorine residual, and b) bacteria, viruses, and protozoa adhere to sediment particles that shield them from disinfection. Considering these source water conditions, a chlorine residual analyzer is an important tool in preventing a waterborne disease outbreak. A chlorine residual analyzer installed with an alarm would alert the water operator to a reduction in chlorine residual (possibly associated with water containing higher amounts of suspended solids and microbes) so the chlorine dose can be adjusted immediately to bring the chlorine residual up and reduce the risk of illness from waterborne pathogens. Alternatively, the chlorine residual analyzer could be installed in a compound loop control system where chlorine dosing is proportional to flow and controlled by chlorine residual measurements. Consult the drinking water officer and/or a professional water treatment / monitoring specialist for specific advice on installing a chlorine residual analyzer.	• #1 Wildlife • #2 Roads • #3 Residences with septic systems near lake • #4 Forest harvesting • #5 Graveyard • #7 Limestone quarry • #8 Recreation • # 9 Small-scale mining	Van Anda Improvement District
2. Inspect septic systems on north side of Priest Lake.	During the field investigation, it was noted that one or two septic systems on the north side of Priest Lake may be closer than the 30 metre setback required	• #3 Residences with septic systems near lake	Vancouver Coastal Health Authority

Recommendation	Rationale	Hazard(s) Addressed	Responsibility for Action
3. Apply water treatment capable of effectively inactivating *Giardia, Cryptosporidium* and other pathogens.	Due to the number of possible animal and human sources of pathogens in the watershed we can be reasonably certain that *Giardia* and *Cryptosporidium* and other pathogenic organisms are present in Priest Lake at least some of the time. To protect human health, water treatment systems for Van Anda Improvement District should be capable of inactivating *Giardia* and *Cryptosporidium* to a standard established by the drinking water officer. Consult the drinking water officer and/or a professional water treatment and monitoring specialist for specific advice on appropriate water treatment methods to inactivate waterborne pathogens.	♦ #1 Wildlife ♦ #3 Residences with septic systems near lake ♦ #5 Graveyard ♦ #8 Recreation	Van Anda Improvement District
4. Develop an emergency response plan that includes responses to emergencies associated with source water.	All community water systems are required to have an emergency response plan under the *Drinking Water Protection Act.* Clear protocols need to be in place for a fast, effective response to emergency situations, including those associated with the water source. A document from the Ministry of Health, *Emergency Response Planning for Small Waterworks Systems* provides guidance on preparing an emergency response plan (http://www.healthservices.gov.bc.ca/protect/pdf/PHI061.PDF).	♦ #2 Roads ♦ #6 Natural Gas Pipeline	Van Anda Improvement District
5. Initiate an integrated watershed management planning and protection process.	Water quality in Priest Lake is approaching the threshold of potability. Action needs to be taken to protect the only drinking water source for Van Anda Improvement District. Integrated watershed management planning is essential to the sustainability of the drinking water source (and for the protection of the endangered Stickleback species pair). Two approaches to meeting this objective are presented below in order of preference: 1. Apply a community-based approach to integrated watershed management planning by bringing together the major interests in the watershed to share information and work cooperatively to plan	♦ All	Van Anda Improvement District / Vancouver Coastal Health Authority

Recommendation	Rationale	Hazard(s) Addressed	Responsibility for Action
5. Initiate an integrated watershed management planning and protection process (cont.)	watershed activities for the future to minimize impacts on water quality. A source of sustainable funding and commitment on the part of stakeholders will be required to carry out this process. Working in collaboration with the Stickleback Species Recovery Team to achieve common goals in the watershed will result in added benefits with higher efficiency for both interests. Planning teams need to have representation from all major watershed interests at the same time as keeping the team a manageable size for decision making. A comprehensive Priest Lake watershed planning team would include representatives from Van Anda Improvement District, Vancouver Coastal Health Authority, Ministry of Forests, Ministry of Sustainable Resource Management, forest tenure holders, Texada Quarrying, the Stickleback Recovery Team, private land owners, and residents. The planning team can start small by identifying and addressing high priority issues, working toward developing a watershed protection plan over the medium term (3 to 10 years). Priority issues for the planning team to address in the short term (within 3 years) are: • Sediment sources • Source of colour in the water (are there sources other than alder?) • Runoff processes in the watershed associated with development such as forestry, mining, roads and residences. The *British Columbia Guide to Watershed Law and Planning* (http://www.bcwatersheds.org/issues/water/bcgwlp/index.shtml) is a good reference document to assist in beginning a planning process.		

Recommendation	Rationale	Hazard(s) Addressed	Responsibility for Action
5. Initiate an integrated watershed management planning and protection process (cont.)	2. The preferred approach to watershed planning is voluntary and community-based. If that approach is not effective, a regulatory approach can be taken using provisions of *the Drinking Water Protection Act* [SBC 2001 Chapter 9]. Under section 25, a drinking water officer may order hazard abatement and prevention orders, and under section 31, a drinking water officer may request that the Provincial Health Officer recommend to the Minister of Health Services to order a drinking water protection plan.		
6. Continue source water quality monitoring program, adding tests for total organic carbon (TOC), and phosphorus.	Van Anda Improvement District currently tests source water quality every one to two years analyzing for a range of physical and chemical constituents. I recommend continuing the monitoring program, measuring during the same month each time, and including tests for total organic carbon to track trends in disinfection by-product precursors, and phosphorus to monitor levels of the limiting nutrient for algae growth.	♦ All	Van Anda Improvement District
7. Redraw Priest Lake community watershed boundary based on air photo interpretation.	Current watershed boundaries exclude the quarry at the south of the catchment area. Available topographic mapping indicates no contour lines through the quarry area, making accurate watershed delineation difficult. Interpretation of recent air photos will provide a more accurate watershed area including the quarry which would be taken into account when planning future forest harvesting.	♦ #4 Forest harvesting	Ministry of Forests

7. References

American Water Works Association (AWWA). 1999. *Water Quality and Treatment: A Handbook of Community Water Supplies*, 5th ed. McGraw-Hill.

British Columbia Provincial Health Officer. 2000. *A Report on the Health of British Columbians. Provincial Health Officer's Annual Report 2000. Drinking Water Quality in British Columbia: The Public Health Perspective.* Victoria, B.C.: Ministry of Health Planning.

Cavanagh, N., R.N. Nordin, L.W. Pommen, L.G. Swain. 1998. *Guidelines for Interpreting Water Quality Data.* Field Test Edition. Ministry of Environment, Lands and Parks.

Dissmeyer, G.E., ed. 2000. *Drinking Water from Forests and Grasslands: A Synthesis of the Scientific Literature.* USDA Forest Service Southern Research Station. General Technical Report SRS-39.

EBA Engineering Consultants Ltd. 2000. *Watershed Assessment (CWAP) for Priest Lake, Texada Island, BC.* Submitted to Ministry of Forests, Sunshine Coast Forest District, Powell River, BC.

Environment Canada. 2004. *Temperature and Precipitation: Indicators of Climate Change.* Accessed June 6, 2004. http://www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm.

Health Canada. 2003. Guidelines for Canadian Drinking Water Quality - Supporting Documents. http://www.hc-sc.gc.ca/hecs-sesc/water/dwgsup.htm.

Ministry of Energy and Mines. 2004. *BCGS Updated Geology – by Lithology.* The Map Place. Province of British Columbia. Accessed May 28, 2004. http://webmap.em.gov.bc.ca/mapplace/maps/minpot/bcgs.mwf?LayersViewWidth=250&WIDTH=50&UNITS=KM&Lat=49.741111&Lon=-124.526389.

Ministry of Water, Land and Air Protection. 2003. *2003/04 Hunting and Trapping Regulations Synopsis.* Province of British Columbia. http://wlapwww.gov.bc.ca/fw/wild/synopsis.htm.

Appendix I. Bathymetric map of Priest Lake