

REPORT

Regional District of Kootenay Boundary

Christina Lake Water Utility Source Water Protection Plan



NOVEMBER 2019

CONFIDENTIALITY AND © COPYRIGHT

This document is for the sole use of the addressee and Associated Environmental Consultants Inc. The document contains proprietary and confidential information that shall not be reproduced in any manner or disclosed to or discussed with any other parties without the express written permission of Associated Environmental Consultants Inc. Information in this document is to be considered the intellectual property of Associated Environmental Consultants Inc. in accordance with Canadian copyright law.

This report was prepared by Associated Environmental Consultants Inc. for the account of Regional District of Kootenay Boundary. The material in it reflects Associated Environmental Consultants Inc.'s best judgement, in the light of the information available to it, at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Associated Environmental Consultants Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

EXECUTIVE SUMMARY

Associated Environmental Consultants Inc. (Associated) was retained by the Regional District of Kootenay Boundary (RDKB) to prepare a Source Water Protection Plan (SWPP) for the Christina Lake Water Utility, which obtains its water from an intake in Christina Lake, BC. Source protection is part of the multi-barrier approach to delivering clean, safe, and reliable drinking water. The goal of a SWPP is to identify and evaluate threats to drinking water safety and sustainability, and to develop recommendations to reduce risks and improve the resiliency of the water supply. The framework for completing a SWPP is provided by the BC Comprehensive Drinking Water Source-to-Tap Assessment Guideline (the Source-to-Tap Guideline) (MHLS 2010), and generally includes characterizing the water source and delineating the assessment area (Module 1), conducting a contaminant source inventory to identify drinking water hazards (Module 2), ranking the identified hazards (Module 7), and recommending actions to improve drinking water safety (Module 8).

The results of the SWPP indicate that the water quality of Christina Lake is good, and that it presents a good, viable water source to satisfy future water demands. A local non-profit organization (the Christina Lake Stewardship Society [CLSS]) has done considerable work to date to assess water quality and ecosystem health and promote the importance of a healthy watershed. The Christina Lake Management Plan, prepared by the CLSS in 2005, provides a comprehensive assessment of the watershed and identifies goals, objectives, and recommendations for maintaining the health of the watershed.

The focus of this SWPP, which builds upon the Christina Lake Management Plan, is drinking water safety and resiliency specifically for the Christina Lake Water Utility. During a workshop with a Technical Advisory Committee developed for this project, several strengths of the water system and source were identified, including the good quality of the source, natural land use and rural community setting, and community enthusiasm for source protection. Some of the identified weaknesses and threats were the lack of a back-up secondary water source, the threat of wildfires, flooding, climate change, and land use changes, and the risk of increased turbidity ultimately necessitating a costly filtration plant.

Although a detailed water balance was not completed as part of this SWPP, annual water extraction rates by the Water Utility are minor relative to the size of the lake and annual inputs. Climate change may affect the hydrologic regime of Christina Lake, with spring freshet expected to occur earlier in the year and warmer, drier, prolonged summers, but the Water Utility demand is likely sustainable (particularly if no significant changes in development or agricultural water use are anticipated). Promoting water conservation efforts, which are already underway, will further help address this risk.

Potential risks to water quality are more varied. In total, 21 hazards that relate to land and water use were identified. Of these, 2 were ranked as very-high risk, 7 as high risk, 6 as moderate risk, and 6 as low risk.¹ Contributing to the complexity of ranking the risk of these hazards is the threat of climate change, which may affect the quality of the source water either directly (e.g., through increased temperatures) or indirectly, by increasing the likelihood of other hazards (e.g., wildfire and flooding).

¹ Risk is determined based on the likelihood of a hazard occurring and the magnitude of the consequence, and can represent risk to human health and/or risk of disruption to normal water system operations, increased maintenance, and increased monitoring.

Recommendations to address the hazards can be complex. Although some actions are within the RDKB's jurisdiction, many others are the responsibility of the Province or fall within the realm of 'best practice' by the private sector. There are already many mechanisms in place to protect source water quality and address risk, including the current Official Community Plan (which addresses land use planning and development), the RDKB's Emergency Response Plan for the Water Utility (included in the annual water system reports), long-term lake water quality monitoring by the Province and CLSS, and other efforts by non-profit groups.

To help further address the hazards identified in this SWPP, and improve on existing practices, recommendations were identified that are based on:

- Engagement with other public agencies and industry.
- Improving public awareness of the water source and importance of source water protection.
- Water system infrastructure management and operations.
- Monitoring and lake studies.
- Legislation and policy (i.e., through the Official Community Plan review process, which is currently underway).
- Emergency preparedness.

The recommendations are presented with recommended time frames (short-term, medium-term, long-term) to allow for implementation as budgets allow.

The recommendations in this SWPP, along with the on-going efforts by the RDKB and other community organizations to monitor water quality and improve public awareness, will help mitigate risks to water quality in the future and improve the long-term sustainability of the source. There are many ways in which source water protection can be strengthened, and the recommendations presented here should be periodically reviewed and updated as new information becomes available.

TABLE OF CONTENTS

SECTION	PAGE NO.
Executive Summary	i
Table of Contents	iii
List of Tables	iv
List of Figures	v
1 Introduction	1-1
1.1 Project Background and Objectives	1-1
1.2 Technical Advisory Committee	1-1
1.3 General Project Approach	1-2
2 Module 1: Delineation and Characterization of Water Source	2-1
2.1 Characterization of Water Source	2-1
2.2 Assessment Area for the SWPP	2-12
3 Module 2: Contaminant Source Inventory	3-1
3.1 Types of Contaminants and Hazards	3-1
3.2 Hazard Inventory	3-3
4 Module 7: Characterize Risks from Source to Tap	4-1
4.1 Risk-Ranking Framework	4-1
4.2 Very High Risk Hazards	4-3
4.3 High Risk Hazards	4-4
4.4 Moderate Risk Hazards	4-7
4.5 Low Risk Hazards	4-9
4.6 Strength, Weaknesses, Opportunities, and Threats Analysis	4-9
5 Module 8: Recommended Actions to Improve Drinking Water Protection	5-1
5.1 Recommendations	5-1
5.2 Long-term Sustainability of the Drinking Water Source	5-6
Closure	
References	
Appendix A – Backgrounder and Public Input Survey	
Appendix B – Hazard Risk Ranking	
Appendix C – Strengths, Weaknesses, Opportunities, and Threats	

LIST OF TABLES

	PAGE NO.
Table 1-1 Technical Advisory Committee members	1-1
Table 1-2 General approach of the SWPP	1-2
Table 2-1 ECA estimates considering hydrologic recovery of harvested areas since 1965	2-5
Table 2-2 Estimated ECA as a percentage of the land base	2-5
Table 2-3 Descriptive statistics of water quality from EMS Site 200078 for key water quality parameters (1972-2019)	2-8
Table 2-4 Projected future climate conditions in the Regional District of Kootenay Boundary	2-12
Table 3-1 Hazards identified within the IPZ or Assessment Areas	3-5
Table 4-1 Assignment of risk categories – likelihood of occurrence	4-1
Table 4-2 Assignment of risk categories – magnitude of consequence	4-2
Table 4-3 Risk (likelihood-consequence) matrix	4-2
Table 5-1 Suggested time categories for risk management actions	5-1

LIST OF FIGURES

	PAGE NO.
Figure 2-1 Overview of the Christina Lake Watershed	2-2
Figure 2-2 Land Use in the Christina Lake Watershed	2-6
Figure 2-3 1981 - 2010 Climate Normals for the Grand Forks Climate Station	2-11
Figure 2-4 Assessment Areas	2-14
Figure 3-1 Identified Point-Source Hazards (General Assessment Area)	3-6
Figure 3-2 Identified Point-Source Hazards (Intake Protection Zone)	3-7

1 INTRODUCTION

1.1 Project Background and Objectives

The Regional District of Kootenay Boundary (RDKB) owns and operates the Christina Lake Water Utility in the community of Christina Lake, BC. The Water Utility, which up until 2017 was owned and operated by the Christina Waterworks District, has approximately 467 connections and services approximately 1430 year-round residents (with substantially higher demand in the summer due to a large influx of seasonal and tourist visitors).

The Water Utility obtains its source water from an intake in the southern part of Christina Lake, at a depth of approximately 12 m. Chlorination is currently the only form of treatment, and the water system is therefore considered a 'single treatment process' system. Current guidelines for drinking water supplies require two treatment processes for surface water supplies (MOH 2012), and we understand that the RDKB intends to install UV treatment to meet this guideline.

Treatment processes make up one of the barriers in the multiple barrier approach that the Ministry of Health follows to provide safe drinking water. Other barriers include choosing an appropriate water source and protecting that source, reducing distribution system risk, operator training and certification, and monitoring (MOH 2012).

In June 2019, the RDKB retained Associated Environmental Consultants Inc. (Associated) to complete a Source Water Protection Plan (SWPP) for the Water Utility in accordance with the BC Comprehensive Drinking Water Source-to-Tap Assessment Guideline (the Source-to-Tap Guideline) Modules 1, 2, 7, and 8 (MHLS 2010). The goal of the SWPP, which is one of the barriers in drinking water protection, is to identify and evaluate threats to drinking water safety and sustainability, and to develop recommendations to reduce risks and improve the resiliency of the water supply.

1.2 Technical Advisory Committee

The Source-to-Tap Guideline recommends assembling a multi-disciplinary Technical Advisory Committee (TAC) to identify potential hazards to the drinking water system and assess the associated risks. In partnership with the RDKB, Associated facilitated the formation of a TAC whose members are listed in Table 1-1.

Table 1-1
Technical Advisory Committee members

Organization	Name and Title
RDKB	Gabe Wiebe, Engineering and Safety Coordinator
RDKB	Goran Denkovski, Manager of Infrastructure and Sustainability
RDKB	Chuck Clemens, Operator
RDKB	Grace McGregor, Area C Director
Interior Health Authority	Pouria Mojtahedi, Specialist Environmental Health Officer
Christina Lake Stewardship Society	Jeff Olsen, President
Christina Gateway	Donna Wilchynski, Community and Economic Development Coordinator and Alternate for Area C Director
Christina Lake Waterfront Property Owners Society	Theresa Dergousoff, Secretary

1.3 General Project Approach

The Source-to-Tap Guideline provides a structured and consistent approach to evaluating risks to drinking water (MHLS 2010). It serves as a tool for water systems to: (a) develop a more comprehensive understanding of risks to drinking water safety and availability, (b) operate effectively, and (c) produce the best possible water quality. The four Source-to-Tap Guideline modules are:

- Module 1: Delineate and characterize the drinking water source
- Module 2: Conduct contaminant source ('hazard') inventory
- Module 7: Characterize risks
- Module 8: Recommend actions to improve drinking water protection

As mentioned above, the scope of this SWPP includes Modules 1, 2, 7, and 8. Modules 3, 4, 5, and 6 are related to engineering and governance, and are not required by the RDKB at this time.

The general approach of the SWPP is summarized in Table 1-2. The methods used for each module, including details of the risk analysis procedure, are described in Sections 3 through 5.

Table 1-2
General approach of the SWPP

Source-to-Tap Module Number	Source-to-Tap Module Name	Section in this Report	Tasks
Module 1	Delineate and Characterize the Drinking Water Source	2	• Characterized the water source by collecting, reviewing, and summarizing available data including the previous Christina Lake Management Plan and other publicly available data. • Delineated the assessment area.
Module 2	Conduct Contaminant Source (Hazard) Inventory	3	• Developed a list of potential drinking water hazards through: ○ Public input (via a survey posted on the RDKB website) ○ Review of existing records ○ Field survey ○ Workshop with the TAC
Module 7	Characterize Risks from Source to Tap	4	• Lead a workshop with the TAC to assess and rank each hazard (following the Source-to-Tap Guideline) as low risk, moderate risk, high risk, or very high risk. • Completed a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis with the TAC.
Module 8	Recommend Actions to Improve Drinking Water Protection	5	• Developed recommendations for all identified moderate, high, and very high-risk hazards. • Prepared the SWPP (this document).

2 MODULE 1: DELINEATION AND CHARACTERIZATION OF WATER SOURCE

Module 1 includes characterizing the water source (Section 2.1) and defining the assessment area for the SWPP (Section 2.2).

2.1 Characterization of Water Source

In 2005, the Christina Lake Stewardship Society (CLSS) developed the Christina Lake Management Plan, which included a comprehensive watershed assessment (CLSS 2005). The Management Plan provides detailed information on the history of the watershed and community, First Nations Traditional Land Use, watershed and lake characteristics including geology and hydrology, land use, water use, habitat and sensitive species, and water quality. It also identifies lake management objectives including five goals, and provides recommendations and an implementation strategy (CLSS 2005). The scope of the Management Plan is broader than this document, which focuses on risks relating to the Water Utility and drinking water quality. The following sections provide a summary of key findings from that plan, as well as information obtained from publicly available databases.

2.1.1 Tributaries

The watershed drainage area for Christina Lake is 494 km² (Figure 2-1). There are 41 mapped tributaries, ranging from first- to fifth-order, that discharge into Christina Lake. Only a few of the streams have perennial (year-round) flows, with most having intermittent (ephemeral) flow patterns. Those that have perennial flow include Sutherland Creek, McRae Creek, Sandner Creek, Troy Creek, Parson Creek, Stewart Creek, and Brooks Creek (Figure 2-1) (CLSS 2005). Annual total inflows from tributaries and runoff are dominated by snowmelt during spring freshet.

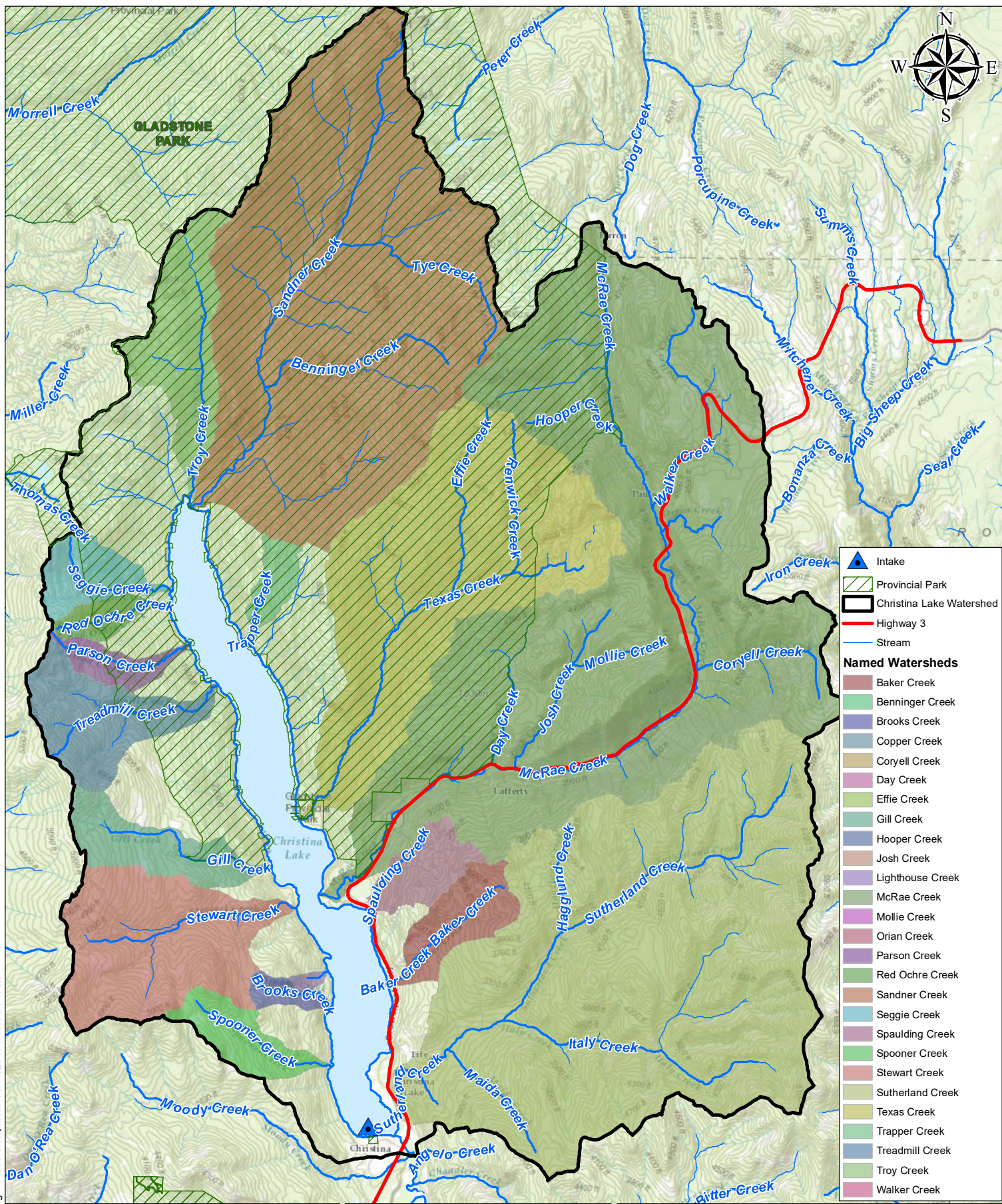
Christina Lake drains via Christina Creek at the southern end of the lake, approximately 750 metres from the water intake (Figure 2-1). The intake is therefore on the “downstream” end of the lake, and land use in the tributaries has the potential to influence water quality near the intake. Christina Creek flows into the Kettle River, which is a tributary of the Columbia River; however, occasionally (approximately once per decade) the creek backflows into the lake during periods of high flow in the Kettle River (CLSS 2005).

2.1.2 Lake Stratification

Christina Lake is approximately 19 km long, with a median width of 600 m and a surface area of 25.6 km². The lake has median and maximum depths of approximately 37 m and 54 m, respectively, a volume of 9.3×10^5 ML, and a flushing rate of approximately 4.5 years (CLSS 2005, Cavanagh et al. 1994). The lake is generally dimictic, mixing twice per year (spring and early winter), with occasional monomictic (i.e., mixing once per year) behaviour in years with warm winters. The lake is distinctly stratified in summer, with an epilimnion² above 8-10 m (Cavanagh et al. 1994). The epilimnion temperature can reach a maximum of 25°C in summer, with temperatures in the hypolimnion as low as 6°C (CLSS 2005). This has implications for contaminant transport mechanisms: the intake is situated at a depth of approximately 12 m, which is likely below the thermocline³. During summer when the lake is stratified, contaminants may be less likely to reach the intake. However, the effectiveness of the epilimnion regarding source protection is difficult to assess without dissolved oxygen and temperature profiles (which show stratification), specifically at the intake.

² The epilimnion is an upper layer of warmer water that essentially floats on top of the colder, denser hypolimnion when lakes are stratified.

³ The thermocline is the area between the upper, warmer epilimnion and lower, colder hypolimnion. It typically has a steep temperature gradient, where mixing occurs between the upper and lower layers.



2.1.3 Land Use and Water Use with the Watershed

Much of the land cover in the Christina Lake watershed is in a natural, predominantly forested condition. CLSS (2005) presented a breakdown of the land use in the watershed. Approximately 39% of the watershed is within Gladstone Provincial Park, and 51% is zoned for natural resources use such as forest harvest (CLSS 2005). The remaining area is zoned residential/commercial (3% of the watershed) and institutional/RDKB protected/rural (1% of the watershed), while the lake surface accounts for 5% of the area.

The entire northern portion of Christina Lake is within Gladstone Provincial Park, which is a protected area (Figure 2-2). This area is primarily forested, with cabins (accessed by boat only) located along the northern and western shorelines. The lack of road access on the northwestern shore and the steep rocky nature of the northeastern shore limits development potential in this portion of the lakeshore.

The Official Community Plan (OCP) for Area C (Bylaw No. 1250), which was formally adopted in 2004, promotes core community values, including the preservation of the ecosystem and the rural nature of the community, and establishes land use designations and development permit areas to guide future development (RDKB 2004).

2.1.3.1 Residential and Commercial Development

The majority of development in the Christina Lake watershed is south and southeast of the lake. Highway 3 runs parallel to the eastern side of the lake until it reaches English Point, at which point it diverts northeast away from the lake (Figure 2-2).

The community of Christina Lake, which is located south and southeast of the lake, is unincorporated and falls within the jurisdiction of the RDKB. Development in this area consists primarily of residential properties, commercial businesses, and campgrounds. According to Statistics Canada, as of the 2016 Census, the population was 1,099 permanent residents (Statistics Canada 2019). However, Christina Lake is a popular summer destination, and the population has been estimated at over 5,000 residents during the busiest summer weekends (CLSS 2005).

The entire community is serviced by private or community septic systems, and inadequate septic systems have historically been identified as a concern for lake water quality (CLSS 2005). This is an important consideration for source protection planning and is addressed further in Sections 4 and 5.

2.1.3.2 Recreational Use

The Christina Lake watershed, and Christina Lake in particular, is a popular summer destination and recreational activities occur during all seasons. The lake is used for boating (motorized and canoeing/kayaking), fishing, swimming, and other watersports, and watershed activities include hiking, biking, and motorized vehicle use (including ATVs and snowmobiles). Land use to support recreation includes numerous boat launches (including within campgrounds) and small public beaches. There is one commercial marina, located near English Point over 6 km from the intake (Figure 3-1) and a main public beach located at the southern end of the lake (approximately 300 m south/southeast of the intake).

2.1.3.3 Agriculture

Agricultural activity in the Christina Lake watershed is relatively limited. This is attributed primarily to poor agricultural capabilities (e.g., shallow soil, steep and rugged topography, and exposed bedrock) (Cavanagh et al. 1994). Figure 2-2

shows the Agricultural Land Reserve within the watershed, which comprise an area of approximately 1.2 km². There are currently two active range licences within the Christina Lake watershed (ENV 2019a).

2.1.3.4 Forestry

Logging within the Christina Lake watershed, which is located in the Interior Cedar Hemlock biogeoclimatic zone, dates back to the early 1900s (CLSS 2005). The Christina Lake watershed is within the Boundary Timber Supply Area. There are three woodlots within the watershed (all in the Sutherland Creek Community Watershed): W1470, W1624, and W2075, which have annual allowable cuts of 1216, 1495, and 2517 m³, respectively (FLNRO 2018). There are two additional Forest Licence tenures that incorporate portions of the watershed and are held by British Columbia Timber Sales (BCTS) and Interfor. Both of their respective Forest Stewardship Plans (FSP) show limited activity planned in the watershed in the next 5 years.⁴ The various forest tenure within the watershed are shown on Figure 2-2.

In addition to the forest tenures, there are two other designated areas in the Christina Lake watershed that govern land use activity. Gladstone Provincial Park, designated a Class A⁵ provincial park in 1995, occupies 20,584 ha of the watershed (39,387 ha total area). All *Forest Act* tenures were extinguished within the park when the park was created (MWLP 1995). The Sutherland Creek Community Watershed is a designated Community Watershed⁶ within the Christina Lake watershed, and occupies 9,318 ha.

A method to assess the potential effects of historical harvesting within a watershed is to determine the Equivalent Clearcut Area (ECA), which is the amalgamated area of harvest. The ECA is a primary factor when evaluating the potential effect of past and proposed forest harvesting on peak flows. The peak flows, in turn, help determine the hazards associated with the likelihood of channel changes caused by runoff. To account for the regeneration of harvested blocks, a % hydrologic recovery is applied to harvested areas based on regeneration height (MOF 2001).

For this SWPP, to provide a high-level and preliminary estimate of the ECA of the watershed, the harvested areas were amalgamated in age groupings and an applicable percent recovery was applied based on anticipated regeneration height. Table 2-1 outlines the areas harvested in the Christina Lake watershed since 1965. It was assumed that harvested areas older than 1965 would have been fully regenerated, and would no longer contribute to the ECA.

⁴ Based on BCTS (2017) and ENV (2019a). The FSP for Interfor was not available, but spatial information on their 5-year plan is available on iMap BC (ENV 2019a).

⁵ Development in a Class A park is limited to that which is necessary for the maintenance of its recreational values. Activities such as grazing, hay cutting and other uses (except commercial logging, mining or hydroelectric development) that existed at the time the park was established may be allowed to continue in certain parks. <http://www.env.gov.bc.ca/bcparks/about/park-designations.html#ClassA>

⁶ The Forest and Range Practices Act (FRPA) addresses the operations of forestry companies on the Crown land portion of community watersheds, to protect water used for drinking. FRPA sets requirements for various activities, such as road-building or harvesting, and the provincial government reviews and approves FSP's for companies operating in community watersheds. <https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/community-watersheds>

Table 2-1
ECA estimates considering hydrologic recovery of harvested areas since 1965

Time Period	Logged Area Within Watershed (ha)	% Hydrologic Recovery	ECA equivalent (ha)
1965-1980	1,753	90%	175
1981-1990	951	75%	237
1991-2000	876	50%	438
2001-2010	1,618	25%	1,213
2011-2019	1,145	0%	1,145
Total	6,343		3,209

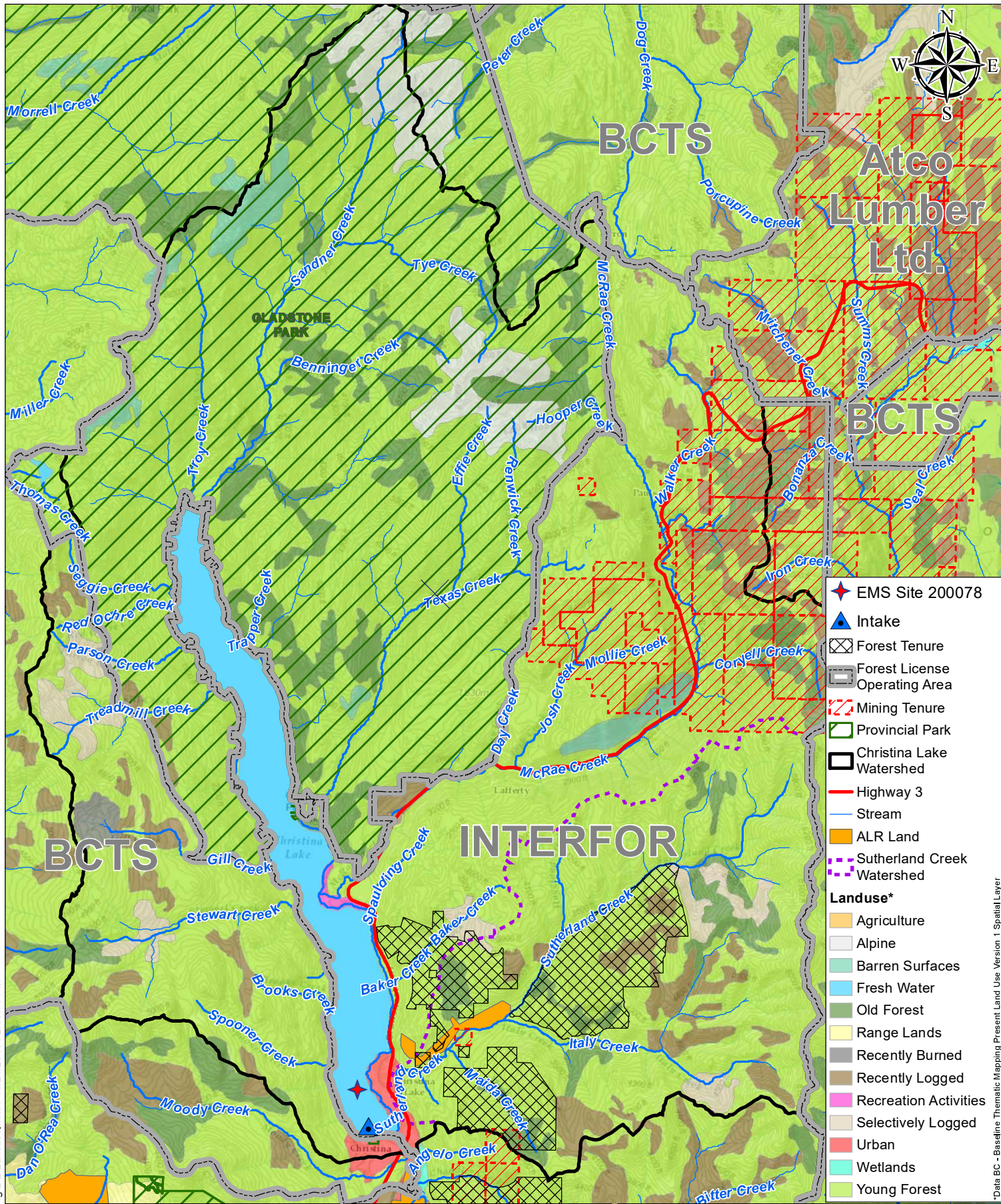
Table 2-2 shows that the estimated ECA is approximately 7% of the land base, which is well below the 20% threshold that is used to determine when increases in peak flows can be anticipated (MOF 2001).

Table 2-2
Estimated ECA as a percentage of the land base

Variable	Area (ha)
Total watershed area	49,370
Area of Christina Lake	2,564
Total watershed land base	46,806
ECA estimate (Table 2-1)	3,209
ECA as % of land base	7%

2.1.3.5 Other

Historical mining activity in the Christina Lake watershed is reported to be relatively limited (Cavanagh et al. 1994, CLSS 2005). A small mine (Donna Mine) near a tributary to McRae Creek operated until 1980, but the mine is no longer active (CLSS 2005). There are currently 22 Mining Tenures in good standing in the watershed (ENV 2019a).



2.1.4 Water Quality

Water quality data for Christina Lake have been collected by numerous organizations, including the CLSS, the Interior Health Authority (which regularly samples surface water at major public beaches to assess recreational safety), and the Ministry of Environment and Climate Change Strategy (ENV). In 1994, the previous Ministry of Environment, Lands and Parks developed site-specific Water Quality Objectives (WQO) for Christina Lake (Cavanaugh et al. 1994). Historically, the Ministry has annually tested deep water and shallow water sites to monitor water quality (typically sampled in fall and spring). The majority of the stations are in the southern basin (ENV 2019b).

As reported by CLSS (2005), sampling results of the ENV water quality monitoring program have indicated that Christina Lake has very good water quality. According to a Water Quality Objective Attainment Assessment completed by ENV in 2005, water quality samples from the lake met water quality objectives 99% of the time (ENV 2007). However, despite the relatively good water quality data, residents have anecdotally reported some changes in lake water quality over time, specifically decreased water clarity and increased aquatic plants and algae (CLSS 2005). Cavanaugh et al. 1994 reported that local physicians had commented on an increased occurrence of throat, eye, and ear infections in residents using the south end of the lake for recreation.

The most comprehensive water quality data sets are available through ENV, via the BC Environmental Monitoring System (EMS) (ENV 2019b,c). The EMS site with the longest available data set is Site 200078, which is approximately 1 km north of the intake (Figure 2-2). Table 2-3 provides a summary of the mean, median, minimum, and maximum concentrations from this site (using data from 1972 to 2019), and is intended to provide a high-level overview of water quality in Christina Lake. Samples from EMS Site 200078 have been collected from various depths, ranging from at surface (i.e., 0 m) to 26 m. For the purposes of this report, the data were generically grouped into the following depth categories:

- Surface: <0.5 m
- Mid-zone: 0.5 - 12 m (based on average Secchi depth readings, and to allow for a high-level comparison of differences in water quality above depths of approximately 12 m (intake depth) vs. below 12 m)
- Deep zone = >12 m

Sections 2.1.4.1 to 2.1.4.4 provide a general summary of water quality by parameter, based on publicly available data (EMS Site 200078), previous reports (CLSS 2005; Cavanaugh et al. 1994), and data provided by the RDKB from samples collected from the water system.

Table 2-3
Descriptive statistics of water quality from EMS Site 200078 for key water quality parameters (1972-2019)

Parameter	Depth Category	n	Mean	Median	Min	Max	Standard Deviation	Guideline Level	Guideline Description
Chloride (mg/L)	Surface (<0.5 m)	5	0.72	0.80	<0.50	0.80	0.13	250 mg/L	Drinking water aesthetic objective (BC and Health Canada)
	Mid (0.5-12 m)	37	1.2	1.4	<0.50	2.0	0.51		
	Deep (>12 m)	38	1.4	1.6	<0.50	2.4	0.55		
Turbidity (NTU)	Surface (<0.5 m)	15	0.28	0.30	<0.10	0.50	0.12	1 NTU	Christina Lake WQO: Drinking water guideline (BC and Health Canada)
	Mid (0.5-12 m)	32	0.38	0.32	<0.10	1.00	0.21		
	Deep (>12 m)	30	0.34	0.30	<0.10	1.00	0.19		
pH	Surface (<0.5 m)	40	7.46	7.44	6.60	8.20	0.32	7.5 – 10.5	Drinking water operational guideline (Health Canada)
	Mid (0.5-12 m)	176	7.53	7.50	6.70	8.90	0.35		
	Deep (>12 m)	162	7.22	7.30	6.40	8.65	0.43		
Dissolved Organic Carbon (mg/L)	Mid (0.5-12 m)	2	2.4	2.4	2.3	2.4	0.05	n/a	n/a
	Deep (>12 m)	2	2.2	2.2	2.0	2.3	0.16		
	Surface (<0.5 m)	2	3.5	3.5	3.0	4.0	0.71		
Total Organic Carbon (mg/L)	Mid (0.5-12 m)	27	2.1	2.1	<1.0	4.0	0.97	4.0 mg/L	Drinking water maximum acceptable concentration (BC)
	Deep (>12 m)	24	2.3	2.0	<1.0	6.0	1.06		
	Surface (<0.5 m)	26	1	2	0	2	0.87		
Fecal Coliforms (CFU/100 mL)	Mid (0.5-12 m)	11	2	2	<1	2	0.30	≤ 10/100 mL (90 th percentile)	Christina Lake WQO; Drinking water maximum acceptable concentration (BC)
	Surface (<0.5 m)	2	0.010	0.010	<0.002	0.020	0.01		
	Mid (0.5-12 m)	29	0.009	0.003	<0.002	0.030	0.01		
Nitrate-N (mg/L)	Deep (>12 m)	27	0.007	0.003	<0.002	0.020	0.01	10 mg/L	Drinking water maximum acceptable concentration (BC and Health Canada)
	Surface (<0.5 m)	6	0.09	0.10	<0.01	0.12	0.04		
	Mid (0.5-12 m)	25	0.09	0.08	<0.02	0.18	0.03		
Organic Nitrogen (mg/L)	Deep (>12 m)	27	0.13	0.08	<0.01	0.90	0.16	n/a	n/a
	Surface (<0.5 m)	20	0.11	0.10	0.08	0.23	0.03		
	Mid (0.5-12 m)	56	0.11	0.10	<0.02	0.50	0.06		
Total Nitrogen (mg/L)	Deep (>12 m)	69	0.11	0.09	<0.02	0.90	0.11	≤ 0.2 mg/L at spring overturn	Christina Lake WQO
	Surface (<0.5 m)	13	2.1	1.0	<1.0	6.0	1.8		
	Mid (0.5-12 m)	79	6.3	2.0	<1.0	50.0	13.8		
Orthophosphate (µg/L)	Deep (>12 m)	75	7.5	2.2	<1.0	50.0	14.9	n/a	n/a
	Surface (<0.5 m)	27	7.6	3.0	<2.0	114.0	21.3		
	Mid (0.5-12 m)	71	3.9	3.0	<2.0	12.0	2.6		
Total dissolved phosphorus (µg/L)	Deep (>12 m)	95	5.5	3.0	<2.0	133.0	13.5	n/a	n/a
	Surface (<0.5 m)	35	8.0	4.0	<2.0	119.0	19.4		
	Mid (0.5-12 m)	90	7.0	4.0	<2.0	100.0	14.4		
Total phosphorus (µg/L)	Deep (>12 m)	115	7.3	4.5	<2.0	136.0	13.2	<7 µg/L @ spring overturn; 10 µg/L	Christina Lake WQO; Drinking water aesthetic objective (BC)
	Surface (<0.5 m)	40	1.1	1.1	0.3	2.5	0.50		
	Mid (0.5-12 m)	112	1.5	1.1	0.4	7.8	1.31		
Chlorophyll <i>a</i> (µg/L)	Deep (>12 m)	4	2.2	2.0	0.9	3.9	1.27	≤ 2.5 µg/L phytoplankton	Christina Lake WQO

Notes:

Descriptive statistics were calculated using all available data between 1972 and 2019. Sampling intervals are not consistent (e.g., surface sites were generally sampled between 1973 and 2007; mid sites between 1972 and 2019, and deep sites between 1972 and 2019). For the purposes of the calculations, result that were below detection were taken at the detection limit.

n = count or number of samples
Guidelines include drinking water guidelines (BC = BC Source Drinking Water Guidelines [ENV 2017]; Health Canada = Health Canada's Guidelines for Canadian Drinking Water Quality [Health Canada 2019]) and the Christina Lake WQO (Cavanagh et. al 1994).

2.1.4.1 Water Clarity and Turbidity

Secchi depth⁷ provides a subjective measure of water clarity or transparency. Generally, lakes with high algal productivity or turbidity tend to have lower transparency, and low productivity lakes have higher transparency. Historically, Secchi depth measurements in Christina Lake have indicated a high level of water quality. According to CLSS (2005), the average Secchi depth based on EMS sites 200078 and E21578 (data up to 2004) was 11.2 to 12.9 m, respectively, which is better than the Christina Lake WQO of an annual mean of 10 m.

The data from EMS Site 200078 indicate low turbidity, with average turbidity levels of <0.40 NTU across all depths, and a maximum of 1 NTU (Table 2-3). However, turbidity can be highly variable with large spikes occurring during spring freshet (for example), and historical sampling events may not have captured these short-term increases, which are important for drinking water safety.

More comprehensive turbidity data at the intake are available from the RDKB (and previously, the Christina Waterworks District [CWD]). In October 2015, the CWD installed an inline turbidity meter and began monitoring turbidity within the water system (initially both prior to chlorination and post-chlorination) at 15-minute intervals (Associated 2016). Over a one-year period, between October 2015 and October 2016, the average turbidity was 0.38 NTU (Associated 2016).

Based on additional data provided by the RDKB, in 2017, average monthly turbidity ranged from 0.263 NTU (January) to 0.561 NTU (May), with an annual average of 0.359 NTU. In 2018, average monthly turbidity ranged from 0.238 NTU (February) to 0.986 NTU (May and June), with an annual average of 0.442 NTU. The elevated average turbidity levels in May and June 2018 are attributed to widespread flooding in the area during spring 2018.

2.1.4.2 Bacteria

As summarized in CLSS (2005) and Cavanagh et al. (1994), fecal coliform bacteria at major beaches, which are routinely sampled by the Interior Health Authority, have generally remained within Health Canada's Guidelines for Recreational Water Quality (200 counts/100 mL). Elevated fecal coliforms (i.e., greater than the Christina Lake WQO of a 90th percentile of 10 counts/100 mL) have been measured in some of the major tributaries (e.g., McCrae and Sutherlands Creeks), likely related to wildlife or possibly livestock. Based on data from EMS Site 200078, fecal coliforms have remained less than 2 counts/100 mL (Table 2-3). However, similar to turbidity, short-term spikes in coliforms can occur and may not have been captured by monitoring at this site.

E. coli and total coliforms are routinely tested from within the distribution system to ensure disinfection is working properly. Although important for drinking water safety, the data are not indicative of water quality at the source (i.e., untreated water). Between March 2016 and October 2016, weekly samples of the untreated water at the intake were also analyzed for total coliforms and *E. coli* (Associated 2016), as part of an assessment as to whether the system meets the Ministry of Health requirements for filtration exclusion (MOH 2012). The requirement is that *E. coli* does not exceed 20/100 mL and that total coliforms do not exceed 100/100 mL in at least 90% of the weekly samples from the previous six months. From March 2016 to October 2016:

- *E. coli* was <1/100 mL during 26 of the 28 weeks it was tested. During the other two weeks (August 8 and September 12, 2016), it was 1/100 mL. These results meet the requirements for filtration exclusion.

⁷ A Secchi disk is a circular opaque disk coloured white and black, which is lowered into the water column. The average of the depth at which the disk is no longer visible and the depth at which the disk becomes visible again is taken as the Secchi depth. This measurement provides a subjective measure of water clarity.

- Total coliforms did not exceed 100/100 mL during any of the 28 weeks. Measurements ranged from < 1/100 mL to 88/100 mL. These results meet the requirements for filtration exclusion.

2.1.4.3 Nutrients and Trophic Status

The trophic status of a lake is a key indicator of lake health, and thus has impacts for drinking water source protection. Trophic status refers to the overall productivity of the lake, which is influenced by the levels of nutrients that are present. With increased nutrient inputs, productivity (i.e., growth) increases and can result in decreased water clarity and lower levels of dissolved oxygen. For most lakes, phosphorus is typically the least abundant and commonly the first nutrient to limit biological productivity; therefore, it is often considered the “limiting nutrient” in lakes (Wetzel 2001). In other cases (e.g. when natural phosphates are present in bedrock), nitrogen may be the limiting nutrient. Eutrophication is the process where waterbodies experience increased nutrient inputs and a resulting increase in productivity.

With respect to drinking water quality and human health concerns, eutrophication can make treatment more difficult and costly (e.g., by reducing water clarity and potentially interfering with the treatment process). It can also impact taste and odour of the water. In addition, some species of Cyanobacteria (commonly referred to as blue-green algae) may produce toxins (cyanotoxins) that are harmful to human and animal health (MOH 2018a).

According to previous studies, Christina Lake is considered to be oligotrophic (Cavanagh et al. 1994). This is supported by the water quality data from EMS Site 200078 (Table 2-3), which show an average total phosphorus concentration of approximately 7-8 µg/L (depending on the sample depth). According to the Canadian Council of the Ministers of Environment (CCME) trigger ranges⁸ for total phosphorus, the range for oligotrophic lakes is 4-10 µg/L. The Christina Lake WQO for total phosphorus is 7 µg/L, specifically during spring overturn.

Previous reports indicate that phosphorus is most commonly the limiting nutrient for Christina Lake, although nitrogen may be co-limiting at times (CLSS 2005, Cavanagh et al. 1994). Although detailed studies have not been completed, from the overall perspective of protecting lake health, increased nutrients (both nitrogen and phosphorus) are considered contaminants of concern. This is addressed further in Sections 3, 4, and 5.

2.1.4.4 Other Parameters

In August 2019, the RDKB collected a water quality sample from within the distribution system (i.e., treated water) and submitted the samples to an accredited laboratory for comprehensive analysis including chloride, fluoride, sulphate, total dissolved solids, colour, alkalinity, total organic carbon, nitrate and nitrite, cyanide, Langelier index, hardness, total metals, haloacetic acids, and trihalomethanes. The results for all of these variables met Health Canada’s Guidelines for Canadian Drinking Water Quality (Health Canada 2019).

2.1.5 Current Climate and Climate Change Projections

2.1.5.1 Historical Climate Data

Figure 2-3 presents average climatic conditions for the most recent climate normal period (i.e., 1981-2010) based on climate records collected at the Grand Forks climate station (Climate ID: 1133270), located approximately 18 km west

⁸ CCME (2004a) provides a range of total phosphorus concentrations and their associated trophic classification. These are considered “trigger ranges”: once the trophic status of a waterbody is established, if the upper limit of the range is exceeded for that classification, it may indicate a problem and thus trigger further investigation (CCME 2004a).

from the community of Christina Lake⁹. Mean daily temperature range from -4.2°C in December to 19.9°C in July, with a mean annual temperature of 8°C (Environment Canada 2019). The normal total annual precipitation is 534 mm (410.3 mm rainfall and 124.1 cm snowfall), with May and June being the two wettest months (Environment Canada 2019).

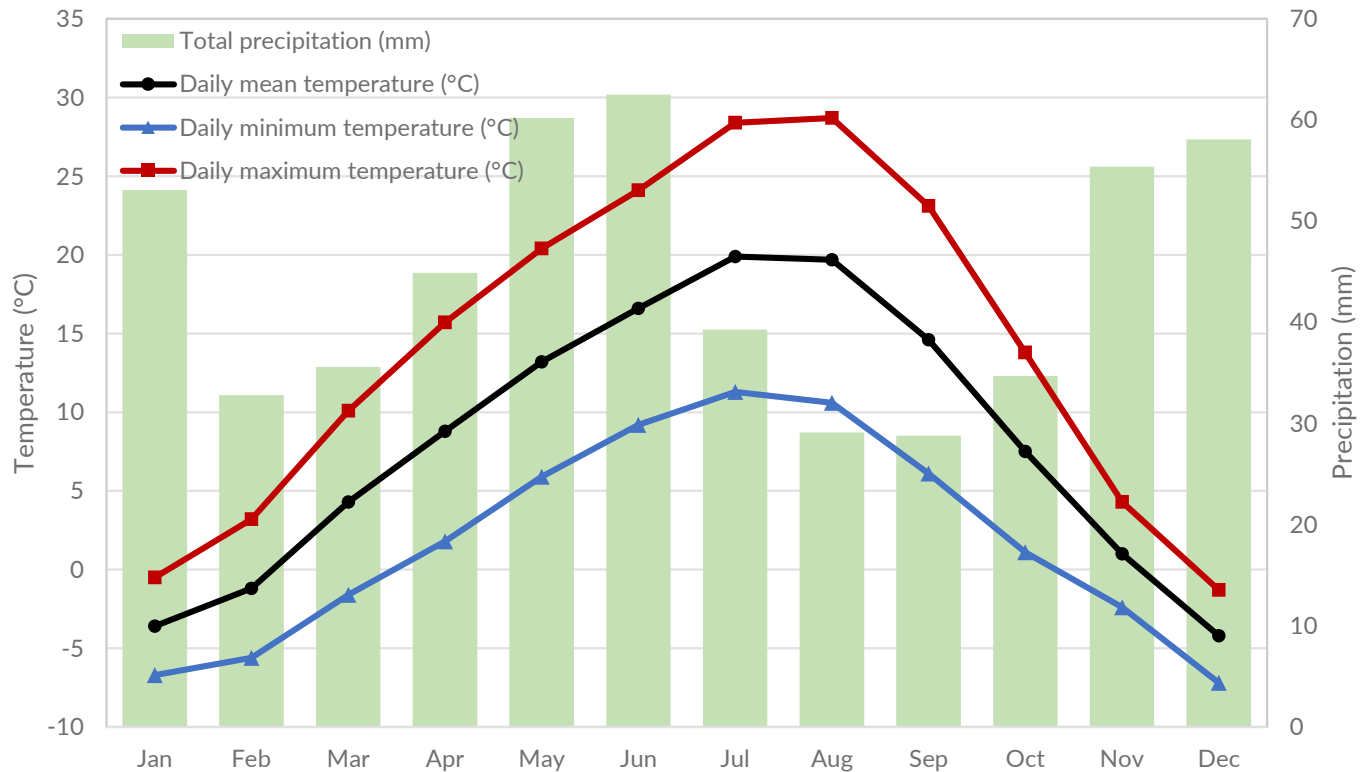


Figure 2-3
1981 – 2010 Climate Normals for the Grand Forks Climate Station

2.1.5.2 Projected Climate Change in the Regional District of Kootenay Boundary

The University of Victoria's Pacific Climate Impacts Consortium (PCIC) has developed tools that provide estimates of future climate variables. The Plan2Adapt tool (PCIC 2019a) uses climate projections to provide a summary of future conditions based on two emission scenarios (i.e., high [SRES A2] and low [B1]) for specified geographic areas (including the RDKB). Projected future conditions for the RDKB are presented herein (Table 2-4) to represent expected future conditions for Christina Lake. It is important to recognize that these future conditions are spatially-averaged for the entire RDKB from an ensemble of gridded Global Climate Models (GCMs) and are not specific to only Christina Lake. Table 2-4 summarizes the ensemble median¹⁰ and the ranges of values expected for select climate variables for the 2020s (2010-2039), 2050s (2040-2069), and 2080s (2070-2099) periods.

⁹ Climate ID 1133270 is the closest climate station with 1981-2010 normal data available.

¹⁰ The ensemble median is the mid-point value within an ensemble of 15 GCM projections.

Table 2-4
Projected future climate conditions in the Regional District of Kootenay Boundary

Climate Variable ¹	Time of Year	Projected Change (from 1961-1990 baseline)					
		2020s		2050s		2080s	
		Median	Range	Median	Range	Median	Range
Mean Air Temp (°C)	Annual	+1.0°C	+0.6°C to 1.4°C	+1.9°C	+1.2°C to +2.8°C	+2.9°C	+1.7°C to +4.6°C
Precipitation (%)	Annual	+4%	-1% to 7%	+6%	-2% to +10%	+6%	+2% to +14%
	Summer	-6%	-13% to +9%	-11%	-23% to -2%	-14%	-31% to +6%
	Winter	+3%	-2% to +11%	+6%	-4% to +17%	+11%	+2% to +27%
Snow Depth (%)	Winter	-5%	-16% to +1%	-14%	-23% to -1%	-21%	-41% to -6%
	Spring	-32%	-57% to +0%	-56%	-76% to -12%	-78%	-89% to -17%
GDD ²	Annual	+182	+88 to +282	+361	+206 to +528	+541	+315 to +955
HDD ³	Annual	-371	-516 to -216	-687	-975 to -417	-1006	-1577 to -606
FFD ⁴	Annual	+14	+8 to +21	+24	+14 to +36	+38	+20 to +62

Notes:

1. Climate variables derived from temperature and precipitation datasets.
2. GDD – Annual average Growing Degree Days (given in degree days). Growing Degree-Days (GDDs) is a derived variable that indicates the amount of heat energy available for plant growth, useful for determining the growth potential of crops in a given area. It is calculated by multiplying the number of days that the mean daily temperature exceeded 5°C by the number of degrees above that threshold.
3. HDD – Annual average Heating Degree Days (given in degree days). Heating Degree-Days (HDDs) is a derived variable that can be useful for indicating energy demand (i.e., the need to heat homes, etc.). It is calculated by multiplying the number of days that the average (mean) daily temperature is below 18°C by the number of degrees below that threshold.
4. FFD – Frost-Free Days. Frost-Free Days (FFDs) is a derived variable referring to the number of days that the minimum daily temperature stayed above 0°C, useful for determining the suitability of growing certain crops in a given area.

The Plan2Adapt tool uses climate projections developed in 2012 to provide estimates for large geographic areas. However, PCIC is currently developing a new tool that will use updated climate model projections - PCIC Climate Explorer (PCIC 2019b). This updated tool allows users to extract future climate projections for specific locations (e.g., Christina Lake), as well as select results from independent GCMs (or ensembles). This new tool is expected to be complete by early 2020 and will allow the RDKB to obtain Christina Lake specific future climate conditions to better understand localized changes.

Potential implications of these climate change projections on the drinking water source are discussed in Section 3.1.3.

2.2 Assessment Area for the SWPP

Module 1 of the Source-to-Tap Guideline provides guidance for delineating the assessment area in which water source hazards are identified (MHLS 2010). In most circumstances, when surface water is used to provide a drinking water source, an Intake Protection Zone (IPZ) should extend a minimum of 100 m radius around the intake location. The extent of the remaining assessment area (intended to capture potential contaminant sources from farther afield) is dependent on the size of the contributing watershed and must also consider any site-specific conditions for a particular drinking water source. For drinking water intakes that have a contributing watershed area of less than 500

km², the Source-to-Tap Guideline recommends that the entire contributing watershed area should be considered the assessment area. Where the contributing watershed area is greater than 500 km², MHLS (2010) describes two different methods that may be used to delineate an appropriate assessment area:

- **Time-of-travel Corridors:** When sufficient information (i.e., channel geometry and stream velocity) is available, time of travel corridors can be delineated by calculating the distance that a particular contaminant would travel over a given period of time. This approach allows the assessment area to target particular contaminants given their dispersion rate, if desired.
- **Fixed Distance Corridors:** The assessment area is delineated to consist of fixed distance corridors, which are determined based on site-specific corridors and professional judgement. This approach is often used when no channel geometry or stream velocity information is available.

Although the Christina Lake watershed is just under 500 km², a significant portion of the watershed is within a provincial park (Section 2.1.3). Therefore, a customized assessment area was developed to allow the SWPP to focus on the highest risk areas. Due to the absence of site-specific information required to delineate time-of-travel corridors, as well as the need for plume modelling and/or tracer studies to accurately estimate travel times within Christina Lake, fixed distance corridors were selected. Within the Christina Lake watershed, the assessment area was separated into two smaller areas (i.e., Assessment Area A and Assessment Area B – Figure 2-4) to specifically identify contaminants around Christina Lake (Assessment Area A) and major tributaries to the lake (Assessment Area B).

The IPZ and assessment areas used for this SWPP were delineated as follows:

- **Intake Protection Zone:** 1 km radius around the intake and a 120 m setback onto land. A 120 m setback was selected to capture lakeside septic tank systems that are expected to present a significant hazard. A 1 km radius was selected (rather than the minimum 100 m guideline) to ensure that hazards associated with nearby boating, other water activities, and campgrounds are captured.
- **Assessment Area A:** The area within a 1 km buffer around the south half of the lake (English Point represents the northern extreme), intended to encapsulate Highway 3 on the east and lakeside properties around the lake (Figure 2-4). The highway is included to assess the risk of any contaminant spills that may occur, as well as potential salt and sediment contributions from winter road conditions. Assessment Area A terminates at English Point since the northern portion of the lake is surrounded by Gladstone Provincial Park. Area A encapsulates all remaining tributaries to Christina Lake.
- **Assessment Area B:** The area within a 500 m buffer on either side of all major tributaries south of Gladstone Provincial Park (Figure 2-4). With the exception of first-order streams (i.e., small headland streams), all tributaries are included to ensure that even contaminants in the upper portion of the contributing area are captured. This approach is more conservative than the methodology outlined by MHLS (2010), which suggests that only streams one order lower than the intake location (i.e., fourth-order streams in this case) should be included.

Figure 2-4 presents the IPZ and Assessment Areas A and B for this SWPP. These assessment areas, which are the focus of the SWPP, provide a conservative, yet practical, interpretation of areas that may present significant vulnerability to the Water Utility's water intake. The remaining areas are either provincial park or forested areas located away from watercourses, and therefore any activities in those areas likely present a low risk to water quality.

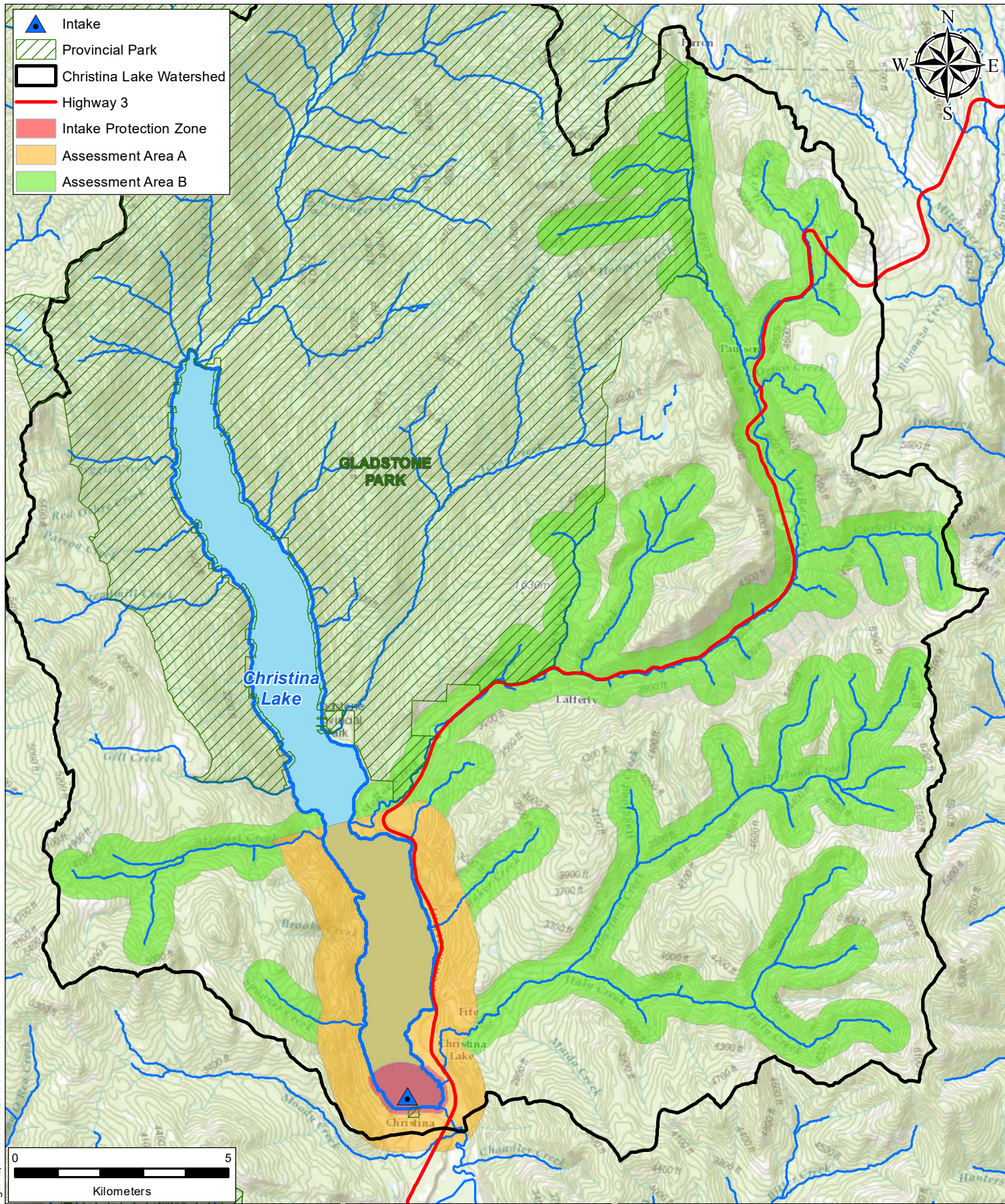


Figure2.mxd / 10/18/2019 / 10:03:30 AM

3 MODULE 2: CONTAMINANT SOURCE INVENTORY

Module 2 includes a contaminant source inventory that identifies potential hazards that could affect source water quality within the assessment area. In this SWPP:

- 'Contaminants' refer to the compound of concern with respect to drinking water quality.
- 'Hazards' refer to the activity or land use that is associated with the contaminant.

Section 3.1 describes the general types of contaminants and hazards. Section 3.2 describes the methods used to identify specific hazards for this SWPP, and provides the list of identified hazards.

3.1 Types of Contaminants and Hazards

Each hazard is associated with one or more contaminants of concern. Contaminants can enter a lake via direct release (e.g., discharge of greywater or hydrocarbon fuel spill from boats), runoff (e.g., overland flow from residential properties, commercial businesses, or roads), or subsurface flow (e.g., leaking septic systems flow through groundwater).

3.1.1 Contaminants

3.1.1.1 Pathogens

Pathogens are disease-causing organisms, including bacteria (e.g. *E. coli*), protozoa (e.g., *Giardia* and *Cryptosporidium*), and viruses (e.g., *Norovirus*, which causes Norwalk infection). Bacteria, viruses, and some protozoa (e.g., *Giardia* but not *Cryptosporidium*) can be removed by disinfection with chlorine (with adequate contact time), which is currently the Water Utility's only form of treatment. *Cryptosporidium*, however, can be resistant to chlorine and requires alternative treatment (e.g., filtration or UV disinfection). Pathogen sources include waste from humans, pets, livestock, and wildlife. Related hazards include residential and community septic fields, boating activities (black water discharge), recreational water use, and creek inflows (wildlife).

3.1.1.2 Turbidity

Turbidity, which is a measure of the relative clarity of water, is caused by the presence of a variety of particles in the water column, including suspended sediment, organic and inorganic matter, bacteria, protozoa, and other organisms. Elevated turbidity can indicate the presence of pathogens (e.g., bacteria and protozoa), and can interfere with water treatment processes (e.g., UV disinfection and chlorination). The key sources of turbidity in Christina Lake are the major tributaries, primarily during spring freshet and storms. Related hazards include natural ones such as flooding and wildfire, as well as forestry activities (e.g., erosion from resource roads and landings) and recreation (e.g., motorized recreational vehicles in the watershed), all of which can increase sedimentation and turbidity in the watershed.

3.1.1.3 Nutrients, Algal Blooms, and Cyanobacterial Toxins

As described in Section 2.1.4.3 (Nutrients and Trophic Status), nutrient levels (primarily phosphorus and nitrogen) can affect overall lake health, as elevated levels of nutrients may stimulate algal growth. This can reduce water clarity, interfere with the treatment process, affect water taste and odour, and in unique circumstances, result in the production of cyanobacterial toxins¹¹. Christina Lake is considered oligotrophic and has good water quality (Section 2.1.4). Although nutrients (e.g., nitrogen and phosphorus) are generally not considered a human health concern (with

¹¹ Cyanobacterial toxins are secondary metabolites that are produced by some species of cyanobacteria (blue-green algae) and can be harmful to human or animal health (MOH 2018a).

the exception of nitrate-N, for which there is an acceptable maximum level in drinking water), they are considered contaminants of concern for the effects they may have on lake eutrophication.

Several hazards are associated with elevated nutrients, including inadequate or malfunctioning septic systems, agriculture, residential, and commercial fertilizer use, greywater discharges from boats, and wildfire and flooding (due to input of nutrients from the watershed).

3.1.1.4 Organic Matter and Disinfection By-Productions

Organic matter in raw drinking water is a concern because it can reduce the water clarity and potentially react with chlorine (used in the disinfection process) to form by-products that are harmful to humans, such as Trihalomethanes (THMs) and Haloacetic Acids (HAAs). Hazards associated with increased organic matter into the system include many of the same hazards that may increase turbidity (e.g., forestry activities, wildfire, recreation).

3.1.1.5 Other Contaminants

Other potential contaminants that could reach Christina Lake include pesticides and herbicides (e.g., from residential, municipal, and commercial use), hydrocarbons (e.g., from fuel spills, either direct to the lake or through runoff from roads), solvents (e.g., from residential and commercial properties), salts (e.g., from road de-icing), metals (e.g. from runoff and tributary inflows), and fire retardant (e.g., firefighting).

Another drinking water hazard that has emerged over several years is Zebra and Quagga Mussels, which have not yet been found in BC waterbodies, have been intercepted on boats entering the province.¹² Zebra and Quagga mussels are an invasive species and if introduced, can clog drinking water intakes and have negative economic impacts on water suppliers, in addition to having impacts on recreation (e.g., from their sharp shells on beaches) and overall lake habitat, as they outcompete native species.

3.1.2 Hazards by Land Use (Point Source and Non-point Sources)

The term “hazards” in the Source-to-Tap Guideline encompasses actual/existing hazards and potential hazards. Hazards are typically categorized as point source or non-point source. Point sources of contamination arise from a single, identifiable location (e.g., a wastewater treatment plant outfall). Non-point sources arise from multiple sources over an area (e.g., runoff from agricultural land, private on-site wastewater treatment systems). In the Christina Lake watershed, the majority of the hazards are non-point source hazards.

Seven main types of land uses can cause a point source or non-point source hazard (MHLS 2010). Examples of hazards from each type of land use are as follows:

- **Naturally occurring:** pathogens from wildlife, organic matter, sedimentation/turbidity from flooding events or increased runoff after wildfire events, metals (from runoff).
- **Agricultural:** nitrates and phosphates from fertilizers, pesticides/herbicides, increased sedimentation, pathogens from livestock, accidental fluid releases from machinery.
- **Forestry:** sedimentation and turbidity, nutrients and pathogens (due to increased runoff from logged areas), motor fuel from vehicle access and logging roads, leachate from decomposing wood waste.

¹² According to OBWB (2019), based on available statistics, watercraft entering BC carrying invasive mussels have been intercepted from Ontario, Utah, North Carolina, and Michigan.

- **Municipal:** fertilizers and herbicides from fields/parks, stormwater runoff, road salt for de-icing, solvents and machinery waste, waste disposal (e.g., landfills).
- **Commercial:** varied, depending on the type of commercial enterprises (e.g., auto repair shops, dry cleaners, boat yards and marinas, campgrounds, gas stations, offices).
- **Industrial:** also varied, depending on the type of industrial enterprises.
- **Residential:** pathogens and nutrients from septic systems, fertilizers, pesticides/herbicides, various solvents, motor fuels.

The level of risk presented by these hazards varies for each watershed, and is addressed specifically for the Christina Lake SWPP in Module 7 (Section 4).

3.1.3 Climate Change

In recent years, extreme weather and weather-related events are thought to becoming more frequent across Canada, including major storms, flooding, drought, wind, and wildfires. Water system infrastructure, including water quality from lake intakes, is vulnerable to the changing climate. Climate change is a broad hazard that has impacted water sources in a variety of ways, and will increase the likelihood of hazards occurring in the future.

The future climate conditions provided by PCIC (Section 2.1.5) indicate the following potential effects on Christina Lake throughout different times of the year:

- **Increased runoff and potential flooding:**
 - Flooding may increase in frequency and magnitude within the region; this can have implications on the effectiveness and adequacy of stormwater infrastructure and septic system design.
 - Increased runoff and erosion may occur on tributary streams and the lakeshore, resulting in increased turbidity. Higher incidences of flooding of major tributaries (and potentially more frequent back-flow of Christina Creek) may result in increased sedimentation and turbidity.
- **Earlier freshet and extended dry season:**
 - Summer water demand may increase.
 - Water use restrictions may become more frequent and prolonged.
- **Increased summer temperature and drier summer conditions:**
 - Wildfires may increase in frequency, intensity, and duration.
 - Nearby watercourses may experience drought conditions resulting in low streamflows and warmer water temperatures.
 - Christina Lake water temperatures may increase. Increased temperatures, if combined with other anthropogenic stressors such as increased nutrient inputs, could promote algal growth (Griffith and Gobler 2019).
- **Increased growing season:**
 - Increased productivity may be possible, resulting in increased and or prolonged agricultural water use.

3.2 Hazard Inventory

3.2.1 General Methods

For this SWPP, hazards were identified by:

- Records review, including a review of publicly available databases (such as iMap, the BC Water Resource Atlas, authorized waste discharges, aerial imagery to identify land use, zoning information, and ALR maps).

- Field windshield survey through the community of Christina Lake completed on August 20, 2019.
- Public input, through a survey posted on the RDKB website (Section 3.2.2).
- Input from the TAC, during a workshop held on August 21, 2019.

3.2.2 Public Input Methods and Results

As described above, to gain public input on potential hazards, Associated prepared a Backgrounder Document and Public Input Survey, which the RDKB posted to their *Join the Conversation* website. The survey was promoted via mail to all residents with a PO box in Christina Lake, and via the community weekly email blast. The Backgrounder Document and Public Input Survey questions are provided in Appendix A.

The survey was open from July 5 until September 30, 2019. A total of 63 responses were received.

- Of those that responded:
 - 49% have lived in Christina Lake for 15 or more years (the remaining respondents were divided relatively equally between < 5 years, 5-9 years, and 10-14 years).
 - 60% receive their water from the Christina Lake Water Utility (33% do not, and 6% did not know). Those that are not connected to the Christina Lake Water Utility receive water either from Sutherland Creek (the other community water utility), via private intakes within Christina Lake, or from a well.
- When asked about how confident respondents were about the quality of their drinking water source:
 - 44% responded “all of the time”
 - 46% responded “most of the time”
 - 6% responded “occasionally”
 - 3% responded “not at all”
- When asked if respondents felt informed about source protection and the role they play in protecting the water source:
 - 13% responded “all of the time”
 - 30% responded “most of the time”
 - 30% responded “occasionally”
 - 27% responded “not at all”
- The highest concern hazards (where 25 or more respondents selected ‘high concern’) included:
 - Residential septic systems (38 respondents)
 - Commercial campgrounds and resorts (28 respondents)
 - Residential waste disposal (28 respondents)
 - Wildfire (27 respondents)
 - Marina (26 respondents)
 - Residential fertilizers and pesticides (25 respondents)

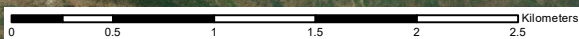
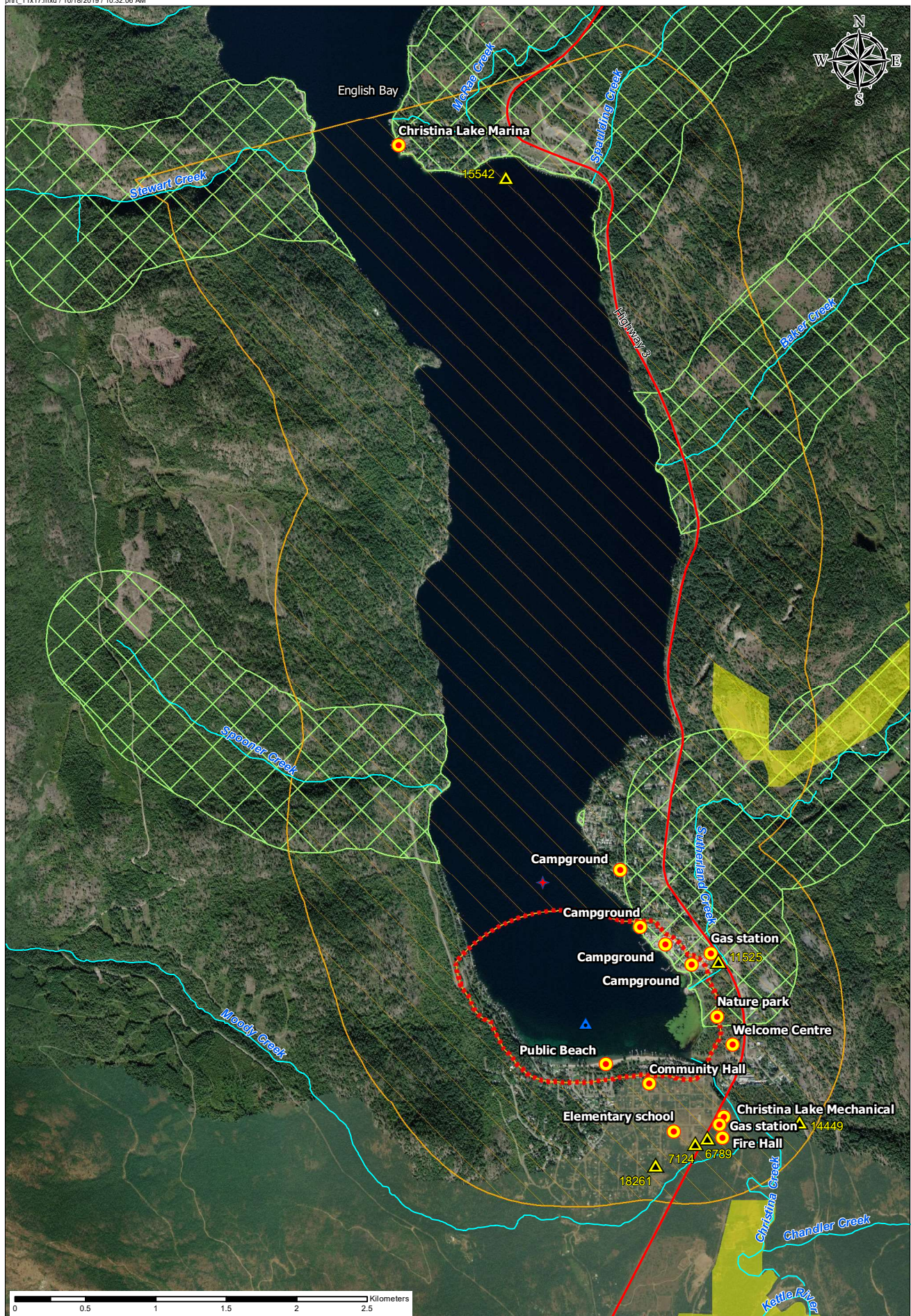
3.2.3 Results

In total, based on the records review, field survey, public input survey, and input from the TAC, 21 hazards were identified (Table 3-1). Point-source hazards are shown on Figure 3-1 (for Assessment Area A) and Figure 3-2 (for the IPZ). All of the hazards within Assessment Area B are either non-point sources or are already identified within Assessment Area A and shown on Figure 3-1.

Table 3-1
Hazards identified within the IPZ or Assessment Areas

Hazard No.	Hazard Name	Hazard Description & Contaminants of Concern	Hazard Type	Location	Contaminant Transport Mechanism
H1	Septic systems - residential	Pathogens and nutrients from inadequate or improperly maintained residential septic systems	Residential	IPZ	Subsurface flow
H2	Septic systems - community (including those with an Authorized Waste Discharge Permit; shown on Figure 3-1)	Pathogens and nutrients from inadequate or improperly maintained community septic systems	Commercial/Industrial	IPZ	Subsurface flow
H3	Boating activities	Hydrocarbons from accidental fuel spills or cumulative minor leaks; pathogens, nutrients, soaps, solvents, etc. from greywater (sinks, showers) and blackwater (sewage) discharges	Commercial/Residential	IPZ	Direct release
H4	Commercial campgrounds	Pathogens and nutrients from humans, pets, and wildlife; runoff from lawns (soaps, fertilizers, pesticides, herbicides) and trailer pads (hydrocarbons, solvents)	Commercial	IPZ, Assessment Area A	Runoff and subsurface flow
H5	Main Public Beach & small public beaches throughout IPZ; nature park	Pathogens and nutrients from human sources, domestic pets, and wildlife; pesticides/herbicides from park areas	Municipal	IPZ, Assessment Area A	Runoff and subsurface flow
H6	Residential lakefront properties (not including septic hazard H1)	Nutrients, sediment, fertilizers, pesticides, solvents etc. from direct runoff	Residential	IPZ	Runoff and subsurface flow
H7	Commercial lakefront operations (e.g., marina)	Pathogens and nutrients from direct discharges; hydrocarbons from fuel spills; solvents	Commercial	Assessment Area A	Direct release and runoff
H8	Invasive mussels	Zebra or Quagga Mussel infestation impacting intake and other water system infrastructure	Natural	IPZ, Assessment Area A	Direct release
H9	Organic matter influx	Formation of disinfection by-products (e.g. THMs and HAAs), due to interaction between organic matter and chlorine	Natural	IPZ, Assessment Areas A/B	Runoff
H10	Algal blooms	Reduced water clarity and interference with treatment; potential for production of Cyanobacterial toxins	Natural	IPZ	Direct release
H11	Roads and stormwater discharges (not including Highway 3)	Sediment, hydrocarbon/chemical releases, nutrients, pathogens, salts, pesticides/insecticides from runoff and direct discharge to lake (via outfalls)	Municipal	IPZ, Assessment Area A	Direct release and runoff
H12	Institutions (Elementary School, Community Hall, Welcome Centre, Fire Hall)	Nutrients, hydrocarbons, solvents, pesticides/herbicides from subsurface flow	Municipal	Assessment Area A	Subsurface flow
H13	Upland Commercial/Industrial (e.g. gas stations, repair shops)	Hydrocarbons and other solvents from subsurface flow	Commercial/Industrial	Assessment Area A	Subsurface flow
H14	Residential non-lake front properties	Nutrients, sediments, fertilizers from subsurface flow	Residential	Assessment Area A	Subsurface flow
H15	Highway 3	Hydrocarbons and other hazardous materials (from accidental spills); stormwater discharges	Municipal/Institutional	Assessment Areas A/B	Direct release and runoff
H16	Watershed recreation - including motorized vehicle use and informal camping (i.e., at locations other than formal campgrounds)	Increased turbidity of inflows due to vehicle use in the watershed; hydrocarbons from accidental fuel spills or cumulative minor leaks; pathogens and nutrients from improper septic disposal (from informal camping)	Commercial/Residential	Assessment Areas A/B	Runoff
H17	Forestry activities (cutblocks and resource roads)	Erosion, sedimentation, nutrients, and organic matter	Forestry	Assessment Areas A/B	Runoff
H18	Flooding (creek inflows & lake)	Turbidity/suspended sediment in inflows; disinfection by-products due to additional organic matter; pathogens/nutrients as a result of flooded septic systems	Natural	Assessment Areas A/B	Runoff
H19	Wildfire	Increased erosion and organic matter due to changed landscape; fire retardant entering tributaries	Natural	Assessment Areas A/B	Runoff
H20	Wildlife	Pathogens from wildlife (via direct release or runoff in tributaries)	Natural	Assessment Areas A/B	Direct release and runoff
H21	Agriculture	Nutrients (fertilizers and livestock); pesticides/herbicides from direct runoff or subsurface flow	Agricultural	Assessment Areas A/B	Runoff and subsurface flow

Notes: IPZ = Intake Protection Zone



- ★ EMS Site
- ▲ Intake
- ▲ Authorized Waste Discharge
- Potential Point Source
- ALR Lands
- Intake Protection Zone
- Assessment Area A
- Assessment Area B

PROJECT NO.: 2019-8386.000.003
 DATE: August 2019
 DRAWN BY: BdJ / DA

FIGURE 3-1: IDENTIFIED POINT-SOURCE HAZARDS (GENERAL ASSESSMENT AREA)
 Regional District of Kootenay Boundary
 Christina Lake Water Utility Source Protection Plan

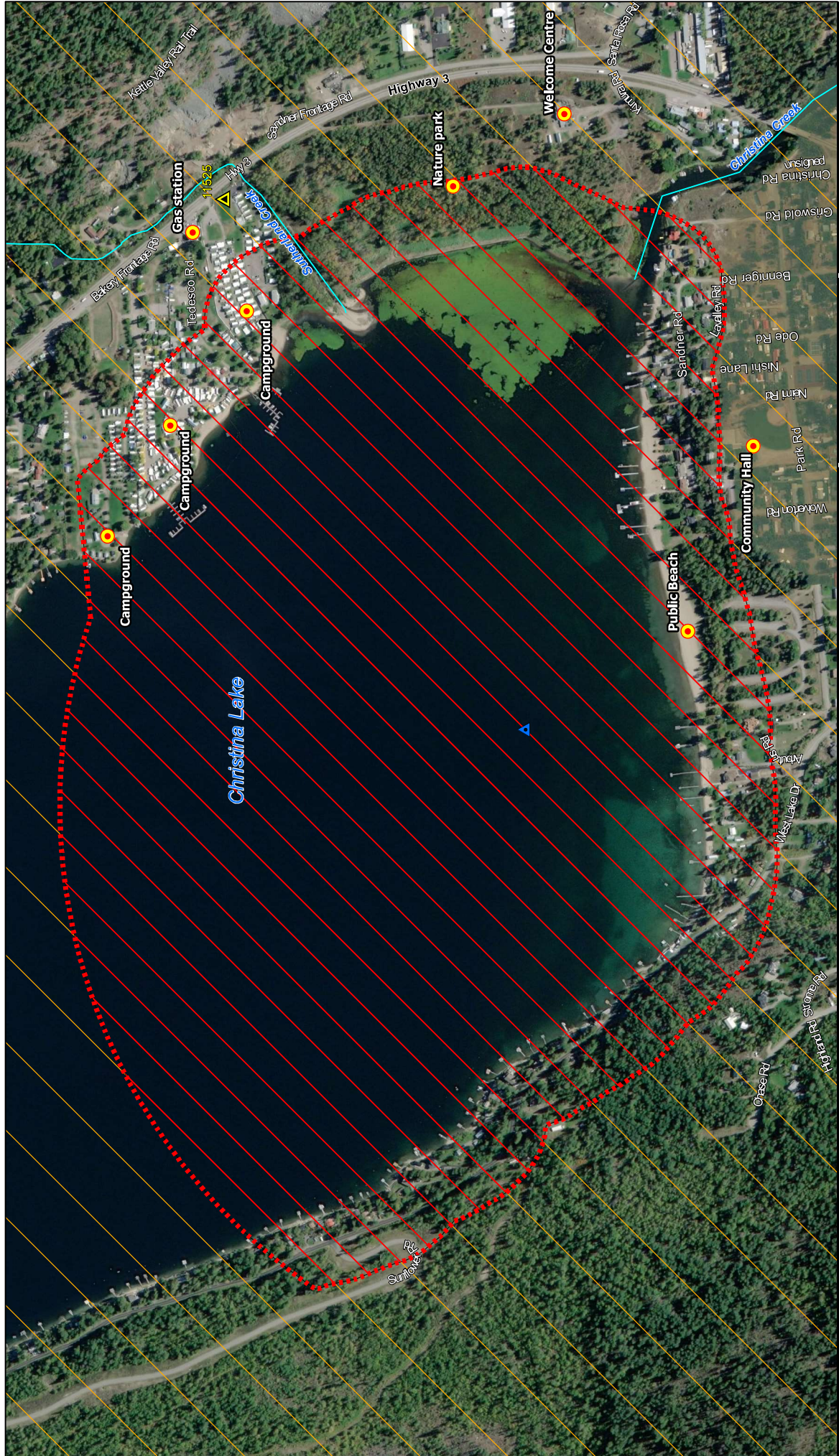


FIGURE 3-2: IDENTIFIED POINT-SOURCE HAZARDS (INTAKE PROTECTION ZONE)

PROJECT NO.: 2019-8386,000.003
 DATE: August 2019
 DRAWN BY: DA

Regional District of Kootenay Boundary
 Christina Lake Water Utility Source
 Protection Plan

0 200 m

N

Intake Protection Zone

Assessment Area A

Possible Point Source Hazard

Authorized Waste Discharge

Intake Location

Associated Environmental

AE

4 MODULE 7: CHARACTERIZE RISKS FROM SOURCE TO TAP

The purpose of Module 7 is to critically assess the adequacy of water protection barriers and assign risk levels to each hazard identified in Module 2. The TAC completed this step during a workshop held on August 21, 2019. The risk matrix provided in Module 7 of the Source-to-Tap Guideline was used to assign each hazard as low risk, medium risk, high risk, or very high risk (Section 4.1). A SWOT (Strengths, Weakness, Opportunities, and Threats) analysis was also completed (Section 4.6).

4.1 Risk-Ranking Framework

According to the Source-to-Tap Guideline, risk is defined as “the combination of the likelihood that a hazard will occur and cause harm, and the extent and degree of that harm” and can be quantitatively evaluated by multiplying the likelihood of a hazard occurring by the consequence of that hazard (MHLS 2010). To determine potential risks, two ratings were applied to each hazard:

1. The likelihood of occurrence (i.e., the probability the event occurs, and that if it occurs, the contaminant will migrate to the lake intake); and
2. The magnitude of consequence if that event was to occur.

Tables 4-1 and 4-2 summarize how each level of risk is assigned using the likelihood of occurrence and magnitude of consequence matrices in MHLS (2010). Note the use of “and/or” in the definitions of the consequence levels (i.e., the occurrence of any one of the factors results in that specific level being assigned). Each hazard identified in Module 2 (Table 3-1) was assigned a likelihood of occurrence and magnitude of consequence score, and then risk was determined using the risk matrix (Table 4-3).

Table 4-1
Assignment of risk categories – likelihood of occurrence

Level	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%

Source: Source-to-Tap Guideline (MHLS 2010)

Table 4-2
Assignment of risk categories – magnitude of consequence

Level	Description
1	Insignificant – no illness, little disruption to normal operation, <u>and/or</u> little or no increase in normal operating costs
2	Minor – small population, mild illness moderately likely, some manageable operation disruption, <u>and/or</u> small increase in operating costs
3	Moderate – minor impact for large population, mild to moderate illness probable, significant moderation to normal operations but manageable, operating costs increased, <u>and/or</u> increased monitoring
4	Major – impact for small population, severe illness probable, systems significantly compromised and abnormal operation if at all, <u>and/or</u> high-level monitoring required
5	Catastrophic – major impact for large population, severe illness probable, <u>and/or</u> complete failure of system

Source: Source-to-Tap Guideline (MHLS 2010)

Table 4-3
Risk (likelihood-consequence) matrix

Likelihood	Consequence				
	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

Source: Source-to-Tap Guideline (MHLS 2010)

Appendix B lists each hazard, the likelihood of occurrence and magnitude of consequence score, the risk rating based on that score, and the rationale behind each assigned risk. The purpose of the risk-ranking matrix is to provide a framework with which to identify the highest risks. Assigning of the scores is a qualitative and subjective process, and in many cases, it is difficult to accurately quantify the probability of an event occurring or the magnitude of the consequence. Furthermore, it is important to note that risks (as per Table 4-2) include those related to human health risk and/or risk of disruption to normal water system operations, increased maintenance, and increased monitoring (i.e., not all high risks necessarily present an immediate human health risk).

The following sections provide discussion on the Very High, High Risk, and Moderate Hazards.

4.2 Very High Risk Hazards

4.2.1 Flooding (H18)

Flooding was assigned a likelihood of B (likely) given the events of recent years. McCrae Creek reportedly flooded in 2017, resulting in an influx of sediment to the lake. Christina Creek periodically backs up (approximately once every 10 years, as reported in CLSS 2005 and by the TAC). This occurred during the 2017 floods, and the backflow of turbid water into Christina Lake was evident in a photo provided by a member of the TAC. Flooding and an influx of sediment from Sutherland Creek, which discharges relatively close to the intake (approximately 750 m), has also been identified as a future risk. Furthermore, the likelihood of flooding is predicted to increase with climate change, which is anticipated to result in higher flows during spring.

The primary concern with flooding is increased turbidity (Section 3.1.1.2). Without further studies and a better understanding of lake flow processes, the extent to which flooding events may affect the intake is not well known; however, past events (turbidity spikes at the intake in May and June 2018; RDKB 2018) suggest that flooding can affect turbidity at the intake. A magnitude of consequence score of 4 was assigned, due to the potential for the treatment system to be compromised and for abnormal operation of the system (i.e., Water Quality Advisory due to elevated turbidity). If increased turbidity over time were to ultimately result in the need for filtration, significant capital and operational costs would be incurred.

The occurrence of flooding cannot be altered by the RDKB. However, select management practices can help mitigate the impact of flooding on the community of Christina Lake. Although the use of Crown Land is managed by the Province, local governments may be able to reduce the effects of flooding through land use management activities such as zoning, flood elevation mapping, and riparian restoration. Specific recommendations to mitigate risk include improving/practicing emergency response (Section 5.1.6) and infrastructure management and operations (Section 5.1.3).

4.2.2 Wildfire (H19)

Wildfires are a natural occurrence in BC, and there are concerns that a changing climate could increase the frequency and severity of fires. According to provincial mapping (ENV 2019a), a total of 25,990 ha or 55% of the land base within the watershed been impacted by fire in the last 100 years. Historical fire suppression efforts have resulted in forest fuel build-up, leading to a higher likelihood that more severe fire events will occur in the future. A likelihood score of C was assigned (possible, range of 31-70% probability in the next 10 years [Table 4-1; qualitatively assigned]). Although the impact on the drinking water system would vary depending on the size, severity, and location of the fire, a consequence score of 4 was assigned due to the potential for the system to be significantly compromised. A wildfire event has the potential to temporarily shut down the entire drinking water system, and could have long-term impacts on source water quality by increasing erosion. Fire retardant (which is primarily water with a nitrogen-based additive) entering a tributary during fire fighting efforts is also a risk, but likely much lower than the risk presented by the overall impact to the watershed due to the short-term nature of use and effects of dilution (MOH 2018b).

Wildfire prevention and management is the responsibility of the provincial government. However, RDKB can continue to promote community activities to reduce fire risk (currently being done via the RDKB website). To mitigate risk, the RDKB can improve/practice emergency response (Section 5.1.6) and engage with other public agencies (Section 5.1.1). Other long-term considerations relate to infrastructure management and operations (Section 5.1.3).

4.3 High Risk Hazards

4.3.1 Highway 3 (H15)

Highway 3 is the only transportation corridor connecting Christina Lake with the rest of the Kootenays and with the Okanagan. There is regular transport of goods along this route. The highway runs parallel to the lake, in some cases within 100 m of a steep drop-off to the lake surface. Sutherland Creek, which flows directly into the IPZ, also crosses the highway. A vehicular accident on Highway 3 resulting in a large spill either direct to the lake or one of the main tributaries was assigned a likelihood score of D (could occur at some time; 10-30% probability of occurrence in the next 10 years). Runoff and cumulative additions of contaminants such as hydrocarbons, road salts, and nutrients to the water source are also a risk, but a less quantifiable one. There have been no studies on water movement patterns (wind, currents) in the lake to date, so the travel time for a spill to reach the intake (or whether it even goes that direction) is unknown. Given the lack of understanding of transport times and flow mechanisms, a consequence score of 4 was assigned (for the potential to significantly compromise the system and result in a higher level of monitoring).

Traffic and highway safety is the responsibility of the provincial government (i.e., Ministry of Transportation and infrastructure [MOTI]). To reduce the likelihood of occurrence, the RDKB can engage with other public agencies, such as MOTI and the RCMP (Section 5.1.1), but risk to the drinking water system will be primarily mitigated through emergency response (Section 5.1.6).

4.3.2 Forestry Activities (Cutblocks and Forest Service Roads) (H17)

Forestry activities were considered by the TAC to be a high risk in the watershed, given that the topography around the lake is very steep and primarily forested, and associated concerns that deforestation could have a large impact on the watershed by increasing sedimentation.

Likelihood was assessed through a preliminary ECA estimate and review of available Forest Stewardship Plans (FSPs). For this SWPP, ECA was estimated at roughly 7% of the land base (Section 2.1.3.4), which is well below the 20% threshold used to determine when increases in peak flows can be anticipated (MOF 2001). Furthermore, available FSPs show limited activity planned in the watershed in the next five years (Section 2.1.3.4). Therefore, a likelihood score of D was assigned (could occur at some time; 10-30% probability in the next 10 years). The consequence was assigned a score of 4 for the same reasons described for flooding; the potential for abnormal operation of the system, increased monitoring, and potentially high capital and operational costs should turbidity increase such that filtration is needed.

The *Forest and Range Practices Act* (FRPA) and its regulations [especially the Forest Planning and Practices Regulation (FPPR)] (FRPP 2014) is the most critical piece of legislation for protecting water quality on Crown land as it applies not only to the forestry sector, but also to other resource roads and trails and range use. All forest tenure holders must prepare FSPs that show how their activities meet provincial Objectives for water quality “associated with riparian areas”, fish habitat, and water in community watersheds (where “community watershed” is a legal term meaning only those watersheds classified as such under the Forest Practices Code before it was replaced by FRPA). The FSP must protect “the water from the waterworks having a material adverse impact on human health *that cannot be addressed by water treatment*” (FPPR Section 8.2(2)(b)).

BCTS FSP #601, which encompasses activities planned between 2017-2022 in their Boundary Forest Development Unit (FDU), presents specific results and strategies consistent with the regulatory requirements that would apply to the Christina Lake watershed (BCTS 2017). An example of these requirements includes the following:

- *Where there are community watershed management groups, BCTS will offer to meet to discuss plans and operations that are, or will be, occurring within the watershed. Such meetings will occur annually when operations are ongoing.*
- *Prior to constructing a road or entering into an agreement that authorizes timber harvesting or road construction within a community watershed, the TSM [Timber Sales Manager] will ensure:*
 - *a hydrologic assessment, including consideration of cumulative effects, is carried out by a QRP [Qualified Registered Professional];*
 - *the design of planned cutblocks and roads and/or prescribed measures are consistent with the recommendations of the hydrologic assessment; and*
 - *while primary forest activities are being conducted, a Qualified Professional will monitor, including documentation in inspection forms, to ensure that all activities are conducted in accordance with the recommendations of the hydrologic assessment.*
- *At the planning and design stage for timber harvesting and road construction, the TSM will provide a referral letter to the water licensee, which includes a description of the planned activities and provides a reasonable opportunity for review and comment.*
- *At least 48 hours before the commencement of any road construction or deactivation in a community watershed, the TSM will provide written notification to the water licensee.*

In addition, the FSP presents results and strategies specific to any Water Licence holder, including the following requirements:

- *For the objective for consumptive use streams set out in Objective 6 of the KBHLPO [Kootenay-Boundary Higher Level Plan Order], as a result or strategy, the TSM will comply with Objective 6 and, as additional strategies, the TSM will, at the planning and design stage for timber harvesting and road construction:*
 - *provide a referral letter to licensed domestic water users, or their designated group representative, which includes a description of the planned activities and provides a reasonable opportunity for review and comment...;*

These results and strategies apply to a specific tenure holder (in this case BCTS), but there are requirements under FRPP for all licensees that relate to the protection of water used by a licenced waterworks. One such requirement is that ‘an authorized person who carries out a primary forest activity must ensure that the primary forest activity does not cause material that is harmful to human health to be deposited in, or transported to, water that is diverted for human consumption by a licensed waterworks,’ as per Section 59 of FRPP.

These regulatory requirements provide a mechanism by which the various forest tenure holders are obliged to engage water license holders and community watershed operators. The licensees are expected to make efforts to engage with the relevant parties, but often the contact information they have is out of date or incorrect. Therefore, recommendations are based on engagement with other public industries (Section 5.1.1) to help ensure the RDKB is proactively engaged at the planning stages to provide meaningful input into forest related activity in the watershed.

4.3.3 Zebra and Quagga Mussels (H8)

There are numerous campaigns underway by non-profit, municipal, and provincial bodies to prevent a mussel infestation, but prevention must rely heavily on awareness campaigns and public support. Given the presence of mussels in nearby states and provinces (e.g., Montana and Manitoba), and the high level of boat tourism at Christina Lake, an infestation of invasive mussels could occur at some time (likelihood = D) and a significant adverse (and costly) effect on the water system is possible (consequence = 4).

Much is already being done to prevent mussels from reaching Christina Lake, including through the CLSS and Boundary Invasive Species (BIS) Society, who have conducted voluntary boat inspections and developed educational information (handed out at boat launches and promoted during events such as the annual Christina Lake Homecoming festival). Recommendations to further reduce the risk of this hazard are through public awareness (Section 5.1.2) and legislation and policy (Section 5.1.5).

4.3.4 Septic Systems (Residential and Community) (H1 and H2)

This section addresses both residential and community septic systems, as the contaminants of concern are the same. Provincial regulations address septic system installation and operation. Community systems that discharge greater than 22.7 m³/day of effluent to ground or discharge to water must be registered under the BC *Municipal Wastewater Regulation*, and have an Authorized Waste Discharge Permit. There are five of these permits within Assessment Area A (Figure 3-1). Systems that process less than this amount (i.e., the majority of the systems in Christina Lake) are regulated under the BC *Sewerage System Regulation*, which sets standards and requires that septic system designers and installers be certified.

The likelihood of occurrence and magnitude of consequence scores are difficult to assign for residential and community septic systems. If improperly installed, located, or maintained, septic systems may present a risk to the drinking water intake either directly by contributing pathogens (e.g., bacteria, viruses, and protozoa) or indirectly by increasing nutrient inputs (e.g., phosphorus and nitrogen) and impacting the long-term lake health. The likelihood and consequence scores are further complicated by the potential cumulative nature of contamination: one malfunctioning system is unlikely to impact the intake, but several systems malfunctioning over time could affect the overall water quality.

Historically, inadequate septic systems have been identified as a high risk for the overall health of Christina Lake, and they were again identified as a concern several times during the public input survey. There is no community sewer system, and all households and campgrounds are serviced by on-site systems. The risk presented by these systems has been discussed in previous investigations, although no recent studies have been completed. Cavanagh et. al (1994) summarized findings from a 1990 study done by Kerr Wood Leidal, which suggested that a high percentage of residential septic systems are not properly maintained and pumped out, and suggested that the topography, soils, and shallow bedrock in much of the area reduce subsurface filtering capabilities and may be resulting in phosphorus contributions to the lake. This may be the case for the area on the west shore of the lake, but based on our high-level review of the topography and a review of soil maps and the well log at the Main Public Beach (Well Tag Number 25668), this may not be the case for the south shore nearest the intake. In this area, many (although not all) of the residences are elevated compared to the lake surface and surficial soils are generally sand and gravel, suggesting subsurface filtration may be better in this area.¹³

Recognizing the public concern and lack of recent studies, Associated completed a high-level review of water quality data from the long-term monitoring station to further quantify the risk. In general, phosphorus and nitrogen levels have remained relatively consistent since 1972 (when monitoring began) at EMS Site 200078 and, as described above, the lake is considered oligotrophic. Relatively low incidences of bacteria, detected through IHA's beach testing and the RDKB's weekly raw water testing, suggest minimal impact from septic systems on the drinking water system to date.

¹³ Based on the uppermost geological unit from 0.3 m to 12.8 m in Well Tag Number 25668 (located at the Main Public Beach), which is described as medium to coarse sand and gravel with occasional thin silt lens, and the soils are mapped as sandy loam, which are rapidly draining (ENV 2019b and BC MOA 2019).

However, the future risk may increase as septic systems age. With climate change, there may also be an increased risk of septic system flooding.

With respect to the consequence, the impact of treatment (e.g., disinfection) of the water must also be considered. Currently, the source water is chlorinated, and coliforms are monitored throughout the distribution system. As long as there is sufficient chlorine concentration and contact time for viruses and *Giardia*, and the RDKB continues to issue a Boil Water Advisory if the system exceeds Ministry of Health surface water treatment objectives for bacteria and/or turbidity, the risk to the population (from an illness perspective) is mitigated. This will be improved with the addition of UV disinfection, which can provide effective treatment for *Cryptosporidium*.

Based on the rationale presented above, the likelihood was assigned a score of C (possible) and the consequence a score of 3 (due to the potential for significant but manageable moderation to normal operations, and potential for increased monitoring).

As described above, provincial regulations address septic system installation and operation. However, the RDKB has some control through the OCP process: this is described further in Section 5.1.5. Recommendations to further reduce this risk are focused on public awareness (Section 5.1.2), infrastructure management and operations (Section 5.1.3), monitoring and lake studies (Section 5.1.4), and legislation and policy (Section 5.1.5).

4.3.5 Residential Lakefront Properties (H6)

Generally, properties along the lakefront appear to be well maintained, but it is possible to have direct runoff into the lake of on-site contaminants (e.g., fertilizers, pesticides, pathogens, sediment).¹⁴ Similar to septic systems, the likelihood and consequence scores are complicated by the potential cumulative nature of contamination. A likelihood score of C (possible) was assigned for conservative purposes (i.e., assuming cumulative impacts from several properties). The highest density of lakefront properties is situated along the southern lakeshore, and many are within the IPZ. A consequence score of 3 was assigned for the potential to increase operating costs and require increased monitoring. Recommendations to reduce this risk are focused on public awareness (Section 5.1.2).

4.3.6 Campgrounds (H4)

Campgrounds within the IPZ may present risks to the drinking water system, similar to those described for private lakefront properties (e.g., fertilizers, pesticides, pathogens, sediment). Likelihood and consequence scores of C and 3 were assigned, respectively, for the same rationale presented for Residential Lakefront Properties. However, the risk may be somewhat higher, due to the high density of people during summer. Furthermore, campground users are primarily tourists and as a result, may be less aware of the importance of Christina Lake as a drinking water source. Therefore, recommendations to reduce this risk are focused on public awareness (Section 5.1.2).

4.4 Moderate Risk Hazards

4.4.1 Boating and Other Watershed Recreation (H3, H16)

Based on local knowledge and discussions with the TAC, the majority of boats on the water do not have blackwater (i.e., sewage) storage capabilities. However, some boats do (including house boats) and there are no septic pump-out locations in the community of Christina Lake. It is possible that blackwater and likely greywater (e.g., soaps) are discharged periodically to the lake. Accidental fuel spills are also a risk; many boats are refuelled within the lake (at the

¹⁴ This hazard is not considered to include malfunctioning septic systems, which are addressed as a separate hazard (H1; Section 4.3.4).

marina) and spillage is possible. The chance of these compounds reaching the intake in detectable levels is likely low, but this is difficult to confirm given the lack of understanding of lake flow processes. This hazard is primarily a concern during summer, when tourism is popular, which may reduce the risk of a contaminant reaching the intake due to lake stratification. However, there is insufficient knowledge of lake flow and stratification patterns near the intake to be able to develop specific management strategies. Furthermore, boating activities also occur in spring and fall, when the lake is not stratified.

Other recreational activities within the watershed that may present a hazard include the use of off-road vehicles (e.g., ATVs), hiking, horseback riding, and mountain biking, particularly when activities are near major tributaries. As reported by CLSS (2005), more recreation is likely water based (e.g. boating, swimming) than watershed based, due to limited access in the watershed. However, ATV use, mountain biking, hiking, and horseback riding are known to occur, and there are several local trails within the watershed. Informal camping (i.e., not at registered camp sites with proper septic systems) is also a hazard, but the extent to which this may be occurring is unknown.

Together, these hazards were assigned a likelihood score of D (could occur at some time; 10-30% probability) and a consequence score of 3 (due to the potential for increased operating costs and/or increased monitoring, such as hydrocarbon testing). Recommendations to reduce the risk of these hazards are focused on increased public awareness (Section 5.1.2).

4.4.2 Algal Blooms (H10)

Given the relatively low nutrient levels (e.g., nitrogen and phosphorus), overall good water quality of the lake, and lack of algal blooms to date (based on local knowledge), algal blooms are considered unlikely (likelihood = D). However, they could have a moderate impact on the drinking water system (consequence = 3; moderate but manageable affect on operations and increased monitoring), and the likelihood could increase if water temperatures warm (i.e., with climate change). The recommendations for other hazards that are intended to reduce nutrient inputs also reduce the risk of algal blooms, and monitoring and lake studies (Section 5.1.4) will help assess the effectiveness and identify increasing trends, which will help indicate a problem before it occurs. If an algal bloom occurs, particularly in the vicinity of the intake, the risk can be addressed through water quality testing (Section 5.1.4).

4.4.3 Organic Matter Influx (H9)

Organic matter can react with chlorine, used in the disinfection process, and form disinfection by-products such as trihalomethanes (THMs) and haloacetic acids (HAAs), which are a human health risk. Organic matter can also affect turbidity and interfere with the treatment process. The likelihood of this occurring is complex and varied, and can only be properly assessed through monitoring. The BC Source Drinking Water Guideline recommends a maximum Total Organic Carbon (TOC) concentration of 4.0 mg/L to reduce the risk of disinfection by-product formation (ENV 2017). On average, TOC levels at EMS site 200078 (Section 2.1.4) are below this guideline (average of approximately 2.6 mg/L across all depths), but a maximum of 6.0 mg/L has been recorded (Table 2-3). Therefore, a likelihood score of D (could occur at some time) was assigned. The consequence score is 3, based on the potential for human-health concerns relating to the formation of disinfection by-products.

Similar to algal blooms, the general recommendations in this SWPP that seek to protect the overall quality (including turbidity levels) will help reduce the risk, but monitoring and lake studies (Section 5.1.4) are needed to help identify problems.

4.4.4 Beach Use (H5)

Small recreational beaches, found throughout the IPZ, have no washroom facilities. The Nature Park and its trails, which are within the IPZ, are used by the public for walking (including pets). The Main Public Beach, which experiences high use in summer, is located near the intake, and provides both vaulted pit toilets, which are periodically pumped out, and an in-ground septic system.¹⁵ It is relatively unlikely for any direct discharges to reach the intake (likelihood = D), which is 300 m offshore and at a depth of approximately 12 m. The consequence is considered the same as for septic systems and campgrounds: 3.

Risk can be mitigated through public awareness (Section 5.1.2) and proper maintenance of the washroom facilities at the Main Public Beach (Section 5.1.3).

4.4.5 Roads (other than Highway 3) and Stormwater Discharges (H11)

Based on local knowledge and input from the TAC and RDKB, stormwater is addressed primarily through infiltration (likely due to high gravel content) and there are no known stormwater outfalls into Christina Lake. Likelihood and consequence scores of C (possible) and 2 (minor; some manageable disruption and/or small increase in operating costs) were assigned. Risk is managed by maintaining ditches and culverts, and effectiveness is assessed through monitoring and lake studies (Section 5.1.4).

4.5 Low Risk Hazards

Hazards identified as low risk include commercial lakefront (H7), municipal institutions (H12), upland commercial/industrial (H13), residential non-lakefront properties (H14), wildlife (H20), and agriculture (H21). Rationales for the low risk designations are provided in the hazard risk-ranking table in Appendix B.

4.6 Strength, Weaknesses, Opportunities, and Threats Analysis

One of the objectives of the Source-to-Tap Guideline is to incorporate information generated on the water supply system into a comprehensive assessment that identifies the strengths and weaknesses of the overall water system as an integrated whole. The TAC achieved this objective by conducting a SWOT analysis on August 21, 2019.

Several strengths were identified, including the good quality of the source, natural land use and rural community setting, community enthusiasm for source protection, and long-standing non-profit groups that actively promote the importance of a healthy watershed (e.g., the Christina Lake Stewardship Society). Key weaknesses and threats include the lack of a back-up secondary water source, potential for water storage limitations in summer, the threat of wildfires and climate change, and the risk of increased turbidity ultimately necessitating a costly filtration plant. Opportunities are primarily address in the recommendations (Section 5.1) but include improved public awareness, better water conservation, and leveraging existing groups and organizations to promote source protection. A full list of items identified during the SWOT is in Appendix C.

¹⁵ Based on discussions with the TAC.

5 MODULE 8: RECOMMENDED ACTIONS TO IMPROVE DRINKING WATER PROTECTION

The outcome of Module 8 is a series of recommendations for each medium and high risk hazard identified in Module 7. The recommended risk management actions follow the SMART (Specific, Measurable, Achievable, Realistic, Time-bound) principles outlined in Module 8 of the Source-to-Tap Guideline and are based on the **multiple barrier** framework¹⁶ for source protection defined by CCME (2004b), which considers practical and cost-effective methods to improve existing barriers or implement new ones, where warranted. The suggested timeframes for risk management actions are presented in Table 5-1; however, the Source-To-Tap Guideline state that risk level is not the only factor to consider when prioritizing actions; ease of implementation can also be a factor (MHLS 2010).

Table 5-1
Suggested time categories for risk management actions

Category	Timeframe	Type of Risk Management Action
Immediate	Within 3 months	Actions addressing regulatory violations, imminent public health threats, or water shortages.
Short Term	Within 1 year	Actions that are easy to implement or those addressing significant public health concerns or water quantity issues, enhancement or weak barriers.
Medium Term	1 to 3 years	Actions addressing moderate water quality or quantity concerns, broad systemic issues.
Long Term	3 years +	Actions addressing hazards representing chronic health implications or long-term threats to water availability, broad systemic issues.

Source: MHLS 2010

5.1 Recommendations

Recommendations to specifically address the very high, high, and moderate risk hazards are provided below. Many of these recommendations will address more than one hazard, and the recommendations are grouped by implementation type. There are many ways in which source water protection can be strengthened, and recommendations should be periodically reviewed and updated as new information becomes available.

5.1.1 Engagement with other Public Agencies and Industry

Although some actions are within the RDKB's jurisdiction, many others are the responsibility of the Province or fall within the realm of 'best practice' by the private sector. In these cases, the RDKB can work with Provincial staff and local businesses to ensure they consider drinking water risk when making decisions. Recommendations that relate to engagement with other public agencies and industry include:

- **Medium-term:** Arrange a meeting with local MOTI officials to review this SWPP and to request that they consider the sensitivity of the lake and key tributaries (including Sutherland Creek) when preparing and implementing their emergency and spill response plans.
- **Medium-term:** Consider reaching out to campground owners (particularly those within the IPZ) to discuss the condition of septic fields and on-site pesticide and fertilizer use. Encourage campground owners to ensure

¹⁶ The multi-barrier approach is an integrated system of procedures, processes, and tools that collectively prevent or reduce the contamination of drinking water from source to tap, in order to reduce risks to public health.

they are following all aspects of their septic treatment and discharge permits, and ensure they are aware of potential implications of lake flooding on their septic systems.

- **Medium-term:** One of the opportunities identified during the SWOT was the RCMP presence on the water during summer months, which provides another avenue to reach out to the public. The RDKB could meet with the RCMP, share the location of the IPZ, and discuss opportunities to improve public awareness during routine RCMP boat stops.
- **Medium-term:** Ensure that all forest tenure holders operating in the watershed have the contact information of a RDKB representative, to ensure that all FSPs and related operating plans are reviewed and adequately address potential water quality impacts.

5.1.2 Increase Public Awareness

Improving public awareness of the water source is a key recommendation of this SWPP, as everyone (e.g., regulators, local residents, business owners, and tourists) has a role to play in source protection. This need was also highlighted during the public input survey, where nearly 60% of respondents indicated that they only 'occasionally' or 'not at all' felt informed about source protection and the role they play in protecting the water source.

Specific recommendations to increase public awareness include the following:

- **Short-term:**
 - **Signage:** Create signage that informs that Christina Lake is the community's drinking water source, and highlights ways the public can reduce contamination risks. Provide and encourage using signage throughout key areas in the community, specifically targeting:
 - Campgrounds, which provide a unique opportunity to reach the large tourist population (e.g., on washrooms and on docks). Small postcards or other pamphlets could also be offered to campgrounds.
 - Other public places (gas stations, grocery store, restaurants, and other local businesses such as the sports rental shop).
 - At trail heads and on commonly used forestry service roads, to reach other users throughout the watershed and address risks presented by motorized vehicle use and informal camping in the watershed.
 - **Email and newspaper notifications:** A 'Source Water Protection' section could be periodically added to local newspapers (e.g., Christina Lake News and Grand Forks Gazette) and included in the weekly email 'blast' that many residents receive from the Christina Lake Community Coordinator. This approach could be used to share the IPZ and watershed boundaries, and remind the public of the importance of lake health. Content could be developed from signage/pamphlets, the Backgrounder document (Appendix A), and local non-profit groups (e.g., Christina Lake Stewardship Society). The RDKB can also leverage source water protection resources provided by other jurisdictions or organizations, such as the Regional District of Nanaimo (<https://www.rdn.bc.ca/dwwp-resources#2>), Okanagan Basin Waterboard (<https://www.obwb.ca/>), and Kettle River Watershed Management Plan (<https://www.rdkb.com/HotTopics/KettleRiverWatershedManagementPlan.aspx>).
 - **Spill reporting:** Encourage the importance of spill reporting, using the RDKB website. An example can be found at <https://www.crd.bc.ca/education/our-environment/concerns/report-a-spill>. This would be relatively easy to achieve and could be promoted periodically (e.g. quarterly) using the email notifications described above.

- **Medium-term:**
 - **Septic system maintenance:** Aim to improve public awareness of the importance of proper installation and maintenance of existing septic systems, focusing first on lakefront properties. This could be achieved by pamphlets (e.g., a Source Protection Guide for homeowners) or postcard mail-outs. The RDKB could dedicate a website page to providing information relating to this hazard (for example: <https://www.crd.bc.ca/docs/default-source/septic-pdf/septic-savvy-household-information-kit-.pdf?sfvrsn=0>), or could consider offering community workshops on how to properly care for residential septic systems. Other hazards presented by lakefront properties could also be addressed here, such as proper storage of chemicals and use of fertilizers and pesticides.
 - **Septic system installations:** Consider hosting a workshop with Registered Onsite Wastewater Practitioners (ROWP). This idea was raised during the TAC Workshop. Only ROWPs can install new septic systems; therefore, by having a workshop locally, best practices can be shared by those that are most likely doing the installations.

5.1.3 Infrastructure Management and Operational Improvements

Other hazards can be addressed through RDKB infrastructure management, capital projects, and ongoing operations. We understand the RDKB already intends to install a UV treatment system. Other recommendations include:

- **Short-term:**
 - Assess the intake (e.g., SCUBA diver or underwater camera) to determine the condition of the intake infrastructure and identify current levels of sedimentation, to help ensure there is enough clearance for some sediment to accumulate due to floods.
 - Ensure that the contact time value (concentration of the disinfectant (e.g., free chlorine) times the contact time with the water being disinfected) has been calculated. This is needed to confirm adequate treatment for all types of pathogens is occurring.
- **Long-term:**
 - Consider a secondary source for redundancy. Currently, the Water Utility only has one source of water for the water supply. If a major water quality event was to occur near the intake, the Water Utility may only have enough water for one or two days in the storage reservoirs (if the event occurred in summer, when use is high). To improve resiliency in the community, a second source of drinking water is recommended. Options for a secondary source include a second intake in a different part of the lake or nearby stream, a groundwater supply well, or an agreement with a neighbouring water source (e.g. Sutherland Creek) to temporarily provide water to the Christina Lake utility customers.

5.1.4 Monitoring and Lake Studies

Water quality monitoring programs to date indicate that the quality of lake water is relatively good, but conditions may change in the future with increased development and climate change. Regular monitoring will help to determine whether water quality is changing over time and can provide a warning of future issues. Additional data increases the reliability; however, this has to be balanced with financial considerations for the Water Utility. The RDKB can continue to work with the CLSS and ENV to leverage existing water quality monitoring programs, to reduce costs.

Specific recommendations to upgrade monitoring include:

- **Short to medium-term:** In addition to the ongoing testing of the treated water throughout the distribution system, the RDKB should:

- Test *E. coli* and total coliforms in the raw water weekly, particularly if the RDKB wishes to pursue filtration exclusion.
 - Consider sampling and testing raw water for a comprehensive list of water quality variables.¹⁷ This should be done quarterly, for a period of two to three years, to assess seasonal variations in water quality. Depending on the findings, the frequency of testing and/or the list of variables could be modified. Results should also be compared with the ENV long-term monitoring station to assess variability between the two sites: if water quality is generally similar; data from that site (which is approximately 1 km north of the intake) can also be used to provide an indication of quality at the intake.
 - Consider quarterly testing of THMs and HAAs (disinfection by-products) from treated water. One test has been completed to date, and results met the drinking water guideline thresholds. However, the guideline is based on a locational running average of a minimum of quarterly samples. The frequency of testing could also be adjusted after a period of two to three years, based on results and following recommendations from the Interior Health Authority.
- **Long-term:** During the Workshop, the TAC expressed interest in completing a lake study to better understand water flow patterns and transport times. Such a study is recommended because it would provide a better understanding of the risk that some hazards present (e.g. accidental spills on Highway 3 or at the marina, sediment plumes from creek mouths during freshet), which are some distance from the intake. Travel time data is also important for emergency response planning by establishing time frames for action.
 - **Long-term:** Look for grant opportunities and partner with the CLSS and the provincial government where possible to support water quality studies that investigate long-term trends in water quality. It may be possible to secure grant funding for a comprehensive “state of the lake” study that includes the water quality and lake current studies outlined above, as well as an overview assessment of the status of private on-site wastewater systems.

5.1.5 Legislation, Policy, and Community Groups

The risk of other hazards can be addressed more broadly through legislation (e.g. bylaws), policy, and by supporting non-profit community groups. One of the key mechanisms through which Local Governments can address and promote source water protection is through land use planning and development. This is addressed in the Official Community Plan (OCP), which is a bylaw enacted by local government to outline community goals and objectives and develop policies to guide decisions on land use management and planning. Once adopted, any bylaws or works the Board of Directors (or Council) undertakes must be consistent with the policies and objectives identified in the OCP.

The OCP for Area ‘C’ (Christina Lake) was adopted in 2004 (RDKB 2004). In the OCP, a healthy ecosystem is identified as a key community value, along with the beauty of the area, recreational opportunities, and rural community nature. There are many goals, objectives, and policies throughout the current OCP that address these values and support the protection of water quality. Some examples include:

- Limiting commercial use of waterfront properties to those already designated as Waterfront Commercial, and not permitting the retail sale of fuel or rental, sales, or maintenance of watercraft in these areas (RDKB 2004). This will limit the potential for a marina or other commercial business to be established within the IPZ.

¹⁷ The recommended list of variables is alkalinity, chloride, sulphate, turbidity, true colour, Langelier Saturation Index, hardness, total organic carbon, nitrogen (nitrate-N, nitrite-N, total nitrogen, and total Kjeldahl nitrogen), phosphorus (total, dissolved, and orthophosphate), chlorophyll *a*, and total metals.

- Encouraging higher levels of sewage treatment – as per policy 2.2.3(6), campgrounds that upgrade sewage treatment such that it exceeds provincial standards may receive higher density privileges and/or other additional permitted uses (RDKB 2004).
- Not supporting the northern extension of roads (West Lake Drive or East Lake Drive) beyond their current location, to limit development in these areas (RDKB 2004).
- Requiring minimum parcel sizes for subdividing, such that lots are large enough to properly accommodate on-site septic systems (RDKB 2004). For example, for areas not serviced by a community water system, the minimum parcel size is 20 ha.
- Limiting future industrial development to currently zoned areas and only permitting ‘non-polluting industries’, prohibiting several industrial land uses (such as hazardous waste processing), and encouraging sound agricultural and forestry practices.

A key aspect of water quality protection addressed in the OCP is the **Environmentally Sensitive Waterfront Development Permit Area (DPA)**, which encompasses all properties (privately owned or leased) that border Christina Lake or a tributary stream. This DPA provides a valuable mechanism for source protection. Currently, a development permit is required prior to constructing a dwelling within this area, and approval requires that a report be prepared by a Qualified Professional demonstrating that the proposed method of septic treatment and disposal is sufficient to protect the environment (and where possible, exceeds provincial treatment standards). There are exceptions to this requirement: a development permit is not required if:

- the septic system will be more than 100 m beyond the natural boundary of the lake or tributary (although in these cases, provincial standards would still need to be followed); or,
- the property is only accessible by boat, the septic system consists of an ‘on-site pit toilet which has been approved by the authority having the jurisdiction and the building(s) on the property do not have internal pressurized plumbing systems that discharge directly to ground or water’.

Recommendations include:

- **Medium-term:** The OCP is currently under review, which provides an opportunity to increase source water protection. As part of the OCP updating process, the review should focus on ways to address hazards identified in this SWPP, and the update should maintain the good practices from the original OCP (as described above). For example, as part of the waterfront DPA, the RDKB could consider implementing additional¹⁸ construction and maintenance standards for pit toilets, where allowed. BC regulations do not provide standards for constructing pit toilets, and the Public Health Inspector will therefore not inspect or issue a permit for a pit toilet. Interior Health provides guidelines on when a pit toilet is suitable, where it should be placed, and how it should be constructed (Interior Health 2006). The IPZ boundaries could also be incorporated into the OCP update.
- **Medium-term:** Continue to support the CLSS and liaise with other water stewardship groups, such as the OBWB, to improve public awareness and to seek information or opportunities for funding sources for a boat check station on Christina Lake (to address the risk of invasive mussels).

¹⁸ In addition to Section 313 of Zoning Bylaw 1300, which states that pit toilets must be at least 30 m from the natural boundary of any watercourse.

5.1.6 Improve Emergency Preparedness

Many hazards cannot be completely prevented. Examples of these high-risk hazards include flooding, wildfire, and an accidental spill on Highway 3. In these cases, risk is addressed through emergency preparedness and response planning. Recommendations that relate to improving emergency preparedness include:

- **Short-term:** Meet with First Responders and practice emergency scenarios for the very high and high hazards to ensure that the RDKB and water operators are prepared, and provide a copy of the SWPP to First Responders. For example, First Responders will be in a unique position to help identify and notify the RDKB in the event that a motor vehicle accident results in a spill either direct to the lake surface, or to one of the major tributaries.
- **Medium-term:** Continually review and update the RDKB emergency response plan related to Source Protection hazards. Review of the emergency response plan may include adding additional details of the system, including intake and storage maps and drawings, this SWPP, and emergency contact numbers that include engineering infrastructure and source protection specialists.

5.2 Long-term Sustainability of the Drinking Water Source

The long-term sustainability of Christina Lake as a drinking water source depends on the water quality and the water quantity. According to data provided by the RDKB, the average annual water consumption from the Christina Lake Water Utility between 2013 and 2018 was 343 ML (or 343,000 m³), which is approximately 0.04% of the total volume of Christina Lake (930,000 ML; Cavanagh et al. [1994]). Furthermore, based on the annual average precipitation (534 mm) and surface area of the lake (25.6 km²), the average annual precipitation directly onto the lake surface is estimated at 13,670 ML (or 40 times the volume extracted). Although a full lake water balance (considering all inputs and outputs, such as evaporation, extraction from private water users, inflows from tributaries, etc.) has not been completed, this initial assessment indicates that the Water Utility demand is sustainable.

Unlike other water sources (such as streams), lakes provide some buffering capacity with respect to climate change effects on water quantity. Prolonged drier summers may result in reduced inflows (due to drought conditions in tributaries) and increased water demand, but also increased flows during spring freshet. While annual precipitation is expected to increase by between 4-6% on average between 2010-2099, the timing and type of precipitation is expected to change (i.e., less summer precipitation and more winter precipitation as rain). In addition, overall snowpack accumulation is expected to be reduced. As a result, spring freshet (e.g., snowmelt) is expected to occur earlier in the year, resulting in changes to the hydrologic regime of Christina Lake, but potentially not substantially affecting the overall availability of water (particularly if significant development or changes in agricultural water use are not anticipated). Promoting water conservation efforts, which are already underway, will further help address this risk.

The risks to water quality are more varied. Data collected to date demonstrate that the quality of Christina Lake is good, and that it presents a good, viable water source. However, the hazards identified throughout this SWPP highlight the importance of source water protection. Although climate change may not have significant impacts on the quantity of water available for the Water Utility, there may be implications on water quality. Climate change may affect the quality of the source water either directly (e.g., through increased temperatures) or indirectly, by increasing the likelihood of hazards (e.g., wildfire and flooding). Other hazards to water quality relate to land use and development.

Source protection is part of the multi-barrier approach to delivering clean, safe, and reliable drinking water. Incidents of water-related health effects are typically a result of a breakdown in more than one barrier. Underpinning the multi-barrier approach are three supporting mechanisms essential to the successful implementation of the approach: sound water-system management, affordability, and effective governance. In this way, everyone in the community plays a role in delivering clean, safe and reliable drinking water. The recommendations in this SWPP, along with the on-going efforts by the RDKB and non-profit groups (e.g., the Christina Lake Stewardship Society, Boundary Invasive Species Society, etc.) to monitor water quality and improve public awareness, will help mitigate risks to water quality in the future and improve the long-term sustainability of the source.

CLOSURE

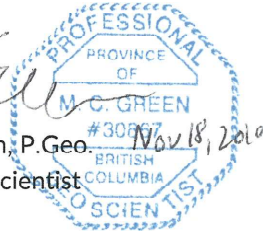
This report was prepared for the Regional District of Kootenay Boundary. The report presents the results of the Christina Lake Water Utility Source Water Protection Plan, following Modules 1, 2, 7, and 8 of the BC Comprehensive Drinking Water Source-to-Tap Assessment Guideline.

The services provided by Associated Environmental Consultants Inc. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Environmental Consultants Inc.



Nicole Penner, B.Sc., A.Ag.
Environmental Scientist



Marta Green, P. Geo.
Senior Geoscientist

REFERENCES

- Associated Environmental Consultants Inc. (Associated). 2016. Support in Application for Filtration Deferral – Turbidity and Bacteria Source Water Assessment. November 2016.
- British Columbia Ministry of Agriculture (MOA). 2019. Soil Information Finder Tool. Available at: <https://www2.gov.bc.ca/gov/content/environment/air-land-water/land/soil/soil-information-finder>
- British Columbia Ministry of Environment (ENV). 2007. Water Quality in British Columbia – Objectives Attainment in 2005. Water and Air Monitoring and Reporting Section, Environmental Quality Branch. Report prepared by Burke Phippen of BWB Consulting Inc. Available at: <http://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do?subdocumentId=2799>
- British Columbia Ministry of Environment and Climate Change Strategy (ENV). 2017. British Columbia Water Quality Guidelines: Drinking Water Sources. Ministry of Environment & Climate Change Strategy, Water Protection and Sustainability Branch. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/drinking-water-and-recreation/source_drinking_water_quality_guidelines_bcenv.pdf
- British Columbia Ministry of Environment and Climate Change Strategy (ENV). 2019a. iMap BC. Available at: <http://maps.gov.bc.ca/ess/hm/wrbc/>
- British Columbia Ministry of Environment and Climate Change Strategy (ENV). 2019b. BC Water Resource Atlas. Available at: <http://maps.gov.bc.ca/ess/hm/wrbc/>
- British Columbia Ministry of Environment and Climate Change Strategy (ENV). 2019c. BC Environmental Monitoring System. Available at: <https://a100.gov.bc.ca/pub/ems/indexAction.do>
- British Columbia Ministry of Forests (MOF). 2001. Watershed assessment procedure guidebook. 2nd ed., Version 2.1. For. Prac. Br., Min. For., Victoria, B.C. Forest Practices Code of British Columbia Guidebook.
- British Columbia Ministry of Forests, Lands and Natural Resource Operations (FLNRO). 2018. Woodlots Within Boundary Timber Supply Area, Available at: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/timber-tenures/woodlots/district-woodlots/boundary_woodlots_location_map.pdf
- British Columbia Ministry of Health (MOH). 2012. Drinking Water Officers' Guide, Part B: Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia. Available at: <http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/waterquality/drinking-water-quality/how-drinking-water-is-protected-in-bc>
- British Columbia Ministry of Health (MOH). 2018a. Decision Protocols for Cyanobacterial Toxins in BC Drinking Water and Recreational Water. Health Protection Branch. August 2018. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/how-drinking-water-is-protected-in-bc/cyanobacteria_decision_protocol_2018.pdf

British Columbia Ministry of Health (MOH). 2018b. HealthLink BC: Wildfire: Its Effects on Drinking Water Quality. Available at: <https://www.healthlinkbc.ca/sites/hlbcprox-prod.health.gov.bc.ca/files/documents/healthfiles/hfile49f.pdf>

British Columbia Ministry of Healthy Living and Sport (MHLS). 2010. Comprehensive Source-To-Tap Assessment Guideline. Available at: <http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators#source-to-tap-assessment>

British Columbia Ministry of Water, Land and Air Protection Parks Division (MWLP). 1995, Management Plan for Gladstone Provincial Park. Available at: <http://www.env.gov.bc.ca/bcparks/planning/mgmtplns/gladstone/gladstonefinal.pdf?v=1571588605920>

British Columbia Timber Sales (BCTS). 2017. Forest Stewardship Plan #601. Available at: <https://www.for.gov.bc.ca/ftp/TKO/external!/publish/FSP/Approved-FSP-2017-2022/Approved%202017%20to%202022%20FSP%20-%20BCTS%20Kootenay%20-%20May%201,%202017.pdf>

Canadian Council of Ministers of the Environment (CCME). 2004a. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. Canadian Environmental Quality Guidelines. Available at: <http://cegg-rcqe.ccme.ca/download/en/205>

Canadian Council of Ministers of the Environment (CCME). 2004b. From Source to Tap: Guidance on the Multi-Barrier Approach to Safe Drinking Water. Available at: https://www.ccme.ca/files/Resources/water/source_tap/mba_guidance_doc_e.pdf

Cavanagh, N., R. Nordin, and J. Bryan. 1994. Christina Lake Water Quality Assessment and Objectives. Technical Appendix. Water Quality Branch, Environmental Protection Department, Ministry Environment, Lands and Parks, Province of British Columbia. September 1994. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/wqo_tech_christina.pdf

Christina Lake Stewardship Society (CLSS). 2005. Christina Lake Management Plan – A Community Watershed-Based Plan. Prepared by Brenda LaCroix and Rebecca McLean.

Environment Canada. 2019. Canadian Climate Normals 1981 – 2010 Station Data. Available at: https://climate.weather.gc.ca/climate_normals/index_e.html

Forest and Range Practices Regulation (FRPP). SBC 2014 c 59, 60

Griffith, A.W. and C.J. Gobler. 2019. Harmful algal blooms: A climate change co-stressor in marine and freshwater ecosystems. Harmful Algae. Available at: <https://www.sciencedirect.com/science/article/pii/S1568988319300344>

- Health Canada. 2019. Guidelines for Canadian Drinking Water Quality Summary Table. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. <https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/water-quality/guidelines-canadian-drinking-water-quality-summary-table.html>
- Interior Health. 2006. Privy and Vault Privy Guideline. Health Protection, Healthy Community Environment. Available at: https://www.fraserbasin.bc.ca/Library/TR/HP-HE-9005_Privy_Guidelines.pdf
- Okanagan Basin Water Board (OBWB). 2019. News Release: Okanagan Water Board Renews Calls for Stronger Invasive Mussel Regulations in BC. July 18, 2019. Available at: https://dontmoveamussel.ca/wp-content/uploads/2019/07/2019-07-18_NR_Okanagan-Water-Brd-renews-call-for-stronger-invasive-mussel-regs-in-B.C.-w-letter-SSC-submiss..pdf
- Pacific Climate Impacts Consortium (PCIC). 2019a. Plan2Adapt Tool. Available at: <https://www.pacificclimate.org/analysis-tools/plan2adapt>
- Pacific Climate Impacts Consortium (PCIC). 2019b. PCIC Climate Explorer Tool. Available at: <https://pacificclimate.org/analysis-tools/pcic-climate-explorer>
- Regional District of Kootenay Boundary (RDKB). 2004. Electoral Area 'C'/Christina Lake Official Community Plan. Bylaw No. 1250. Available at: <https://www.rdkb.com/Services/Planning/Bylaws.aspx>
- Regional District of Kootenay Boundary (RDKB). 2018. Annual Water Report 2018 – Christina Lake Water Utility. Facility #0210685.
- Statistics Canada. 2019. Census Profile, 2016 Census. Christina Lake, Unincorporated Place, British Columbia. Available at: <https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=DPL&Code1=590037&Geo2=PR&Code2=35&Data=Count&SearchText=Christina%20Lake&SearchType=Begin&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=590037&TABID=1>
- Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. Academic Press, New York, 1006 pp. (formerly published in 1983).

APPENDIX A – BACKGROUNDER AND PUBLIC INPUT SURVEY

BACKGROUND

Do you care about protecting our clean drinking water? The RDKB is completing a Source Water Protection Plan for the Christina Lake Water Utility, and wants your input!

The RDKB is responsible for providing safe drinking water to the southern part of the community of Christina Lake, which is serviced by the Christina Lake Water Utility. The Water Utility obtains its water from an intake in the southern portion of the lake. The RDKB operates and manages the Christina Lake Water Utility according to the conditions in the permit issued by the Interior Health Authority.

What is a Source Protection Plan?

A Source Protection Plan is one important part of a multibarrier approach to provide safe drinking water. Figure 1 illustrates the five main components of a plan. The objective of a Source Protection Plan is to identify threats to drinking water safety, and to develop recommendations to reduce risks and improve the resiliency of the water supply.



Figure 1: Components of the multi-barrier approach to delivering safe drinking water

Development of a Source Protection Plan is guided by a **Technical Advisory Committee**, which is made up of a Drinking Water Officer, Water Operators, Managers, Technical Experts, and other stakeholders. The process follows the [BC Ministry of Health's Comprehensive Drinking Water Source-to-Tap Assessment Guideline](#) Steps 1, 2, 7, and 8. The four main steps of a Source Protection Plan are shown in Figure 2:



Figure 2: Four main steps of a Source Protection Plan

Hazard Identification

Step 2 of the Source Protection Plan is identifying hazards that may contaminate the water supply. Some examples of hazards and their potential contaminants include:

- Naturally occurring: pathogens from wildlife, such as *E. coli* and protozoa such as *Giardia*
- Agriculture: fertilizers (e.g., nitrates and phosphates) and pesticides
- Residential: pathogens from septic tanks, solvents, pesticides, fertilizers
- Municipal: storm water runoff from roads
- Recreational: boat use, ATVs in the watershed

The contaminants can enter the water supply through runoff and surface water inflows, groundwater inflows, and direct inputs. A Source Protection Plan is meant to identify these hazards and develop actions that can help prevent contamination or refine response plans to reduce the impact if not preventable.

Do you know of any hazards?

We are looking for your input on hazards around Christina Lake that could potentially contaminate the water supply. **If you know of any, please take the following survey and help us protect your drinking water.**



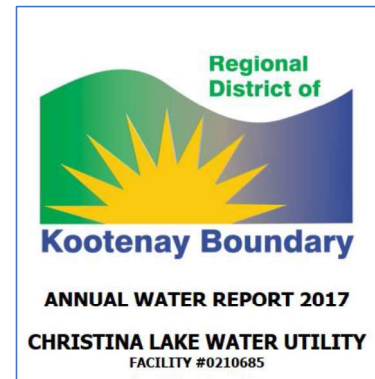
Next Steps

Once hazards are identified, the Technical Advisory Committee will work together to rank the level of risk presented by each hazard and develop recommendations to mitigate those risks and improve the safety of the water supply system.

Climate Change

In recent years, we have experienced extreme weather and weather-related events across Canada, including storms, flooding, drought, wind, and wildfires. Source water and water system infrastructure is vulnerable to a changing climate. The changing climate increases the vulnerability of source water and the water system infrastructure, and will be considered throughout the Source Protection Planning process.

Read the [Christina Lake Water Utility 2017 Annual Report](#)



SURVEY

Part 1: Respondent Information

Are you a permanent or seasonal resident of Christina Lake?

- a. Permanent
- b. Seasonal
- c. Neither
- d. If you responded c, please describe your connection to Christina Lake (fillable box)

How long have you lived in Christina Lake?

- a. Less than 5 years
- b. 5 – 10 years
- c. 10 – 15 years
- d. Greater than 20 years

Do you receive your water from the Christina Lake Water Utility?

- a. Yes
- b. No

Include a map of the boundaries, from the RDKB's 2017 Annual Drinking Water Report.

In general, do you feel confident about the quality of your drinking water source?

- a. Not at all
- b. Occasionally
- c. Most of the time
- d. All the time

In general, do you feel you are informed about source protection in Christina Lake and the role you play in protecting the quality of water in Christina Lake?

- a. Not at all
- b. Occasionally
- c. Most of the time
- d. All the time

Part 2 Hazard Identification

Please rank the hazards listed below, based on your level of concern for Christina Lake's drinking water:

Hazard Category	Hazard Type	High concern	Medium concern	Low concern	Not present
Agriculture	Fertilizers				
	Pesticides				
Commercial	Campgrounds and resorts				
	Hobby shops				
	Gas stations & auto repair shops				
	Marina				
Forestry	Forestry activities (cutblocks, logging roads)				
Industrial	Industrial production (mills, metalworks)				
Natural	Wildfire				
	Flooding				
Recreational	In-water (boating, swimming, etc.)				
	On-land (ATV use)				
	Camping (non-commercial sites)				
Municipal	Parks and playing fields				
	Highway and roads				
Residential	Septic tanks				
	Fertilizers and/or pesticides				
	Fuel storage				
	Waste disposal				

Can you think of any other hazards not listed above?

Fillable box

Do you have a particular water quality concern in Christina Lake that you would like to share with us (for example, a specific spill you are aware of)? If so, please describe the hazard and approximate location:

Hazard Category	Spill or Concern (please describe)
Agriculture	
Commercial	
Forestry	
Industrial	
Natural	
Recreational	
Residential	

During the Source Protection Plan development process, we may be seeking local knowledge about specific hazards. Are you willing to be contacted about other listed hazards?

Yes / No

If yes, please enter your contact info:

- Name:
- Phone number:
- Email:

Thank you for taking the survey!

APPENDIX B - HAZARD RISK RANKING

Appendix B Table B-1
Christina Lake SWPP: Identified Hazards and Risk-Ranking Rationale

Hazard No.	Hazard Name	Hazard Description & Contaminants of Concern	Hazard Type	Location	Contaminant Transport Mechanism	Type	Likelihood of Occurrence	Magnitude of Consequence	Risk	Risk Ranking Rationale and Discussion
H1	Septic systems - residential	Pathogens and nutrients from inadequately or improperly maintained residential septic systems	Residential	IPZ	Subsurface flow	Non-point source	C	3	High	Provincial regulations address septic system installation and operation. Community systems that discharge greater than 22.7 m ³ /day of effluent to ground or discharge to water must be registered under the BC <i>Municipal Wastewater Regulation</i> , and have an Authorized Waste Discharge Permit. There are five of these permits within Assessment Area A (Figure 3-1; #15542, 18261, 7124, 14449, and 11525). Systems that process less than this amount (i.e., the majority of the systems in Christina Lake) are regulated under the BC Sewerage System Regulation, which sets standards and requires that septic system designers and installers be certified. The likelihood of occurrence and magnitude of consequence scores are difficult to assign for residential and community septic systems. If improperly installed, located, or maintained, septic systems may present a risk to the drinking water intake either directly by contributing pathogens (e.g., bacteria, viruses, and protozoa) or indirectly by increasing nutrient inputs (e.g., phosphorus and nitrogen) and impacting the long-term lake health. The likelihood and consequence scores are further complicated by the potential cumulative nature of contamination: one malfunctioning system is unlikely to impact the intake, but several systems malfunctioning over time could affect the overall water quality. Historically, inadequate septic systems have been identified as a high risk for the overall health of Christina Lake, and they were again identified as a concern several times during the public input survey. The risk presented by these systems has been discussed in previous investigations (Cavanagh et al. 1994), although no recent studies have been completed. Historical studies suggested relatively high risk due to systems not being adequately maintained and because of local topography. Available subsurface information was reviewed for this report, and suggests that some areas in the southern part of the community may have better subsurface filtration. Further information is provided in Section 4.3.4.
H2	Septic systems - community (including those with an Authorized Waste Discharge Permit)	Pathogens and nutrients from inadequately or improperly maintained community septic systems	Commercial/Industrial	IPZ	Subsurface flow	Non-point source	C	3	High	With respect to the magnitude of consequence, the impact of treatment (e.g., disinfection) of the water must also be considered. Currently, the source water is chlorinated, and coliforms are monitored throughout the distribution system. As long as there is sufficient chlorine concentration and contact time for viruses and <i>Giardia</i> , and the RDXB continues to issue a 'Boll Water Advisory' if the system exceeds Ministry of Health surface water treatment objectives for bacteria and/or turbidity, the risk to the population (from an illness perspective) is mitigated. This will be improved with the addition of UV disinfection, which can provide effective treatment for <i>Cryptosporidium</i> . Based on the rationale presented above, the likelihood was assigned a score of C (possible) and the consequence a score of 3 (due to the potential for significant but manageable moderation to normal operations, and potential for increased monitoring).
H3	Boating activities	Hydrocarbons from accidental fuel spills or cumulative minor leaks; pathogens, nutrients, soaps, solvents, etc. from greywater (sinks, showers) and blackwater (sewage) discharges	Commercial/Residential	IPZ	Direct release	Non-point source	D	3	Moderate	Based on local knowledge and discussions with the TAC, the majority of boats on the water do not have blackwater (i.e., sewage) storage capabilities. However, some boats do (including house boats) and there are no septic pump-out locations in the community. It is possible that blackwater and likely greywater (e.g., soaps) are discharged periodically to the lake. Accidental fuel spills are also a risk: many boats are refueled within the lake (at the Marina) and spillage is possible. The chance of these compounds reaching the intake in detectable levels is likely low, but this is difficult to confirm given the lack of understanding of lake flow processes. This hazard is primarily a concern during summer, when tourism is popular, which may reduce the risk of a contaminant reaching the intake due to lake stratification. However, there is insufficient knowledge of lake flow and stratification patterns near the intake to be able to develop specific management strategies. Furthermore, boating activities also occur in spring and fall, when the lake is not stratified.
H4	Commercial campgrounds	Pathogens and nutrients from humans, pets, and wildlife; runoff from lawns (soaps, fertilizers, pesticides, herbicides) and trailer pads (hydrocarbons, solvents)	Commercial	IPZ, Assessment Area A	Runoff and subsurface flow	Non-point source	C	3	High	Campgrounds within the IPZ may present risks to the drinking water system, similar to those described for private lakefront properties (e.g., fertilizers, pesticides, pathogens, sediment). Likelihood and magnitude scores of C and 3 were assigned, respectively, for the same rationale presented for Private Lakefront Properties (H6). However, the risk may be somewhat higher, due to the high density of people during summer. Furthermore, campground users are primarily tourists and as a result, may be less aware of the importance of Christina Lake as a drinking water source.
H5	Main Public Beach & small public beaches throughout IPZ, nature park	Pathogens and nutrients from human sources, domestic pets, and wildlife; pesticides/herbicides from park areas	Municipal	IPZ, Assessment Area A	Runoff and subsurface flow	Point-source	D	3	Moderate	Small recreational beaches, found throughout the IPZ, have no washroom facilities. The Nature Park and its trails, which are within the IPZ, are used by the public for walking (including pets). The Main Public Beach, which experiences high use in summer, is located near the intake, and provides both pit toilets and an in-ground septic system. It is relatively unlikely for any direct discharges to reach the intake (likelihood = D), which is 300 m offshore and at a depth of approximately 12 m. The consequence is considered the same as for septic systems and campgrounds: 3.
H6	Residential lakefront properties (not including septic hazard H1)	Nutrients, sediment, fertilizers, pesticides, solvents etc. from direct runoff	Residential	IPZ	Runoff and subsurface flow	Non-point source	C	3	High	Generally, properties along the lakefront appear to be well maintained, but it is possible to have direct runoff into the lake of on-site contaminants (e.g., fertilizers, pesticides, pathogens, sediment). Similar to septic systems, the likelihood and consequence scores are complicated by the potential cumulative nature of contamination. A likelihood score of C (possible) was assigned for conservative purposes (i.e., assuming cumulative impacts from several properties). The highest density of lakefront properties is situated along the southern lakeshore, and many are within the IPZ. A magnitude score of 3 was assigned due to potential to increase operating costs and require increased monitoring.
H7	Commercial lakefront operations (e.g. marina)	Pathogens and nutrients from direct discharges; hydrocarbons from fuel spills; solvents	Commercial	Assessment Area A	Direct release and runoff	Point source	E	2	Low	There is only one commercial marina with re-fueling capability, and it is located within Assessment Area A. The likelihood of an accidental fuel spill reaching the intake (over 6 km away) at detectable levels is considered rare (E) and the consequence is considered minor (2). Localized minor impacts due to cumulative inputs (either from small minor spills or runoff from the site) may occur, but are unlikely to reach the intake. The current OCP limits commercial use of waterfront properties to those already designated as Waterfront Commercial, and does not permit retail sale of fuel or rental sales or maintenance of watercraft in these areas (RDXB 2004). This will limit the potential for a marina or other commercial business to be established within the IPZ.
H8	Invasive mussels	Zebra or Quagga Mussel infestation impacting intake and other water system infrastructure	Natural	IPZ, Assessment Area A	Direct release	n/a	D	4	High	There are numerous campaigns underway by non-profit, municipal, and provincial bodies to prevent a mussel infestation, but prevention must rely heavily on awareness campaigns and public support. Given the presence of mussels in nearby states and provinces (e.g., Montana and Manitoba), and the high level of boat tourism at Christina Lake, an infestation of invasive mussels could occur at some time (likelihood = D) and a significant adverse (and costly) effect on the water system is possible (magnitude = 4).

Appendix B Table B-1
Christina Lake SWPP: Identified Hazards and Risk-Ranking Rationale

Hazard No	Hazard Name	Hazard Description & Contaminants of Concern	Hazard Type	Location	Contaminant Transport Mechanism	Type	Likelihood of Occurrence	Magnitude of Consequence	Risk	Risk Ranking Rationale and Discussion
H9	Organic matter influx	Formation of disinfection by-products (e.g. THMs and HAAs), due to interaction between organic matter and chlorine	Natural	IPZ, Assessment Areas A/B	Runoff	n/a	D	3	Moderate	Organic matter can react with chlorine, used in the disinfection process, and form disinfection by-products such as trihalomethanes (THMs) and haloacetic acids (HAAs), which are a human health risk. Organic matter can also affect turbidity and interfere with the treatment process. The likelihood of this occurring is complex and varied, and can only be properly assessed through monitoring. The BC Source Drinking Water Guideline recommends a maximum Total Organic Carbon (TOC) concentration of 4.0 mg/L to reduce the risk of disinfection by-product formation (ENV 2017). On average, TOC levels at EMS Site 200078 (Section 2.1.4) are below this guideline (average of approximately 2.6 mg/L across all depths), but a maximum of 6.0 mg/L has been recorded (Table 2-1). Therefore, a likelihood score of D could occur at some time) was assigned. The magnitude is 3, based on the potential for human-health concerns relating to the formation of disinfection by-products.
H10	Algal blooms	Reduced water clarity and interference with treatment; potential for production of Cyanobacterial toxins	Natural	IPZ	Direct release	n/a	D	3	Moderate	Given the relatively low nutrient levels (e.g., nitrogen and phosphorus), overall good quality of the lake, and lack of algal blooms to date (based on local knowledge), algal blooms are considered unlikely (likelihood = D). However, they could have a moderate impact on the drinking water system (consequence = 3; moderate but manageable effect on operations and increased monitoring), and the likelihood could increase if water temperatures warm (i.e., with climate change).
H11	Roads and stormwater discharges (not including Highway 3)	Sediment, hydrocarbon/chemical releases, nutrients, pathogens, salts, pesticides/insecticides from runoff and direct discharge to lake (via outfalls)	Municipal	IPZ, Assessment Area A	Direct release and runoff	Non-point source	C	2	Moderate	Based on local knowledge and input from the TAC and RDKB, stormwater is addressed primarily through infiltration (likely due to high gravel content) and there are no known stormwater outfalls into Christina Lake. Likelihood and consequence scores of C (possible) and 2 (minor; some manageable disruption and/or small increase in operating costs) were assigned.
H12	Institutions (Elementary School, Community Hall, Welcome Centre, Fire Hall)	Nutrients, hydrocarbons, solvents, pesticides/herbicides from subsurface flow	Municipal	Assessment Area A	Subsurface flow	Point source	E	2	Low	Given that the likelihood of a significant spill at these institutions is relatively low, and that the transport mechanism would be subsurface flow to the lake and then transport to the intake (further reducing the likelihood of reaching the intake at detectable levels), the likelihood is considered rare (E). The consequence is considered minor (2); manageable operational disruption and some increased monitoring costs.
H13	Upland Commercial/Industrial (e.g. gas stations, repair shops)	Hydrocarbons and other solvents from subsurface flow	Commercial/Industrial	Assessment Area A	Subsurface flow	Point source	E	2	Low	Although an accidental spill may be more significant than at municipal institutions (H12), the transport mechanism for this hazard would be subsurface flow to the lake and then transport to the intake (further reducing the likelihood of reaching the intake at detectable levels); therefore, the likelihood is considered rare (E). The consequence is considered minor (2); manageable operational disruption and some increased monitoring costs. There was one Authorized Waste Discharge Permit (6789; location shown on Figure 3-1) within Assessment Area A that allowed for the discharge of effluent to ground from a laundromat (as long as permitted conditions were met); however, it was cancelled in 2016.
H14	Residential non-lake front properties	Nutrients, sediments, fertilizers, from subsurface flow	Residential	Assessment Area A	Subsurface flow	Non-point source	E	1	Low	Low likelihood given contaminant transport mechanism (subsurface flow), relatively low housing density, and set-back from the lake surface (note: lakefront properties are addressed separately), the likelihood is considered rare (E). The consequence to the water system is considered insignificant (1).
H15	Highway 3	Hydrocarbons and other hazardous materials (from accidental spills); stormwater discharges	Municipal/Institutional	Assessment Areas A/B	Direct release and runoff	Non-point source	D	4	High	Highway 3 is the only transportation corridor connecting Christina Lake with the rest of the Kootenays and with the Okanagan. There is regular transport of goods along this route. The highway runs parallel to the lake, in some cases within 100 m of a steep drop-off to the lake surface. Sutherland Creek, which flows directly into the IPZ, also crosses the highway. A vehicular accident on Highway 3 resulting in a large spill either direct to the lake or one of the main tributaries was assigned a likelihood score of D (could occur at some time, 10-30% probability of occurrence in the next 10 years). Runoff and cumulative additions of contaminants such as hydrocarbons, road salts, and nutrients to the water source are also a risk, but a less quantifiable one. There have been no studies on water movement patterns (wind, currents) in the lake to date, so the travel time for a spill to reach the intake (or whether it even goes that direction) is unknown. Given the lack of understanding of transport times and flow mechanisms, a consequence score of 4 was assigned (for the potential to significantly compromise the system and result in a higher level of monitoring).
H16	Watershed recreation – including off-road motorized vehicle use and informal camping (i.e., at locations other than formal campgrounds)	Increased turbidity of inflows due to vehicle use in the watershed; hydrocarbons from accidental fuel spills or cumulative minor leaks; pathogens and nutrients from improper septic disposal (from informal camping)	Commercial/Residential	Assessment Areas A/B	Runoff	Non-point source	D	3	Moderate	Other recreational activities within the watershed that may present a hazard include the use of off-road vehicles (e.g., ATVs), hiking, horseback riding, and mountain biking, particularly when activities are near major tributaries. As reported by CLSS (2005), more recreation is likely water based (e.g. boating, swimming) than watershed based, due to limited access in the watershed. However, ATV use, mountain biking, hiking, and horseback riding are known to occur, and there are several local trails within the watershed. Informal camping (i.e., not at registered camp sites with proper septic systems) is also a hazard, but the extent to which this may be occurring is unknown. The likelihood of these activities affecting the intake water quality is considered D (could occur at some time), and the consequence is considered 3 due to the potential for increased operating costs and/or increased monitoring as a result of elevated turbidity and associated contaminants.
H17	Forestry activities (cutblocks and resource roads)	Erosion, sedimentation, nutrients, and organic matter	Forestry	Assessment Areas A/B	Runoff	Non-point source	D	4	High	Forestry activities were considered by the TAC to be a high risk in the watershed, given that the topography around the lake is very steep and primarily forested, and associated concerns that deforestation could have a large impact on the watershed by increasing sedimentation. Likelihood was assessed through a preliminary FCA estimate and review of available FSPs. For this SWPP, FCA was estimated at roughly 7% of the land base (Section 2.1.3.4), which is well below the 20% threshold used to determine when increases in peak flows can be anticipated (MOF 2001). Furthermore, available FSPs show limited activity planned in the watershed in the next 5 years (Section 2.1.3.4). Therefore, a likelihood of occurrence score of D was assigned (could occur at some time; 10-30% probability of occurrence in the next 10 years). The magnitude of consequence was assigned a score of 4 for the same reasons described for flooding (H18); the potential for abnormal operation of the system, increased monitoring, and potentially high capital and operational costs should turbidity increase such that filtration is needed.

Appendix B Table B-1
Christina Lake SWPP: Identified Hazards and Risk-Ranking Rationale

Hazard No.	Hazard Name	Hazard Description & Contaminants of Concern	Hazard Type	Location	Contaminant Transport Mechanism	Type	Likelihood of Occurrence	Magnitude of Consequence	Risk	Risk Ranking Rationale and Discussion
H18	Flooding (creek inflows & lake)	Turbidity/suspended sediment in inflows; disinfection by-products due to additional organic matter; pathogens/nutrients as a result of flooded septic systems	Natural	Assessment Areas A/B	Runoff	Non-point source	B	4	Very High	Flooding was assigned a likelihood of B (likely) given the events of recent years. McCrae Creek reportedly flooded in 2017, resulting in an influx of sediment to the lake. Christina Creek periodically backs up (approximately once every 10 years, as reported in CLSS 2005 and by the TAC). This occurred during the 2017 floods, and the backflow of turbid water into Christina Lake was evident in a photo provided by a member of the TAC. Flooding and an influx of sediment from Sutherland Creek, which discharges relatively close to the intake (approximately 750 m), has also been identified as a future risk. Furthermore, the likelihood of flooding is predicted to increase with climate change, which is anticipated to result in higher flows during spring. The primary concern with flooding is increased turbidity. Without further studies and a better understanding of lake flow processes, the extent to which flooding events may affect the intake is not well known; however, past events (turbidity spikes at the intake in May and June 2018; RDKB 2018) suggest that flooding can affect turbidity at the intake. A magnitude of consequence score of 4 was assigned, due to the potential for the treatment system to be compromised and for abnormal operation of the system (i.e., Water Quality Advisory due to elevated turbidity). If increased turbidity over time were to ultimately result in the need for filtration, significant capital and operational costs would be incurred.
H19	Wildfire	Increased erosion and organic matter due to changed landscape; fire retardant entering tributaries	Natural	Assessment Areas A/B	Runoff	Non-point source	C	4	Very High	Wildfires are a natural occurrence in BC, and there are concerns that a changing climate could increase the frequency and severity of fires. According to provincial mapping (ENV 2019a), a total of 25,990 ha or 55% of the land base within the watershed has been impacted by fire in the last 100 years. Historical fire suppression efforts have resulted in forest fuel build-up, leading to a higher likelihood that more severe fire events will occur in the future. A likelihood score of C was assigned (possible, range of 31-70% probability in the next 10 years [Table 4-1; qualitatively assigned]). Although the impact on the drinking water system would vary depending on the size, severity, and location of the fire, a consequence score of 4 was assigned due to the potential for the system to be significantly compromised. A wildfire event has the potential to temporarily shut down the entire drinking water system, and could have long-term impacts on source water quality by increasing erosion. Fire retardant (which is primarily water with a nitrogen-based additive) entering a tributary during fire fighting efforts is also a risk, but likely much lower than the risk presented by the overall impact to the watershed due to the short-term nature of use and effects of dilution (MOH 2018b).
H20	Wildlife	Pathogens from wildlife (via direct release or runoff in tributaries)	Natural	Assessment Areas A/B	Direct release and runoff	Non-point source	D	2	Low	The likelihood of pathogens from wildlife reaching the intake during non-flood conditions is considered unlikely (D) and the consequence is considered minor (2), particularly once a UV disinfection system is in place to augment chlorine disinfection.
H21	Agriculture	Nutrients (fertilizers and livestock); pesticides/herbicides from direct runoff or subsurface flow	Agricultural	Assessment Areas A/B	Runoff and subsurface flow	Non-point source	E	2	Low	Given the overall lack of agriculture in the watershed, limited ALR lands, and set-back from the lake, agriculture is not considered a key risk for the watershed. There are some ALR lands near Sutherland Creek, and runoff from these areas would represent the highest risk, but the likelihood of agricultural-related contaminants reaching the intake is considered rare (E). The consequence is considered minor (2); manageable operational disruption and some increased monitoring costs.

APPENDIX C - STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREATS

Table C-1 provides notes from the SWOT analysis completed with the TAC during the workshop held on August 21, 2019.

Table C-1
SWOT Analysis

SWOT	Notes
Strengths	• Good water quality. • Natural land use makes up much of the watershed. • Community has high enthusiasm and desire for source protection. • Non-profit organizations promote the importance of watershed protection (e.g., the Christina Lake Stewardship Society). • In general, good community knowledge of flooding concerns and potential impacts on septic. • Agriculture in the watershed is limited. • Relatively quick flushing rate in the lake (around 4 years). • Lake source – with the relatively large volume and longer residence time, lakes provide greater buffering capacity than other types of water sources (such as streams), and the stratification characteristics of lakes may provide added protection from surface contaminants, depending on the time of the year. • Location – Christina Lake is relatively far from major population centres, which may limit development to some extent. • Large portion of the watershed is encompassed by Gladstone Park, which is a protected park. • Lakeside development at the south end of the lake is generally built well above floodplain (not as many issues as could be expected during flooding, and have thick soils so septic fields should work well). • RCMP presence on the water in the summers. • RDKB professional administrators/operators.
Weaknesses	• Only one source • Private septic systems are only registered; there are not issued permits like larger community systems; therefore, there are no inspections or mechanisms to ensure proper maintenance. • Summer water extraction - 80% of yearly water system volume is used in two months, and there is insufficient storage within the water system. • Lack of filtration. • No sani-dump in Christina Lake (increases likelihood of blackwater discharges).
Opportunities	• Second line/intake could help with wet well operations (the well is not working effectively). • There is reportedly a pipe in the ground that could support future development of a second lake intake. Some infrastructure is also in place for a secondary intake on Moody Creek. The condition of this infrastructure would need to be confirmed. • There is a large gravel aquifer that could support a future groundwater supply. • Building permits/inspections (planning) could help to check septic field design/setbacks.

SWOT	Notes
	• Realtors could be used to help spread message of septic maintenance. • Non-profit organizations and societies (e.g., Christina Lake Stewardship Society and Gateway) have the ability to reach out to residents (e.g., via weekly email subscribers). • IHA could support a workshop with registered onsite wastewater practitioners, so that best practices can be shared by those that are most likely doing the installations. • Better conservation in summer months will help keep operation simpler, will need to invest less in storage, and could focus attention more on source protection. • The Christina Lake Water Utility's distribution infrastructure is apparently close to the Sutherland Creek Water Utility (which services the northeastern part of the community) in one location. There could be an opportunity to connect sources during an emergency (i.e., to provide a second source); however, the ability of Sutherland Creek water utility to provide sufficient supply during summer months may be limited. Other opportunities may exist for a secondary source, such as Moody Creek, or groundwater. • Improving public awareness of source protection may help the Water Utility in other ways (e.g., by increasing the value of the water source and improving public understanding of the importance of treatment and water system maintenance).
Threats	• Forest fires, and the associated increased risk with climate change. • Although currently relatively low, turbidity could increase over time (e.g., with climate change or changing land use), ultimately resulting in need for a costly filtration plant. • Nutrient (nitrogen) inputs may also affect the water source over time. • The RDKB has very limited control over many watershed activities. • Monitoring of point of use/point of entry difficult.