Mill Creek
Source Assessment Report

Prepared for the
Glenmore-Ellison Improvement District

Prepared by

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1.0 INTRODUCTION

1.1 PROJECT SCOPE

The Mill Creek Source Assessment Plan has been prepared to address a requirement of the water system Permit to Operate issued by the Interior Health Authority to the Glenmore-Ellison Improvement District (GEID) for each of its sources. The primary reason for this Plan is that Source Protection serves as the foundation for a multi-barrier approach to safe drinking water. The first step and cornerstone to a multiple barrier approach is the protection of high quality water. A potential outcome of the Source Assessment report could be an application by GEID for a filtration deferral. The IHA has developed an issue paper titled *Planning for Drinking Water Filtration Recommendation* that provides additional information in this regard [refer to http://www.bcwwa.org/annual_conference/documents/1.01IssuePaperFiltration.pdf]. Mill Creek is a source of surface water supply for GEID. This plan also includes the drainage area supplying the McKinley Reservoir since this area also has the potential to affect the water quality (refer to the *McKinley Reservoir Map* in Appendix A). The district supplies drinking water to approximately 14,000 residents within its service area. The GEID Mill Creek source, services an area that extends from the Ellison area (east of the Kelowna Airport), west to the Glenmore Valley (refer to the *Watershed Map* in Appendix A).

The intent of this plan is to identify and evaluate the hazards to drinking water quality and quantity, characterize the risks and proposed risk management strategies. Source water protection is the first barrier in a multi-barrier approach to protecting drinking water. Guidance is provided in the draft *Comprehensive Drinking Water Source to Tap Assessment Guideline* released by the Ministry of Health and the Ministry of Water, Land and Air Protection, March 2005. The key elements to be considered in this project are: Modules 1, 2, 7 and 8 of the guideline. The four guideline modules are summarized in the following sections:

MODULE 1

- Delineate the watershed and characterize the water source above the intake.
- Characterize the watershed including the influences of the mountain pine beetle (MPB).
- Consider the potential impacts of climate change on the water supply.
- Consider the possibility of developing new storage and the impacts of raising existing dams.

- Prepare maps illustrating the location of all infrastructure, the source area and assessment area boundaries, and bio-geophysical information; digital mapping should to be compatible with local government and water purveyors GIS system.

MODULE 2

- Update the *Interior Watershed Assessment Procedure* (IWAP) report using the IWAP Guidebook produced by the Ministry of Forests dated April 1999 as guidance. The IWAP report includes a summary of the overall equivalent clear-cut area (ECA) and the road densities to 2007.
- Conduct contaminant source inventory within the watershed area upstream of the intake for potential contaminants including reconnaissance level field inspections.

MODULE 7

- Evaluate the public health protection barriers in place in the watershed.
- Provide a drinking water risk assessment based on the identified hazards and barriers.

MODULE 8

- Provide recommendations to improve drinking water safety and sustainability.

WATERSHED ASSESSMENT REPORT

Complete a Watershed Assessment Report based on the results from the *Comprehensive Drinking Water Source to Tap Assessment Guideline* Modules 1, 2, 7 and 8 including the results of the updated IWAP and best practices for protection of source water quality.

1.2 PROJECT TECHNICAL ADVISORY COMMITTEE (TAC)

The *Drinking Water Protection Act* provides the authority to the drinking water officer to order a water supplier to prepare an assessment. Since a watershed protection plan has been included as a requirement in the Operating Permit issued by IHA to GEID, it was appropriate to create a technical advisory committee that included representatives from IHA and the Ministry of Environment (MoE) as part of the planning process that could provide input and offer review comments as the plan was developed. The advisory committee for this plan includes the following:

- Dale Thomas - IHA
- Solvej Patschke – MoE

The project consultant Dobson Engineering Ltd.

1.3 DESCRIPTION OF THE GLENMORE-ELLISON IMPROVEMENT DISTRICT INFRASTRUCTURE

The current infrastructure that has been developed by the GEID is presented on the *Watershed Map* in Appendix A and includes:

- Intake works
- Moore Reservoir
- Postill Reservoir
- South Lake Reservoir, and
- McKinley Reservoir (terminal reservoir).

The water system intake for raw water is located on Mill Creek approximately 2 km upstream from the Kelowna Airport. Water is then delivered to the Ellison area and to the McKinley Reservoir, which supplies the Glenmore Valley. Water is passed through a screening plant at the intake and treated with chorine. For the Ellison distribution system water is also chlorinated as it enters the Glenmore Valley distribution system at the McKinley Reservoir (a second point of raw water intake). GEID holds water licenses for approximately 15,115 ML of water from Mill Creek. The actual water used in 2006 was 6,360 ML.

GEID holds water licenses to store approximately 9,065 ML in its reservoirs. GEID operates its system by storing the spring runoff in the upland reservoirs, Postill, Moore, and South Lake, and releasing water from storage as required meeting downstream demand.

1.4 ASSESSMENT APPROACH

This draft report presents the results for Modules 1, 2, and 7. The IWAP update has been included as part of Module 2. The Ministry of Forests describes the purpose of a watershed assessment as:

> *The Watershed Assessment Procedure (WAP) is an analytical procedure to help forest managers understand the type and extent of current water-related problems that may exist in a watershed, and to recognize the possible hydrological implications of proposed forestry-related development or restoration in that watershed. The WAP considers the cumulative effects of forest practices on the aquatic environment. The assessment of hydrological impacts focuses on: 1) the potential for changes to peak streamflow; 2) the potential for accelerated landslide activity; 3) the potential for accelerated surface erosion; 4) channel bank erosion and changes to channel morphology as a result of logging the riparian vegetation; 5) the potential for change to the stream channel; and 6) the interaction of all of these processes, an evaluation of which indicates the sensitivity of the watershed to further forest development. The assessment also draws attention to natural processes occurring in the*

watershed. Using the results of a WAP, forest managers can make recommendations to prevent or mitigate the impacts of forestry-related activities in the watershed. Results can also be used to guide watershed restoration activities.[1]

The WAP process is modified to include a review of all impacts in the watershed that have the potential to affect the source water. The process provides useful data on the change in disturbances resulting from forest development over time and this data can also be used to assess the change in other impacts such as cattle movement and recreation that are related to changes in access.

Section 18(c) of the DWPR states: This section of the regulations specifies that the assessment is to identify, inventory and assess the monitoring requirements for the drinking water source and water supply system. Provide such in the assessment report with a view towards the adequacy of the existing monitoring program for source conditions and to provide data tending for future treatment infrastructure.

The purpose and typical content of a source assessment report as outlined in Section 18 of the *Drinking Water Protection Act* are:

The purpose of an assessment is to identify, inventory and assess:

(a) the drinking water source for the water supply system, including land use and other activities and conditions that may affect that source,
(b) the water supply system, including treatment and operation,
(c) monitoring requirements for the drinking water source and water supply system, and
(d) threats to drinking water that is provided by the (water) system.[2]

A 1:20,000 scale map of the watershed detailing the hydrography, waterworks infrastructure, historical forest development and TRIM data is provided in Appendix A (refer to the *Watershed Map*).

The results from the 2008 Contaminant Field Inventory are provided in Appendix B as well as the results of the Road Summary. A copy of the *Field Map* that indicates the location of all the identified crossings in the watershed with identification (ID) numbers is provided in Appendix A. The column "Xing ID" refers to the crossing numbers shown on the Field Map.

1.5 REFERENCES

- BC Ministry of Health Services, BC Ministry of Water, Land and Air, 2005. *Comprehensive Drinking Water Source to Tap Assessment Guideline*.

[1] Interior Watershed Assessment Procedure Guidebook. Second Edition, Version 2.1, 1999. Ministry of Forests.

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1.6 ABBREVIATIONS

CFU	Colony Forming Unit	MoTCA	Ministry of Tourism, Culture and the Arts
GIS	Geographical Information System	NTU	Nephelometric Turbidity Unit
HAA	Haloacetic Acid	Q	Refers to volume over time (L/s, m^3/s CFS)
IMAC	Interim Maximum Acceptable Concentration	RDCO	Regional District of Central Okanagan
IHA	Interior Health Authority	SCADA	Supervisory Control and Data Acquisition
IWAP	Interior Watershed Assessment Procedure	TCU	True Color Units
km^2	square kilometre	THMs	Trihalomethanes
L	litre	TOC	Total Organic Carbon
L/s	litres per second (flow rate)	µg/L	micrograms / litre (parts per billion)
m	metres (length)	WAP	Watershed Assessment Procedure
m^3/s	cubic metre per second, (flow rate)	GEID	Glenmore Ellison Improvement District
mg/L	milligrams/litre (parts per million)	SCHR	Stream Crossing Hazard Rating
ML	megalitre (one million litres)	WTP	Water Treatment Plant
MOE	Ministry of Environment	WSC	Water Survey of Canada
MoFR	Ministry of Forests & Range		

2.0 MODULE 1 – CHARACTERIZATION OF THE MILL CREEK SOURCE

2.1 DESCRIPTION OF PROJECT AREA

2.1.1 SOURCE AREA

The Mill Creek watershed above the intake has a watershed area of ~74 km^2, generally speaking, this is a relatively small source area. There are three reservoir lakes (Moore, Postill and South Lakes) and numerous other small lakes (Geen, Meadow, Rodney, Hereron, and Conroy Lakes) and swamps. The Mill Creek Mainstem channel drains the Postill Lake Reservoir, and receives flow from three tributary channels; Bulman, Conroy, and Morrison Creeks. Of the three main tributary channels only Conroy Creek does not have an upland reservoir. The community watershed is that portion of the watershed upstream of the GEID intake. Detailed maps of the Mill Creek watershed are provided in Appendix A (refer to the *Watershed Map*).

2.1.2 INTAKE

The water system intake is located approximately 2 km northeast of the Kelowna Airport and 15 km upstream from Okanagan Lake. The intake is not buffered from the unregulated runoff downstream of the upland reservoirs. The travel time from the reservoirs to the intake is a matter of hours (identified as approximately 7 to 8 hours by GEID). Activities and contaminants within the unbuffered area pose the greatest risk from turbidity[3] and bacteriological contamination especially as a result of localized extreme rainstorms. Unfortunately there was no available data to correlate these impacts at the intake at this time.

Runoff upstream of the upland reservoirs is buffered from the intake, as it has to pass through the reservoirs before entering the mainstem creek. Residence time in the reservoirs will vary depending upon the time of year but typically GEID will use approximately 50% of its stored water during the year. This would suggest that water could reside in the reservoirs for up to two years depending upon climate conditions and downstream demand. The buffered area provides a level of protection at the intake from contamination if releases from the reservoir can be controlled should there be a contamination event upstream. Although not designed as settling ponds (and should not be treated as such) the reservoirs do provide the opportunity for some contaminants and sediment to settle. During the spring freshet once the reservoirs are full and spilling, this buffering benefit is reduced.

[3] Turbidity has been used in this report as a surrogate for suspended sediment. Refer to the paper *Establishing the Relationship between turbidity and Suspended Sediment Concentrations,* 2003, C.P. Holliday, T.C. Rasmussen, and W.P. Miller, Proceedings of the 2003 Georgia Water Resources Conference for details on the relationship between turbidity and suspended sediment.

2.1.3 McKinley Reservoir

The McKinley Reservoir, a terminal reservoir, is supplied from Mill Creek. The reservoir has a small watershed area that drains it but there are no surface streams. A public road crosses the west side of the reservoir creating a risk from a vehicle accident affecting water quality. (Recently a vehicle did plunge into the reservoir, fortunately with limited impacts to the water quality.) There is also a sanitary sewer trunk line within the road right of way along the west side of the reservoir. GEID is working with others including the City of Kelowna to realign the road and the sewer trunk to reduce the risks to the reservoir.

The reservoir is surrounded by private land to the west and north that is under development as a golf course. GEID has worked closely with the developers to protect the reservoir from any impacts from the development including the installation of a security fence restricting access to the reservoir area.

2.2 Licensed Stakeholders and other Interested Parties

The following is a list of the stakeholders and other parties with an interest in the watershed:

- Glenmore-Ellison Improvement District (GEID) – Water licensee, water purveyor for domestic and agricultural water
- Other Water Licensees
- Tolko Industries Ltd., BC Timber Sales – Forest licensees
- Coldstream Ranch, Albert Pelligrini - Grazing licensees
- Interior Health Authority – Safe drinking water
- Ministry of Environment, Water licensing, Water allocation, Fisheries, Ecosystems, Pollution and Prevention – Source water protection
- Ministry of Forests and Range – Forest and range resources
- Ministry of Energy, Mines & Petroleum – Mineral/aggregate resources
- Ministry of Tourism, Culture and the Arts – Recreation sites
- First Nations – Land stewardship
- Postill Lake Lodge – Recreation and tourism
- City of Kelowna - Planning and development of municipal boundaries
- Regional District of Central Okanagan - Planning and development on Crown land within regional district boundaries

2.3 Biophysical Characterization of Source Area

Within the Interior Plateau physiographic subdivision, the Mill Creek community watershed is located on the east side of the Okanagan Valley where the Thompson Plateau joins the Okanagan Highlands. Several small to medium sized lakes/reservoirs are located in the uplands of the watershed including Moore Reservoir, Upper/lower Conroy lake, Postill Reservoir, South Lakes Reservoir, Hereron, Rodney, Meadow, and Geen lakes.

The western portion of the watershed area is located on the east slope of the Okanagan Valley where the mainstem channel descends through a deep canyon to the intake in an east to west direction. Downstream of the intake, the creek turns sharply to the south through the City of Kelowna into Okanagan Lake. Elevations for the watershed range from 540m at the Intake to 1650m near Geen Lakes southeast of the Postill Reservoir.

The upper watershed area is generally a benign, gently rolling plateau terrain with limited evidence of instability. Along its mid portions Mill Creek flows through a deep entrenched bedrock canyon before emerging within the urban areas of the City of Kelowna. The soil erosion potential is low in the upper elevations of the watershed and the areas around Postill Reservoir and the Conroy Creek mainstem. Areas identified as moderate to high soil erosion potential are located along the middle and lower reaches of the watershed along the Mill Creek mainstem channel and Bulman Creek below Moore Reservoir.

Biogeoclimatic zones range from Interior Douglas Fir (IDF xh1 to mw1) along the lower reaches of the creek above the Intake; there is a band of Interior Cedar Hemlock (ICH mk1) in the middle reaches and Montane Spruce (MSdm1) to Engelmann Spruce Subalpine Fir (ESSF dc1) in the uplands. Annual precipitation for lower and mid elevations would be similar to those reported for Environment Canada's Kelowna Airport weather station (*#1123970*) that reported the normal monthly range of precipitation of 220mm to 370mm for the period 1961-1990. There is also a snow course in the upper watershed, "Postill Lake" (snow course # 2F07) that has been operated since 1950. The maximum snow water equivalent as recorded for April 1st is 224mm of water.

2.4 HYDROLOGIC CHARACTERIZATION OF SOURCE AREA

Mill Creek is a snow-dominated hydrologic system with peak flows occurring from late-April to mid-June. Water Survey of Canada operated the hydrometric station *Kelowna Creek near Kelowna (stn # 08NM053)*. The station was established in 1922 with continuous record from 1969 until 1996 when it was discontinued. The runoff hydrographs for low, normal and high flow periods are illustrated in Figure 1. This graph is provided to illustrate the shape and timing of runoff. GEID operates streamflow stations at the intake, on Mill Creek below Postill Reservoir, and on Postill Reservoir. Figure 2 illustrates the typical daily discharges in Mill Creek below the GEID intake for the year 2005-2008.

Peak flows at the intake are generated in the upper watershed area typically above the 1,450 m contour from snowmelt or rain-on-snow events during the spring freshet. The natural hydrologic regime of the Mill Creek watershed has been altered as a result of the construction of the upland reservoirs, Postill Reservoir, Moore Reservoir and South Lake Reservoir. Changes to the peak flows are variable depending upon the amount of storage available in the reservoirs but are generally reduced when reservoirs are still filling (below spillway elevation).

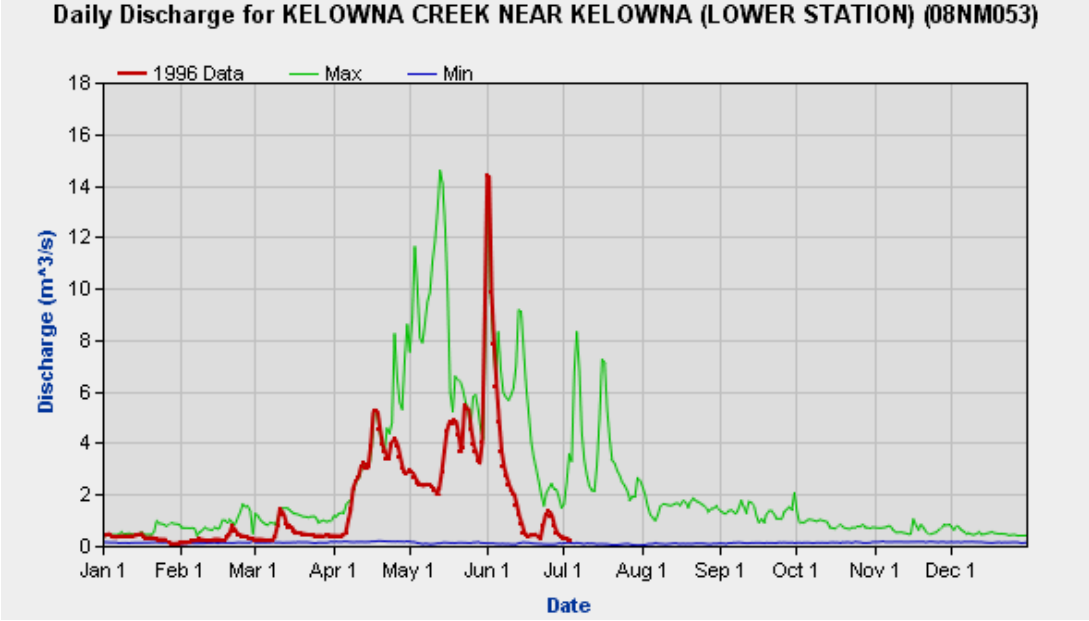


Figure 1. Daily discharge data for Mill Creek near Kelowna

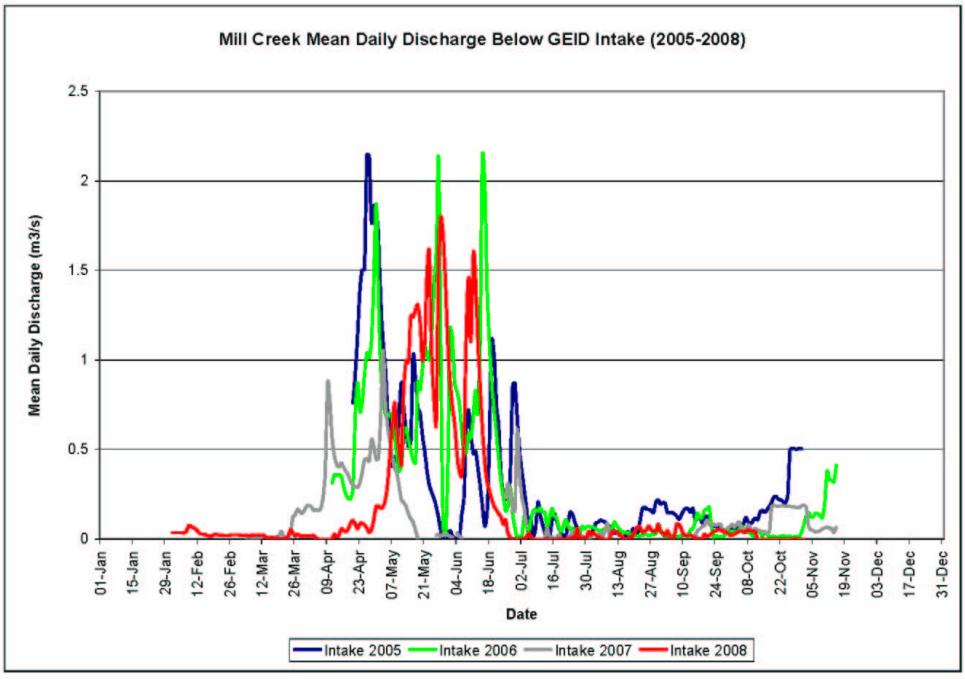


Figure 2. Daily discharges for Mill Creek below GEID Intake

The GEID has installed three hydrometric stations in the watershed to provide it with water level and streamflow data for water planning and management purposes. They include one station on the Postill Reservoir monitoring reservoir levels, another downstream of the reservoir monitoring stream flows, and a third station at its intake monitoring flows.

The watershed has been divided into three hydrologic zones, and is identified on the Watershed Map in Appendix A. Zone 1 is the un-buffered area immediately upstream of the intake. This zone is considered un-buffered because any sediment or contaminants that enter the streams will be transported directly to the intake. Zone 2 is the partially buffered zone above lower Conroy Lake, it is assumed the lakes and swampy area will allow for settlement of some sediments or contaminants. Zone 3 is the buffered area upstream of the Moore, Postill and South Lake reservoirs. These areas above the reservoirs have the greatest buffering effect due to the storage capacities of the reservoirs and outflow control below full pool levels. Although they should not be considered as settling ponds and are not designed as such, the reservoirs do catch and settle sediment and some contaminants from inflow. The effect of these reservoirs will vary depending upon the climate conditions and the downstream demand. The McKinley Reservoir is considered un-buffered, as it is a terminal reservoir with a raw water intake.

Based on limited data from sampling in the Duteau Creek watershed it is likely that fecal coliform and sediment loading at the Mill intake is a function of stream discharge (bankfull flow) and level of physical activity in the watershed (manure deposits on the stream margins). Following the spring freshet, as flows decline, activity increases in and around streams from wildlife, cattle and humans resulting in sediment disturbance and fecal deposits. This activity continues through the fall until winter. As the snow melts in the spring and the flows begin to increase starting with runoff from the un-buffered zone, it will mobilize the disturbed sediment and fecal material resulting in increasing levels at the intake. The highest sediment and fecal coliform levels normally occur at the peak of the hydrograph when the reservoirs are full and spilling. The high turbidity and fecal coliform levels are typically of short duration, and the levels decline rapidly as the available source material is scoured from the channels and as the stream flows decline. The process repeats itself annually. Extreme rain events can also increase the stream discharge dramatically increasing the likelihood of downstream delivery of sediments and fecal coliform. GEID collects samples for coliform analysis at a number of permanent sample sites around the watershed but the analysis does not include RNA analysis. Burke Phippen reported in 2001 that the distribution of E.coli based on ribosomal RNA results suggest that within the GEID watershed that ~34% was attributable to cattle, ~26% to humans and ~32% to wildlife.[4]

[4] The Effects of Recreation on Drinking Water Quality within the Lambly, Kelowna and Mission Creek Watersheds, Kelowna, British Columbia 2000. Burke Phippen, RPBio, BWP Consulting, May 2001.

GEID manages the water storage through the collection of spring runoff during the snowmelt period from April through June in the three upland reservoirs. Water demands during the spring runoff period are normally met through the diversion of stream flows originating from those unregulated portions of the watershed below the reservoirs, as well as groundwater and drawdown of McKinley Reservoir. As the water system demand increases above natural stream flow in June, additional flow is released from the reservoirs.

2.5 SOURCE HAZARDS TO DRINKING WATER QUALITY AND QUANTITY

The identification of potential hazards to drinking water in the source area was initially undertaken as a component of Module 1. This involved reviewing the activities that occur in the watershed and the potential hazards that they may pose to drinking water, including consultation with the GEID staff to confirm the likely hazards, and to identify any that may have been overlooked. The results of this review provided the basis for the field assessment tasks that were undertaken in Module 2.

The primary anthropogenic hazards to drinking water quality in the source watershed are related to forest development activities, grazing use, and recreation use. With the exception of the area surrounding McKinley Reservoir, there are only limited private lands and subdivisions upstream of the intake. There is fishing lodge with 12 cabins plus a private residence on the Postill Reservoir that were built several decades ago. There is also a single cabin on Twin Lakes that is part of the lodge facilities. The lodge has 13 campsites on and near the reservoir, and there is a designated recreation site with campsites on the reservoir as well.

The province has proposed the sale of lease lots in the watersheds in the Okanagan to the leaseholders and the conversion of the lots to private lots. This proposal has been opposed by the GEID, all other water suppliers in the valley local governments and the IHA. The province has deferred any decision on this proposal at this time.

In addition there is significant recreation day use in the watershed. The intake is located at the Crown land/private land interface. Recreational vehicle use was noted on most roads in the watershed, and includes numerous trails created by riders connecting lakes, reservoirs and wetlands. In general, locked gates and signs do not deter access to sensitive areas. Also included under the recreational banner is illegal dumping, which was noted in numerous locations over steep fill on Postill Lake Road and other locations. The location of the watershed, in close proximity to urban areas, adds to the influx of people into the watershed. Anthropogenic hazards to the drinking water quality at McKinley Reservoir (a terminal reservoir) are related to urban development and recreational use.

The potential hazards to the drinking water at the Intake and the McKinley terminal reservoir are summarized in Table 2-1. Sediment sources in the table were separated by source initiation between natural, industry, range and recreation. It was

Table 2-1. Module 1 – Potential Hazards to Drinking Water Quality and Quantity at Intake

Hazard Type	Drinking Water Hazard	Possible Effects
Physical	Natural sediment load from channel erosion and mass wasting	Turbidity levels that exceed the exclusion criteria set out in the IHA issue paper *Planning for Drinking Water Filtration Recommendation* may require filtration[5] Compromised disinfection process [MC][6] Risk to human health
	Sedimentation from industrial roads and road crossings	Increased sediment load resulting in turbidity levels that exceed the exclusion criteria set out in the IHA issue paper *Planning for Drinking Water Filtration Recommendation* may require filtration [MC] Compromised disinfection process [MR] Risk to human health
	Sedimentation from range use in and around streams	Increased sediment load resulting in turbidity levels that exceed the exclusion criteria set out in the IHA issue paper *Planning for Drinking Water Filtration Recommendation* may require filtration [MC] Compromised disinfection process [MR] Risk to human health
	Increased turbidity from natural and human activities including unregulated off-road vehicle use	Turbidity levels that exceed the exclusion criteria set out in the IHA issue paper *Planning for Drinking Water Filtration Recommendation* may require filtration [MC] Compromised disinfection process [MR] Risk to human health
	Organic material	Reaction of organics (total organic carbon) with water disinfection resulting in formation of Trihalomethanes (THMs) in drinking water exceeding TTHM 100 ug/L IMAC and the production of Haloacetic acid (HAA) as a disinfection by-product [MC] Risk to human health
	Water quantity	Lack of adequate supply could result in public health issues [MC] Interruption to water supply could occur if a failure occurred at a critical infrastructure location [MC] Increased peak flows due to loss of forest cover and associated increase in sediment transport [MC]
	Wildfire	There will be an increasing risk of wildfire in the watershed as the mature pine dies. A wildfire could cause a serious degradation in water quality related to increased sediment load, phosphates, nitrates, fire retardants and metal mobility increasing treatment costs [MC]
Biological	Bacteriological contamination from wildlife/cattle/human presence in and along streams and reservoirs	Contravention of DWP Regulation for fecal coliform bacteria, E.coli, and total coliforms in drinking water [MC] [MR] Risk to human health resulting in pathogen loading beyond the water system treatment capacity.
	Protozoa (Giardia, Cryptosporidium)	Risk to human health resulting in pathogen loading beyond the water system treatment capacity.
	Viruses	Risk to human health resulting in pathogen loading beyond the water system treatment capacity.
	Algal blooms in reservoirs	Risk to human health Cytotoxin contamination, Trihalomethanes (by-product of disinfection process) **[MC] [MR]** Increased turbidity from algal cells reaching intakes [MC] [MR]
Chemical	Total Organic Carbon	Reaction of organics (total organic carbon) with water disinfection resulting in formation of Trihalomethanes (THMs) and, HAA's in drinking water exceeding TTHM 100 ug/L IMAC [MC] Risk to human health resulting in pathogen loading beyond the water system treatment capacity.
	Petroleum contamination from an industrial fuel spill or vehicle accident and gas powered boats on reservoirs	Contamination of drinking water [MR] Risk to human health
	Herbicides	Contamination of drinking water [MR] Risk to human health

[5] IHA Issue Paper: *Planning for Drinking Water Filtration Recommendation*, HPIP019 February 2008

[6] Abbreviations [MC] refer to possible effects in the Mill Creek source area and [MR] refer to possible effects in McKinley Reservoir.

not possible to separate the pathogens by source due to lack of data. The only pathogen sampling in the watershed was undertaken for the Ministry of Environment in 2000 by BWP Consulting that submitted a report titled *The effects of Recreation on Drinking Water within the Lambly, Kelowna and Mission Creek Watersheds, Kelowna, British Columbia*, that indicated likely sources of *E.Coli* based on ribosomal RNA analysis of the samples collected. Details on where the actual samples were collected were not available.

2.6 SOURCE WATER QUALITY AND QUANTITY

2.6.1 WATER QUALITY

The Ministry of Environment, Lands and Parks operated a network of water quality stations in the Mill Creek watershed from 1996 –1998 (automated station). The results of sampling program are summarized in the report *Water Quality Objectives for Kelowna Creek Community Watershed* dated January 2001. GEID provided raw water data from 2007 at specific sites in the watershed including at the intake. (For laboratory summaries refer to Appendix C.) A summary of the available data at the district's intake is provided in Table2-2. The mean raw water turbidity at the intake reported for 2008 was approximately 3 NTU during the period June to October. Table 2-2 below provides a summary. Additionally, GEID collected grab samples at seven locations within the watershed, including the intake, and are also included in that report. The results indicate that the raw water turbidity was generally low although the maximum reading was 29 NTU at the intake. The temperature, conductivity and pH were all within the acceptable range. However, both coliform and E.Coli levels at the intake exceeded the 90th percentile threshold of 10 total coliform/100 mL.

Table 2-2. Water Quality Summary

Parameter	Objective	1996-1998	2007[1]	2008[1]	2009[1]
Turbidity (NTU)	95th percentile of at least 5 samples in 30 days ≤ 5 NTU July 1 – March 31 95th percentile of at least 5 samples in 30 days ≤ 5 NTU April 1 – June 30	3.8 NTU for 149 samples, max = 29 NTU	Raw water at intake (av. for July – Sept = 4.03 NTU)	Raw water at intake (av. for June – Oct = 3.32 NTU)	Raw water at intake (av. for June – Sept = 3.07 NTU)
Temperature	15 °C	7.3°C		-	-
Conductivity	700 µS/cm	183 µS/cm	-	-	50 µS/cm
pH	6.5-8.5	7.72	6.03	6.74	7.05
Dissolved Oxygen	8 mg/L 30-day mean (aquatic)	12.0 mg/L	-	-	-
Fecal Coliform	≤10 CFU/100 mL (90th percentile of 10+ samples collected over a 30-day period)	31.2	Total Coliform Aug/Sept = 130-2600	Total Coliform Jun 6 = 94	Total Coliform Aug 10 = ≥690

Table 2-2 cont'd. Water Quality Summary

Parameter	Objective	1996-1998	2007[1]	2008[1]	2009[1]
E.Coli	≤10 CFU/100 mL (90th percentile of 10+ samples collected over a 30-day period)	27	Av. for Aug/Sept =30.7 CFU	Jun 6 = 4 CFU	Aug 10 = ≥49 CFU
Phosphorous	10µg/L	0.036mg/L	-	-	-
Dissolved solids	500 mg/L	6.5 mg/L	-	-	-

1. Results from data summaries provided by GEID. Copies of laboratory summaries are provided in Appendix C.

In 2001 the report *The Effects of Recreation on Drinking Water Quality within the Lambly, Kelowna and Mission Creek* was released by the ministry. The ribosomal RNA for *E.coli* results reported for the watershed is summarized in Table 2-3. The table indicates a significant cattle, wildlife, and human fecal contribution. It would be very useful to have current information on *E.coli* sources in the watershed to compare with this earlier data.

Table 2-3. *E.Coli* Sources and Distribution in Mill Creek*

Source	No. of Samples	Percent
Cattle	57	34.1
Wildlife	54	32.3
Humans/domestic animals	43	25.7
Unknown	13	7.8

* Based on samples collected in 2000.

2.6.2 WATER QUANTITY

Water demand for GEID has been relatively constant over the past decade even with land use changes in the Glenmore Valley, from predominantly agriculture to predominantly urban. GEID supplements its surface water supply with groundwater but its surface supply will always be an important component of its total supply. The key issues relative to quantity are the amount of spring runoff in the upper watershed upstream of the storage reservoirs and the opportunity to increase the volume of water available to meet future demands. GEID is presently in the process of developing an intake on Okanagan Lake that would involve an existing water license on the lake plus a relocation of the point of diversion for some of its volume under license on the creek. It would still maintain its intake on the creek to supply water during the winter when it meets the necessary water quality requirements as well as for water for blending with groundwater.

Mountain pine beetle infestations are a concern in the watershed. There has been harvesting of beetle-infested stands in the past and these areas are in

recovery. There are however stands of mature lodgepole pine remaining in the watershed that are under attack at this time by the pine beetle and it is projected by the Ministry of Forests and Range that most of the mature lodgepole pine will be killed by the beetle over the next 3 – 5 years during which time the runoff will gradually increase. The loss of the forest cover may result in increased runoff and increased peak flows. It is estimated that there may be increased runoff for several decades until the stands recover. Additional details on the impacts of the pine beetle are provided in section 2.8.

Water yields could be compromised by the potential decrease in snow pack as a result of the changing climate. Recent estimates by the Atmospheric Environment Service for the April 1st snow pack in the Okanagan indicate that by 2020 the mid-elevation snow pack may be reduced by 11%, 40% by 2050 and 50%[7] by 2080. These decreases in snow pack combined with increasing summer temperatures may result in long-term supply issues for the GEID.

2.7 INTEGRITY AND VULNERABILITY OF INTAKE

The intake on Mill Creek is an on-stream intake that is vulnerable to impacts from contaminants and sediment loads. The intake is very small and provides minimal opportunity for settling anything but bedload. The intake includes automated screening works but this would be overwhelmed should there be an extreme event that would transport excessive amounts of bedload and debris into the intake pond. The terrain in the proximity of the intake is primarily bedrock that does not offer GEID many feasible opportunities to modify the intake to reduce the risks. On the other hand the district is fortunate in that it does have an alternate groundwater well in the Ellison area that can provide sufficient water to meet limited domestic demands should the district lose the surface supply temporarily. The wells would not provide sufficient flows to meet the irrigation demands in the Ellison area and, depending upon the time of year the loss of irrigation supply could result in significant crop losses and/or tree damage (orchard trees).

GEID has the McKinley Reservoir located in the Glenmore Valley that is supplied with water from the intake on Mill Creek and not only provides a further opportunity for settling but it also could supply the Glenmore Valley area with water from groundwater wells to meet limited domestic demand if the intake was temporarily shut down. The reservoir is connected to the Mill Creek intake by a large diameter pipeline.

For the long-term, when the intake is developed on Okanagan Lake, GEID would have the ability to supply from the lake and/or from the Mill Creek intake. The lake intake would offer another source barrier against hazards in the watershed and those associated with the existing intake.

[7] Friscka, G., Atmospheric Environment Service, 2007, Presentation to City of Kelowna.

2.8 FOREST DEVELOPMENT

Activities have been conducted in the Mill Creek watershed over the past 70 years. In the early years, partial cutting systems such as diameter limit and selection logging were employed in the lower elevation stands of timber. Over the last 35 years, more clear-cut harvesting has occurred in the even-aged lodgepole pine and Engelmann spruce-sub alpine fir stands at higher elevations. In the last 20 years, a significant portion of the annual harvest has come from salvage logging of lodgepole pine stands infested by the mountain pine beetle. The 2007 equivalent clear-cut area in the Mill Creek watershed is ~18% that is a ~3% increase since 1998.

Since 1996, there have been several Forest Renewal BC (FRBC) projects completed in the watershed. Field visits confirm that the work appears to be effective at reducing sediment sources to the stream network. A section of the Postill Lake Road was relocated that eliminated numerous sedimentation and stability issues along the old road. Roads and trails on either side of the Moore Reservoir saddle dam have been deactivated and appeared functional although some impacts from recreational use was evident (rutted crossditches/waterbars). The road around the Postill Reservoir has been deactivated to a semi-permanent state (culverts typically in place) and gated at either end although recreational vehicles are bypassing these barriers and ignoring the signs. Numerous roads above the Postill Reservoir have been deactivated to a semi-permanent level although there are still some culverts in place including wood culverts.

A bridge crossing (Site 59 on *Field Map* Appendix A) on the mainstem channel above Postill Reservoir (unnamed creek draining Hereron Lake) has been removed and closed to vehicle traffic, however recreational vehicles bypass the closure using a ford upstream, which is introducing sediment into the creek. Roads west of the South Lake Reservoir have been deactivated to a semi-permanent level with the exception of those nearest to Mill Creek where the culverts have been removed. These roads are heavily used by recreational vehicles. Many crossings in this area were considered to be contributing moderate amounts of sediment due to the disturbed and exposed soils (refer to Sites 26, 29, 30 on *Field Map* Appendix A and also details in Appendix B).

2.9 HISTORY OF WATER USE

Built in 1911 the Postill Reservoir was designed to supply 4,000 acres of irrigation in Glenmore and 800 acres in the Bulman subdivision. The dam was reconstructed in 1932, and raised in 1947 by five feet to increase storage. Raised and rebuilt twice since then, the dam now holds 4,538 acre-feet. The gravity fed water supply system originated at the intake on Mill Creek east of Ellison, and included the Postill Reservoir, South Lake Reservoir, McKinley Regulating Reservoir, and 34 miles of concrete ditches, flumes and steel pipelines. The South Lake Reservoir, originally built in 1918, was reconstructed and raised in the 1950's. Improvements in the 1960's included the complete rehabilitation of its distribution system from open

canals to underground, pressurized pipelines. Chlorine was added in the 1970's. Moore Lake Reservoir was also constructed in the 1970's.

Glenmore and Ellison Irrigation Districts were amalgamated on April 5, 1990 to form the Glenmore-Ellison Improvement District an independent public water utility. Currently the district supplies water to approximately 14,000 people (6,000 services) in Kelowna. The district has a serviceable area of 3,645 hectares. Water is still collected and stored in Postill, Moore, South, and McKinley reservoirs. Five wells augment the district's water supply. In 2004 the district took over the McKinley Landing area that is serviced by water from Okanagan Lake.

As indicated previously the district is currently developing plans for a large intake on Okanagan Lake near McKinley Landing that would be the major intake for its system.

2.10 SUMMARY

The intent of this section is to characterize Mill Creek upstream of the GEID intake, which includes a source watershed area of 74km^2 with elevations ranging from 540m at the intake to 1,650m in the Geen Lake area. The *Mill Creek Community Watershed* is that portion of the watershed upstream of the GEID intake.

Biogeoclimatic zones range from Interior Douglas Fir (IDF xh1 to mw1) along the lower reaches of Mill Creek above the intake, to Interior Cedar Hemlock (ICH mk1) in the middle reaches, to Montane Spruce (MSdm1) and Engelmann Spruce Subalpine Fir (ESSF dc1) in the mid and upper elevations.

There are at least 17 stakeholders and interest parties in the watershed. The terrain ranges from a canyon upstream of the intake to rolling plateau in the uplands. The hydrology is snow dominated with peak flows occurring between late-April to mid-June. No Water Survey of Canada Hydrometric Station is currently active in the Mill Creek watershed however the GEID does operate three hydrometric stations in the watershed.

The watershed has been separated into three hydrologic zones. Zone 1 is the un-buffered area immediately upstream of the intake but downstream of the reservoirs. In this zone any sediment and fecal material that enters streams will be transported directly to the intake. Zone 1 is the high-risk zone. Zone 2 is the partially buffered area above lower Conroy Lake. Zone 3 is the buffered area upstream of the Moore, Postill and South Lake reservoirs and is considered as a moderate risk zone. These areas above the reservoirs have the greatest buffering effect due to the storage capacities. Although not designed as settling ponds the reservoirs do settle sediment and fecal material. The effect of the reservoirs is to modify the peak flows through storage. Depending on the volume and timing of runoff, the reservoirs will have varying effects on downstream peak flows. Upper and lower Conroy Lake also

provides some buffering but freshet flows are not controlled. Zone 3 is rated as a low risk zone, however the area in the immediate proximity of the reservoir outlets should be treated as high-risk since any contamination at these locations could place the water quality at the intake at risk.

The long-term identified hazards to drinking water include: sediment from increased peak flows (natural and anthropogenic), roads, recreation use and grazing, bacteria, protozoa and viruses from humans, wildlife and cattle, cytotoxins from algae, wildfire as the fuel loads increase from the death of the lodgepole pine, herbicides from the application to noxious weeds, and hydrocarbons from a fuel spill.

The present raw water quality is considered to be reasonably good but the levels of fecal coliform and E.coli are an increasing concern at the intake. Water quality data collected by GEID since 2007 indicate total coliform levels up to 2600CFU/100ml and E.coli levels up to 80CFU/100ml. The vulnerability of the intake to impacts from sediment, debris and contaminants is a concern since the current water treatment processes may not be adequate to ensure compliance with the IHA treated water protocol The IHA protocol required treated water to have a turbidity level <1NTU. The Guidelines for Canadian Drinking Water Quality recommend a filtered water turbidity level of <0.1NTU or for chemically assisted filtration of 0.3NTU, slow sand filtration of ≤1.0NTU, or for membrane filtration ≤0.1NTU. These hazards can be better managed when the district completes the installation of its new intake on Okanagan Lake.

Forest development activities have been conducted in the Mill Creek watershed over the past 70 years. There is a high likelihood that the mountain pine beetle will kill most of the mature lodgepole pine in the watershed over the next three to five years. As the pine dies and salvage harvesting occurs, the peak flow hazard could increase from low to high increasing the turbidity and sediment loading at the intake and the upland reservoirs.

3.0 MODULE 2 – RESULTS OF CONTAMINANT INVENTORY

The objectives of Module 2 are to inventory the land uses and impacts within the community watershed and inventory the potential sources of contamination associated with these land uses that could affect drinking water quality within the watershed. In addition it includes an update of the Interior Watershed Assessment Procedure. The combination of the watershed characterization and the preliminary hazard inventory completed in Module 1, and the contaminant inventory (hazard identification), were used to evaluate the risks to the drinking water supply required in Module 7. Reconnaissance field inspections were completed as part of Module 2 that included approximately five field days between August and September of 2008.

3.1 INTERIOR WATERSHED ASSESSMENT PROCEDURE UPDATE (DEC. 31, 2007)

As summarized in Section 1.4 the IWAP procedure is an analytical tool designed to help forest managers understand the water-related problems associated with past forest development that may exist in a watershed, and to recognize the possible hydrological implications of proposed forestry-related development. The original IWAP was completed for the watershed in 1996, updated in 1998 and again in 2008 as part of this project. The following sections provide a summary of the results of the 2008 IWAP update.

The IWAP procedure has evolved since the original guidebook was released in 1995 (and the revised guidebook in 1999) into a professional assessment process that relies on the judgment of a qualified professional (PEng, PGeo, or RPF) with experience in watershed assessments in the interior of BC. The 1999 guidebook is used for guidance only. It is important to note that the hazard ratings in the IWAP process are directed at forest development impacts and do not necessarily reflect the hazards that are of concern for the protection of drinking water.

Since the 2008 update was initiated as part of the Source Assessment Project, the update focused on more than just forestry impacts. The fieldwork included inspections and assessments of identifiable forms of human impacts in the watershed that could affect drinking water quality including recreational use, forestry activities, range and other industrial activities such as mining. Uses such as refuse disposal, and other illegal activities are included in the recreation category.

3.1.1 RECOMMENDATIONS FROM THE 1996 IWAP

The following recommendations related to water quality were presented in the 1996 IWAP report. There is an “Action” after each recommendation regarding whether or not any action was taken on the recommendation.

- According to the Level I IWAP guidelines a Level II IWAP assessment should be carried out. A Level II assessment (channel assessment) was initiated in

1995 but the field component had to be postponed to 1996 due to accumulations of snow >10cm.
- **Action:** The channel assessment was completed and included as a section within the 1998 IWAP update report.
- Surface erosion concerns should be addressed based on the results and recommendations of the Level 1 and Level 2 road assessments.
- **Action:** Deactivation of numerous roads identified in the level I and II have been completed, ranging from temporary to permanent, including the Postill Lake Road Re-location project.
- Remediation work to address the high hazard associated with mass wasting should be undertaken based on the results of the Level II road assessment carried out on Postill Lake Road and also the gully assessment work.
- **Action:** Instability concerns at five of the sites were addressed through remedial works in 1996.The completion of the Postill Lake road re-location significantly reduced the slope and gully instability hazards related to road drainage. Road deactivation based on level II assessments appears to have been completed based on field investigations
- Riparian buffers should be assessed in the Bulman and Residual sub-units in 1996. Restoration work, if required, should be developed based on the results of the surveys and the nature of the impact on the water resource.
- **Action:** The Riparian buffers assessment was completed and included as a section within the 1998 IWAP update report. Two of five sites identified in the assessment are located on a section of deactivated road (Old Postill Main at 9 and 11km). It is unknown if the other three sites have been addressed.

3.1.2 RECOMMENDATIONS FROM THE 1998 IWAP

The following recommendations related to water quality were presented in the 1998 IWAP report. Following each recommendation is a comment on whether or not any action was taken on the recommendation.

- Ensure that road construction, maintenance and deactivation programs are coordinated to include measures to control sediment and maintain natural drainage patterns throughout the life of the newly constructed and upgraded road/trails. This is an ongoing concern.
- **Action:** Was formerly regulated through the Forest Practices Code, now part of *Forest and Range Practices Act* (FRPA).
- Following the completion of the proposed development, roads associated with the cutting permits should be deactivated or maintained to a level appropriate with their anticipated future use. A high priority should be placed on those roads above the H_{40} elevation. . This is an ongoing concern.
- **Action:** Was a Forest Practices Code requirement, now part of FRPA.
- Grass-seed all exposed soils on cutbanks, fillslopes and ditchlines. This is an ongoing concern.
- **Action:** Was formerly regulated through the Forest Practices Code, now part of FRPA.

- Minimize sediment transported along ditches and locate cross-drain culverts so that runoff is filtered onto the forest floor, not directed into streams or non-classified drainages. . This is an ongoing concern.
- **Action:** Was formerly regulated through the Forest Practices Code, and road use permits now part of FRPA.
- Before any future forest development (beyond 2003) takes place in the watershed, assess the sediment delivery potential associated with the (1998 to 2003) constructed/deactivated status roads, deactivated non-status roads and the Postill Lake Road.
- **Action:** Currently being addressed indirectly through this plan.
- Long-term equivalent clear-cut area (ECA) levels should be established based upon the potential sediment delivery to the streams and stream channel stability.
- **Action:** Incomplete, however current ECA levels have not significantly changed since 1998.
- Establish a channel-monitoring site on Kelowna Creek above Postill Lake to aid in determining an acceptable ECA level.
- **Action:** Not implemented.
- Complete the relocation and deactivation program for the Postill Lake Road.
- **Action:** Re-location of the Postill Lake Road was completed. Sections that were pulled back appeared stable and well vegetated, however cattle trails were noted. Sections where the road prism is still intact (culverts removed) are considered a low to moderate hazard for sediment delivery due to the recreational and cattle use evident at crossings.
- Deactivate the roads adjacent to the Postill Reservoir.
- **Action:** Roads in the Postill Reservoir area have been deactivated ranging from permanent to semi-permanent, with some vehicle access closures, however recreational vehicles and cattle are still accessing these areas regularly.

3.1.3 2008 IWAP UPDATE

The GIS data for the 2008 IWAP update includes forest development data current to December 2007, which is the latest year that data was available at the time that the update was completed. In addition, hydrological recovery predictions are provided, but actual future ECA's cannot be predicted as they depend on future harvest schedules, pine beetle effects and potential wildfires.

Based on the small size of the Mill Creek watershed, no sub-basins or residual areas were delineated off the mainstem channel; rather the watershed was assessed above and below the snow sensitive zone (H_{40} elevation, the elevation above which 40% of the watershed is situated). Ratings are also included for the total watershed above the intake.

The zones previously mentioned (Zone 1 and Zone 2) are referenced only to areas upstream and downstream from the reservoirs. These zones are not

specifically addressed in the IWAP. The following table (Table 3-1) lists the parameters that are considered when assessing the impacts of forest development on the watershed. Following each parameter is a brief description of the importance of the parameter. These parameters are used to develop hazard ratings for the impacts of past forest development on peak flow, surface erosion, riparian buffers, and landslides.

Table 3-1. Watershed Parameters used in Assessing Forest Development Impacts

Parameter	Significance
Gross watershed area	Used to calculate ECA
Total harvested area	Used to calculate ECA
Current equivalent clear-cut area (ECA)	Used to assess logging impacts on peak flows
ECA below the H40 elevation	Part of watershed ECA
ECA above the H40 elevation	Peak flow sensitive zone
Total road density	Part of surface erosion assessment
Total road length	Part of surface erosion assessment
Length of road deactivated	Part of surface erosion assessment
Length of road rated as high and moderate sediment sources	Part of surface erosion assessment
Number of landslides entering a stream	Used to assess watershed slope stability
Amount of road of class IV and V terrain	Used to assess watershed slope stability
Number of stream crossings	Part of surface erosion assessment
Length of stream logged to the bank	Used to assess channel stability
Length of mainstem channel with non-functioning riparian area	Used to assess channel stability
Length of disturbed mainstem channel	Used to assess channel stability

3.1.4 WATERSHED CONCERNS

The following list summarizes the types of concerns that forest development and recreation uses can pose to drinking water quality and quantity. (The list is not intended to be exhaustive but illustrates typical potential impacts.)

- Impacts of forestry and range management on water quality and quantity;
- Potential impacts to water quantity and quality if forest health issues, e.g. the impacts from the mountain pine beetle, increase the equivalent clear-cut area above 50%.
- Increases in turbidity levels and presence of pathogenic organisms that may require special treatment of drinking water;
- Increased access for recreation and range use that may result from forest road construction in and around streams;
- Slope stability issues in the lower watershed area adjacent to the canyon reaches that is the most sensitive area with respect to forest development;

- Hydrologic effects and water quality impacts, e.g. increased nutrient, metal and sediment transport, from increased wildfire risk related to the impacts from the mountain pine beetle;
- Potential long-term water supply issues related to changes in climate (temperature and precipitation patterns);
- Increased runoff rates into the upper reservoirs if accelerated by forest development and the impacts from the mountain pine beetle;
- Long-term sustainable water supply
- Unregulated recreational use including off road vehicles (i.e. motorcycle, ATV, 4wd), camping/parties, refuse disposal, and other activities in or about a watercourse, stream, lake or reservoir.

3.1.5 2008 IWAP REPORT CARD

The watershed report card was updated as part of this project. The results provided in Table 3-2 summarize the data for the watershed area above the intake for the snow sensitive zone (SSZ, area above the H_{40} elevation), the area below, and the road density to the end of 2007. The IWAP results from 1998, and the current results can only be compared in general terms as the 1996 and 1998 IWAPs were completed prior to the revised guidebook in 1999. Additionally the H_{60} elevation has been adjusted to reflect the snow sensitive zone that is the area that contributes to peak flows in the watershed.

3.1.6 HAZARD INDICES SUMMARY

Using the results provided in the watershed report card, hazard ratings are derived for the four hydrologic hazards, peak flow, surface erosion, riparian buffers and landslides that are summarized below and in Table 3-3.

PEAK FLOW

The current (2007) peak flow hazard (pre-beetle) is rated as low for the watershed. The estimated peak flow hazard would increase to high for an ECA of ~70+%, should all the mature pine die, or for the proposed retention plan.

Past results identify that the 1998 ECA for the entire watershed was 14% and would increase to 22% by 2003 based on proposed harvesting. It stated that the increase in ECA should not exacerbate channel conditions in the watershed.

The current ECA (includes all harvest to the end of 2007) for the Mill Creek watershed is at ~18%, which equates to a ~3% increase since 1998 but remains ~5% lower then the projected value for 2003. Road density has increased since 1998, from 1.15km/km^2 to 1.7km/km^2, and a total road length of 162km. There were roads and trails not identified on the maps; roads appeared to be non-status trails were developed from recreational users such as motorcycles, ATV's and mountain bikes.

In 1998, the Mill Creek mainstem channel was identified as adversely affected by peak flows. Disturbances noted consisted of logjams, eroding banks, small bank slumps and aggradation attributed to discharge cycles from the reservoirs. These disturbed areas were reported as unrelated to the more localized disturbances such as slides along the old Postill Lake Road.

In 2008 channel stops along the mainstem and tributary channels, including Bulman, and Conroy Creeks (near SCHR Sites 59, 52, 51, 46, 16, 14 on Mill Creek, Sites 17, 9, 8, 4, and 1 on Bulman Creek, and Sites 83, 16, 12, and 13) did not identify peak flow related channel disturbances attributable to harvesting. The current peak flow hazard rating remains at low for the entire watershed, and is considered low above the H_{40} line with ECA's of ~18% and ~23% respectively. Refer to the *Field Map* in Appendix A for the locations of the sites referred to in the preceding text.

The residual impacts from past harvesting, the proposed salvage harvesting combined with the loss of the mature pine to the pine beetle as presented on the *Watershed Map* in Appendix A, has the potential to increase peak flow upstream of Moore, Postill, and South Lake reservoirs. Tolko recently completed an analysis of the cumulative hydrologic impacts of past harvesting plus the loss of the mature lodgepole pine in the Mill Creek watershed. The ECAs, assuming all the mature pine dies, would be ~73% for the snow sensitive zone, and ~54% for the entire watershed. Based on the results reported in the Extension Note 67[8], an ECA of 73% could increase the 50-year peak flow by approximately 37% for the snow sensitive zone that would represent a high peak flow hazard whereas an ECA of 54% would increase the 50-year peak flow by approximately 25% for the watershed that would represent a moderate peak flow hazard. This would result in a shift of the flood frequency curve resulting in less frequent events occurring more frequently, e.g. the 1 in 100 year flood could become the 1 in 50 year flood. As a result, significant changes are likely to occur in the watershed hydrology due to the current beetle infestation regardless of whether there is any salvage harvesting or not.

SURFACE EROSION

Ditchlines along Postill Lake Road were generally vegetated with grass although there were some sections of erosion and deposition noted. Road fill erosion due to road surface flow was noted along numerous sections (post rainfall), but generally does not appear to be reaching the mainstem channel. Historic failures along mainline appear unchanged other then fill erosion along Postill Lake Road due to local surface run-off. Deactivated stream crossings, and cross ditch/waterbars in the watershed were generally functioning as designed, although steep sided crossings (i.e. Site 27) along with recreational and cattle/animal traffic push sediment into the crossings to be flushed during higher

[8] Extension Note 67, Schnorbus et al, Ministry of Forests, Forest Sciences Program, 2004

flows. Traffic volume (industrial, recreational, and cattle) also increases the likelihood of sediment delivery at each crossing; dust from these roads is also a source of fine sediments, and can be stored on channel beds/banks, and on vegetation.

The road density (and road length) has increased in the watershed since 1998 from 1.15km/km^2 (1998) to 1.7km/km^2 in 2008. The number of stream crossings has increased from 26 in 1998 to 84 in 2008. The 1998 report identified approximately 24km of new road, 14km in the Postill sub-basin, 2km in the Conroy sub-basin and 8km in the residual area. In contrast approximately 38km of road is identified as deactivated in the current data set. This would include sections of old Postill Road and the roads adjacent to Moore and Postill reservoirs.

Although generally well maintained, and stable, there were still a number of stream crossings that were identified as slight to moderate sediment sources. For the deactivated roads that were inspected, deactivation measures appeared to be functioning as designed although recreational vehicle use impairs the re-establishment of vegetation at stream crossings. Four wood culverts were identified at various stages of failure (holes in road, sunken sections). Three of the four wooden culverts are identified as “low to moderate” sources of sediment (Site 57, 58, and 56); the fourth (Site 28) was rated as a low.

Based on the site conditions encountered in 2008, low SCHR scores, the fact that most roads are away from the mainstem channels, and the deactivation of the old Postill Road and other high priority roads identified in the 1996 and 1998 IWAP reports, the surface erosion hazard is considered to be at low for the Mill Creek watershed.

Proposed forest development should have a limited impact on sediment production provided that the natural drainage patterns are maintained and erosion and sediment control measures are implemented at all stream crossings. Soil erosion potential mapping was completed in 1995 for the watershed and the majority of the proposed harvesting is located on soil polygons with a low to moderate erosion potential. The proposed harvesting west of South Lake Reservoir is located on a high erosion potential soil polygon, however the existing sites assessed in the area (Site 42, 43, 44) scored low to very low based on the SCHR calculations due to the channel types that illustrates the potential problems between landscape level marring and site specific sampling. Based on the location and area of the proposed salvage harvest the surface erosion hazard is increased to moderate for the area above the snow sensitive zone as well as the entire watershed.

RIPARIAN BUFFERS

The riparian buffer rating as represented by the extent of stream logged to the bank remains unchanged for the watershed. For streams that require buffers or reserves under the *Forest and Range Practices Act*, the riparian area should be intact. Any increase in 'streams logged to the bank' should be for the very small streams where, although there may have been harvesting to the bank, the streams are normally protected by 5 m 'no machine' buffers. The riparian hazard rating remains low for the watershed.

LANDSLIDES

There was a high concern about landslides in the watershed associated with the Postill Lake Road in the 1996 and 1998 reports due to the frequency of slope failures into Mill Creek related to the road. The relocation and rehabilitation of sections of Postill Lake Road have reduced some of this risk. Naturally occurring mass wasting was noted along the mainstem channel. No new landslides have been identified within the watershed. A field review of some of these sites did not identify any obvious instabilities or sources of sediment; some chronic fill erosion sites were identified along the Postill Lake Road at some gulley locations. Sediment from these sites did not appear to be impacting the mainstem channel. The landslide hazard remains at low for current conditions and low for the proposed harvest since no harvesting is proposed directly above the steep slopes bounding Mill Creek. This risk could increase in the future if the peak flow hazard increases to high following the loss of forest cover to the pine beetle.

Table 3-2. Mill Creek 2008 IWAP Update Watershed Report Card

Watershed Inventory category	Upstream of GEID Intake
Gross Area (ha)	7,391.2
Total area harvested (ha/%)	1,924.0/26
ECA (ha/%)	1298.7/17.6
ECA below the H40 (ha/%)	689.0/14.5
ECA above the H40 (ha/%)	609.7/23.1
Total Road Density (km/km2)	1.7
Total Road Length (km)	161.7
Road Deactivation (km)	37.9
High/moderate sediment source roads (km)	0.0
Landslides entering streams	0
Roads on Class IV or V terrain (km)	0.0
Number of Stream Crossings	84
Length of stream logged to the streambank (km/km)	19.5
Length of mainstem channel with Non-functional RMA (km)	0.0
Length of disturbed mainstem channel (km /km)	0.0

Table 3-3. 2008 Hazard Indices for the Mill Creek Watershed

Watershed	Hazard Category			
	Peak Flows	**Surface Erosion**	**Landslides**	**Riparian**
Current Watershed Condition	Low	Low	Low	Low
With Proposed Forest Development Below H_{40}	High	Moderate	Low	Low
With Proposed Forest Development Above H_{40}	High	Moderate	Low	Low

3.2 CHANNEL CONDITIONS

The Mill Creek mainstem channel was identified in 1998 as adversely affected by peak flows. Disturbances noted consisted of logjams, eroding banks, small bank slumps and aggradation, which were attributed to discharges from the storage reservoirs. The channel assessment noted these disturbed areas as unrelated to more localized disturbances such as slides and roads. GEID has subsequently upgraded its works at the Postill Reservoir spillway that has eliminated most of these problems.

In 2008, the channel inspections along the mainstem and tributary channels, including Bulman, and Conroy Creeks (near SCHR Sites 59, 52, 51, 46, 16, 14 on Mill Creek, Sites 17, 9, 8, 4, and 1 on Bulman Creek, and Sites 83, 16, 12, and 13) did not identify peak flow related channel disturbances attributable to harvesting.

Mill Creek upstream from the Postill Reservoir is typically stable with low gradient swampy sections and boulder/cobble dominated sections. Downstream from the reservoir the channel is stable to partially aggraded cascade pool channel (CP_B:S-$A1^{lwd}$) with a boulder/cobble channel and functioning large wood. The channel conditions are similar to those observed during the 1996 and 1998 assessments, however vegetative recovery was noted along the deactivated section of the old Postill Lake Road.

Moderate and high levels of stream channel disturbance were identified in the 1998 channel assessment along the mainstem of Mill Creek downstream from Postill Reservoir. The disturbances were associated with the instabilities along the Postill Lake Road. Since the deactivation of the “old Postill Lake Road” many of these instabilities have been remediated, including re-vegetation along the old right-of-way.

Currently the channel stability hazard rating is considered low for the upper Mill Creek watershed in the snow sensitive zone. The channel stability hazard rating is maintained at moderate for the entire watershed upstream of the intake.

3.3 Overview of Potential Contaminants and Inventory Process

The potential contaminants to drinking water are typically a function of land use. As has been summarized in Section 2.5 the land uses within the watershed include water supply, forest development, grazing, wildlife, recreation, and other industrial activities. The primary contaminants associated with these land uses are by priority:

- Bacteriological and pathogen contamination from cattle, and wildlife around streams and reservoirs;
- Bacteriological and pathogen contamination from human activity around streams, diversion ditches, and reservoirs;
- Sedimentation to streams from motorized recreation disturbance at road crossings, along stream banks and reservoirs;
- Sedimentation to streams from cattle disturbance at road crossings, along stream banks and reservoirs; and
- Sedimentation to streams from forest access roads;
- Petroleum spills.

The risk of the contaminants entering the drinking water increases with increased watershed activity. The most likely points of contamination are those sites that permit direct access to the stream network at stream crossings. Pierre Beaudry and Associates has developed a method to numerically assess the impact of stream crossings on water quality called the *Stream Crossing Quality Index*. This method considers potential erosion sites at each assessed stream crossing; the road surface on either side of the crossing and the ditches/cutslopes/fill slopes on the high and low sides of the stream at each crossing (refer to Appendix D for details on the procedure). Since the Stream Crossing Quality Index procedure is proprietary, the procedure was only used as a guide for the stream crossing hazard rating (SCHR) developed for this project. The pre-field assumption was that, by default, all stream crossings were considered to be affecting water quality and are given a score of 1. The field assessment results consider soil type, level of road use, and sediment delivery potential to determine the actual score for each crossing. Soil textures were determined based on visual observations.

The contaminant inventory process involved the following four-step process:

- Step 1 – Office review of past reports and IWAP results, the updated IWAP report card, changes in forest development since last assessments and review of forest development maps, review of historical and recent air photographs.
- Step 2 – Preparation of new field maps indicating all road crossings and updated forest development, prepare field cards to record results.

- Step 3 –Field inspections to identify and record contamination related to anthropogenic activities in the watershed, e.g. roads, stream crossings, channel conditions, recreational use, recent logging, as well as those from natural sources, e.g. unstable channels, unstable slopes, etc.
- Step 4 – Evaluate and summarize results.

Since stream crossings represent the most likely point source for contamination especially from sediments and road runoff, the stream crossing hazard rating system permitted a consistent rating of sediment production, sediment delivery and cattle disturbance that resulted in a final overall hazard rating for each crossing. The condition of roads with regard to intercepting and diverting runoff and sediment was noted for all roads assessed. In addition, channel assessments were completed for selected reaches using sites that had been assessed during previous work where practical. Riparian condition was also assessed at a sufficient number of locations to characterize the sub-basins. Recreational use was recorded throughout the assessment area with additional emphasis placed on areas of concentrated use around lakes and reservoirs.

3.4 NATURAL FACTORS THAT IMPACT WATER QUALITY AND QUANTITY

This section addresses the natural impacts that are/may occur in the watershed and impact the hazard ratings associated with anthropogenic activities. The intent of the discussions regarding climate change, mountain pine beetle and wildfire is to provide an overview summary of these potential hazards.

3.4.1 CLIMATE CHANGE IMPACTS

Climate change could cause significant long-term impacts to the Mill Creek watershed. According to research by the Atmospheric Environment Service, temperatures in the Okanagan are increasing by 0.1^{o}C/year over the spring, summer and fall seasons and by 0.2^{o}C/year over the winter season. There is also a projected decrease in the April 1st snow pack of 10% by 2020, 40% by 2050 and 50% by 2080. The decrease in snowfall is accompanied by an increase in rainfall, i.e., the snowfall/rainfall partitioning is shifting towards more rain and less snow during the winter season.

In summary, the research suggests warming summers resulting in increased water demand by agriculture, and less snow (but perhaps more rain) during the winter that may result in less runoff. The climate models also indicate a shift in the snowmelt period by two weeks earlier.

3.4.2 MOUNTAIN PINE BEETLE IMPACTS

One of the most obvious impacts, currently affecting the watershed, is the mountain pine beetle and the likely loss of most of the mature lodgepole pine in the watershed. Lodgepole pine is the dominant conifer species in the watershed, especially in the upper snow-sensitive zone (upper 40% of the watershed).

Stands with a high percentage of mature pine will have the greatest impact on peak flow increases where the loss of canopy closure will result in increased snow accumulation and water yields. These areas will provide greater water yield for the next several decades, and could result in significantly increased peak flows as well as a shift in the timing of the runoff to earlier in the spring. The buffered zones in the watershed coincide with a large portion of the snow-sensitive zone and could lesson the impacts to the un-buffered channel sections. There is a risk that the magnitude of peak flows will increase as the lodgepole pine dies and that the frequency of larger flow events will increase. There is a potential for the larger peak flows to exceed the design criteria of existing stream culverts and bridges leading to increased risk of failures of these structures. Increased peak flows could also result in increased channel erosion and subsequent sediment transport that would degrade water quality.

As stands die and are salvaged there will be increased access to streams and wetlands for wildlife and cattle. Grasses and brush species may dominate many sites temporarily until conifer stands recover, enhancing the food supply for cattle and wildlife. The loss of forest cover may also increase recreational access into the wetland and riparian areas with associated increased risks to water quality.

Combining the impacts of the loss of forest cover to the pine beetle and climate change, there may be some benefits from less snow in the short-term that might offset the potential increase in peak flows associated with the loss of forest cover. However, the snowmelt period could be advanced by as much as two weeks resulting in the GEID having to rely on storage for a much longer period of the year. Over the long-term, indications are that there will be less water supply from the watershed to meet an increasing demand.

3.4.3 WILDLIFE IMPACTS

Wildlife movement in the watershed is unknown but it is likely that during the course of a year most of the stream crossings are used by wildlife. However, during the fieldwork very little evidence of wildlife impacts was noted. Where pine stands die or are salvaged there will likely be increased forage for wildlife. Where natural barriers to animals are lost in the dead and salvaged stands, it will be important to assess the requirement for strategically locating barriers to protect the source water quality. As a result of the increased wildlife use there will be the associated increases in sediment and fecal loading in the streams.

3.5 ANTHROPOGENIC USES THAT IMPACT WATER QUALITY AND QUANTITY

3.5.1 FOREST DEVELOPMENT IMPACTS

Past forest development in the watershed is discussed in Module 1, Section 2.8. Forest development can increase sediment delivery to streams as summarized in section 3.1. The impacts from forest development including road building, for the

short-term, i.e. the next three to five years, will result from the proposed salvage harvesting of pine beetle affected stands.

Tolko has prepared a retention plan for the watershed that focuses on salvaging lodgepole pine attacked by the mountain pine beetle. A retention plan is a forest development planning process that considers all the resource values in the watershed, timber and non-timber, and identifies what stands need to be retained to protect the non-timber values such as water, wildlife, fish, recreation, etc. This process was developed by Tolko to assist in planning salvage logging of mountain pine beetle infested stands. (The plan included a review of the hydrologic impacts that may occur as a result of the loss of forest cover in the upper watershed that is the source of peak flows, i.e. the snow sensitive zone.) In summary the report indicated that for the snow sensitive zone past harvesting has occurred on ~28% of the area and the mature pine >40% of the stand accounts for 59% of the area. Stands with pine composition <40% plus non-pine types account for a total of 37% of the area The area that will impact the hydrology will total ~87% of the snow sensitive zone area. The distribution of forest cover for the snow sensitive zone in the watershed is illustrated in Figure 3. The color-coded sections in the pie chart refer to the percentage area of forest stands in the Mill Creek watershed. For example, 55% of the forest in the watershed is comprised of stands with greater than 70% mature pine trees where there is less than 30% other tree species.

The proposed harvest impacts are likely to be minimal compared to the larger scale hydrologic impacts that are going to occur as a result of the loss of all the mature lodgepole pine, especially in the snow-sensitive upper watershed, as it is the source of peak flows. The loss of forest through natural causes and salvage logging will result in increased exposure of streams to industrial traffic as well as recreational use and wildlife and cattle access. As the forest cover is reduced there is greater opportunity for increases in grasses and brush species due to improved light, moisture and nutrients. The expansion of these species will encourage greater use by ungulates and cattle into areas along streams not previously accessible or attractive to these animals. Increased animal presence will result in increased sediment and fecal coliform loading. It is the forest licensee's responsibility to replace natural barriers to cattle movement that are lost as a result of harvesting.

The sources of sediment in the watershed include roads at stream crossings; channel erosion due to increased peak flows, and from landslides that impact stream channels. This latter source will likely increase as a function of the loss of forest cover to the pine beetle; channel erosion can also be a natural function of the system, as woody debris moves and shifts flow or steep undercut banks fail.

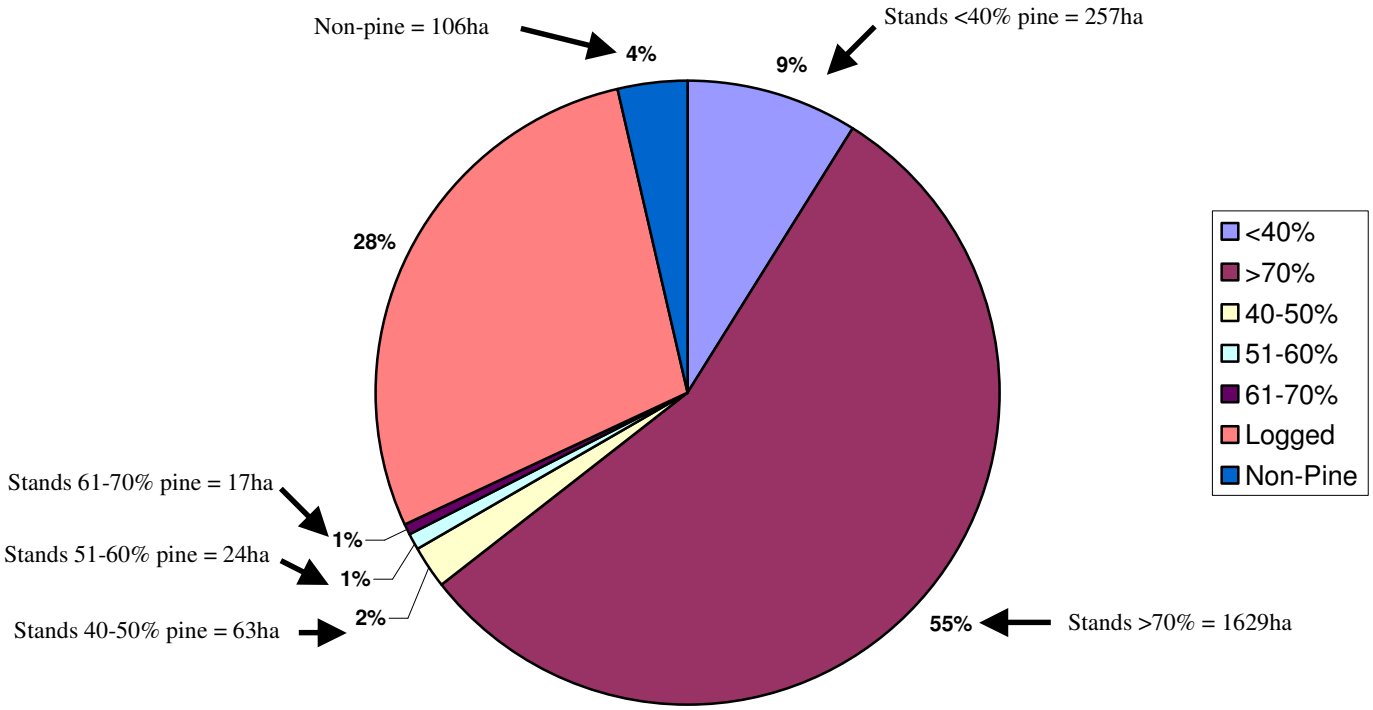


Figure 3. Forest cover distribution in the snow sensitive zone above GEID intake

The dominant forest development impact is from roads. Prior to initiating the 2008 fieldwork, the road network in the watershed was reviewed using GIS and a field map, which identified each road crossing with an identifier number. The GIS analysis and field assessment identified 84 sites. During the fieldwork, 41 (49 %) sites were identified as actual stream crossings, 25 (30%) were considered to be a non-classified drainage or crossdrains, and 13 (15%) were not assessed. Based on the combined ratings for the sites assessed, 52 sites (62%) were ranked as low to very low hazards, 24 sites (29%) were low to moderate hazards, and 2 sites (Site 8 and Site 27) are rated moderate. Site 8 (photo 16), site 9 (Photo 17) and site 27 (Photo 14) are all moderate hazard sites that require rehabilitation work to reduce the sediment delivery to the streams. There was no high hazard road crossing sites.

Since there were no high hazarsd sites, Table 3-4 lists the moderate hazard sites that were identified during the fieldwork. The detailed assessment tables and related photographs are provided in Appendix B. The *Field Map* in Appendix A includes the numbered stream crossings as Sites.

Table 3-4. Road crossings with moderate hazards Identified in 2008.

Crossing No.[9]	Hazard	Likelihood	Zone buffered or Unbuffered	Hazard Rating
27	Road surface erosion at deactivated crossing of tributary stream to Mill near its confluence	During freshet and rainstorms	unbuffered	Moderate
8	Road/fill erosion/delivery at crossing, accessibility to cattle and recreational users to Bulman Creek	During freshet and rainstorms	unbuffered	Moderate
9	Running surface erosion to Bulman Creek	During freshet and rainstorms	unbuffered	Moderate

Tolko is considering plans to salvage up to 1,680 ha of the 2,037 ha of beetle-infested pine in the upper watershed over the next three to five years, if there is acceptable wood quality. Most of the pine stands are pure pine with no other conifer species. As a result, based on preliminary research results on snow accumulation and melt in the Okanagan[10], there may be little difference hydrologically between areas retained but dead and stands salvaged. That is to say, whether or not there was any salvage harvesting, the impact of the death of the remaining mature pine combined with the past harvesting will have affected more than 73% of the forested area in the snow sensitive upper watershed with associated increases in peak flow. Areas that are harvested and prepared for either natural regeneration or planted should have significant hydrologic recovery in approximately 30 years. For those areas not logged, left to recover naturally, hydrologic recovery will likely take 50-60 years[11]. Based on the Tolko report the equivalent clear-cut area in the upper watershed will likely decline from the projected level of ~73% after the mature pine dies to approximately ~54% within 30 years[12]. With salvage logging the equivalent clear-cut area is projected to decrease from ~77% to ~25% within 30 years as a result of more rapid regeneration.

As noted previously, the loss of forest cover to the mountain pine beetle may result in significant changes to the watershed hydrology. The Ministry of Forests and Range Forest Road design requirements are that major culverts and bridges must have a capacity to pass the Q_{100} peak flows. These design flows may be larger after the pine dies and it is likely that there will be stream crossings

9 Refer to Field Map in Appendix A, Crossing No. refers to "Stream Crossing ID" on the map. A summary of the 2008 road assessments is provided in Appendix B in the Road Summary table. The column "Xing ID" in the table in Appendix B refers to the Crossing No. in the table above.

10 Research in the Ashnola River watershed undertaken for Gorman Bros. Lumber Ltd. by Dobson Engineering Ltd. In 2007 and 2008 – not published.

11 ibid

12 Dobson Engineering Ltd., *Mill Creek Community Watershed Cumulative Hydrologic Impact Assessment of Mountain Pine Beetle Infested Stands and Proposed Retention Plan*, 2007.

downstream from the areas affected by the beetle that may be undersized. The failure of a culvert or bridge on a mainstem, particularly in the non-buffered zone upstream of Intake could cause serious impacts to water quality at the intake.

3.5.2 RANGE USE IMPACTS

Grazing activity was noted throughout the watershed. According to the information provided by the Ministry of Forests and Range there are currently four grazing licences (two stakeholders) issued over the watershed with a total of 2257 AUMs (animal unit months). The dates of use vary, but in general cattle are permitted to graze the watershed from June 1 through October 30. Each tenure holder has a Grazing License issued by the Ministry of Forests and Range. The presence/absence of cattle impacts were noted at each road crossing assessed. Cattle frequently use road corridors as primary access routes through the watershed. Stream crossings along the roads offer easy access to water as well as to the riparian areas along streams where there is forage especially in the late summer and fall.

During the 2008 field inspection it was identified (based on presence or absence) that cattle were contributing sediment and fecal material at 42 of the 66 (70%) sites that were assessed in the field. The details for all the sites are provided in Appendix B. Cattle were observed at or near all upland lakes and reservoirs, either observed cattle presence or by evidence left behind. Cattle were also observed in and around Mill Creek at Sites 51, 52, 14, 19, and 59, along Bulman Creek Sites 1, 4, 8, 9, and 17, and along Conroy Creek, Sites 13, and 83. With increased cattle use there is also the associated increase in manure deposits in the reservoirs, stream channels and adjacent riparian area. This is a concern in the un-buffered zone below the reservoirs due to the direct connection to the Intake. Cattle guards and fences were noted in the watershed, however open gates permitted cattle access across Mill Creek at Site 14. This was likely left open by motorized recreational users, as this is a popular crossing).

3.5.3 RECREATIONAL USE IMPACTS

Recreational use is considered high in the watershed, particularly around reservoirs and mainstem channels. Recreational uses vary in the watershed from camping/hunting/fishing (somewhat regulated) to off-road motorcycles/ATV/4wd vehicles (unregulated) to hikers (High Rim Trail) and mountain bike riders.

Unmanaged recreational vehicle use of roads in this area is increasing the sediment sources; rutted roads unable to revegetate at crossings, pooling of water in deep holes in running surfaces, widening of the running surface for passage around large pools, and turbid flow due to fine textured soils.

The upland reservoirs and lakes are popular locations for all users and gated roads are not entirely effective at restricting vehicular access in these areas, particularly by motorcycles and ATVs. Trails have been cut through stream crossings around barriers placed to discourage traffic (sites 8, 59, and 84).

Vehicle disturbance was noted below the full pool level in the three reservoirs, as well as other upland lakes. Motorcycles and ATV riders have created trails connecting lakes and wetlands in the upper watershed. Stream crossings of concern with regards to recreational vehicle impacts include Sites 4, 8, 14, 16, 17, 18, 19, 27, 29, 30, 46, 51, 81, and 84. Mud bogging appeared to be concentrated in an area disconnected from the mainstem and major tributary channels and considered a low hazard, however, evidence of 4wd vehicles was noted in the Moore Reservoir area.

The proximity of the watershed to the populated areas in the Okanagan Valley and easy access has resulted in a significant increase in unregulated uses in the watershed including using the area for garbage disposal. The worst areas were along Postill Lake Road in the area of Site 51 and 52, as well as between Site 20 and 23. In these areas garbage (i.e. abandoned cars, fridges, mattresses, etc) have been dumped over steep banks, in gullies above Mill Creek and along the side of the road. Groups of people were also noted on a regular basis off Postill Lake Road at approximately 0.1 km directly upstream of the intake that appears to be a popular party site.

3.5.4 MINING AND QUARRIES

There are 6 mineral tenures within the Mill Creek watershed based on the 2004 (last update) Mineral Titles Map. Five of the six tenures are located in the upper watershed area in the Rodney and Meadow Lakes area (>1000 ha), the fifth is located along the middle reaches of Mill Creek extending north to he watershed boundary (~311 ha). Although no current activity was noted in the field inspections a gravel pit does exist along Postill Lake Road but is not associated with tenures identified. Development of these tenures could be cause for a variety of water quality impacts if there are streams near the site. There may also be increased industrial traffic on the roads that also increases the risks to the water sources. Currently mining activities are considered a low hazard due to the absence of activity, however any activity near a stream would increase the risk.

3.6 DRINKING WATER HAZARD SUMMARY

Table 2-1 in Module 1 provided an initial summary of the potential hazards to drinking water in the watershed. Table 3-5 expands on the information in Table 2-1 and provides a summary of the current preventative measures in place to reduce the hazards on the drinking water. Additional information on future actions that might be undertaken is provided in Module 8.

Table 3-5. Module 2 – Hazards to Drinking Water Quality at the Intake and Current Preventative Measures

Hazard Type	Drinking Water Hazard	Impacts	Current Preventative Measures/Responsibility
Physical	Natural sediment load from channel erosion and mass wasting	Exceed turbidity threshold of 1 NTU in treated water [MC][13] Compromised disinfection process Risk to human health	Planning – Avoid development activities in sensitive areas / Forest licensees
	Sedimentation from industrial roads and road crossings	Increased sediment load resulting in exceeding turbidity threshold of 1NTU in treated water [MC] [MR] Compromised disinfection process Risk to human health	Planning – Avoid developing roads in sensitive areas / Forest licensees Implementation – Use best management practices during development to limit impacts / Forest licensees
	Sedimentation from range use in and around streams and road crossings	Sediment load exceeding turbidity threshold of 1NTU in treated water [MC] Compromised disinfection process Risk to human health	Planning – Prepare plans to limit cattle/recreation use around streams / Grazing licensee, MoFR, MTCA Implementation – Aggressive herd management, development of off-stream watering / Grazing licensee, MoFR
	Sedimentation from recreation activity on roads in/around streams and reservoirs	Sediment load exceeding turbidity threshold of 1NTU in treated water [MC] Compromised disinfection process Risk to human health	Education – Inform stakeholders and the public about watershed sensitivities. / GEID, MTCA Signage – Use signs to remind users of the importance of protecting the water quality / GEID, MTCA
	Water Quantity	Increased peak flows and risks to culverts and bridges [MC] Lack of adequate supply could result in public health issues [MC]	- Review culvert capacities and requirement for revised design guidelines / MoFR - Plan for additional storage to meet future needs / GEID
	Wildfire	Increasing risk of wildfire, degradation in water quality related to increased sediment load. Potential loss of control at the intake [MC]	- Develop a wildfire plan for the watershed to reduce potential impacts / GEID, MoFR - Plan future harvesting to reduce fuel loads and to create defensible zones / GEID, Forest Licensees, MoFR
Biological	Bacteriological contamination from wildlife/cattle/human presence in and along streams	Risk to human health Contravention of DWP Regulation for fecal coliform bacteria, *E.coli.*, and total coliforms in drinking water [MC] [MR]	Planning – Prepare grazing plans to limit cattle use around streams / Grazing licensees, MoFR, MTCA Implementation – Aggressive herd management, development of off-stream watering / Grazing licensees, MoFR Education – Educate stakeholders and public about the safe disposal of human waste in the watershed including signs / GEID, Agencies
	Protozoa (Giardia, Cryptosporidium)	Risk to human health Contravention of DWP Regulation for fecal coliform bacteria, *E.coli.,* and total coliforms in drinking water [MC] [MR]	Planning – Prepare grazing plans to limit cattle use around streams / Grazing licensees, MoFR Implementation – Aggressive herd management, development of off-stream watering / Grazing licensees, MoFR Education – Educate stakeholders and public about the safe disposal of human waste in the watershed including signs / GEID, Agencies
	Viruses	Risk to human health Contravention of DWP Regulation for fecal coliform bacteria, *E.coli.*, and total coliforms in drinking water [MC] [MR]	Planning – Prepare grazing plans to limit cattle use around streams / Grazing licensees, MoFR Implementation – Aggressive herd management, development of off-stream watering / Grazing licensees, MoFR Education – Educate stakeholders and public about the safe disposal of human waste in the watershed including signs / GEID, Agencies
	Algae blooms in reservoir	Cyanobacteria contamination [MC] [MR] Trihalomethanes, by-product of disinfection process	Planning – Limit soil disturbance to limit sediment and nutrient loading in streams upstream of reservoirs / GEID, Agencies Restrict access by wildlife, cattle and the public in reservoir pond areas / Agencies, GEID, MTCA Education – Inform stakeholders and the public about watershed sensitivities and the potential to cause algae blooms. / GEID Signage – Use signs to remind users of the importance of protecting the water quality / GEID, Agencies
Chemical	TOC	Reaction of organics (total organic carbon) with water disinfection resulting in formation of Trihalomethanes (THMs) in drinking water [MC] Risk to human health	Planning – Plan roads and harvesting to limit sediment and nutrient loading that would increase biological activity in water column and subsequently TOCs – Forest Licensees
	Petroleum contamination from industrial fuel spill or vehicle accident and gas powered boats on reservoirs	Contamination of drinking water [MC] [MR] Risk to human health	Education – Stakeholders to educate contractors about safe industrial activities including use of spill kits, use of vegetable based lubricants, etc. / MoFR, MTCA, Forest Licensees Educate public on road safety protocols and spill reporting, MoFR, Forest Licensees, GEID
	Herbicides	Contamination of drinking water [MR] Risk to human health	Compliance with Pest Management Regulations - MoFR
	Wildfire	Contamination of drinking water from fire retardant application [MC] Risk to human health	MoFR Protection Branch standard operating procedures - MoFR

[13] Abbreviation [MC] refers to possible impacts in the Mill Creek source area and [MR] refers to possible impacts to the McKinley reservoir.

4.0 MODULE 7 – RISK CHARACTERIZATION & ANALYSIS

Module 7 considers the hazards to drinking water quality identified in Modules 1 and 2, along with the consequence to the drinking water should a contaminant or combination of contaminants reach the intake. The following sections review the barriers currently in place, and assess the related risks.

4.1 EVALUATION OF SOURCE PROTECTION BARRIERS

The barriers currently in place in the watershed include varying levels of source protection as set out in the *Forest and Range Practices Act, Water Act* and the *Drinking Water Protection Act* and related regulations. However, regardless of the intent by the regulating agencies and the licensed stakeholders to comply with the legislation and regulations and to implement best management practices, the reality is that there is increased sedimentation to all of the streams dispersed throughout the watershed from roads and from disturbances from cattle and recreational use. In addition, there are those 'natural' hazards such as contamination from wildlife, increased runoff due to the loss of forest cover to the mountain pine beetle and impacts from climate change, for which the only effective barrier will be drinking water treatment. This is not to suggest that enhancing barriers to contamination, such as improved sediment control practices at forest road stream crossings, improved cattle management, improved reservoir monitoring and management, should be ignored. To the contrary, recognizing the significant challenges to water quality and quantity that GEID faces, all the agencies and stakeholders in the watershed should make every effort to limit the impacts on the source water. Simply, the higher the raw water quality that arrives at the intake, the lower public health risk for those who use this source for their drinking water.

4.2 CONSEQUENCE TO DRINKING WATER QUALITY AND QUANTITY

The impacts from natural factors that affect water quality, such as climate change and the mountain pine beetle as well as the anthropogenic activities in the watershed, including recreation, forest development and grazing, summarized in section 3, are considered in the risk assessment as the source area hazards that could affect the drinking water quality and quantity. The intent of this section is to address the issue of the 'consequence(s) to the drinking water quality and quantity that will be used to estimate the risks. *Consequence* may be defined as the effect on human well-being, property, the environment, or other things of value or a combination of these (adapted from CSA 1997). Conceptually, in the case of drinking water, consequence is the change, loss, or damage to the water quality caused by contaminants. Table 4-1 provides a summary for the ranking of consequences to drinking water quality, rated from insignificant to catastrophic. Table 4-2 summarizes the consequence ratings for each of the hazards listed in Table 3-5.

For Mill Creek the most likely consequences to drinking water source quality will be as a result of:

- increased sediment loads;
- increased fecal material/increased pathogen loading;
- increased organics (THM, HAA precursors); and/or
- increased nutrients (algal growth, taste and odour problems and THM/HAA precursors);
- increased metals, sediment and nutrients following wildfires.

Table 4-1. Qualitative Measures of Consequence to Drinking Water Quality

Level	Descriptor	Description
1	**Insignificant**	Insignificant impact, no illness, little disruption to normal operation, little or no increase in normal operating costs.
2	**Minor**	Minor impact for small population, mild illness moderately likely, some manageable operation disruption, small increase in operating costs.
3	**Moderate**	Minor impact for large population, mild to moderate illness probable, significant modification to normal operation but manageable, operating costs increase, increased monitoring.
4	**Major**	Major impact for small population, severe illness probable, systems significantly compromised and abnormal operation if at all, high level monitoring required,
5	**Catastrophic**	Major impact for large population, severe illness probable, complete failure of systems.
Reproduced from Module 7 of the *Comprehensive Drinking Water Source to Tap Assessment Guideline* (BC Ministry of Health Services and Ministry of Water, Land and Air Protection 2005).		

Table 4-2. Consequences to Drinking Water Quality/Quantity at Intake

Hazard Type	Drinking Water Hazard	Consequence Level
Physical	**Sediment** - Natural sediment load from channel erosion and mass wasting	3-4
	Sediment - Sedimentation from industrial roads and road crossings	3
	Sediment - Sedimentation from range use in and around streams and road crossings	3
	Sediment – Sedimentation from recreation activity on roads, road crossings and in/around streams and reservoirs	3
	Water Quantity – Increased peak flows or reduced/loss of supply	3
	Wildfire – increased sediment load and loss of control at intake from evacuation order and/or damage	3-5

Table 4-2 cont'd. Consequences to Drinking Water Quality/Quantity at Intake

Hazard Type	Drinking Water Hazard	Consequence Level
Biological	**Bacteria** - Bacteriological contamination from wildlife/cattle/human presence in and along streams	4
	Protozoa – presence of Giardia, Cryptosporidium	4
	Viruses - presence	4
	Algae – algal blooms in reservoirs	3
Chemical	**Organic material** - (Total Organic Carbon)	2
	Hydrocarbons -Petroleum contamination from an industrial fuel spill or vehicle accident and gas powered boats on reservoirs	2
	Herbicides /pesticides – contamination of water by herbicide spill or mis-use	3
	Wildfire – Contamination of drinking water from fire retardant application	2

The main drinking water hazard present in the watershed is pathogens from various sources. Certain pathogens can be harmful in extremely small concentrations and ingestion can result in short and long-term illness, and possibly death for vulnerable individuals (e.g., the very young, very old, or those with a compromised immune system). Ultimately, water quality in McKinley Reservoir is directly linked to that of the intake on the Mill Creek source. Although there is other inflow into McKinley Reservoir, the inflow from Mill Creek is the largest source. Hazards that impact Mill Creek will also impact the McKinley Reservoir.

PHYSICAL HAZARDS

Turbidity/sediment alone are not generally harmful in drinking but can compromise the disinfection process and therefore the consequence from all sources is assumed to be at least moderate ('3', Table 4 -2). The consequence level of 3 is based on the assumption that turbidity/sediment alone, would be a minor impact for a large population and could result in mild to moderate illness. Turbidity and sediment levels in drinking water can be managed, but at increased costs. The reservoirs in the upper watershed provide some buffering at the intake by settling the sediment loads/turbidity upstream from the reservoirs. The settling action can reduce the consequence from sediment and turbidity introduced upstream from the reservoirs to drinking water quality at the intake. Increased sediment/nutrient delivery to the reservoirs can result in degraded water quality and lead to eutrification of these waters. Increased loading of dissolved/suspended organic compounds increases the risk at the intake of taste and odour problems and contributes to THM formation following disinfection. Sediment loads and turbidity introduced to the watershed downstream from the reservoirs are more likely to affect water quality at the intake, but remains rated as a moderate consequence.

Mass wasting events can cause increased turbidity and have the potential to completely block stream channels and/or destroy infrastructure. The consequence of

hazards related to mass wasting events range from 3 (moderate) to 5 (catastrophic) depending on the severity of the event (i.e. small landslide track reaches creek, increased turbidity results – consequence =3 vs. large landslide blocks creek and destroys water intake – consequence =5 catastrophic).

The consequence level for changes in water quantity is 3. The severity of the event covers everything from manageable increases or decreases in water supplies to complete loss of water due to extreme drought conditions or catastrophic peak flow events that could render the water intake/distribution system inoperable.

The physical consequences of wildfire in the watershed ranges from 3-5 depending upon the location, size and severity of the fire. Increased sediment loads and increased turbidity following wildfires would constitute a 3 or moderate consequence based on the same assumption summarized in the first paragraph above. Interruption of water service resulting from wildfire (evacuation order or order to remove chlorine supplies at the chlorinator) would constitute a level 4 consequence since a disruption to the water supply could have a major impact on the population and on agriculture. The destruction of the disinfection facility resulting from wildfire could constitute a level 5 consequence for similar reasons.

BIOLOGICAL HAZARDS

The presence of bacteria, protozoa and viruses represents a level 4 consequence since the potential for small concentrations of these contaminants in drinking water could lead to impaired human health of a large population. Algal growth in the reservoirs and stream network constitute a level 3 consequence since it typically has a limited impact on the water users. Although algae alone is a biological water quality parameter, the presence of algal cells (organics) in water supplies contribute to turbidity readings (physical parameter) and are precursors to THM formation (chemical parameter) when water is disinfected with chlorine/chlorine compounds. Blue green algae can be problematic as some species are associated with toxic compounds. Algae in drinking water supplies represent a level 3 consequences due to the potential health risks associated with exposure to potentially harmful algae species

The upper reservoirs are most likely to be affected by algal blooms during the summer months/growing season. Increased sediment/nutrient delivery to the reservoirs can exacerbate the conditions and lead to more frequent and intense algal growth. Increased loading of dissolved and suspended organic compounds increases the risk of taste and odour problems at the intake and are precursors to THM formation following disinfection.

CHEMICAL HAZARDS

Chemical hazards to drinking water (TOC including hydrocarbons, herbicides/pesticides and potential chemical contamination related to wildfire suppression agents/chemical retardants) constitute a level 2 consequence since

herbicide and pesticide use in the watershed is restricted and the current wildfire retardants have a low risk to human health. The presence of total organic carbon is an indicator of organic compounds that could contribute to THM/HAA formation. Small volumes of hydrocarbons from fuel spills can contaminate large volumes of water. The contaminants are typically less dense than water and affect the surface water only (do not penetrate to lower depths of reservoirs). The hydrocarbon compounds associated with petro-chemical spills are also volatile and can evaporate quickly, depending on water and air temperatures.

The toxicity of various herbicide and pesticide products ranges widely. However, in high concentrations these compounds can affect human health when ingested, inhaled or touched. It is unlikely that through proper use, high concentrations of these compounds would be present in drinking water supplies, however chronic exposure to low concentrations can also affect human health. For these reasons, pesticides and herbicides are given a consequence level of 3, moderate.

The potential for chemical contamination of drinking water from fire retardant application exists, but the compounds are designed to adhere to any substrate they contact (trees, shrubs, rocks) which reduces the likelihood of these compounds being washed into watercourses. In the event they are inadvertently applied directly into streams and/or reservoirs they pose a more significant threat to drinking water quality. The constituents of concern in fire retardants are primarily nutrients, which are designed to assist plant regeneration following the fires. These nutrients can encourage algal growth and for this reason the consequence on water quality related to fire suppressants is rated level 3.

4.3 QUALITATIVE RISK ASSESSMENT

A semi-qualitative risk assessment has been undertaken for the hazards identified in Module 2 (intrinsic watershed hazards and contaminant sources). The risk is assessed at the intake on Mill Creek prior to disinfection. Therefore, the assessed source risk at the intake will be different from the risk at the tap following disinfection. The unabated risk to the drinking water described above is the worst-case scenario, i.e., in the event of a failure of the intake/chlorination works.

ASSESSMENT OF LIKELIHOOD

Risk is the product of likelihood and consequence. Qualitative measures of likelihood are presented in Table 4-3 as provided in the Assessment Guidelines. A time horizon of 10 years is suggested in the guidelines when attributing likelihood of occurrence to identified hazards.

Table 4-3. Qualitative Measures of Likelihood

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

Reproduced from Module 7 of the *Comprehensive Drinking Water Source to Tap Assessment Guideline* (BC Ministry of Health Services and Ministry of Water, Land and Air Protection 2005).

Modules 1 and 2 have identified the hazards to drinking water quality summarized in Table 3-5. Assessment of likelihood for the hazards is summarized in Table 4-4 followed by a brief summary for each hazard.

Table 4-4. Likelihood of a Hazard Affecting Drinking Water Quality at the Intake

Hazard Type	Drinking Water Hazard	Likelihood
Physical	**Sediment** - Natural sediment load from channel erosion and mass wasting	C
	Sediment - Sedimentation from industrial activity including roads and road crossings	B
	Sediment - Sedimentation from range use in and around streams and road crossings	B
	Sediment – Sedimentation from recreation activity on roads, road crossings and in/around streams and reservoirs.	A
	Water Quantity – increased peak flows - lack of supply related to climate change	C
	Wildfire – increased sediment load, metals and nutrient transport resulting in increased treatment costs and infrastructure implications) - loss of control at intake from evacuation orders and/or damage	C
Biological	**Bacteria** - Bacteriological contamination from wildlife/cattle/human presence in and along streams and also wildfowl use and sanitary sewer at McKinley Reservoir.	A
	Protozoa – presence of Giardia, Cryptosporidium	A
	Viruses - presence	A
	Algae – algal blooms in reservoirs	B
Chemical	**Organic material** - (Total Organic Carbon)	B
	Hydrocarbons - Petroleum contamination from an industrial fuel spill or vehicle accident and gas powered boats on reservoirs	E
	Herbicides – likelihood of a spill or misuse is unlikely	E
	Wildfire – Retardant chemicals in the water supply	D

4.3.1 PHYSICAL HAZARDS

SEDIMENT/TURBIDITY

As indicated in Table 2-2 the raw water turbidity levels at the intake in 2008 averaged 3.3NTU during the June to October period that is within the objectives. As indicated in section 2.10 the IHA *treated water protocol* require turbidity levels <1NTU and the GCDWQ recommend *filtered water turbidity* levels ranging from <0.1NTU to ≤1.0NTU depending upon the type of filtration. If GEID can meet the requirements proposed in the IHA issue paper *Planning For Drinking Water Filtration Recommendation*, it may be able to defer filtration. During the watershed inspections it was evident that sediment is being contributed to watercourses as a result of resource development activities that increase the amount of soil exposure and disturbance. The sediment and turbidity that reaches the intake is a combination of natural and anthropogenic sources. The likelihood of sediment/turbidity affecting the intake varies depending upon the source. The cumulative risk considering all sources are rated as 'B' i.e. it is likely that there will be sediment/turbidity impacts to the source water.

WATER QUANTITY

As the mature lodgepole pine dies over the next several decades there is a risk of increased peak flows which could result in failures of road crossings that were designed using pre-beetle impact design criteria. Increased peak flows could also result in increased sediment transport as channels adjust to more frequent, larger flows. The impacts on water quality would be increased suspended and bed load sediment at the intake. These impacts could continue for decades until undersized structures are replaced and the channel has adjusted to a new state of equilibrium.

Over the longer term possibly 50 years and beyond, if the precipitation and temperature patterns change as suggested by the Atmospheric Environment Service, runoff may decline as a result of less snow and warmer temperatures. Lower water yields would mean less supply and subsequent water shortages if demand exceeds supply. These conditions could persist for an indeterminate period of time. In 2006 GEID used approximately 42% of its licensed supply. Over the next 20 years as domestic and irrigation demands increase the district could eventually use the majority of its licensed allotment. The cumulative risk for changes in water quantity is rated as 'C' or possible based on the level of uncertainty of the future climate.

WILDFIRE

There will be an increasing risk of wildfire in the watershed as the mature pine dies. A wildfire could cause a serious degradation in water quality related to increased sediment load, the release of metals from burned soils as well as increased nutrient loading from fire fighting activities as well as post fire effects. The risk of increased turbidity related to wildfire is rated as 'C' based on the location, extent and severity of future wildfires.

4.3.2 BIOLOGICAL CONTAMINANTS - FECAL COLIFORM/*E.COLI.*/ALGAE

FECAL COLIFORM/E. COLI.

Wildlife, livestock and humans are all identified potential pathogen and turbidity sources in the watershed. Livestock was noted at most of the assessed stream crossing where there are few barriers preventing access. Human waste was not identified but is likely present based on the observed presence of human activity in the watershed. Pathogens enter the stream network from manure, evidence of which was noted in the proximity of many watercourses during the field assessment. Contamination from wildfowl is an issue at the McKinley Reservoir as is the location of a sanitary sewer line adjacent to the west boundary.

Water quality sampling conducted at the intake and various other points in the watershed indicates that pathogens (*Escherichia coli* and fecal coliforms) were found throughout the watershed. The Health Canada criteria for exclusion of filtration for *E.coli* levels in raw water should not exceed 20/100 ml and total coliform should not exceed 100/100 ml in at least 90% of the weekly samples for the previous six months.. Water quality samples collected at the intake and at selected points throughout the watershed confirm that fecal coliform and *E. coli* are present at the intake and at each sampling site in the watershed. Based on the GEID sampling results, the likelihood of fecal coliform and *E.coli* being present in raw water at the intake is rated as 'A'.

ALGAE

There is a history of algae blooms in the Moore Reservoir, and the McKinley Reservoir as a result of the nutrient concentrations in the raw water entering the reservoir and from nutrients derived from wildfowl droppings in the reservoir. Algae blooms have not been problematic at Postill and South Lake reservoirs.

Blooms typically occur as a result of increased nutrient loading into the reservoir, combined with warm water temperature. Increased nutrient loading can occur as a result of heavy spring runoff, and low reservoir levels, or from runoff from intense rainstorms during the summer months. Nutrient loading is also influenced by avian presence (migratory game birds and their droppings) on a reservoir. Increased reservoir water temperature can result from low water levels and from high air temperature during the summer months. Because the McKinley reservoir is directly linked to the Mill Creek source water, and based on the known algae bloom occurrences in the upper watershed, the hazard rating is considered to be 'B'.

4.3.3 CHEMICAL

TOTAL ORGANIC CARBON (TOC)

Total organic carbon is of concern during the disinfection process as it can produce a by-product known as Trihalomethanes that may be carcinogenic. The BC Guideline for TOC is maximum 4 mg/L for source water that will be chlorinated (http://www.env.gov.bc.ca/wat/wq/BCguidelines/orgcarbon/ocarbon_over.html#guide).

There is no longer a guideline for TOC in the Guidelines for Canadian Drinking Water Quality. The likelihood that there will be elevated TOC levels at the intake is rated as 'B' due to the likelihood of increased organic loads in streams from the increased mortality of the mature lodgepole pine in the upper watershed.

HYDROCARBONS

The potential impacts on drinking water from a fuel spill is a concern since there is considerable industrial and recreational vehicle use throughout the watershed. McKinley Reservoir does not experience the same type of recreational traffic as the upland reservoirs and lakes but a paved public road winds along the southern end of the reservoir. Small amounts of oil or diesel fuel can contaminate large volumes of water. In the event that water at the intake was contaminated by an oil or fuel spill GEID would have to close the intake and provide water for its users from alternate sources. To date there are no reported incidents of fuel or oil being detected at the intakes on Mill and McKinley and the likelihood of this occurring is rated as a 'E.

HERBICIDES

Herbicides may be used by the Range Program or by the Ministry of Transportation to control noxious weeds in the watershed. A proposed golf course on the north side of the McKinley Reservoir would likely be an area of herbicide use. Herbicides are normally applied by a licensed applicator in accordance with a Pest Management Permit. The permit typically includes detailed requirements for the protection of water sources and the protocols if there was a chemical spill. The likelihood of contamination of the water supply is considered to be to be 'E' since the use of pesticides and herbicides on Crown land in the watershed is unlikely.

WILDFIRE

There is an increased wildfire risk due to the mountain pine beetle and dying mature pine. In the event of wildfires, there is a risk to water quality from chemical pollution related to fire retardant applications. The risk of chemical contamination of the water supply related to fire retardant application is rated as 'D' based on type of retardant currently in use and the care taken the MoFR to avoid contaminating water.

4.4 RISKS TO DRINKING WATER QUALITY AND QUANTITY

Risk is the product of likelihood and consequence. Using the risk matrix presented in Table 4-5 the risk for each identified hazard is presented in Table 4-6.

Table 4-5. Qualitative Risk Analysis 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

Reproduced from Module 7 of the *Comprehensive Drinking Water Source to Tap Assessment Guideline* (BC Ministry of Health Services and Ministry of Water, Land and Air Protection 2005).

For the physical hazards, the risk from natural sediment sources is rated as “high to very high” based on the potential increases in peak flows. The risk from sediment delivery related to industrial activity on roads is rated “high” since there is a large inventory of road crossings that are a primary source of the sediment. If there is increased industrial activity as a result of salvage logging the risk may increase over the next 3 –5 years. The risk of sedimentation from range use is rated “high” and the risk of increased sedimentation from recreation activity in the watershed is “very high”. The impacts from unregulated access for off-road vehicles on inactive roads is increasing significantly, resulting in additional sediment delivery to streams on roads that would otherwise be considered low hazard sources of sediment.

Water quantity risks are considered “high” due to the uncertainty in predicting the actual impacts from climate change and MPB. The risk from wildfire is rated as “moderate to very high”. The wildfire risk will increase significantly if the mature pine dies over the next few years.

For the biological hazards, bacteria, protozoa and viruses the risks are rated as “very high” due to the known levels of occurrence at the intake and the limited barriers currently in place. The data from water sampling indicates that bacteria are present in the Mill Creek source water at levels that exceed the water quality objectives for raw water. Bacteria levels in McKinley are identified as much lower than at the Intake on Mill Creek.

The risk from algae blooms in the McKinley Reservoir is considered to be “high”. There have been blooms in the past and the frequency is likely to increase with warmer summer temperatures and increased nutrient loading into the reservoirs associated with increased peak flows related to the loss of forest cover to the pine beetle. It is the by-products associated with the decay of algae that are the concern.

The chemical risks from hydrocarbons are rated as “low”. This risk results from a fuel spill, a rupture of a hydraulic hose on an excavator or from a vehicle accident into a mainstem channel or reservoir. The likelihood of hydrocarbons entering a stream and affecting the water quality at the intake is considered to be “low”. Total organic carbon is considered a “high” risk.

4.5 SUMMARY

This section is focused on determining the risks to water quality, quantity and the disruption of service based on the results of the contaminant inventory completed in the previous section and the barriers that are currently in place. The barriers are generally based on the requirements established in the legislation that governs licensed activities in the watershed. These include the *Forest and Range Practices Act*, the *Water Act*, the *Mines Act*, and the *Drinking Water Protection Act.* The barriers are the application of the requirements by the licensees. For example, for forest development it is the application of the expected results for water specified in the *Forest and Range Practices Act* and *Regulations*. Risk is the product of the hazards and the consequences. In this case the consequence of a hazard will be a reduction in the drinking water quality. The risk analysis considers the consequence for a specified hazard and the likelihood that it might occur. The results as summarized in Table 4-6 indicate that there are moderate risks associated with herbicides; moderate to high risks of increased sedimentation related to wildfires; high risks associated with sediment from cattle, recreation, algae and organic materials. High to very high risks related to natural sources of sediment, Very high risks related to sediment from recreation activities on roads and biological hazards (bacteria, protozoa and viruses). The risk rating was low for hydrocarbons and wildfire retardants.

Table 4-6. Mill Creek Watershed Qualitative Risk Assessment

Hazard Type	Drinking Water Hazard	Likelihood	Consequence	Risk	Comment/Assumption
Physical	**Sediment** - Natural sediment load from channel erosion and mass wasting [MC][14]	C	3-4	High-Very High	The mass wasting risk should be low provided development is restricted on class IV and V terrain. Natural sediment loads will increase with increasing peak flows but the reservoirs and wetlands provide substantial buffering
	Sediment - Sedimentation from industrial roads and road crossings [MC]	B	3	High	It is assumed that there will always be some sediment transport at road crossings
	Sediment - Sedimentation from range use in and around streams and road crossings [MC]	B	3	High	It is assumed that cattle will continue to graze in the watershed
	Sediment – Sedimentation from recreation activity on roads, road crossings and in/around streams and reservoirs [MC]	A	3	Very High	It is assumed that recreational use in the watershed will continue to increase.
	Water Quantity – Increased peak flows as pine dies; decreased runoff from lower snow packs [MC]	C	3	High	Over the next 30 years there could be increased peak flows related to the loss of forest cover to the pine beetle. Over the long-term, 50 years and beyond, if there is a long-term decline in snow packs, there may be a supply problem. Catastrophic peak flows or loss of supply from drought are possible.
	Wildfire – Increased sedimentation from fire fighting activity and post wildfire effects, plus loss of control at intake due to evacuation order and/or damage [MC]	D	3-5	Moderate to Very High	There will be an increasing risk of a wildfire over the next several years when the attacked pine is in the “red attack” stage. An intense wildfire could result in the loss of the watershed for water supply for an extended period of time.
Biological	**Bacteria** - Bacteriological contamination from wildlife/cattle/human presence in and along streams [MC] [MR]	A	4	Very High	The likelihood for increased contamination will be very high as recreational use increases and as the forest mosaic changes as a result of the loss of the pine.
	Protozoa – presence of Giardia, Cryptosporidium [MC] [MR]	A	4	Very High	
	Viruses – presence [MC] [MR]	A	4	Very High	
	Algae – algal blooms in reservoirs [MC] [MR]	B	3	High	
Chemical	**Organic material** - (Total Organic Carbon) [MC]	B	2	High	Organic material in streams will increase as the mature pine stands die.
	Hydrocarbons -Petroleum contamination from an industrial fuel spill or vehicle accident and gas powered boats on reservoirs [MR]	E	2	Low	Even with increased activity in the watershed the likelihood of a spill affecting the water at the intake is low.
	Herbicides [MR]	E	3	Moderate	Since herbicides should only be used under permit and by licensed applicators, the likelihood of a spill is low.
	Wildfire – Retardant chemicals in the water supply [MC]	D	2	Low	With trees dying due to the pine beetle, there is increased potential for wildfires.

[14] Abbreviation [MC] refers to possible hazard in the Mill Creek source area and [MR] refers to possible hazard to the McKinley reservoir.

5.0 MODULE 8 – RECOMMENDATIONS TO IMPROVE DRINKING WATER SOURCE PROTECTION AND SUSTAINABILITY IN MILL CREEK WATERSHED

The foundation for delivering safe drinking water is the use of multiple barriers to limit the exposure of drinking water to a particular hazard. This starts with barriers in the source watershed and source protection is the first barrier in the multi-barrier approach to protecting drinking water quality.

In 2006 seven Provincial ministries, the Office of the Provincial Health Officer and the five B.C. Health Authorities signed a Memorandum of Understanding (MOU) that commits the parties to inter-agency accountability and coordination for the protection of drinking water. A Southern Interior Regional Drinking Water Team (SIRDWT), has been formed as required in the MOU, with representation from the seven Ministries and the Interior Health Authority. The Mill Creek Source Assessment is supported by SIRDWT. A copy of the MOU and the list of members of the SIRDWT is provided in Appendix E. Establishing an effective working relationship with the SIRDWT is critical to achieving the objectives of this Plan.

The intent of the Source Protection Plan is to recommend a process to address the hazards that are a threat to drinking water safety and sustainability of the Mill Creek drinking water supply. The recommendations herein address the documented source hazards. Based on the risks to drinking water quality presented in Module7 (Section 4), there is a need for protection of the source water quality through the implementation of strengthened and additional barriers in the watershed area.

The district is currently developing plans for a large intake on Okanagan Lake near McKinley Landing that would be the major intake for its system.

Section 5.1 provides a SWOT analysis for protection of the Mill Creek source water quality. Section 5.2 provides a Source Protection Plan with actions to improve the raw water quality in Mill Creek.

5.1 SWOT ANALYSIS

A SWOT analysis is an effective approach to summarize, understand and balance the *strengths, weaknesses, opportunities* and *threats* to the water source in the Mill Creek watershed. Table 5-1 provides a summary of the SWOT analysis based on the information provided in the previous sections of this report.

Table 5-1. SWOT Analysis Summary

Strengths	Weaknesses
- Forest and range uses are regulated by the *Forest and Range Practices Act*. - GEID has a good working relationship with the agencies and stakeholders in the watershed. - The *Drinking Water Protection Act* and related regulations provide support for source protection. - There are established comprehensive planning processes for forest and range development in the watershed that include assessment of potential impacts. - Alternate groundwater well in the Ellison area that can provide sufficient water to meet limited domestic demands should the district lose the surface supply temporarily. - McKinley Reservoir provides a further opportunity for settling but it also could supply the Glenmore Valley area in combination with groundwater wells to meet limited domestic demand if the intake was temporarily shut down. - The GEID monitors hydrometric stations at key source locations to help predict current run-off trends and potential future water supply for their customers. - For the long-term, when the intake is developed on Okanagan Lake, GEID would have the ability to supply from the lake and/or from the Mill Creek intake.	- Recreation use has limited restrictions- There are limited means to regulate off-road vehicle activity. - The present source protection analysis assesses individual impacts and activities but there is no cumulative impact analysis that combines the impacts from all activities on source water quality and quantity. - Funding for ongoing assessments is limited. - Funding to implement remedial works is limited. - McKinley, and Moore Reservoirs are susceptible to algal blooms during the warm summer months. The reservoirs are very sensitive to increased nutrient levels from poor quality water. - The Mill Creek intake location has limited opportunities to improve the configuration to reduce its vulnerability to inflow impacts. - Accessibility of the reservoirs and mainstem channels from industrial roads and recreational trail network. - Terrain around reservoirs and good road access allows for unrestricted access to the reservoirs. - The wells would not provide sufficient flows to meet the irrigation demands in the Ellison area and, depending upon the time of year the loss of irrigation supply could result in significant crop losses and/or tree damage (orchard trees) - Limited means to enforce littering laws (i.e. refuse disposal). - GEID has only one form of water treatment, chlorination that does not eliminate Cryptosporidium. - The only E.coli ribosomal RNA data for the watershed is from the 2001study. - The intake on Mill Creek small with limited opportunities for improvements at the present location

Table 5-1 cont'd. SWOT Analysis Summary

Opportunities	Threats
- Confirm the availability of funding available through the Environmental Farm Plan program to assist ranchers in developing off-stream water sites and construct fencing to limit cattle access to sensitive sites. - There is a significant opportunity for GEID and the agencies to improve public education and awareness of the importance of protecting the water source. - Pursue opportunities to have Sections 46 and 58 of the Forest and Range Practices Act applied in the watershed to protect source water. - Pursue opportunities for additional OBWB funding for source protection. - Update the 2001 report on the sources of E.coli in the watershed to assist in addressing problem sources detected at the intake. - Develop the water license sharing from proposal with range tenure holders for off-channel watering. - Amend Range Use Plans to increase protection to watercourses. - Encourage assistance from the Southern Interior Drinking Water Team to implement source water protection strategies. - Coordinate with other watershed initiatives such as Water Use Plans, Sustainable Water Strategies, Forest Retention Plans, and Environmental Assessments for Development Applications. - Encourage the development of a regional source assessment database availability to local planners. - Use the British Columbia Draft Trails Strategy as a guide for strategies to consider reducing impacts from recreation use in the watershed. - Work with MoFR to develop a wildfire management plan for the watershed. - Encourage the province to implement ATV regulations and licensing. - Update the Drought Management. - Identify funding for source water protection as a GEID budget item. - Archive this report in the provincial EcoCat online library. - Encourage the province to consider user fees for backcountry users to generate funding to improve opportunities and protect source water supplies.	- Wildfire (natural or human related) is an increasing threat as the mature Lodgepole pine forests die from the mountain pine beetle. - Significantly increased ECA due to loss of the mature lodgepole pine to the mountain pine beetle which has the potential to cause significant changes to the watershed hydrology resulting in degraded water quality at the intake. - Salvage harvesting of lodgepole pine could increase road density and ground disturbance resulting in impacts on water quality. - Increased deciduous trees and shrubs may dominate riparian areas following the loss of pine. Beaver populations could increase resulting in beaver related problems. - Changes in climate may result in a long-term decrease in water yields and a reduced supply for GEID. - Increasing population in the Okanagan Valley will increase recreation pressures in the watershed, increasing the risks to water quality. - Demand for water in the GEID service area may increase due to increased population and warmer summer temperatures. - Ongoing unregulated access for off-road vehicles will result in increased dispersed sources of sediment to streams. - Ongoing refuse disposal along Mill Creek off of Postill Lake Road. - Use of watershed for activities not related to recreation such as; party/gathering area, disposal of stolen cars, and other illegal activity. - Complete blockage of mainstem channel from a slope failure in the steeper canyon sections, disrupting supply.

5.2 SOURCE PROTECTION PLAN

Several of the following paragraphs have been reproduced from Section 3. The intent is to reinforce the conclusions from Module 2 and support the recommendations made in this module.

The following sub-headings and recommendations are presented in general order of priority by use, with the objective of reducing risks to the Mill Creek source water supply.

5.2.1 RECREATION USE

Recreational use is considered high in the watershed, particularly around reservoirs and mainstem channels. Recreational uses vary in the watershed from camping/hunting/fishing (somewhat regulated) to off-road motorcycles/ATV/4wd vehicles (unregulated) to hikers (High Rim Trail) and mountain bike riders.

The upland reservoirs and lakes are popular locations for all users and gated roads do not appear to be discouraging vehicular access in these areas, particularly by motorcycles and ATVs. Trails have been built around stream crossings barriers placed to discourage traffic (sites 8, 59, and 84) Vehicle disturbance was noted below the full pool level in the three reservoirs, as well as other upland lakes. Motorcycles and ATV riders have created trails connecting lakes and wetlands in the upper watershed. Stream crossings of concern with regards to recreational vehicle impacts include Sites 4, 8, 14, 16, 17, 18, 19, 27, 29, 30, 46, 51, 81, and 84. Mud bogging appeared to be concentrated in an area disconnected from the mainstem and major tributary channels and considered a low hazard, however, evidence of 4wd vehicles was noted in the Moore reservoir area.

The proximity of the watershed to the populated areas in the Okanagan Valley and easy access has resulted in a significant increase in unregulated uses in the watershed including using the area for garbage disposal. The worst areas were along Postill Lake Road in the area of Site 51 and 52, as well as between Site 20 and 23. In these areas garbage (i.e. abandoned cars, fridges, mattresses, etc) have been dumped over steep banks, in gullies above Mill Creek and along the side of the road. Groups of people were also noted on a regular basis off Postill Lake Road at approximately 0.1km directly upstream of the intake that appears to be a popular party site.

There are fishing opportunities at all the reservoirs in the watershed, including McKinley, and recreational activity on the reservoirs increases the risk to the drinking water supply. The risks have not been well defined and research to date has been unable to fully quantify risks to water quality from recreational activity on/near reservoirs.

Recreation Use Recommendations

Recommendations for source protection related to sediment and turbidity from recreational use are as follows:

1. **The reservoirs are sensitive sites and recreation use on/or about the reservoirs should be consistent with the LRMP. ATV or any motorized vehicle use within the full pool area of any reservoir should be forbidden. (MoTCA)**
2. **It is recommended that a 'recreation brochure' be prepared that is focused on source protection and distributed with hunting and fishing licenses, firewood cutting permits, to ATV and motorcycle dealers, and by the Ministry of Tourism, Culture and the Arts at recreation sites. (MoTCA, GEID, MoE, MoFR)**
3. **Consider using a social marketing approach to engage recreational users.**
4. **The GEID, MoFR and MoTCA should continue to communicate with recreation users through local media, signage or verbally on responsible conduct in community watersheds.**
5. **It is recommended that GEID request that the Ministry of Forests and Range Compliance and Enforcement personnel and the Ministry of Environment Conservation Officers apply Section 46 of the *Forest and Range Practices Act* to charge individuals engaging in any activity on Crown land that results in damage to the environment, as defined in the *Act.* (GEID, MoFR, MoE)**
6. **It is recommended that GEID request that the RCMP patrol Postill Lake road on a regular basis in order to deter illegal activities such as refuse disposal, stolen car abandonment, and parties. (GEID, RCMP, CoK, RDCO)**
7. **It is recommended that access control measures be reviewed and revised to ensure that sensitive areas (i.e. stream crossings, wetlands, lakes) are not subject to motorized recreation and grazing activities. (GEID, MoTCA, ILMB)**
8. **Camping, if it is permitted near reservoirs should be restricted to designated controlled locations with proper design (including surface drainage) and maintenance of liquid and solid waste to limit the risks of contamination to the reservoirs. (MoTCA)**
9. **GEID should work with other water suppliers in the Okanagan to lobby the government to pass Off Highway Vehicle legislation that would require the licensing of all off highway motorized vehicles and regulations to control the use of these vehicles on Crown land. (GEID)**
10. **It is recommended that GEID request that the Minister of Forests and Range apply Section 58 of the *Forest and Range Practices Act* to restrict the use of motorized vehicles in specified sensitive areas in the watershed including reservoirs. (GEID, MoFR)**
11. **Unauthorized stream crossings, e.g. sites 4, 8, 14, 16, 17, 18, 19, 27, 29, 30, 46, 51, 59, 81, and 84, should be permanently closed and posted and the channels restored. (MoFR)**

5.2.2 RANGE USE

Grazing activity was noted throughout the watershed. According to the information provided by the Ministry of Forests and Range there are currently four grazing licences (two stakeholders) issued over the watershed with a total of 2257 AUMs (animal unit months). The dates of use vary, but in general cattle are permitted to graze the watershed from June 1 through October 30. Each tenure holder has a Grazing License issued by the Ministry of Forests and Range. The presence/absence of cattle impacts were noted at each road crossing assessed. Cattle frequently use road corridors as primary access routes through the watershed. Stream crossings along the roads offer easy access to water as well as to the riparian areas along streams where there is forage especially in the late summer and fall.

During the 2008 field inspection it was identified (based on presence or absence) that cattle were contributing sediment and fecal material at 42 of the 66 (70%) sites that were assessed in the field. The details for all the sites are provided in Appendix B. Cattle were observed at or near all upland lakes and reservoirs, either observed cattle presence or by evidence left behind. Cattle were also observed in and around Mill Creek at Sites 51, 52, 14, 19, and 59, along Bulman Creek Sites 1, 4, 8, 9, and 17, and along Conroy Creek, Sites 13, and 83. With increased cattle use there is also the associated increase in manure deposits in the reservoirs, stream channels and adjacent riparian area. This is a concern in the un-buffered zone below the reservoirs due to the direct connection to the Intake. Cattle guards and fences were noted in the watershed, however open gates permitted access across Mill Creek at Site 14. This was likely left open by motorized recreational users, as this is a popular crossing).

Salvage logging and the natural loss of beetle affected mature lodgepole pine will likely result in loss of natural barriers that normally limit access to watercourses by cattle. If the pine beetle epidemic and related loss of pine stands results in additional riparian areas becoming available for range use, there is the potential increase in manure deposits and soil disturbance in these areas unless increased cattle management keeps them away from these areas. Controlling cattle movement in the watershed is important, but may become more critical following changes to the landscape related to the pine beetle epidemic.

Specific cattle movement in the watershed is not known, however GEID is currently working with ranchers to improve off-channel watering and restricting cattle movement through fencing.

Range Use Recommendations

Recommendations for source protection related to sediment and turbidity from range use are:

1. **Review the results of the stream crossing assessments and prioritize sites affected by cattle use for potential remediation to reduce sediment and fecal material loading to the stream network. Consider creating and maintain boundaries to deter cattle from entering streams and reservoirs. (MoFR, Range Licensees)**
2. **Assess the shoreline areas at all major reservoirs to determine if measures to reduce cattle activity can be achieved. Any plans to reduce cattle impacts should be carried out in partnership with the MoFR and the range license holders. Funding for similar projects in the Okanagan has been secured by application to the OBWB for annual water quality improvements grants. (MoFR, Range Licensees**
3. **Identify riparian areas that may be affected by the pine beetle epidemic and subsequent loss of forest cover. These areas may require increased range management to prevent increased livestock access. (MoFR, Forest Licensees)**
4. **Post signs at all cattle gates indicating dates when gate must be either open or closed to that other users. (MoFR, Range Licensees)**
5. **Consider undertaking a cattle impact on water quality study in the watershed. (MoFR)**
6. **Explore opportunities to fund an E.coli RNA study in the watershed to determine current level of E.coli and sources. (MoFR, IHA, GEID)**

5.2.3 Sediment/Turbidity from Industrial Activity

There are two general sources of sediment related to the current industrial activities in the watershed. The most common being from roads at stream crossings, the second is related to channel erosion due to increased peak flows from the loss of all mature pine in the upper watershed. Channel erosion will likely increase as a function of the loss of forest cover to the pine beetle. Channel erosion can also be a natural function of the system, as large wood moves and shifts flow or steep undercut banks fail.

Although generally well maintained, and stable, there were still a number of stream crossings that were identified as slight to moderate sediment sources. For the deactivated roads that were inspected, measures appeared to be functioning as designed although recreational vehicle use deters the re-establishment of vegetation at stream crossings and generally disturbs soils. Four wood culverts were identified at various stages of failure (holes in road, sunken sections). A preliminary review of the field data determined that 24 of the 84 stream crossing sites were low to moderate sources of sediment to the stream channel system based on the calculated scores from the Stream Crossing Hazard Rating (SCHR)

tables in Appendix D. No high sediment sources related to stream crossings were identified related to road surface run-off. Ditchlines along Postill Lake Road were generally vegetated with grass although there were some sections of erosion and deposition noted. Road fill erosion due to road surface flow was noted along numerous sections (post rainfall), but generally does not appear to be reaching the mainstem channel. Historic failures along mainline appear unchanged other then fill erosion along Postill Lake Road due to local surface run-off. Deactivated stream crossings, and cross ditch/waterbars in the watershed were generally functioning as designed, although steep sided crossings (i.e. Site 27) along with recreational and cattle/animal traffic push sediment into the crossings to be flushed during higher flows. Traffic volume (industrial, recreational) also increases the likelihood of sediment delivery at each crossing; dust from these roads is also a source of fine sediments, and can be stored on channel beds/banks, and on vegetation.

The Ministry of Forests and Range forest road design criteria is that major culverts and bridges must have the capacity to pass the Q_{100} peak flow (statistical peak flow event that would occur once in any 100 year period). Stream flows may be greater after the pine dies and it is likely that there are stream-crossing structures in the watershed that will be affected by increased peak flows and will be undersized.

Maintenance of active forest roads is important (especially those sections of road near streams and reservoirs) and is the responsibility of the primary road permit holder. Inactive roads should be deactivated to a level that meets current and future access requirements: temporary, semi-permanent or permanent deactivation. The forest licensees and the MoFR should provide an annual update on the condition of active forest roads and the effectiveness of works to reduce sources of sediment to streams.

Salvage logging of beetle affected mature lodgepole pine will likely result in loss of natural barriers that limit access to watercourses by cattle and people.

It is the responsibility of the licensed stakeholders to plan, implement, monitor and revise their works consistent with the legislation, regulations and policies established under their permits/licenses for the protection of soil and water.

It is the responsibility of the Ministries that provide the authority to licensed stakeholders, in accordance with the MOU, to ensure that compliance monitoring of activities is undertaken consistent with their respective policies for source protection.

Industrial Use Recommendations

Recommendations for source protection related to sediment and turbidity from industrial activities are:

1. **Direct road surface runoff away from streams and stream crossings. Ditch lines should include cross drains with ditch blocks so that runoff that accumulates in the ditches is dispersed onto the forest floor away from the streams. In addition, ditch lines and culverts should be kept clear of debris and the ditch lines should be vegetated with grasses to limit erosion and capture sediments. A grass species that discourages grazing would be the preferred species. (Tolko, BCTS)**
2. **Forest licensees should consider developing a wet weather operational guideline that regulates industrial road activity during periods when this activity has a high likelihood of increasing sediment loads to source water supplies. (Tolko, BCTS)**
3. **High use roads adjacent to streams and reservoirs should be considered for surface treatments to control dust during dry periods. (Tolko, BCTS)**
4. **Roads not required for active use should be deactivated to a level that meets current and future access requirements: temporary, semi-permanent or permanent deactivation. (Tolko, BCTS, MoFR)**
5. **Review the sites in Table 3-4 of Module 2 with "low to moderate" hazard ratings, and greater, and take actions to reduce sediment delivery to streams so that the hazard rating is reduced to "low". (Tolko, BCTS)**
6. **The Ministry of Forests and Range should develop and implement a review of stream crossing structures that are downstream from the beetle affected areas in the Mill Creek watershed to ensure they are adequately sized to safely convey projected future peak flows. (MoFR)**
7. **Access to sensitive areas along watercourses, lakes and wetlands should be restricted as the forest cover changes to protect the water quality. (GEID, MoFR, MoTCA, Forest and Grazing Licensees). Planning should also consider best management practices where these are available**
8. **Tolko Industries Ltd. should consider including recognition of the Mill Creek Source Protection Plan in their forest stewardship plan. (Tolko, BCTS, GEID, Grazing Licensees, Mineral Licensees)**
9. **The MoFR should provide an annual report to the Drinking Water Officer describing compliance of activities undertaken in the Mill Creek watershed under its jurisdiction. (IHA, MoFR)**

5.2.4 OTHER ISSUES

The following issues may also require action to protect the Mill Creek water source.

Recommendations for other issues

- ***Source Protection Response Plan –*** The next step in the source protection process should be to develop a "source protection response plan".
- ***Reservoirs*** – Implement an action plan to educate the public about the protection of the reservoirs from contamination including proper disposal of human waste when recreating near water sources. Post the reservoir perimeter areas as prohibited access for vehicles except at designated boat launches.

- ***Pesticides/Herbicides –*** It is recommended that all applications for the use of herbicides and pesticides in the watershed upstream of GEID intake be referred to GEID for review (Includes McKinley Reservoir).

- ***Monitoring*** – Monitoring is an essential component of the Source Protection Plan and the GEID has a raw water-monitoring program. The program has established baseline monitoring and problem identification. There should be a co-operative plan to implement source tracking and identification of contaminants similar to that carried out by Cynthia Meays in 2005. The support for the source tracking and contaminant identification program should to come from the ministries that signed the MOU, and from the stakeholders. The sampling results should be reported to the Drinking Water Officer, SIRDWT members and stakeholders annually.

- ***Watershed Hydrology and Flow Monitoring –*** It is recommended that the GEID continue with the stream flow-monitoring program (Mill Creek at the Intake, and the Postill Lake spillway weir) to monitor future stream flows to understand the effects of pine beetle attack and climate change on the watershed hydrology.

- ***Compliance Reporting*** - The Source Protection Plan must have an annual compliance-reporting requirement. Based on the MOU there should be annual reports provided by the agencies to the DWO that report on source protection. A summary report should be provided to the SIRDWT and the stakeholders, and be reviewed at an annual watershed meeting. Based on results of the source water quality monitoring by GEID and the compliance report, appropriate changes can be made to the Source Protection Plan.

- ***Education*** – Install information signs at each of the upland reservoirs and McKinley that would provide information to the public about the Community Watershed and the importance in protecting the water. Continue to install and maintain 'Community Watershed' and 'RAPP' signs on all access roads to the upland watershed. Consider developing a 'Watershed Fact Sheet' that could be supplied to the public, government agencies and stakeholders to provide information regarding the watershed, the importance of protecting the water, and what the reader can do to help, e.g., avoid contaminating the water with human waste and refuse.

  Consider establishing an annual 'watershed awareness day' to raise awareness of the water supply. This could also be taken to the local schools as well.

- ***Wildfire*** – Wildfire is a concern in the watershed, and with the advance of the mountain pine beetle, the fuel load will increase as will the risk of fire. Consideration should be given to developing a wildfire preparedness plan that would address drinking water related concerns. This should include a long-term fuel reduction plan and firebreak plan. Funding for a fuel reduction plan may be available from UBCM through the RDCO to assist in the development and implementation of a fuel reduction plan. Future harvesting plans should consider the location of new cut blocks as part of a landscape level firebreak plan.

- ***Mines/Quarries/Mineral Claims*** – There are 6 mineral tenures within the watershed area (none active). The agency responsible for issues permits for these uses is the Ministry of Energy, Mines and Petroleum Resources (MEMPR). MEMPR is also a signatory to the Drinking Water Source Protection Memorandum of Understanding. It is recommended that GEID contact the MEMPR office in Kamloops that is responsible for claims in the watershed and arrange a meeting to present the Mines Inspector with a copy of this report as well as review the issues and concerns specific to MEMPR with the Inspector. A field tour would assist the inspector to appreciate the concerns. All development proposed by MEMPR in the watershed should be referred to the GEID for review.

- ***Salvage Harvesting -*** It is recommended that GEID review the expansion of the pine beetle in the watershed annually with the forest licensees. It also recommended that GEID and the forest licensees review proposed salvage harvesting plans and options to protect the water resources.

- ***Source Protection Plan Review -*** The Mill Creek Source Assessment and Source Protection Plan should be reviewed annually by GEID and IHA and updated on a five-year basis or as a result of a significant increase in risks to the source water quality.

5.2.5 IMPLEMENTATION

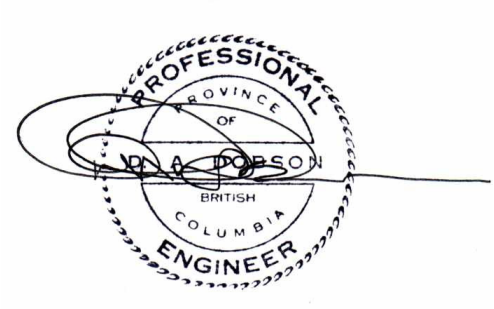
The implementation stage is the key to a successful source water protection program. As presented in the foregoing SWOT analysis, many agencies and stakeholders, who have a common goal of improved source water quality and public health protection, support the GEID. The Technical Advisory Committee (TAC) to GEID for this Plan was limited to representation from IHA and MOE that will be responsible for assisting in the implementation of the Plan. The stakeholders were intended to be an inclusive group that should consider the merits of continuing forward with members from the TAC to assist in the eventual implementation of the response plan that will be developed to address specific risks. As implementation proceeds, the steering group should be responsive to the inevitable unexpected challenges and barriers to implementing the action items.

To secure support from the stakeholders, and to provide for the necessary resource planning, it is recommended that GEID and the TAC undertake a prioritization exercise as follows (adapted from the *Source to Tap Assessment Guideline*, Module 8, Section 2.1):

- confirm the most critical problems for the water supply and public health;
- direct resources to those actions with the highest potential for water quality improvement;
- protect areas that have not been disturbed from degradation;
- identify areas where there is a need to coordinate multiple remedial or protective priorities;
- follow the SMART principles in the development and implementation of the risk management activities and make goals specific, measurable, realistic and time bound.

Module 8 in the *Comprehensive Drinking Water Source to Tap Assessment Guideline* contains useful suggestions for prioritizing and assessing effectiveness of risk management activities.

Prepared by:



Don Dobson, PEng

STATEMENT OF LIMITATIONS

This document has been prepared by Dobson Engineering Ltd (DEL) and for the exclusive use and benefit of **Glenmore Ellison Improvement District** for the **Mill Creek Source Assessment.** No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document. This document represents DEL's best professional judgment based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practicing under similar conditions. No warranty, express or implied, is made.

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Appendix A

Watershed Maps

Glenmore Ellison Improvement District

Mill Creek
Watershed Map

Legend

Boundaries
- Watershed
- HA0
- 123456 Mineral Tenure
- Recreation Reserve
- Recreation Site
- Range Tenure (ID RAN012345)
- Private Land

Water
- Reservoir
- Lake
- Wetland
- Stream
- Intake Pipe
- GVW Works

Logging
- Existing Harvest
- Proposed Harvest

Roads
- Public
- Main Line
- Logging
- 64 Stream Crossing

Contours
- Index (100m)
- Intermediate (50m)
- Intermediate (20m)
- Intermediate (10m)

Projection: UTM Zone 11
Datum: NAD83

1:20,000

400 200 0 400 800 1,200
Meters

DOBSON Engineering Ltd.

Map Prepared for:
Dobson Engineering Ltd.
2580 Dunsmuir Road, Kelowna, BC, V1W 2V3

FPS Drafting & Geomatics Ltd.

Map Prepared by:
FPS Drafting & Geomatics Ltd.
2784 Paris Street, Penticton, BC, V2A 8G2

Moore Buffered Zone

Conroy
Partly Buffered Zone

Unbuffered Sensitive Zone

South Lakes
Buffered Zone

Postill Buffered Zone

Swalwell Reservoir

Moore Reservoir

Postill Reservoir

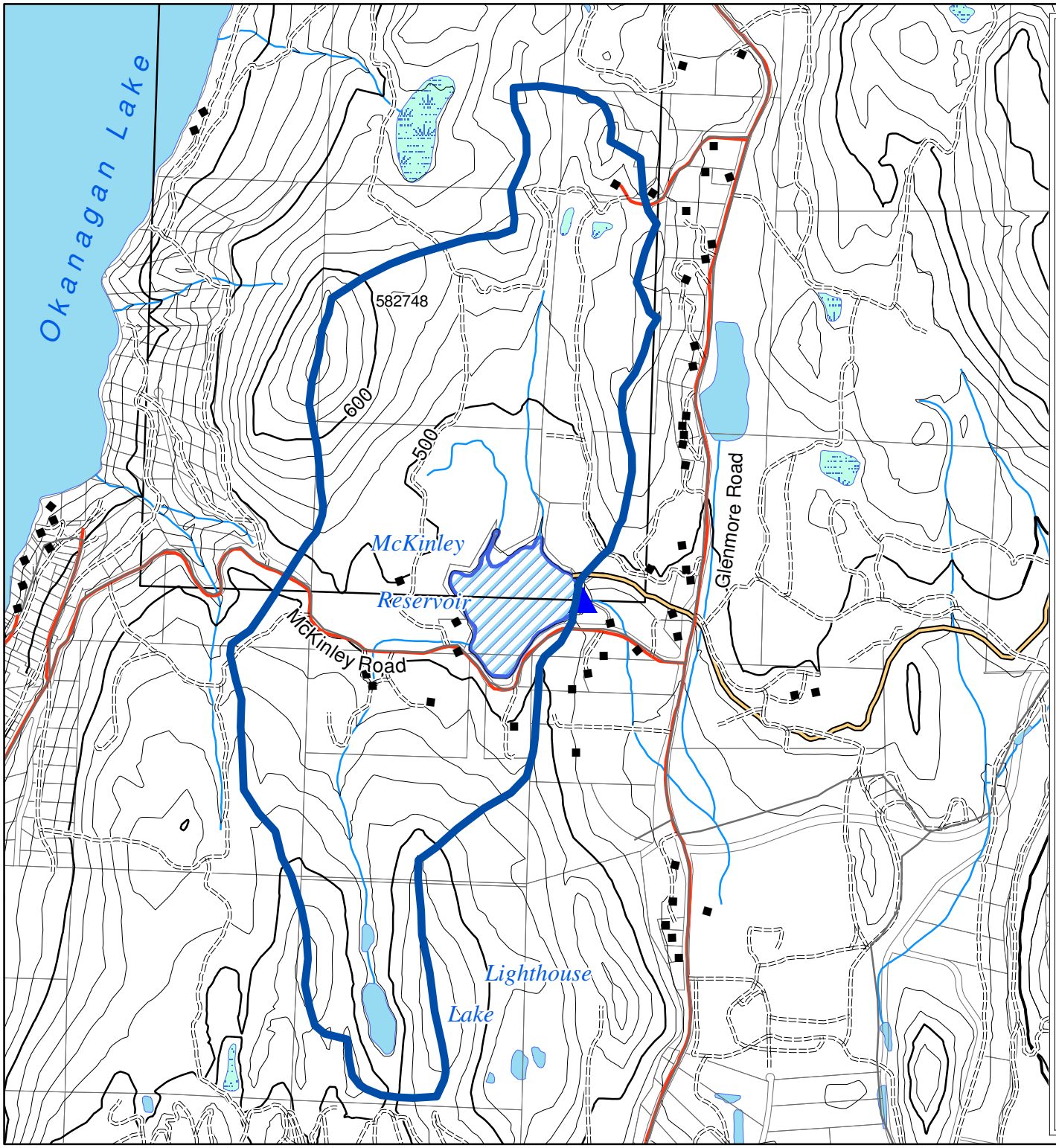
South Lake Reservoir

James Reservoir

GEID Intake

RAN071396
RAN075040
RAN075481

File:205-001\Project 28041_FPSGDL_28041_final_v1\A0L20.mxd



Glenmore Ellison Improvement District

McKinley Reservoir Map

Legend

Boundaries
- Watershed
- 123456 Mineral Tenure
- Private Land
- Building

Water
- Reservoir
- Lake
- Wetland
- Stream
- Inflow - Mill Creek Source Water
- GVW Works

Roads
- Public
- Minor

Contours
- Index (100m)
- Intermediate (50m)
- Intermediate (20m)

Projection: UTM Zone 11
Datum: NAD83

1:20,000

400 200 0 400 800

metre

DOBSON Engineering Ltd.

Map Prepared for:
Dobson Engineering Ltd.
2580 Dunsmuir Road, Kelowna, BC, V1W 2V3

FPS Drafting & Geomatics Ltd.

Map Prepared by:
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2784 Paris Street, Penticton, BC, V2A 8G2

File:205-001 Project:28041 - FPSDGL - 28041_final_u11_mckinleyLtL20.mxd

Appendix B

Field Assessment Results and Photographs

Photo 1 – GEID intake

Photo 2 – Mill Creek near old weir location (removed)

Photo 3 – Crossing on Mill Creek at Site 14 used by recreation and cattle

Photo 4 – Outlet at Moore Reservoir, Site 1

Photo 5 – Bulman Creek between Site 8 and 17

Photo 6 – Bulman Creek between Site 9 and 17

Photo 7 – Crossing on Bulman Creek at Site 17 used by recreation and cattle

Photo 8 – Conroy Creek at Site 102

Photo 9 - Recreation site on Postill Lake showing surface erosion at boat launch

Photo 10 – Vehicle tracks below full-pool on Postill Reservoir

Photo 11 – Cattle at South Reservoir near the dam

Photo 12 – Moore Reservoir recreation use, vehicles accessing below full pool

Photo 13 – Running surface erosion along Postill Lake Road during rain

Photo 14 – Sediment delivery to tributary Site 27 below Postill Lake Road

Photo 15 – Failing wood culvert upstream of Hereron Lake, Site 57

Photo 16 – Recreational vehicle damage along Bulman Creek, Site 8

Photo 17 – Running surface erosion to Bulman Creek at Postill Lake Road, Site 9

Photo 18 – Recreation vehicle crossing tributary to Mill Creek at Site 29

Photo 19 – Recreation access between Site 29 and 30

Photo 20 – View of Old Postill Lake Road at section of pullback

Photo 21 – Recreation vehicle crossing of Mill Creek above Postill Lake at Site 59

Photo 22 – Tributary to Postill Lake crossing Site 81, recreation vehicle and cattle use

Photo 23 – Postill Lake Road at Postill Lake Lodge

Photo 24 – Recreation vehicle trail across Conroy Creek, Site 102

Photo 25 – Mountain bike use in lower watershed off Postill Lake Road near 1 km

Photo 26 – Garbage along Postill Lake Road near Site 52

Photo 27 – Garbage along Postill Lake Road

Photo 28 – Active forest development new in-block road on left of frame

Appendix C

GEID Water Quality Laboratory Summaries

CERTIFICATE OF ANALYSIS

CARO ANALYTICAL SERVICES

CLIENT	**Glenmore Ellison Improvement District** 445 Glenmore Road KELOWNA, BC V1V 1Z6	TEL FAX	(250) 763-6506 (250) 763-5688
ATTENTION	**Andrew Cammell**		

G.E.I.D.
SEP 09 2009
RECEIVED

RECEIVED / TEMP	Aug-31-09 13:55 / 19.0 °C	**WORK ORDER #**	K9H1036
REPORTED	Sep-08-09	**PROJECT FILE**	Bulman Reservoir - Annual
COC #(s)	40046.50788		

General Comments:

CARO Analytical Services employs methods which are based on those found in "Standard Methods for the Examination of Water and Wastewater", 21st Edition, 2005, published by the American Public Health Association (APHA); US EPA protocols found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW846", 3rd Edition; and protocols published by the British Columbia Ministry of Environment (BCMOE).

Methods not described in these publications are conducted according to procedures accepted by appropriate regulatory agencies, and/or are done in accordance with recognized professional standards using accepted testing methodologies and quality control efforts except where otherwise agreed to by the client.

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirity. CARO is not responsible for any loss or damage resulting directly or indirectly from error or omission in the conduct of testing. Liability is limited to the cost of analysis. Samples will be disposed of 30 days after the test report has been issued unless otherwise agreed to in writing.

- All solids results are reported on a dry weight basis unless otherwise noted

- Units: mg/kg = milligrams per kilogram, equivalent to parts per million (ppm)
  mg/L = milligrams per litre, equivalent to parts per million (ppm)
  ug/L = micrograms per litre, equivalent to parts per billion (ppb)
  ug/g = micrograms per gram, equivalent to parts per million (ppm)
  ug/m3 Air = micrograms per cubic meter of air

- "RDL" Reported detection limit
- "<" Less than reported detection limit
- "AO" Aesthetic objective
- "MAC" Maximum acceptable concentration (health-related guideline)
- "LAB" RMD = CARO - Richmond location, KEL = CARO - Kelowna location, SUB = Subcontracted

Please contact CARO if more information is needed.

CARO Analytical Services

Final Review Per: **Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H1036
PROJECT FILE	Bulman Reservoir - Annual	**REPORTED**	Sep-08-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes

General Parameters

Bulman 0.5m (K9H1036-01) Matrix: Water Sampled: Aug-31-09 12:45

Alkalinity, Total as CaCO3	**25.4**	1.0	mg/L	Sep-01-09	APHA 2320 B	KEL
Carbon, Total Organic	**20.3**	0.5	mg/L	Sep-02-09	APHA 5310 B	KEL
Chlorophyll-a	**3.4**	0.1	ug/L	Sep-04-09	APHA 10200H	KEL
Colour, True	**86**	5	Color Unit	Sep-01-09	APHA 2120 B	KEL
Nitrogen, Ammonia as N	**0.09**	0.02	mg/L	Aug-31-09	APHA 4500-NH3 F	KEL
Nitrogen, Nitrate+Nitrite as N	**0.03**	0.01	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate as N	**0.03**	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Total Kjeldahl	**0.85**	0.05	mg/L	Sep-01-09	APHA 4500-Norg	KEL
Nitrogen, Dissolved Kjeldahl	**0.73**	0.05	mg/L	Sep-02-09	APHA 4500-Norg	KEL
Nitrogen, Total	**0.88**	0.05	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate+Nitrite as N	**0.03**	0.02	mg/L	Sep-01-09	[CALC]	KEL
Nitrogen, Total Dissolved	**0.75**	0.05	mg/L	Sep-02-09	[CALC]	KEL
Nitrogen, Organic	**0.77**	0.05	mg/L	Sep-01-09	CALC	KEL
pH	**7.36**	0.10	pH Units	Sep-01-09	APHA 4500-H+	KEL
Phosphorus, Total	**0.05**	0.01	mg/L	Sep-01-09	APHA 4500P:B.5/E	KEL
Phosphorus, Dissolved	**0.03**	0.01	mg/L	Sep-02-09	APHA 4500P:B.5/E	KEL
Solids, Total Dissolved	**79**	5	mg/L	Sep-02-09	APHA 2540 C	KEL
Transmissivity @ 254nm	**27.2**	0.1	%	Sep-03-09	APHA 5910B	KEL
Turbidity	**2.5**	0.1	NTU	Sep-01-09	APHA 2130 B	KEL

Bulman 4m (K9H1036-02) Matrix: Water Sampled: Aug-31-09 12:55

Alkalinity, Total as CaCO3	**25.3**	1.0	mg/L	Sep-01-09	APHA 2320 B	KEL
Carbon, Total Organic	**21.3**	0.5	mg/L	Sep-02-09	APHA 5310 B	KEL
Colour, True	**88**	5	Color Unit	Sep-01-09	APHA 2120 B	KEL
Nitrogen, Ammonia as N	**0.09**	0.02	mg/L	Aug-31-09	APHA 4500-NH3 F	KEL
Nitrogen, Nitrate+Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Total Kjeldahl	**0.68**	0.05	mg/L	Sep-01-09	APHA 4500-Norg	KEL
Nitrogen, Dissolved Kjeldahl	**0.68**	0.05	mg/L	Sep-02-09	APHA 4500-Norg	KEL
Nitrogen, Total	**0.68**	0.05	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate+Nitrite as N	<0.02	0.02	mg/L	Sep-01-09	[CALC]	KEL
Nitrogen, Total Dissolved	**0.68**	0.05	mg/L	Sep-02-09	[CALC]	KEL
Nitrogen, Organic	**0.59**	0.05	mg/L	Sep-01-09	CALC	KEL
pH	**7.08**	0.10	pH Units	Sep-01-09	APHA 4500-H+	KEL
Phosphorus, Total	**0.05**	0.01	mg/L	Sep-01-09	APHA 4500P:B.5/E	KEL
Phosphorus, Dissolved	**0.04**	0.01	mg/L	Sep-02-09	APHA 4500P:B.5/E	KEL
Solids, Total Dissolved	**82**	5	mg/L	Sep-02-09	APHA 2540 C	KEL
Transmissivity @ 254nm	**27.3**	0.1	%	Sep-03-09	APHA 5910B	KEL
Turbidity	**3.2**	0.1	NTU	Sep-01-09	APHA 2130 B	KEL

Dissolved Metals by ICPMS

Bulman 0.5m (K9H1036-01) Matrix: Water Sampled: Aug-31-09 12:45

Iron	**0.458**	0.100	mg/L	Sep-04-09	EPA 6020A	RMD

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H1036
PROJECT FILE	Bulman Reservoir - Annual	**REPORTED**	Sep-08-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes
Dissolved Metals by ICPMS, Continued							
Bulman 4m (K9H1036-02) Matrix: Water Sampled: Aug-31-09 12:55							
Iron	**0.475**	0.100	mg/L	Sep-04-09	EPA 6020A	RMD	
Total Recoverable Metals by ICPMS							
Bulman 0.5m (K9H1036-01) Matrix: Water Sampled: Aug-31-09 12:45							
Iron	**0.61**	0.10	mg/L	Sep-04-09	EPA 6020A	RMD	
Bulman 4m (K9H1036-02) Matrix: Water Sampled: Aug-31-09 12:55							
Iron	**0.70**	0.10	mg/L	Sep-04-09	EPA 6020A	RMD	
Microbiological Parameters							
Bulman 0.5m (K9H1036-01) Matrix: Water Sampled: Aug-31-09 12:45							
Coliforms, Total	**≥ 300**	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Coliforms, Fecal	<1	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Sep-01-09	APHA 9223	KEL	
Bulman 4m (K9H1036-02) Matrix: Water Sampled: Aug-31-09 12:55							
Coliforms, Total	**35**	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Coliforms, Fecal	<1	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Sep-01-09	APHA 9223	KEL	

CERTIFICATE OF ANALYSIS

CARO ANALYTICAL SERVICES

CLIENT	**Glenmore Ellison Improvement District** 445 Glenmore Road KELOWNA, BC V1V 1Z6		TEL (250) 763-6506 FAX (250) 763-5688	G.E.I.D. SEP 09 2009 RECEIVED
ATTENTION	**Andrew Cammell**			
RECEIVED / TEMP	Aug-31-09 13:55 / 19.0 °C	**WORK ORDER #**	K9H1038	
REPORTED	Sep-08-09	**PROJECT FILE**	South Reservoir - Annual	
COC #(s)	40046.50788			

General Comments:

CARO Analytical Services employs methods which are based on those found in "Standard Methods for the Examination of Water and Wastewater", 21st Edition, 2005, published by the American Public Health Association (APHA); US EPA protocols found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW846", 3rd Edition; and protocols published by the British Columbia Ministry of Environment (BCMOE).

Methods not described in these publications are conducted according to procedures accepted by appropriate regulatory agencies, and/or are done in accordance with recognized professional standards using accepted testing methodologies and quality control efforts except where otherwise agreed to by the client.

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  mg/L = milligrams per litre, equivalent to parts per million (ppm)
  ug/L = micrograms per litre, equivalent to parts per billion (ppb)
  ug/g = micrograms per gram, equivalent to parts per million (ppm)
  ug/m3 Air = micrograms per cubic meter of air

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- "<" Less than reported detection limit
- "AO" Aesthetic objective
- "MAC" Maximum acceptable concentration (health-related guideline)
- "LAB" RMD = CARO - Richmond location, KEL = CARO - Kelowna location, SUB = Subcontracted

Please contact CARO if more information is needed.

CARO Analytical Services

Final Review Per: **Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H1038
PROJECT FILE	South Reservoir - Annual	**REPORTED**	Sep-08-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes

General Parameters

South 0.5m (K9H1038-01) Matrix: Water Sampled: Aug-31-09 11:30

Alkalinity, Total as CaCO3	**25.4**	1.0	mg/L	Sep-01-09	APHA 2320 B	KEL
Carbon, Total Organic	**13.4**	0.5	mg/L	Sep-02-09	APHA 5310 B	KEL
Chlorophyll-a	**2.2**	0.1	ug/L	Sep-04-09	APHA 10200H	KEL
Colour, True	**41**	5	Color Unit	Sep-01-09	APHA 2120 B	KEL
Nitrogen, Ammonia as N	<0.02	0.02	mg/L	Aug-31-09	APHA 4500-NH3 F	KEL
Nitrogen, Nitrate+Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Total Kjeldahl	**0.41**	0.05	mg/L	Sep-01-09	APHA 4500-Norg	KEL
Nitrogen, Dissolved Kjeldahl	**0.41**	0.05	mg/L	Sep-02-09	APHA 4500-Norg	KEL
Nitrogen, Total	**0.41**	0.05	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate+Nitrite as N	<0.02	0.02	mg/L	Sep-01-09	[CALC]	KEL
Nitrogen, Total Dissolved	**0.41**	0.05	mg/L	Sep-02-09	[CALC]	KEL
Nitrogen, Organic	**0.41**	0.05	mg/L	Sep-01-09	CALC	KEL
pH	**7.57**	0.10	pH Units	Sep-01-09	APHA 4500-H+	KEL
Phosphorus, Total	**0.01**	0.01	mg/L	Sep-01-09	APHA 4500P:B.5/E	KEL
Phosphorus, Dissolved	**0.01**	0.01	mg/L	Sep-02-09	APHA 4500P:B.5/E	KEL
Solids, Total Dissolved	**65**	5	mg/L	Sep-02-09	APHA 2540 C	KEL
Transmissivity @ 254nm	**49.4**	0.1	%	Sep-03-09	APHA 5910B	KEL
Turbidity	**0.7**	0.1	NTU	Sep-01-09	APHA 2130 B	KEL

South 2m (K9H1038-02) Matrix: Water Sampled: Aug-31-09 11:40

Alkalinity, Total as CaCO3	**25.5**	1.0	mg/L	Sep-01-09	APHA 2320 B	KEL
Carbon, Total Organic	**11.7**	0.5	mg/L	Sep-08-09	APHA 5310 B	KEL
Colour, True	**43**	5	Color Unit	Sep-01-09	APHA 2120 B	KEL
Nitrogen, Ammonia as N	<0.02	0.02	mg/L	Aug-31-09	APHA 4500-NH3 F	KEL
Nitrogen, Nitrate+Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Total Kjeldahl	**0.44**	0.05	mg/L	Sep-01-09	APHA 4500-Norg	KEL
Nitrogen, Dissolved Kjeldahl	**0.42**	0.05	mg/L	Sep-02-09	APHA 4500-Norg	KEL
Nitrogen, Total	**0.44**	0.05	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate+Nitrite as N	<0.02	0.02	mg/L	Sep-01-09	[CALC]	KEL
Nitrogen, Total Dissolved	**0.42**	0.05	mg/L	Sep-02-09	[CALC]	KEL
Nitrogen, Organic	**0.44**	0.05	mg/L	Sep-01-09	CALC	KEL
pH	**7.48**	0.10	pH Units	Sep-01-09	APHA 4500-H+	KEL
Phosphorus, Total	**0.02**	0.01	mg/L	Sep-01-09	APHA 4500P:B.5/E	KEL
Phosphorus, Dissolved	**0.01**	0.01	mg/L	Sep-02-09	APHA 4500P:B.5/E	KEL
Solids, Total Dissolved	**53**	5	mg/L	Sep-02-09	APHA 2540 C	KEL
Transmissivity @ 254nm	**48.9**	0.1	%	Sep-03-09	APHA 5910B	KEL
Turbidity	**1.1**	0.1	NTU	Sep-01-09	APHA 2130 B	KEL

Dissolved Metals by ICPMS

South 0.5m (K9H1038-01) Matrix: Water Sampled: Aug-31-09 11:30

Iron	<0.100	0.100	mg/L	Sep-04-09	EPA 6020A	RMD

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H1038
PROJECT FILE	South Reservoir - Annual	**REPORTED**	Sep-08-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes
Dissolved Metals by ICPMS, Continued							
South 2m (K9H1038-02) Matrix: Water Sampled: Aug-31-09 11:40							
Iron	<0.100	0.100	mg/L	Sep-04-09	EPA 6020A	RMD	
Total Recoverable Metals by ICPMS							
South 0.5m (K9H1038-01) Matrix: Water Sampled: Aug-31-09 11:30							
Iron	**0.12**	0.10	mg/L	Sep-04-09	EPA 6020A	RMD	
South 2m (K9H1038-02) Matrix: Water Sampled: Aug-31-09 11:40							
Iron	**0.12**	0.10	mg/L	Sep-04-09	EPA 6020A	RMD	
Microbiological Parameters							
South 0.5m (K9H1038-01) Matrix: Water Sampled: Aug-31-09 11:30							
Coliforms, Total	**21**	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Coliforms, Fecal	<1	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Sep-01-09	APHA 9223	KEL	
South 2m (K9H1038-02) Matrix: Water Sampled: Aug-31-09 11:40							
Coliforms, Total	**49**	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Coliforms, Fecal	<1	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Sep-01-09	APHA 9223	KEL	

CERTIFICATE OF ANALYSIS

CARO ANALYTICAL SERVICES

G.E.I.D.
SEP 09 2009
RECEIVED

CLIENT **Glenmore Ellison Improvement District**
445 Glenmore Road
KELOWNA, BC
V1V 1Z6
TEL (250) 763-6506
FAX (250) 763-5688

ATTENTION **Andrew Cammell**

RECEIVED / TEMP	Aug-31-09 13:55 / 19.0 °C	**WORK ORDER #**	K9H1039
REPORTED	Sep-08-09	**PROJECT FILE**	Postill Reservoir - Annual
COC #(s)	40046.50788		

General Comments:

CARO Analytical Services employs methods which are based on those found in "Standard Methods for the Examination of Water and Wastewater", 21st Edition, 2005, published by the American Public Health Association (APHA); US EPA protocols found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW846", 3rd Edition; and protocols published by the British Columbia Ministry of Environment (BCMOE).

Methods not described in these publications are conducted according to procedures accepted by appropriate regulatory agencies, and/or are done in accordance with recognized professional standards using accepted testing methodologies and quality control efforts except where otherwise agreed to by the client.

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirity. CARO is not responsible for any loss or damage resulting directly or indirectly from error or omission in the conduct of testing. Liability is limited to the cost of analysis. Samples will be disposed of 30 days after the test report has been issued unless otherwise agreed to in writing.

- All solids results are reported on a dry weight basis unless otherwise noted

- Units: mg/kg = milligrams per kilogram, equivalent to parts per million (ppm)
  mg/L = milligrams per litre, equivalent to parts per million (ppm)
  ug/L = micrograms per litre, equivalent to parts per billion (ppb)
  ug/g = micrograms per gram, equivalent to parts per million (ppm)
  ug/m3 Air = micrograms per cubic meter of air

- "RDL" Reported detection limit
- "<" Less than reported detection limit
- "AO" Aesthetic objective
- "MAC" Maximum acceptable concentration (health-related guideline)
- "LAB" RMD = CARO - Richmond location, KEL = CARO - Kelowna location, SUB = Subcontracted

Please contact CARO if more information is needed.

CARO Analytical Services

Final Review Per: **Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H1039
PROJECT FILE	Postill Reservoir - Annual	**REPORTED**	Sep-08-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes

General Parameters

Postill 0.5m (K9H1039-01) Matrix: Water Sampled: Aug-31-09 10:45

Alkalinity, Total as CaCO3	**13.6**	1.0	mg/L	Sep-01-09	APHA 2320 B	KEL
Carbon, Total Organic	**12.2**	0.5	mg/L	Sep-08-09	APHA 5310 B	KEL
Chlorophyll-a	**1.9**	0.1	ug/L	Sep-04-09	APHA 10200H	KEL
Colour, True	**44**	5	Color Unit	Sep-01-09	APHA 2120 B	KEL
Nitrogen, Ammonia as N	<0.02	0.02	mg/L	Aug-31-09	APHA 4500-NH3 F	KEL
Nitrogen, Nitrate+Nitrite as N	**0.01**	0.01	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate as N	**0.01**	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Total Kjeldahl	**0.36**	0.05	mg/L	Sep-01-09	APHA 4500-Norg	KEL
Nitrogen, Dissolved Kjeldahl	**0.31**	0.05	mg/L	Sep-02-09	APHA 4500-Norg	KEL
Nitrogen, Total	**0.37**	0.05	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate+Nitrite as N	<0.02	0.02	mg/L	Sep-01-09	[CALC]	KEL
Nitrogen, Total Dissolved	**0.33**	0.05	mg/L	Sep-02-09	[CALC]	KEL
Nitrogen, Organic	**0.36**	0.05	mg/L	Sep-01-09	CALC	KEL
pH	**7.30**	0.10	pH Units	Sep-01-09	APHA 4500-H+	KEL
Phosphorus, Total	**0.02**	0.01	mg/L	Sep-01-09	APHA 4500P:B.5/E	KEL
Phosphorus, Dissolved	**0.01**	0.01	mg/L	Sep-02-09	APHA 4500P:B.5/E	KEL
Solids, Total Dissolved	**46**	5	mg/L	Sep-02-09	APHA 2540 C	KEL
Transmissivity @ 254nm	**47.3**	0.1	%	Sep-03-09	APHA 5910B	KEL
Turbidity	**0.9**	0.1	NTU	Sep-01-09	APHA 2130 B	KEL

Postill 5m (K9H1039-02) Matrix: Water Sampled: Aug-31-09 10:55

Alkalinity, Total as CaCO3	**16.3**	1.0	mg/L	Sep-01-09	APHA 2320 B	KEL
Carbon, Total Organic	**13.2**	0.5	mg/L	Sep-08-09	APHA 5310 B	KEL
Colour, True	**92**	5	Color Unit	Sep-01-09	APHA 2120 B	KEL
Nitrogen, Ammonia as N	**0.05**	0.02	mg/L	Aug-31-09	APHA 4500-NH3 F	KEL
Nitrogen, Nitrate+Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Nitrite as N	<0.01	0.01	mg/L	Sep-01-09	APHA 4110 B	KEL
Nitrogen, Total Kjeldahl	**0.55**	0.05	mg/L	Sep-01-09	APHA 4500-Norg	KEL
Nitrogen, Dissolved Kjeldahl	**0.38**	0.05	mg/L	Sep-02-09	APHA 4500-Norg	KEL
Nitrogen, Total	**0.55**	0.05	mg/L	Sep-01-09	Calc	KEL
Nitrogen, Nitrate+Nitrite as N	<0.02	0.02	mg/L	Sep-01-09	[CALC]	KEL
Nitrogen, Total Dissolved	**0.38**	0.05	mg/L	Sep-02-09	[CALC]	KEL
Nitrogen, Organic	**0.50**	0.05	mg/L	Sep-01-09	CALC	KEL
pH	**6.80**	0.10	pH Units	Sep-01-09	APHA 4500-H+	KEL
Phosphorus, Total	**0.07**	0.01	mg/L	Sep-01-09	APHA 4500P:B.5/E	KEL
Phosphorus, Dissolved	**0.04**	0.01	mg/L	Sep-02-09	APHA 4500P:B.5/E	KEL
Solids, Total Dissolved	**65**	5	mg/L	Sep-02-09	APHA 2540 C	KEL
Transmissivity @ 254nm	**33.0**	0.1	%	Sep-03-09	APHA 5910B	KEL
Turbidity	**10**	0.1	NTU	Sep-01-09	APHA 2130 B	KEL

Dissolved Metals by ICPMS

Postill 0.5m (K9H1039-01) Matrix: Water Sampled: Aug-31-09 10:45

Iron	**0.135**	0.100	mg/L	Sep-04-09	EPA 6020A	RMD

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H1039
PROJECT FILE	Postill Reservoir - Annual	**REPORTED**	Sep-08-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes
Dissolved Metals by ICPMS, Continued							
Postill 5m (K9H1039-02) Matrix: Water Sampled: Aug-31-09 10:55							
Iron	**2.14**	0.100	mg/L	Sep-04-09	EPA 6020A	RMD	
Total Recoverable Metals by ICPMS							
Postill 0.5m (K9H1039-01) Matrix: Water Sampled: Aug-31-09 10:45							
Iron	**0.19**	0.10	mg/L	Sep-04-09	EPA 6020A	RMD	
Postill 5m (K9H1039-02) Matrix: Water Sampled: Aug-31-09 10:55							
Iron	**2.19**	0.10	mg/L	Sep-04-09	EPA 6020A	RMD	
Microbiological Parameters							
Postill 0.5m (K9H1039-01) Matrix: Water Sampled: Aug-31-09 10:45							
Coliforms, Total	**78**	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Coliforms, Fecal	<1	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Sep-01-09	APHA 9223	KEL	
Postill 5m (K9H1039-02) Matrix: Water Sampled: Aug-31-09 10:55							
Coliforms, Total	**10**	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Sep-01-09	APHA 9222	KEL	
Coliforms, Fecal	<1	1	CFU/100mL	Sep-01-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Sep-01-09	APHA 9223	KEL	

Table 3 - September 2009 - Watershed Water Quality Data

Date	pH	Field Apparent Color (ACU)	Lab Apparent Color	Lab Turbidity (NTU)	Field Turbidity (NTU)
Site #2 - Postill Outlet					
12-Jun-09	6.38	77	40	1.40	1.48
3-Jul-09					
17-Jul-09	6.30	110	60	1.50	1.61
24-Aug-09	6.49	107	50	1.10	1.43
10-Sep-09	6.69	118	40	1.70	1.99
28-Sep-09	6.64	125	50	3.20	3.37
Site #3 - Bulman/Moore Lake Outlet					
12-Jun-09	6.17	169	80	2.80	2.66
3-Jul-09		210			4.32
17-Jul-09	6.06	234	100	4.30	4.48
24-Aug-09	6.36	251	100	5.80	6.18
10-Sep-09	OFF				
28-Sep-09	OFF				
Site #4 - South Lake Outlet					
12-Jun-09	No flow				
3-Jul-09					
17-Jul-09	6.71	87	50	1.00	1.07
24-Aug-09	6.95	112	40	1.00	1.80
10-Sep-09	OFF				
28-Sep-09	OFF				
Site #7 - Morrison Creek					
12-Jun-09	No flow				
3-Jul-09					
17-Jul-09	7.14	92	50	1.00	2.19
24-Aug-09	6.89	129	50	5.50	6.40
10-Sep-09	OFF				
28-Sep-09	OFF				
Site #5 - Mill Creek Below Conroy Creek					
12-Jun-09	7.00	106	60	1.60	1.89
3-Jul-09					
17-Jul-09	6.89	119	60	1.80	2.20
24-Aug-09	6.91	104	50	1.10	1.25
10-Sep-09	6.98	107	50	1.80	1.79
28-Sep-09	7.19	120	50	2.60	2.97
Site #8 - Mill Creek Upstream of Bulman/Moore					
12-Jun-09	7.06	104	70	2.20	2.65
3-Jul-09		109			2.53
17-Jul-09	7.14	112	60	2.20	1.80
24-Aug-09	7.07	109	50	1.80	2.16
10-Sep-09	7.17	146	40	1.80	2.69
28-Sep-09	6.99	119	50	2.60	2.59
Mill Creek Raw Pre Screen					
12-Jun-09	7.15	115		3.30	3.45
3-Jul-09		118			3.02
17-Jul-09	6.96	137	70	3.20	3.37
24-Aug-09	6.83	145	60	2.90	4.05
10-Sep-09	7.2	105	40	2.20	2.40
28-Sep-09	7.1	107	50	2.30	2.12

$\frac{55.24}{5} = 7.05$

$\bar{x} = \frac{18.41}{6} = 3.07$

Table 3 - October 2008 - Watershed Water Quality Data

	Date	pH	Field Apparent Color (ACU)	Lab Apparent Color	Lab Turbidity (NTU)	Field Turbidity (NTU)	Total Coliforms (CFU/100 ml)	E. Coli (CFU/100 ml)	Dissolved Organic Carbon (mg/L)	Total Organic Carbon (mg/L)	Total Suspended Solids (mg/L)	
Site #2 - Postill Outlet												
	6-Jun-08	6.1	127	40	1.4	1.58						
	20-Jun-08	5.9		80	1.1	1.1						
	4-Jul-08	5.9		70	0.8	0.96						
	18-Jul-08	6.0		60	0.8	0.67						
	1-Aug-08	5.8		60	1.2	1.25						
	15-Aug-08	5.9		60	1.3	1.09						
	29-Aug-08	NA		60	2.9	1.29						
	19-Sep-08	6.3		60	1.2	NA						
	10-Oct--08	6.3		60	3.6	3.89						
October 10, 2008 cows in Postill Outlet, Turbidity Spike												
Site #3 - Bulman/Moore Lake Outlet												
	6-Jun-08	6.2	210	100	1.6	2.22						
	20-Jun-08	6.1		100	3.6	4.26						
	4-Jul-08	5.8		200	4.4	4.81						
	18-Jul-08	5.8		80	4.2	4.2						
	1-Aug-08	5.8		100	5.6	3.3						
	15-Aug-08	5.7		100	5.4	1.95						
	29-Aug-08	NA		200	6.4	2.16						
	19-Sep-08	Outlet Off										
Site #4 - South Lake Outlet												
	6-Jun-08	6.7	111	30	6.6	0.58	Operator disturbance of spillway during sampling on June 6th, 2008					
weir	20-Jun-08	6.5		70	0.8	0.49						
	4-Jul-08	5.9		70	0.6	0.77						
	18-Jul-08	6.0		50	0.6	0.72						
	1-Aug-08	6.1		60	0.8	0.72						
	15-Aug-08	6.3		100	1.0	0.98						
	29-Aug-08	NA		40	1.0	1.09						
	19-Sep-08	Outlet Off										
Site #7 - Morrison Creek												
	6-Jun-08		NA			NA						
	20-Jun-08		NA			NA						
flow	4-Jul-08	6.7		60	1.1	2.06						
	18-Jul-08	6.8		40	1.6	1.41						
	1-Aug-08	6.8		60	2.1	2.29						
	15-Aug-08	6.6		50	2.5	3.47						
	29-Aug-08	NA		50	1.9	3.12						
	19-Sep-08	No Flow										

Table 3 - September 2008 - Watershed Water Quality Data. (Continued)

Date	pH	Field Apparent Color (ACU)	Lab Apparent Color	Lab Turbidity (NTU)	Field Turbidity (NTU)	Total Coliforms (CFU/100 ml)	E. Coli (CFU/100 ml)	Dissolved Organic Carbon (mg/L)	Total Organic Carbon (mg/L)	Total Suspended Solids (mg/L)
Site #5 - Mill Creek Below Conroy Creek										
6-Jun-08	6.6	170	50	1.8	2.02					
20-Jun-08	6.5		90	1.6	1.67					
4-Jul-08	6.5		80	1.0	1.29					
18-Jul-08	6.6		60	1.2	1.34					
1-Aug-08	6.6		60	1.5	1.59					
15-Aug-08	6.4		60	1.3	1.33					
29-Aug-08	NA		50	1.4	1.13					
19-Sep-08	6.5		60	1.5	NA					
10-Oct-08	6.4		60	2.2	3.09					
Site #8 - Mill Creek Upstream of Bulman/Moore										
6-Jun-08	6.7	180	40	3.8	4.51					
20-Jun-08	6.6		90	1.6	2.66					
4-Jul-08	6.6		80	1.4	1.88					
18-Jul-08	6.7		60	1.6	1.49					
1-Aug-08	6.7		60	1.5	1.93					
15-Aug-08	6.4		60	2.5	2.29					
29-Aug-08	NA		60	3.0	3.21					
19-Sep-08	6.4		60	1.7	NA					
10-Oct-08	6.5		60	2.5	3.32					
Mill Creek Raw Pre Screen										
6-Jun-08	6.9	194	100	4.7	5.01	94	4	21.4	21.4	6
20-Jun-08										
4-Jul-08	6.7		80	2	2.8					
18-Jul-08	6.8		60	2.5	3.27					
1-Aug-08	6.9		60	2.6	3.81					
15-Aug-08	6.6		60	3.4	4.25					
29-Aug-08	NA		60	2.9	3.46					
19-Sep-08	6.6		60	2.6	NA					
10-Oct-08	6.7		60	1.7	2.33					

$\frac{13.2}{2} = 6.24$

$\frac{19.92}{6} = 3.32$

Table 3 - July/August/September 2007 - Watershed Water Quality Data

Date	pH	Apparent Color (ACU)	Lab Turbidity (NTU)	Field Turbidity (NTU)	Total Coliforms (CFU/100 ml)	E. Coli (CFU/100 ml)	Dissolved Organic Carbon (mg/L)	Total Organic Carbon (mg/L)	Total Suspended Solids (mg/L)
Site #2 - Postill Outlet									
16-Jul-07	5.6	100	3.9	4.38					
27-Jul-07	5.8	80	4.6	3.69					
10-Aug-07	6	80	2.9	2.35	98	32	14.2	14.5	1
24-Aug-07	6.1	80	1.2	0.88	30	2			
12-Sep-07	6.1	80	2.2	2.11	16	<1	13.4	14.2	<1
28-Sep-07	6	80	3.5	4					
Site #3 - Bulman/Moore Lake Outlet									
16-Jul-07	5.8	90	3.8	5.18					
27-Jul-07	5.8	200	8.7	3.43					
10-Aug-07	5.9	200	10	2.48	13	1	22.4	23.2	4
24-Aug-07	Outlet Off No Flow								
12-Sep-07	Outlet Off No Flow								
28-Sep-07	Outlet Off No Flow								
Site #4 - South Lake Outlet									
16-Jul-07	5.8	80	0.8	0.65					
27-Jul-07	6.1	80	1.3	1.97					
10-Aug-07	6.3	70	0.9	0.83	98	32	13.6	14.1	<1
24-Aug-07	Outlet Off No Flow								
12-Sep-07	Outlet Off No Flow								
28-Sep-07	6.3	50	1.2	1.49					
Site #7 - Morrison Creek									
16-Jul-07	6.3	80	2.7	1.55					
27-Jul-07	6.5	80	3.5	3.39					
10-Aug-07	6.4	80	1.8	2.46	3500	4	12.6	13.1	4
24-Aug-07	No Flow								
12-Sep-07	No Flow								
28-Sep-07	No Flow								
Site #5 - Mill Creek Below Conroy Creek									
16-Jul-07	6.2	100	3.3	2.71					
27-Jul-07	6.5	80	2.6	2.81					
10-Aug-07	6.4	80	2.7	2.59	350	29	14	14.1	2
24-Aug-07	6.3	90	1.1	1.36	350	7			
12-Sep-07	6.6	80	2.2	2.08	260	53	13.4	14.1	<1
28-Sep-07	6.3	100	1.2	4					

Table 3 - July/August/September 2007 - Watershed Water Quality Data. (Continued)

Date	pH	Apparent Color (ACU)	Lab Turbidity (NTU)	Field Turbidity (NTU)	Total Coliforms (CFU/100 ml)	E. Coli (CFU/100 ml)	Dissolved Organic Carbon (mg/L)	Total Organic Carbon (mg/L)	Total Suspended Solids (mg/L)
Site #8 - Mill Creek Upstream of Bulman/Moore									
16-Jul-07	6.3	90	3.8	2.81					
27-Jul-07	6.6	80	2.5	2.17					
10-Aug-07	6.2	80	2.6	2.14	2000	58	13.7	13.8	1
24-Aug-07	6.3	90	1.1	1.92	520	5			
12-Sep-07	6.4	80	2.1	2.42	200	70	13.7	14.1	<1
28-Sep-07	6.4	80	3.5	4.2					
Mill Creek Raw Pre Screen									
16-Jul-07	6.8	80	4.8	4.75					
27-Jul-07	6.4	200	4.1	3.89					
10-Aug-07	6.4	80	4.3	4.12	2600	80	14.5	15	7
24-Aug-07	6.4	80	3.2	3.75	200	8			
12-Sep-07	6.9	90	3.8	3.85	130	4	12.9	13.3	4
28-Sep-07	6.6	40	3.4	3.8					

39.5 / 6 = 6.58

24.16 / 6 = 4.03

2930 / 3 = 976.7

92/3 = 30.7

CERTIFICATE OF ANALYSIS

CARO ANALYTICAL SERVICES

CLIENT	**Glenmore Ellison Improvement District** 445 Glenmore Road KELOWNA, BC V1V 1Z6	TEL FAX	(250) 763-6506 (250) 763-5688
ATTENTION	**Andrew Cammell**		

RECEIVED / TEMP	Jun-12-09 13:25 / 15 °C	**WORK ORDER #**	K9F0505
REPORTED	Jun-19-09	**PROJECT FILE**	Watershed
COC #(s)	18271		

General Comments:

CARO Analytical Services employs methods which are based on those found in "Standard Methods for the Examination of Water and Wastewater", 21st Edition, 2005, published by the American Public Health Association (APHA); US EPA protocols found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW846", 3rd Edition; and protocols published by the British Columbia Ministry of Environment (BCMOE).

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  mg/L = milligrams per litre, equivalent to parts per million (ppm)
  ug/L = micrograms per litre, equivalent to parts per billion (ppb)
  ug/g = micrograms per gram, equivalent to parts per million (ppm)
  ug/m3 Air = micrograms per cubic meter of air

- "RDL" Reported detection limit
- "<" Less than reported detection limit
- "AO" Aesthetic objective
- "MAC" Maximum acceptable concentration (health-related guideline)
- "LAB" RMD = CARO - Richmond location, KEL = CARO - Kelowna location, SUB = Subcontracted

Please contact CARO if more information is needed.

CARO Analytical Services

Final Review Per: **Ed Hoppe, B.Sc. For Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9F0505
PROJECT FILE	Watershed	**REPORTED**	Jun-19-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes

General Parameters

Mill Creek Raw Pre-Screen (K9F0505-01) Matrix: Water Sampled: Jun-12-09 08:18

Alkalinity, Total as CaCO3	**23.9**	1.0	mg/L	Jun-15-09	APHA 2320 B	KEL
Chloride	**0.66**	0.10	mg/L	Jun-13-09	APHA 4110 B	KEL
Colour, True	**110**	5	Color Unit	Jun-12-09	APHA 2120 B	KEL
Conductivity (EC)	**50**	5	uS/cm	Jun-15-09	APHA 2510 B	KEL
Cyanide (total)	<0.01	0.01	mg/L	Jun-19-09	APHA 4500-CN	KEL
Fluoride	<0.10	0.10	mg/L	Jun-13-09	APHA 4110 B	KEL
Hardness, Total (Total as CaCO3)	**23.9**	2.91	mg/L	Jun-16-09	APHA 2340 B	RMD
Nitrogen, Nitrate as N	<0.01	0.01	mg/L	Jun-13-09	APHA 4110 B	KEL
Nitrogen, Nitrite as N	<0.01	0.01	mg/L	Jun-13-09	APHA 4110 B	KEL
pH	**7.48**	0.10	pH Units	Jun-15-09	APHA 4500-H+	KEL
Solids, Total Dissolved	**45**	5	mg/L	Jun-17-09	APHA 2540 C	KEL
Sulfate	**1.9**	1.0	mg/L	Jun-13-09	APHA 4110 B	KEL
Transmissivity @ 254nm	**35.7**	0.1	%	Jun-15-09	APHA 5190B	KEL
Turbidity	**3.3**	0.1	NTU	Jun-12-09	APHA 2130 B	KEL

Postill Outlet (K9F0505-02) Matrix: Water Sampled: Jun-12-09 11:32

Colour, Apparent	**40**	5	Color Unit	Jun-15-09	APHA 2120 B	KEL
Turbidity	**1.4**	0.1	NTU	Jun-12-09	APHA 2130 B	KEL

Mill Creek above Bulman (K9F0505-03) Matrix: Water Sampled: Jun-12-09 12:43

Colour, Apparent	**70**	5	Color Unit	Jun-15-09	APHA 2120 B	KEL
Turbidity	**2.2**	0.1	NTU	Jun-12-09	APHA 2130 B	KEL

Bulman Outflow (K9F0505-04) Matrix: Water Sampled: Jun-12-09 09:48

Colour, Apparent	**80**	5	Color Unit	Jun-15-09	APHA 2120 B	KEL
Turbidity	**2.8**	0.1	NTU	Jun-12-09	APHA 2130 B	KEL

Mill Creek below Conroy (K9F0505-05) Matrix: Water Sampled: Jun-12-09 11:44

Colour, Apparent	**60**	5	Color Unit	Jun-15-09	APHA 2120 B	KEL
Turbidity	**1.6**	0.1	NTU	Jun-12-09	APHA 2130 B	KEL

Total Recoverable Metals by ICPMS

Mill Creek Raw Pre-Screen (K9F0505-01) Matrix: Water Sampled: Jun-12-09 08:18

Aluminum	<0.050	0.050	mg/L	Jun-16-09	EPA 6020A	RMD
Antimony	<0.0010	0.0010	mg/L	Jun-16-09	EPA 6020A	RMD
Arsenic	<0.0050	0.0050	mg/L	Jun-16-09	EPA 6020A	RMD
Barium	**0.0080**	0.0050	mg/L	Jun-16-09	EPA 6020A	RMD
Beryllium	<0.0010	0.0010	mg/L	Jun-16-09	EPA 6020A	RMD
Boron	<0.020	0.020	mg/L	Jun-16-09	EPA 6020A	RMD
Cadmium	<0.00010	0.00010	mg/L	Jun-16-09	EPA 6020A	RMD
Calcium	**6.4**	1.0	mg/L	Jun-16-09	EPA 6020A	RMD
Chromium	<0.0050	0.0050	mg/L	Jun-16-09	EPA 6020A	RMD
Cobalt	<0.00050	0.00050	mg/L	Jun-16-09	EPA 6020A	RMD
Copper	**0.0012**	0.0010	mg/L	Jun-16-09	EPA 6020A	RMD
Iron	**0.48**	0.10	mg/L	Jun-16-09	EPA 6020A	RMD
Lead	<0.0010	0.0010	mg/L	Jun-16-09	EPA 6020A	RMD

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9F0505
PROJECT FILE	Watershed	**REPORTED**	Jun-19-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes

Total Recoverable Metals by ICPMS, Continued

Mill Creek Raw Pre-Screen (K9F0505-01) Matrix: Water Sampled: Jun-12-09 08:18, Continued

Magnesium	**1.90**	0.10	mg/L	Jun-16-09	EPA 6020A	RMD
Manganese	**0.0165**	0.0020	mg/L	Jun-16-09	EPA 6020A	RMD
Mercury	<0.00050	0.00050	mg/L	Jun-16-09	EPA 6020A	RMD
Molybdenum	<0.0010	0.0010	mg/L	Jun-16-09	EPA 6020A	RMD
Nickel	<0.0020	0.0020	mg/L	Jun-16-09	EPA 6020A	RMD
Phosphorus	<0.20	0.20	mg/L	Jun-16-09	EPA 6020A	RMD
Potassium	**0.60**	0.10	mg/L	Jun-16-09	EPA 6020A	RMD
Selenium	<0.0030	0.0030	mg/L	Jun-16-09	EPA 6020A	RMD
Silicon	**5.9**	2.0	mg/L	Jun-16-09	EPA 6020A	RMD
Silver	<0.00050	0.00050	mg/L	Jun-16-09	EPA 6020A	RMD
Sodium	**1.99**	0.10	mg/L	Jun-16-09	EPA 6020A	RMD
Uranium	<0.00020	0.00020	mg/L	Jun-16-09	EPA 6020A	RMD
Zinc	<0.010	0.010	mg/L	Jun-16-09	EPA 6020A	RMD

Microbiological Parameters

Mill Creek Raw Pre-Screen (K9F0505-01) Matrix: Water Sampled: Jun-12-09 08:18

E. coli	**18**	1	CFU/100mL	Jun-12-09	APHA 9223	KEL

CERTIFICATE OF ANALYSIS

CARO ANALYTICAL SERVICES

CLIENT **Glenmore Ellison Improvement District**
445 Glenmore Road
KELOWNA, BC
V1V 1Z6
TEL (250) 763-6506
FAX (250) 763-5688

G.E.I.D.
AUG 10 2009
RECEIVED

ATTENTION **Andrew Cammell**

RECEIVED / TEMP	Aug-07-09 15:05 / 18.0 °C	**WORK ORDER #**	K9H0216
REPORTED	Aug-10-09	**PROJECT FILE**	Watershed
COC #(s)	18637		

General Comments:

CARO Analytical Services employs methods which are based on those found in "Standard Methods for the Examination of Water and Wastewater", 21st Edition, 2005, published by the American Public Health Association (APHA); US EPA protocols found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW846", 3rd Edition; and protocols published by the British Columbia Ministry of Environment (BCMOE).

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  ug/L = micrograms per litre, equivalent to parts per billion (ppb)
  ug/g = micrograms per gram, equivalent to parts per million (ppm)
  ug/m3 Air = micrograms per cubic meter of air

- "RDL" Reported detection limit
- "<" Less than reported detection limit
- "AO" Aesthetic objective
- "MAC" Maximum acceptable concentration (health-related guideline)
- "LAB" RMD = CARO - Richmond location, KEL = CARO - Kelowna location, SUB = Subcontracted

Please contact CARO if more information is needed.

CARO Analytical Services

Final Review Per: **Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H0216
PROJECT FILE	Watershed	**REPORTED**	Aug-10-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes

General Parameters

Mill Creek Raw Pre-Screen (K9H0216-01) Matrix: Water Sampled: Aug-07-09 08:33

Colour, Apparent	**70**	5	Color Unit	Aug-10-09	APHA 2120 B	KEL
pH	**7.64**	0.10	pH Units	Aug-07-09	APHA 4500-H+	KEL
Turbidity	**3.0**	0.1	NTU	Aug-07-09	APHA 2130 B	KEL

Morrison Creek (K9H0216-02) Matrix: Water Sampled: Aug-07-09 10:24

Colour, Apparent	**40**	5	Color Unit	Aug-10-09	APHA 2120 B	KEL
pH	**7.66**	0.10	pH Units	Aug-07-09	APHA 4500-H+	KEL
Turbidity	**2.8**	0.1	NTU	Aug-07-09	APHA 2130 B	KEL

Postill Outflow (K9H0216-03) Matrix: Water Sampled: Aug-07-09 12:45

Colour, Apparent	**60**	5	Color Unit	Aug-10-09	APHA 2120 B	KEL
pH	**7.10**	0.10	pH Units	Aug-07-09	APHA 4500-H+	KEL
Turbidity	**2.1**	0.1	NTU	Aug-07-09	APHA 2130 B	KEL

Mill Creek below Conroy (K9H0216-04) Matrix: Water Sampled: Aug-07-09 13:52

Colour, Apparent	**60**	5	Color Unit	Aug-10-09	APHA 2120 B	KEL
pH	**7.43**	0.10	pH Units	Aug-07-09	APHA 4500-H+	KEL
Turbidity	**1.4**	0.1	NTU	Aug-07-09	APHA 2130 B	KEL

Bulman Outflow (K9H0216-05) Matrix: Water Sampled: Aug-07-09 09:58

Colour, Apparent	**100**	5	Color Unit	Aug-10-09	APHA 2120 B	KEL
pH	**7.03**	0.10	pH Units	Aug-07-09	APHA 4500-H+	KEL
Turbidity	**6.5**	0.1	NTU	Aug-07-09	APHA 2130 B	KEL

Mill Creek above Bulman (K9H0216-06) Matrix: Water Sampled: Aug-07-09 10:56

Colour, Apparent	**40**	5	Color Unit	Aug-10-09	APHA 2120 B	KEL
pH	**7.56**	0.10	pH Units	Aug-07-09	APHA 4500-H+	KEL
Turbidity	**1.5**	0.1	NTU	Aug-07-09	APHA 2130 B	KEL

South Lakes Outflow (K9H0216-07) Matrix: Water Sampled: Aug-07-09 12:18

Colour, Apparent	**40**	5	Color Unit	Aug-10-09	APHA 2120 B	KEL
pH	**7.64**	0.10	pH Units	Aug-07-09	APHA 4500-H+	KEL
Turbidity	**0.8**	0.1	NTU	Aug-07-09	APHA 2130 B	KEL

Microbiological Parameters

Mill Creek Raw Pre-Screen (K9H0216-01) Matrix: Water Sampled: Aug-07-09 08:33

Coliforms, Total	**≥ 690**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL
E. coli	**77**	1	CFU/100mL	Aug-08-09	APHA 9223	KEL

Morrison Creek (K9H0216-02) Matrix: Water Sampled: Aug-07-09 10:24

Coliforms, Total	**≥ 1200**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL
E. coli	**49**	1	CFU/100mL	Aug-08-09	APHA 9223	KEL

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9H0216
PROJECT FILE	Watershed	**REPORTED**	Aug-10-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes
Microbiological Parameters, Continued							
Postill Outflow (K9H0216-03) Matrix: Water Sampled: Aug-07-09 12:45							
Coliforms, Total	**≥ 280**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Aug-08-09	APHA 9223	KEL	
Mill Creek below Conroy (K9H0216-04) Matrix: Water Sampled: Aug-07-09 13:52							
Coliforms, Total	**≥ 490**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL	
E. coli	**14**	1	CFU/100mL	Aug-08-09	APHA 9223	KEL	
Bulman Outflow (K9H0216-05) Matrix: Water Sampled: Aug-07-09 09:58							
Coliforms, Total	**60**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL	
E. coli	<1	1	CFU/100mL	Aug-08-09	APHA 9223	KEL	
Mill Creek above Bulman (K9H0216-06) Matrix: Water Sampled: Aug-07-09 10:56							
Coliforms, Total	**≥ 950**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL	
E. coli	**64**	1	CFU/100mL	Aug-08-09	APHA 9223	KEL	
South Lakes Outflow (K9H0216-07) Matrix: Water Sampled: Aug-07-09 12:18							
Coliforms, Total	**370**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL	
E. coli	**1**	1	CFU/100mL	Aug-08-09	APHA 9223	KEL	
Bulman Creek before Kelowna Creek (K9H0216-08) Matrix: Water Sampled: Aug-07-09 10:56							
Coliforms, Total	**≥ 1100**	1	CFU/100mL	Aug-08-09	APHA 9222	KEL	
Background Colonies	**≥ 200**	200	CFU/100mL	Aug-08-09	APHA 9222	KEL	
E. coli	**10**	1	CFU/100mL	Aug-08-09	APHA 9223	KEL	

CERTIFICATE OF ANALYSIS

CARO ANALYTICAL SERVICES

CLIENT	**Glenmore Ellison Improvement District** 445 Glenmore Road KELOWNA, BC V1V 1Z6	TEL FAX	(250) 763-6506 (250) 763-5688
ATTENTION	**Andrew Cammell**		

RECEIVED / TEMP	Jul-17-09 12:45 / 13 °C	**WORK ORDER #**	K9G0575
REPORTED	Jul-20-09	**PROJECT FILE**	Watershed
COC #(s)	18007		

General Comments:

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  ug/m3 Air = micrograms per cubic meter of air

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- "<" Less than reported detection limit
- "AO" Aesthetic objective
- "MAC" Maximum acceptable concentration (health-related guideline)
- "LAB" RMD = CARO - Richmond location, KEL = CARO - Kelowna location, SUB = Subcontracted

Please contact CARO if more information is needed.

CARO Analytical Services

Final Review Per: **Ed Hoppe, B.Sc. For Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CARO ANALYTICAL SERVICES

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K9G0575
PROJECT FILE	Watershed	**REPORTED**	Jul-20-09

Analyte	Result	RDL	Units	Analyzed	Method	Lab	Notes
General Parameters							
Mill Creek above Bulman (K9G0575-01) Matrix: Water Sampled: Jul-17-09 10:13							
Colour, Apparent	**60**	5	Color Unit	Jul-20-09	APHA 2120 B	KEL	
Turbidity	**2.2**	0.1	NTU	Jul-17-09	APHA 2130 B	KEL	
Mill Creek Raw Pre-Screen (K9G0575-02) Matrix: Water Sampled: Jul-17-09 08:07							
Colour, Apparent	**70**	5	Color Unit	Jul-20-09	APHA 2120 B	KEL	
Turbidity	**3.2**	0.1	NTU	Jul-17-09	APHA 2130 B	KEL	
Bulman Outflow (K9G0575-03) Matrix: Water Sampled: Jul-17-09 10:30							
Colour, Apparent	**100**	5	Color Unit	Jul-20-09	APHA 2120 B	KEL	
Turbidity	**4.3**	0.1	NTU	Jul-17-09	APHA 2130 B	KEL	
Mill Creek above Conroy (K9G0575-04) Matrix: Water Sampled: Jul-17-09 11:58							
Colour, Apparent	**60**	5	Color Unit	Jul-20-09	APHA 2120 B	KEL	
Turbidity	**1.8**	0.1	NTU	Jul-17-09	APHA 2130 B	KEL	
Morrison Creek (K9G0575-05) Matrix: Water Sampled: Jul-17-09 10:03							
Colour, Apparent	**50**	5	Color Unit	Jul-20-09	APHA 2120 B	KEL	
Turbidity	**1.6**	0.1	NTU	Jul-17-09	APHA 2130 B	KEL	
Postill Outflow (K9G0575-06) Matrix: Water Sampled: Jul-17-09 11:42							
Colour, Apparent	**60**	5	Color Unit	Jul-20-09	APHA 2120 B	KEL	
Turbidity	**1.5**	0.1	NTU	Jul-17-09	APHA 2130 B	KEL	
South Lakes Outflow (K9G0575-07) Matrix: Water Sampled: Jul-17-09 11:11							
Colour, Apparent	**50**	5	Color Unit	Jul-20-09	APHA 2120 B	KEL	
Turbidity	**1.0**	0.1	NTU	Jul-17-09	APHA 2130 B	KEL	

CERTIFICATE OF ANALYSIS

CLIENT **Glenmore Ellison Improvement District**
445 Glenmore Road
KELOWNA, BC
V1V 1Z6
TEL (250) 763-6506
FAX (250) 763-5688

ATTENTION **Andrew Cammell**

RECEIVED / TEMP	12-Sep-08 13:50 / 15 °C	**WORK ORDER #**	K8I0463
REPORTED	19-Sep-08	**PROJECT NAME**	Bulman Reservoir - Annual
COC #(s)	14025		

General Comments:

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- "<" Less than reported detection limit

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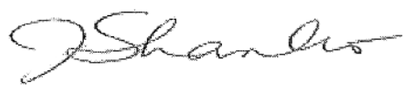

Final Review Per: **Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K8I0463
PROJECT NAME	Bulman Reservoir - Annual	**REPORTED**	19-Sep-08

Bulman Surface (K8I0463-01) Matrix: Water Sampled: 12-Sep-08

Analyte	Result	RDL	Units	Analyzed	Notes
Dissolved Metals by ICPMS					
Iron	**0.322**	0.200	mg/L	18-Sep-08	
Manganese	**0.0076**	0.0050	"	"	
General Parameters					
Alkalinity, Total as CaCO3	**21.1**	1.0	mg/L	18-Sep-08	
Carbon, Total Organic	**17.2**	0.5	"	15-Sep-08	
Chlorophyll-a	**1.3**	0.1	ug/L	19-Sep-08	
Colour, True	**92**	5	Colour Units	16-Sep-08	
Nitrogen, Nitrate+Nitrite as N	**0.02**	0.02	mg/L	12-Sep-08	
Nitrogen, Nitrate as N	**0.02**	0.01	"	"	
Nitrogen, Nitrite as N	**< 0.01**	0.01	"	"	
Nitrogen, Total Kjeldahl	**0.61**	0.05	"	15-Sep-08	
pH	**6.8**	0.1	pH Units	12-Sep-08	
Phosphorus, Total	**0.02**	0.01	mg/L	18-Sep-08	
Phosphate, Ortho as P	**0.013**	0.010	"	12-Sep-08	
Turbidity	**1.3**	0.1	NTU	16-Sep-08	
Microbiological Parameters					
Coliforms, Total	**21**	1	CFU/100mL	12-Sep-08	
Background Colonies	**>200**	200	"	"	
E. Coli	**< 1**	1	"	"	
Total Recoverable Metals by ICPMS					
Iron	**0.45**	0.20	mg/L	18-Sep-08	
Manganese	**0.0139**	0.0050	"	"	

SAMPLE DATA

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K8I0463
PROJECT NAME	Bulman Reservoir - Annual	**REPORTED**	19-Sep-08

Bulman 7m (K8I0463-02) Matrix: Water Sampled: 11-Sep-08

Analyte	Result	RDL	Units	Analyzed	Notes
Dissolved Metals by ICPMS					
Iron	**1.39**	0.200	mg/L	18-Sep-08	
Manganese	**0.244**	0.0050	"	"	
General Parameters					
Alkalinity, Total as CaCO3	**23.6**	1.0	mg/L	18-Sep-08	
Carbon, Total Organic	**20.0**	0.5	"	15-Sep-08	
Colour, True	**95**	5	Colour Units	16-Sep-08	
Nitrogen, Nitrate+Nitrite as N	**< 0.02**	0.02	mg/L	12-Sep-08	
Nitrogen, Nitrate as N	**< 0.01**	0.01	"	"	
Nitrogen, Nitrite as N	**< 0.01**	0.01	"	"	
Nitrogen, Total Kjeldahl	**0.65**	0.05	"	15-Sep-08	
pH	**5.9**	0.1	pH Units	12-Sep-08	
Phosphorus, Total	**0.07**	0.01	mg/L	18-Sep-08	
Phosphate, Ortho as P	**< 0.010**	0.010	"	12-Sep-08	
Turbidity	**19**	0.1	NTU	16-Sep-08	
Microbiological Parameters					
Coliforms, Total	**9**	1	CFU/100mL	12-Sep-08	
Background Colonies	**>200**	200	"	"	
E. Coli	**< 1**	1	"	"	
Total Recoverable Metals by ICPMS					
Iron	**2.69**	0.20	mg/L	18-Sep-08	
Manganese	**0.261**	0.0050	"	"	

CERTIFICATE OF ANALYSIS

CLIENT **Glenmore Ellison Improvement District**
445 Glenmore Road
KELOWNA, BC
V1V 1Z6
TEL (250) 763-6506
FAX (250) 763-5688

ATTENTION **Andrew Cammell**

RECEIVED / TEMP	12-Sep-08 13:50 / 15 °C	**WORK ORDER #**	K8I0470
REPORTED	19-Sep-08	**PROJECT NAME**	Postill Reservoir - Annual
COC #(s)	14025		

General Comments:

CARO Analytical Services employs methods which are based on those found in "Standard Methods for the Examination of Water and Wastewater", 21st Edition, 2005, published by the American Public Health Association (APHA); US EPA protocols found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW846", 3rd Edition; and protocols published by the British Columbia Ministry of Environment (BCMOE).

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CARO Analytical Services

Final Review Per: **Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K8I0470
PROJECT NAME	Postill Reservoir - Annual	**REPORTED**	19-Sep-08

Postill Surface (K8I0470-01) Matrix: Water Sampled: 12-Sep-08

Analyte	Result	RDL	Units	Analyzed	Notes
Dissolved Metals by ICPMS					
Iron	**0.234**	0.200	mg/L	18-Sep-08	
Manganese	**0.0112**	0.0050	"	"	
General Parameters					
Alkalinity, Total as CaCO3	**13.0**	1.0	mg/L	18-Sep-08	
Carbon, Total Organic	**11.6**	0.5	"	15-Sep-08	
Chlorophyll-a	**1.1**	0.1	ug/L	19-Sep-08	
Colour, True	**47**	5	Colour Units	16-Sep-08	
Nitrogen, Nitrate+Nitrite as N	**< 0.02**	0.02	mg/L	12-Sep-08	
Nitrogen, Nitrate as N	**< 0.01**	0.01	"	"	
Nitrogen, Nitrite as N	**< 0.01**	0.01	"	"	
Nitrogen, Total Kjeldahl	**0.32**	0.05	"	15-Sep-08	
pH	**6.4**	0.1	pH Units	12-Sep-08	
Phosphorus, Total	**< 0.01**	0.01	mg/L	18-Sep-08	
Phosphate, Ortho as P	**< 0.010**	0.010	"	12-Sep-08	
Turbidity	**1.0**	0.1	NTU	16-Sep-08	
Microbiological Parameters					
Coliforms, Total	**69**	1	CFU/100mL	12-Sep-08	
E. Coli	**< 1**	1	"	"	
Total Recoverable Metals by ICPMS					
Iron	**0.32**	0.20	mg/L	18-Sep-08	
Manganese	**0.0200**	0.0050	"	"	

SAMPLE DATA

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K8I0470
PROJECT NAME	Postill Reservoir - Annual	**REPORTED**	19-Sep-08

Postill 6m (K8I0470-02) Matrix: Water Sampled: 12-Sep-08

Analyte	Result	RDL	Units	Analyzed	Notes
Dissolved Metals by ICPMS					
Iron	**1.39**	0.200	mg/L	18-Sep-08	
Manganese	**0.244**	0.0050	"	"	
General Parameters					
Alkalinity, Total as CaCO3	**14.0**	1.0	mg/L	18-Sep-08	
Carbon, Total Organic	**12.4**	0.5	"	15-Sep-08	
Colour, True	**68**	5	Colour Units	16-Sep-08	
Nitrogen, Nitrate+Nitrite as N	**< 0.02**	0.02	mg/L	12-Sep-08	
Nitrogen, Nitrate as N	**< 0.01**	0.01	"	"	
Nitrogen, Nitrite as N	**< 0.01**	0.01	"	"	
Nitrogen, Total Kjeldahl	**0.36**	0.05	"	15-Sep-08	
pH	**5.7**	0.1	pH Units	12-Sep-08	
Phosphorus, Total	**0.04**	0.01	mg/L	18-Sep-08	
Phosphate, Ortho as P	**< 0.010**	0.010	"	12-Sep-08	
Turbidity	**8.8**	0.1	NTU	16-Sep-08	
Microbiological Parameters					
Coliforms, Total	**21**	1	CFU/100mL	12-Sep-08	
Background Colonies	**>200**	200	"	"	
E. Coli	**< 1**	1	"	"	
Total Recoverable Metals by ICPMS					
Iron	**1.90**	0.20	mg/L	18-Sep-08	
Manganese	**0.226**	0.0050	"	"	

CERTIFICATE OF ANALYSIS

CLIENT **Glenmore Ellison Improvement District**
445 Glenmore Road
KELOWNA, BC
V1V 1Z6
TEL (250) 763-6506
FAX (250) 763-5688

ATTENTION **Andrew Cammell**

RECEIVED / TEMP	12-Sep-08 13:50 / 15 °C	**WORK ORDER #**	K8I0469
REPORTED	19-Sep-08	**PROJECT NAME**	South Reservoir - Annual
COC #(s)	14025		

General Comments:

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  mg/L = milligrams per litre, equivalent to parts per million (ppm)
  ug/L = micrograms per litre, equivalent to parts per billion (ppb)
  ug/g = micrograms per gram, equivalent to parts per million (ppm)
- "RDL" Reported detection limit
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Please call the lab if you need more information.

CARO Analytical Services

Final Review Per: **Jennifer Shanko, AScT**
Coordinator, Operations/Admin

SAMPLE DATA

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K8I0469
PROJECT NAME	South Reservoir - Annual	**REPORTED**	19-Sep-08

South Surface (K8I0469-01) Matrix: Water Sampled: 12-Sep-08

Analyte	Result	RDL	Units	Analyzed	Notes
Dissolved Metals by ICPMS					
Iron	**< 0.200**	0.200	mg/L	18-Sep-08	
Manganese	**0.0069**	0.0050	"	"	
General Parameters					
Alkalinity, Total as CaCO3	**22.1**	1.0	mg/L	18-Sep-08	
Carbon, Total Organic	**11.2**	0.5	"	15-Sep-08	
Chlorophyll-a	**0.7**	0.1	ug/L	19-Sep-08	
Colour, True	**41**	5	Colour Units	16-Sep-08	
Nitrogen, Nitrate+Nitrite as N	**0.06**	0.02	mg/L	12-Sep-08	
Nitrogen, Nitrate as N	**0.06**	0.01	"	"	
Nitrogen, Nitrite as N	**< 0.01**	0.01	"	"	
Nitrogen, Total Kjeldahl	**0.38**	0.05	"	15-Sep-08	
pH	**6.6**	0.1	pH Units	12-Sep-08	
Phosphorus, Total	**0.01**	0.01	mg/L	18-Sep-08	
Phosphate, Ortho as P	**< 0.010**	0.010	"	12-Sep-08	
Turbidity	**1.0**	0.1	NTU	16-Sep-08	
Microbiological Parameters					
Coliforms, Total	**15**	1	CFU/100mL	12-Sep-08	
Background Colonies	**>200**	200	"	"	
E. Coli	**< 1**	1	"	"	
Total Recoverable Metals by ICPMS					
Iron	**< 0.20**	0.20	mg/L	18-Sep-08	
Manganese	**0.0126**	0.0050	"	"	

SAMPLE DATA

CLIENT	Glenmore Ellison Improvement District	**WORK ORDER #**	K8I0469
PROJECT NAME	South Reservoir - Annual	**REPORTED**	19-Sep-08

South 5m (K8I0469-02) Matrix: Water Sampled: 12-Sep-08

Analyte	Result	RDL	Units	Analyzed	Notes
Dissolved Metals by ICPMS					
Iron	**< 0.200**	0.200	mg/L	18-Sep-08	
Manganese	**< 0.0050**	0.0050	"	"	
General Parameters					
Alkalinity, Total as CaCO3	**22.6**	1.0	mg/L	18-Sep-08	
Carbon, Total Organic	**11.9**	0.5	"	15-Sep-08	
Colour, True	**44**	5	Colour Units	16-Sep-08	
Nitrogen, Nitrate+Nitrite as N	**< 0.02**	0.02	mg/L	12-Sep-08	
Nitrogen, Nitrate as N	**< 0.01**	0.01	"	"	
Nitrogen, Nitrite as N	**< 0.01**	0.01	"	"	
Nitrogen, Total Kjeldahl	**0.36**	0.05	"	15-Sep-08	
pH	**6.6**	0.1	pH Units	12-Sep-08	
Phosphorus, Total	**< 0.01**	0.01	mg/L	18-Sep-08	
Phosphate, Ortho as P	**< 0.010**	0.010	"	12-Sep-08	
Turbidity	**1.0**	0.1	NTU	16-Sep-08	
Microbiological Parameters					
Coliforms, Total	**21**	1	CFU/100mL	12-Sep-08	
Background Colonies	**>200**	200	"	"	
E. Coli	**< 1**	1	"	"	
Total Recoverable Metals by ICPMS					
Iron	**0.21**	0.20	mg/L	18-Sep-08	
Manganese	**0.0135**	0.0050	"	"	

Appendix D

Stream Crossing Assessment Procedure

The Stream Crossing Quality Index:
A Water Quality Indicator for Sustainable Forest Management

Beaudry P.G., van Geloven C., McConnachie J. L. and Newman N.J.
P. Beaudry and Associates Ltd., 2274 S. Nicholson, Prince George, V2N 1V8

Abstract
One of the goals of sustainable forest management is the maintenance of water quality. One of the biggest forestry related impacts to water quality is accelerated sediment delivery to streams at road crossings. Good road building and maintenance practices will minimize the erosion hazard and related negative impacts to water quality. Based on this, several divisions of Canadian Forest Products Ltd. have recognized that a good water quality indicator should be based on a field-survey that evaluates effectiveness of controlling accelerated erosion and sediment delivery at stream crossings. This has led to the development of a sediment source hazard assessment procedure called the Stream Crossing Quality Index (SCQI). The procedure evaluates and scores the size and characteristics of road-related sediment sources at crossings and the potential for the eroded sediment to reach the stream environment. A high score infers that there is a significant erosion problem which may in turn cause sediment-related water quality problems. The SCQI is a good management tool because it identifies specific problems in the landscape and provides future direction to minimize them.

Introduction

One of the goals of sustainable forest management (SFM) is to implement best management practices so that water quality is maintained within natural ranges of variability (CCFM 2000). Within an SFM framework there is a requirement for a set of clearly defined performance criteria and indicators to gauge progress towards the goal of maintaining water quality. Designing a meaningful indicator to address this goal is not an insignificant challenge. Forestry activities are an extensive type of disturbance that generally cover many hundreds of square kilometers and numerous watersheds. Forest harvesting activities can affect many water quality characteristics, but increased sediment loading has been identified as one of the most detrimental (MacDonald *et al.* 1991). Several forest harvesting activities can cause increased erosion rates and sediment delivery to aquatic environments. However, road building and maintenance, particularly at stream crossings, is the dominant point source for forestry-generated sediment in landscapes where landslides are not a dominant process (Beaudry 2001, Beschta 1978, Bilby *et al. 1989,* Cafferata and Spittler 1998) (Figure 1).

Figure 1. Ditches, road surfaces and cut/fill slopes can be significant sources of sediment at stream crossings.

Within any given watershed, there may be dozens or even hundreds of stream crossings, each being a potential source of sediment. Although the impacts of forestry disturbances on water quality can be relatively small and subtle at any given point within a watershed, the sum of the impacts may add up to significant downstream cumulative effects. If good road building and maintenance practices can minimize (or eliminate) accelerated erosion and sediment delivery to streams, then negative impacts to water quality will be minimized. Based on this assumption, several B.C. and Alberta Divisions of Canadian Forest Products Ltd. (Canfor) have decided that a good water quality indicator should be based on a field survey that evaluates how well accelerated erosion and sediment delivery are being controlled in the vicinity of stream crossings. The stream crossing quality index (SCQI) was developed as an SFM indicator to provide a meaningful measure of the potential hazard that a stream crossing may present for water quality.

Development and Refinement of the SCQI

In 2000, the Prince George Division of Canfor considered a variety of SFM indicators for use in its forestry certification program. As an indicator of protection of water quality, Canfor was considering the concept of the stream crossing density used in the BC Watershed Assessment Procedure (WAP), i.e. # of stream crossings counted on a map divided by the watershed area (BC Government 1995). We suggested that although the stream crossing density is very simple and inexpensive to measure, a better alternative would be to complete a field assessment of the crossing and score its real potential for accelerated erosion and sediment delivery to the stream. Such a procedure would provide accurate field-based information and would be a large improvement on the stream crossing density concept that assumes that all crossings produce the same amount of sediment to the stream environment. Thus was born the concept of the SCQI, a field-based hazard assessment of the potential for accelerated erosion and sediment delivery at stream crossings.

The origins of the SCQI methodology were based on the concepts of the sediment source survey (SSS) presented in version 2.01 of the WAP (B.C. Government 1999). In the WAP, the road-related SSS is used as an indicator of the level of hazard that forestry roads have for delivering sediment to the aquatic ecosystem and thus potentially reducing water quality. One of the major refinements provided by the SCQI methodology is the systematic description and evaluation of all individual sediment sources at a crossing that have

the potential to deliver sediment to the stream network.

As an SFM indicator, the basic assumption that underlies the SCQI is that if erosion and sediment delivery in the vicinity of stream crossings is minimized, through proper road building and maintenance practices, then the potential impact to water quality from increased sediment delivery is also minimized (Figure 2). The SCQI is a useful management tool because it provides a clear incentive to improve erosion and sediment control (ESC) practices in the vicinity of stream crossings since it documents practices that create a water quality hazard and those that minimize it. Improvement of forest management practices over time is a clearly explicit goal of all forest certification schemes. The Canadian Council of Forest Ministers (CCFM 2000) clearly recognizes the potential negative impacts to water quality associated with road crossings. In their sustained forest management program they have defined one of the aquatic indicators as being: "percentage of forest area having road construction and stream crossing guidelines in place" (Indicator 3.2.2).

Figure 2. Hay mulch used effectively for both erosion and sediment control.

Method

The execution of an SCQI survey begins with the mapping of current access within the watershed and planning an effective way of completing a 100% sampling of stream crossings with that watershed. In many situations 100% sampling is not possible but at least 90 to 95% sampling is usually achieved. Stream crossings are accessed using trucks, quads or by walking.

Once the surveyor has arrived at the stream crossing, the procedure begins by evaluating the size and characteristics of all sediment sources that can potentially contribute sediment to the aquatic environment. Each stream crossing is divided into eight distinct and independent "elements". These include four road ditches that run into the stream, two road fill slopes and two road running surfaces, each of these potential sediment sources being assessed independently. The sediment source hazard score for each individual element is a product of the *erosion potential* and the *delivery potential* of that source. The *erosion potential* is calculated as a function of several factors which are:

1. the size of the sediment source
2. the soil texture of the source
3. the slope gradient of the source
4. the percentage of non-erodible cover
5. the level of road use (for road surface) and
6. the shape of the ditch (for ditch elements)

The cornerstone of the SCQI procedure is the measurement of the size of the sediment source (m^2). The other variables act as modifiers to increase or decrease the hazard associated with the size of the sediment source (Appendix 1). Each of the modifiers is scaled from 0 to 1, where zero (0) represents a condition that would eliminate the hazard (e.g. coarse gravel, no slope or an abandoned fully revegetated road) and one (1) represents a condition that would maximize the hazard (e.g. silt, slope greater than 15% or active mainline). The size of the sediment source (m^2) is multiplied by the value of each modifier to generate an *erosion potential* score for the particular element being assessed. This is then multiplied by the *delivery potential* (scaled from 0 to 1) to obtain the element score. The *delivery potential* represents a qualitative assessment of the percentage of the eroded material that will likely reach the stream. A series of definitions are provided to assist in the determination of the delivery potential, e.g. 0 means that there is no connection between the erosion source and the stream and no delivery is possible, 0.5 means that the delivery is indirect and filtered through trees grasses and/or sediment control structures, 0.8 is used when sediment is weakly filtered through a sparse grass cover and most of the material reaches the stream and 1.0 means that

delivery is evident, direct and uninterrupted with no obvious depositional zones before reaching the stream. The total score for the crossing is simply the sum of the eight scores for each of the individual elements. The final SCQI crossing score generates five hazard classes as defined in Table 1.

Table 1. Correspondence between SCQI score and hazard class.

Score	Sediment Source Hazard Class
0	None
0< score <0.4	Low
0.4 ≤ score ≤ 0.7	Moderate
0.7 < score ≤ 1.6	High
Greater than 1.6	Very High

The values for each of the modifiers are based on the concepts and values developed for the Revised Universal Soil Loss Equation (RUSLE) presented by Wall *et. al*. (2002). The universal soil loss equation was initially developed by Wischmeier and Smith (1965). The objective of the RUSLE was to provide a quantitative tool to assess the potential for soil erosion at a given site.

The SCQI procedure is a useful management tool because it identifies the specific location and magnitude of erosion problems. If scores are high, the crossing can be improved through remedial actions and current practices can be altered to avoid high scores in the future. If scores are low, then it shows that good erosion and sediment control practices are being implemented and by extension water quality is being protected. The procedure has been presented to numerous field practitioners in a series of field workshops and received a favourable response because it clearly identifies the specific location of the problem and the practice that generates the problem.

It is important to note that the SCQI method was designed to be quick (about 15 minutes per crossing) so that a maximum number of crossings can be assessed, thus providing a better landscape level perspective. The SCQI has evolved over the last three years from its initial structure based mostly on subjective assessments. The procedure is now more objective, repeatable and transparent, using values based on the RUSLE.

It must be noted that the whole SCQI approach is largely a conceptual model, based on the general concepts of the RUSLE, and was not developed based on an experimentally acquired set of empirical relationships. It provides a score in a consistent way that can be compared with other crossings in a given watershed and evaluated for how "good" or "bad" the crossings are. The SCQI does not provide a quantitative evaluation (e.g. kg/ha/yr) of exactly how much sediment is entering the stream or what the impact of that sediment has on the stream environment. The SCQI approach tells you where there are erosion and sediment control problems, how frequent in the landscape those types of problems appear and provides a basis of information to judge the magnitude of the problem and how to fix it so that impacts to water quality will be minimized. It is important to emphasize that the SCQI focuses exclusively on the evaluation of the sediment source and the potential of that sediment to reach a stream (i.e. the "hazard"). It does not in any way attempt to measure, evaluate or score the sensitivity of the stream or the impact of increased sediment delivery to the aquatic environment (i.e. it does not evaluate "consequence"). Work is currently underway to develop a methodology to evaluate the sensitivity of a stream to increased sediment loads. If this effort is successful, it could be combined with the SCQI approach to produce a true risk assessment procedure.

Evaluation of the SCQI Procedure

In 2001 an evaluation program was initiated by Canfor, Prince George Division, to test the validity of the SCQI procedure by monitoring stream turbidity levels at selected stream crossings. Several hundred stream crossings ranging over a variety of topographic and climatic conditions across the Prince George Timber Supply Area (TSA) were surveyed in the spring of 2002 to generate a population of possible sampling sites. From this database, we eliminated all large streams (relatively rare occurrence in the landscape) and streams that were too small to be instrumented. Our objective

was to focus the measurements on "small" streams with an average bankfull width of 1 to 3 metres (Figure 3) since about 90% of stream crossings in the Prince George region occur on small streams (P. Beaudry and Associates Ltd. 2002). The crossing scores were then grouped into one of three hazard levels, i.e. low, moderate or high (see Table 1). A random selection of seven stream crossings, per hazard level, was selected to serve as our experimental sample (i.e. total of 21 crossings).

Figure 3. Example of size of stream monitored and instrument set-up for measurement of turbidity. Note water is turbid as a result of rainstorm.

Each crossing was instrumented with electronic continuous turbidity sensors in an "upstream-downstream" experimental design. The assumption behind this approach is that the difference between the upstream and downstream measurements can be attributed to the erosion and sediment delivery at the stream crossing (i.e. induced turbidity). An example of the induced turbidity results, obtained from one of the monitored crossings, is provided in Figure 4. The objective was then to compare the measured induced turbidity with the hazard score generated by the SCQI procedure to see if there was an acceptable correlation.

Both the provincial (Government of BC 2001) and federal (DFO 2000) governments have produced some guidelines that relate increases in turbidity to the risk to the aquatic environment. We used an adaptation of these guidelines to define five hazard classes for our SCQI scores. The classes range from no hazard to very high hazard (Table 2). As an example, a hazard level of "high" is defined as a site that generates enough sediment to the stream that it will consistently cause an increase in turbidity between 70 NTU and 130 NTU, when significant rainfall occurs. The maximum induced turbidity for every rainfall-turbidity event measured during the field season was tabulated and crossing averages were calculated. The event-frequency distributions for each crossing were analyzed and the right tail 10% of the distributions were removed to account for extreme events occurring at very low frequencies (i.e. one large event over the entire field season) that might skew the average. It is also our opinion that most of these extreme events do not actually represent increases in turbidity, but rather an anomaly caused by debris passing over the turbidity sensor, and thus should be removed from the database.

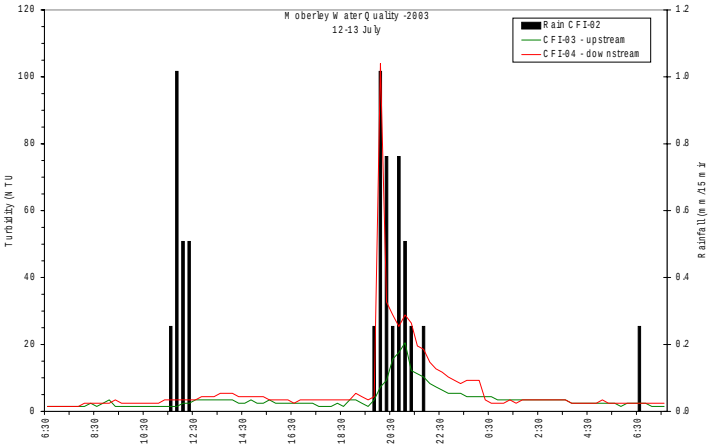

Figure 4. Example of measurement of induced (red) turbidity, where the downstream turbidity peak is about 80 NTU greater than the upstream peak (green).

Results from the 2002 turbidity measurements generally showed a good correspondence between the assessed hazard level and induced turbidity measurements. The validation process also identified some specific problems with the procedure and improvements were made accordingly during the 2003 field season. One of the major refinements was the introduction of an objective measurement of the actual size of each of the sediment sources, rather than the previously used subjective assessment of the "level of erosion". This refinement provided an opportunity to generate a more quantitatively-based score with no pre-defined upper limit. The individual crossing scores for each of the 21 sites were related to the average induced turbidity of the entire monitoring

site to determine if the SCQI score was a reasonable predictor of induced turbidity.

Table 2. Levels of risk associated with increases in turbidity (adapted from Fisheries and Oceans, 2000)

Induced Turbidity (NTU)	Risk to Fish Habitat	Sediment Source Hazard Class
0	None	None
1 to 8	Low	Low
8 to 70	Moderate	Medium
70 to 130	High	High
>130	Unacceptable	Very High

The regression analysis has shown that indeed the relationship is quite good, at least for SCQI score less than 3.5 (Figure 5). Two of the monitored crossings had scores greater than 8, and yet did not generate turbidity levels as high as the scores suggest they should have. These two points were not included in the dataset as they render the linear relationship insignificant. Based on these two "outliers", it appears that the SCQI procedure needs to be further refined for situations where the sediment source is very large. Currently, we think that as a sediment source increases in size (e.g. > 150 m^2) and the complexity and variability of the characteristics of the sediment source also increase, it becomes increasingly difficult to predict how much of the eroded material will actually reach the stream.

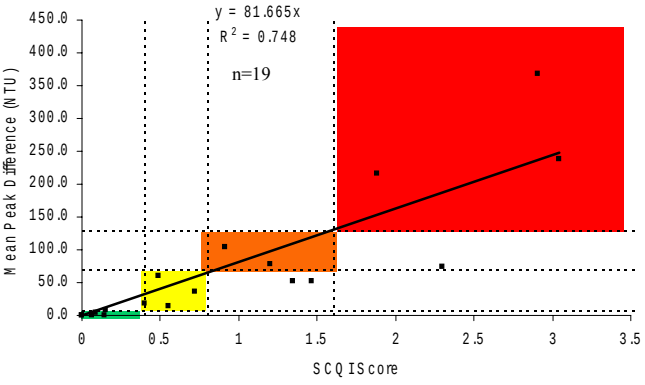

Figure 5. Relationship between SCQI score and induced turbidity (mean peak difference NTU).

Further improvements to the SCQI procedure are necessary to accommodate the complexities of larger sediment sources. Another related issue is that the upper limit of the induced turbidity scale is dependent on the sediment saturation potential of the volume of water transported in the stream and when the water is very dirty the relationship between delivery of sediment and increases in turbidity may no longer be linear.

In Figure 5, we added coloured rectangles to illustrate the areas on the graph that represent the different hazard rating classes used in the SCQI procedure and how these relate to the expected range of induced turbidity. These results clearly suggest that the procedure is very good at predicting induced turbidity (within the expected range) for the low and moderate hazard levels, and although somewhat less accurate, also good for the high and very high classes (up to scores of about 3). The three points that are outside of the coloured areas all represent the same situation, i.e. the SCQI score is predicting a situation that is a little bit worse than the actual problem, but only for situations where a significant problem already exists. Thus, for a proportion of crossings surveyed, the SCQI procedure may be overstating the size of a problem where a significant problem exists, but it accurately predicts the size of the problem where the problems are small or non-existent. Consequently, we believe that the SCQI is a good tool to identify the proportion of problem and non-problem crossings across the landscape and is thus a good SFM indicator to address the goal of protection of water quality. Work is continuing on the development and refinement of this procedure.

Hazard rating = Low.
Turbidity < 8 NTU.
SCQI < 0.4.

Hazard rating = Moderate.
8 NTU < Turbidity < 70 NTU.
0.4 ≤ SCQI ≤ 0.7.

Hazard rating = High.
70 NTU < Turbidity < 130 NTU.
0.8 ≤ SCQI ≤ 1.6.

Hazard rating = Very High.
Turbidity > 130 NTU.
SCQI > 1.6.

Conclusions

Canfor has completed SCQI surveys over a wide range of their operating areas as part of their forest certification programs (well over 3,000 crossings). These include areas within central and northern B.C. and eastern Alberta. Several independent certification audits have identified this approach as a meaningful and well structured process to objectively document the extent of effective erosion control practices in the landscape. Road construction and maintenance supervisors find this a useful tool because it locates and identifies specific problems and provides direction for remedial action with the built-in incentive of obtaining a better SCQI score in the future. The SCQI tool is also useful to show improvements in erosion control practices over time, a requirement of many forestry certification schemes.

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Appendix 1. **Modifier score values** (subject to change with further validation work)

Table A1. Sediment Source Area Scores

Size (m^2)	Score	Size (m^2)	Score
0	0	**50-100**	2
0-1	0.1	**100-150**	3
1-2	0.2	**150-200**	4
2-4	0.3	**200-250**	5
4-8	0.4	**250-300**	6
8-14	0.5	**300-350**	7
14-20	0.6	**350-400**	8
20-26	0.7	**400-450**	9
26-32	0.8	**450-500**	10
32-40	0.9	**500-550**	11
40-50	1	**550-600 etc**	12, etc

Table A2. Soil texture class modifier scores.

Soil Textural Class	***Score/Compactness Level***		
	M	***L***	***H***
Very Fine Sand	1.0	0.90	0.80
Silt	0.97	0.86	0.77
Silt -Loam	0.88	0.80	0.70
Silty Clay Loam	0.74	0.70	0.60
Clay	0.51	0.46	0.41
Sandy Loam	0.3	0.27	0.24
Medium Sand	0.16	0.14	0.13
Coarse Sand	0.014	0.013	0.011
Stones and Gravel	.007	0.006	0.006

Table A3. Slope modifier scores.

Gradient	**Score**
>12%	1.0
9-12%	.97
7-9%	.85
5-7%	.75
3-5%	0.60
1-3%	0.25
<1%	0.15
away from stream	0.00

Table A4. Road use level modifier scores.

Road Use Level	***Score***
Active mainline	1.0
Active branch line	0.99
Moderate activity (occasional grading)	0.95
Low activity (no grading, x-ing structure still present)	0.96
De-activated (xing structures removed)	
-used extensively by 4 wheelers	0.98
-minor use by 4 wheelers	0.92
-no 4 wheeler use evident	0.85
Abandoned – no access (too much veg)	0.80

Table A5. Ditch shape modifier scores

Ditch shape	***Score***
"V"shape-V.steep&V.steep	1.55
"V"shape-Steep&V.steep	1.45
"V"shape-Gentle&V.steep	1.35
"V"shape-Flat&V.steep	1.10
"V"shape-Steep&Steep	1.35
"V"shape-Gentle&Steep	1.25
"V"shape-Flat&Steep	1.00
"V"shape-Gentle&Gentle	1.15
"V"shape-Flat&Gentle	0.90
"U"shape-V.steep&V.steep	1.40
"U"shape-Steep&V.steep	1.30
"U"shape-Gentle&V.steep	1.20
"U"shape-Flat&V.steep	1.10
"U"shape-Steep&Steep	1.20
"U"shape-Gentle&Steep	1.10
"U"shape-Flat&Steep	1.00
"U"shape-Flat&Gentle	0.90
"U"shape-Flat&Flat	0.85
"U"shape-Gentle&Gentle	1.00

Appendix E

Drinking Water Source Protection Memorandum of Understanding, Southern Interior Drinking Water Team Membership

MEMORANDUM OF UNDERSTANDING

BETWEEN

Ministry of Agriculture and Lands
Ministry of Energy, Mines and Petroleum Resources
Ministry of Environment
Ministry of Community Services
Ministry of Health
Ministry of Forests, Range and Housing
Ministry of Transportation
Office of the Provincial Health Officer
Fraser Health Authority
Interior Health Authority
Northern Health Authority
Vancouver Coastal Health Authority
Vancouver Island Health Authority

REGARDING

INTER-AGENCY ACCOUNTABILITY AND COORDINATION ON DRINKING WATER PROTECTION

VERSION 7: OCTOBER 16 · 2006

1 Background

1.1 In March, 2002 the Province adopted an *Action Plan for Safe Drinking Water in British Columbia* which sets out a multi-faceted and multi-agency approach to the protection of public health as it relates to drinking water quality.

1.2 The Action Plan sets out government's commitment to an integrated approach for drinking water protection. The ADMs' Committee on Water and the Directors' Inter-Ministry Committee on Drinking Water are the facilitating bodies for the Action Plan.

1.3 The Action Plan also states the accountability of different ministries for the coordination of source protection, land use planning and infrastructure:

(a) The Ministry of Environment will be responsible for source water quality standards, monitoring, compliance and enforcement, and resource ministries will continue to be responsible for protecting drinking water sources under their legislated mandates.

(b) The Ministry of Agriculture and Lands will work with communities to help make appropriate land use decisions that carefully consider drinking water protection.

(c) The Ministry of Community Services will work in partnership with federal and local governments to help ensure required infrastructure is in place.

1.4 The *Drinking Water Protection Act* (DWPA) is one element of the Action Plan. It is the principal statute concerning drinking water protection.

1.5 Many other statutes deal with matters of relevance to drinking water protection, and through which government seeks to achieve various legislative objectives related to matters such as resource extraction, land use and environmental practices. Many of these statutes contain their own provision for drinking water protection, most particularly source water protection.

1.6 The role of drinking water officers under the DWPA complements the roles of statutory officials under other statutes, and the DWPA contains numerous provisions to balance respect for other statutory mandates while at the same time ensuring that public health protection respecting drinking water is achieved.

1.7 The DWPA requires the Provincial health officer to perform an oversight and accountability function regarding the administration of the DWPA. This includes a duty to report to the Minister of Health and potentially to Cabinet any situation that

(a) in the opinion of the Provincial health officer, significantly impedes the protection of public health in relation to drinking water, and

(b) arises in relation to the actions or inaction of one or more ministries, government corporations or other agents of the government.

1.8 In light of all the above, the parties to this MOU have entered into this understanding with a view to ensuring each agency's accountability in respect of their actions concerning drinking water protection.

1.9 This MOU is not intended to address issues of consultation and/or coordination between the parties to this agreement and federal agencies.

2 Guiding principles

2.1 In fulfilling the terms of this MOU the parties[1] will be governed by the following guiding principles:

Constructive – The parties will foster constructive working relationships.

Proactive – The parties will work to ensure that any potential concerns regarding inter-agency cooperation are identified in a proactive manner and that steps are taken to avoid them, or to address them as soon as possible.

Information sharing – Each agency, through either the ADMs' or the Directors' Committees, will share with the other agencies information relevant to the matters covered by the MOU. This will include:

- sharing of information respecting the development or amendment of legislation, policy, practices, etc. that may affect drinking water protection (in advance where possible)
- sharing information from the ADMs' and Directors' Committees with officials[2] responsible for implementing the regional protocols (discussed below)
- clear communication regarding the goals and purposes of the various regulatory mandates, particularly those which are results based.

Respect for mandates – All of the parties will recognize and respect the mandates and statutory decision-making functions of the other parties.

Partnership – The parties will give effect to this MOU in manner that reflects a sense of partnership and shared responsibility for drinking water protection and risk management.

Efficiency and Practicability – The parties seek to ensure that the goals of the MOU are achieved in a manner that minimizes the need for the development of additional referrals systems and other activities that will impose significant resource requirements on staff. The parties will also support an appropriate degree of flexibility among regions in implementing the regional protocols (discussed below), so as to reflect the particular needs and circumstances of the various regions. Communication and referrals on resource activities that are part of the regional protocol will be based on best available information at the time of the application.

[1] "Parties" means the agencies as represented on the ADMs' Committee on Water.
[2] i.e., officials from any agency.

3 Establishment of regional drinking water teams

3.1 For each region, a regional drinking water team will be established, with representation from each agency that is party to this agreement, as well as representation from local governments that wish to participate.

3.2 The members of the regional drinking water teams will serve as the principal contact for discussion of regional inter-agency drinking water issues.

3.3 Each health authority will designate a drinking water officer to serve as a coordinator of the respective regional drinking water teams. The coordinator will maintain an up-to-date contact list for members of the regional drinking water team and make that available to all team members.

3.4 Regional drinking water teams may communicate by whatever means is considered the most efficient and effective and all may meet, in whole or in part, at times mutually agreeable to all the members. The coordinator for each team will schedule at least one meeting each year to which all members of the regional drinking water teams will be invited to attend. If a subset of the membership meets, the coordinator of the drinking water team will communicate the outcome of the meeting to all members within a week of the meeting.

4 Commitment to the establishment of regional protocols

4.1 Each of the Parties to this MOU will participate in the development of regional protocols to give operational effect to the purposes of this MOU.

4.2 For the purposes of the regional protocols, the regions will be defined by the geographic areas of each of the five health authorities, as set out in Appendix A. Due to the absence of coincident boundaries among the agencies, discussions may need to occur among multiple offices to identify appropriate committee membership for each regional protocol.

4.3 The regional protocols will be developed by the regional teams, and they will set out the types of decisions that should as a general rule be the subject of some form of coordination or consultation, recognizing however that the decision whether or not to undertake inter-agency coordination in any particular case is ultimately a matter for the discretion of officials[3] (unless some legal requirement to do so exists).

4.4 Regional drinking water teams may develop whatever form of protocol they determine appropriate to achieve the goals and meet the requirements of this MOU, but they are encouraged to consider using the form of protocol set out in Appendix B, and to consider coordination regarding those activities set out in Appendix C that are relevant to that

[3] i.e., officials from any agency.

region. Regional protocols may include strategies for engaging local stakeholders interested in community drinking water issues.

4.5 Regional protocols must be developed for each region no later than October, 2007. A copy of such protocols must be provided to the Directors' Inter-agency Committee on Drinking Water when it is completed, and at any time it is amended.

4.6 Nothing in this MOU or any regional protocol developed under it is intended to be legally binding, and neither creates any legal rights or duties. Moreover, nothing in this MOU or a regional protocol shall be taken to limit or constrain the exercise of discretion by a party in respect of a statutory power or decision.

5 Commitment to include drinking water coordination activities within each ministry and agency

5.1 Each agency that is party to this MOU will undertake the necessary internal steps to ensure its commitment to inter-agency coordination of drinking water issues and the implementation of this MOU.

6 Process for review and performance management

6.1 On or before June 30 of each year, beginning June 2008, each drinking water team will provide to the Directors' Inter-agency Committee on Drinking Water a summary report of its activities for the previous fiscal year.

6.2 The Directors' Inter-agency Committee on Drinking Water will review the reports of the regional drinking water teams and provide an annual overview report to the ADMs' Committee on Water.

6.3 The Directors' Inter-agency Committee may at any time provide recommendations to the regional drinking water teams, with a view to ensuring the effective and efficient implementation of this MOU.

7 Process for dealing with disagreements or unresolved issues

Disagreements or unresolved issues in implementation of regional protocols

7.1 Responsibility for addressing disagreements or unresolved issues concerning implementation of the regional protocols rests with the regional team members and their supervisors as appropriate. If however the regional teams draw to the attention of the Directors' Inter-agency Committee on Drinking Water any disagreements or unresolved issues arising in relation to the implementation of a regional protocol, the Directors' Committee may review and discuss the matter, with a view to recommending to the ADMs' Committee any amendments to this MOU that may prevent such occurrences from occurring in future.

Disagreements or unresolved issues in implementation of this MOU

7.2 If any disagreements or unresolved issues arise in the implementation of this MOU , the relevant members of the Directors' Inter-agency Committee on Drinking Water will discuss the matter and attempt to resolve it. If that does not prove successful, those parties will refer the matter to the relevant members of the ADMs' Committee. In the event that the Assistant Deputy Ministers of the agencies concerned are unable to resolve the disagreement in a mutually acceptable manner, they will refer to matter to the Deputy Provincial health officer, who may consult with the parties with a view to resolving the matter.

8 Costs

8.1 Each agency will bear its own costs of undertaking the activities associated with this MOU.

Grant Parnell, Assistant Deputy Minister, Crown Land Administration, Ministry of Agriculture and Lands — Dec 8/06. — Date

Harvey Sasaki, Assistant Deputy Minister, Risk Management and Competitiveness, Ministry of Agriculture and Lands — 06.12.08 — Date

Eric Partridge, Assistant Deputy Minister, Mining and Minerals, Ministry of Energy, Mines and Petroleum Resources — 06.11.07 — Date

Jim Mattison, Assistant Deputy Minister, Water Stewardship, Ministry of Environment — 2006.12.11 — Date

Dale Wall, Assistant Deputy Minister, Ministry of Community Services — 2006.12.14 — Date

Andrew Hazlewood, Assistant Deputy Minister, Population Health and Wellness, Ministry of Health — Nov 03/06. Date

Jim Snetsinger, Chief Forester, Ministry of Forests, Range and Housing — Dec 12/06 Date

for Peter Milburn, Assistant Deputy Minister, Highways Department, Ministry of Transportation — 06/12/4 Date

Dr. Perry Kendall, Provincial Health Officer, Office of the Provincial Health Officer — 31/Oct/2006 Date

Dr. Roland Guasparini, Chief Medical Health Officer, Fraser Health Authority — 24 January 2007 Date

Dr. Rob Parker, Chief Medical Health Officer, Interior Health Authority — Dec 28/2006 Date

Dr. David Bowering, Chief Medical Health Officer, Northern Health Authority — Jan 9/2007 Date

for Dr. John Blatherwick, Chief Medical Health Officer, Vancouver Coastal Health Authority — 02/NOV/2006 Date

Dr. Richard Stanwick, Chief Medical Health Officer, Vancouver Island Health Authority — Jan 17/07 Date

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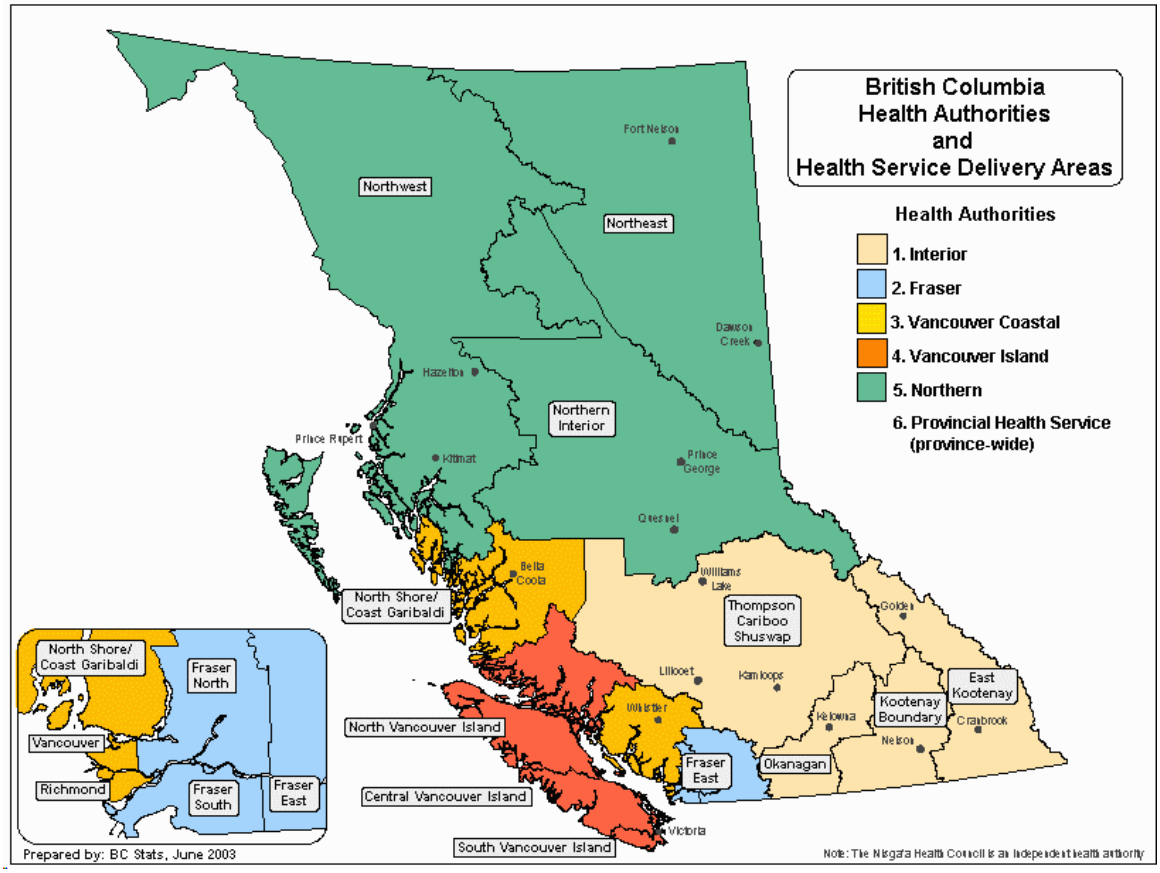
Appendix A

Map of Health Authorities



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Appendix B

Suggested template for Regional Protocols

REGIONAL DRINKING WATER TEAM

The members of the _____ Regional Drinking Water Team, including contact information and the names of alternate members, are set out in the attached table.

Each agency will bear the costs of its participation in the Regional Drinking Water Team and the meetings referred to below.

MEETING SCHEDULE

Regular meetings

The Regional Drinking Water Team will hold a regular meeting at least *[SPECIFY FREQUENCY]*. Such meetings will be arranged by *[SPECIFY DRINKING WATER OFFICER OR OTHER PERSON]* upon at least 3 weeks notice to all the other parties. All parties will send a representative to such meetings.

Parties will attempt to participate in regular meetings in person, but may arrange to participate by conference call if personal attendance is not practicable.

The team members will rotate the responsibility for organizing and hosting regular meetings, and in preparing minutes that result from such meetings.

Additional meetings

Additional meetings may be held at any time that any of the team members wishes to propose and organize such a meeting. In providing notice of additional meetings, the person proposing the meeting should give as much notice as is reasonable in the circumstances, and must indicate the purpose of subject matters(s) to be addressed in the meeting. The other parties may attend such additional meetings at their discretion.

Parties may participate in additional meetings in person or by teleconference.

Matters for consideration at meetings

The Regional Drinking Water Team will establish its own agendas for regular and additional meetings. This may include, but is not limited to:

- Discussion of routine consultation and activities taken pursuant to the protocol (see next section)

- Proactive identification of drinking water protection issues that may warrant inter-agency consultation and coordination even before a specific statutory decision or function is contemplated

- Consultation with local stakeholders interested in community drinking water/watershed protection issues

- *[Others?]*

MATTERS FOR WHICH COORDINATION AND CONSULTATION WILL BE ROUTINELY CONSIDERED

Staff of the parties to the protocol will, as a general matter, apply the principles set out in the following chart concerning inter-agency consultation when exercising their statutory functions relevant to drinking water protection.

However, in any case where an official from an agency determines that some other approach is more appropriate on the facts of any particular case, he or she may adopt the principles that are considered appropriate.

[Insert chart based on proposal set out in Appendix C of MOU[4], but tailored to needs and circumstances of the region.]

DEALING WITH DISAGREEMENT OR UNRESOLVED ISSUES

In the event issues arise about which the team members disagree, or cannot be resolved, and which have potential impact on drinking water protection and related matters, the team members involved will refer the matter to their immediate supervisors for consideration and direction.

If as a result of the referrals discussed above a team members considers that a matter is not resolved to the mutual satisfaction of the agencies concerned, he or she must advise the person from that agency that is a member of the Directors' Inter-agency Committee on Drinking Water.

COMMUNICATION STRATEGIES

The parties will adopt the following communication techniques and strategies to ensure open and effective communication regarding drinking water protection issues:

- Copies of this protocol and the related MOU will be provided to [specify]
- The parties will share information in a timely way regarding developments within their respective agencies that are relevant to the matters covered in this protocol.
- *[Others?]*

[4] Appendix C is a table including agencies' decisions related to drinking water and the associated legislation.

PREPARATION OF AN ANNUAL REPORT

8.2 On or before June 30, beginning June 2008, of each year, each drinking water team will provide to the Directors' Inter-agency Committee on Drinking Water a summary report of its activities for the previous fiscal year. Responsibility for preparing the report will rotate annually among members of the Regional Drinking Water Team.

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Appendix C

Please note: THE FOLLOWING EXAMPLE IS FOR ILLUSTRATIVE PURPOSES ONLY. This chart is intended to be completed by the regional drinking water teams. The actual contents of the chart would need to be discussed and considered by relevant ministry staff.

Chart of key statutory decisions for which regional inter-agency coordination may be appropriate

ACT	DECISION OR ACTION BEING CONSIDERED OR TAKEN	AGENCIES WITH WHICH TO COORDINATE* "c" - consider consulting and pursue as appropriate "i" - share for information purposes "r" - request input before decision-making (*May be departed from where the official concerned views the type or degree of coordination set out below is not appropriate in the circumstances)									
		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
Dike Maintenance Act											
Drinking Water Protection Act	Construction permits										
	Operating permits										
	Hazard Abatement Orders										
	Public reporting requirements (e.g., boil water notices)										
	Assessment (technical committee)										
	Assessment response plan										
	Emergency Plans										
	DWPP (request for)										

ACT	DECISION OR ACTION BEING CONSIDERED OR TAKEN	AGENCIES WITH WHICH TO COORDINATE* "c" - consider consulting and pursue as appropriate "i" - share for information purposes "r" - request input before decision-making (*May be departed from where the official concerned views the type or degree of coordination set out below is not appropriate in the circumstances)									
		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
Environmental Assessment Act											
Environment Management Act	Pollution abatement order										
	Pollution prevention orders										
	Pollution information order										
	Waste discharge (Schedule 1)										
	Area-based planning										
	Substitution orders										
	Remediation orders (CS)										
	Animal Waste Control Regulation										
	Organic Matter										
	Recycling Regulation										
Farm Practices Protection Act	Farm bylaws through the local government act										
Fisheries Act											
Fish Protection Act	Riparian Area Regulation										
Forest Act	Tenure/licence award										

ACT	DECISION OR ACTION BEING CONSIDERED OR TAKEN	AGENCIES WITH WHICH TO COORDINATE* "c" - consider consulting and pursue as appropriate "i" - share for information purposes "r" - request input before decision-making (*May be departed from where the official concerned views the type or degree of coordination set out below is not appropriate in the circumstances)									
		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
Forest Practices Code	Road construction permits										
	Watershed Assessments in community watersheds(until 2006)										
	Forest Development Plan Approval										
	Cutting permits										
	Setting water quality objectives (known)										
Forest and Range Practices Act	Forest Stewardship Plans										
	Range Stewardship Plans										
	Range Use Plan										
	Woodlot Regulation										
	Community Watershed designation (MSRM)										
	Community Watershed objectives (MWLAP)										
Geothermal Resources Act	Tenure (MEM)										
	Exploration and Development Approvals (MEM?)										

ACT	DECISION OR ACTION BEING CONSIDERED OR TAKEN	AGENCIES WITH WHICH TO COORDINATE* "c" - consider consulting and pursue as appropriate "i" - share for information purposes "r" - request input before decision-making (*May be departed from where the official concerned views the type or degree of coordination set out below is not appropriate in the circumstances)									
		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
Integrated Pest Management Act	Service license approvals (including conditions)										
	Directives and orders										
	Selective permitting										
Land Act	Plan approvals and objectives										
	Fee simple										
Land Amendment Act	Water Objectives (MSRM)										
Lands, Parks and Housing Act	Same powers under both (Land Act LWBC) Land Act: application-based, proactively look for opportunities (e.g., sale of Crown land)										
	Crown Land Allocation Framework (CLAF)										
	Recreational Lot Sales Strategy										
Livestock Act	Fencing										
	Land clearing										
Local Government	Regional Growth Strategies										

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		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
Act/ Community Charter	OCPs										
	Subdivsion zoning bylaws										
	Variances										
	Borrowing powers regarding water DWO determines non-potable										
	Liquid Waste Management Plans										
	Amendments to municipal boundaries										
	Adoption of OCP										
	Adoption of Zoning Bylaws										
Local Government Grants Act	Infrastructure funding										
Local Services Act	Subdivision regulation (unserviced areas within RDs, approval by MOT)										
Mines Act	Sand and gravel, placer, and hardrock. mining										
	Approvals and permits										

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		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
	Remediation orders										
	Dumps										
	Dams										
	Remediation for acid rock drainage										
	Gravel pits										
Parks Act	Water supplier provisions										
	Park Use Permits										
Petroleum and Natural Gas Act	Tenure (MEM)										
	Exploration and Development Approvals										
Range Act											
Transportation Act	New highway development										
	Road maintenance standards and agreements for 10 years										
	Permit to construct works on Crown lands										
	Transportation of Dangerous Goods										
Water Act	Water licences										
	Dam building										

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		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
	Storage										
	Water Users' Communities										
	Section 9 approvals: "changes in and about a stream"										
	Issuance of permits over Crown land (pipes);										
	Dam and dyke approvals. (Potential for flooding of intake works for wells or surface intakes.)										
	Flood proofing of wells										
	Well construction										
	Water Management Plans (MSRM/MWLAP)										
Water Utilities Act	Excludes sections strictly for energy utilities										
	Certificate of public convenience and necessity										
Water Utilities Commission Act											

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		DWO	**MAL**	**MCS**	**MEMPR**	**MOFR**	**Local Gov't**	**MOE**	**MOT**	**PHO**	
Weed Act	Spraying										
Wildfire Act											
Wildlife Act											

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