REPORT

Penticton Creek Source Assessment

City of Penticton

Don Dobson, November 2013

Reference: 1017.0057.01

URBAN systems

304 – 1353 Ellis Street

Kelowna, BC V1Y 1Z9

250-762-2517

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City of Penticton
171 Main Street
Penticton, BC
V2A 5A9

Attention: Brent Edge

RE: Penticton Creek Source Assessment Report

After receiving comments back from stakeholders we have revised the report toreflect the comments and submit the revised final Penticton Creek Source Assessment Report.

Please feel free to contact the undersigned should you have any questions.

Sincerely,

URBAN SYSTEMS LTD.

Don Dobson, P.Eng.
Senior Water Engineer

/dd

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1.0 Background

Community watersheds in the province of BC supply many local communities with their drinking water. These watersheds also have a variety of other uses including forestry, mining, agriculture, urban development, and recreation, and are known as multi-use watersheds (BC Provincial Health Officer, 2001). In the City of Penticton, drinking water comes from Penticton Creek and Okanagan Lake. The Penticton Creek watershed is a multi-use community watershed.

The key to ensuring clean, safe, and secure drinking water is to implement multiple barriers throughout the drinking water system. The multi-barrier approach aims to reduce the risk of drinking water contamination and to increase the feasibility and effectiveness of remedial controls or preventative options (Canadian Council of Ministers of the Environment (CCME), 2004).

The *Drinking Water Protection Act* established in BC in 2003, requires a Source to Tap Assessment of drinking water supply systems across the province. These assessments are to be undertaken by the water supplier at the request of a drinking water officer. Surface water sources – lakes, streams, creeks, rivers and precipitation, are open to the atmosphere, making these sources particularly vulnerable to contamination by the actions of humans or animals or by natural events in the watershed such as landslides, fires or extreme runoff from heavy rain (BC Provincial Health Officer, 2001).

Source water protection is an important component of the multi-barrier approach to ensuring safe drinking water. The Action Plan for Safe Drinking Water in BC recognizes “source protection as a critical part of drinking water protection.”

One of the prime objectives of the Source to Tap Assessment is to identify and evaluate existing and possible threats to, and vulnerabilities of, drinking water safety and sustainability. These hazards can be: physical or less tangible in nature; pre-existing or potential; and/or naturally occurring; or a function of human action or inaction.

2.0 Introduction

2.1 Project Scope

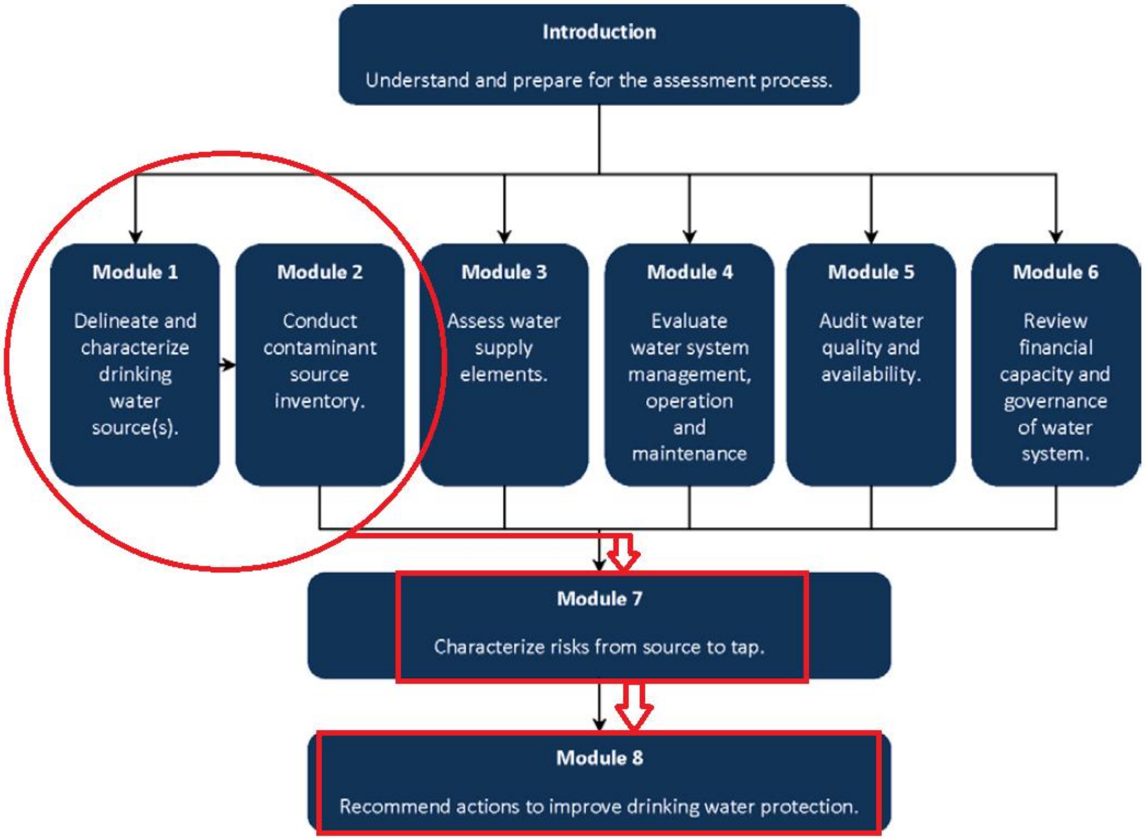
The City of Penticton (City) Source Assessment Report has been prepared in response to a requirement in the water system Operating Permit issued by the Interior Health Authority to the City. The City has operated as a water supplier since the 1920s and services a population of approximately 35,000 residents. Total distribution of water for the year 2011 was ~6,851 mega liters (ML). The City water distribution system has six storage reservoirs, 160 kilometers of water mains, 900 fire hydrants, and 9,000 service connections.

Although the City has several sources of water, this assessment is limited to the Penticton Creek watershed. The area of concern is the watershed upstream of the City intake. The source area is approximately 175 km^2 (refer to Penticton Creek Source Protection Plan Map in Appendix A).

The intent of a source assessment is to identify and evaluate the hazards in the watershed upstream of the intake to drinking water quality and quantity, characterize the risks and propose risk management strategies. Water Source Assessments, as referenced in Part 3, Section 18 of the *Drinking Water Protection Act* is the first step in Health Canada's multi-barrier approach to safe drinking water. The Ministry of Health (MoH) and the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), provide guidance in the Comprehensive Drinking Water Source-to-Tap Assessment Guideline released in 2010. This assessment has been guided by Modules 1, 2, 7 and 8 of the Guideline (refer to Figure 1). The four modules are summarized in the following sections.

In determining physical, biological, and chemical hazards within the assessment area, historic, current and potential future conditions were taken into account. All potential hazards identified during the watershed characterization step were then summarized in a Hazard Summary.

Figure 1: Schematic of Comprehensive Drinking Water Source-to-Tap Assessment Guideline Process



Source: Adapted from the Comprehensive Drinking Water Source-to-Tap Assessment Guideline

2.2 Licensed Stakeholders and Interested Parties

The provincial agencies and licensed stakeholders in the watershed include:

- Interior Health Authority
- Ministry of Forest, Lands and Natural Resource Operations
  - Water Stewardship
  - Range
  - Resource Management
- City of Penticton
- Weyerhaeuser Ltd.
- Ministry of Mines
- Ministry of Jobs, Tourism and Skills Training
- Licensed Trappers
- Grazing Licensees

2.3 Technical Advisory Committee (TAC)

Section 19 of the *Drinking Water Protection Act* provides the authority to the drinking water officer to order a water supplier to prepare an assessment. Since the requirement for a plan has been included as a requirement in the Operating Permit issued by Interior Health Authority (IHA) to the City, it was appropriate to create a technical advisory committee that included representatives from the IHA and the MFLNRO 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 included the following:

- IHA
- MFLNRO (Resource Management, Water Stewardship, Range)
- Ministry of Jobs, Tourism and Skills Training
- Ministry of Mines
- Weyerhaeuser Ltd.

The project consultant is Urban Systems, Kelowna, BC.

2.4 The City of Penticton's Source Water Infrastructure

The City obtains its drinking water from two sources; Okanagan Lake and Penticton Creek. This source assessment report is limited to the Penticton Creek watershed upstream of the City intake (Map – Appendix A). Existing infrastructure above the Penticton Creek intake includes; Greyback Reservoir, Greyback Dam, Campbell Mountain Diversion Dam, Penticton #2 Dam, Penticton Creek Intake Pond.

Penticton Creek is a Community Watershed supplying drinking water to the City. The Greyback Reservoir is located in the headwaters of Penticton Creek, approximately 19km northeast of Penticton (Photo 3, 22, and 23 – Appendix B) (Map – Appendix A). Greyback Reservoir has a live storage capacity of approximately 12.33ML. The reservoir is used by the City to store and control water for their domestic water and north irrigation system. The dam is approximately 35 meters in height and 610 meters in length. An emergency spillway is located on the east abutment. Greyback Reservoir covers an area of approximately 120 hectares and drains into Penticton Creek.

In 1967, the Campbell Mountain Diversion Dam was constructed approximately 3.5km upstream from the main City intake (Map – Appendix A). Water is diverted through a 3km tunnel to irrigate farms, orchards and wineries along Naramata Road north of Penticton (EarthTech 2005). The Campbell Mountain Diversion Dam intake pond has a storage capacity of 31,000m^3 of water.

Water that is not diverted flows to Penticton #2 Dam at the community intake. The City's main intake is located at Penticton #2 Dam, a concrete arch dam originally constructed in about 1930 (Map – Appendix A). This dam is approximately 16 meters in height and spans 22 meters between abutments. The intake pond has a storage capacity of 71,500m^3 of water (Photo 1 – Appendix B). The intake pond behind the dam is approximately two hectares. Water is diverted to the water treatment plant located immediately downstream.

The current water treatment facility was constructed in 1996 and a capacity upgrade including high rate Dissolved Air Flotation (DAF) clarification was completed in 2008/2009. Water is supplied to the treatment plant from two sources – Penticton Creek, through the gravity system, and can be pumped from Okanagan Lake. The City also maintains the Warren Avenue Well as a backup source that can provide 12 ML per day if required in an emergency.

About 75 to 80% of Penticton Creek water withdrawals are for domestic use with the rest going to agriculture. Penticton Creek also supplies about 80% of the City's irrigation demand, with the balance supplied by Ellis Creek.

In 2011, the City pumped 5,054ML from the Okanagan Lake and diverted 1,841ML from Penticton Creek to the Penticton Water Treatment Plant. Penticton Creek provided 27% of the total water diverted to the treatment plant in 2011 (City, 2012).

2.5 Assessment Approach

This report has been guided by Modules 1, 2, 7, and 8 of the Comprehensive Drinking Water Source-to-Tap Assessment Guideline. A brief summary for the modules is provided below. For more details, please refer to http://www.health.gov.bc.ca/protect/pdf/cs2ta-intro.pdf.

Module 1

- Delineate the contributing watershed.
- Define the assessment area in which to conduct the source characterization and potential contaminant source inventory.
- Characterize the watershed and water body.
- Evaluate the integrity and location of the intake.

Module 2

- Identify potential contaminant sources by reviewing:
  - existing sources of information; and
  - historical land use.
- Conduct a contaminant source inventory of the watershed area upstream of intake based on an office review of potential contaminants and reconnaissance 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

- Develop recommendations to improve drinking water safety and sustainability.

Source Assessment Report

The Source Assessment Report will summarize the results of the four modules and form the basis of the Assessment Response Plan as required by Part 3, Section 22 of the *Drinking Water Protection Act*.

2.6 References

The following documents were reviewed:

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Provincial Health Officer, Province of British Columbia, 2001. Provincial Health Officer's Annual Report 2000. *Drinking Water Quality in British Columbia: The Public Health Perspective*. Victoria, B.C.: Ministry of Health Planning.

Redding, T., Rita Winkler, David Spittlehouse, R.D. Moore, Adam Wei and Pat Teti, 2008b. *Mountain Pine Beetle and Watershed Hydrology: A Synthesis focused on the Okanagan Basin*. Can. Water Res. Ass., One Watershed – One Water conference proceedings. Oct 21 to 23, 2008. Kelowna, B.C.

Scott, D., and Pike, R. 2003. *Wildfires and Watershed Effects in Southern B.C. Interior*. Streamline Watershed Management Bulletin. Vol.7, No.3.

Singleton, H., 2001. *Ambient Water Quality Guidelines (Criteria) for Turbidity, Suspended and Benthic Sediments*. Ministry of Water, Land and Air Protection.

Winkler, R., 2006. Snow, Road, *Soil Moisture and Harvest Distribution Effects on Streamflow and Water Quality at Upper Penticton Creek*, Executive Summary. FIA-FSP Project Y073115. BC Ministry of Forests, Kamloops.

Winkler, R., D. Spittlehouse, Y. Alila, B. Heise and G. Hope. 2006. *The Upper Penticton Creek Watershed Experiment: A summary of research into logging effects on water resources*. In: Extended Abstracts from the Conference on Forest and Water in a Changing Environment, Beijing, China, August 8-10, 2006. Eds. S. Liu, G. Sun and P Sun. pp.47-50.

Winkler, R.D., R.D. Moore, T.E. Redding, D.L. Spittlehouse, B. Smerdon and D.L. Carlyle-Moses. 2010. *The Effects of Disturbance on Hydrologic Processes and Watershed Response* (Chapter 7). In Compendium of Forest Hydrology and Geomorphology in British Columbia [In Press]. R.G. Pike et al. (editors). B.C. Ministry of Forests, Lands and Natural Resource Operations Research Branch, Victoria, B.C. and FORREX Forest Research Extension Partnership, Kamloops, B.C. Land Management Handbook 66. http://www.forrex.org/program/water/compendium.asp

Comprehensive Drinking Water Source-to-Tap Assessment Guideline (Introduction, Modules 1, 2, 7 and 8)

2.7 Abbreviations

Interior Health Authority	IHA
Mountain Pine Beetle	MPB
Equivalent Clear-cut Area	ECA
City of Penticton	City
Ministry of Forests, Lands, and Natural Resource Operations	MFLNRO
Canadian Council of Ministers of the Environment	CCME
Mega Liters (one million liters)	ML
Total Organic Carbon	TOC

3.0 Characterization of the City of Penticton Drinking Water Source (Module 1)

3.1 Objective

The source-to-tap assessment involves delineating and characterizing the drinking water source area, and the extent and boundaries of the land area contributing water to the intake (Module 1).

In this section you will find references to:

- map showing:
  - watershed source area boundaries,
  - important biogeophysical information, and
  - the location of the City intake;
- source area and assessment delineation;
- description and characterization of the source area, including intrinsic hazards and vulnerabilities; and
- Potential Hazard Identification Summary.

3.2 Methodology

A literature review using a number of previous reports was undertaken to characterize the watershed. A list of resources consulted is included in the References section. This report utilizes extensive previously published materials on Penticton Creek watershed conditions, as well as ground inspections.

In determining natural biological, physical and chemical hazards within the assessment area, historic, current and potential future conditions were taken into account. All potential hazards identified during the watershed characterization step were then summarized in a hazard identification summary. The definition of hazards provided by the CCME (2004) has been adopted: “a source of potential harm to the functioning of any aspect of the drinking water system or to human health” (CCME, 2004).

3.3 Source Assessment Area

The source area supplies water to the drinking water system. Activities and conditions in this area determine the quality and amount of water being supplied to the intake. Penticton Creek is a tributary to Okanagan Lake that enters from the east side of the Okanagan Valley through the City of Penticton. The Penticton Creek watershed source water area is 175km^2 (Map – Appendix A).

Several small lakes and wetlands exist in the watershed, mostly at higher elevations; including Reed Lake at the headwaters of Reed Creek, Howard Lake at the headwaters of James Creek, and a chain of small lakes at the headwaters of Corporation Creek (Photo 17 – Appendix B). Some of these small lakes have been dammed and used as reservoirs in the past.

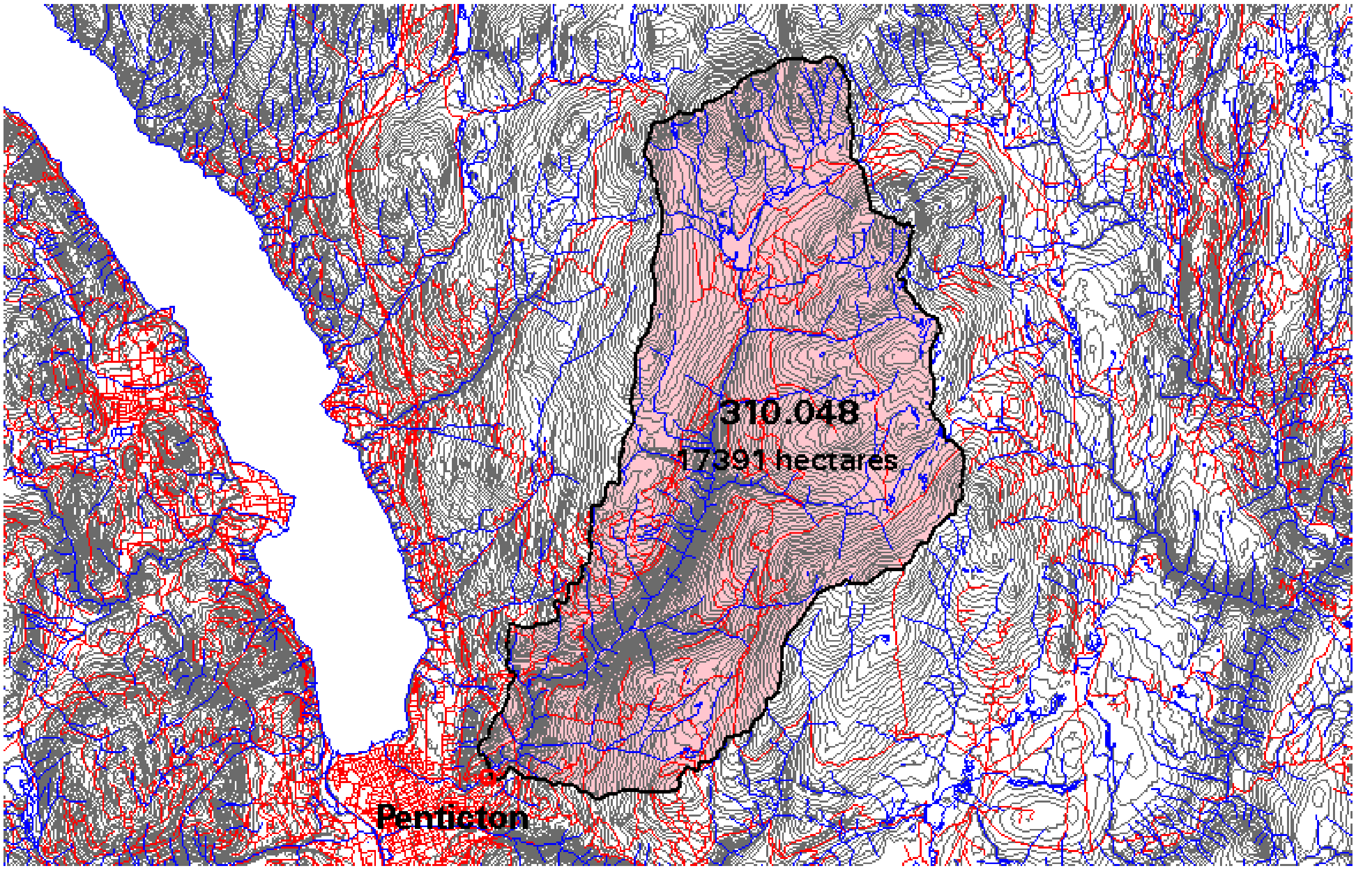
The assessment area for the Penticton Creek Source Assessment Report includes the area defined as the contributing watershed upstream of the water intake as well as an area within 100m radius intake protection zone surrounding the intake. The assessment area was selected to include the entire contributing watershed and the intake protection zone, as recommended by the Guideline (Map – Appendix A).

The Penticton Creek watershed can be partitioned into three parts, the buffered area upstream of the Greyback Reservoir where runoff quality downstream is buffered by the reservoir. Since the water stored in the reservoir has a “long” residence time, it can eliminate sediment and most turbidity from the inflow. The second area is the “partially buffered” section which is the area downstream of the Greyback Reservoir to the Campbell Mountain Diversion. The diversion intake pond has the ability to remove coarse sediment and some of the finer grained sediment, but the residence time in the pond is too short to reduce turbidity. The last area is that portion of the watershed that drains into the mainstem creek downstream of the Campbell Mountain Diversion, an upstream of the intake that has no buffering. The intake has no buffering from the sediment/turbidity in the runoff that flows into this last reach of the creek.

3.4 Characterization of the Watershed

The Penticton Creek watershed is a designated Community Watershed (Figure 2). The total watershed area is 194km^2 (175km^2 above the intake) ranging in elevation from 342m at the confluence with Okanagan Lake to 2,154m at the summit of Greyback Mountain. The primary source of runoff is the upper 40% of the watershed (the watershed above the 1,660m elevation) that is also known as the snow sensitive zone where the majority of the runoff is derived (see Map – Appendix A).

Figure 2: Penticton Community Watershed, Ministry of Environment, Water Stewardship Division, Community Watershed



Source: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/comm_watersheds/images/310_048.gif

3.4.1 History of the Watershed

Penticton Creek has been used as a water source since early settlement in the area. The earliest water licence issued to the City is dated 1892. Numerous control structures have been built and decommissioned over the years, and gauged stream flows represent regulated flows. No recent natural hydrograph data exist for the entire watershed.

Penticton Creek originates at Greyback Mountain approximately 19km northeast of Penticton. The major sub-basins to Penticton Creek referred to in this report include Upper Greyback, Dennis Creek, Municipal Creek, Harris Creek and Steward Creek (Map – Appendix A). There is also a residual area referred to as Penticton Creek Residual above Intake that includes the balance of the watershed not in any sub-basin.

Many human activities take place in the watershed. They include industrial/resource road use, forest development, range use, and continually growing recreational activities.

3.4.2 Water Licences and Requirements

The City holds seven water licences on Penticton Creek with the earliest licence dated September 1, 1892. The City is licensed to divert 6,704ML for domestic use (Waterworks Local Authority) and 5,415ML for irrigation annually. This demand is supported by 12,643ML of storage.

In recent years the actual demand from Penticton Creek has been substantially less than the available licensed volume. The large storage capacity of the Greyback Reservoir and the irrigation water availability from Ellis Creek are more than adequate to meet the foreseeable demand (EarthTech, 2005).

Total daily City allotted capacity for irrigation from Penticton Creek is calculated to be 46.26ML/d. Peak day for Penticton Creek irrigation system usually occurs in August. Total irrigation demand from Penticton Creek in 2011 was 2,755ML.

3.4.3 Climate

Climate influences both the quantity and quality of the source water in the Penticton Creek watershed. The climate in the watershed area is warm to hot in the summer and mild in the winter.

The Environment Canada climate normals for the Penticton A* weather station (ID 1126150) have average temperature in the valley bottom in July and August around 20^0C, and December and January around -10^0C. The total annual precipitation for the region ranges from approximately 250 mm in the valley bottom, with 29% occurring as snow, to 700mm at 1,250m where 53% occurs as snow (Dobson 1998). High precipitation events cause increased runoff and erosion, and have lead to landslides in the past.

Peak flows during the spring freshet can lead to increased bed load transport and bank erosion in the stream channel (Photo 19 – Appendix B) with a significant increase in turbidity at the intake. This is typical for most surface water supplies in the Okanagan.

3.4.4 Geology, Geomorphology and Terrain

The Penticton Creek watershed is located in the Okanagan Highlands region of the Interior Plateau. The watershed is elongated with rolling topography in the headwater areas and a steep walled valley along much of the mainstem channel.

Streams on the plateau have low drainage density due to the relatively gentle terrain, well-drained soils and dry climate. This upper section of the watershed is dominated by a rolling, flat (<7%) to gentle (7 to 30%) sloping, glaciated upland plateau between 1,300m and 1,800m elevation.

A steep walled valley is incised into the plateau along the mainstem channel below about 1,300m elevation, as Penticton Creek descends from the upland plateau to Okanagan Lake. The valley sidewalls are frequently gullied, with steep slopes ranging from 60% to 100%. Much of these lower valley walls appear to be incised into bedrock; however, there are several large landslides in thick unconsolidated material that have contributed sediment to the mainstem in the past, and continue to do so (Grainger and Streamworks, 2010).

Grainger and Streamworks, 2010, preformed a review of 1938, 1970 and 2007 air photos which show a group of three debris slides initiating at the slope break from the plateau to the steeper Penticton Creek escarpment. The landslides, located in the upper west mainstem escarpment, would have delivered large amounts of sediment into Penticton Creek, resulting in downstream channel aggradation. They have also likely continued to periodically deliver sediment into the creek over the 70 years since the first one was recorded. The relatively few, but large and persistent landslides observed in unconsolidated sediments on upper escarpment slopes are an indication that these are areas more sensitive to disturbance, and they have probably contributed significant sediment to streams, influencing channel morphology.

Bedrock types in the watershed include granite, gneiss and schist. Soils are derived from sandy glacial moraines and some finer grained glaciolacustrine deposits. Soil horizons are generally low in clay and high in coarse fragments, leading to low water holding capacity and well-drained surface soils (Winkler 2006). Small areas in the upper region of the watershed contain soils derived from volcanic ash (Dobson 2001).

In the gently-sloping upland areas, most sediment is generated from channel bed and bank erosion during high flows. In lower more deeply incised reaches, sediment from natural or development-related valley wall slope failures can introduce significant sediment to the channel where it can be transported downstream, eventually to the water intake and other downstream elements. Overall, however, Penticton Creek and its lower tributaries are predominantly incised into bedrock which is relatively resistant to erosion.

3.4.5 Vegetation

The biogeoclimatic (BEC) stand types in the watershed include Ponderosa Pine (PP), Interior Douglas Fir (IDF), Montane Spruce (MS) and Engelmann Spruce Sub-alpine Fir (ESSF).

3.4.6 Fish and Wildlife

There are fish present and high habitat values along much of the Penticton Creek mainstem and some tributaries. In general, fish habitat is widespread through the watershed, mostly due to the presence of lakes at the headwaters of streams. Penticton Creek is a fish-bearing stream with brook and rainbow trout, kokanee and longnose dace.

The area provides important habitat for many wildlife species. The watershed contains a diversity of habitats for a number of wildlife species and healthy populations of deer and elk are present in the watershed.

3.4.7 Hydrology

Penticton Creek is a snow-dominated hydrologic system with peak flows occurring from late April to mid-June. The following ten hydrometric stations were located in the Penticton Creek watershed 08NM168, 08NM076, 08NM118, 08NM031, 08NM170, 08NM063, 08NM032, 08NM 240, 08NM214 and 08NM242. Currently only stations 08NM241 and 08NM242 are active. There were seven snow courses and three water quality stations established in the watershed by the Research Program at the Kamloops Forest Region as part of the Upper Penticton Creek Watershed Experiment. Currently there are four active snow courses.

The Upper Penticton Creek Watershed Experiment was established in 1984 by the Ministry of Forests and one of the few that is still active. The project is currently a collaborative project led by the BC Government with support from Environment Canada, FORREX, Gorman Brothers Lumber Co. Ltd., the Okanagan Basin Water Board, the Okanagan Nation Alliance, Simon Fraser University, Thompson Rivers University, University of British Columbia, University of Lethbridge, University of Saskatchewan, and Weyerhaeuser Ltd. Early research focused on seasonal and annual water yield. Study topics now include the water balance, nutrient transport, forest-snow interactions, water quality, aquatic ecology, channel morphology, groundwater, and the effects of climate change on water supplies. Research approaches include stand-scale field projects, assessment of watershed responses, and hydrologic modeling. For further information refer to http://www.for.gov.bc.ca/rsi/research/penticton/index.htm.

The typical runoff for the watershed can be illustrated using the Water Survey of Canada station Penticton Creek below Harris Creek (08NM170) for the mainstem flows and Two Forty One Creek near Penticton (08NM249) for the headwater runoff. The typical annual hydrographs for each station are presented in Figure 3 and Figure 4.

Although the annual peak flow typically occurs between April and June, intense summer and fall rainstorms can cause increased steam flows. However, the magnitude of the rain-generated stream flow events are less than the annual snowmelt-related peak flow events. For snowmelt dominated watersheds such as Penticton Creek, it is largely the upper portion of the watershed that produces peak flows during the spring freshet melt (Photo 25 – Appendix B).

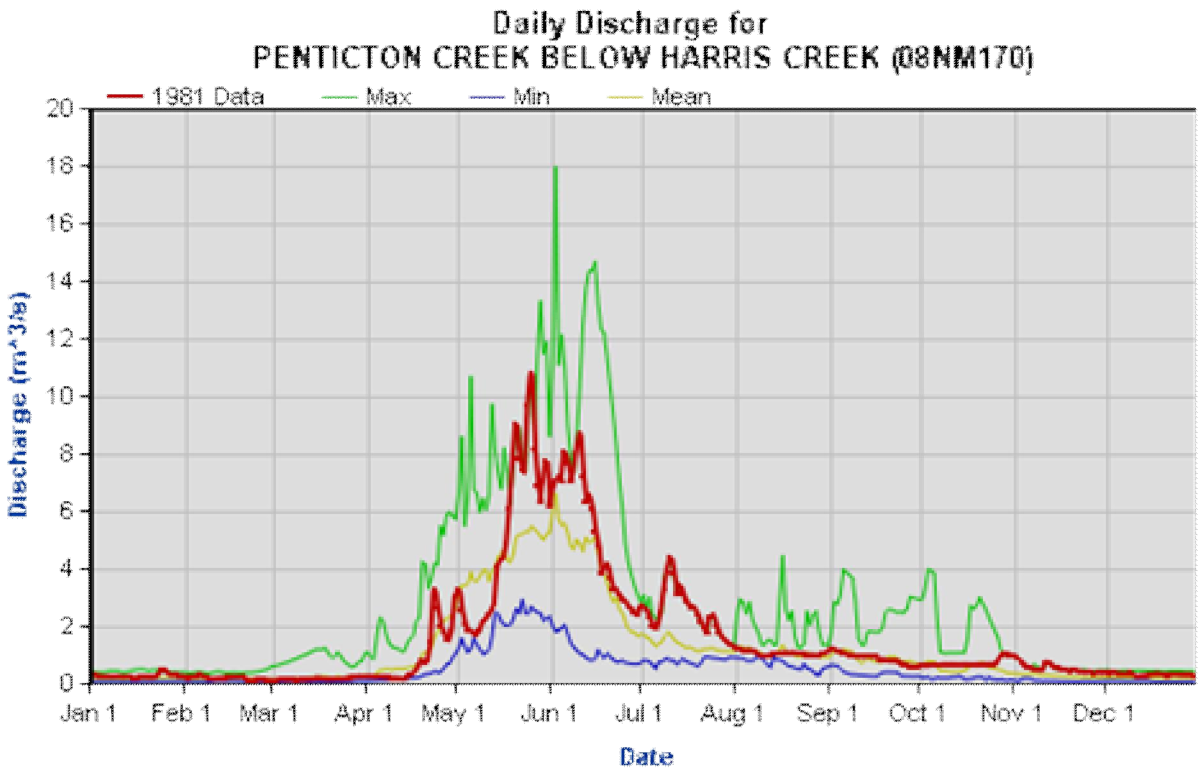
The hydrologic effect of the upland reservoirs such as Greyback Reservoir is to desynchronize the runoff and peak flows through storage. Depending on the volume and timing of runoff into the reservoirs, peak flows will vary downstream. For example, peaks may be reduced or eliminated during low runoff years but may be unaffected during high runoff years. There is no evidence for Interior snowmelt dominated hydrologic regimes that logging decreases water quantity (Pike and Scherer, 2003).

In the 90s research was undertaken in the Okanagan to determine the elevation of the snowline when the flows in streams such as Penticton Creek peaked in the spring (Dobson 2004). Based on this research the snow sensitive zone for the Penticton Creek watershed is the watershed above the 1,660 m elevation.

As indicated in section 2.6 there have been a number of hydrologic assessments completed for the watershed over the years, Dobson (2006, 2004, 1998), Grainger et al (2010), Winkler (2006), Winkler et al (2010). When the watershed assessment was completed in 1998 that watershed was partitioned into the following five sub-basins and a residual area; Upper Greyback, Dennis Creek, Municipal Creek, Harris Creek and Steward Creek with the remainder of the watershed included in the Penticton Creek Residual above Intake (refer to Map – Appendix A). Each of the sub-basins and the residual area are characterized in the following sections.

Figure 3: Penticton Creek below Harris Creek (08NM170)

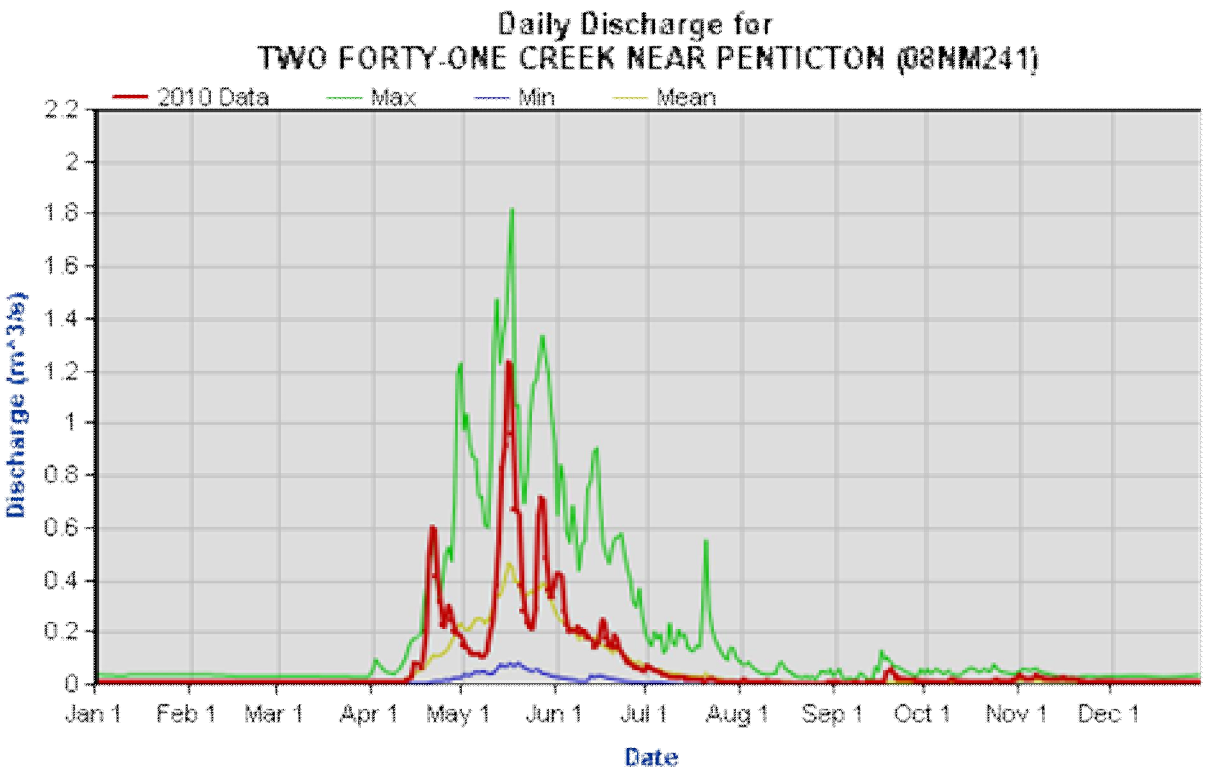
Mean daily discharges based on data from1970 to 1981



*Statistics corresponding to 12 years of data recorded from 1970 to 1981.**

Figure 4: Two Forty One Creek near Penticton (08NM249)

Mean daily discharges based on data from 1983 to 2010



*Statistics corresponding to 28 years of data recorded from 1983 to 2010.**

Upper Greyback Sub-basin

The Upper Greyback sub-basin that includes Corporation Creek, Corporation Lake, (Photo 14 – Appendix B) Creek, and 241 Creek has an area of ~30km^2. It is the largest sub-basin in the watershed. 240 Creek and 241 Creek are two of the research watersheds for the Upper Penticton Creek Watershed Experiment (Photo 15 – Appendix B). This is an upper plateau sub-basin with rolling terrain and mountain ridges. Many of the channels in this sub-basin that drain the upper plateau area are relatively small, with intermittent low gradient and low stream power watercourses flowing through relatively coarse bed materials (Photo 16-Appendix B). Flows are small and intermittent and also flow through occasional wetlands. Greyback Reservoir, the largest reservoir in the watershed, captures and stores much of the upstream runoff each spring thereby attenuating downstream peak flows. The reservoir also provides an opportunity for any suspended sediment to settle reducing potential water quality impacts. Channel sensitivity in the channels draining into Greyback Reservoir is considered to be low. Logging has been focused in the eastern portion of the sub-basin including in 241 Creek. 240 Creek has been reserved as a control watershed with no logging to date (Photo 29 – Appendix B). Also, the area to the west of 240 Creek including Corporation Creek have not been logged yet but there are blocks proposed in this area.

Dennis Creek Sub-basin

Dennis Creek is a 9.8km^2 sub-basin located to the southeast of Greyback Reservoir. This sub-basin was also part of the Upper Penticton Creek Watershed Experiment. Unfortunately, as a result of a severe spruce bark beetle outbreak in the watershed, it was decided to harvest most of the mature spruce to try to control the spread of the beetle. This resulted in very high cut levels and as a result the sub-basin was eventually dropped from the research project. All cutblocks have been reforested and non-essential roads deactivated. Peak flows increased significantly as a result of the logging and the channel increased its cross-section through erosion to accommodate the increased peak flows. Since the soils in the area are typical of those on the upper plateau being a cobble boulder glacial till, the channels are very robust due to boulder/cobble bed and banks and therefore stabilized quickly. The channel is rated as stable (Photo 20 – Appendix B).

Municipal Creek Sub-basin

Municipal Creek is a ~28km^2 third order sub-basin that flows ~9km west into Penticton Creek, entering approximately 7 km downstream of the Greyback Reservoir (Photo 32 – Appendix B). This is the second largest sub-basin and contributes the most unregulated runoff. There are three main sections to the Municipal Creek mainstream channel. The upper third is a series of cascade-pool reaches separated by low gradient wetland areas. Harvesting has been fairly extensive in the upper basin, however riparian areas have been mostly left undisturbed. The middle area is a section of channel covered in grassy banks, moss-covered bed material and woody debris, and the lower reach has a partially degraded channel morphology (Photos 5 and 6 – Appendix B).

Three landslides in Municipal Creek have been documented as the channel becomes more incised where it steepens toward Penticton Creek (Dobson 1998). The channel morphology changes to boulder steps in the lower steeper section.

The channel sensitivity in Municipal Creek is moderately sensitive to increased peak flow, and increased sediment delivery. Combined channel sensitivity is moderate due to increased flows which have the potential to increase bank erosion and sediment loading (Grainger and Streamworks, 2010).

Harris Creek Sub-basin

Harris Creek is a ~14km^2 sub-basin that flows west into the mainstem approximately 7km upstream from the intake. This is a mid/low elevation sub-basin with only a small portion in the snow sensitive zone. Water yields are much lower in Harris Creek than in Municipal Creek. The lower third of the sub-basin has burned. Channels are rated as stable (Photo 7 – Appendix B).

Stewart Creek Sub-basin

Stewart Creek is a ~16km^2 sub-basin located on the east side of the mainstem approximately 1.25km upstream of the intake. The peat mining operation is located in the Stewart Creek headwaters. This is a low elevation sub-basin with low water yields and runoff (Photo 11 – Appendix B). The lower third of this sub-basin has also been burned. Channels are stable.

Penticton Creek Residual Above Intake

The residual area above the intake is ~78km^2 or approximately 44% of the watershed area and includes the James Creek (Photo 4 – Appendix B) and Reed Creek (Photo 33 – Appendix B) catchments on the east side of the watershed as well as all the small catchments on the west side of the mainstem below Greyback Reservoir. The mainstem channel of Penticton Creek extends ~19km from the City water intake to the Greyback dam. The majority of the mainstem is confined in a deep canyon with canyon walls that extend up to 500m up from the creek. Minimal development has occurred along this section of the creek due the steep terrain. The residual area is all below the snow sensitive zone, so water yields within the area are typically low; however, there are unregulated flows into the mainstem from all of the sub-basins below Greyback Reservoir and regulated (plus freshet spill) from the reservoir.

The mainstem channel below Greyback Reservoir becomes increasingly incised as it flows south. The channel is mostly stable with coarse substrates and bedload with bedrock controls. The valley walls become increasingly higher with exposed bedrock canyon walls. Numerous gullies have formed, with some raveling of coarse material into the channel. Although the channel is mostly confined, there is some fluvial floodplain in the valley bottom providing some buffering from the canyon wall sediment sources. There is evidence of old landslides which have impacted the channel. The mainstem of Penticton Creek is considered to be in a dynamically stable condition. This means that it has an active bed load component that can be mobilized during spring freshet. This is evident from the amount of sediment that accumulates in the Campbell Mountain diversion pond and the main intake pond downstream. Overall, Penticton Creek has a stable channel with boulder bed materials and a mature riparian forest. The primary disturbance to the mainstem channel had been with the construction of the two dams, which has altered natural stream flows and sediment transport.

3.4.8 Wildfires

In 1970, a major forest fire burned 1,620 hectares in the middle portion of the drainage, on the south side of Penticton Creek. As a result, the City's water quality was adversely impacted for four years after the burn (personal communication: B. Muir) (Dobson, 1991). In 1994, a second wildfire known as the Garnet Fire burned approximately 5,500 hectares. Concerns have been raised about increased risks of wildfires in the watershed where there is MPB mortality that increases the fuel load. In the Penticton Creek watershed the pine beetle infestation is limited. Refer also to the mountain pine beetle section.

3.4.9 Mountain Pine Beetle

Mountain pine beetle infestations affect watershed hydrological processes through the loss of forest canopy and decreased evapotranspiration when the pine beetle kills pine trees in a stand. This can alter the water balance by: increasing water yields as a result of decreased evapotranspiration and increased rain and snow reaching the ground; increased soil moisture and hillslope flow; changes in site level energy balances leading to earlier onset of spring snowmelt; more rapid streamflow response to storms; increased total stream flow; and increased magnitude and frequency of peak flows (Winkler et al. 2008). Watershed elements potentially at risk from the hydrological effects of MBP include water quality, water quantity and fish populations and habitat.

Grainger and Streamworks (2010) concluded that there is little evidence of links between MPB effects and the water quality parameters of total organic carbon, true colour, metals and total phosphorous, and measurable change in these parameters in Penticton Creek are not expected. Reservoir storage may mitigate MPB related freshet timing change effects on reservoir withdrawal timing. The partial risk analysis for water quality at the water intake completed by Grainger and Streamworks estimates a moderate risk to the water quality at the intake under MPB-related pine mortality.

3.4.10 Climate Change

A decrease in water yield of 15% by 2050 and 30% by 2080 is predicted in Penticton Creek. (EarthTech and Aqua Consultants 2005). There is also expected to be a decrease in freshet peak flows as more precipitation falls as rain in the winter and less is stored snow. Throughout the Okanagan, studies of recent past and expected future climate change effects suggest there will be impacts to the City's water demand, supply and timing of runoff. It is estimated climate change related increased temperature and dryness during the growing season will increase water use for agriculture and residential irrigation in the Okanagan. Higher temperatures will also result in earlier snowmelt that may affect the demands on storage. The magnitude of the combined effects of climate change related decreased water availability, increased demand, and earlier storage depletion, are not known at this time.

3.5 Penticton Creek Water Intake

The Penticton Creek water intake is located at the end of Penticton Avenue on the east side of the city (Photo 2 – Appendix B). The reservoir is accessed off of Adams Crescent. Large debris is typically trapped in the intake pond before the water is diverted into the treatment plant. Penticton Creek water is delivered to the treatment plant by gravity from the intake pond. Okanagan Lake water is pumped to the treatment plant from the lakeshore pump station. The advanced water treatment system uses coagulation, flocculation and filtration to treat the raw water.

3.5.1 Infrastructure

The City has a robust intake that consists of a concrete dam and intake pond. Coarse bedload settles out as the flow enters the pond and wood debris is contained by a log boom. The intake works and pond are protected from unauthorized access by a security fence. The City excavates the accumulated sediment out of the pond on an as-required basis and collects and removes wood debris from the boom. It was determined that there has been increasing scour on the channel below the spillway. The City is undertaking repairs to the channel in 2012 and 2013.

3.5.2 Vulnerability

The intake pond was designed as an instream pond with a spillway over the dam that permits excess flows to safely pass through. Typically, this type of design is vulnerable to extreme events that result in high sediment delivery. For this intake it is somewhat less vulnerable since it is afforded a degree of protection by the Campbell Mountain diversion upstream that collects most of the sediment and debris.

3.5.3 Backup Water Source

The City is fortunate to have two back up sources: Okanagan Lake and the Warren Avenue Well. The intake on Okanagan Lake has the capacity to meet the normal demands. The well has a limited supply that on its own would meet reduced demands only.

3.6 Hazards to Drinking Water Quality and Quantity

3.6.1 Surface Water Quality

Water quality parameters and monitoring results in Penticton Creek are discussed in MoE (2008), EarthTech (2005) and Giles (2006). Penticton Creek source waters have elevated microbiological indicator levels, with elevated fecal coliform and E.coli values from June to August (MOE, 2008). In 2011, raw water quality at the water treatment plant showed that fecal coliform counts ranged from 0 – 2419CFU/100mL and E.coli counts ranged from 0 – 16.4CFU/100mL (100 samples). The results suggest that elevated concentrations of microbiological indicators are present in Penticton Creek source waters. True colour levels are seasonally elevated in Penticton Creek source waters as well (EarthTech, 2005).

The City has a comprehensive water quality monitoring program in place. In the latest annual report for 2011 it reported maximum turbidities in the creek ranging from 5.7 to 8.4NTU. It is understood that during periods of elevated turbidity, typically during the spring freshet, that the City will switch to the lake source from the creek as required. (http://www.penticton.ca/assets/City~Hall/Documents/2011%20Year%20End%20Water%20Report.pdf).

3.6.2 Surface Water Quantity

The City has sufficient water to meet the demands from Penticton Creek. The effects of changing climate is not well known; however, it is estimated that water yields could decrease by 30% by 2080 (Earth Tech and Aqua Consultants 2005).

3.6.3 Potential Hazard Identification Summary

Based on the review of previously published materials, and the description and characterization of the source area, the potential historical, current and future hazards that could likely occur in the watershed are listed below. They are grouped into potential physical, biological and chemical hazards.

Potential Physical Hazards

- Increased sediment loads from:
  - natural sources
    - peak flows
    - landslides
    - disturbance in snow sensitive portions of the watershed
  - anthropogenic sources (Module 2)

  - industrial/resource roads
  - forest development
  - range use
  - recreational activities

- Water quantity:
  - licenced amount (domestic and irrigation)
  - increased peak flow timing
  - climate change
    - reduced/loss of supply
- Wildfires
- Mountain Pine Beetle

Potential Biological Hazards

- Bacteriological contamination from:
  - wildlife
  - cattle
  - humans
- Protozoa including Giardia and Cryptosporidium
- Viruses

Potential Chemical Hazards

- Total Organic Carbon (TOC)
- Petroleum contamination
- Wildfire

4.0 Contaminant Source Inventory (Module 2)

4.1 Objectives

A contaminant source inventory involves identifying and describing contaminant sources identified through field assessments. Because the emphasis of the source-to-tap assessment is on public health, particular attention is paid to microbiological contaminants or hazards that have immediate acute effects on health. This section provides the following information.

- A brief description of each land use, activity or facility
- Possible contaminants of concern and contaminant transport mechanisms
- Discussion of factors influencing susceptibility and magnitude of contamination
- Any additional comments, such as management practices or other observation
- A Hazard Identification Table

4.2 Methodology

The contaminant source inventory was conducted for the entire assessment area as defined in Section 3. It was completed through a review of relevant maps, reports and scientific literature, a watershed field investigation of land use and related drinking water contaminants.

The Hazard Summary (section 3.6) identified potential historical, current and natural hazards within the assessment area separated in the three categories, physical, biological and chemical.

4.3 Contaminant Source Inventory

4.3.1 Natural Processes

The natural processes occurring in Penticton Creek have been characterized in detail in Module 1. The watershed is basically stable but natural processes do have the potential to impact the City's drinking water. Sediment delivery is a commonly occurring process in the watershed as a result of stream bank erosion and the occasional landslides. Field observations and the review of orthophotos noted a number of eroding stream banks that are currently contributing sediment. Higher than normal peak flows, caused by deep snow packs and rain-on-snow events contribute to the erosion processes.

Overall, in terms of impacts on the quality of drinking water, the current natural sediment yields are considered a low hazard. Episodic events, such as large-scale avulsions and slope failures may occur but are uncommon.

The area provides important habitat for many wildlife species. The watershed contains a diversity of habitats for a number of wildlife species and healthy populations of deer and elk are present in the watershed. Wildlife can be a source of Giardia, and Cryptosporidium as well as fecal coliform.

4.3.2 Industrial and Resource Roads

Risks from roads and road-related “gentle-over-steep” landslides on the Penticton Creek fan are considered moderate following the unharvested MPB scenario studied by Grainger and Streamworks. A sample of cutblocks and forest roads throughout the watershed were inspected in the fall of 2012. There were no slope failures noted within the areas inspected. Roads assessed were generally found to be in good conditions and not connected to streams. However it was noted on inactive roads that sediment delivery on the running surface was a concern near stream crossings as a result of a lack of waterbars to disperse runoff (Photo 36 – Appendix B).

Ground disturbance from roads and skid trails can lead to soil compaction, reduced infiltration, shallow groundwater interception in road cuts, and redirection of intercepted water to streams. These processes can increase the “flashiness” of watershed response to rain and snowmelt, and contribute to elevated peak flows. Grainger and Streamworks, 2010 commented that in their experience with ground and road disturbance in the mostly well drained coarse textured soils found in the region, the effects of “flashiness” of watershed response is relatively small with the current forest harvest and road drainage practice.

Only one road crossing of Penticton Creek exists between the intake and Greyback Reservoir. This is the Greyback FSR crossing near the Dennis Creek confluence, approximately 1km downstream of the Greyback dam. The GIS analysis determined that there were in excess of 140 road/stream insects noted in the watershed, that is, sites where roads cross a stream (Map – Appendix A). Many of these sites are on old inactive, deactivated roads where the crossing has likely been removed. However, they are all potential hazards with regards to delivery points for sediment. During the fieldwork a selection of active and inactive roads were inspected. It was determined that drainage management on active roads was generally good with limited instances where there was active sediment delivery to streams (Photo 35 – Appendix B). On deactivated roads where the stream crossings had been removed the sites were generally stable (Photo 27 and 28 – Appendix B). Recreation use was common with vehicles driving through streams where crossings were removed resulting in sediment delivery to the streams. There are many old trails and roads that are overgrown and no longer accessible to vehicles. On these roads sediment delivery was minimal. The section of lower Penticton Creek on the west side has been an area of concern over the years particularly along the lower Greyback FSR. The roads in this area were deactivated in the 90s resulting in very limited use. Although this area was not inspected on the ground, it is understood that there are few concerns now particularly in those areas recovering after the 1994 wildfire.

As indicated previously there are concerns on some of the inactive roads where it was noted that there sediment delivery down the running surface on the grades approaching stream crossings. The roads had been temporarily deactivated using waterbars but frequently the spacing of the waterbars near stream crossings was too far resulting in chronic sediment delivery to streams during spring runoff and rainstorms.

4.3.3 Forest Development

Loss of forest cover changes the watershed hydrology. In the Penticton Creek watershed, where peak flows are generally the result of spring snowmelt, the equivalent clear-cut area (ECA) is used as an indicator of peak flow hazards. Calculations of ECA on a sub-basin level are included in the tables below. Grainger and Streamworks, 2010 completed an analysis of Mountain Pine Beetle (MPB) and salvage harvesting-related risks to water quality, water supply, fish habitat and infrastructure in the Penticton Creek Community Watershed. They found that the current equivalent clear-cut area for Penticton Creek is low.

The majority of forest development in the Penticton Creek watershed has taken place since the early 1970s. Recent harvesting activities in the watershed have focused on the control of the Spruce Bark Beetle and the Mountain Pine Beetle infestations. Clear cutting has been the dominant silviculture system. Weyerhaeuser Ltd. (Forest License A18674) and British Columbia Timber Sales (BCTS) are currently operating in the watershed. The current ECAs for the watershed are summarized in Table 1.

Table 1: Equivalent Clear-cut Areas for Penticton Creek Watershed to December 31, 2012

Basin	*Gross Area (ha)*	*Total Harvested Area Ha %*	*ECA ha %*	*ECA below Snowline ha %*	*Area Above Snowline ha*	*ECA Above Snowline ha %*
Upper Grayback	2,986.3	616.8 20.7	542.7 18.2	144.4 15.0	2,020.5	398.3 19.7
Dennis Creek	984.0	595.5 60.5	379.5 38.6	36.3 16.0	756.2	343.2 45.4
Municipal Creek	2,775.1	722.6 26.0	568.3 20.5	18.8 2.5	2,018.9	549.6 27.2
Harris Creek	1,370.6	367.7 26.8	0.5 0.0	0.5 0.0	352.8	0.0 0.0
Steward Creek	1,582.1	142.7 9.0	99.1 6.3	95.2 6.2	50.1	3.8 7.6
Penticton Creek Residual Above Intake	7,788.0	1,574.2 20.2	937.4 12.0	533.2 9.3	2,071.4	404.2 19.5
Penticton Creek Watershed Above Intake	17,486.2	4,019.4 23.0	2,527.5 14.5	828.4 8.1	7,269.9	1,699.1 23.4

The ECAs levels for all sub-basins and the entire watershed are <30% except in Dennis Creek that is ~39% overall and ~45% above the snowline. The peak flow hazard is rated as low for all sub-basins and for the watershed except in Dennis Creek where it is high for the zone above the snowline and moderate overall. Peak flow hazard is the potential or likelihood that a sub-basin will have increased peak flows following changes in forest cover.

The Upper Penticton Creek Watershed Experiment Area

The 240 Creek, 241 Creek and Dennis Creek sub-basins have been monitored as part of a long-term hydrology study into the effects of forest harvesting on water resources. The Upper Penticton Creek Watershed Experiment is located on the Okanagan Plateau approximately 21km upstream of the intake. Each watershed covers approximately 5km^2 and the area extends from 1,600 to 2,100 meters in elevation. The study was initiated in 1984 and is ongoing. The three sub-basins were monitored and the snowpack and runoff in logged sub-basins compared to those in a control (unlogged) sub-basin. Four snow courses are still active as part of the research project. Water quality in the study streams is generally good, however increases in concentrations of nitrogen and phosphorus, as well as fecal coliform, have been observed as the logging has increased. The water in all three creeks is highly coloured during peak flow events. Elevated suspended sediment concentrations are observed in spring and during fall rains. At no time have sediment concentrations exceeded 20mg/L of water and most were lower than 5mg/L (Winkler 2006). Although water quality in all study streams is generally good, statistically significant changes have been observed as the logging has increased, particularly in Dennis Creek where more than 50% of the watershed area has been harvested. A decline in turbidity following the final logging indicates that sediment delivery to streams observed during the first season following logging subsequently decreases. While increased turbidity and sediment levels in study streams appear to be associated with logging operations, the effect is short lived (2 to 3 years post-logging) in the low gradient, sediment-supply limited channels found in the study area (Giles 2008).

4.3.4 Range Use

There is one active grazing licence in the watershed (RAN077332) with a total of 1,133 animal unit months of use. Cattle often follow road systems as they move from cutblock to cutblock (Photo 34 – Appendix B). Disturbance was noted along streams near road crossings where cattle would access the stream. Depending on the site conditions and forage cattle would use some these areas more intensively resulting in trampled streambanks increasing sediment delivery, and also increased fecal material near the stream.

4.3.5 Peat Extraction

There is one parcel of private land upstream of the intake, Plan 1189, DL 2710, SL 8 SDYD located in the Steward Creek sub-basin (Map – Appendix A). This is the site of the peat mining operation. Peat mining has the potential to contribute nutrients, heavy metals, dissolved organic carbon and sediments to the watershed. It was noted during the field inspections that there was an elevated fine sediment load in Steward Creek downstream from the peat operation (Photo 12 – Appendix B). It is not known what the source of the sediment was.

4.3.6 Recreational Activities

The Penticton Creek watershed has considerable recreational use. The area is used by local residents for off-road vehicle use, snowmobiling, fishing, hunting, hiking and mountain biking trails, cross country skiing and snowshoeing. Recreational use in the watershed can result in increased sediment delivery off deactivated and inactive roads, increased refuse, increased risk of the introduction of pathogens, and fecal coliforms from humans and dogs and increased wildfire risks. Sediment delivery from ATV use was noted and can be expected to increase particularly at location where they traverse streams or wetland areas. With continued expansion of resource road network throughout the watershed, there will be increased opportunities for unauthorized access into environmentally sensitive areas by off-road vehicles.

During the field investigation, broken and vandalized gates were observed. Pat Farkas from Weyerhaeuser reported that the vandalism is continuous. The gates are either cut off or cut up; the locks are taken off with bolt cutters; or shot off with high powered rifles. The worst vandalism occurs at the Ellis and Municipal gates on a continuous basis.

4.3.7 Wildfire

Wildfires destroy the forest cover and expose soils. The changes to the hydrology of the burned areas can result in degraded water quality due to increased sediment loads and the release of nutrients and heavy metals. There have been two significant wildfires in the watershed over the past few decades that burned much of the lower to mid –elevation stands. A major forest fire in 1970 burned approximately 1,620 hectares in the middle portion of the drainage, on the south side of Penticton Creek. In 1994 a second wildfire known as the Garnet Fire burned approximately 5,500 hectares on the south on north sides of the watershed. Wildfires are a concern but due to the past fires that removed much of the fuel loads in the burned areas near the forest interface and the logging of mature pine stands infested with pine beetle and spruce bark beetle, the current hazard is limited.

4.3.8 Contaminant Source Inventory Table

The results of the contaminant source assessment have been summarized in the Contaminant Source Inventory Table (Table 2). The table lists the following:

- types of contaminant sources within the assessment area;
- nature of contaminants that have been or potentially could be released;
- location of contaminant sources within the assessment area; and
- contaminant transport mechanisms.

Table 2: Contaminant Source Inventory Table

Source of Contamination and Description	Licensee/ Jurisdiction	Location	Distance to the Source	Possible Contaminants of Concern	Contaminant Transport Mechanism
Natural Processes	City of Penticton	Throughout Crown land upstream of intake	Varies	Sediment, fecal coliforms	Runoff
Industrial and Resource Roads	Weyerhaeuser Ltd., BCTS/MFLNRO	Throughout Crown land upstream of intake	Varies	Sediment, total organic carbon, organic acids	Runoff
Forest Development	Weyerhaeuser Ltd., BCTS/MFLNRO	Forest License areas	Varies	Sediment, total organic carbon, organic acids	Runoff
Range Use	Grazing Licensee/ MFLNRO	Grazing Lease	Varies	Fecal coliforms, Sediment, total organic carbon, organic acids	Runoff
Peat Extraction	Lease holder/ MoM	Peat Lease	6 Km	Nutrients, heavy metals, dissolved organic carbon, and sediments	Runoff
Recreational activities	MJTS	Throughout Crown land upstream of intake	Varies	Sediment, fecal coliforms, viruses	Runoff
Wildfire	Weyerhaeuser Ltd., BCTS/ MFLNRO	Forest license area upstream of intake	Varies	Increased sediment load, phosphates, nitrates, fire retardants and metal mobility	Runoff

4.4 Source Hazards to Drinking Water Quality and Quantity

Identification of the source hazards is the key to development of the source protection plan for the watershed. The hazards identified in Module 1 in the Hazard Summary provide the basis for the contaminant inventory fieldwork undertaken in Module 2. The hazards are confirmed, additional hazards added and details summarized regarding the location, extent and severity of the hazard in the source area and the vulnerability of the drinking water.

The hazards to drinking water quality in the watershed are, elevated turbidity and sediment loads due to both natural causes and from industrial activities in the watershed (typically during the spring runoff period) and; fecal coliform and E coli bacteria associated with wildlife, cattle, and humans. The activities in the watershed area include industrial and resource road use, forest development, range use, peat mining, and recreation. Based on these activities and contaminant sources listed from natural process, the identified hazards to drinking water in the watershed are summarized below grouped into physical, biological and chemical hazard groups.

4.4.1 Physical Hazards

Sedimentation from natural sources

The current natural sediment yields from natural sources are considered a low hazard. Episodic events, such as large-scale avulsions and slope failures may occur but are uncommon. Suspended sediment compromises the disinfection process and exceeds the turbidity in raw water affecting the threshold of 1NTU in treated water. Increased sedimentation is a risk to human health.

Sedimentation from industrial/resource roads and road crossings

Some of the inactive roads where it was noted that there sediment delivery down the running surface on the grades approaching stream crossings in contributing increased sediment to Penticton Creek. Drainage management on active roads was generally good with limited instances where there was active sediment delivery to streams (Photo 31 – Appendix B).

Suspended sediment compromises the disinfection process and exceeds the turbidity in raw water affecting the threshold of 1NTU in treated water. Increased sedimentation is a risk to human health.

Sedimentation from range use in and around streams and road crossings

Disturbance was noted along streams near road crossings where cattle would access the stream. Depending on the site conditions and forage cattle would use some these areas more intensively resulting in trampled streambanks increasing sediment delivery.

Sedimentation from recreation activity on roads in and around streams and reservoirs

Recreation use was common with vehicles driving through streams where crossings were removed resulting in sediment delivery to the streams (Photo 8, 10, 18, 21, 26, and 30 – Appendix B). Suspended sediment compromises the disinfection process and exceeds the turbidity in raw water affecting the threshold of 1NTU in treated water. Increased sedimentation is a risk to human health. Sediment delivery from ATV use was noted and can be expected to increase particularly at location where they traverse streams or wetland areas.

Flow Changes

Changes in peak flow can be cause by forest development, wildfires, climate change, and the mountain pine beetle.

Wildfire

Wildfires cause water repellant soils leading which to erosion. Wildfires also contribute large amounts of ash causing increased nutrient and heavy metal loadings in streams. The changes to the hydrology of the burned areas can result in degraded water quality due to increased sediment loads and the release of nutrients and heavy metals. Post fire there is a change in vegetation species composition.

4.4.2 Biological Hazards

Bacteriological contamination from wildlife, cattle and humans

The watershed has a healthy wildlife population including deer, elk, moose and black bears etc. There are also active grazing licences in the watershed and evidence that lands are frequently used by cattle (Photo 9 – Appendix B). Human activity in the watershed includes those involved in forestry activities, forest research and recreation. Animal and human presence in the watershed increases the risk of potential biological contamination of the water with fecal material, and E.coli.

Protozoa including Giardia and Cryptosporidium

Animals and humans also increase the risk of the introduction of giardia and cryptosporidium into the source water. In the 1980s a significant number of residents were diagnosed as suffering from Giardia that was traced back to wildlife in the intake pond.

Viruses

Human presence in the watershed increases the risk of introducing viruses into the water supply. Although none have been detected to date, with the increased use of the watershed for recreation, the risk will continue increase.

4.4.3 Chemical Hazards

Total Organic Carbon (TOC)

Chemical hazards to drinking water (TOC and hydrocarbons) are a concern. The presence of total organic carbon is an indicator of organic compounds that could contribute to THM 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.

Petroleum contamination from an industrial fuel spill or vehicle accident

The potential for chemical contamination of drinking water from fire suppressant application exists, but since the formula for the retardant has been changed to eliminate most harmful additives, impacts on water are limited.

4.5 Hazard Identification Table

The Hazard Identification Table (Table 3) summarizes the following:

- types of hazards within the assessment area;
- hazard type split into physical, biological and chemical;
- measures in place to prevent such contaminant releases;
- potential effects at the source level; and
- existing preventative measures and associated barriers at the source level.

Table 3: Hazard Identification Table

Hazard Type	Drinking Water Hazard	Possible Effects	Existing Preventative Measures at the Source Level	Associated Barrier at the Source Level	Comments	Report Section #
Physical	Sediment from natural sources	• Compromised disinfection process • Risk to human health • Increased sediment load resulting in exceeding turbidity in raw water affecting the threshold of 1NTU in treated water	Intake ponds, screens at the intake Planning - avoid development activities in sensitive areas	BMPs, Intake ponds and screen	Continuous turbidity monitoring at the WTP can indicate problems in the watershed.	4.3.1
	Sedimentation from industrial/resource roads and road crossings	• Compromised disinfection process • Risk to human health • Increased sediment load resulting in exceeding turbidity in raw water affecting the threshold of 1NTU in treated water • Drainage alteration, increased runoff and flow alteration	BMPs, road deactivation	Reservoirs, Intake ponds and screens	Reduce road inventory Utilize temporary roads where possible.	4.3.2
	Sediment - from range use in and around streams and road crossings	• Compromised disinfection process • Risk to human health • Increased sediment load resulting in exceeding turbidity in raw water affecting the threshold of 1NTU in treated water	BMPs	Cattle guards, drift fences, range riders	Cattle use appeared limited in most of the watershed. It is not know what the current utilization level is by the licensees.	4.3.4
	Sedimentation from recreation activity on roads in and around streams and reservoirs	• Compromised disinfection process • Risk to human health • Increased sediment load resulting in exceeding turbidity in raw water affecting the threshold of 1NTU in treated water	Signage to inform stakeholders and the public that it is a Community Watershed	Deactivate roads not required Use gates to restrict access	Access management planning	4.3.6
	Flow Changes	• Changes in timing	Forest planning by licensees includes assessment of peak flow impacts	ECAs are kept at or below the moderate peak flow hazard level	The only sub-basin with flow concerns is Dennis Creek as a result of the spruce bark beetle control.	4.3.3
	Wildfire	• Can cause water repellant soils leading to erosion. • Can contribute large amounts of ash causing increased nutrient and heavy metal loadings in streams. • Can result in a change in vegetation species composition.	Education BMPs	The City has the option to turn off its creek intake and switch to its Okanagan Lake supply in the event source concerns from a wildfire	The interface fire risk is somewhat reduced due to past fires. The natural wildfire risk may be somewhat less than similar watersheds as a result of past fires and limited current forest health issues.	4.3.7

Hazard Type	Drinking Water Hazard	Possible Effects	Existing Preventative Measures at the Source Level	Associated Barrier at the Source Level	Comments	Report Section #
Biological	Wildlife, cattle and human presence	• Risk to human health • Contravention of DWP Regulation for fecal coliform bacteria, E.coli, and total coliform in drinking water	Grazing plans Hunter education	Fences Management plans	The City continues to detect varying levels of fecal coliform material in the raw water. It is not known if there is Giardia in the raw water however the City's disinfection process provides for deactivation of cysts and no cases of illness have been reported since 1986.	4.3.4; 4.3.6
	Protozoa (Giardia, Cryptosporidium)	• Risk to human health • Contravention of DWP Regulation for fecal coliform bacteria, E.coli, and total coliforms in drinking water.	Grazing plans Hunter education	Fences Management plans		4.3.4; 4.3.6
	Viruses	• Risk to human health • Contravention of DWP Regulation for fecal coliform bacteria, E.coli, and total coliforms in drinking water.	Prepare grazing plans to limit cattle use around streams Education	Fences Management plans		4.3.6
Chemical	Total Organic Carbon (TOC)	• Reaction of organics (total organic carbon) with water disinfection resulting in formation of Trihalomethanes (THMs) in drinking water • Risk to human health	BMPs	Road deactivation Riparian protection	Planning – Plan roads and harvesting to limit sediment and nutrient loading that	4.3.5
	Petroleum contamination from an industrial fuel spill or vehicle accident	• Contamination of drinking water • Risks to human health	Educate contractors about safe industrial activities including the use of spill kits, use of vegetable based lubricants, etc		Limit amount of active road	4.3.2; 4.3.3; 4.3.6

4.6 Cumulative Effects

While minor contributions of contaminants, whether suspended sediment, bacteria or chemicals, considered individually may pose a limited risk to water quality, collectively they have a cumulative impact on the drinking water supply. This is complicated by the inherent difficulty in managing for contaminants on a watershed scale because BC legislation does not define Total Maximum Daily Loads (TMDL) and background loading sources and non-point source inputs are almost untraceable. These problems underscore the importance of developing a watershed plan where all stakeholders and the public work collaboratively to manage cumulative effects.

Suspended sediment is a concern in the Penticton Creek watershed requiring attention. Resource roads can extend the drainage network unless the natural drainage systems are carefully maintained, and they can expand the area that contributes runoff and sediment to streams. Considering the continued forest harvesting activities, particularly in response to the mountain pine beetle, the cumulative impacts (hazards) affecting the water supply will increase unless additional care is taken. Forest development planning should consider:

- The implication for slope stability and soils on sediment delivery to streams;
- The implications of peak flow increases; and
- The opportunities to limit the expansion of permanent roads through the use of temporary roads.

Sediment contributions from recreational users and off road vehicle use in the watershed are an increasing concern because there is very limited legislation to control it. It was noted during the field assessments that most if not all roads/trails in the watershed have continuing vehicle use. It was reported by Weyerhaeuser that the use of gates to restrict access and road use is not successful due to ongoing vandalism when gates are locked (Photo 24 – Appendix B). It was also noted that the Steward Creek North FSR that had been closed to vehicles by the installation of a lock block barrier was similarly unsuccessful. Several blocks had been pushed off the road and there was frequent vehicle traffic on the road beyond the closure point (Photo 13 – Appendix B).
As unmanaged recreational use increases in the watershed so does the risk of the introduction of biological hazards, i.e. Giardia, cryptosporidium and viruses from humans and domestic animals (dogs). The City reported detectable levels of fecal coliforms in the Penticton Creek water again in 2011 so it is a fact that potential hazards to human health are present in the raw water. The source of the fecal coliform is unknown but it is present and the likelihood of a cumulative impact over time is very high.

5.0 Risk Characterization and Analysis (Module 7)

5.1 Objectives

Module 7 considers the hazards to drinking water quality identified in Module 1 and 2, along with the consequence to 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. The risk ranking forms the basis for developing a drinking water protection plan.

5.2 Methodology

This risk assessment is consistent with the principles outlined in the *Comprehensive Drinking Water Source to Tap Assessment Guidelines*.

The risk characterization consists of four steps:

- determination of the assessment areas vulnerabilities
- determination of source protection barrier effectiveness
- characterization of potential risks; and,
- summary of the information in a Risk Characterization Table

5.3 Evaluation of Source Protection Barriers

Source protection is the first barrier in the multi barrier approach to protecting drinking water. The source protection barriers currently in place include regulations and guidelines set out in the *Forest and Range Practices Act, Water Act and the Drinking Water Protection Act*. However, regardless of the intent of the regulating agencies and the licensed stakeholders to comply with the legislation and regulations and to implement best management practices, there is increased sedimentation to all of the streams in the watershed from roads and from disturbances from cattle and recreational use. In addition, there are natural hazards such as contamination from wildlife, increased runoff due to the loss of forest cover due 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, instead, recognizing the challenges to water quality and quantity that the City faces, all the efforts from agencies and stakeholders in the watershed should continue and limit the impacts on the source water in Penticton Creek. The higher the raw water quality at the intake the lower the costs of treatment.

As indicated previously the watershed can be partitioned into three parts, the area upstream of the Greyback Reservoir where runoff quality downstream is buffered by the reservoir. Since the water stored in the reservoir has a “long” residence time, it can eliminate sediment and most turbidity from the inflow. The second area is the “partially buffered” section which is the area downstream of the Greyback Reservoir to the Campbell Mountain Diversion. The diversion intake pond has the ability to remove coarse sediment and some of the finer grained sediment, but the residence time in the pond is too short to reduce turbidity. The last section is that portion of the watershed that drains into the mainstem creek downstream of the Campbell Mountain Diversion an upstream of the intake. The intake has no buffering from the sediment/turbidity in the runoff that flows into this last reach of the creek.

5.4 Consequence of Hazards to Source 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 are the basis for the risk assessment. The intent of this section is to address the issue of the consequences to the drinking water quality that will be used to estimate the risks. Consequence is 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). In the case of drinking water, consequence is the change, loss, or damage to the water quality caused by contaminants. Table 4 provides a summary for the ranking of consequences to drinking water quality/quantity, rated from insignificant to catastrophic. Table 5 summarizes the consequence ratings for each of the hazards.

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

- increased sediment loads;
- increased fecal material/increased pathogen loading;
- increased organics; and/or
- increased nutrients (algal growth, taste and odour problems).

Table 4: Qualitative Measures of Consequence to Drinking Water Quality/Quantity

Level	Descriptor	Description
1	Insignificant	Insignificant impact, no illness, little disruption to normal operation, little or no increase in normal operating costs. Manageable changes in water supply, both increased or decreased stream flow
2	Minor	Minor impact for small population, mild illness moderately likely, some manageable operation disruption, small increase in operating costs. Restrictions on watering due to drought/decreased supply or increased operating/treatment costs due to regular flow events
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. Loss of drinking water and fire suppression supplies.

Based on Module 7 of the Comprehensive Drinking Water Source to Tap Assessment Guideline (BC Ministry of Healthy Living and Sport, 2010).

Table 5: 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	2
	Sediment – Sedimentation from industrial roads and road crossings	2
	Sediment – Sedimentation from range use in and around streams and road crossings	2
	Sediment – Sedimentation from recreation activity on roads, road crossings and in/around streams and reservoirs	3
	Flow Changes	1
	Wildfire – increased sediment load and loss of control at intake from evacuation order and/or damage	2
Biological	Bacteria – Bacteriological contamination from wildlife/cattle/human presence in and along streams	4
	Protozoa – presence of Giardia, Cryptosporidium	4
	Viruses – presence	4
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

The City has a water treatment plant that has been designed to address most of the potential hazards in the watershed as long as the plant is operating and provide drinking water that meets the regulation requirements. For the purpose of this assessment the consequence ratings for the identified hazards are based on the assumption that the plant is not operating other than the disinfection process – a worst-case scenario.

The highest consequences to water quality in the Penticton Creek watershed are related to suspended sediment/turbidity and pathogens. High levels of suspended sediment/turbidity can compromise the disinfection process and increases the risk that viable pathogens could enter the drinking water system. 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).

5.4.1 Physical Consequences

Suspended sediment/turbidity is not directly harmful but can compromise the disinfection process and therefore the consequence from all sources is assumed to be at least moderate. The Greyback Reservoir provides a degree of buffering at the intake by settling the sediment loads/turbidity from inflow. The Campbell Mountain diversion located closer to the domestic intake provides a further degree of buffering of the inflow upstream but has limited ability to reduce turbidity spikes due to the small size of the intake pond and the short residence time. The settling action can reduce the consequence from sediment and turbidity introduced upstream from the reservoirs to drinking water quality at the intake. 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.

Sediment from natural sources such channel erosion will continue to occur especially during periods of high flow however the majority of the watershed is buffered. It is the unbuffered areas in the zone between the intake and the Campbell Mountain diversion that that have the highest potential hazard but this is a relatively small low elevation area that does not contribute much runoff. Several old landslides have been identified along the mainstem of the creek that may still contribute some sediment occasionally. The risk of new landslides is considered to be low.

Sediment from human activities and cattle grazing has been identified throughout the watershed however overall it is limited. Ongoing attention to roads is recommended. Other than the section of the Greyback FSR that is used for access to the Greyback Reservoir and the research watersheds, roads not required for active logging use should be deactivated (temporary or permanent). A watershed access plan would help determine appropriate levels of deactivation for existing roads as well as future roads. A map that indicated which roads were open and which were closed in conjunction with education material might reduce some of the impacts from the public use. It was noted during the field assessments that there are access control gates on some of the roads. They were all open at the time. It is not known if there is any formal plan to use the gates to restrict access.

High peak flows during freshet can degrade water quality as a result of increased sediment loads. Greyback Reservoir provides very effective buffering of inflow from upstream. The zone downstream of the reservoir has limited buffering from peak flows and the consequence is higher. Reduced runoff during a drought is a concern but due to the large size of the Greyback Reservoir and the current level of demand the City has a robust supply.

The consequence from a wildfire in the watershed is low. There have been two large wildfires in the watershed over the past several decades burned through the low elevation stands and the burned areas are revegetated. Currently, the risks of new fires in these areas are low since much of the fuel has been burned. Wildfires remain a concern but since the City can switch its supply to Okanagan Lake, the consequence is rated as low.

5.4.2 Biological Consequences

The presence of bacteria, protozoa and viruses represents a level 4 consequence as the potential for small concentrations of these contaminants in drinking water could lead to impaired human health.

5.4.3 Chemical Consequences

Chemical hazards to drinking water (TOC and hydrocarbons) present a level 2 consequence. The presence of total organic carbon is an indicator of organic compounds that could contribute to THM 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 potential for chemical contamination of drinking water from fire retardants is rated as low since the retardant formula has been changed so that the health impacts on drinking water are now low.

5.5 Likelihood Assessment for Hazards to Source Water Quality and Quantity

A qualitative risk assessment has been undertaken for the hazards identified (intrinsic watershed hazards and contaminant sources). The risk is assessed at the City intake on the creek, prior to treatment. The source risk at the intake will be different from the risk at the tap following treatment. The source or unabated risk to the drinking water is the worst-case scenario that is the delivery of untreated drinking water to the community.

Risk is the product of the hazard (likelihood of occurrence) and the consequence. Qualitative measures of likelihood are presented in Table 6. A time horizon of 10 years is suggested in the guidelines when attributing likelihood of occurrence to identified hazards.

Table 6: 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 Healthy Living and Sport, 2010).*

Modules 2 identified the hazards to drinking water quality that are summarized in Table 3. Assessment of likelihood for the hazards is summarized in Table 7 followed by a brief summary for each hazard.

Table 7: 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
	Flow Changes	C
	Wildfire – Increased sediment load, loss of control at intake from evacuation orders and/or damage	D
Biological	Bacteria – Bacteriological contamination from wildlife/cattle/human presence in and along streams	A
	Protozoa – Presence of Giardia, Cryptosporidium	A
	Viruses – Presence	A
Chemical	Organic material – (Total Organic Carbon)	D
	Hydrocarbons – Petroleum contamination from an industrial fuel spill or vehicle accident	D

5.5.1 Physical Likelihood Assessment

Sediment

The maximum recommended turbidity level in raw drinking water is 1NTU (Singleton, 2001). The maximum turbidity levels at the intake averaged ~6.9NTU in 2011 with a maximum of 8.4NTU during the spring freshet. The average minimum turbidity was 0.37NTU. During the watershed inspections it was evident that sediment is being contributed to watercourses as a result of forestry activities, cattle activity near streams and off-road vehicles. The sediment and turbidity that reaches the intake is from natural and anthropogenic sources. The likelihood of sediment/turbidity affecting the intake varies depending upon the source. The likelihood considering all sources is rated as 'B'.

Flow Changes

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 however based on the current and projected demand

and the robust supply, and on a time horizon of 10 years as is suggested in the guidelines when attributing likelihood of occurrence to identified hazards the cumulative risk for changes in water quantity is rated as ‘C’.

Wildfire

There will always be a wildfire risk in the watershed as is evident from the past two fires. Since the fuel loads in the lower watershed have been reduced by past fires and the extent of mature lodgepole pine in the watershed that may be impacted by the pine beetle is limited, the risk to the source water quality related to wildfire is rated as ‘D’.

5.5.2 Biological Likelihood Assessment

Fecal Coliform/E.coli

Wildlife, livestock and humans are all identified potential pathogen and turbidity sources in the watershed. 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. Livestock and wildlife activity erodes stream bank and bed material, and may contribute to erosion of fine sediment. Pathogens enter the stream network from manure, evidence of which was noted in the proximity of many watercourses during the field assessment.

Section 3.3 of the *Health Canada Guidelines for Drinking Water, Supporting Documentation on Turbidity*, addresses the criteria for the exclusion of filtration for waterworks systems indicates that “Prior to the point where the disinfectant is applied, the number of *Escherichia coli* bacteria in the source water does not exceed 20/100mL (or, if E. coli data are not available, the number of total coliform bacteria does not exceed 100/100mL) in at least 90% of the weekly samples from the previous 6 months” (Health Canada, 2003).

E.coli samples at the intake in 2011 ranged from 0 to 27.2 counts/100ml. Based on the sampling results, the likelihood of E.coli being present in raw water at the intake is rated as ‘A’.

5.5.3 Chemical Likelihood Assessment

Total Organic Carbon (TOC)

Sample results by City confirm that the TOC levels in the raw water collected at the intake during 2011 ranged from 4.2 – 20.4mg/L. The recommended level in raw water is 4mg/L so this is a parameter that should be monitored to determine if there if there is a trend year over year. The likelihood that there will be elevated TOC levels in the raw water is rated as ‘A’.

Hydrocarbons

The potential impacts on drinking water from a fuel spill are a concern since there is industrial and recreational vehicle use throughout the watershed. 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 the City has the option to switch to the lake intake. To date there are no reported incidents of fuel or oil being detected at the intake and the likelihood of this occurring is rated as a ‘D’.

5.6 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 8.

Table 8: 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 Healthy Living and Sport, 2010).*

The results of the risk assessment summarized in Table 9 indicate that there are risks to the City's drinking water quality at the intake.

5.6.1 Physical Risks

For the physical hazards, the risk from natural sediment is rated as moderate to very high. There are limited natural sources that are a concern other than channel instability related to natural causes such as the pine beetle. However, sediment from industrial activity (including roads) is considered to be a high risk since there is a large inventory of road crossings that are unlikely to be reduced and are the primary source of the sediment. If there is increased industrial activity as a result of salvage logging the risks may increase over the next 3 to 5 years. The risk from increased sedimentation from cattle disturbance in and along streams and related increased turbidity levels are both considered to be high since they are related to the increased likelihood of pathogenic organisms contaminating drinking water and affecting public health. Also of concern is the risk to the source water from increased recreational activity in the watershed. Unregulated access for off-road vehicles, ATVs, motorcycles and four-wheel drive vehicles, on inactive roads is resulting in additional sediment delivery to streams on roads that would otherwise be considered low hazard sources of sediment.

5.6.2 Biological Risks

The risks from biological contaminants are all rated as high to very high due to the known levels of occurrence at the intake and the limited barriers currently in place prior to the water treatment system. The construction of the new water treatment plant provides an additional barrier that delivers water that meets all IHA requirements for drinking water quality.

5.6.3 Chemical Risks

The risks from chemical hazards are rated as low to moderate. These risks could results from a fuel spill, a rupture of a hydraulic hose on an excavator or from a vehicle accident. The likelihood of hydrocarbons entering a stream and affecting the water quality at the intake is considered to be low. Herbicides are not licensed for use in the watershed, therefore the likelihood of contamination is low but the consequence should a spill occur is rated as moderate. Although the likelihood of a wildfire is increasing, the impacts from retardant chemicals are at worst moderate due to the composition of the new retardants.

Table 9. Penticton 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	C	2	Moderate	Natural sediment loads will increase with increasing peak flows but the reservoir and intake ponds provide buffering
	Sediment – Sedimentation from industrial roads and road crossings	B	2	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	B	2	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	A	3	Very High	It is assumed that recreational use in the watershed will continue to increase.
	Flow Changes	D	1	Low	Over the long-term, 50 years and beyond, if there is a long-term decline in snow packs, there may be reduced runoff but due to the robust supply the risk is low.
	Wildfire – Increased sedimentation from fire fighting activity and post wildfire effects, plus loss of control at intake due to evacuation order and/or damage	D	2	Low	The risk from a wildfire is considered to be low.
Biological	Bacteria – Bacteriological contamination from wildlife/cattle/human presence in and along streams	A	4	Very High	The likelihood for increased contamination will be very high as recreational use increases.
	Protozoa – presence of Giardia, Cryptosporidium	A	4	Very High	
	Viruses – presence	A	4	Very High	
Chemical	Organic material – (Total Organic Carbon)	D	2	Low	TOC samples indicate the current level is above the guideline for raw water of 4 mg/l
	Hydrocarbons – Petroleum contamination from an industrial fuel spill or vehicle accident and gas powered boats on reservoirs	D	2	Low	Even with increased activity in the watershed the likelihood of a spill affecting the water at the intake is low.

5.7 Risk Assessment Summary

It is important to understand that the risk assessment summarized in Table 9 is based on the assumption that the City's water treatment <u>is not</u> operating; the only active treatment barrier would be chlorination. The <u>source</u> protection barriers are generally the requirements established in the legislation that governs licensed activities in the watershed. These include the *Forest and Range Practices Act, the Water Act and the Drinking Water Protection Act*. The barriers are the application of the legislation 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 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 summarized in Table 9 indicate that the risks are low for hydrocarbons, moderate for herbicides and fire retardants, moderate to very high for increased sedimentation from wildfire, high for sediment from industrial roads, cattle impacts, algae, and organic carbon, and high to very high for sediment from natural causes, sediment from recreational activities, bacteria, protozoa, and viruses.

6.0 Recommendations to Improve Drinking Water Source Protection and Sustainability (Module 8)

The recommendations in Table 10 were prepared with input from the Technical Advisory Committee at the May 9, 2013 meeting.

Table 10. Recommendations

Hazard	Risk Rating	Recommended Action
Natural sediment	Moderate	• City to continue to monitor raw water quality and switch from creek to lake source if turbidity levels in treated water exceed 1NTU.
Sediment from roads	High	• Forest licensees to address current problem sites identified in the report in 2013. • Licensees to build roads ahead whenever practical to reduce sediment delivery to streams. • Licensees to build temporary in-block roads and rehabilitate these roads as soon as practical after harvesting. • The Forest Service and licensees to continue to explore options to restrict road access in the watershed where possible.
Sediment from range use	High	• The rancher to continue to monitor cattle use and move cattle away from sensitive areas or those areas with limited forage. • Range Program and ranchers to continue to explore innovative approaches to limiting cattle/water impacts. • Forest licensees and the rancher to use innovative approaches such as wood debris lines to limit cattle access to streams in future logged blocks.

Hazard	Risk Rating	Recommended Action
Sediment from recreation activity	Very High	• Recreation Officer from FLNRO in Vernon to meet with the City to discuss options to reduce impacts. • Forest licensees to limit the expansion of permanent roads and rehabilitate roads no longer required for industrial access. • All stakeholders to monitor recreation use and advise City of any concerns. • City and Recreation Officer to explore public education opportunities.
Bacteriological contamination	Very High	• Range Program and ranchers to continue to implement measures to keep cattle away from streams particularly in the partially buffered and unbuffered zones. • Ranchers to identify any opportunities for off-stream watering sites. • Forest licensees and ranchers to identify opportunities to use wood debris to limit cattle access to streams in future cutblocks.
Protozoa	Very High	• City to continue to monitor intake ponds at Campbell Mountain and Water Treatment Plant for presence of beaver, muskrats, etc and remove if present. • City/IHA to explore cost effective options to monitor for cysts in raw water.
Viruses	Very High	• City to ensure that chlorination system is working and that there is adequate contact time.

The intent is that stakeholders/agencies would initiate actions to address the high/very high risk issues identified in Table 10 immediately. Some actions are already being implemented such as the use of temporary roads, monitoring cattle use, monitoring intake ponds etc. Other actions such as how to address recreation issues and opportunities to limit cattle access to streams requires ongoing commitments from the agency staff and licensees.

Sincerely,

URBAN SYSTEMS LTD.

M Cook

Michelle Cook,
Water Resource Planner

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Appendix A

Map

Appendix B

Field Investigation Photos