Silverton Creek Watershed Report

The Hydrogeology of the Silverton Creek Watershed

Prepared for: Slocan Lake Stewardship Society
By: Richard Johnson and Susan Johnson, Opus Petroleum Engineering

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November 3, 2016

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Richard Johnson and Susan Johnson
Opus Petroleum Engineering Ltd.

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Cover photo of glacier from USGS.
Cover image from Google Earth

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Silverton Creek Watershed Report

Executive Summary

The Silverton Creek Watershed is located directly east of the Village of Silverton in the West Kootenay Region of British Columbia. The water supply for the Village of Silverton comes from wells that were drilled into the Silverton Aquifer underlying the Village. The water in that aquifer receives all of its water from the Silverton Creek Watershed, so the watershed is an eco-asset of the Village. The Slocan Lake Stewardship Society initiated this study to determine the state of the watershed and to assist the Village in determining the condition and needs of this eco-asset.

There are two types of bedrock in the watershed. The southern two-thirds is igneous granite and the northern one-third is metamorphosed shales and sandstone. Glacial deposits overlay the bedrock and are mainly lateral and medial moraine tills. There are some sand and gravel deposits related to the reworking of glacial material by meltwater as well as more recent water action. The location of the high-altitude bedrock outcrops, the colluvium, till and glaciofluvial deposits are mapped using data from the Province of B.C. databases. The location of sand deposits, observed by the authors, is noted in the write-up. There are no aquifers of significant size that were observed or recorded in the literature and databases.

Water flow in the watershed consists of surface streams and subsurface movement through colluvium and soils. The subsurface movement dissolves material, mainly Calcium and Bicarbonate, which is revealed by the increase in specific conductivity in waters that have travelled underground. The water quality samples have been taken at various times since 2010. All are well below the Canadian Water Quality Guideline of 500 milligrams per litre of Total Dissolved Solids.

The major threats to the water quality and quantity are surface disturbances such as those caused by human activities (e.g. logging, development, mining) and natural events (e.g. slides, erosion, wildfires, climate change).

Monitoring of the watershed is recommended, the simplest monitoring being quality and quantity measurements of Silverton Creek as it enters the Village. Further monitoring to consider is remote monitoring through analysis of the vast amount of free, easily accessible data being gathered by satellites.

It is in the best interests of the Village to ensure that development, surface disturbances and recreational uses of the watershed do not impact the needs of the Village for clean, safe water. The watershed was designated as a "Community Watershed" but it appears that this designation has been cancelled. It is recommended that the Village consider getting the watershed re-instated as a Community Watershed because of the importance of the watershed to the village as its source of drinking water.

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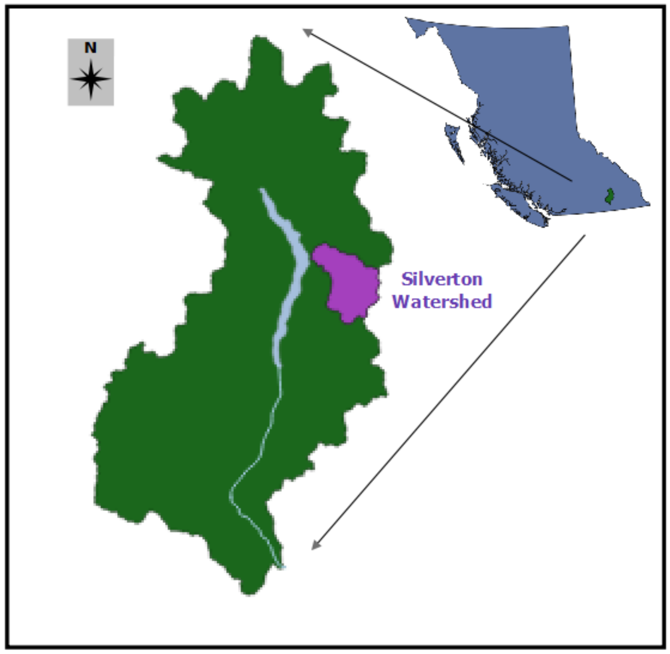
Introduction

A watershed is a complete ecosystem. The action of water on the geological material in the watershed is the foundation upon which the other ecosystems function. Human interference changes a watershed as do natural forces such as abnormal precipitation, fire, climate and disease. Measuring water quality and quantity is one of the ways that a community can monitor changes to the watershed.

The Slocan River Watershed (green on the map) drains into the Columbia River system. The Silverton Creek Watershed (lilac on the map) is one of the many smaller watersheds that form the Slocan River Watershed. It is formed by a series of interconnected valleys that are surrounded by peaks and ridges of the Selkirk Mountains.



Water flowing from the Silverton Creek Watershed exits the valley at the “Notch”, a sharp cut in the bedrock that is located at the eastern edge of the Village of Silverton, about 30 metres upstream of the point where the Village water pipeline connecting to the reservoir tank crosses the creek. (See Johnson, 2016 for pictures)

The “Geology” section of this report describes the geology of the watershed as it relates to the bedrock and glacial deposits within the watershed. The “Hydrology” section describes the water movement through the watershed and its impact upon the water quality and quantity. It also addresses the impact of water upon the landscape, particularly the erosion and stability of the soil and other material. Finally, a section on “Monitoring” is included to address the things that we, as a community, can do to keep track of changes in the watershed. These may lead to proactive maintenance of this eco-asset.

Data and reports in provincial files relating to the watershed were used to help understand the current condition of the watershed. The Bibliography lists reports used in this study. The report also draws upon the numerous databases provided freely by the province
In particular, data included in the province’s Terrain Ecosystem Inventory (TEI) and the Vegetation Resource Inventory (VRI) were used to create most of the maps in this report. A Glossary of significant technical terms used in the report is also included.

All the significant maps and illustrations are included in the Appendices, as well as data that relates to this report. The maps are sized to fit on an 8 ½ by 11-inch page to make a manageable report. These were created, using QGIS, at a resolution to be printed on 11 inch by 17-inch paper. The digital versions could be expanded, with little loss of quality, to 22 inch by 34 inches.

Conclusions

1. The watershed topography and soils are the result of deposits left by continental glaciation.
2. The quality of the water is related to the rock, colluvium and soil through which it has moved and the time and distance it was in contact with these surficial deposits.
3. The major changes to the watershed are expected to be caused by human disturbances, wildfire and abnormal climatic events such as heavy precipitation.
4. A well designed water monitoring program can be used to alert the community to changes in the health of the watershed.
5. Satellite data will play a larger role in watershed monitoring in the future because of the number and frequency of images being collected and being released to the public for free.

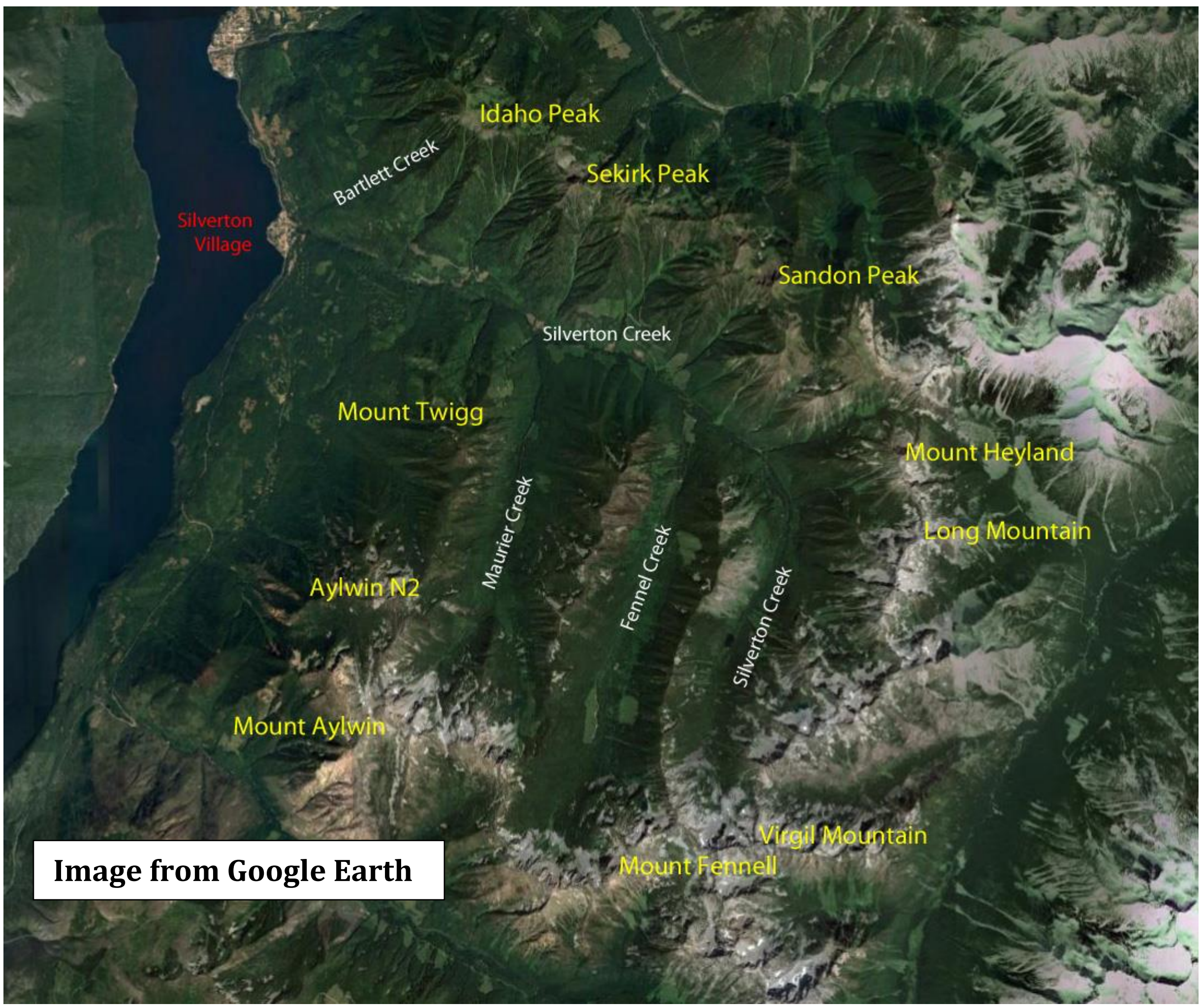
Recommendations

1. The community should play a larger role in monitoring the watershed.
    a. It is recommended that a continuous water monitoring program be maintained, with regular sampling for Specific Conductivity, Turbidity and pH and a one-time full water analysis that includes the trace metals (such as arsenic, iron, lead, zinc. aluminum).
    b. It is recommended that the Village maintain a system to record and archive this information.
    c. Monitoring can also be done by the community by reporting visual problems to a central agency.
    d. Ground disturbances such as landslide, erosion and snow slides should be monitored and recorded as well.
    e. Organizing a continuous public relations program to inform the community of things they can do to keep their water supply in good condition.
2. It is recommended that Silverton Creek Watershed be re-instated as a community watershed since it is the source of the Village's drinking water. Under the "Community Watershed" designation the community has the right and obligation to monitor the watershed and the activities within it.
3. A plan to understand and predict wildfire travel paths and a plan to minimize the impact of future wildfires should be undertaken. The community should consider creating or working with a community forest group for fire protection and timber harvesting.
4. More work should be undertaken to document what is present in the watershed from a complete ecological relationship, e.g. the SWAMP methodology, studies of fish, lichen, benthic invertebrates.

Geology

Topographic Setting

The Silverton Creek watershed is formed by the main valley which runs east-south-east from the Village of Silverton and three tributary valleys that join it from the south at approximately right angles to the main valley. A fourth tributary valley containing Bartlett Creek joins the main valley immediately east of the Village of Silverton boundary. The other three tributary valleys are roughly parallel to each other and join the main valley at about 6 kilometers 9.5 kilometers and 11 kilometers east southeast of the Village. The first valley coming in from the south is the Maurier Creek valley. The second valley contains Fennel Creek. About 11 kilometers up the valley Silverton Creek makes a 90 degree turn to the south. The creek in this valley is still called Silverton Creek.

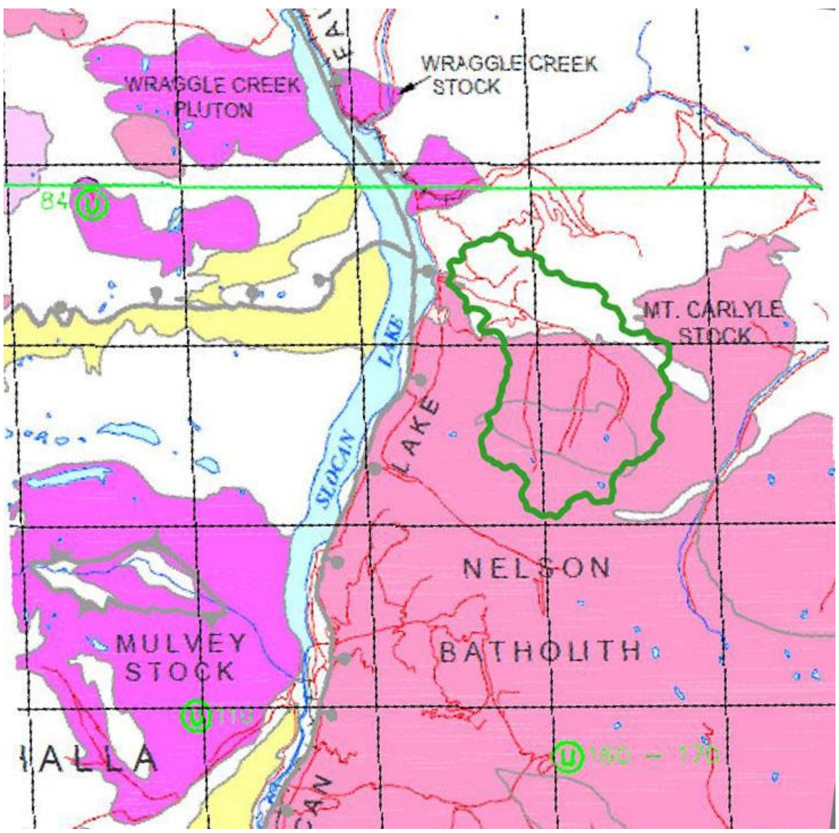


The northern side of the watershed is formed by a long ridge of mountains containing Idaho Peak (2282 m.), Selkirk Peak (2324 m.) and Sandon Peak (2346 m.) The eastern edge of the watershed is formed by Mount Hayland (2523 m.) and Long Mountain (2637 m.) The southern border is a ridge of mountains running from Virgil Mountain (2557 m.) through Mount Fennell (2476 m.), Fennell W1 (2459 m.) and ending at the high mountain complex of Mount Aylwin (2521 m.). A ridge runs north from Mount Aylwin to Aylwin N2 (2309 m.) and then to Mount Twigg (2013 m.). The north slope of Mount Twigg forms the south side of the entrance to the Silverton Creek valley.

Silverton Creek exits the main valley through a V-shaped cut in the bedrock at the eastern edge of the Village of Silverton … “the Notch”. From the Notch, the creek continues through the Village to Slocan Lake, travelling across the top of the unconfined Silverton Aquifer.

Bedrock Geology

The map below has been extracted from a larger map produced by the Province of BC (Logan, 2002). The green outline is the edge of the Silverton Creek watershed. The red lines are roads and trails.



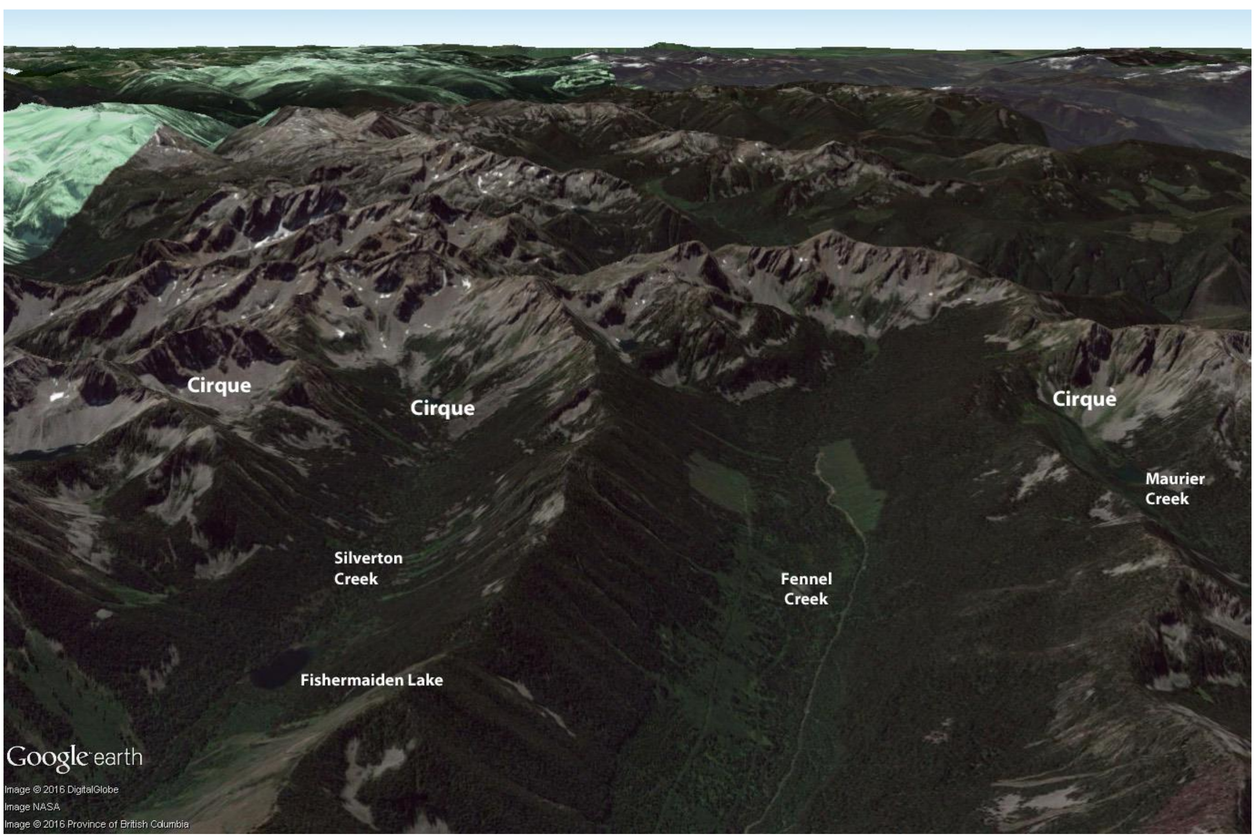
The bedrock in the south portion of the watershed is dioritic granite. It is part of the Nelson Batholith. The north portion of the watershed, white on the map, is metamorphosed shales and sandstones. The bedrock is exposed in numerous places in the watershed, at the tops of the mountains and in cliffs throughout the watershed.

One can easily find samples of rocks from these two rock types on the beach in the Village of Silverton (Turner et al, 2009). The same reference gives a further description of the geology of this area.

Glacial Geology

The Silverton Creek Valley deposits are related to the glacial history of the valley. When the entire area was covered with ice and snow the movement of the ice scoured the underlying bedrock producing the three U-shaped valleys which make up the Silverton Creek watershed. The photo at the right shows a modern day, glacier filled mountainous area. (All the glacier photos are from the USGS).

The Silverton Watershed begins with three valleys that start at their high end with typical glacial cirques, often containing a tarn (lake). The picture below, from Google Earth, shows the south end of the Silverton Creek watershed, looking south. The south end of Maurier Creek can be seen on the extreme right hand side of the image, with a labelled cirque at its head. The image was taken in July 2015 and is draped over the Google Earth elevation data. Some of the nicely defined cirques have been labelled.

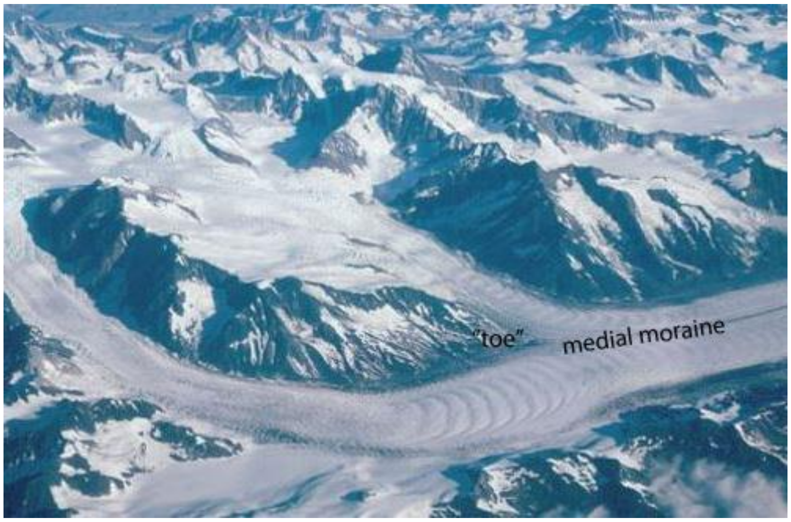


Below the cirques the valleys open into the typical U-shape of glaciated valleys. The sides of these valleys have lateral moraines made up of till (unsorted glacial material).

Occasionally the glacier in a valley became stationary. The ice continued to flow but the terminal portion remained in the same place because the rate at which the ice moved down the valley was equal to the rate at which it melted. This produced a terminal moraine at that location as the ice continued to bring more till as it moved down the valley.

The large Fennell Creek wetland, shown in the Google Earth clip above (looking south), is interpreted to have been formed by that process. The wetland is the remains of a lake that formed south of the terminal moraine. The north end of the wetland has a lot of sand indicating much washing and sorting of the till occurred here on the shores of that lake.

Medial Moraines



The northwest end of the ridge separating Silverton Creek and Fennell Creek is the start of a medial moraine. The remains still cling to the "toe" of the ridge but the main "stream" of glacial debris would have ended up on the valley floor and been reworked by water flowing down the valley.

The same thing occurred at the junction of Maurier Creek and Silverton creek. One can see the shape of a "toe" at the northwest end of both these ridges. The low slope indicates underlying till rather than scoured bedrock.

In both locations there are significant sand deposits. One can easily see this on the Maurier Creek road immediately south of the bridge across Silverton Creek. Another exposure is further up the same road where the road turns left, rounding the toe and continuing south. The occurrence of sand indicates that flowing water sorted the sediment, removing the small particles and leaving sand at the location.

Lateral Moraines

Lateral moraines occur along the sides of all the valleys in the Silverton Creek watershed. There a several places along the road between Silverton and the Maurier Creek junction where construction machinery has exposed the underlying till. The following section shows the location of these till deposits on maps of the watershed.

Surficial Deposits

The material that is at the surface in the Silverton Creek Watershed is classified into five categories: bedrock, colluvium, till, glaciofluvial and undefined. These data are available from DataBC using their Terrain Ecosystem Mapping data and have been mapped herein using the QGIS program.

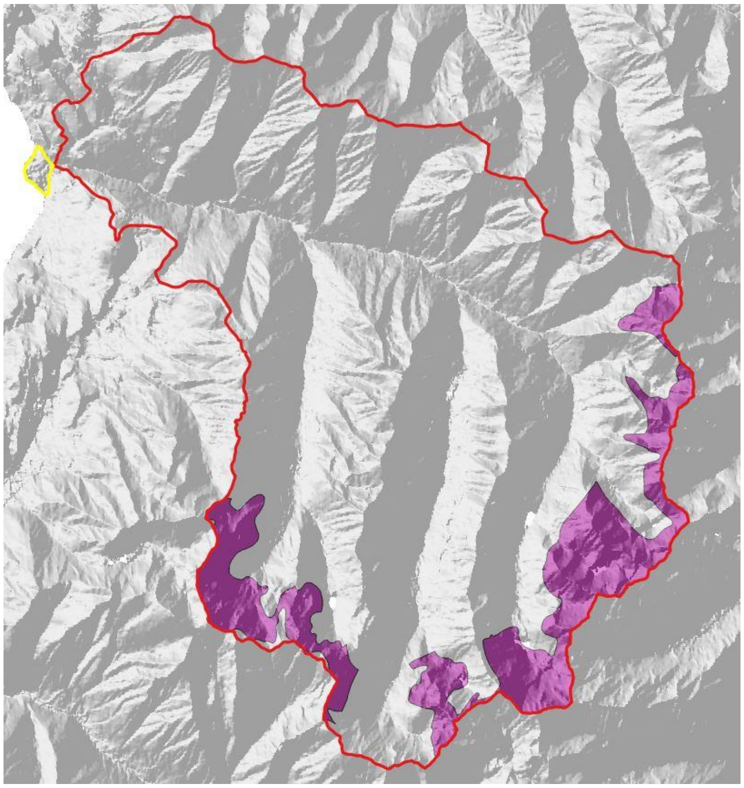
The maps show the outline of the Silverton Creek Watershed in red and the outline of the Silverton Aquifer in yellow.

> "The terrain classification system is scale independent and provides base data applicable for a wide range of natural resource applications including ecosystem mapping, planning, land and water management, impact assessment and research. The data is conveyed in map form by the use of terrain symbols and is conducive to computer digital storage, management and processing. The terrain classification system for BC is similar to the landform classification system defined in The Canadian System of Soil Classification, and was developed to support mapping of BC's very complex terrain." *From DataBC*

Bedrock

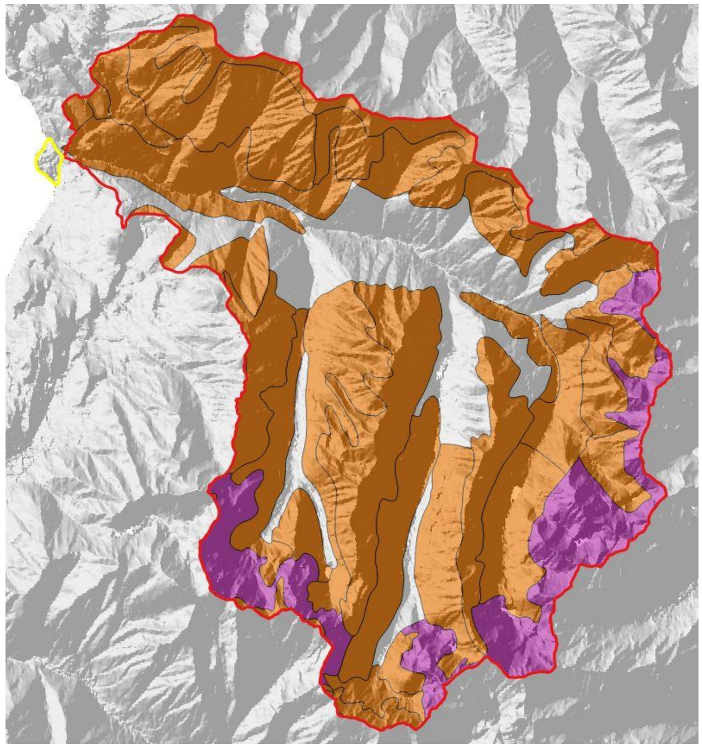
The Silverton Creek Watershed has large areas of exposed bedrock. At high elevations the mountain tops are largely unglaciated and the bedrock is exposed. Above the tree line there is little soil so the bedrock is usually visible if there is any significant slope.

The map at right, made from the Province's TEM database, shows the exposed high elevation bedrock. There are many other places within the watershed where bedrock is exposed in cliffs and the sides of eroded creeks. These are too numerous to be recorded in the TEM database.



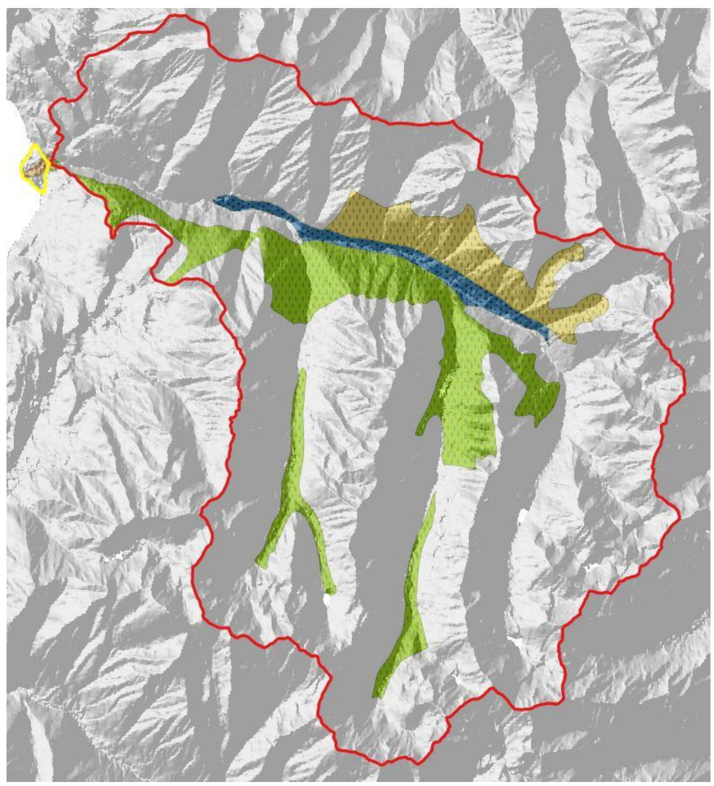
Colluvium

The talus (scree) that is broken from the bedrock is called colluvium. It is shown on the map at right in orange. It is covered in most places by soil and trees. Some small areas, shown in the TEM database as colluvium, are actually cliffs of exposed bedrock. This report does not identify them nor does the TEM database because they are small areas.



Glacial Deposits

The map at right shows the glacial till (light green) and the glaciofluvial sand and gravel (blue) deposits in the watershed. The yellow area is "undefined" in the TEM data. It is probably largely till based upon observations of the author.



Sand and Gravel Deposits

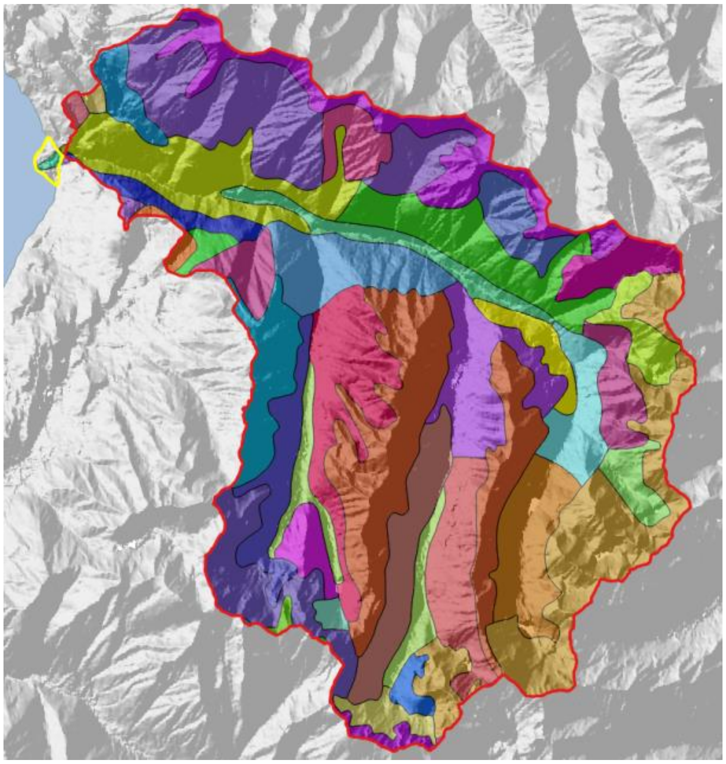
There are some sand occurrences located at the toes of the two ridges and a sandy deposit was noted at the north end of the Fennell Creek wetland. These were observed by the author and are not part of the TEM data set. There are probably other sand and gravel deposits that have not been mapped.

Aquifers

The glaciofluvial deposit shown on the previous map forms an aquifer. There are no wells drilled into this aquifer so the thickness is not defined. The behavior of this aquifer, e.g. how fast water drains from it, is not defined either, due to lack of data. There may be small aquifers in sand deposits in the lateral valleys as well. There is no known large aquifer system.

The Silverton Aquifer, which is under the Village of Silverton, is a fluvial delta created by gravel and sand carried out of the valley by Silverton Creek and dumped into Slocan Lake. See Johnson, 2016, for a complete description of the hydrogeology of the Silverton Aquifer.

Soils



The entire watershed area, other than the cliffs and mountain tops, is covered by a layer of soil. In the heavily treed areas the soil thickness varies, based upon observations of similar locations in this area. The bottoms of the valleys have more soil and wide valley bottoms usually have thicker soil than narrow valley bottoms.

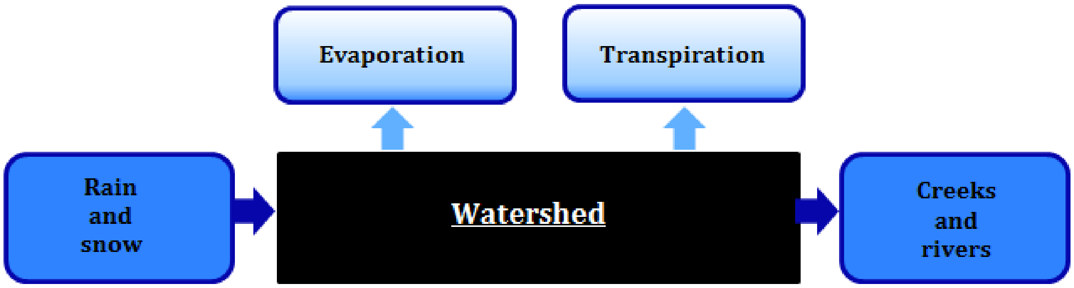
The provincial files contain a large amount of data on soils. The illustration at the right is included only to show that a large variety of soil classifications have been made for this watershed by the province.

A study of the soils and their stability in this watershed can be found in Dobson, 1998. The Dobson Report is discussed in more detail later in this report.

Hydrology

Introduction

Water or the lack thereof is the main cause of changes in a watershed. A watershed can be modelled as a "Black Box" into which rain and snow fall and from which evaporation, transpiration and water outflow remove the water. Within the black box water flow is slowed by lakes, aquifers, wetlands and soil but eventually leaves by one of the above mechanisms. Modelling a watershed is complicated because evaporation and transpiration can only be estimated and water holdup creates a time lag from the water input to the water discharge. To model the behavior of this watershed and the impacts of changes within it we need several years of data showing precipitation, air temperature and creek flow volumes. Environment Canada records the precipitation and temperature. We should continue to record the creek flow rates so that we can model this watershed at a later date.



The water in the watershed changes the land by erosion, land movement and snow slides. The weight of water in a soil and the lubrication and buoyancy changes caused by too much water change the stability of material and cause mass movements like slumps and landslides. Too little water can make the watershed susceptible to wildfires. Lack of water changes the vegetation as does too much water. Disease and insect attacks change the vegetation. It is a complex ecosystem that changes with changes in climate.

Human involvement in a watershed impacts it when we change the landscape with roads, building sites, timber harvesting and fires. It is up to the community to manage the impact that we have on it through our direct involvement as well as proactive timber harvesting and fuel removal to mitigate the effects of wildfire. The watershed is a community eco-asset that needs to be managed because of our impacts on it.

To understand a watershed a bit better we should look at how the water moves through it or is held up by lakes, wetlands, aquifers and soil. We need to see how we can monitor the watershed and take steps to mitigate the factors that impact it. We need to know what data is already available and what needs to be gathered. And finally, we need to interpret the data and decide what actions should be taken.

Water Movement and Water Quality

All the water in the watershed is derived from precipitation. When rain falls or snow melts the water moves on the surface of the land or underground through the colluvium, the soil and through fluvial deposits such as gravel, sand and silt. The amount that flows through clays is negligible. Bedrock that is extremely fractured can conduct water but water flow through bedrock is probably insignificant in this watershed because the bedrock is not highly fractured.

Surface flow is the predominant movement of water over bedrock. Igneous and metamorphic rock, such as we have in this watershed, does not have significant amounts of dissolvable material. Consequently, the water that accumulates in high altitude lakes (the tarns in the cirques mentioned earlier) is very fresh.

Flowing water goes underground when it encounters blocky scree. At the foot of scree slopes the water either moves on as a stream or continues underground if the scree is overlain by soil or fluvial sediments. The geology section of this report shows the location of the colluvium in the watershed. It is usually on the higher sides of the valleys and has an angle of repose close to 45 degrees.

Glacial till is unsorted material and the matrix is usually clay so it sheds water. The largest deposits of till are in the main east-west valley.

Water, when it reaches silt, sand and gravel flows through if there is an outlet, otherwise it is trapped in the pore spaces and an aquifer is created. The main aquifer in the valley is that shown in the geology section and indicated on the maps as a glaciofluvial deposit. This aquifer will slowly drain water back into the main Silverton Creek before it reaches the Village.

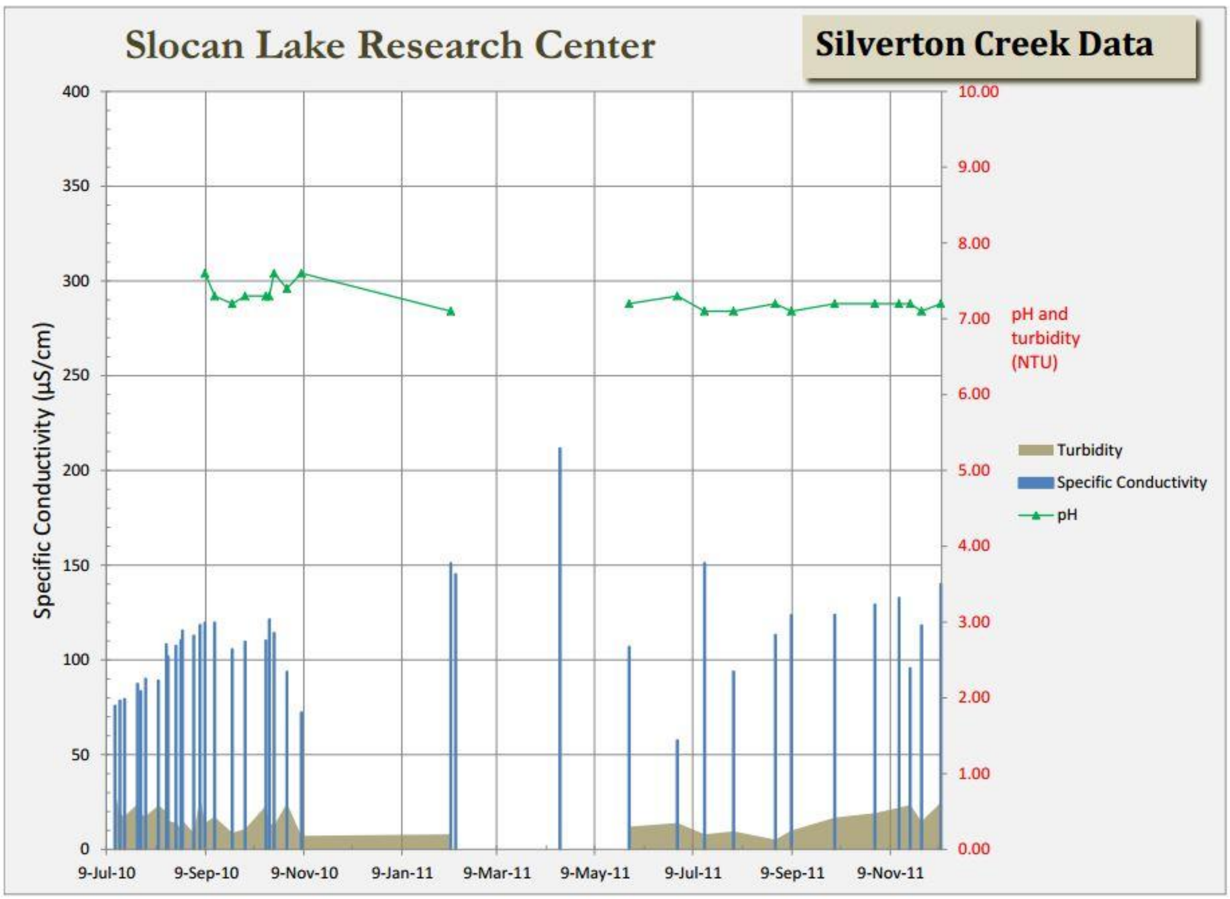
Samples of water were taken throughout the whole Slocan Watershed and the results published in Quamme, 2016. The result showed that all the waters in the watershed are Calcium Bicarbonate type waters. The following is quoted from the Opus section of that report:

"The 21 samples in this study are all typical surface waters which are Calcium-Bicarbonate type waters. The term "Calcium-Bicarbonate" is a descriptor used in the hydrogeology community to describe a water based upon the dominant cation and anion. All the samples are below the Canadian and US drinking water standard of 500 mg/l. The human palate does not usually notice ion concentrations until the 1500 mg/l range (Personal experience ... taste plain San Pelligrino (940 mg/l) bottled water or Gerolsteiner (2488 mg/l).

The TDS of Calcium Bicarbonate waters can be thought of as measure of the "age" of the water. Precipitation falling upstream from a wetland reaches the wetland in three ways. The simplest is surface run off. The next is travel through the soil. The third way that water *reaches a wetland is through aquifer flow below the soil. The latter is the most complex and the slowest and gives the most time and opportunity for an increased TDS concentration. A variation of this is probably happening in the Bonanza Marsh where subsurface water is coming to the surface through a fractured limestone bedrock.*

Water moving underground is initially affected by the higher concentration of Carbon Dioxide in the soil which is controlled by temperature and depth (CO2 partial pressure). It also has more opportunity to dissolve salts and other material from the soil and/or aquifer. This is fully explained in Kehew (2001)."

Water samples were taken from Silverton Creek during the period July 2010 to December 2011. Measurements were made of Conductivity, pH and Turbidity. The graph below shows the variation of these parameters during that time period.



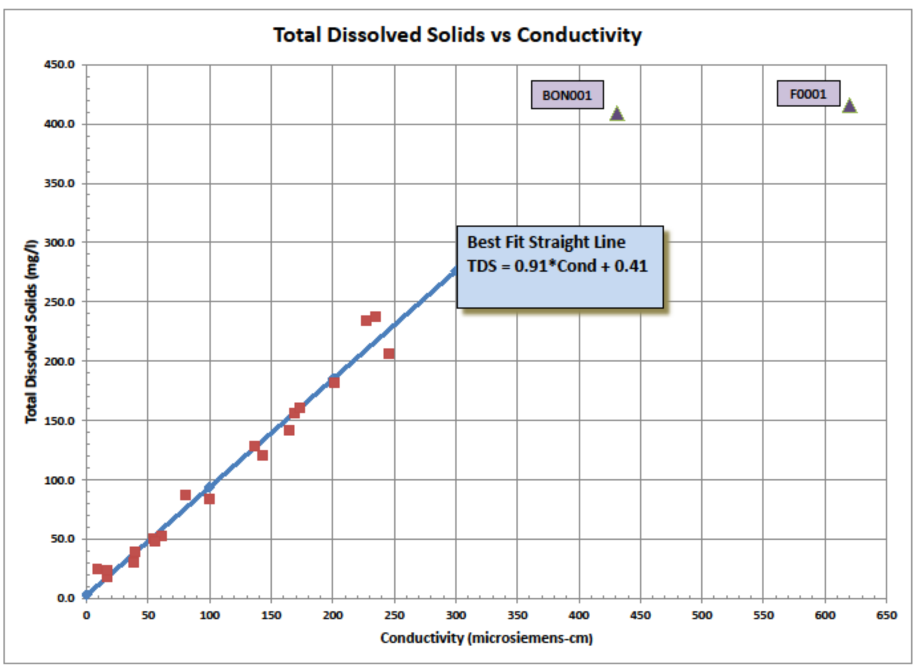
The water samples, shown on the previous graph, were taken from Silverton Creek (at the Highway 6 Bridge). They have a Specific Conductivity varying from 57.6 microsiemens (June 29, 2011) to 151.1 microsiemens (Feb 22, 2011). The 2015 water samples, shown in the next table, fall in the same range. This range corresponds to total dissolved solids (TDS) of 50 mg/l to 140 mg/l which is well below the maximum for drinking water standards of 500 mg/l.

The Slocan Lake Stewardship Society began a Water Quality Monitoring Program in April 2015. The table below shows measurements made in 2015. The data has not been added to the graph on the previous page.

2015-2016 WQMP Cumulative Field Chemistry

Date	Site Code	Dissolved Oxygen	Specific Conductivity	pH	Turbidity	Water Temperature	Air Temperature	Velocity (m/s)	Flow (m3/s)
October 13, 2015	NJSLV01	13	82.5	8.4	1.6	6.5	10	0.47	1.75
September 20, 2015	NJSLV01	10	88.6	8.25	0.41	9.4	15.8	0.64	2.58
August 10, 2015	NJSLV01	11	91.7		0.52	13.7	22.5	0.771	3.405
July 13, 2015	NJSLV01	9	82.2	7.73	0.32	11	19.5		
June 15, 2015	NJSLV01	12	77.1	7.84	0.92	10	22		
May 11, 2015	NJSLV01	12	94.8	7.94	1.24	7.35	20		
April 20, 2015	NJSLV01	12	95.8	7.65	0.26	5.5	15	1.227	5.421

The following graph shows the correlation between specific conductivity and Total Dissolved Solids in the Slocan area (from Quamme, 2016).



In May and July of 2016 water samples were taken from various locations in the Silverton Creek Watershed. These were analyzed for specific conductivity, pH and turbidity. The table below shows the results of those analyses. Turbidity was very low (less than 1 NTU) and is not shown on the table.

Location	Elevation	Conductivity	pH	Date
N.SideCreek1	1073	124	7.7	19-Jul-16
SilvertonCk_lower	1133	69	7.8	19-Jul-16
SilvertonCk_lower	1133	49	7.3	31-May-16
N.SideCreek2	678	319	8.2	19-Jul-16
Fishermaiden_Lake	1639	52	7.3	31-May-16
Silverton_Creek_upper	1349	74	7.4	31-May-16
Fennell_Creek	1448	70	7.8	31-May-16

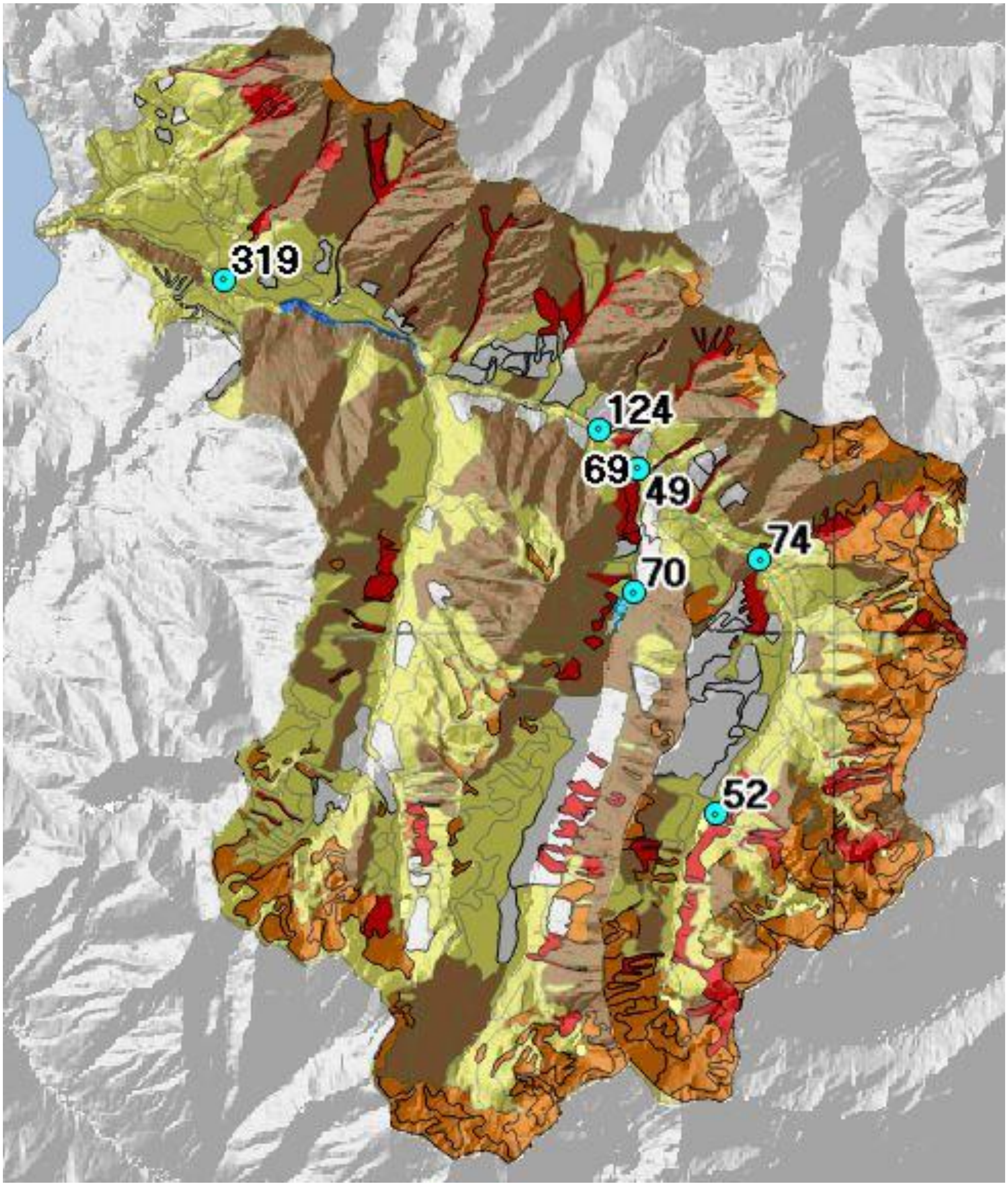
These samples also have Specific Conductivities that fall between 50-150 microsiemens, except for the sample taken from the mouth of N. Side Creek 2 which has a Specific Conductivity of 319 microsiemens.

This indicates that this water in N. Side Creek 2 has dissolved more minerals that the other creeks. More study is required to determine whether this is due to the minerals in this valley, the residence time of the water or from some human cause. Obviously, the volume of water entering from N. Side Creek 2 is insignificant compared to the total volume of water flowing into Silverton Creek as it does not significantly affect the Specific Conductivity measurement taken downstream at the Highway 6 Bridge. We recommend that this creek be monitored with regular sampling for Specific Conductivity, Turbidity and pH and a one-time full water analysis that includes the trace metals (such as arsenic, iron, lead, zinc. aluminum).

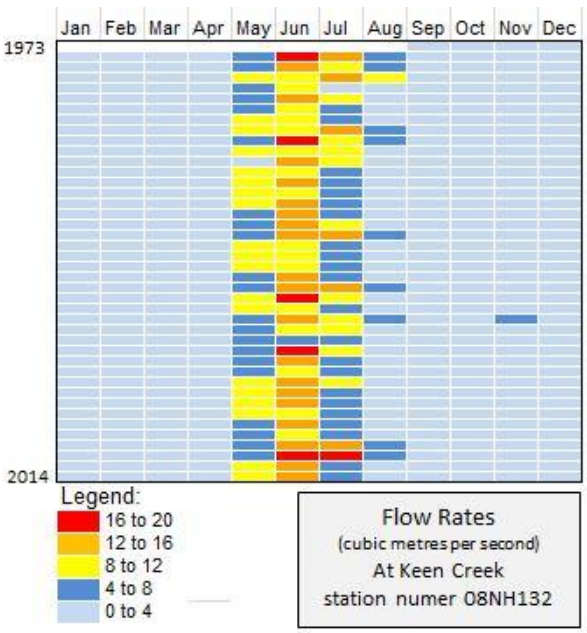
Specific Conductivity measurements were taken from Carpenter Creek, in New Denver, during the same period. Carpenter Creek's TDS is lowest in the spring freshet and increases through the summer, fall and winter each year. This is because the slower moving water that is coming from the soil storage in this watershed has had more time to dissolve minerals from the soil than the fast running melting snow and rains that come down in the Spring. Samples taken from other creeks and springs in the Slocan Watershed vary in TDS from 24 mg/l at high mountain lakes on bedrock to 1300 mg/l from a lower valley spring that is coming up from underground. This data indicates that our mountain creeks are vulnerable to drought. If the area around Silverton were to experience a long drought, or a dry period due to climate change, the TDS of the water in Silverton Creek would increase.

We also recommend that care be taken in the watershed to avoid contamination of the water by spills of any soluble material like Calcium Chloride (used for dust control), road salt, BTEX (in some fuels) or antifreeze. Anything soluble can affect the water in the Silverton aquifer as it will not be filtered out by the sand and gravel of the aquifer.

The map below shows the location where the 2016 samples were taken. The values shown are the specific conductivities.



Streamflow data



The nearest hydrometric station, operated by Environment Canada, is on Keen Creek, on the east side of Long Mountain. Daily stream flow data is available from that monitoring station from 1973 to the present. The graph shows the monthly average flow rate in Keen Creek from 1973 to 2014. The red colour indicates high flow rates; the light blue indicates low flow rates. The graph shows the low flow rates in winter followed by the freshet occurring in May and June each year. Summer rains show in July and August as the orange, yellow and dark blue colours. Flow rate is in cubic meters per second. Peak rates can be 50 times the winter rates. The flow in Silverton Creek probably behaved the same, since the Keen Creek hydrometric station is immediately east of the Silverton Creek watershed.

Water Holdup and Storage

Water that falls as snow remains in the watershed until it evaporates or melts. Much of the snow that falls on a forest is held up in the tree branches. Much of this snow never reaches the ground. Research by Dr. John Pomeroy has shown that "… about one-third of annual snowfall is lost to sublimation in dense coniferous forests throughout Canada." (Sandford, 2012, page 112).

Snow that does reach the ground still sublimates but not to the same extent. Wind increases the rate of sublimation both in the trees and on the ground, even in cold weather.

Much of the water from rain and snow enters the soil in the watershed. Vegetation absorbs a large amount of this water and transpires the water vapour into the atmosphere. Water that stands in wetlands and lakes evaporates back to the atmosphere as well.

"Thus we see that forests affect hydrology in at least three significant ways. They capture, store, and redistribute water over the landscape: into aquatic ecosystems, the soil and subsurface aquifers. During periods of high physiological activity in spring and summer, forests transpire large volumes of water into the atmosphere, which becomes available as precipitation elsewhere. Through the engine of sublimation, forests also put a great deal of water back into the atmosphere, even during the coldest periods of winter. Forests are the living link between the earth and its atmosphere. They are the corals that thrive in our ocean of air."
From "Cold Matters",
Robert William Sandford, 2012

The steepness of the terrain in a watershed affects the speed with which water moves through the valleys. Slopes of greater than 45 degrees indicate that the exposed material is bedrock. Bedrock that is highly fractured will hold a little bit of water but water moves easily through fractures and the amount retained is very small.

Colluvium (scree, talus) is rock that has broken away from the bedrock and slid down to its current position by gravity. The length of time that water stays in the colluvium is controlled by the amount and location of material that impedes the flow and the slope of the underlying bedrock. Colluvium, being simply broken rock, does not slow down the movement of water significantly because there is no storage capacity and the underlying bedrock, apart from fractures, sheds the water. So, the water flows through these zones of high hydraulic conductivity quickly, often in a matter of days. Most colluvium is on steep surfaces.

Till is glacial material which often underlays the colluvium. The glacial ice removed most, if not all, of the colluvium that was in the valley before glaciation. Till is an unsorted mix of material that grades from clay to boulders. The clay forms the matrix of till and does not allow any significant water movement nor usable storage capacity, since the water in the till is held there by the clay particles.

The soil in the watershed holds large amounts of water, more than the lakes, wetlands and aquifers in this watershed. The hydraulic conductivity of soils, because of the fine material, clays and decomposed vegetation, is far less than that of sands and gravels so water is retained well by soils. Water that is not used by plants or lost through evaporation is held for a long time in the soil but some moves out through springs and enters the active surface flow system.

There are several sand deposits of unknown size that were observed by the author. These were on slopes and probably do not hold much water because it drains through them by gravity. The aquifers that act as storage reservoirs are in the valley bottoms. The amount of water that is retained by a valley is related to the broadness of the valley bottom. Wide valley bottoms often contain aquifers that will hold water and release it slowly over time. The Silverton Creek watershed only has one defined aquifer in the main valley bottom, as described previously. There is potentially more in the three north-south valleys where the valley bottom is wide, such as at Fishermaiden Lake and the Fennell Creek wetland.

In the Silverton Watershed there are several larger wetlands and potentially many small ones. Wetlands often have aquifers associated with them because they are in flat areas where the water flows more slowly and sediment such as sand and silt drop out because of the decreased energy of the stream. Water that pauses in wetlands has a longer time to enter low permeability aquifers that are associated with the wetland.

Land Movement

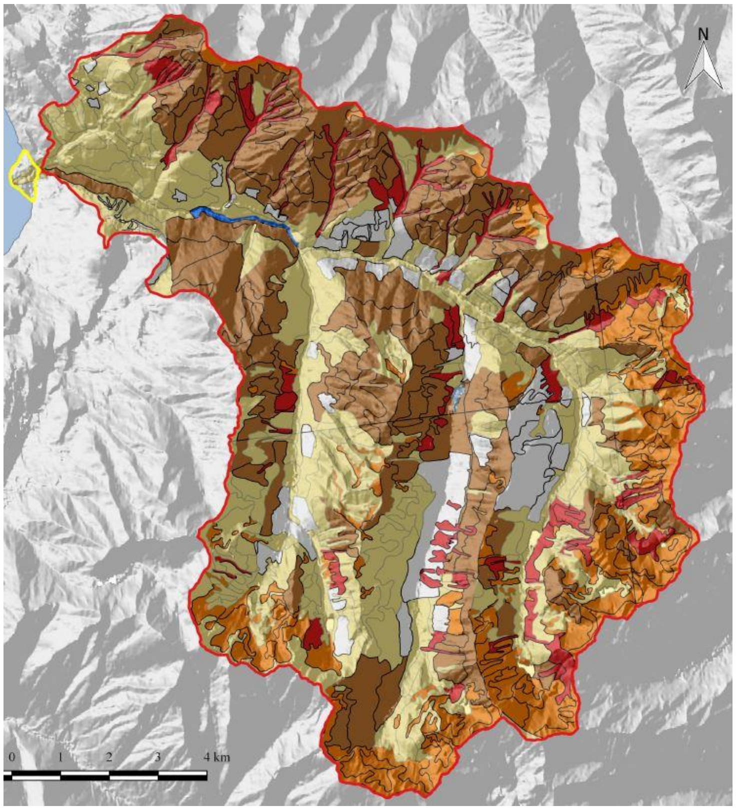
Landslides and soil slumps are natural events that occur in a watershed. They are usually triggered by heavy rain fall. Climate change is forecast to create abnormal rainfalls so we can expect a corresponding increase in land movements.

Snow slides are common and have a more complex trigger mechanism but with climate change causing more unusual weather patterns we can expect more snow slides.

Both of these mass movements are exacerbated by certain human activities such as road building and tree removal. Wildfires also remove the strengthening power of tree roots. These activities also create opportunities for increased soil erosion.

Earthquakes can also trigger mass movements. This area of the province is very stable and earthquakes are almost non-existent. Even though there are faults in the bedrock, including the major Slocan Lake Fault running along the eastern side of Slocan Lake, there has been no recorded movement nor is there any geological evidence that this fault has moved for millions of years.

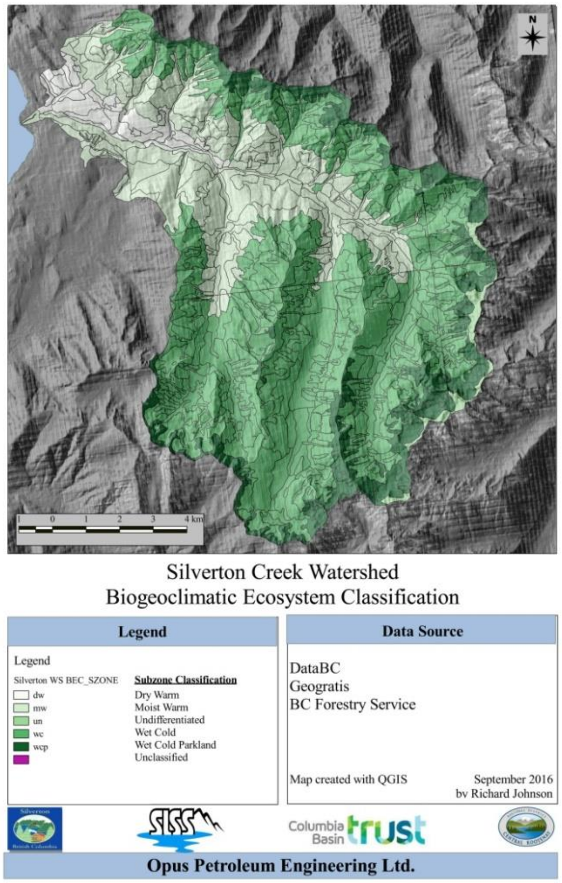
Vegetation Resource Inventory



The Province of BC has a large amount of data in its Vegetation Resource Inventory (VRI) database. These data can be used to look at various aspects of this watershed. One of the classifications included in that database is the factor that has the greatest "modifying effect" on the land.

The map to the right, produced from the VRI data, shows the location and type of "modifying effect" that shapes the valley and impacts how the valley can change. In particular, note the red areas which are slopes that are shaped by avalanches. These areas are places that should be monitored to watch for landslides that could impact the water quality by creating turbidity and increasing the total dissolved solids. The brown colour on the map represents areas that are modified by gully erosion. A larger version of this map is shown as Map 4 in Appendix A.

Slides often block streams which then build up water behind the blockage. When these "dams" let go they release the water behind them which then rushes down the valley as a "flash flood". If the banks of Silverton Creek cannot contain this rush of water it will spill over and result in sudden flooding within the Village.



The map at the left is from the same database and shows the Biogeoclimatic Ecosystem Classification (BEC) Subzones for the watershed. The location of tree species, plant and animal distribution, birds, insects, lichen and all related interactivity (ecosystems) is related to the BEC zone. The map shows the current classification; with climate change these zones could change. A larger version of this map is shown a Map 3 in Appendix A.

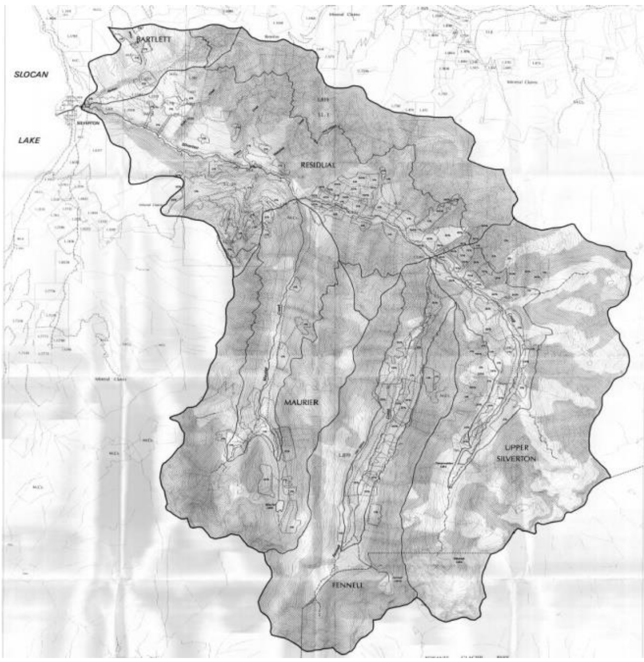
Other ways of understanding the vegetation in the watershed is through various remote sensing methods such as satellite images. Images and data from Landsat, Sentinel-1, Sentinel 2 and Aster satellites have been made available to the public for free and are easily downloadable. Free software such as SNAP and QGIS are easy to use and one can manipulate the data to look at an area using various methods. For instance, the data from a satellite's sensors can be combined to show the amount of chlorophyll in an area using a technique called Normalized Difference Vegetation Index (NDVI).

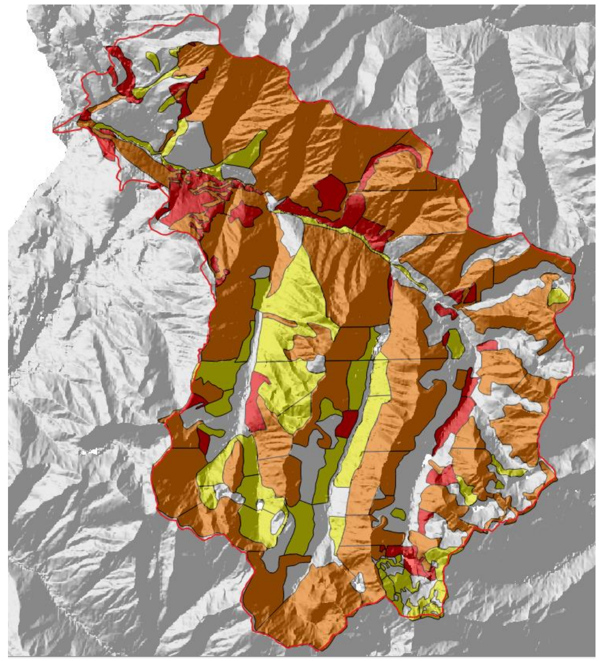
There is also more data available in the form of public reports. A search of Ecocat, the B.C Ministry of Environment's Ecological Reports Catalogue, produced several reports on the fish aspects of Silverton Creek. It also linked to an Interior Watershed Assessment Procedure (IWAP) report which discusses, among other things, slope stability and erosion.

Silverton Creek was designated as a community watershed, however, the status is now shown as "cancelled". In response to the Forest Practices Code requirements for community watersheds, an IWAP report for Silverton Creek watershed was produced by Dobson Engineering Ltd. (Dobson, 1998). It was initiated by Slocan Forest Products Ltd. (Slocan Division). The purpose of that watershed assessment was to determine if there is a potential for cumulative hydrologic impacts on Silverton Creek from past and proposed forest development. The four primary impact categories addressed in the IWAP are: 1) Peak Flows; 2) Surface Erosion; 3) Riparian Buffers; 4) Mass Wasting.

The field work was carried out by Dobson in 1995, 1996 and 1997. The report contains a great deal of information and the Executive Summary is included in Appendix C. The link where one can read the full report is included in the bibliography. Note that the file is secured so one can read it but not easily print the report.

The study contains a map that is downloaded separately from the document. It shows the Erodible Soils and Unstable Slopes. The map was digitized by Opus and georeferenced. Since the Opus version of the map was done without access to the full-scale original, the original map must be used for any detailed purposes.





Map from Dobson IWAP Report

Map colour coded by Opus

The Opus version is shown here because it is easier to interpret than the small copy shown above. The coloured version gives an idea of the conditions in the valley. The yellow areas are areas that have erodible soils only, the red areas are slope stability sensitive areas and the brown/orange areas are both soil erosion and slope stability sensitive areas.

Monitoring

Introduction

The Village of Silverton supplies drinking water to the village residents from two wells that pump water from the Silverton Aquifer. The Silverton Aquifer receives a continuing supply of water from Silverton Creek which flows from the Silverton Creek Watershed (Johnson, 2016). The Village is, therefore, vitally interested in the quality and quantity of water coming from the Watershed.

The Slocan Lake Stewardship Society in cooperation with the Village is currently monitoring Silverton Creek. The monitoring is being done under the guidance and support of the Columbia Basin Water Quality Monitoring Program administered by the Mainstreams Environmental Society (http://mainstreams.ca/) using the Environment Canada CABIN protocol.

Both the Province of British Columbia and the Ministry of Environment (Canada) have prepared field manuals describing how to sample and preserve water samples. Links to the manuals can be found in the Bibliography. (Prov. of BC, 2003) & (Ministry of Environment, 2009)

Water quality, quantity and timing of flow monitoring can be done by recording these data at the Notch and elsewhere within the watershed.

- **It is recommended that a continuous water monitoring program be maintained. Monitoring can also be done by the community by reporting visual problems to a central agency.**
- **It is recommended that the Village maintain a system to record and archive this information.**

The water quality and quantity in Silverton Creek is controlled by the amount of rainfall and snowmelt as well as the condition of the material through which the water flows.

- **Ground disturbances such as landslide, erosion and snow slides should be monitored as well.**
- **There is no system in place in the community to monitor the conditions and changes in the watershed. This should also be established.**

Silverton Creek Watershed shows on iMapBC as a cancelled Community Watershed, however, Bartlett Creek is shown as an active Community Watershed.

- **It is recommended that Silverton Creek Watershed be re-instated as a community watershed since it is the source of the Village's drinking water. Under the "Community Watershed" designation the community has the right and obligation to monitor the watershed and the activities within it.**

In addition to the visual reports from the community and the water quality and quantity measurements there are many remote sensing products that are free and take very little training to use. In times of crisis satellite data is available fast enough to monitor land movement, wildfire and flood events every few days.

The Forest Practices Board has issued two publications of interest to communities that have a Community Watershed. The first, Special Investigation, "Community Watersheds: From Objectives to Results on the Ground" (Forest Practices Board, 2014) is a downloadable ".pdf" document (See Bibliography for the link). A second document, "Forest Practices Code Community Watershed Guidebook" (Forest Practices Board, 2014) is available on-line. (See Bibliography for the link). It states "*The purpose of this guidebook is to explain resource development practices that are intended to prevent long-term change to background water quality, quantity, and timing of flow. Short-term changes may occur within the natural variability of the water supply. The community watershed guidelines in this guidebook recognize water quality, quantity and timing of flow as the principal values in community watersheds. The guidelines protect watersheds by guiding and regulating forest resource activities."*

Water Quality and Quantity

Water quality

The Water Movement and Water Quality section of this report described the results of measurements performed on water samples taken at various times and places in the watershed. Many of these are simple measurements that need specialized instruments but the procedure to make the measurement is simple to do.

Simple measurements

Water quality measurements can be taken with simple instruments which are simple to use and relatively inexpensive. The usual measurements are Conductivity and Turbidity and pH.

Water carries material in two forms, suspended solids and dissolved material. The dissolved material (ions) affect the Conductivity, so measurements of the Conductivity highlight changes to these dissolved solids. Conductivity will vary naturally with the volume of flow in the creek.

Turbidity is a measure of the amount of suspended solids in the water. It is affected by erosion and mass land movements (slides, slumps).

The pH is a measure of the acidity or alkalinity of water based upon a 0 to 14 scale where 7 represents neutral water. The normal range of pH for water in the Slocan watershed is between 7.0 and 8.0 (Quamme et al, 2016).

These three measurements can be used to quickly and cheaply monitor the health of the watershed. An automatic logging system can be set up, such as that used on creeks by Kaslo, to record these measurements.

Lab measurements

Other measurements that describe the quality of water are done in commercial laboratories. Analysis of metals dissolved in the water is done by taking a sample of the water, saving it in a special manner and sending it to a commercial laboratory. This analysis costs just over $200 as of the date of this report. Metals are in such small amounts that they do not affect the conductivity significantly.

Metals are significant because they affect human health. The village water supply is periodically checked for metals. Coliform is a measure of contamination of the water from animal or human waste and also affects health.

Water Quantity

The volume of water exiting the watershed can be used to monitor changes in the watershed. It will vary depending upon rainfall, snowmelt and the amount of water holdup in the watershed. Changes in the volume can be caused by other events as well. A sharp reduction in flow is often caused by a landslide or ice dam. These are often followed by a sudden release of water and flooding.

Measurement of water flow volumes can be done using recording instruments at the "Notch", described in the "Report on the Silverton Aquifer" (Johnson, 2016) in conjunction with water quality and quantity recordings. The remote hydrographic station on Keen Creek is one such station that reports daily flow rates. It is recommended that a hydrographic station be set up in Silverton Village to do similar measurements.

Remote Monitoring

As time progresses, more and more information is available from remote sensing devices such as air photos and Lidar (from planes) and radar, visual spectrum and other frequency bands (from satellites). Some of these require specialized training to interpret but recently a lot of data has been made freely available from the various agencies that have collected it.

The satellites collect data from both visual and non-visual bands and free, open-source software to manipulate and display the data is available. For instance, images from Landsat-8 (11 bands), Sentinel-1 (radar), Sentinel-2 (13 bands) and ASTER (14 bands) are all downloadable for free from various websites. Because these satellites are constantly "taking pictures" one can get images as frequently as a few days apart and the amount of historical data continues to grow.

Bibliography

Chatwin, S.C. et al, 1994, "A Guide for Management of Landslide-Prone Terrain in the Pacific Northwest, Second Edition", Land Management Handbook NUMBER 18, Research Branch, Ministry of Forests, B.C. 220 pp

Curran,D., et al, 2009, "The Groundwater Bylaws Toolkit", Okanagan Basin Water Board http://www.obwb.ca/fileadmin/docs/groundwater_bylaws_toolkit.pdf

Quamme, D.; MacKenzie, R.; Johnson, R.; Durand, R.; Ehlers, T. , 2016, "Slocan Valley Wetland and Assessment Program - Wetland Invertebrate Assessment Tool", prepared for the Fish and Wildlife Compensation Program

Dobson Engineering, 1998, "Interior Watershed Assessment of the Silverton Creek Watershed" prepared for Slocan Forest Products by Dobson Engineering Ltd., 28 pp http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=8791

Forest Analysis and Inventory Branch, March 2016, "Vegetation Resources Inventory, Photo Interpretation Procedures" Version 3.2, Ministry of Forests, Lands and Natural resource Operations https://www.for.gov.bc.ca/hts/risc/pubs/teveg/vri_photointerp_2016/VRI_Photo_Interpretation_ProceduresVer3.2.pdf

Forest Practices Board, 1995, "Riparian Management Area Guidebook" file:///C:/Users/Public/Documents/Organizations/SWAMP/Operations/Phase%20II%20Season/Forestry%20Practices%20Guidebook/Riparian%20Management%20Area%20Guidebook%20%20Table%20of%20Contents.htm

Forest Practices Board, 1996, "Forest Practices Code Community Watershed Guidebook", available on-line at https://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCguide/WATRSHED/watertoc.htm

Hall, E.H., Long, M.T. and Remboldt, M.D., 1994, "Slope Stability Reference Guide for National Forests in the United States, Volume II", US Dept. of Agriculture, Forest Service

Heath, Ralph C., 2004, "Basic Ground-Water Hydrology", USGS Water Supply Paper 2220 (revised from 1983), 86p.

Howes, D.E., and Kenk, E., 1997, "Terrain Classification System For British Columbia (Version 2)", Ministry of Environment, Province of British Columbia https://www.for.gov.bc.ca/hts/risc/pubs/teecolo/terclass/index.html

Johnson, R.H., 2016, "Hydrogeological Report on the Silverton Aquifer", Opus Petroleum Engineering Ltd.

Kehew, A.E., 201, "Applied Chemical Hydrology", Prentice Hall

Kreye, R., Ronneseth, K. and Wei, M., 1994. "An Aquifer Classification System for Ground Water Management in British Columbia", 6th National Drinking Water Conference, Victoria, BC.
http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/Aq_Classification/Aq_Class.html

Logan, J., 2002, "Geoscience Map 2002-1: Intrusion - Related Mineral Occurrences of the Cretaceous Bayonne Magmatic Belt, Southeast British Columbia", BC Geological Survey, Ministry of Energy, Mines and Petroleum Resources of BC.
http://www.empr.gov.bc.ca/MINING/GEOSCIENCE/BEDROCKMAPPING/GEOLOGICALMAPS/Pages/GeoscienceMap2002-1.aspx

Manger, G.E.,1963, "Porosity and Bulk Density of Sedimentary Rocks", Geological Survey Bulletin 1144-E, US Department of the Interior
https://pubs.usgs.gov/bul/1144e/report.pdf

Ministry of Environment, 2009, "The Canadian Aquatic Biomonitoring Network, Field Manual, Version 1.", Ministry of Environment, Science & Information Branch, Watershed and Aquifer Science Section for the Resources Information Standards Committee.
http://www.ilmb.gov.bc.ca/risc

Operation Matters Blog, 2012, "Groundwater", Kentucky Department for Environmental Protection
https://kyocp.wordpress.com/2012/04/25/groundwater/

Prov. Of BC, 2003, "British Columbia Field Sampling Manual", Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection, Province of British Columbia
http://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/field_sample_man2013.pdf

Turner, R.J.W. et al, 2009, "GeoTour Guide for the West Kootenay, British Columbia" Geological Survey of Canada Open File 6135.

Glossary

Acronyms

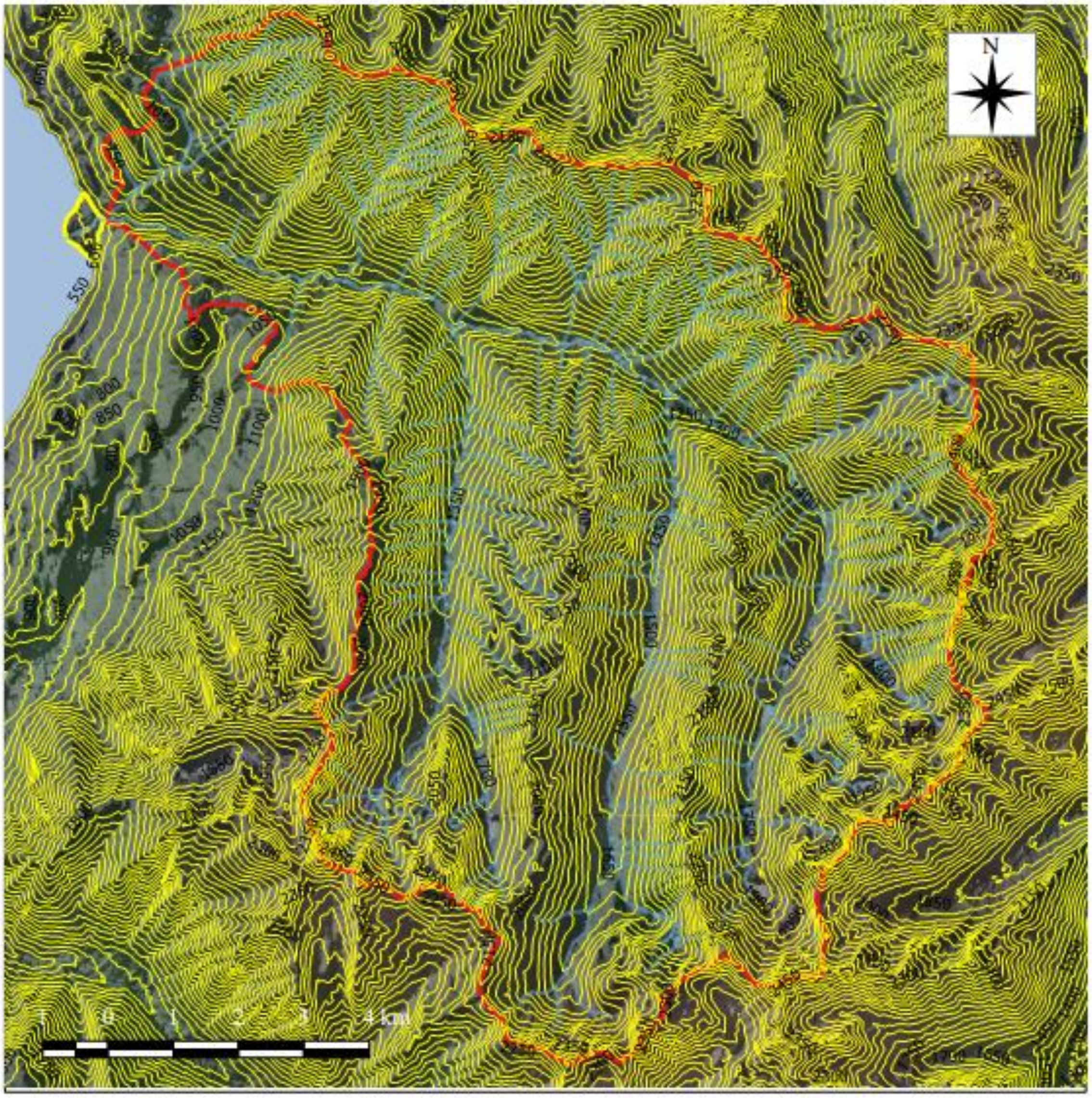
FLNRO: Ministry of Forests, Lands and Natural Resource Operations (B.C.)
RISC: Resource Inventory Standards Committee, Integrated Land Management Bureau, BC
TEI: Terrestrial Ecosystem Inventory
TEM: Terrestrial Ecosystem Mapping
VRI: Vegetation Resource Inventory
NTU: Nephelometric Turbidity Unit

Definitions

ANGLE OF REPOSE**:** The angle, measured from the horizontal, at which the material is stable. Scree slopes have different angles of repose, depending upon the rock from which they came. For example, shale scree has a lower angle of repose than blocky limestone.
CIRQUE: A steep–walled, half bowl-like recess, horseshoe or semi–circular in plan, situated high on the side of a mountain and produced by the erosive activity of a mountain glacier.
COLLUVIUM: Materials that have reached their present positions as a result of direct, gravity–induced movement involving no agent of transportation such as water or ice, although the moving material may have contained water and/or ice.
DRIFT: Any material, such as boulders, till, gravel, sand or clay, transported by a glacier, and subsequently deposited by ice or meltwater.
ESKER: A sinuous low ridge composed of sand and gravel formed by deposition from meltwater running through a channel beneath or within glacier ice.
FEN: An area covered or filled with peat material which generally consists of well to moderately decomposed sedge (Carex spp.) species.
FLOODPLAIN: Flat land that is subject to flooding bordering a river; consists of unconsolidated depositional material transported by the related river.
FRESHET: Period of time in spring when snow melt combined with rainfall creates high water flows in creeks and rivers and lake levels rise.
HYDRAULIC CONDUCTIVITY: The rate at which water moves through the material. It is measured in distance per time such as meters per day or feet per minute.
KAME: A steep sided hill or short ridge of stratified drift, formed in contact with glacier ice.
KAME TERRACE: A remnant terrace of stratified drift deposited between a valley ice lobe and the bounding side slope of the valley.
RESIDENCE TIME: Amount of time that water remains in the material.
TALUS (SCREE) SLOPE: An accumulation of sharp angular rock fragments at the base of a cliff; produced by frost action and other processes from an exposed bedrock slope.
TILL**:** Till consists of well-compacted to non-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, often a mixture of sand, silt and clay.
WATERSHED: The area of land within which any rainfall tends to flow toward a common discharge point.

Appendix A

Maps



Silverton Watershed Topographic Map

Legend

Watershed Outline:

Silverton Aquifer Outline:

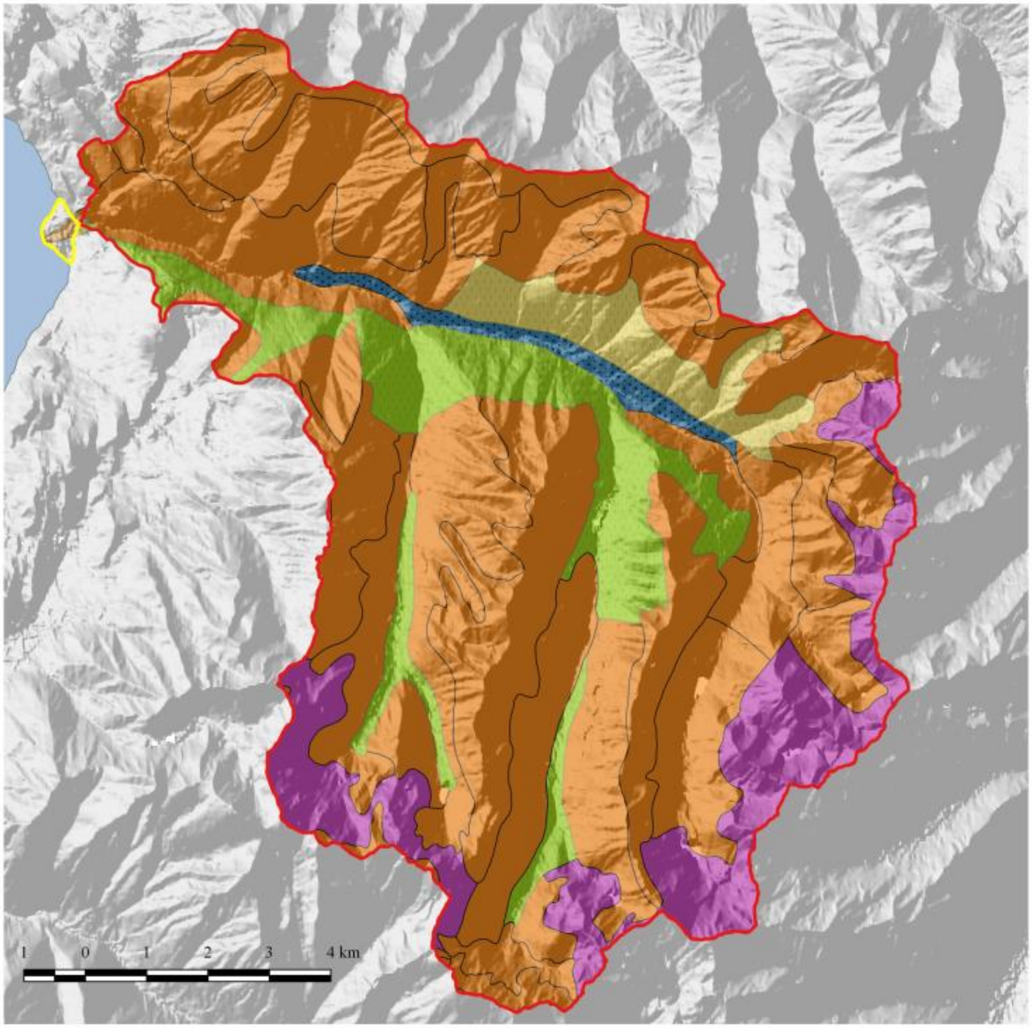
Contour Interval: 100 meters

Data Source

DataBC
Geogratis
USGS/NASA

Richard Johnson September 2016

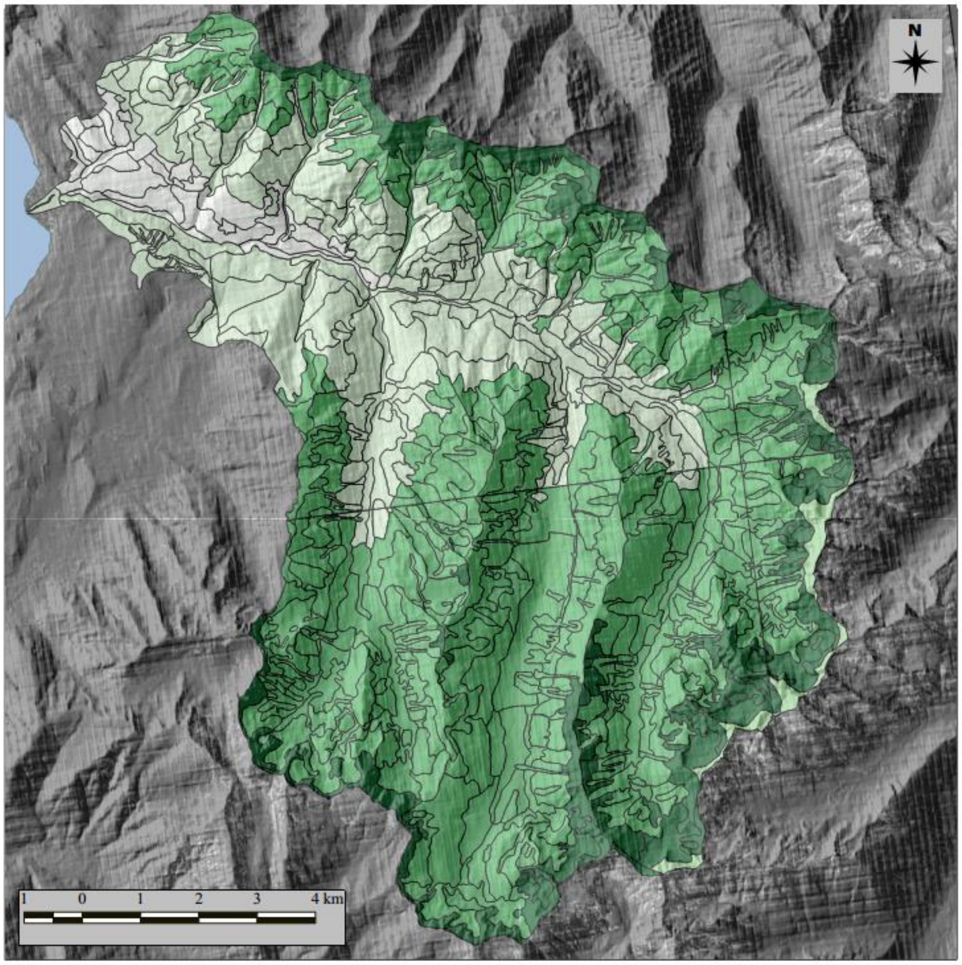
Opus Petroleum Engineering Ltd.



Silverton Watershed:Surficial Geology Map

Description	Data Source
Watershed outline **Aquifer Outline** Legend Silverton Watershed TEM Bedrock Colluvium Fluvial Material Glaciofluvial Material Morainal Mateiral (till) Not Classified	DataBC Geogratis USGS/NASA Richard Johnson October 2016

Opus Petroleum Engineering Ltd.



Silverton Creek Watershed
Biogeoclimatic Ecosystem Classification

Legend

Legend

Silverton WS BEC_SZONE	Subzone Classification
dw	Dry Warm
mw	Moist Warm
un	Undifferentiated
wc	Wet Cold
wcp	Wet Cold Parkland
	Unclassified

Data Source

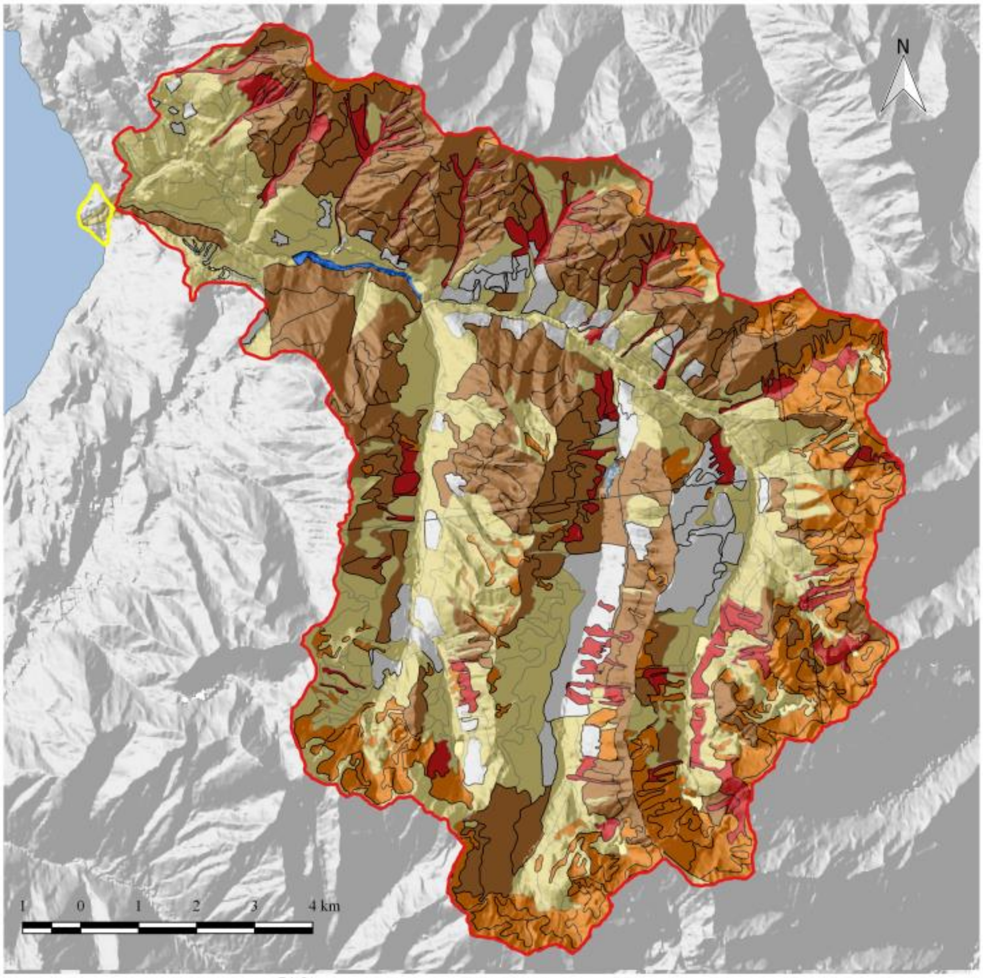
DataBC
Geogratis
BC Forestry Service

Map created with QGIS

September 2016
by Richard Johnson

Columbia Basin trust

Opus Petroleum Engineering Ltd.



Silverton Watershed: Surficial Modification Process

Description	Data Source
Watershed outline (red) **Aquifer Outline** (yellow) Legend Surficial_Modification_process Undefined Avalanching River Channelling Mass Movement No Process Observed Flooding Gully Erosion	DataBC Geogratis USGS/NASA Richard Johnson October 2016

Columbia Basin trust

Opus Petroleum Engineering Ltd.

Appendix B

Silverton Water Quality Monitoring Data

From the Slocan Lake Stewardship Society

2015-2016 WQMP Cumulative Field Chemistry

Date	Site Code	Dissolved Oxygen	Specific Conductivity	pH	Turbidity	Water Temperature	Air Temperature	Velocity (m/s)	Flow (m3/s)
October 13, 2015	NJSLV01	13	82.5	8.4	1.6	6.5	10	0.47	1.75
September 20, 2015	NJSLV01	10	88.6	8.25	0.41	9.4	15.8	0.64	2.58
August 10, 2015	NJSLV01	11	91.7		0.52	13.7	22.5	0.771	3.405
July 13, 2015	NJSLV01	9	82.2	7.73	0.32	11	19.5		
June 15, 2015	NJSLV01	12	77.1	7.84	0.92	10	22		
May 11, 2015	NJSLV01	12	94.8	7.94	1.24	7.35	20		
April 20, 2015	NJSLV01	12	95.8	7.65	0.26	5.5	15	1.227	5.421

Water Chemistry, Silverton Creek, from Slocan Lake Stewardship Society

Non-Metals

Stewardship Group	Sample Date (dd/mm/yy)	Site Code	Site Name	Nitrite (N)	Nitrate (N)	Alkalinity (Total as CaCO3)	Alkalinity (PP as CaCO3)	Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Orthophosphate (P)	Nitrate plus Nitrite (N)	Dissolved Oxygen	Specific Conductivity	pH	Turbidity
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	uS/cm		NTU
			Guideline	BC App: 0.02 CCME: 0.060. HC Drinking: 1	CCME: 3. HC Drinking: 10 BC App: 3.0	no steam guideline	no guideline	no guideline	no guideline	no guideline	no guideline	no guideline	BC App: 8 all stages other than embryo BC App11 buried embryo	no guideline	BC App and CCME:6.5-9.0	no mean guideline
k Stewardshi	10/13/2015 18:00	NJSLV01	SILVERTON CREEK WQM	<0.0050	0.042							0.042	13	82.5	8.4	1.6
k Stewardshi	9/20/2015 0:00	NJSLV01	NJSLV01	<0.0050	<0.020	41	<0.50	50	<0.50	<0.50	<5.01	<0.020	10	88.6	8.25	0.41
k Stewardshi	8/10/2015 18:00	NJSLV01	NJSLV 01	<0.0050	0.024						<5	0.024	11	91.7		0.52
k Stewardshi	7/13/2015 18:45	NJSLVO1	ERTON CURB WQMP, NJS	<0.0050	<0.020						<5	<0.020	9	82.2	7.73	0.32
k Stewardshi	6/15/2015 18:00	NJSLV01	/ERTON CRK WQMP NJS	<0.0050	0.034						<5	0.034	12	77.1	7.84	0.92
k Stewardshi	5/11/2015 18:00	NJSL V01	NJSLV01	<0.0050	0.129						<5	0.129	12	94.8	7.94	1.24
k Stewardshi	4/20/2015 13:30	NJSLV01	ERTON CREEK WQMP/ NJ	<0.0050	0.114							0.114	12	95.8	7.65	0.26

Grey	BC Approved Water Quality Guidelines (Gover nment of BC 2006)
Blue	BC Working Water Quality Guidelines (Nagpal et al. 2006)
Orange	Canadian Water Quality Guidelines (CCME 19 99a)

Water Temperature	Air Temperature	Total Hardness (CaCO3)	Dissolved Hardness (CaCO3	Notes	Total Phosphorus (P)	Total Nitrogen (N)	Conductivity	Total Suspended Solids	Dissolved Calcium (Ca)	Dissolved Magnesium (Mg)	Sulphate (SO4)	Dissolved Chloride (Cl)	Total Ammonia (NH3)	E. Coli
C	C	mg/L	mg/L	µg/L		mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	CFU	
Max. daily 19oC. Max. incubation (spring/fall) is 12 oC.	no guideline	no guideline	no guideline	CCME: 1.5 X background , see next column. HC Drinking =10	CCME: trophic range (based on backgrd values for site).	no guideline	no guideline	No mean guideline	no stream guideline	no guideline				
6.5	10					0.099		<4.0				0.62		2
9.4	15.8	49.1			<0.0050	0.095		<4.0				1.6		<1
13.7	22.5				<0.0050	0.074		<4.0				<0.50		4
11	19.5				<0.0050	0.027		<4.0				<0.50		15
10	22	35			<0.0050	0.059		<4.0				<0.50		<1
7.35	20				0.0069	0.183		<4.0				<0.50		<1
5.5	15					0.151		<4.0				<0.50		<1

Water Chemistry, Silverton Creek, from Slocan Lake Stewardship Society

Metals

Stewardship Group	Sample Date (dd/mm/yy)	Site Code	Site Name	pH	Total Hardness (CaCO3)	Total Aluminum (Al)	Total Antimony (Sb)	Total Arsenic (As)	Total Barium (Ba)	Total Beryllium (Be)	Total Bismuth (Bi)	Total Boron (B)	Total Cadmium (Cd)		Total Calcium (Ca)	Total Chromium (Cr)
			Units	ph units	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L		mg/L	µg/L
			Guideline	BC App & CCME:6.5-9.0		CCME: 100 when pH is > 6.5. HC: 100 (max)	BC Work: 20. HC: 6 (max)	BC App: 5. HC: 10 (max)	BC Work (mean) 1000. HC: 1000 (max)	BC Work: 5.3. BC Work: 4.0 (max)	no guideline	BC App: 1200. HC: 5000 (max)	CCME: (10^0.86[log10(Hardness)]-3.2). HC: 5 (max)	Guideline Value Guideline provided is also BC Working	no guideline	HC: 50 (max)
k Stewardshi	9/20/2015 0:00	NJSLV01	NJSLV01		49.1	8.2	<0.50	0.38	11.2	<0.10	<1.0	<50	0.163		16.3	<1.0
k Stewardshi	6/15/2015 18:00	NJSLV01	/ERTON CRK WQMP NJSLV01		35	36.1	<0.50	0.36	8.3	<0.10	<1.0	<50	0.096		11.7	<1.0

BC Approved Water Quality Guidelines (Governme nt of BC 2006)

BC Working Water Quality Guidelines (Nagpal et a 2006)

Canadian Water Quality Guidelines (CCME 1999a)

red italics input using results from other dates or sites (e.g. av erages)

Total Cobalt (Co)	Total Copper (Cu)	Total Iron (Fe)	Total Lead (Pb)		Total Lithium (Li)	Total Magnesium (Mg)	Total Manganese (Mn)	
µg/L	µg/L	µg/L	µg/L		µg/L	mg/L	µg/L	
BC App: 4.0	2.0 µg/L when hardness is 50 mg/L; and 0.04*hardn	CCME: 300. HC: 300 (aesthetic) and BC App 1000	when hardness ?8: (3.31 + e(1.273 ln [hardness] - 4.704). HC:	BC App. guideline calculation	BC Work: 14	no guideline	BC App. = (0.0044*hardness+0.605)*1000. HC: 50 (aesthetic)	BC App. guideline calculation
<0.50	<0.50	14	0.33		<5.0	2.05	<1.0	
<0.50	1.22	38	0.35		<5.0	1.4	1.6	

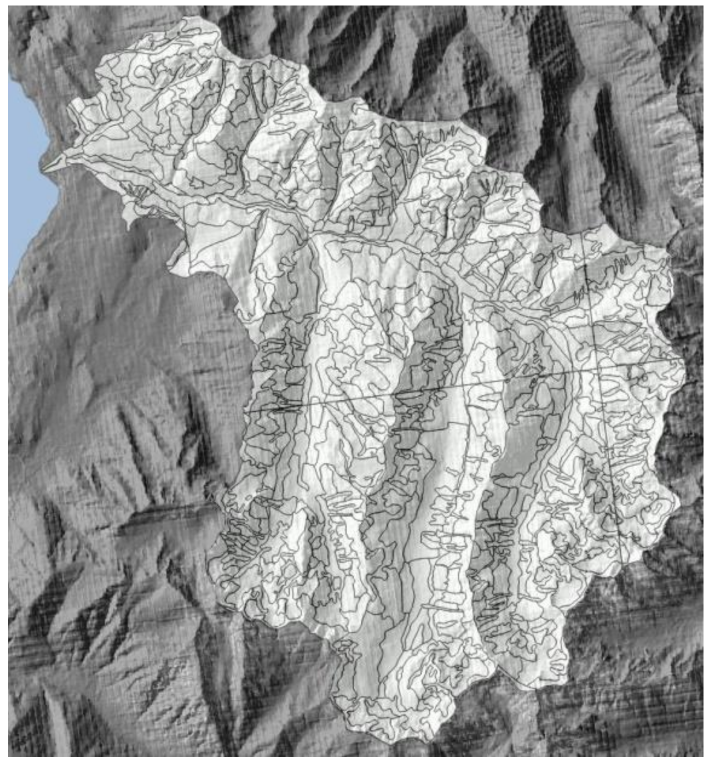
Total Mercury (Hg)	Total Molybdenum (Mo)	Total Nickel (Ni)	Total Potassium (K)	Total Selenium (Se)	Total Silicon (Si)	Total Silver (Ag)	Total Sodium (Na)	Total Strontium (Sr)
µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L
CCME 0.026	BC App. 1000; CCME 73. BC App: 250 (max)	CCME: e0.76[ln(hardness)]+1.06	BC Work: 372-432 mg/L	BC App. 2.0. HC and BC App: 10 (max)	no guideline	1.5 if hardness>100, 0.05 if hardness is <100. CCME 0.1.	HC: 200 (aesthetic)	no guideline
<0.010	1.1	<1.0	1.17	0.52	3540	<0.020	1.34	122
<0.010	<1.0	<1.0	0.861	0.31	3180	<0.020	0.959	87.5

Appendix C

Other Reports and Data

Forestry data

The Research Branch of the British Columbia Ministry of Forests, Lands and Natural Resource Operations (FLNRO) have a large database that shows detailed breakdowns of the watershed with parameters that relate to each of the areas.



Using this database and a GIS program such as ArcGIS or the free QGIS program, one can look at various aspects of the vegetation in the watershed. The data were constructed in detail by professionals from aerial photos, satellite images and on-the-ground examinations.

The polygons shown on the map at the right show the amount of detail used for these classifications. There are 762 individual polygons that have been defined for the Silverton Watershed.

The polygons each have up to 185 fields of data associated with them which allow the user to create maps that classify the vegetation within the polygon as to such things as the age of the trees (1 to 10 plus years), tree heights and diameters, and similar breakdowns that show what the forest is in the watershed.

The database can be accessed at the following website:
https://www.for.gov.bc.ca/HRE/becweb/resources/maps/index.html

RDCK WEBMAP

The Rural District of Central Kootenay has a Webmap service that displays an aerial photo of the watershed, with other layers that can be selected by the user. Also, Google Earth can display satellite images and print maps from various historical dates. These are easy to use and do not take much training.

Executive Summary from the Dobson Report, 1998

http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=8791

SLOCAN FOREST PRODUCTS LTD.
Slocan Division

Results of the Interior Watershed Assessment Procedure
for the
SILVERTON CREEK WATERSHED

(Arrow Forest District)

Executive Summary

Silverton Creek is designated as a community watershed for Silverton but except for occasional withdrawals from an intake in Bartlett Creek, it has not been developed as a community water supply. In 1995, an IWAP was initiated in the Silverton Creek watershed. Field work was carried out in August of 1995 and 1996 and in June 1997. Based on the office application of the IWAP and field surveys the following conclusions are presented for peak flow, surface erosion, riparian buffers, mass wasting and channels in the Silverton Creek watershed.

Office Assessment

Four sub-basins (Bartlett, Maurier, Fennell and Silverton above Fennel) were identified as well as the residual area and the total watershed for assessment. Peak flow increases associated with past and proposed forest development are not a hydrologic concern in this watershed due to low ECA's. The current ECA in the total watershed is 14.0% and in sub-basins it ranges from 3.9% to 19.3%. The five -year proposed ECA is 14.0% for the total watershed and range from 7.4% to 15.4% in sub-basins.

The results of the office assessment of the IWAP for Silverton Creek indicate there is no change between current hazard ratings and those associated with proposed development of Slocan Forest Products Ltd. In its five -year development plan. A low hazard rating is calculated for peak flows in all sub-basins and the total watershed. There are high hazard ratings for surface erosion in all sub-basins and the total watershed. Riparian buffers are a low hazard in all sub-basins and the total watershed, except Fennell which is high. Mass wasting is a low hazard in the Bartlett and Silverton above Fennell sub-basins, moderate in the Maurier and Fennell sub-basins and moderate over the total watershed.

Field Assessment

Hazard ratings were revised based upon a field assessment to reflect actual conditions in the watershed. There is no concern for peak flows in the entire watershed and low peak flow hazard ratings are confirmed for each sub-basin.

Stream channels assessed in the Silverton Creek watershed had stable

File: 525-010 Project: 97036 Date: March '98 DOBSON ENGINEERING LTD.

banks that were well vegetated with no obvious indications of erosion. Large boulders, frequently moss covered, provide a robust control. Debris in streams is naturally introduced from blowdown or snow avalanches.

High surface erosion hazard ratings were maintained due primarily to sediment delivery at active stream crossings and several high risk road fill slope locations. The exception is in the Fennell sub-basin where the combination of stable roads, distance of roads away from creeks and low proportion of crossings contributing sediment to streams reduced the hazard rating to low.

The riparian buffers hazard rating was reduced to moderate in the Fennell sub-basin, and the low riparian buffer hazard rating was maintained over the total watershed. One reason for reducing and maintaining the hazard rating is the prevalence of 30 year old selective harvesting near stream banks that has had limited impact to the riparian area.

The low and moderate mass wasting hazard ratings were maintained in all sub-basins. The moderate hazard rating is increased to high for the total watershed due to new landslides in the Residual area and on private land.

In accordance with the guidelines provided in the IWAP manual, a reconnaissance level channel assessment (RECAP) could be considered for Silverton Creek due to the moderate riparian buffers hazard rating and a high mass wasting hazard rating. Due to the low ECA in the watershed and the observed stability of channels, a full CAP is not required. A reconnaissance level channel assessment identifying overall channel stability, landslide effects, gross channel change, sediment movement and delivery potential, and channel restoration opportunities would be adequate. Prescriptions developed from this survey could address rehabilitation of landslides, restoration of channels to a stable morphology, and a risk assessment of the expected success of restoration efforts.