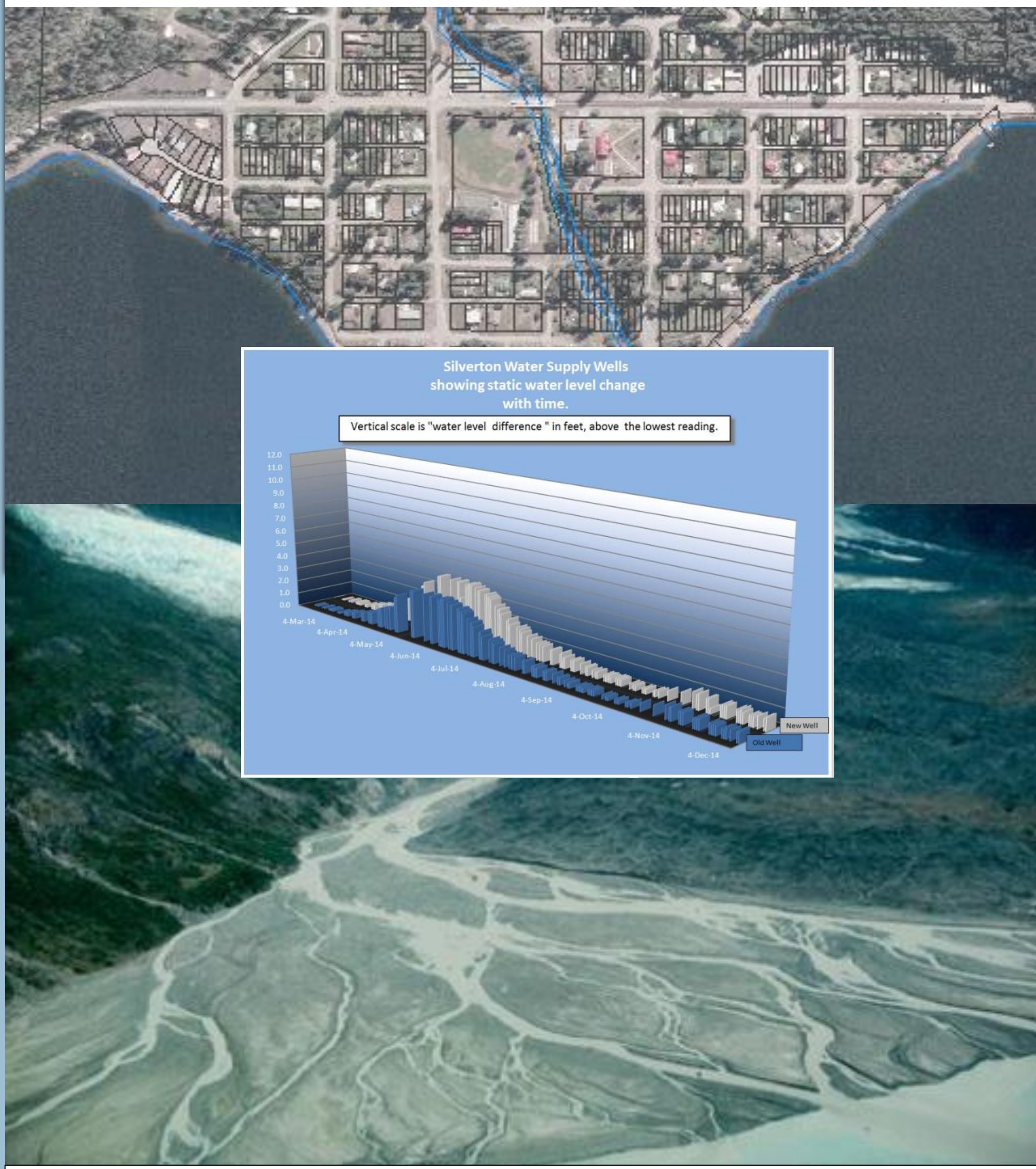
Silverton Aquifer Report

The Hydrogeology of the Silverton Aquifer



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

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September 13, 2016

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Richard Johnson
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Funding provided by: Columbia Basin Trust through the Community Initiatives and Affected Areas Program, Administered by the Regional District of Central Kootenay
Data from Village of Silverton files

Cover photo from USGS. "*Northwest looking oblique aerial photograph of the stagnant terminus of Rendu Glacier, Fairweather Range, Glacier Bay National Park, Alaska, showing a braided outwash plain fan delta that originates from a subglacial stream on the west side of the glacier*"
Cover map: From RDCK Webmap (beta version)

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Silverton Aquifer Report

Executive Summary

The Silverton aquifer underlies the Village of Silverton in the West Kootenay region of south-eastern British Columbia, Canada. It is composed of gravels and sands that were deposited in an outwash delta formed where Silverton Creek empties into Slocan Lake. The Village water supply is pumped from two wells that were drilled into the aquifer to a depth of approximately 48 meters (157 feet). The water in the aquifer enters from the bottom and sides of Silverton Creek as it flows across the gravel to the lakeshore. Because of the high *hydraulic conductivity* of the aquifer the water immediately flows down to the water table and then to the lake, so there is a constant flow of water underground from the creek to the lake through this unconfined aquifer.

The aquifer is very vulnerable to contamination from the surface because it has no confining overburden. The Village water supply is largely protected from surface contamination because of the lateral water flow within the aquifer, the screening effect of the creek and the pumping depth of the wells. On the other hand the aquifer is highly at risk from major contamination upstream in the Silverton Creek watershed because the contaminant would immediately be carried down and into the aquifer.

The Slocan Lake Stewardship Society monitors the creek monthly under its Water Quality Monitoring program. During 2015 all water quality guidelines were met. It is important that this monitoring continues because it will flag problems when they arise and it establishes a baseline that can be used for monitoring changes in the watershed.

The Village wells are located about 180 meters southwest of the notch in bedrock where the creek exits the mountain valley. The wells are about 30 meters south of the creek and 460 meters from the lakeshore. During *freshette* in May and June the high flow rate of water from rain and melting snow in the watershed caused a rise in the water table of about 1.4 meters (4.5 feet).

During 2014 the Village recorded pumping and water level data on the wells. When the Old Well was pumping at 390 US gallons (1.48 cubic meters) per minute it drew down 9.5 feet (2.9 meters). The static water level in the New Well, 25 feet (7.6 meters) away, only drew down 1.7 feet (0.52 meters). When the New Well was pumping at 460 US gallons (1.74 cubic meters) per minute it drew down 20 feet (6.1 meters). The drawdown in the static level in the Old Well was 1.8 feet (0.55 meters) at the same time. These data show that the *hydraulic conductivity* is excellent in this aquifer and that the wells *zone of influence* is probably less than 100 feet (30 meters) from the wells.

The aquifer is classed as IIIA using the BC aquifer classification system.

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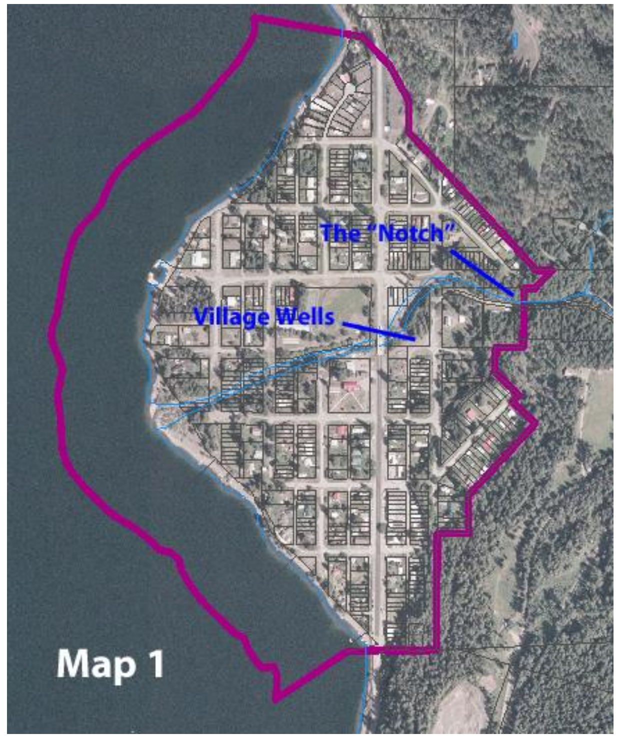
Introduction



The Silverton aquifer is located in the West Kootenay region of south-eastern British Columbia. It is an outwash delta formed by coarse sediments deposited by Silverton Creek as it leaves the igneous and metamorphic bedrock of the Selkirk Mountains at the "Notch" and enters Slocan Lake. It forms the relatively flat area upon which the Village of Silverton was built and is completely within the village boundary (coloured outline on the map at right). The Silverton Aquifer provides the Village of Silverton with its drinking water.

The Village wells are located 180 meters from the Notch. The distance from the Notch to the lake shore is 640 meters.

The aquifer is composed of gravel with boulders and cobbles but has minor horizontal interbeds of discontinuous sands, silts and clays. The aquifer is not directly connected to any significant aquifers in the valley upstream. It is classed as an unconfined aquifer because it has no confining clays above it.

The water within the aquifer is supplied by Silverton Creek as it flows across the gravel that is exposed in the creek bed. The water within the aquifer flows outward laterally from the creek and then turns toward the west where it discharges into Slocan Lake below the lake surface.

The aquifer is extremely important to the residents of the Village as it is their water supply. Previously the village used surface water from Bartlett creek and the ability to return to that system is still possible in the event of a catastrophe but using naturally filtered subsurface water is preferable to using easily contaminated surface water.

Opus Petroleum Engineering Ltd. was retained by the Slocan Lake Stewardship Society to provide a hydrological study of the Silverton Aquifer. This study is based upon public data, Village data, personal communications and personal observation. The Village provided the author access to all of its files and personnel, including historical pumping data. Leonard Casley, Public Works Foreman of the Village, was especially helpful. The author also spoke to Tim McCrory, the independent electrician who installed the pressure recording equipment in the Village wells. Water quality monitoring data of Silverton Creek was provided by the Slocan Lake Stewardship Society. The hydrogeology of the aquifer was interpreted by the author based upon the above data, personal knowledge of the geology of the area and published reports (See bibliography). This report addresses the water quality, quantity and the potential threats that could contaminate the water. Terms used in this report that are in *italics* are defined in the Glossary.

Conclusions

- All of the water in the Silverton aquifer comes from Silverton Creek.
  - Climate change could impact the amount of water in the creek.
  - If Silverton creek were to dry up, the aquifer would receive water through reverse flow from the lake.
- The aquifer is very susceptible to contamination from material spilled into the watershed and creek.
- The aquifer has a very high *hydraulic conductivity* and recovers very quickly after pumping.
- The *zone of influence* of the village wells is less than 100 feet (30 meters) from the wells.
- The Village wells do not remove a significant amount of water from the aquifer when compared to the total volume in the aquifer.
- The Village wells are not very vulnerable to contamination from within the Village
  - They are protected from contamination from north of the creek by the constant inflow of water from the creek which pushes contamination northward.
  - The wells pump from deep within the aquifer. Contamination from the surface near the wells would be confined to the top of the water table and be moved away from the wells by the constant flow of water toward the lake within the aquifer.
  - The depth of the wells helps the gravels and sands to filter any contamination before it reaches the intake screen of the well.

Recommendations

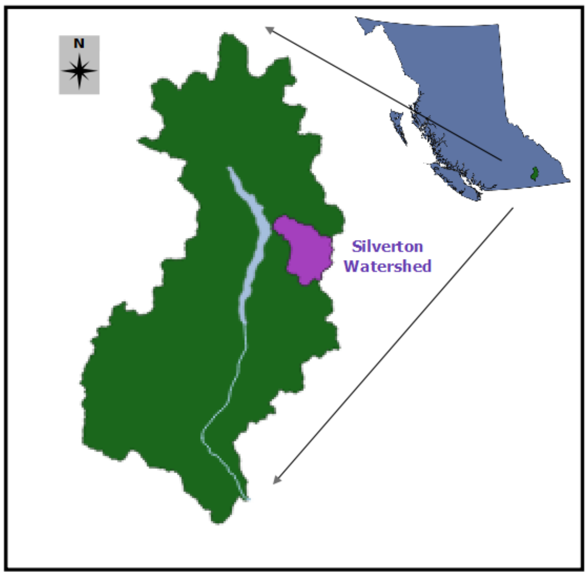
- Continue to avoid surface spills in the area around the wells.
- Monitor any activity in the watershed that could cause contamination of the water.
  - Monitor mining, logging, recreation, construction and all surface disturbances in the watershed.
  - Maintain the health of wetlands in the watershed.
- Continue water monitoring of Silverton creek.
  - The creek flow measurements should be made near the point where the pipeline crosses the creek. The flow is laminar at this point and the full volume of water exiting the valley is not yet influenced by percolation of the water into the aquifer.

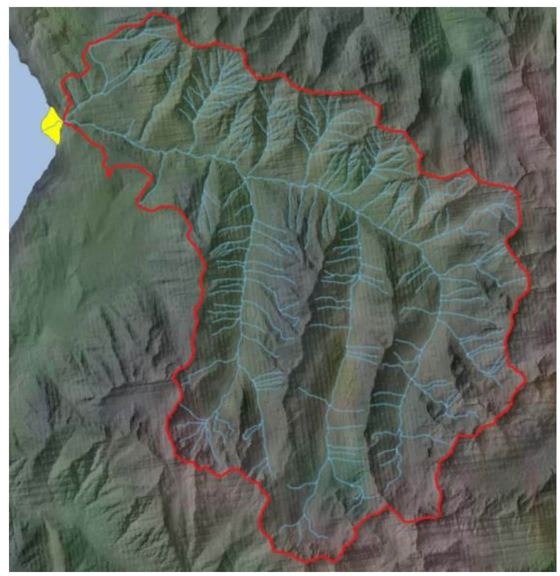
Discussion

Geology

Topographic Setting

The Silverton watershed is defined by the ridges and mountains that surround Silverton Creek and its tributaries. The map (below, left) shows the location of the Silverton Watershed (lilac) in relation to the Slocan River watershed (dark green).

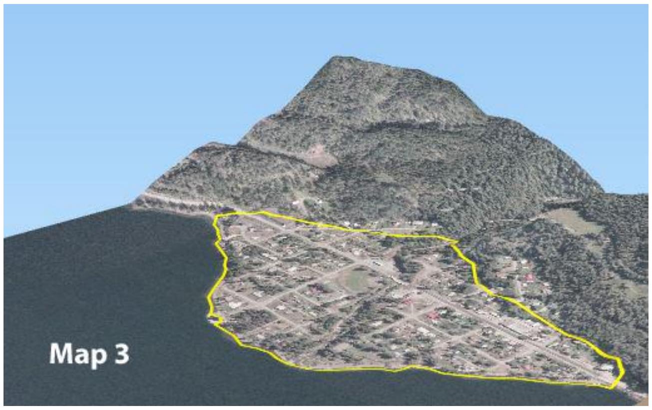




The boundary of the Silverton Creek watershed is shown by the red outline on the map (above, right) and the Silverton aquifer underlays the yellow. All rain and snow that falls inside the boundary either returns to the atmosphere through evaporation or makes its way to the Silverton aquifer. Evaporation and transpiration, the loss of water vapour through growing plants, both play a large role in determining how much water reaches the aquifer. Water flow within the watershed is slowed by soil, wetlands and aquifers in the watershed. There is only one significantly sized aquifer in the watershed and it is not directly connected to the Silverton aquifer (See companion report, Johnson, 2016)

A good description of all of these processes can be found in the report called "The Groundwater Bylaws Toolkit" published by the Okanagan Basin Water Board. The bibliography has a link to the website where this document can be found.

Regional Geology



The fluvial delta upon which the Village is built was probably created in the last 10,000 years, since the last continental ice sheet melted. Sediments carried down the valley by glacial meltwater, and later by ordinary creek water, dropped out of the water as the creek slowed when it reached the delta. The movement of the ice sheet probably removed any previous delta that had been deposited. Since the ice melted, Silverton Creek has been eroding glacial deposits, land-slides and talus slopes and dropping the rocks, gravel and sand on the delta. Water carries silt and clay particles and these are carried out into the lake. The meandering of the creek across the delta formed a relatively flat surface. The steep surface just off-shore where the slope of the surface is based upon *angle of repose* (see Glossary) of rocks in water is locally called the "drop-off". The yellow outline on the map above shows the visible top surface of the aquifer.

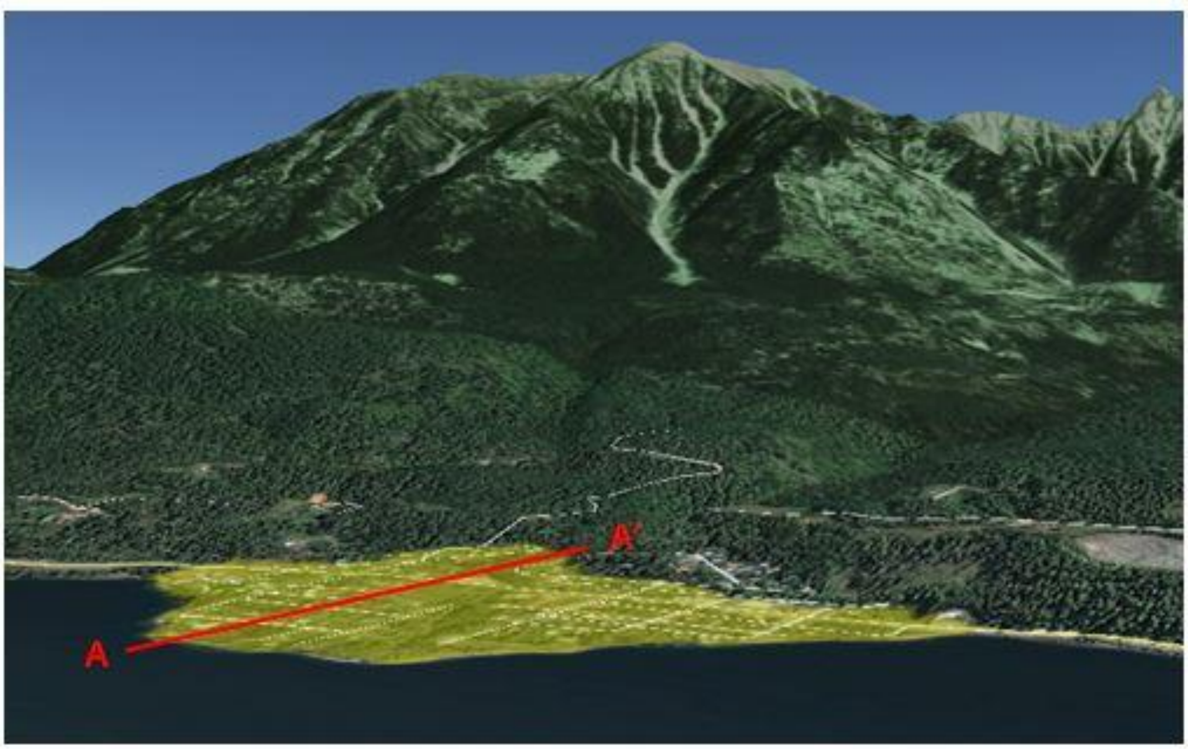
The picture on the front cover shows a modern day delta forming from the Rendu Glacier in Alaska.

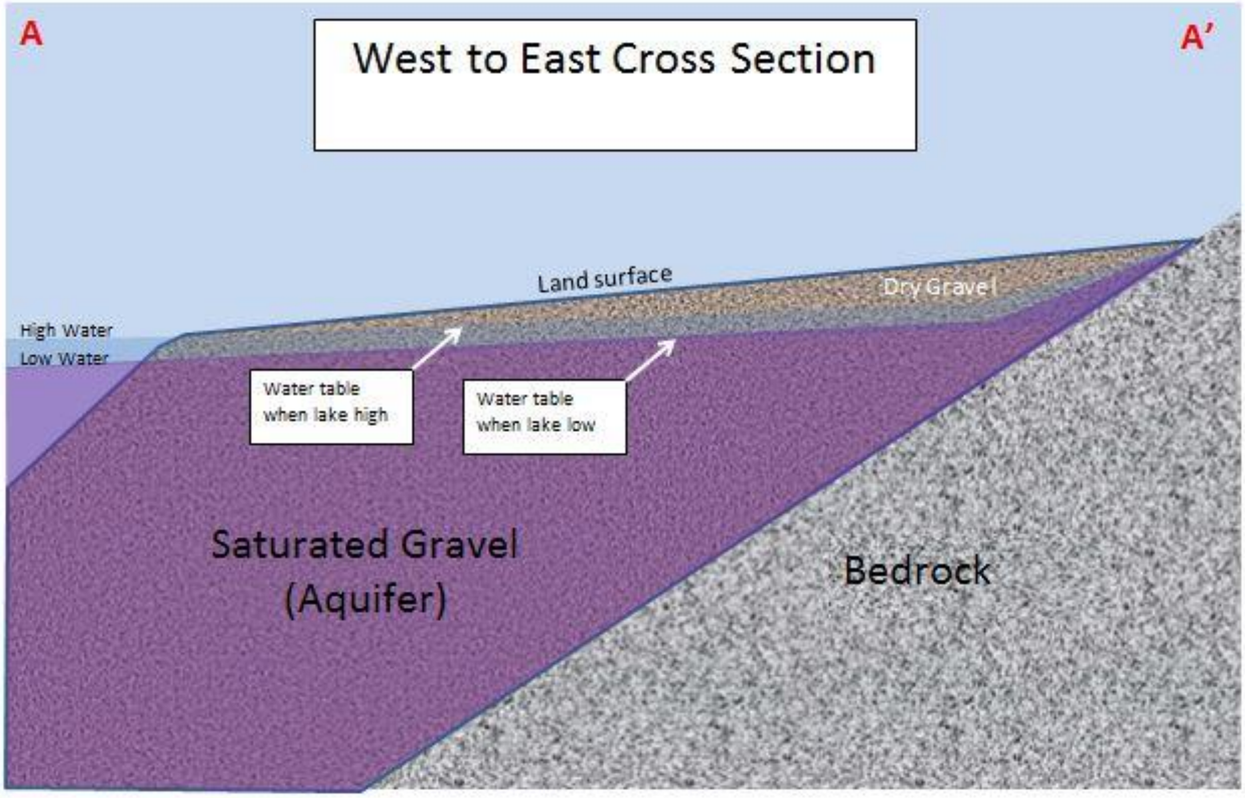
Aquifer Geology

The eastern-most point of the delta starts where the creek leaves the steep sided notch in the bedrock. This can be seen immediately upstream of where the water lines from the village reservoir tank cross the creek. From that point east, up the creek about 100 meters, there are numerous bedrock outcrops. The picture at left shows the view looking east from the pipeline crossing.

The picture at left was taken looking in the opposite direction and shows the "Notch" in the bedrock through which Silverton Creek exits the valley and the outwash delta begins. The picture was taken looking west from a point about 100 meters east of the previous picture. The pipeline crossing is shown by the white structure, the line cover, above the creek.

If we were to slice the delta vertically at the red line shown on the picture below we would get a cross section similar to that illustrated by the "West to East Cross Section" on the following page.





The cross section above shows a west-east slice from the lake to the Notch. The continuation of the bedrock upon which the delta sediments were deposited is shown as a slope at an angle similar to that exposed on the sides of the valley. The exact angle is not crucial to the calculations in this report. The sediments (mostly gravel with interbeds of sand and silt) that were deposited in the delta at the mouth of Silverton Creek make up the Silverton Aquifer, as it lies on the bedrock. The sediments have an *angle of repose* of slightly less than 45 degrees to the horizontal. This can be seen in the lake and is commonly called "the drop-off".

Thus the delta underlying the Village is composed of the large detrital material that has been carried down by the creek. Over time topsoil has built up both naturally and manmade (yellow on the picture on the previous page) which covers the coarse material so people driving through the Village do not notice the nature of the underlying deposit. But a look at the creek-bed from the highway bridge or a look into an excavation for a basement reveals the aquifer composition.

Wells drilled in British Columbia normally have a driller's log submitted to the province after the well has been drilled. This describes the type of material and the depth that it was found as recorded by the water well driller when the wells were drilled. No logs were found in the provincial database. The Village has a report (Kala, 1988) on the first well, the "Old Well" , that contains the driller's litholog. It is included here as Table 1. It shows that the aquifer is composed of gravel, sand silt and minor clay. The nature of this type of deposit is that the sands, silts and clays bands are discontinuous, tabular beds of limited areal extent.

The flat area of the village is the surface of the aquifer. The edge can be seen by the dramatic increase in the slope of the land at the edges of the delta. These can be seen as one leaves town going south behind the Silverton Hotel and going north where the highway leaves town and immediately turns west to get around the bedrock and glacial till. From those two points the margin of the aquifer follows the edge of the steep banks eastward to the Notch, forming a triangle, hence the word "delta".

The aquifer is approximately 0.36 square kilometers in areal extent and has a perimeter of 2.6 kilometers.

The depth of the sediment in the delta is a function of the distance westward from the Notch. One can estimate this depth by projecting a line from the edge of the delta with a slope that approximates the slope of the bedrock above the delta. (See cross-section).
The actual depth and the volume that can be calculated from that projected surface is insignificant in understanding the aquifer because it is only the upper portion of the aquifer that is affected by the fluctuations of the water table.

Hydrology

Water Source

Silverton Creek is fed by rainfall and snow melt from the Silverton Creek watershed. A report on this watershed by Opus Petroleum Engineering Ltd. (Johnson, 2016) describes the characteristics of this watershed. Of significance to this report is the fact that there are no large aquifers in the watershed that are directly connected to the Silverton aquifer, so all of the water in the aquifer is supplied by Silverton Creek, after it leaves bedrock at the notch.

There is little storage of water in the watershed because there are no large aquifers in it. What storage exists is supplied by the thin soil zone, several lakes and wetlands and small aquifers that run along the valley bottoms. These provide small reservoirs which slow down the rate at which the water runs out of the valley. It is important that the watershed have a means of slowing down the runoff after a rainfall to keep the water supply to the aquifer as clean as possible.

When Silverton Creek exits the valley at the Notch and enters the delta, it runs over a very permeable gravel deposit which readily admits water. As long as the creek supplies more water than the amount removed by the village pumps, assuming that there are no more wells drawing water from the aquifer, then the flow of water downward from the creek into the aquifer will continue to be the source of recharge for the aquifer (See the following section, Water Movement).

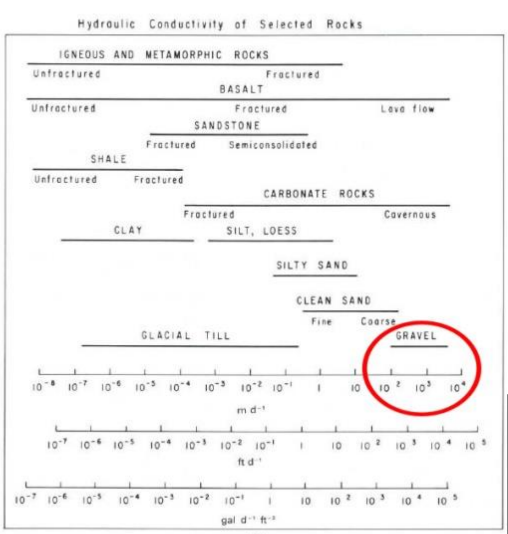
This recharge will continue to maintain a slope on the surface of the water table because the slope of this surface is related to the velocity of the flow toward the outlet, which is the area or 'face' of the unconfined aquifer that is in contact with the lake. (We are neglecting the small amount of water that may reach the aquifer from a heavy rainfall in the Village.)

But what happens when the creek no longer supplies enough water to supply the village? This could happen under prolonged drought, perhaps caused by climate change. In this case we would see a reverse flow where the lake would be the source of the water and the slope of the water level in the aquifer would be towards the east and water would flow toward the wells from the west. The top of the screens in the wells is about 130 feet (40 meters) below the wellhead so as long as the lake level does not drop below this depth the wells will not 'run dry'.

Water Movement

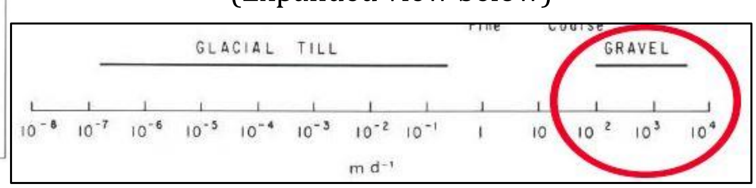
The Silverton Aquifer, being composed of sands and gravel is easy for water to flow through. The water flow within the aquifer is nearly horizontal from the east at its initial source of recharge from the creek, or laterally from the creek bed as it wends its way to the lake. Any fine sand and silt beds that will impede the flow of water vertically are in horizontal lenses so they do not have much effect on the horizontal flow.

The *hydraulic conductivity* of an aquifer can be calculated from water level changes in the well in the short time, immediately after starting or stopping a pump. During the pump test in 1988, when the well was first completed the well reached maximum drawdown within a minute and completely built back up to static level within three minutes (See Table 2). This is extremely high *hydraulic conductivity*. For the purpose of this study we do not need to do an exact calculation of the *hydraulic conductivity* because the amount of water delivered by the wells is limited by the capacity of the pumps, not the aquifer.

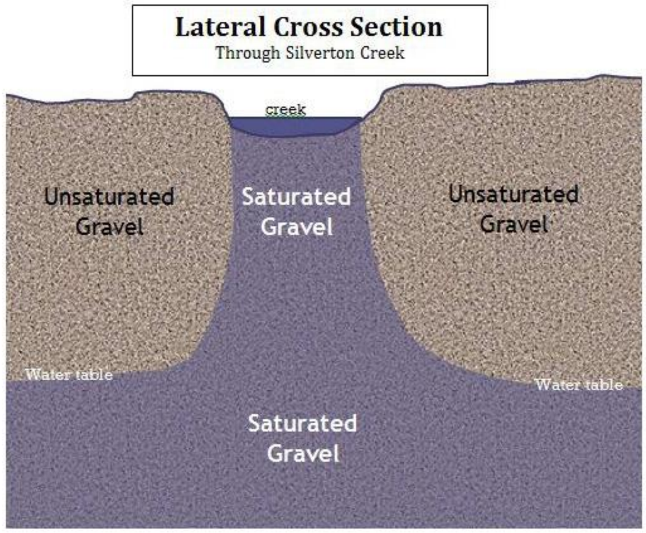


The table to the left, from Heath (2004), shows some typical *hydraulic conductivities* of various rocks or sediments. The circle shows that gravels have *hydraulic conductivities* that allow water velocities in the aquifer to vary from 100 meters per day to over 1 kilometer per day. This explains the rapid return to static water level when the pump stops and the steepness of the sides of the *cone of depression*.

(Expanded view below)



The reverse of the cone of depression (see Dynamic Water Level later in this report) around a pumping well occurs under the creek. Because of the high *hydraulic conductivity* of the gravel the water easily moves downward and outward. The diagram at right shows the general location of the saturated and unsaturated gravels beneath Silverton Creek.



In real life vertical movement of water in sediment, because of horizontal beds of sand, will have some lateral flow under a creek.

Water Volumes

The volume of water in the aquifer cannot be estimated based upon the current data because the depth to the surface of the bedrock covered by the delta is unknown. The surface area of the delta can be used to give us an approximate value for the volume of water in a meter thick layer of the aquifer. With an area of 0.36 square kilometers, a one meter thick layer has a volume of 360,000 cubic meters. Gravel has a porosity varying from 24% to 40% (Manger, 1963). If we use a conservative value of 25% the volume of water is then about 90,000 cubic meters (24 million U.S. gallons). The water level rise during spring *freshette* in 2014 was 1.4 meters. This means that about 34 million US gallons of water was added to the aquifer.

Table 8 in Appendix B is data that has been recorded by the Slocan Lake Stewardship Society under its current Water Quality Monitoring Program of Silverton Creek. The flow rate has been measured at the footbridge, about 190 meters downstream from the highway bridge and 200 meters upstream from the lake. The lowest flow rate measured was 1.75 cubic meters per second which equals about 151,000 cubic meters per day (40 million US gallons per day). The highest rate was 5.4 cubic meters per second, about 467,000 cubic meters per day (123 million US gallons per day).

The daily volume of water pumped from the wells varies from about 57,000 US gallons (206 cubic meters) in the winter months to a maximum of 265,000 US gallons (1003 cubic meters) in the summer. This latter volume is about 1% of volume in one meter thickness of the aquifer. However, since the aquifer is constantly being replenished by the creek, there is no measurable change in the water table after a heavy day of pumping. The pump in the Old Well produces at about 390 US gallons (1.48 cubic meters) a minute. The pump in the New Well produces about 460 US gallons (1.74 cubic meters) a minute. So even at times of heavy usage the pumps work less than 10 hours in a day.

Analysis of village well data

Silverton Water System

The Village of Silverton has two drilled wells, 25 feet (8 meters) apart, which provide all of the water for the Village water system. There are no other wells within the Village boundary recorded on the provincial government database.

The wells were drilled to approximately 48 meters (157 feet) and cased with steel pipe. A diagram for the old well (from Kala, 1988) is shown as Table 3 in Appendix C. The water enters the casing through a screen at the bottom of the well. Each well has a downhole electric pump which delivers the water to the surface and then through a pipeline to the reservoir tank which is located above the Village just north of the Notch. Only one well is pumped at a time and this meets the needs of the village even during the days of highest demand in summer. The pumps run less than 5 hours on most days.

The pump in the Old Well delivers water at an average rate of about 390 US gallons (1.48 cubic meters) per minute. When it is pumping the water level in the Old Well drops 9.3 feet (2.8 meters). The New Well water level drops only 1.8 feet (0.55 meters) when the old well is pumping.
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The New Well pumps water at a rate of 460 US gallons (1.74 cubic meters) a minute. When the New Well is pumping, the water level in it drops 12.3 feet (3.7 meters). The water level in the Old Well drops 1.7 feet (0.52 meters)when the New Well is pumping.

The elevation of the *Bench Mark,* located in the south end bridge abutment of the highway bridge crossing Silverton Creek (see Table 5, Appendix C) is 552.1 meters above sea level (ASL). The elevation of the wellhead is estimated to be 555 meters ASL. (In 2013 the sea level reference was changed. The old reference has been used in this report because other elevation sources are still using the old reference.) See Table 6 for elevations.

The fluid level in 1988, when the Old Well was pump tested, was 19 meters below the top of the casing (see Table 2 and Table 3). The elevation of the water table, using that depth and the estimated elevation of the top of the casing, was about 536 meters, which was probably close to lake level, although we do not have lake levels for 1988.

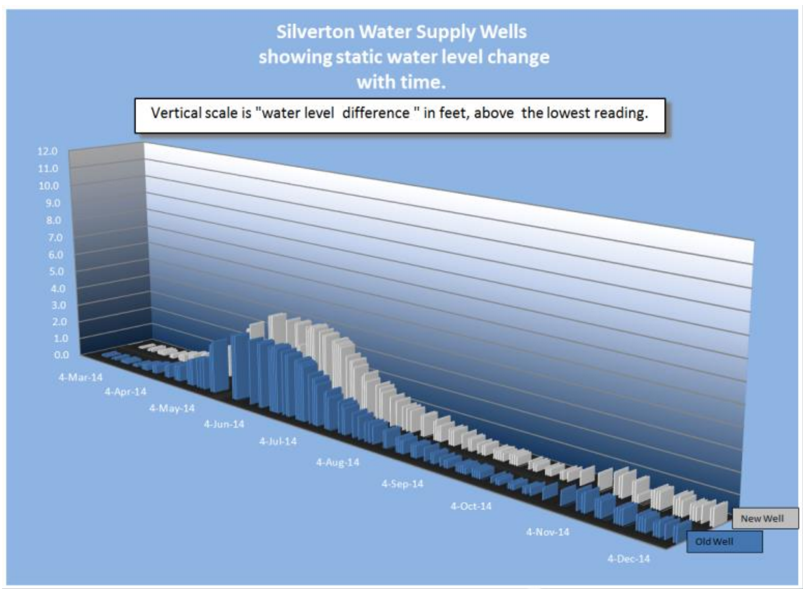
The high water level of Slocan Lake is set at 537.5 meters ASL. The water in the lake only reaches the high water level for a few days (See Graph 2, Appendix B). The level of the water in the creek, offsetting the wells is about 4 meters lower than the wells. See Table 6, Appendix C for more measurements and calculations concerning the aquifer.

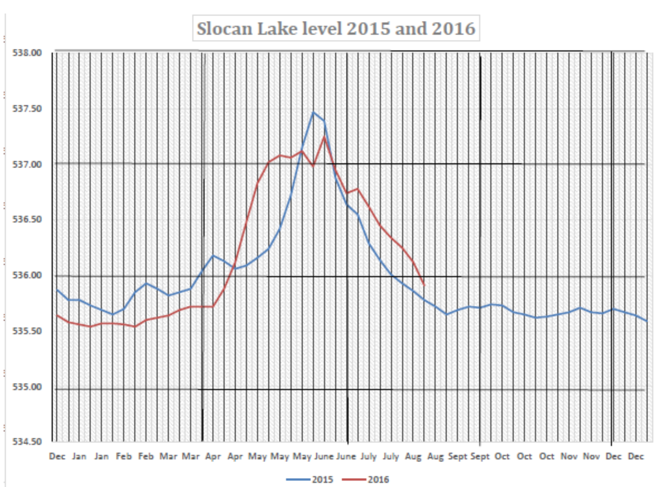
The fluid level is read from an electronic meter which was set to the depth of the pressure transducer when it was installed (Personal communication with Tim McCrory, the electrician who installed the equipment). No record was found of the water level in either well when the pressure recorders were installed. Table 4 shows the fluid level and pumping data recorded by Village employees during 10 months of 2014.

Static Water Level

As previously noted the electronic readout does not measure the actual water level in each well but measures changes to the water level based upon the depth at which the transducer was set. This means that the changes in the depth reading on the meter are real changes in the elevation of the water level but are not the true “depth to water”. This still gives us useful information because the change in the water level shows the connection of the wells to the creek. A plot of this water level change illustrates the connection.

The graph at the right shows the change in the *static water level* over the period March 4, 2014 to December 16, 2014. The water level in the Old Well (blue bars) rose about 4 feet (1.2 meters) during the spring *freshette*. The grey bars on the graph are for the New Well. This rise was 4.5 feet (1.4 meters). Both wells are about 30 meters from the creek. The New Well is about 25 feet (8 meters) closer to the lake than the Old Well. (See Graph 1 in Appendix B for a larger version of this graph.)

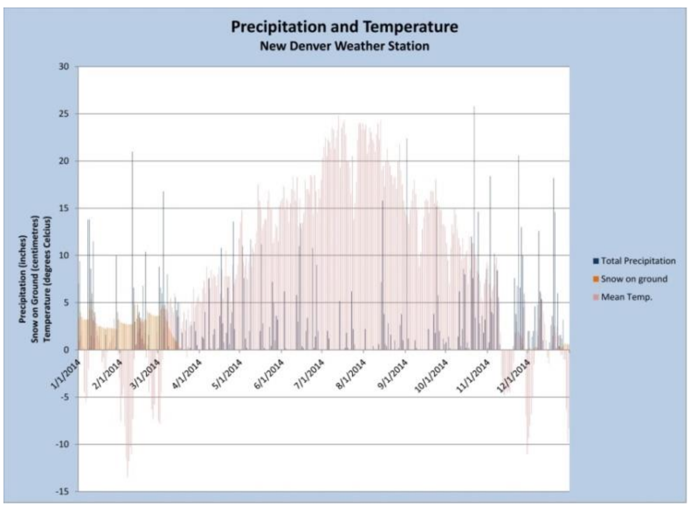




It is interesting to compare the rise in water level in the lake to the rise in water level in the wells. Henning Von Krogh has been recording the elevation level of Slocan Lake at New Denver since December 2015. The graph on the left shows these elevation changes. (See Graph 2 in Appendix B for a larger version of this graph.)

Although the graph of the water level in the wells is for 2014, one can see the rise in the lake level due to the snow melt and the spring rains. The rise was about 1.8 meters (5.5 feet) in both 2015 and 2016.

It is unfortunate that we do not have lake water levels for 2014 so that we could compare the two graphs directly. If the rise in the lake level was similar to that shown for 2015 and 2016 then the rise in the water table at the wells is less, which is what is expected because the tilt in the water table is controlled by the two "ends" of the table. Referring back to the East to West Cross Section, the lake "end" of the water table rises but the creek "end" at the Notch remains unchanged. This is similar to raising one end of a lever. The water table rise is approximately proportionate to the distance from the fixed end, i.e. the Notch.

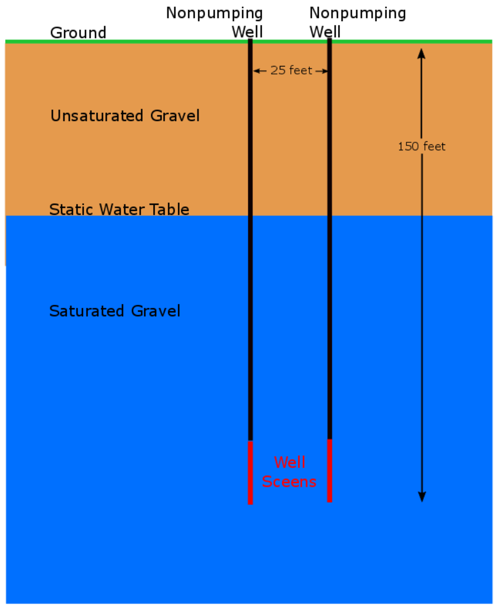


The graph on the left is meteorological data for the 2014 calendar year. The data was obtained from the Environment Canada Website, http://climate.weather.gc.ca/historical_data/search_historic_data_e.html The graph shows the total precipitation (rain and snow) in blue, the depth of snow on the ground (orange) and the mean daily temperature (pink). The data is for the weather station in New Denver, but gives an idea of the amount of rain involved, the timing of the snow melt and the rise in temperature which would be melting the snow at the higher elevations.

The snow was gone in March in New Denver. The pink lines are the daily air temperature, which reaches its maximum in July and August. The blue lines show daily precipitation. From this graph we can see why the *freshette* occurs by the melting of the snow at higher elevations in the Silverton Creek watershed combined with the large number of rainfalls in April of 2014.

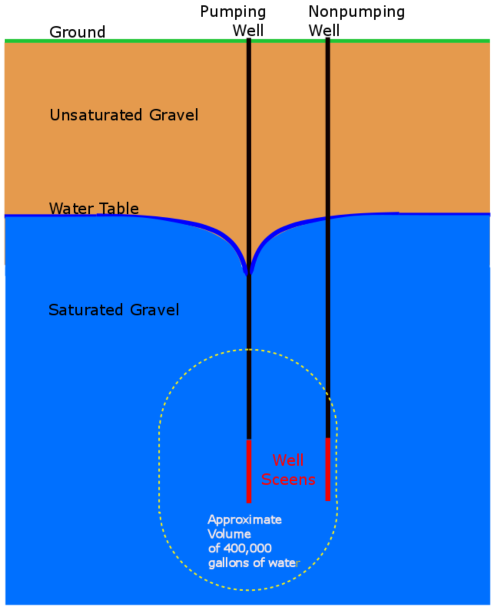
Larger versions of all three of these graphs are included in Appendix B.

Dynamic Water Level



The diagram on the left shows the Silverton water wells drawn to scale. The *Static Water Table* is approximately the level of Slocan Lake. When the wells are not pumping the water table is level, at the scale of the diagram.

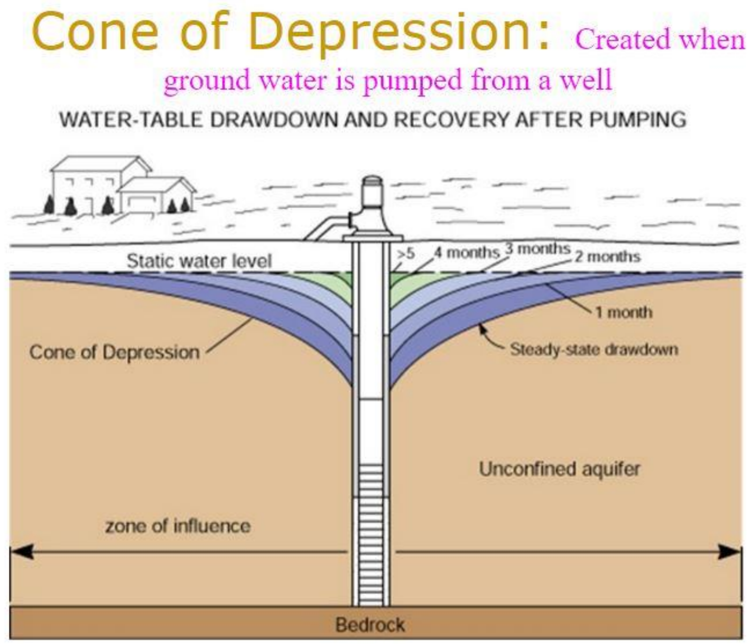
When the New Well starts to pump the level of the water quickly drops to the stable "pumping level" which is approximately 20 feet (6.1 meters) lower than the static level. This forms a *cone of depression* around the well. This is illustrated in the lower diagram on the left. This cone stays stable as long as the well is pumping but almost immediately returns to the static level when the well stops pumping.



The oval in the lower diagram represents a cross section of the volume of aquifer that would be drained if the well produced 400,000 US gallons (1515 cubic meters) of water. This would represent an abnormally high day of pumping. The radius is about 33 feet (10 meters)

When the well is pumped the water moves in from all sides and also from above and below the screen. The diagram assumes that the gravel is uniform in all directions and has a porosity of 25%. One is to visualize that the diagram represents a cylindrical volume around the screened area with a hemisphere on the top and bottom.

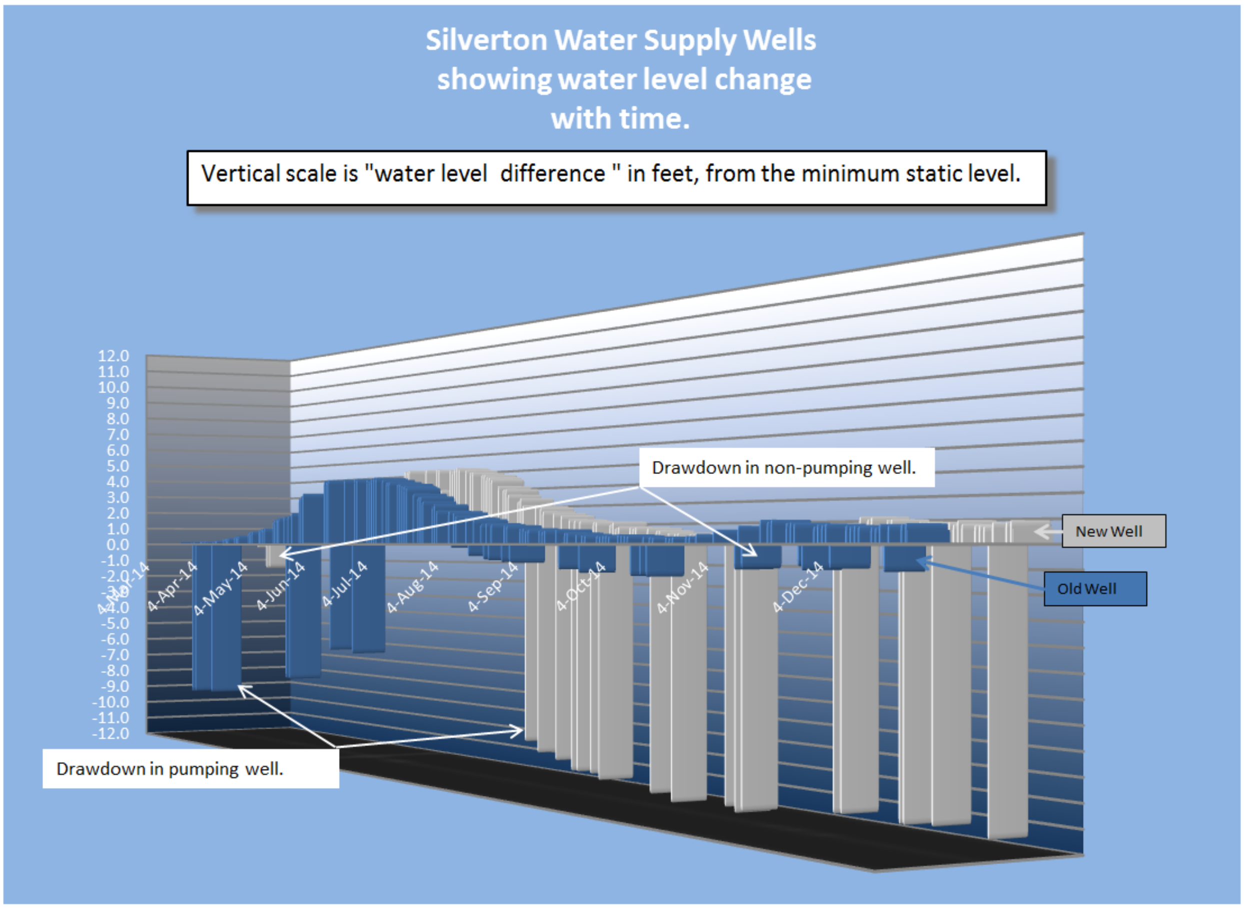
Table 4 shows the maximum day volume pumped during the ten months that we have data for in 2014 to be 487,584 US gallons in July. That day was unique for the 2014 data and it would expand the radius shown in the diagram from 10 meters (33 feet) to 10.7 meters (35 feet).



The diagram on the right, from the Kentucky DEP (Operation Matters Blog, 2012) shows the cone of depression in a sand cross section. It shows that when a well has been pumping at a steady rate long enough for the cone to be stable, and then shut in, the cone will fill in over time, so that the water again reaches its static level. This diagram shows time to refill the cone takes over five months in this example of an aquifer with a small *hydraulic conductivity.*

It is important to note that, although the surface of the water table drops when the well is pumping, the water from the surface is not entering the well. The water is moving in from the surrounding aquifer.

Table 2 in Appendix C shows the water level when the well was first tested after it was drilled. It shows that the water level in the Old Well fell to its stable pumping level within the first minute after starting the pump. When the pump was stopped the water level in the well returned to its pre-pumping level within three minutes. This indicates that the cone forms and fills within minutes of the start or stop of the pump. So the c*one of depression* diagram for the Silverton Aquifer would show water level returning to the static level within three minutes not months, as it does in the example above.



The above graph contains the same data as the previous graph of Static Water Level but the water levels recorded when a well was pumping have been added. The drawdown in the new well (grey bars on the graph), is greater because the pump produces about 460 US gallons (1.74 cubic meters) per minute while the old well (dark blue bars) only pumps at about 390 US gallons (1.48 cubic meters) per minute. When the old well is pumping the water level is only about 9.5 feet (2.9 meters) lower than the static level while the level in the new well, 25 feet (8 meters) away, is 1.7 feet (0.52 meters) lower than the static water table. In the later part of the year, when the new well is pumping the drawdown in it is about 20 feet (6.1 meters) lower than the static level the previous day, while the old well is about 1.8 feet (0.55 meters) lower than the static level the previous day. (See Graph 4, Appendix B for a larger version of this graph.)

Water Quality

SLSS is monitoring Silverton Creek in collaboration with the Village of Silverton and the Columbia Basin Water Quality Monitoring Program (WQMP), using the WQMP protocols and equipment. Some of their results from 2015 are included as Tables 8 in Appendix C. The water quality meets all relevant standards.

Monitoring

The community needs to continue water quality and quantity monitoring to ensure that the water in Silverton creek is protected. These data collected over time form the basis upon which changes in the status of the watershed can be measured.

The entire watershed from which the Village gets its water needs to remain free from contamination that could be harmful to the people that are relying on this water. It is recommended that the monitoring station site for flow rates be moved to the point where the pipeline crosses the creek. The flow is laminar at this point and the full volume of water exiting the valley is not yet influenced by percolation of the water into the aquifer.

Vulnerability to Contamination

The aquifer is unconfined and therefore any significant surface spill will make its way to the aquifer, but the actual risk to the Village from spills within the Village is small because of the location of the wells. The Village wells are protected from contamination from the area north of the creek because water flow into the aquifer moves outward from the creek, pushing any contamination on the north side of the creek away from the wells. By the same dynamics flow into the aquifer from the creek beside the village wells pushes the water to the south. There are no residences between the creek and the wells so most of the houses and developed land on the south side of the creek are “downstream” from the wells. Downstream, in this case, means relevant to the flow of water in the aquifer.

But the aquifer is highly vulnerable to any contamination within the Silverton Creek watershed. For instance, a fuel spill upstream of the Village, such as the one that happened in Lemon Creek in 2013, would immediately travel down the creek and enter the aquifer. Since the wells are so close to the creek one would expect almost immediate contamination of the well water should the wells continue to be pumped after the spill occurred.

It is recommended that the Village monitor any activities occurring in the watershed to ensure the quality and quantity of is drinking water supply.

Aquifer Protection

The flow of water within the Silverton Creek Aquifer is outward from the creek and westward toward the lake where it discharges into the lake. Most of the discharge is not seen because it occurs below the water level in the lake.

Since the water flow is outward from the creek any influx of fluids from the surface (e.g. fertilizer, fluid spills) is pushed away from the creek by the subsurface water flow. This creates a natural protection for the village wells because the flow is from the creek to the wells and most of the water coming into the wells is from deep within the aquifer and from a very close proximity to the wells (less than 100 feet (30 meters) at current pumping rates.)

The Well Protection Toolkit (see bibliography) presents the well protection planning process in six steps:
1. Form a community planning team;
2. Define the capture zone (recharge area) of the community well; (called *zone of influence* in this report)
3. Map potential sources of pollution in the capture zone;
4. Develop and implement protection measures to prevent pollution;
5. Develop a contingency plan against any accidents; and
6. Monitor, evaluate, and report on the plan annually.

Silverton Aquifer Classification

Classification of Aquifers

The Province of BC has set out guidelines for classifying aquifers in B.C. using numerous components (Kreye, R., Ronneseth, K. and Wei, M., 1994). These components take into account the type of aquifer and the vulnerability of the aquifer to contamination. The diagrams on this page show how the system is organized.

Figure 1. Structure of Classification System

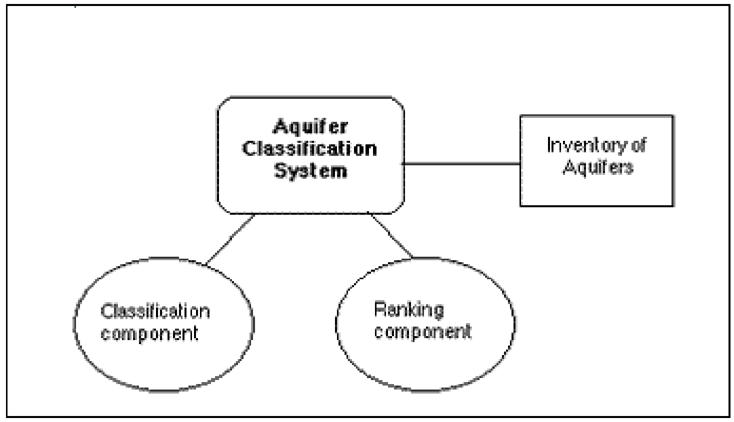


Table 1. Classification Component

Development Sub-class

I	II	III
Heavy (demand is high relative to productivity)	Moderate (demand is moderate relative to productivity)	Light (demand is low relative to productivity)

Vulnerability Sub-class

A	B	C
High (highly vulnerable to contamination from surface sources)	Moderate (moderately vulnerable to contamination from surface sources)	Low (not very vulnerable to contamination from surface sources)

Aquifer Class

	I	II	III
A	**IA**-heavily developed, high vulnerability aquifer	**IIA**-moderately developed, high vulnerability aquifer	**IIIA**-lightly developed, high vulnerability aquifer
B	**IB**-heavily developed, moderate vulnerability aquifer	**IIB**-moderately developed, moderate vulnerability aquifer	**IIIB**-lightly developed, moderate vulnerability aquifer
C	**IC**-heavily developed, low vulnerability aquifer	**IIC**-moderately developed, low vulnerability aquifer	**IIIC**-lightly developed, low vulnerability aquifer

Classification Component

Development Sub-class = III
Vulnerability Sub-class = A
Aquifer Class = IIIA

Ranking Component

Productivity = 3 (High abundance of water)
Vulnerability = 3 (High potential for water degradation)
Size = 1 (less than 5 square kilometers)
Demand = 3 (High reliance on the resource for supply)
Type of Use = 3 (diversity of resource)
Quality Concerns = 2 (local, not regional concern)
Quantity concerns = 2 (local, not regional)

Table 2. Ranking Component

Criteria	Point Value 1	Point Value 2	Point Value 3	Rationale
Productivity	low	moderate	high	abundance of the resource
Vulnerability	low	moderate	high	potential for water quality degradation
Size	<5 km^2	5 - 25 km^2	>25 km^2	regionality of the resource
Demand	low	moderate	high	level of reliance on the resource for supply
Type of Use	non-drinking water	drinking water	multiple/ drinking water	variability/ diversity of the resource for supply
Quality concerns	isolated	local	regional	actual concerns
Quantity concerns	isolated	local	regional	actual concerns

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Glossary

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.

Bench Mark

A permanent monument or tablet installed by an authority, usually the Canadian Geodetic Survey, the precise elevation of which has been measured and recorded.

Cone of depression

The surface of the saturated zone (water table) around a pumping well. It becomes a conical depression when the well is pumping.

Freshette

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 aquifer. It is measured in distance per time such as meters per day or feet per minute.

Static Water Level

The level of the water when the well is not pumping.

Water table

The surface of the water (saturated zone) in an unconfined aquifer.

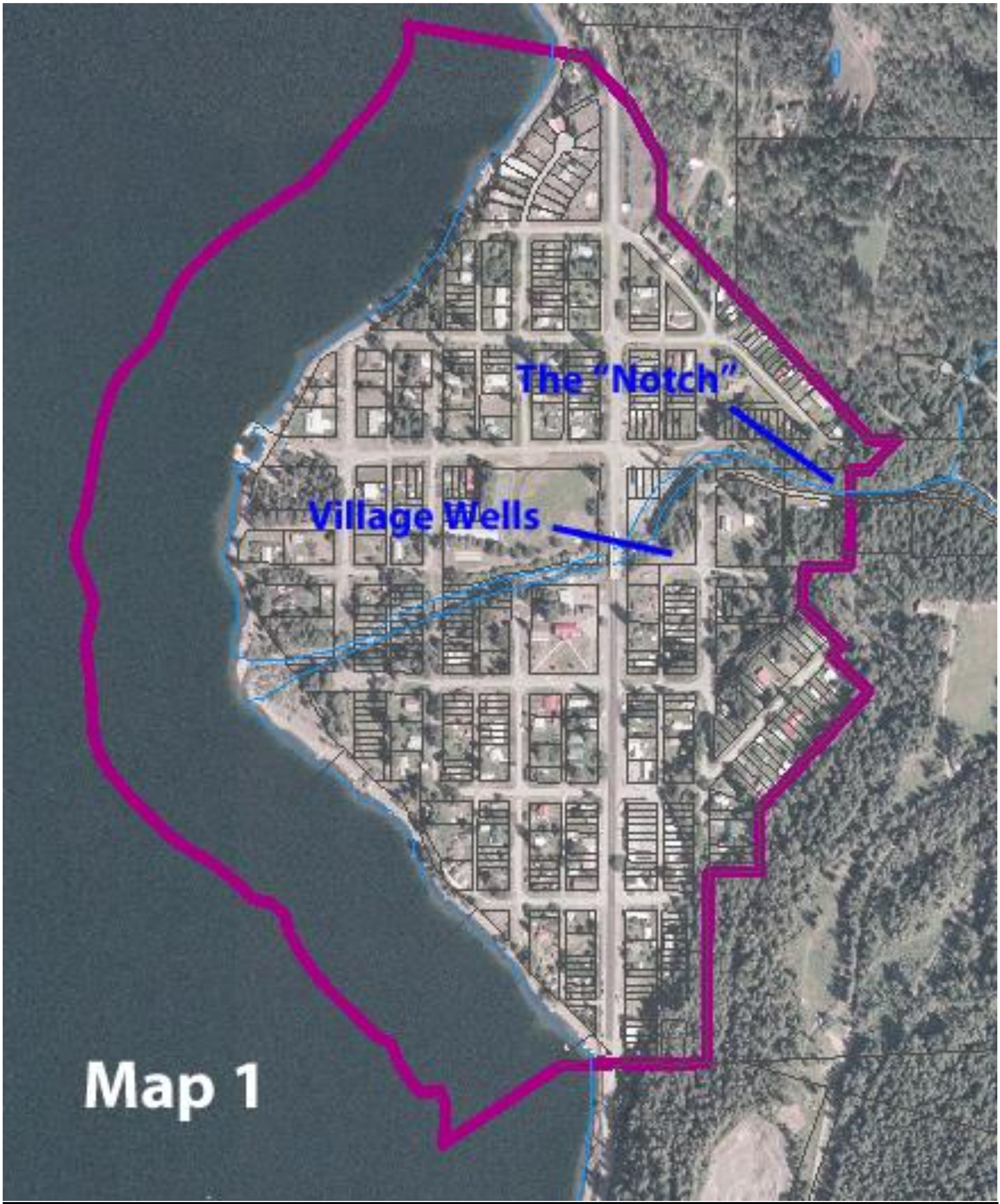
Watershed

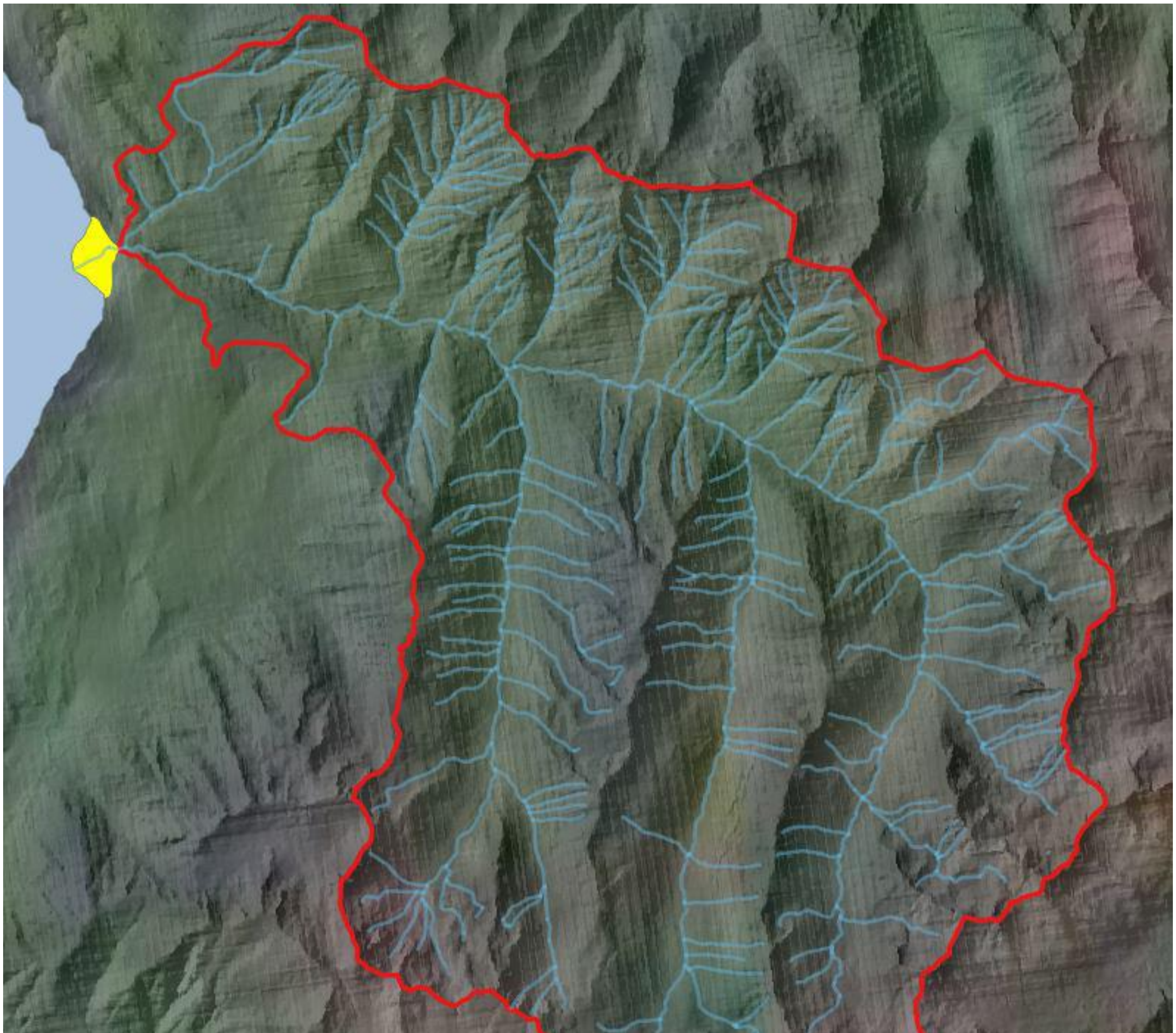
The area of land within which any rainfall tends to flow toward a common discharge point.

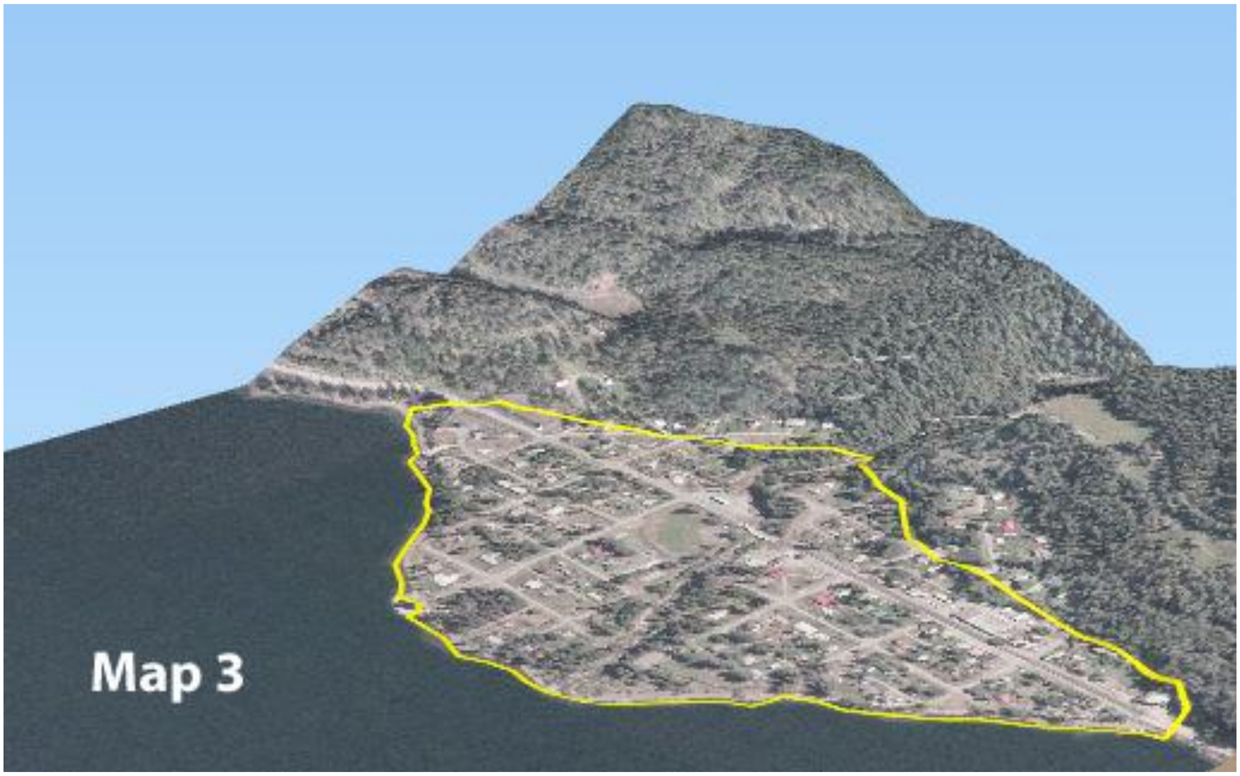
Zone of Influence

The distance from a pumping well where the drawdown is less than 1% of the total drawdown. Also called area of capture and radius of influence.

Appendix A

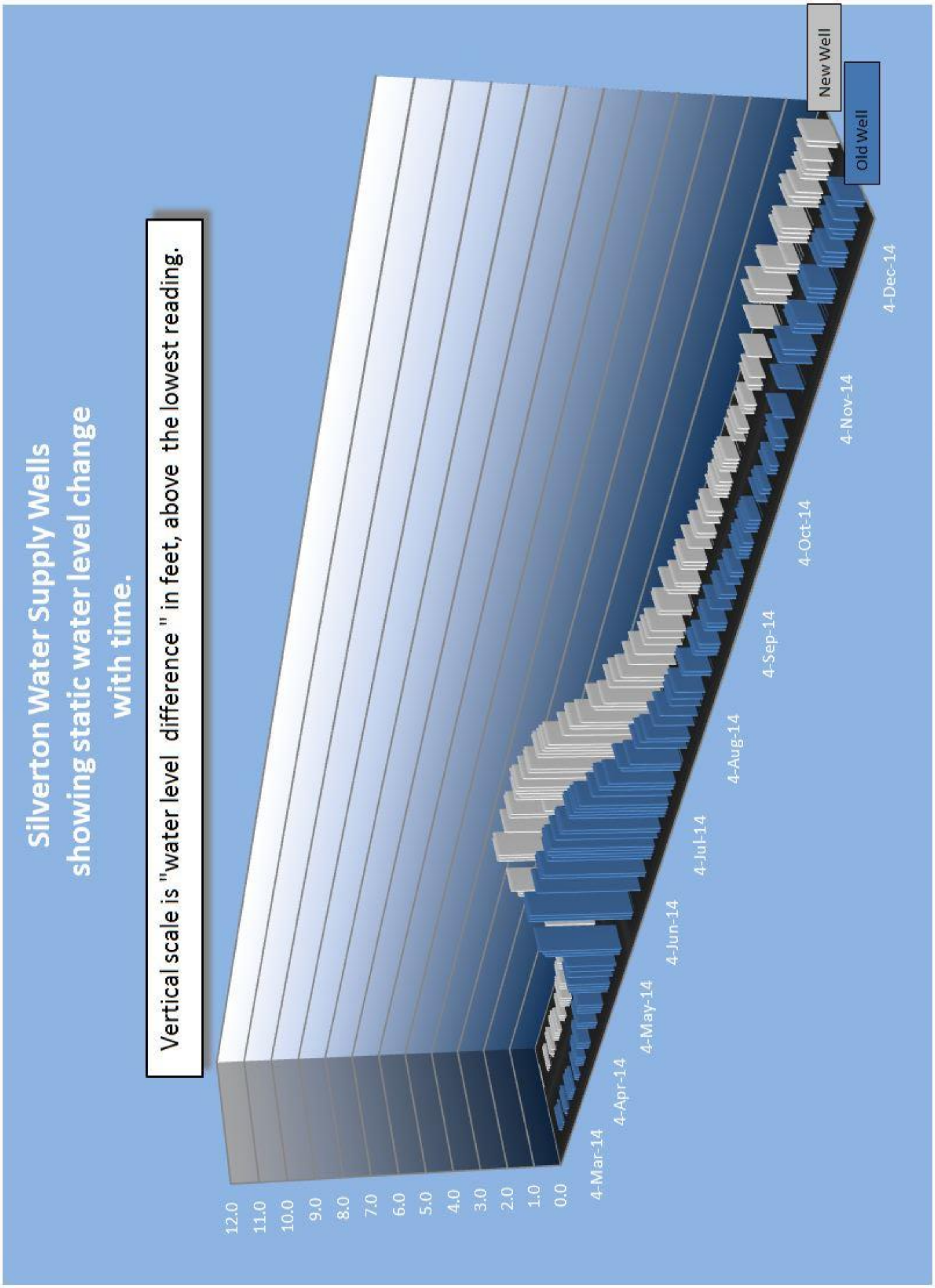

The "Notch"
Village Wells
Map 1


Map 2

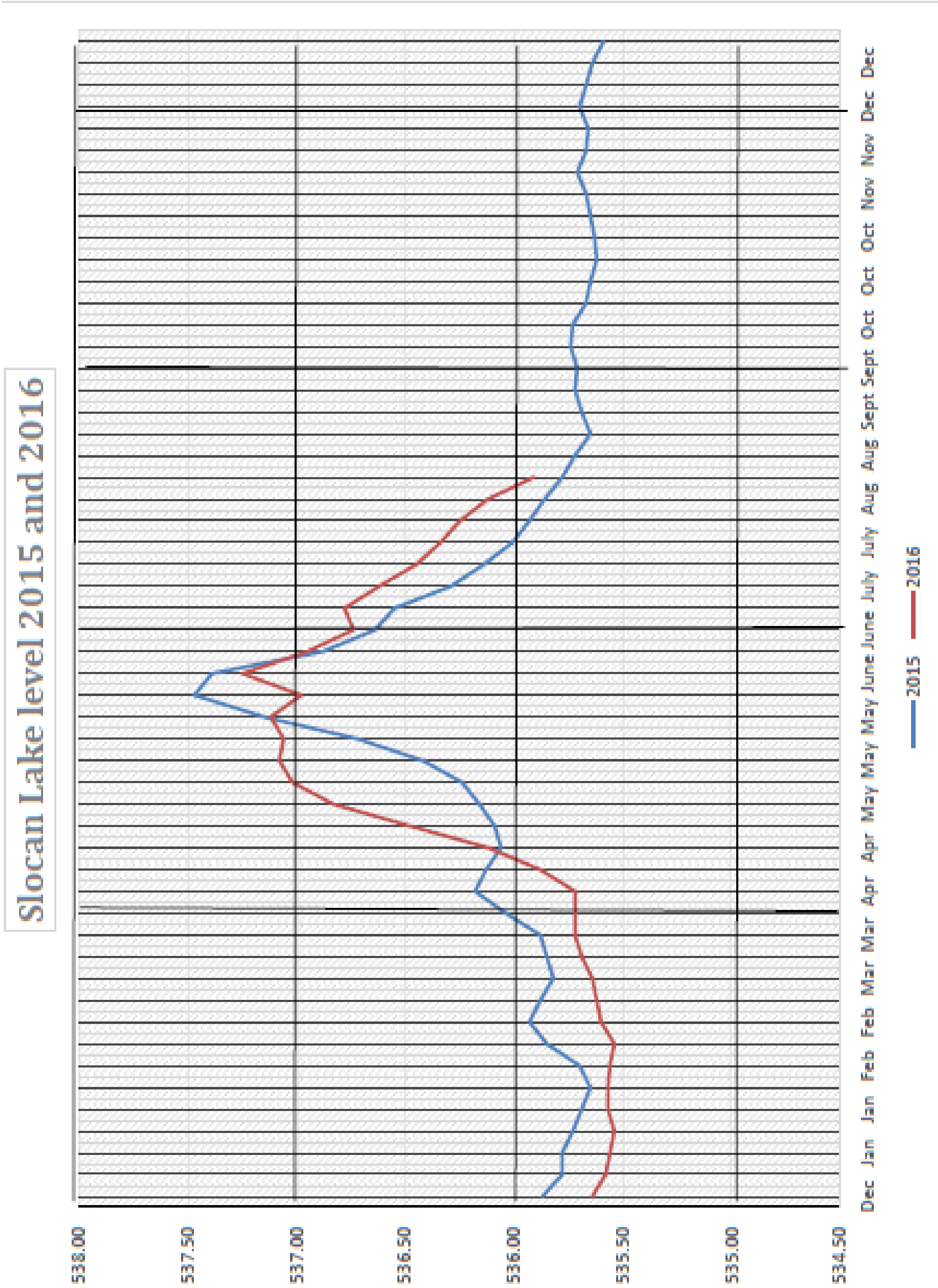

Map 3

Appendix B

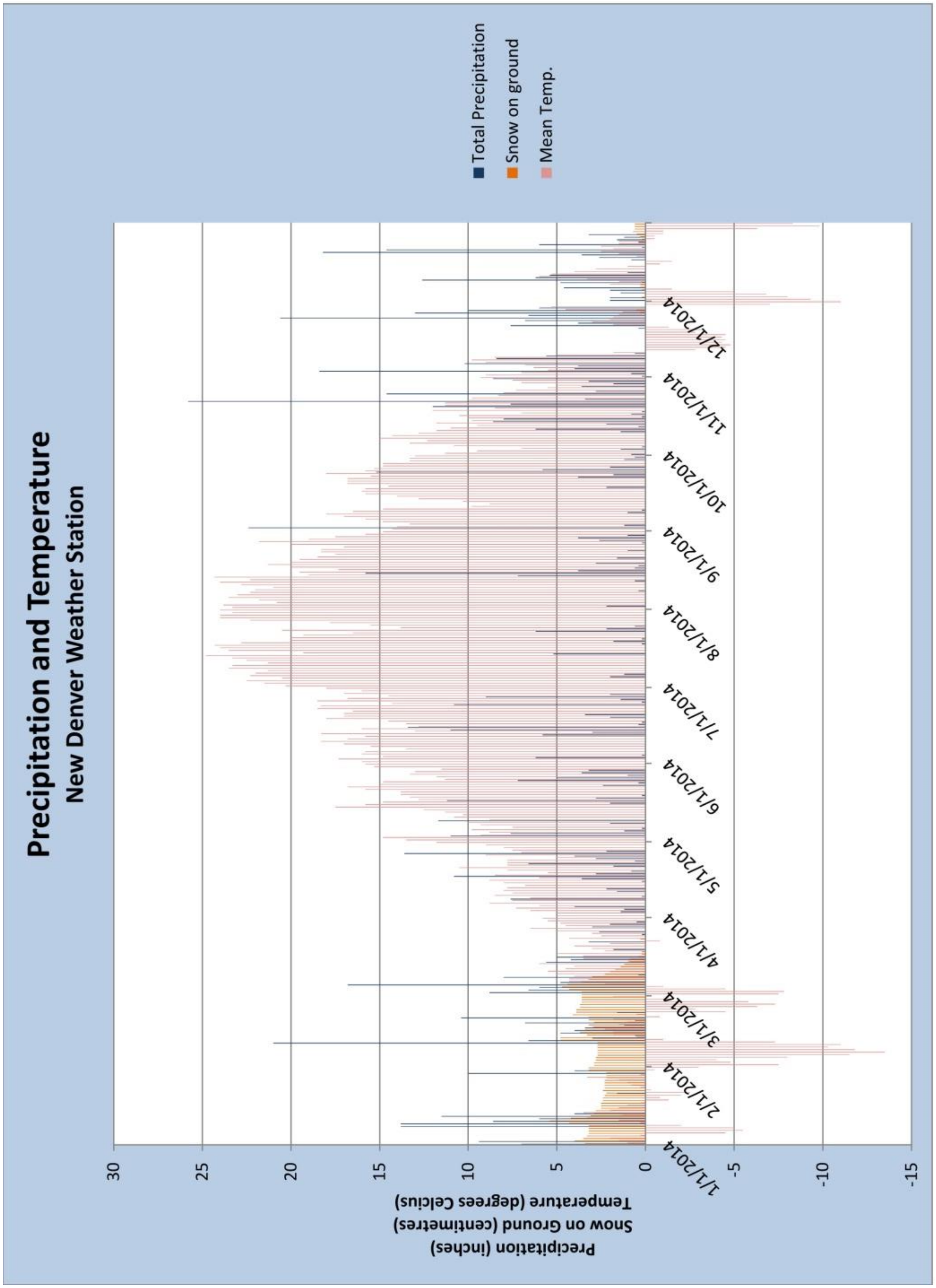
Graph 1 Static Water Level Comparison



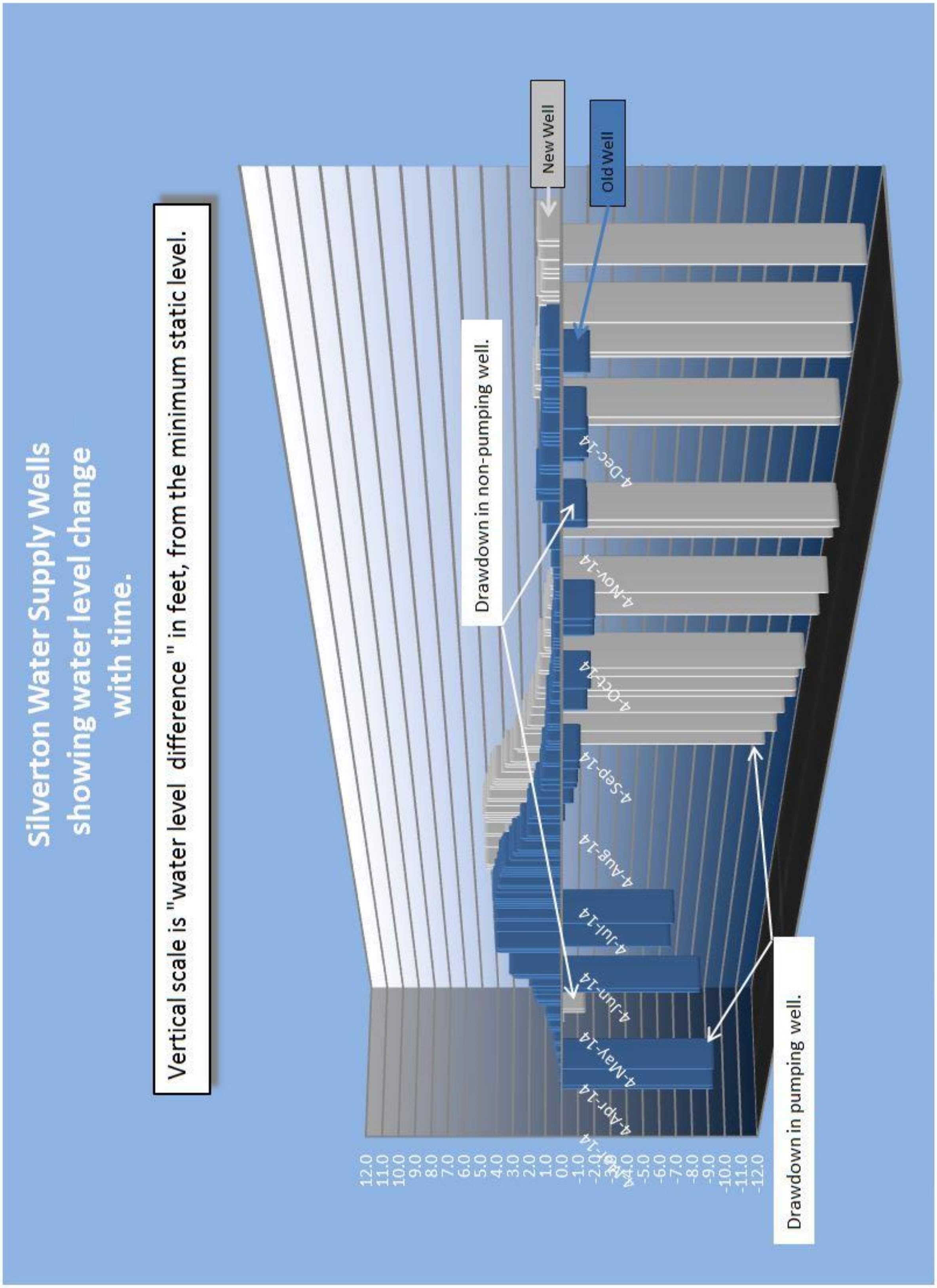
Graph 2 Slocan Lake Water Levels 2015 and 2016



Graph 3 Temperature and Precipitation Data 2014



<u>Graph 4 Pumping and Static Water Level Comparisons</u>



Appendix C

Tables and Diagrams

Table 1 Drillers Litholog

Table 2 Pumping Drawdown and Buildup

Table 3 Well Diagram

Table 4 Water Level and Pumping Data

Table 5 Canadian Geodetic Survey Bench Mark Data

Table 6 Silverton Aquifer Metrics

Table 7 1988 Water Chemistry Analysis

Table 8 SLSS data: Flow Rates, Non-metal water chemistry, Metal Chemistry

Table 1

VILLAGE OF SILVERTON
TEST/PRODUCTION WELL
DRILLER'S LITHOLOG

Depth Interval in feet	Lithologic Description
0 - 4	Silty sand and gravel with cobbles
4 - 12	Boulders, up to 3 feet diameter
12 - 16	Silty sand and gravel with cobbles and boulders
16 - 33	Silty sand with gravelly zones
33 - 57	Silty gravel, grey, moist
57 - 80	Silty gravel with lenses of silty sand
80 - 95	Gravel with silt and silty clay, wet
95 - 98	Silty sand with gravel, moist
98 - 117	Silty gravel, loose intervals, wet
117 - 119	Silty clay, grey
119 - 136	Clayey silt with gravel, wet
136 - 148	Sand and gravel, water-bearing, material grading from fine sand to med. gravel
148 - 151	Sand with some gravel
151 - 158	Sand and gravel

Table 2 (1/2)

VILLAGE OF SILVERTON
GROUNDWATER DEVELOPMENT PROGRAM
NEW TEST/PRODUCTION WELL

Date test started: May 17/88
Time test started: 12:00 AM
Pre-test water level: 19.22 m

Reference point: Top of csg.
Ht. of ref.: 0.53 metres
Depth of well: 47.9 metres

PUMPING INTERVAL

Time (t) since pumping started in minutes	Depth to water (metres)	Drawdown in metres	Comments
1	24.19	4.97	Pump rate: 390 USgpm
2	24.21	4.99	Water clear
3	24.23	5.01	
4	24.23	5.01	
6	24.23	5.01	
8	24.24	5.02	
10	24.23	5.01	
13	24.22	5.00	
16	24.22	5.00	
20	24.23	5.01	
25	24.23	5.01	
32	24.23	5.01	
40	24.23	5.01	
50	24.23	5.01	
64	24.23	5.01	Obtain water sample
80	24.21	4.99	
100	24.21	4.99	
120	24.21	4.99	
150	24.21	4.99	
190	24.22	5.00	
240	24.22	5.00	
300	24.22	5.00	Pump rate: 390 USgpm

Cont'd. ./2

Table 2 (continued2/2)

Silverton, Groundwater Development, Pumping Test

PUMPING INTERVAL

Time (t) since pumping started in minutes	Depth to water (metres)	Drawdown in metres	Comments
380	24.23	5.01	Pump rate: 390 USgpm
480	24.23	5.01	
600	24.23	5.01	
780	24.25	5.03	
960	24.25	5.03	
1200	24.25	5.03	
1440	24.23	5.01	Pump rate: 390 USgpm

RECOVERY INTERVAL

1	19.17
2	19.29
3	19.30
4	19.30
6	19.295
8	19.295
10	19.29
13	19.29
16	19.29
20	19.285

Table 3

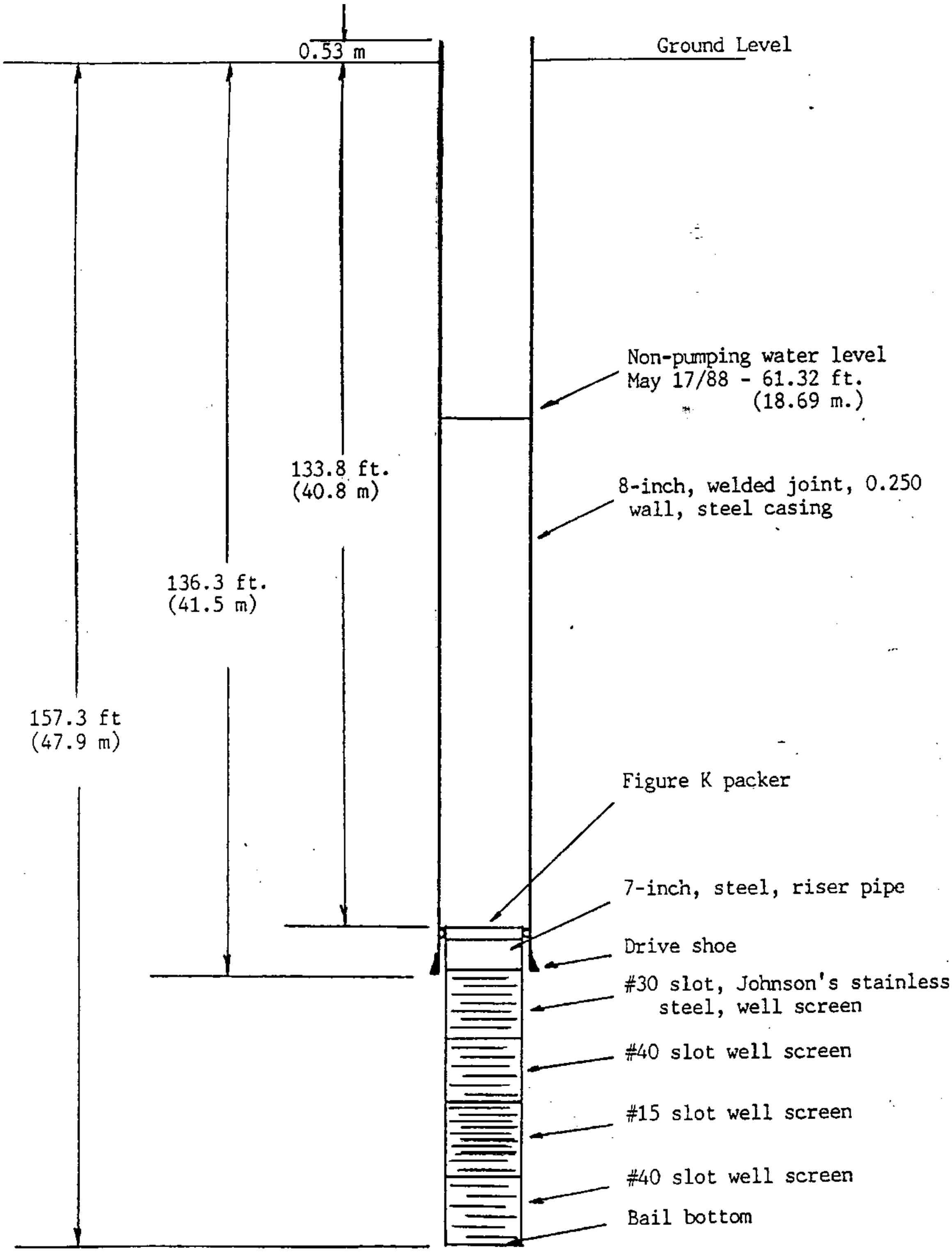

0.53 m
Ground Level
Non-pumping water level
May 17/88 - 61.32 ft.
(18.69 m.)
133.8 ft.
(40.8 m)
8-inch, welded joint, 0.250
wall, steel casing
136.3 ft.
(41.5 m)
157.3 ft
(47.9 m)
Figure K packer
7-inch, steel, riser pipe
Drive shoe
#30 slot, Johnson's stainless
steel, well screen
#40 slot well screen
#15 slot well screen
#40 slot well screen
Bail bottom

Table 4 (1/3)

Silverton Water Wells

2014 well data, as recorded by Village staff. Calculated columns by Opus

Recorded Data									Calculated	
Date	Time	Volume Meter	Daily Volume	Hour Meter	Daily Hours	Level Old Well	Level New Well	Flow Meter	Flow Rate gal/hr	Flow Rate gal/min
3-Mar-14	1:30	2136507	331906	136.1	14.1				23539	392
4-Mar-14	11:00	2196982	60475	138.6	2.5	93.6	103.171	0.026	24190	403
10-Mar-14	10:00	2766732	569750	162.8	24.2	93.628	103.2	0.026	23543	392
11-Mar-14	7:18	2825729	58997	165.3	2.5	93.454	103.106	0.026	23599	393
12-Mar-14	7:19	2881608	55879	167.7	2.4	93.503	103.071	0.026	23283	388
13-Mar-14	7:20	2997303	115695	172.6	4.9	93.536	103.093	0.026	23611	394
14-Mar-14	9:43	3056241	58938	175.1	2.5	93.486	103.42	0.026	23575	393
17-Mar-14	8:04	3349565	293324	187.5	12.4	93.531	103.093	0.026	23655	394
18-Mar-14	7:15	3409242	59677	190.1	2.6	93.447	102.993	0.026	22953	383
19-Mar-14	7:32	3500720	91478	193.9	3.8	102.745	104.708	389.546	24073	401
20-Mar-14	7:28	3580058	79338	197.3	3.4	93.425	102.974	0.026	23335	389
21-Mar-14	7:31	3648350	68292	200.2	2.9	102.7	104.65	389.652	23549	392
24-Mar-14	8:30	3929367	281017	212.1	11.9	93.422	102.974	0.026	23615	394
25-Mar-14	7:22	3987818	58451	214.6	2.5	93.411	102.951	0.026	23380	390
26-Mar-14	7:11	4103882	116064	219.5	4.9	93.444	102.983	0.026	23687	395
27-Mar-14	7:15	4164302	60420	222.1	2.6	93.417	102.951	0.026	23238	387
28-Mar-14	7:19	4279718	115416	227	4.9	93.467	103.016	0.026	23554	393
31-Mar-14	7:01	4466421	186703	234.9	7.9	102.636	104.618	387.016	23633	394
1-Apr-14	7:25	4556709	90288	238.8	3.9	93.447	103	0.026	23151	386
2-Apr-14	7:29	4608457	51748	241	2.2	93.4	102.929	0.026	23522	392
3-Apr-14	7:35	4661380	52923	243.2	2.2	93.369	102.903	0.026	24056	401
7-Apr-14	7:49	4860443	199063	251.7	8.5	93.283	102.819	0.026	23419	390
8-Apr-14	7:42	4917298	56855	254.1	2.4	93.264	102.79	0.026	23690	395
9-Apr-14	7:39	4972136	54838	256.5	2.4	93.241	102.764	0.026	22849	381
10-Apr-14	7:20	5028505	56369	258.9	2.4	93.219	102.735	0.026	23487	391
14-Apr-14	7:17	5262011	233506	268.8	9.9	93.119	102.618	0.026	23586	393
15-Apr-14	7:26	5319524	57513	271.3	2.5	93.1	102.583	0.026	23005	383
16-Apr-14	7:27	5374564	55040	273.6	2.3	93.086	102.56	0.026	23930	399
22-Apr-14	7:34	5744482	369918	289.3	15.7	92.894	102.354	0.026	23562	393
23-Apr-14	7:13	5799412	54930	291.7	2.4	92.866	102.318	0.026	22888	381
24-Apr-14	7:32	5855880	56468	294.1	2.4	92.835	102.276	0.026	23528	392
28-Apr-14	7:16	6129238	273358	305.7	11.6	92.746	102.182	0.026	23565	393
29-Apr-14	7:19	6173505	44267	307.6	1.9	92.699	102.15	0.026	23298	388
30-Apr-14	7:16	6228535	55030	309.9	2.3	92.685	102.121	0.026	23926	399
1-May-14	7:20	6285660	57125	312.3	2.4	92.663	102.092	0.026	23802.1	397
6-May-14	7:26	6622689	337029	326.7	14.4	92.232	101.588	0.026	23404.8	390
7-May-14	7:16	6677002	54313	329	2.3	92.171	101.511	0.026	23614.3	394
8-May-14	7:19	6733393	56391	331.3	2.3	92.129	101.459	0.026	24517.8	409
9-May-14	7:08	6792203	58810	333.8	2.5	92.084	101.417	0.026	23524.0	392
12-May-14	9:00	7020010	227807	343.5	9.7	92.015	101.346	0.026	23485.3	391
13-May-14	7:11	7096697	76687	346.7	3.2	101.271	103.032	389.77	23964.7	399
14-May-14	7:08	7194017	97320	350.9	4.2	91.968	101.291	0.026	23171.4	386
15-May-14	7:09	7301780	107763	355.4	4.5	101.265	102.98	389.826	23947.3	399
16-May-14	7:29	7375729	73949	358.6	3.2	91.806	101.091	0.026	23109.1	385
20-May-14	7:16	7725391	349662	373.3	14.7	90.994	100.157	0.026	23786.5	396
21-May-14	7:10	7843643	118252	378.3	5	90.888	100.157	0.026	23650.4	394
22-May-14	7:20	7905898	62255	380.9	2.6	90.73	99.844	0.026	23944.2	399
2-Jun-14	2:30	8737412	831514	415.8	34.9	90.082	99.091	0.026	23825.6	397
3-Jun-14	1:10	8860160	122748	420.9	5.1	90.104	99.101	0.026	24068.2	401
4-Jun-14	9:00	8914024	53864	423.2	2.3	90.051	99.052	0.026	23419.1	390
5-Jun-14	16:00	9025776	111752	427.9	4.7	99.399	100.716	0.026	23777.0	396
9-Jun-14	8:00	9399632	373856	443.6	15.7				23812.5	397
12-Jun-14	2:30	9747368	347736	458.2	14.6	90.073	99.081	0.026	23817.5	397
16-Jun-14	9:20	63132	315764	471.4	13.2	99.491	100.813	0.026	23921.5	399
17-Jun-14	9:50	130353	67221	474.2	2.8	90.068	99.088	0.026	24007.5	400
18-Jun-14	10:30	184609	54256	476.5	2.3	90.101	99.117	0.026	23589.6	393
19-Jun-14	10:40	289321	104712	480.9	4.4		100.226	0.026	23798.2	397

Table 4 (continued 2/3)

Silverton Water Wells

2014 well data, as recorded by Village staff. Calculated columns by Opus

Recorded Data									Calculated	
Date	Time	Volume Meter	Daily Volume	Hour Meter	Daily Hours	Level Old Well	Level New Well	Flow Meter	Flow Rate gal/hr	Flow Rate gal/min
23-Jun-14	10:20	608747	319426	494.3	13.4	90.118	99.146	0.026	23837.8	397
24-Jun-14	7:12	720920	112173	499	4.7	90.224	99.253	0.026	23866.6	398
25-Jun-14	11:21	776881	55961	501.4	2.4	90.087	99.111	0.026	23317.1	389
26-Jun-14	7:08	831634	54753	503.7	2.3	90.054	99.059	0.026	23805.7	397
27-Jun-14	7:02	948491	116857	508.6	4.9	90.096	99.107	0.026	23848.4	397
30-Jun-14		1176030	227539	518.1	9.5	90.171	99.204	0.026	23951.5	399
2-Jul-14	7:11	1411663	235633	528	9.9	90.299	99.343	0.026	23801	397
3-Jul-14	7:10	1537187	125524	533.3	5.3	90.313	99.356	0.026	23684	395
6-Jul-14	16:30	2091833	554646	554.5	21.2				26163	436
7-Jul-14	8:05	2098337	6504	556.8		90.427	99.492	0.026		
8-Jul-14	7:14	2098337	0	0	0	90.424	99.495	0.026		
9-Jul-14	7:09	2389182	290845	569	12.2	90.532	99.611	0.026	23840	397
10-Jul-14	7:11	2583222	194040	577.1	8.1	90.577	99.66	0.026	23956	399
11-Jul-14	7:21	2777408	194186	1964.6	7.5	90.652	99.747	0.026	25891	432
14-Jul-14	8:30	3487168	709760	1990	25.4	90.972	100.135	0.026	27943	466
16-Jul-14	10:25	4144999	657831	2013.8	23.8	91.144	100.328	0.026	27640	461
17-Jul-14	7:13	4285519	140520	2018.9	5.1	91.13	100.306	0.026	27553	459
18-Jul-14	6:17	4685937	400418	2033.4	14.5	91.386	100.603	0.026	27615	460
21-Jul-14	6:00	5331336	645399	2057	23.6				27347	456
22-Jul-14	7:10	5689674	358338	2069.8	12.8	91.684	100.961	0.026	27995	467
23-Jul-14	7:23	5771957	82283	2072.8	3	91.556	100.81	0.026	27428	457
24-Jul-14	7:07	6259537	487580	2090.5	17.7	91.878	101.175	0.026	27547	459
25-Jul-14	6:55	6579300	319763	2102.2	11.7	93.561	113.317	453.276	27330	456
29-Jul-14	6:30	7051987	472687	2119	16.8	91.92	101.213	0.026	28136	469
30-Jul-14	7:07	7237504	185517	2125.8	6.8	93.764	113.804	462.183	27282	455
31-Jul-14	7:29	7365142	127638	2130.4	4.6	91.998	101.31	0.026	27747	462
1-Aug-14	6:39	7702003	336861	2142.5	12.1	92.162	101.511	0.026	27840	464
5-Aug-14	7:09	8387441	685438	2167.1	24.6	92.271	101.627	0.026	27863	464
6-Aug-14	7:12	8595404	207963	2174.6	7.5	94.177	114.056	455.634	27728	462
7-Aug-14	7:20	8688158	92754	2178	3.4				27281	455
8-Aug-14	6:38	8943156	254998	2187.2	9.2	92.36	101.74	473.438	27717	462
11-Aug-14	7:30	9627260	684104	2211.8	24.6	92.582	101.934	0.026	27809	463
12-Aug-14	7:26	9735486	108226	2215.7	3.9	94.337	114.45	461.822	27750	463
13-Aug-14	7:14	9948416	212930	2223.4	7.7	92.557	101.963	0.026	27653	461
14-Aug-14	7:04	52905	104489	2227.1	3.7	94.376	114.45	456.807	28240	471
15-Aug-14	6:40	260418	207513	2234.7	7.6	92.604	102.018	0.026	27304	455
19-Aug-14	7:20	603220	342802	2247.1	12.4	94.451	114.454	456.807	27645	461
20-Aug-14	7:11	699352	96132	2250.6	3.5	92.674	102.092	0.026	27466	458
21-Aug-14	7:11	699352	0	2250.6	0	92.685	102.102	0.026		
22-Aug-14	7:24	738420	39068	2252	1.4	94.485	114.696	462.451	27906	465
26-Aug-14	7:07	1243215	504795	2270.4	18.4	92.824	102.226	0.026	27435	457
27-Aug-14	7:24	1243215	0	2270.4	0	92.83	102.092	0.026		
28-Aug-14	7:05	1508511	265296	2280.1	9.7	92.93	102.396	0.026	27350	456
29-Aug-14	7:06	1508511	0	2280.1	0	92.874	102.328	0.026		
2-Sep-14	7:15	1768604	260093	2289.5	9.4	92.924	102.373	0.026	27669	461
3-Sep-14	7:19	2029703	261099	2299.1	9.6	92.958	102.425	0.026	27198	453
4-Sep-14	7:32	2029703	0	2299.1	0	92.916	102.373	0.026		
8-Sep-14	9:30	2289082	259379	2308.9	9.8	92.895	102.421	0.026	26467	441
9-Sep-14	7:07	2346006	56924	2310.6	1.7	94.754	114.945	460.079	33485	558
10-Sep-16	7:18	2551781	205775	2318.1	7.5	93.019	102.499	0.026	27437	457
11-Sep-14	7:25	2551781	0	2318.1	0	93.041	102.525	0.026		
12-Sep-14	7:42	2551781	0	2318.1	0	93.058	102.544	0.026		

Table 4 (continued 3/3)

Silverton Water Wells

2014 well data, as recorded by Village staff. Calculated columns by Opus

Recorded Data									Calculated	
Date	Time	Volume Meter	Daily Volume	Hour Meter	Daily Hours	Level Old Well	Level New Well	Flow Meter	Flow Rate gal/hr	Flow Rate gal/min
15-Sep-14	7:17	2809531	257750	2327.5	9.4	93.113	102.65	0.026	27420	457
16-Sep-14	7:16	2834810	25279	2328.4	0.9	94.893	115.216	463.988	28088	468
17-Sep-14	7:13	3076094	241284	2337.3	8.9	93.172	102.67	0.026	27111	452
18-Sep-14	7:12	3076084	-10	2337.3	0	93.172	102.651	0.026		
22-Sep-14	8:12	3266824	190740	2344.4	7.1	93.189	102.696	0.026	26865	448
23-Sep-14	7:17	3506775	239951	2353	8.6	93.23	102.744	0.026	27901	465
24-Sep-14	7:28	3506775	0	2353	0	93.211	102.719	0.026		
25-Sep-14	7:10	3506775	0	2353	0	93.169	102.677	0.026		
26-Sep-14	7:24	3724888	218113	2361	8	93.241	102.757	0.026	27264	454
29-Sep-14	8:12	3890352	165464	2367	6	93.151	102.66	0.026	27577	460
30-Sep-14	7:24	3990068	99716	2370.6	3.6	93.189	102.69	0.026	27699	462
1-Oct-14	7:15	3990068	0	2370.6	0	93.18	102.68	0.026		
2-Oct-14	7:45	4094210	104142	2374.4	3.8	93.202	102.712	0.026	27406	457
3-Oct-14	7:44	4179794	85584	2377.6	3.2	94.991	114.98	447.148	26745	446
6-Oct-14	10:20	4295164	115370	2381.9	4.3	94.963	115.177	457.185	26830	447
7-Oct-14	7:26	4376009	80845	2384.7	2.8	93.244	102.754	0.026	28873	481
8-Oct-14	7:29	4444530	68521	2387.2	2.5	95.005	115.061	457.348	27408	457
9-Oct-14	7:16	4475822	31292	2388.4	1.2	93.258	102.77	0.026	26077	435
10-Oct-14	7:25	4675749	199927	2395.8	7.4	93.305	102.822	0.026	27017	450
14-Oct-14	7:32	4999163	323414	2407.7	11.9	93.286	102.809	0.026	27178	453
15-Oct-14	7:12	5149509	150346	2413.3	5.6	93.325	102.848	0.026	26847	447
16-Oct-14	7:32	5289043	139534	2418.5	5.2	93.283	102.799	0.026	26833	447
20-Oct-14	9:30	5623111	334068	2430.9	12.4	93.252	102.778	0.026	26941	449
21-Oct-14	9:40	5789602	166491	2437	6.1	93.258	102.708	0.026	27294	455
23-Oct-14	9:40	5954247	164645	2443.1	6.1	93.161	102.678	0.026	26991	450
27-Sep-14	9:16	6354633	400386	2458	14.9				26872	448
28-Oct-14	10:40	6486536	131903	2462.9	4.9	92.988	102.46	0.026	26919	449
3-Nov-14	9:30	7055739	569203	2483.9	21	94.632	114.51	446.569	27105	452
4-Nov-14	9:20	7129445	73706	2486.6	2.7	92.838	102.307	0.026	27299	455
5-Nov-14	9:40	7323264	193819	2493.8	7.2	94.587	114.489	447.38	26919	449
10-Nov-14	7:13	7871690	548426	2514.1	20.3	92.607	102.04	0.026	27016	450
12-Nov-14	7:18	8107381	235691	2522.8	8.7	92.688	102.153	0.026	27091	452
13-Nov-14	7:35	8107381	0	2522.8	0	92.607	102.053	0.026		
17-Nov-14	10:30	8510196	402815	2537.7	14.9	92.735	102.202	0.026	27035	451
18-Nov-14	7:22	8510196	0	2537.7	0	92.727	102.179	0.026		
19-Nov-14	7:20	8648694	138498	2542.8	5.1	92.76	102.763	0.026	27156	453
20-Nov-14	7:10	8661180	12486	2543.2	0.4	94.46	114.505	453.541	31215	520
21-Nov-14	7:37	9010780	349600	2556.2	13	94.621	114.522	447.346	26892	448
24-Nov-14	9:16	9280866	270086	2566.2	10	92.891	102.367	0.026	27009	450
25-Nov-14	7:15	9280866	0	2566.2	0	92.81	102.286	0.026		
26-Nov-14	7:06	9425016	144150	2571.5	5.3	92.844	102.338	0.026	27198	453
27-Nov-14	7:08	9425016	0	2571.5	0	92.789	102.315	0.026		
28-Nov-14	7:12	9653450	228434	2580	8.5	94.549	114.399	0.026	26875	448
1-Dec-14	8:30	9883279	229829	2588.4	8.4				27361	456
2-Dec-14	7:08	9977536	94257	2591.9	3.5	92.852	102.315	0.026	26931	449
3-Dec-14	7:20	121069	143533	2597.2	5.3	92.919	102.405	0.026	27082	451
4-Dec-14	7:16	121069	0	2597.2	0	92.869	102.247	0.026		
5-Dec-14	7:14	265651	144582	2602.6	5.4	92.913	102.396	0.026	26774	446
8-Dec-14	8:50	674828	409177	2617.8	15.2	92.947	102.441	0.026	26920	449
9-Dec-14	7:10	823722	148894	2623.3	5.5	92.972	102.463	0.026	27072	451
10-Dec-14	7:20	979996	156274	2629.1	5.8	92.832	102.493	0.026	26944	449
11-Dec-14	7:12	1090550	110554	2633.2	4.1	94.637	114.573	445.026	26964	449
12-Dec-14	7:36	1157922	67372	2635.6	2.4	92.869	102.347	0.026	28072	468
15-Dec-14	11:56	1653956	496034	2654	18.4	92.841	102.328	0.026	26958	449
16-Dec-14	7:35	1653956	0	2654	0	92.813	102.279	0.026		

Table 5

Canadian Geodetic Survey Bench Mark Data

Station Report

Site Identification

Name	Province	NTS map sheet	Unique Number	Provincial Identifier
1538J	British Columbia	082F14	60C076	

Horizontal Data

Coordinates scaled from map

Geographic

Latitude	Longitude
49° 57' 10.8"	117° 21' 18.0"

UTM

Zone	Easting (metres)	Northing (metres)	Scale
11	474533.422	5533465.444	.99961

Vertical Data

Vertical Datum	Elevation (m)	Order	Method	Gravity (mGal)	Published Year
CGVD2013 (2010.0)	552.405	First order	Differential	980768.4 ± 1.2	2013
CGVD28	552.129	First order	Differential	980768.4 ± 1.2	1985

Station Marker

Marker Type	Inspected in	Established by	Status	Comments
Permanent agency marker	1985	Geodetic survey division - nrcan	Good	None

Location

Accessible by passenger car or light truck and a walk of less than 50 m.

Silverton

Steel truss bridge over silverton creek in village, tablet in north face of south retaining wall at southwest corner of bridge, 1.8 m below top of wall, 70 cm from steel girder, 34 cm above bridge seat.

Table 6

Metrics of Silverton Aquifer

Distances

		meters	**Source**
Notch to Wells		180	Google Earth
Wells to Lake shore		460	Google Earth

Elevations (above sea level, CGVD28 datum)

	Google Earth	**meters**	
Benchmark on Bridge		552	Canadian Geodetic Survey
Wellhead	558	555	Estimated
Creek bed by wellhead	554	551	Estimated
Notch	564	561	Estimated
Lake, High water	540	537.5	RDCK

Gradient of Silverton Creek

	561-537.5/640	0.4 m/m	calculated

Areas (square kilometers)

		sq. km.	
Silverton Creek watershed		74	Opus mapping
Silverton Aquifer		0.36	Opus mapping

Volumes (264 gallons per cubic meter)

		gallons	**cubic meters**	
One cubic meter of aquifer				
	rock volume		1	calculated
	water volume	66	0.25	calculated
One meter thick slice of aquifer				
	rock volume		360,000	calculated
	water volume	24 million	90,000	calculated
Pumped volumes				
	Maximum day	265,000	1003	measured
	Low day	57,000	216	measured
	Abnormal day	488,000	1848	measured

Table 7 (1/2)

1988 Water Chemistry Analysis

CANTEST

CanTest Ltd

Professional
Analytical
Services

Suite 200
1523 West 3rd Ave
Vancouver, BC
V6J 1J8

Fax: 604 731 2386

Tel: 604 734 7276

RECEIVED AUG 11 1988

REPORT ON: Analysis of Water Sample

REPORTED TO: Urban Systems Ltd.
214 - 1826 Richter Street
Kelowna, B.C.
V1Y 2M3

Att'n: Dick Fletcher

FILE NO: 1022H

DATE: June 22, 1988 **(amended)**

We have tested the sample of water submitted by Kala Groundwater and report as follows:

SUMMARY:

For the chemical parameters tested, the sample met the limits set by the "British Columbia Drinking Water Quality Standards, 1982", Province of B.C., Ministry of Health and "Guidelines for Canadian Drinking Water Quality, 1978", published by authority of Health and Welfare Canada, as indicated in the "Results of Testing".

Parameters are limited for health or aesthetic reasons.

For the bacteriological parameters tested, the sample met the limits (i.e. coliform bacteria was not detected).

In summary, the water represented by the sample submitted may be characterized as moderate with respect to hardness and dissolved mineralization.

SAMPLE IDENTIFICATION:

The sample was identified as:

PROJECT NAME: Water Quality
DATE SAMPLED: May 18, 1988
DATE SUBMITTED: May 19, 1988 (by Larry Topp)
TYPE OF CONTAINER: Plastic

For further identification, see "Results of Testing".

CAN TEST LTD.

Don M. Enns, B.Sc., M.B.A.
Supervisor
Water Quality Laboratory

DME/csd
C:WATER

Table 7 (continued 2/2)

CANTEST

Urban Systems Ltd.
File No: 1022H
Page No: 2

SAMPLE IDENTIFICATION AND RESULTS OF TESTING:

SAMPLE # / CLIENT SAMPLE I.D.		1022 VILLAGE OF SILVERTON NEW WELL - MAY 18/88 AFTER 23 HRS PUMPING	MAXIMUM ACCEPTABLE CONC.***
PHYSICAL TESTS			
pH (pH units)		7.07	6.5-8.5
Conductivity (us/cm)		142.	-
True Color (CU)		5.	15.
Turbidity (NTU)		0.54	5.
Hardness as CaCO3		70.	-
Total Dissolved Solids (mg/L)		125.	500.*
DISSOLVED ANIONS (mg/L)			
Alkalinity:			
Bicarbonate	HCO3	72.0	-
Carbonate	CO3	Nil	-
Hydroxide	OH	Nil	-
Chloride	Cl	0.42	250.
Sulfates	SO4	14.4	500.
Nitrates/Nitrites	N	0.096	10.**
Fluorides	F	< 0.05	1.5
DISSOLVED METALS (mg/L)			
Calcium	Ca	22.7	-
Magnesium	Mg	3.01	-
Sodium	Na	1.53	-
Potassium	K	1.12	-
Lead	Pb	<0.001	0.05
Iron	Fe	< 0.030	0.30
Manganese	Mn	< 0.003	0.05
Silicon	Si02	8.44	-
Zinc	Zn	<0.010	5.0
TOTAL METALS (mg/L)			
Magnesium	Mg	3.08	-
Iron	Fe	< 0.030	0.30
Manganese	Mn	< 0.003	0.05
Uranium	U	0.0005	0.02
RADIOLOGICAL (Bq/L)			
Radium 226	Ra 226	< 0.05	1.
COLIFORM BACTERIA (MPN/100mL*R)			
Total (Confirmed)		< 1.	-
Fecal		< 1.	Not detected

* = filtered a 0.45 micron membrane
** = total nitrate and nitrite nitrogen
*** = maximum acceptable concentration as set by "B.C. Drinking Water Quality Standards, 1982" and "Guidelines fo Canadian Drinking Water Quality, 1978"
< = less than; mg/L = milligrams per litre

Table 8 (1/3)

Water Chemistry, Silverton Creek (from Slocan Lake Stewardship Society)

Flow Rates

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

Table 8 (continued 2/3)

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)
			Units	mg/L	mg/L	mg/L	mg/L
			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
k Stewardshi	10/13/2015 18:00	NJSLV01	SILVERTON CREEK WQM	<0.0050	0.042		
k Stewardshi	9/20/2015 0:00	NJSLV01	NJSLV01	<0.0050	<0.020	41	<0.50
k Stewardshi	8/10/2015 18:00	NJSLV01	NJSLV 01	<0.0050	0.024		
k Stewardshi	7/13/2015 18:45	NJSLVO1	ERTON CURB WQMP, NJS	<0.0050	<0.020		
k Stewardshi	6/15/2015 18:00	NJSLV01	/ERTON CRK WQMP NJS	<0.0050	0.034		
k Stewardshi	5/11/2015 18:00	NJSL V01	NJSLV01	<0.0050	0.129		
k Stewardshi	4/20/2015 13:30	NJSLV01	ERTON CREEK WQMP/ NJ	<0.0050	0.114		

Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Orthophosphate (P)	Nitrate plus Nitrite (N)	Dissolved Oxygen	Specific Conductivity	pH	Turbidity
mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	uS/cm		NTU
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
				0.042	13	82.5	8.4	1.6
50	<0.50	<0.50	<5.01	<0.020	10	88.6	8.25	0.41
			<5	0.024	11	91.7		0.52
			<5	<0.020	9	82.2	7.73	0.32
			<5	0.034	12	77.1	7.84	0.92
			<5	0.129	12	94.8	7.94	1.24
				0.114	12	95.8	7.65	0.26

- BC Approved Water Quality Guidelines (Gover rnment of BC 2006)
- BC Working Water Quality Guidelines (Nagpal et al. 2006)
- 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
C	C	mg/L	mg/L	µg/L		mg/L	uS/cm	mg/L
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
6.5	10					0.099		<4.0
9.4	15.8	49.1			<0.0050	0.095		<4.0
13.7	22.5				<0.0050	0.074		<4.0
11	19.5				<0.0050	0.027		<4.0
10	22	35			<0.0050	0.059		<4.0
7.35	20				0.0069	0.183		<4.0
5.5	15					0.151		<4.0

Dissolved Calcium (Ca)	Dissolved Magnesium (Mg)	Sulphate (SO4)	Dissolved Chloride (Cl)	Total Ammonia (NH3)	E. Coli
mg/L	mg/L	mg/L	mg/L	CFU	
no stream guideline	no guideline				
			0.62		2
			1.6		<1
			<0.50		4
			<0.50		15
			<0.50		<1
			<0.50		<1
			<0.50		<1

Table 8 (continued 3/3)

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

grey	BC Approved Water Quality Guidelines (Governme nt of BC 2006)
blue	BC Working Water Quality Guidelines (Nagpal et a l. 2006)
orange	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