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PRELIMINARY STEPS IN THE DEVELOPMENT OF A GROUNDWATER PROTECTION PLAN

Beaver Falls Waterworks District, Montrose, BC

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REPORT

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) is pleased to present this report, which outlines the initial stages in the development of a Groundwater Protection Plan (GWPP) for the water supply wells of Beaver Falls Waterworks District (BFWD) located near Fruitvale, BC (Figure 1). This work was completed at the request of the Interior Health Authority (IHA) in a letter dated November 21, 2007.

This work was authorized by Ms. Kandy Schroder of BFWD on September 15, 2008 and follows the methodology contained in a proposal submitted by Golder on January 24, 2008.

2.0 PROJECT UNDERSTANDING

The BFWD's potable water supply has been sourced for several years from groundwater extracted from two production wells operated by BFWD near Fruitvale, BC. The two production wells (Wells No.1 and No.2) are located approximately 42 m apart and are situated adjacent to Beaver Creek, just outside the southwest municipal boundary of the Village of Fruitvale. Well No.1 was recently taken out of service and since then, BFWD's potable water supply is entirely sourced from Well No.2. Given the age of Well No.1 (1973) and due to a decline in the well's production capacity, a third production well (Well No.3) was drilled in 2005 (approximately 3 m from Well No.1), with the intention of using it as a replacement well for Well No. 1.

In 2008, Golder conducted a 26-hour constant rate pumping test on Well No.3 and a short-duration step-drawdown pumping test on Well No.1 to assess the sustainable yields available from both wells. Based on the results of the pumping tests, the sustainable yield from Well No.3 in its present condition is 6.0 L/s (96 USgpm) whereas the results from short duration pumping of Well No.1 indicate the well yield in its present condition is 9.6 L/s (153 USgpm). Down-hole camera surveys conducted in each well confirmed that both wells are heavily plugged and encrusted by calcareous deposits and/or iron and manganese oxides. In order to increase the specific capacity and the well yield of these wells, re-development and rehabilitation was recommended.

A preliminary GWUDI (Groundwater Under the Direct Influence of surface water) assessment was also conducted as part of this initial investigation. Given the close proximity to Beaver Creek, the production wells were flagged as potentially being under the direct influence of surface water. It is our understanding individual septic fields are used to dispose of sewage within the boundaries of the BFWD, but that most of the residences associated with these septic fields appear to be located downgradient or side-gradient of the production wells. The Village of Fruitvale, located north of the BFWD wells, operates a municipal sewage treatment plant. The treated effluent is ultimately discharged to Beaver Creek at a location that is approximately 600 m upstream of the wells.

IHA has expressed concern in regards to the possible impact, if any, that the discharge of the Village of Fruitvale's treated sewage effluent into Beaver Creek may have on the BFWD wells. In a letter to BFWD, dated November 21, 2007, IHA stated the importance of ensuring that the water provided to the users of the BFWD water system remains potable at all times. A condition of the operating permit for the BFWD is to determine whether or not the production wells draw groundwater from a source that is GWUDI and to plan for disinfection or other treatment that may be required to address other physical or chemical concerns.

IHA requested that the BFWD submit a Hydrogeological Report to characterize the aquifer from which the production wells extract groundwater for their potable water system. IHA has stipulated that the Hydrogeological Report address, but not be limited to, the following:

- Provide an overview of the hydrogeology and aquifer characteristics, including an assessment of the aquifer's vulnerability to potential impacts;
- Provide a capture zone analysis and GWUDI assessment;

- If the aquifer is not confined and there appears to be hydraulic connection with Beaver Creek, provide an estimated transit time for water from the creek to reach the pumping wells;
- Assess whether contamination of the aquifer could occur if the sewage lagoons are not maintained and operated in a proper fashion (i.e. assess the aquifer's vulnerability to land use practices) and provide recommendations for monitoring;
- Identify any other potential sources of contamination of the aquifer that lie within the capture zone of the wells (i.e. land-use inventory); and
- Provide recommendations for the development of a groundwater protection plan.

Although IHA has indicated the Hydrogeological Report need only contain recommendations for the development of an aquifer or groundwater protection plan (GWPP), many of the tasks that IHA requested be completed, actually form the basic components of a GWPP. Ultimately, the development of a GWPP will provide the BFWD with the necessary guidance tools to ensure that a safe and sustainable water supply is maintained for the users of the system.

3.0 METHODOLOGY

The Well Protection Toolkit (WPT) was used as a guide in the development of the GWPP. The WPT was developed jointly by the Ministry of Environment (known previously as the Ministry of Water, Land and Air Protection) and the Ministry of Health in 2000, and consists of a six-step process created to assist communities that utilize groundwater to better manage and protect their drinking water sources.

The six steps outlined in the WPT are as follows:

Step 1. Form a Community Planning Team;

Step 2. Define the Well Protection Areas;

Step 3. Identify Potential Contaminants;

Step 4. Develop Management Strategies;

Step 5. Develop Contingency Plans; and

Step 6. Monitor Results and On-going Evaluation of the Plan.

For this study, the basic components of the first four steps (Steps 1 to 4) of the WPT were followed. However, based on Golder's experience with developing GWPPs, it was determined that the best approach in completing the GWPP for BFWD was to complete the technical aspects of the study before forming a Community Planning Team With this in mind, the initial emphasis of the study was on defining the time-of-travel capture zones for the BFWD wells, providing a GWUDI assessment, identifying potential threats to the water source from surrounding land use and recommending groundwater protection measures. Once the technical information presented in this report is reviewed and finalized, it can be presented to the public for review and input.

The following provides the specific scope of work for this initial phase of the GWPP:

- Gather and review available information on the production wells and local aquifer(s);
- Complete a location and elevation survey of the BFWD wells and Beaver Creek and collect static water levels of the surveyed wells to estimate a groundwater flow direction and hydraulic gradient;

- Identify aquifer characteristics in the area and estimate the extent of the time-of-travel capture zones for the BFWD wells by incorporating the groundwater flow direction and hydraulic gradient information;
- Complete a GWUDI assessment; and
- Complete a preliminary contaminant inventory for the BFWD wells, including a review of available information (land use maps, zoning bylaws, air photographs, etc.), completing a search of the Ministry of Environment (MOE) Contaminated Sites Registry Database, conducting interviews with local representatives and conducting a windshield survey of the area.

It is understood that further progress in the development of the GWPP for BFWD wells (the completion of Steps 4, 5 and 6) will be based on the findings of this report and will be a function of funding availability.

4.0 STUDY AREA

4.1 Location

The BFWD wells are situated adjacent to Beaver Creek, just outside the southwest municipal boundary of the Village of Fruitvale in the vicinity of Scout Camp, which is accessed from Bluebird Avenue on the east side of Highway 3B (Figure 1). The BFWD's potable water supply is currently sourced from Well No.2 located approximately 17 m northwest of Beaver Creek. Well No.1, which is located approximately 42 m to the northeast of Well No.2, was recently taken out of service. A third production well (Well No.3) was drilled in 2005, approximately 3 m to the north of Well No.1. Wells No.1 and No.3 are located in the same pumphouse. The pumphouse is located approximately 37 m north of Beaver Creek. Well No.3 was drilled as a replacement for Well No.1, but has yet to be placed in service.

The local topography in the Study Area is characterized by a flat and narrow valley bottom surrounded by steep slopes to the west and east. The valley generally runs in a northeast to southwest direction and is bounded to the northwest by the Bonnington Range. The elevation of the study area is approximately 575 meters above sea level (masl). The land use within the study area is zoned rural and residential.

4.2 Overview of Surficial and Bedrock Geology

The BFWD wells are constructed in alluvial sediments associated with the Beaver Creek valley. The alluvial sediments form a relatively narrow strip along the creek and are bordered by bedrock on both sides. According to the well logs, the unconsolidated sediments in the vicinity of the BFWD wells consist of sand and gravel with variable amounts of silt and clay. The bedrock geology in the area is described as mudstone, siltstone, shale and fine clastic sedimentary rocks from the Lower Jurassic Period. Apart from providing a physical boundary that the unconsolidated sediments of the valley are situated within, the bedrock in the Study Area is expected to provide recharge to the local groundwater flow regime.

5.0 HYDROGEOLOGY

5.1 BFWD Water Supply System

5.1.1 Water Consumption Record

Water consumption data from November 2007 to April 7, 2009 were provided to Golder by the BFWD. According to the available records, the total water consumption in 2008 was approximately 125,000 m^3 (33,000,000 US gal). This is equivalent to a pumping rate of 4 L/s (62.7 USgpm) if pumping continuously 24-hr/day, 365 days a year. Well No.1 has recently been taken out of service and therefore, the BFWD's water supply is sourced entirely by Well No.2. In 2008, Well No.2 was pumping at an average discharge rate of 16.4 L/s (260 USgpm) for periods of time varying between 3 hr to 12.6 hr per day.

5.1.2 Existing Information on Well No.1

Well No.1 is located inside a locked and secured masonry pumphouse (Pumphouse No.1) with a concrete slab around the well. The well casing is approximately 0.33 m above the pumphouse floor. No surface seal is reported on the detailed well record provided in Livingston's report (1973). According to the well log provided in Kala (1998), Well No.1 was drilled to a total depth of 20.7 m (68 ft) below ground surface in 1973. The well is completed with 250 mm (10 inch) diameter well casing and nominal 200 mm (8 inch) telescopic, stainless steel well screen. The well screen assembly is approximately 7.6 m (25 ft) in length, and consists of five, 1.5 m (5-ft) lengths of well screen, with slot sizes varying between 60-slot (0.060 inch) and 100-slot (0.100 inch). The largest slot-size well screen (100-slot) is located at the bottom of the assembly and the smallest slot size (60-slot) is at the middle of the assembly. The screen is equipped with a K-packer located at 12.5 m (41 ft) below ground surface. The log for Well No. 1 is provided in Appendix I.

At the time of construction in 1973, the specific capacity of Well No.1 was reported at 2.1 L/s/m (10.2 USgpm/ft) of drawdown at a pumping rate of 19.4 L/s (307 USgpm). Following rehabilitation of Well No.1 in 1999, the specific capacity had increased to 2.8 L/s/m (13.5 USgpm/ft) (Precision Service and Pumps, 1999). However, Well No.1 was recently taken out of service due to a decline in capacity. When tested by Golder in 2008, the specific capacity of Well No.1 at a pumping rate of 12.4 L/s (196 USgpm) was 1.3 L/s/m (6.2 USgpm/ft). Based on the results of the short duration pumping test conducted on Well No.1, the sustained yield of the well in its present condition is 9.6 L/s (153 USgpm) (Golder, 2008).

5.1.3 Existing Information on Well No.2

Well No.2 is located inside a locked and secured masonry pumphouse with a concrete floor (Pumphouse No.2). The detailed well record provided in Pacific Hydrology's report (1985) indicates that a 300 mm (12 in) surface casing was installed to a 3 m (10 ft) depth but there is no indication that the casing was removed and that sealant material was added in the annular space. According to the well record, Well No.2 was drilled to a total depth of 28.1 m (92 ft) below ground surface in 1985. The well is completed with 250 mm (10 inch) diameter well casing and nominal 200 mm (8 inch) telescopic, stainless steel well screen. The well screen assembly is approximately 7.6 m (25 ft) in length, and consists of five, 1.5 m (5-ft) lengths of well screen, with slot sizes varying between 20-slot (0.020 inch) and 120-slot (0.120 inch). The largest slot-size well screen (120-slot) is located at the top of the assembly and the smallest slot size (20-slot) is at the middle of the assembly. The screen is equipped with a K-packer located at 19.9 m (65 ft) below ground surface. The log for Well No.2 is provided in Appendix I.

At the time of construction in 1985, the original specific capacity of Well No.2 was reported at 1.4 L/s/m (6.9 USgpm/ft) of drawdown at a pumping rate of 19 L/s (302 USgpm).

5.1.4 Existing Information on Well No.3

Well No.3 is located inside Pumphouse No.1 approximately 3 m from Well No.1. As mentioned above, there is a concrete slab around Well No.1 but there is no concrete slab around Well No.3. The well casing is approximately 1.13 m above the soil that forms the floor of Pumphouse No.1 around Well No.3. No surface seal is reported on the detailed well record provided by BFWD (Appendix I). According to the water well record, Well No.3 was drilled to a total depth of 26.8 m (88 feet) below ground surface in May 2005. The well is completed with 250 mm (10 inch) diameter well casing and nominal 200 mm (8 inch) telescopic, stainless steel well screen, to a depth of 23.2 m (76 ft). The well screen assembly is approximately 6.7 m (22 ft) in length, and consists of four, 1.5 m (5-ft) lengths of well screen, with slot sizes varying between 50-slot (0.050 inch) and 150-slot (0.150 inch). The largest slot-size well screen (150-slot) is located at the bottom of the assembly and the smallest slot size (50-slot) is at the top of the assembly, which is equipped with a K-packer located at 16.5 m (54 feet) below ground surface. The well screen assembly was set adjacent to a sand and gravel formation, which is noted on the well log to be present between 11.6 m and 23.5 m below ground surface (38 ft to 77 ft). The formation overlying and underlying the screened section of the aquifer is identified as clay and gravel on the well log. The static water level in the well, at the time of drilling, was at 7.6 m (25 feet) below ground surface. The well was reportedly developed, using the air-lifting capabilities of the drill rig. Details of well development (including estimation of well yield) were not noted on the well log by the driller and a pumping test had not been conducted on the well, so the well yield had not been quantified. However, the driller (Owens Drilling) was contacted by Golder to enquire about the potential yield from the well. The driller stated he could not quantify the volume of water coming from the well during development with air, but indicated it was significant. It should be noted that the well log provided by the driller denotes a recommended pump setting depth of 21.9 m (72 ft), but this would place the pump within the well screen assembly, close to the bottom of the well. This is not a good practice for several reasons, including the potential for improper cooling of the pump motor, cascading water effects if drawdown is taken below the top of the well screen, and potentially higher entrance velocities, leading to rapid corrosion and/or encrustation of the well screen.

In 2008, Golder conducted a 26-hour constant rate pumping test on Well No.3, When tested, the specific capacity of Well No.3 at a pumping rate of 6.3 L/s (100 USgpm) was 0.6 L/s/m (3.0 USgpm/ft). Based on the results of the pumping tests, the sustainable yield from Well No.3 in its present condition is 6.0 L/s (96 USgpm) (Golder, 2008).

5.2 Aquifer Characteristics

The BC MoE has completed the delineation and classification of aquifers in this part of the Province under the BC Aquifer Classification System. Currently, the sand and gravel aquifer in which the BFWD wells are completed is not identified within the classification system but BC MoE has identified a bedrock aquifer to the east of the wells on the other side of Beaver Creek. Aquifer No. 486 is classified as a bedrock aquifer with a low demand, low productivity and moderate vulnerability (Aquifer Classification IIB).

According to the well logs, approximately 11 m of silty sand and gravel overlies the sand and gravel aquifer intercepted by the BFWD's wells, providing some level of protection. However, there is no information available on the continuity of this silty layer. In 2008, Golder conducted a 26-hour constant rate pumping test on Well No.3 and a short-duration step-drawdown pumping test on Well No.1 to assess the sustainable yields available from both wells. Based on the drawdown and recovery data obtained from Well No.1, Well No.2 and Well No.3 during the constant-rate pumping test, the aquifer transmissivity and storativity were calculated using AQTESOLV^{TM}, a commercial software package for pumping test analysis. Transmissivity (T) is the rate at which groundwater is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Storativity is defined as the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

The pumping test responses obtained for the pumping well (Well No.3) and the observation wells (Well No.1 and Well No.2) indicates the presence of a confined aquifer with a constant-head boundary located upstream approximately 80 m from Well No.1. The derivative plots for all wells also confirmed the presence of a constant-head boundary. The drawdown data recorded during the constant-rate pumping test were analyzed using the analytical, type-curve solution by Theis (1935) and Cooper-Jacob (1946), available in AQTESOLV™. In order to provide a conservative value of transmissivity for the capture zone analysis, an analysis based on the composite plot approach was also used to estimate the transmissivity of the aquifer using the early-time data. Copies of the output file and plots of the solutions generated using the AQTESOLV™ program are included in Appendix II.

The aquifer transmissivity is estimated to be 175 m^2/day. The hydraulic conductivity (K) of the aquifer is estimated to be in the order of 1 x 10^{-4} m/s (10.3 m/day), assuming the approximate 17 m thickness of the sand and gravel aquifer material in which the wells are completed. This is consistent with data found in the literature which provides a hydraulic conductivity range of 10^{-4} m/s to 10^{-2} m/s for sand and gravel (Freeze & Cherry, 1979).

5.3 Groundwater Flow Direction and Hydraulic Gradient

To determine the hydraulic gradient and groundwater flow direction in the vicinity of the BFWD wells, the location and relative elevation of the BFWD wells were surveyed along with a staff gauge installed in Beaver Creek while conducting the pumping test in July 2008. The static water levels were measured prior to starting the pumping test and varied between 2.0 to 3.0 m below the top of casing of the wells. The resultant groundwater flow direction was determined to be generally from north to south, towards Beaver Creek (Figure 2) and the localized hydraulic gradient was calculated to be approximately 0.005 m/m. However, it should be noted that the location and configuration of the existing wells do not allow for a good representation of the groundwater flow direction and hydraulic gradient. Additional observation wells would be required to be able to determine the exact groundwater flow direction and hydraulic gradient. In addition, groundwater flow direction and hydraulic gradient may also experience seasonal variations.

6.0 GROUNDWATER PROTECTION PLANNING

6.1 Community Planning

During the development and implementation of a GWPP, it is important to include the interests of community members and land-users. Step 1 of the WPT consists of the formation of a Community Planning Committee to assist in the GWPP development. However, based on Golder's past experience and on the limited number of BFWD users, it was determined that the best approach would be to focus on gathering the technical information required for a GWPP before soliciting input from the public.

6.2 Well Protection Areas and GWUDI Assessment

6.2.1 Capture Zone Analysis

6.2.1.1 Methodology

During the pumping of a well, groundwater is removed from a finite volume of the aquifer. In the initial phases of pumping, the drawdown cone created by the well expands and groundwater is removed from storage within the aquifer (due to pore drainage, aquifer matrix compression, and water compressibility). In later stages, once the drawdown cone attains sufficient dimensions and/or intersects a constant-head boundary, groundwater flows radially towards the well and the aquifer is replenished by recharge due to precipitation and/or leakage from streams, rivers, and geologic units bounding the aquifer.

To efficiently manage and protect a groundwater supply, an understanding of the well “capture zone” and the “time of travel” are required. A capture zone is the area of an aquifer from which all groundwater will eventually arrive at the well after an infinite amount of time. The capture zone should not be confused with the zone of influence or the cone of depression, which is the area surrounding a pumping well within which the water table or potentiometric surface has been lowered due to groundwater withdrawal. A time of travel zone is the area within the capture zone from which groundwater will be derived in a predefined amount of time. For example, if a conservative aqueous contaminant is released at the boundary of the 1-year time of travel zone, it can be expected to arrive at the well within approximately 1 year. Once the capture zone and time of travel zones are estimated, the appropriate monitoring and protective measures can be implemented.

Several methods of capture zone analysis are provided within the WPT including: 1) Calculated Fixed Radius (CFR), 2) Analytical Equations, 3) Analytical Groundwater Flow Models and 4) Numerical Flow and Transport Models. The methods vary in their accuracy and applicability. Method 1, or the CFR method, is the least technically rigorous as it uses only the pumping rate and assumptions regarding the aquifer porosity and thickness to approximate a circular well capture zone. The remaining methods are based on hydrogeologic principles, with Method 2 being used to represent relatively simple groundwater regimes, while Methods 3 and 4 are capable of representing more complicated stratigraphy, hydrogeologic boundaries, and variable pumping scenarios and can be used as a forecasting tool. Although more technically rigorous, Methods 3 and 4 require considerably more effort and data regarding hydrogeologic conditions.

Since the hydraulic gradient and groundwater flow direction were measured as part of this study and a number of the aquifer parameters have been estimated from previous studies, analytical equations (Method 2) were considered to be the most applicable tools for calculating the capture zones for the BFWD wells.

The analytical equations methodology is most applicable to simple groundwater flow regimes; however, this requires knowledge of the groundwater flow direction and aquifer properties (transmissivity, hydraulic gradient, aquifer thickness, and porosity) in addition to the pumping rates for the production well. To assist with the selection of the most appropriate analytical solution for delineation of the time-of-travel capture zones, a dimensionless time-of-travel parameter (T*) derived by Ceric and Haitjema (2005), was calculated. The results of this calculation provided a basis for selection from three types of analytical solutions for capture zone estimation: the Centric Circular (CC) (this method is similar to the CFR method), the Eccentric Circular (EC), and the Boat-Shaped (BS) capture zone.

Calculations and detailed descriptions of these solutions and T* are provided in Appendix III. The travel times for the wells were computed for:

- 100 days (0.274 year) – generally considered to be the approximate time required by biological pathogens moving in groundwater to degrade based on BC MoE draft GWUDI guidance document (2007); and
- 1 year – intermediate time selected based on the hydrogeologic conditions prevailing in the area.

6.2.1.2 Time-of-Travel Capture Zone Results

The capture zones for each well were calculated using an aquifer thickness of 17 m, a porosity of 0.25 (conservative estimate for sand/gravel aquifers), a hydraulic conductivity of 1×10^{-4} m/s and an average flow rate of 4.0 L/s (63 USgpm). Golder assumed that the BFWD would be sourced by a maximum of two wells (Well

No.2 and either Well No.1 or Well No.3). In addition, the average flow rate was calculated based on the total annual consumption for each well. This is a conservative estimate because in reality, if two wells are operating to supply potable water to BFWD, the average flow rate for each well would be less and therefore the individual capture zones would be smaller. As discussed in the previous section, the groundwater flow direction is inferred to be to the south and the inferred hydraulic gradient calculated in the vicinity of the wells is 0.005 m/m. The results of the 100-day and 1-year capture zones for the BFWD using the analytical solution methodology are summarized in Table 1. The selection of the Eccentric Circular (EC) capture solution for 100-day and 1-year time of travel was based on the results obtained for the dimensionless time-of-travel parameter ($0.1 < T^* < 1$). A description of the analytical solution methodology, with calculations for T* and the 100-day and 1-year capture zones are provided in Appendix III. The calculated capture zones for 100-day and 1-year are presented on Figure 3 and are the same size for all three wells. Because, it is assumed that either Well No.1 or Well No.3 would be in operation in addition to Well No.2, the capture zones for only two wells are presented on Figure 3. It should be noted that the capture zones for Well No.1 and Well No.3 are considered to be coincident since the wells are only 3 m apart.

Table 1: Time-of-Travel Zone Estimates

Parameter	**BFWD Wells**	
	100-day	1-year
Capture Zone Type	EC	EC
R=Fixed-radius	51 m	102 m
δ=amount of upgradient shift of the circle centre	12 m	41 m

The results obtained using the analytical solution indicate that the extent of the 100-day and 1-year time-of-travel zones intersect Beaver Creek for both wells. However, as indicated in section 5.3, the groundwater flow direction and hydraulic gradient were inferred based on limited data. Additional observation wells would be required to determine the exact groundwater flow direction and hydraulic gradient. A steeper hydraulic gradient would shift the capture zones upgradient (i.e away from the creek).

6.2.1.3 Limitations of Capture Zone Delineation Method Employed

The analytical solution used to estimate the time-of-travel capture zones for the BFWD wells are calculations based on simple physical assumptions of the aquifer system. The methodology assumes that:

- The aquifer is homogeneous and isotropic with a constant thickness and porosity;
- The aquifer has an infinite aerial extent;
- The hydraulic conditions within the aquifer are at steady state; and,
- The flow field is simple (unidirectional) in that there is an absence of interfering flow features.

The analytical methodology is considered fairly accurate for short travel times. Capture zone distances for longer time-of-travels are less accurate because other physical characteristics of the aquifer for which there is little to no data (variation in hydraulic gradients, stratigraphic changes at increased distances from the well, increased likelihood of encountering aquifer boundaries), are not considered using this method. Also, once the capture zones overlap with surface water bodies or physical boundaries, they are considered invalid.

It should be noted that the analytical solution method does not account for the following:

- Seasonal fluctuations in precipitation and recharge from surface water bodies (streams, creeks, rivers or lakes);
- Interferences due to bedrock or stratigraphic changes;
- Interactions with other wells;
- Dispersion, retardation or degradation of contaminants in groundwater; and,
- Changes in pumping rates, based on daily and seasonal variations controlled by water supply demands and down time due to maintenance.

6.2.2 Water Quality

6.2.2.1 Historical Bacteriological Data

The BFWD collects water samples from the water distribution system at six (6) different locations from the water distribution system on a bi-monthly basis, submitting the samples to CARO Environmental Services (CARO) in Kelowna for the analyses of total coliforms and *E.coli*. Historical bacteriological data collected at Well No.2 for 2007, 2008 and 2009 (January to May only for 2009) were provided by IHA and reviewed by Golder. The results indicate that *E.coli* was never detected in any of the water samples collected since 2007. One (1) total coliform was detected on the sample collected on Christie Road on November 12, 2008. It should be noted that the BFWD have been providing potable water to the Village of Montrose during the fall of 2008 when the Village of Montrose were changing a watermain on their distribution system. This sampling event corresponds to the date when the water sharing between Montrose and BFWD ended. Christie Road had been using water solely from the upper reservoir in Montrose during the period when BFWD was providing water to the Village of Montrose. This meant that a section of watermain between the easternmost house on Christie Road and the valve that shut Christie Road off from the BFWD system contained stagnant water which could explain the positive result. Interior Health was notified, hydrants were flushed and Christie Road was re-sampled by Interior Health. No total coliforms were detected in the sample collected on November 18, 2008. Because water samples collected from the distribution system do not allow for the identification of the source of contamination (aquifer or distribution system) when sampling results exceed the applicable guidelines, Golder recommends the BFWD start collecting water samples at the production well in addition to their normal sampling program of the distribution system.

6.2.2.2 Water Chemistry of Groundwater and Surface Water

Water sampling for general chemistry was not part of the scope of work of the present study. However, water quality results available for Well No.1, Well No.2, Well No.3, and Beaver Creek, together with field parameters were assessed for general water chemistry. Water quality results for water samples collected on May 9, 2006 and on May 25, 2009 at Well No.2 were provided to Golder by the BFWD. Water samples were also collected at Well No.3 and Beaver Creek on July 22, 2008 by Golder when conducting the pumping test (Golder, 2008). Only limited water quality data are available for Well No.1. Water samples collected on February 27, 2008 at

Well No.1 were analyzed for total metals only. The water quality results available are presented in a table format in Appendix IV.

A cation-anion balance was performed and indicated that the cation-anion difference was equal or less than 5%, confirming the validity of the chemical analysis. Based on the major ion chemistry, groundwater and surface water in the area have the same calcium bicarbonate hydrochemical facies even though common ion concentrations are higher in groundwater compared to surface water. This is not surprising as the hydrochemical facies are a function of the lithology. The composition of natural waters is a function of a multiplicity of factors, including the initial composition of the water, the partial pressure of the gas phase, the type of mineral matter the water contacts, and the pH and oxidation potential of the solution. Both groundwater and surface water in the area are in contact with similar geological formations. The BFWD wells are constructed in a relatively shallow sand and gravel aquifer adjacent to Beaver Creek. The higher constituent concentrations measured in groundwater would usually indicate a longer contact time with geological material.

Significant differences in water chemistry were observed for field and laboratory results, as follows:

- Field pH higher for Beaver Creek (7.8) compared to Well No.2 (6.8) and Well No.3 (6.8);
- Water temperature higher on July 21, 2008 for Beaver Creek (15.7 °C) compared to Well No.3 (9.4 °C);
- Dissolved oxygen content lower for Well No.2 (4.77 mg/L) compared to the Beaver Creek (11.07 mg/L) on July 21, 2008;
- Conductivity lower in Beaver Creek (196 uS/cm) compared to Well No.2 (382 uS/cm) and Well No.3 (415 uS/cm);
- Hardness lower in Beaver Creek (80 mg/L) compared to Well No.2 (159 mg/L) and Well No.3 (165 mg/L);

Although the field-measured DO concentrations in both wells indicate the groundwater is oxidized, the DO in the well water samples is lower than that of the surface water samples. The DO concentration in groundwater or surface water is a function of contact time with air, temperature, pressure, and to a lesser degree, of the concentration of other constituents in the water (Hem, 1985). Typically, deeper groundwater, or groundwater with a long residence time has a lower DO concentration than shallow groundwater or “fresh” surface water. The source of oxygen for groundwater is through recharge from surface sources and/or by movement of air through the unsaturated zone above the water table.

6.2.2.3 Water Quality Monitoring

A water quality monitoring program was implemented in the spring of 2009 to determine whether groundwater is hydraulically connected to surface water. During freshet, several surface water quality parameters, such as conductivity and turbidity, are expected to vary considerably in response to snow melt. The water quality monitoring program was implemented during this period to assess if variation in groundwater quality would also be observed and correlated with variation of surface water quality, thus indicating a hydraulic connection.

During the spring of 2009, the BFWD started monitoring water quality weekly at Well No.2 and in Beaver Creek in addition to the distribution system in order to have water samples representative of the water quality of the aquifer. The BFWD started collecting water samples at Well No.2 on April 24, 2009 and in Beaver Creek on May 18, 2009. The water samples collected were sent to CARO and analysed for total coliforms, *E.coli*, heterotrophic plate count, pH, conductivity, turbidity and UV transmittance. The water samples collected in Beaver Creek were not analyzed for the bacteriological parameters except for one occasion to confirm the presence of total coliforms and *E.coli* in the creek. In addition, field parameters (pH, conductivity, temperature, oxidation-reduction potential, and dissolved oxygen) measured by Golder during the pumping test conducted in July 2008 and at every site visit conducted during the course of the project were included as monitoring data.

The tabulated results are presented in Appendix IV. Total coliforms and *E.coli* were not detected in any of the samples collected in Well No.2. Temperature remained constant (9ºC) in Well No.2. During the same period, the temperature in Beaver Creek varied from 8ºC in May to 16 ºC at the end of July. UV transmittance was also monitored in Well No.2 and oscillated between 94.7% and 99.2%. Figures 4 and 5 present graphs of electrical conductivity and turbidity versus time for well No.2 and Beaver Creek. Figure 4 shows that the electrical conductivity measured in Well No.2 remained relatively constant during the monitoring period, ranging between 363 uS/cm and 390 uS/cm. In comparison, the electrical conductivity measured in Beaver Creek varied considerably between baseline conditions measured in July 2008 and July 2009 (189 uS/cm-196 uS/cm) and freshet (low of 106 uS/cm measured on June 1, 2009). Figure 5 shows that turbidity measurements in Beaver Creek were higher during freshet (May and beginning of June) whereas they remained low and constant (< 0.1 NTU to 0.3 NTU) in Well No.2. It was therefore not possible to correlate the variations of conductivity and turbidity observed in Beaver Creek with the values measured at Well No.2.

6.2.2.4 MPA Testing

As part of the GWUDI assessment, Microscopic Particulate Analysis (MPA) testing was conducted on Well No.2. MPA testing was conducted in accordance with the United States Environmental Protection Agency (EPA) "Consensus Method for Determining Groundwater Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (Consensus Method)" (USEPA, 1992). The intent of the test is to identify organisms that only occur in surface water (as opposed to groundwater) and whose presence in groundwater would provide indication of hydraulic connection with a surface water source.

A MPA test was conducted on Well No.2 on June 10, 2009. The test was conducted after the peak of freshet which is the time of the year when there is the greatest potential for impact from nearby surface water. The test was conducted after the peak of freshet to consider time of travel delays. The MPA sample was collected using a MPA Sampling Device which consists of an inlet hose with a backflow preventer, a ten-inch cartridge filter housing, a water meter, a flow control valve and a discharge hose. The sample, collected using ten-inch yarn wound (string) filters, was sent to Hyperion Research Ltd. (Hyperion) for analysis. Hyperion is accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA) to conduct MPA analysis. The sample was collected following the sampling procedure proposed by USEPA (1992) as recommended by Peter Wallis, analyst at Hyperion. A sample size between 2000 L and 4000 L was obtained at a flow rate not exceeding 10 L/min. Prior to starting the test, the sampling apparatus was flushed without a filter with the source of water for approximately 15 minutes. The filter was then placed in the filter holder and sampling proceeded. The sampling unit was allowed to run for approximately 6-7 hours at a flow rate of 10L/min. The total volume filtered for Well No.2 was 3,830 L. The filter was transferred to a labelled bag and sealed for transport. The sample was immediately placed in a cooler with ice for shipment (under chain-of-custody) to Hyperion for analysis.

The MPA testing result indicates a risk factor of zero based on the numerical range of each primary bio-indicator counted per 100 gallons water. According to the USEPA Consensus method, the risk of surface water contamination is considered low (risk factor <9), moderate (risk factor 10-19) or high (risk factor >20). Therefore, a risk factor of zero represents a low risk of surface water contamination. The field measurements also support the hypothesis that the well water is significantly different from the nearby surface water sources. The MPA testing result is summarized in Table 2 along with the risk of surface water contamination according to the USEPA Consensus Method. The Certificates of Analysis from the laboratory including the numerical range of each primary bio-indicator and the relative surface water risk factors associated with scoring of primary bio-indicators are presented in Appendix IV.

Table 2: MPA Testing Results

Production Well	Well No.2
Date	10-06-2009
Method	MPA test
Risk Factor	0
Risk of Surface Water Contamination[1]	Low

1 Based on Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (USEPA, 1992).

6.2.3 GWUDI Assessment Result

The time-of-travel capture zone results indicate that the 100-day and the 1-year capture zones calculated using the analytical solution method intercept Beaver Creek for all three wells. It should be noted that the capture zones calculated using the analytical solution method assumed that the aquifer is homogeneous and isotropic and does not account for vertical separation between the aquifer and the surface water bodies. In addition to the horizontal distance between the BFWD wells and Beaver Creek, which is about 17 m for Well No.2 and 37 m for Well No.1 and Well No.3, the vertical separation between the creek bed and the top of the aquifer is a minimum of 11 m. The geological material above the aquifer was described as silty sand and silty gravel in the well logs. Typically, the hydraulic conductivity of such material is expected to be at least one order of magnitude lower than the hydraulic conductivity of sand and gravel and therefore, the travel time expected for surface water to reach the aquifer would be longer than what was calculated using the analytical solution method.

The general chemistry of groundwater compared to surface water, the results of the water quality monitoring program conducted between April 2009 and July 2009, along with the historical data reviewed do not indicate that the groundwater extracted from Well No.2 is under the direct influence of surface water. The concentrations of the major ions, as well as conductivity, turbidity, total dissolved solids, dissolved oxygen and pH measurements of groundwater compared to Beaver Creek indicate a longer residence time for groundwater, suggesting that most of the water supplying the wells comes from a water source located some distance upgradient from the wells. Groundwater quality remained constant during the monitoring period and could not be correlated with surface water quality fluctuations measured in Beaver Creek. In addition, MPA testing conducted on Well No.2 indicated that the risk of surface water contamination was low based on Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (USEPA, 1992).

Even though the capture zone analysis indicated that the 100-day capture zone intercepted Beaver Creek, the water chemistry and the MPA test result indicate that the wells are not under the direct influence of surface water and that there is sufficient stream bank filtration to likely eliminate any risk of pathogens reaching the wells under the present operating conditions. Because neither Well No.1 nor Well No.3 is in operation at the moment, it was not possible to conduct the monitoring program and the MPA test on these wells. However, based on the general chemistry and similar depth of construction, it is inferred that the water source for Well No.1 and Well No.3 is similar to Well No.2. Also, because Well No.1 and Well No.3 are located at a greater distance from Beaver Creek compare to Well No.2, the risk of surface water contamination for Well No.1 and Well No.3 is also expected to be low.

6.3 Contaminant Inventory

6.3.1 Methodology

A contaminant inventory was carried out to identify any existing and potential sources of groundwater contamination in the vicinity of the BFWD wells. The inventory was comprised of two components:

1. A regional inventory to identify general environmental concerns in the area;
2. A preliminary assessment of the potential impact of the presence of the Fruitvale Sewage Treatment Plant on groundwater quality at the BFWD wells; and
3. A preliminary contaminant inventory within the 100 day and 1-year time-of-travel zones.

6.3.2 Results of Regional Contaminant Inventory

The BFWD wells are located within the boundary of the Village of Fruitvale in a rural zone according to the Village of Fruitvale Bylaw No 348 Zoning Map. The wells are located adjacent to a Scout Camp. The results of the regional contaminant inventory are presented below.

6.3.2.1 Residential Properties

There are three properties located southwest of the wells and two of the properties are located within the 1-year capture zone of Well No.2. Some sources of groundwater contamination potentially associated with these properties could include lawn care chemicals, common household products, and wastes related to property maintenance and automotive repair.

6.3.2.2 Septic and Sanitary Sewer Systems

According to the BFWD's representatives, all homes within the BFWD boundaries are serviced by private septic systems. As indicated above, there are three properties located west and southwest of the wells. It is inferred that these properties are serviced by private septic systems. According to the Sewerage System Standard Practise Manual (SPM), prepared by the BC Ministry of Health (MoH, 2007), the minimum horizontal distance (setback) for a sewerage system from a water well is 30 m. The SPM serves as a guideline for standard practice in construction of sewerage systems in BC, as required under the BC Ministry of Healthy Living and Sport (BCHLS) Sewerage System Regulation (SSR, 2004).

The exact location of the private septic systems is unknown. Two properties are located at a fair distance from the wells (i.e. more than 75 m away) with their septic systems inferred to be outside the 30 m setback. The exact distance of Well No.2 to the closest property is unknown but inferred to be between 20 m to 40 m. It is unknown if the location of the private septic system meets the 30 m setback requirement for the property immediately west of Well No.2. The scout camp where the BFWD wells are located is also serviced by a private septic system. The sewage disposal field is located in the open area next to the sanitary building approximately 100 m northwest of Wells Nos. 1 and 3, and hydraulically upgradient.

Septic systems can be a potential source of groundwater contamination, contributing bacteria, viruses, nitrates, detergents, oils and chemicals to groundwater. Groundwater contamination from septic systems results in cases where systems are poorly sited, designed or constructed, where systems are poorly maintained, or where septic system densities are too high to allow sufficient renovation. However, since there is only one septic system located in the vicinity of the well located at a distance inferred to be close to the 30 m setback requirement, the presence of private septic systems within the capture zones of the BFWD wells is probably not a major concern.

The Fruitvale Sewage Treatment Plant (STP) is located approximately 600 m upstream from the BFWD wells. A discussion on the potential impact on the water quality of the BFWD wells is discussed in the following section.

6.3.2.3 Search of MOE Contaminated Sites Registry

Golder conducted a review of the BC MoE Site Registry system, which identifies those properties for which the MoE holds environmental information. These records are limited to information obtained since approximately 1989. The existence of a property within the Site Registry system does not necessarily imply that the site is contaminated, as under the existing Contaminated Sites Regulation, the site registration process can be triggered by a number of mechanisms including property transactions and facility upgrades, and not only subsurface contamination. Similarly, there may be a number of contaminated sites within the BFWD that have not been identified by the site registry. The search found that there were no properties registered. The result of the Contaminant Sites Registry search is included in Appendix V.

6.3.2.4 Regional Mining Activity

The Mineral Activity Map available from the Ministry of Energy, Mines, and Petroleum Resources (http://webmap.em.gov.bc.ca/mapplace/minpot/minEconomy.cfm#) for the Montrose and Fruitvale area was reviewed. No historic or current mining activities were identified in the vicinity of the BFWD. A project (ID 334) by Teck Cominco Ltd (2002 Mine and Exploration Projects) was identified approximately 4 km to the east, along Kelly Creek. No gravel extraction locations or tailing dumps were identified upgradient of the BFWD Wells.

6.3.2.5 Agricultural Issues

The Agricultural Land Reserve (ALR) map for the area was obtained from the RDKB Interactive Mapping System (http://www.sgrc.selkirk.ca/imf5_1/sites/rdkb/jsp/launch.jsp). The lands in the vicinity of the BFWD wells are not located within the ALR. The closest properties within the ALR are located on the other side of Beaver Creek about 200 m to the east (inferred to be hydraulically side-gradient) and 160 m south of the wells (inferred to be hydraulically downgradient). The lands located upgradient from the BFWD wells are not located within the ALR.

6.3.2.6 Existing and Inactive Water Supply Wells

Five water wells are registered with the BC MoE Water Resources Atlas (WRA), (Appendix VI and Figure 3) within the study area. Based on available information, all of these wells, except for one, were drilled as part of the groundwater exploration programs conducted for BFWD between 1963 and 1983. WTN 27582 corresponds to Well No.1 (drilled in 1973 with a total depth of 68 ft). However, it should be noted that the location of WTN 27582 in the WRA database differs from the location of Well No.1 as shown on Figure 3. The well coordinates in the WRA database are often not accurate and not representative of the exact location of the wells. WTN 52396 is a test well drilled in 1983 to 65.2 m (214 ft) to assess if there was a potential to extract groundwater from a deeper aquifer. The test well was unsuccessful (Pacific Hydrology, 1985). Two other wells were drilled in the sand and gravel aquifer, likely as test wells (WTN 18231 and WTN 25275). It is unclear whether or not these test holes were completed as water wells, test wells or merely boreholes (i.e. casing removed from the ground). None of these wells could be correlated with the other BFWD wells; therefore, it appears that Well No.2 and Well No. 3 are not registered in the BC WRA database.

Only one of the five wells (WTN 53839) is identified as a private well. WTN 53839 is located approximately 300 m northwest of the BFWD wells and was drilled in the bedrock aquifer. There are likely more wells in the study area that are not registered in the BC WRA; however, identifying other private wells in the area was beyond the scope of this study.

Inactive and old wells, if not decommissioned properly, present a risk of contamination, as they can provide a direct conduit for contaminants to underlying aquifers. As per the BC Groundwater Protection Regulation, wells that are abandoned should be properly decommissioned. In some extreme cases, abandoned wells are used for the disposal of wastes such as motor oil.

All of the wells identified in the BC WRA database were constructed previous to the BC Groundwater Protection Regulation (GWPR) enacted in 2004. The GWPR requires that wells be constructed with an annular seal to ensure that surface contaminants do not have a migration pathway to the underlying aquifers through the annular space. Since all these wells were constructed previous to the GWPR, it is unknown if these wells have annular seals, as annular seals were installed only at the discretion of the driller and well designer before the GWPR was enacted. Wells which are not properly sealed, poorly sited or have corroded casings can act as direct conduits for the migration of surface contaminants to the underlying aquifer(s).

6.3.2.7 Surface Water Influences and Flooding

Surface water degradation or contamination of local creeks and streams could pose a risk to groundwater quality if the BFWD wells were identified as GWUDI. As discussed in previous sections, the BFWD wells do not meet the criteria to be identified as GWUDI based on water quality results.

Wells could also be vulnerable to surface water contamination from flooding if they are not properly cased and/or sealed. Based on the well logs, Well No.1 and Well No.2 were not completed with an annular seal. Both wells were constructed previous to the GWPR enacted in 2004. Although Well No.3 was constructed in 2005, no surface seal is reported on the well log. Therefore, it inferred that none of the BFWD wells were constructed with a proper surface seal. However, because all three wells are located inside a pumphouse and Well No.1 and Well No.2 are encased in a concrete pad, surface water is not likely to infiltrate toward the well heads as long as both pumphouses are properly protected from flooding or infiltration of surface water.

6.3.3 Fruitvale Sewage Treatment Plant

6.3.3.1 Background Information

The Fruitvale Sewage Treatment Plant (STP) is located approximately 600 m upstream from the BFWD wells. Since June 1965, the Village of Fruitvale has been discharging secondarily treated sewage to Beaver Creek. In 1995, major upgrades were completed at the Fruitvale STP in response to pollution concerns expressed by the MoE resulting from low dilution rates of the effluent and potential impacts on the water quality and health of Beaver Creek. The selected upgrades to the plant included a ground disposal system that incorporated primary and secondary aeration with the addition of polyaluminium chloride as a flocculant, followed by further holding and settling of effluent, then finally discharging to the ground through rapid infiltration (RI) basins. The Fruitvale RI basins were tested in 1996 and the infiltration rates were found to be unsatisfactory for effluent disposal. As a result, a series of underdrains were installed in 1997, which collect the treated effluent approximately 0.6 m below the RI basin. The effluent flows through the underdrains to a 3 m cement outfall pipe, which discharges the effluent into Beaver Creek.

Golder contacted the MoE to obtain more information on the Fruitvale STP. The MoE representative indicated that the Village of Fruitvale had expressed interest in being a part of the Liquid Waste Management Plan that would most likely include a large Sewage Treatment Plan near Trail with an interceptor line to Fruitvale. Under this scenario, the current Fruitvale STP would then be decommissioned.

6.3.3.2 *Beaver Creek Environmental Impact Assessment*

In 1999, the MoE undertook a study to assess the water quality and ecological structure and function of Beaver Creek, in response to concerns that contaminants, primarily nutrients and pathogens, may play a role in deteriorating the water quality of Beaver Creek (Westcott, 2004). The study's emphasis was to investigate the potential impacts of the discharge of treated sewage from the Fruitvale STP following improvements at the plant during the 1990s. The study included a sampling program over a period of five weeks in September 1999 at six discrete locations along the creek and at Fruitvale's effluent discharge location. Effluent quality, receiving water quality and biological sampling data were used to assess the potential impacts on the water and benthic stream ecology of Beaver Creek, with comparison made to historical water quality data collected in 1990 and 1993.

The key results and conclusions of the study are the following:

- The STP effluent contained much higher nutrient (nitrogen and phosphorus) concentrations, but lower bacterial levels than background water quality in Beaver Creek, suggesting the STP effectively removes bacteria but does not remove nutrients in sewage to background levels in the creek;
- Along Beaver Creek, ammonia, nitrate, total nitrogen, total phosphorus and orthophosphate increased at the site immediately downstream of the STP outfall (approximately 400 m downstream of the point of discharge). These increases are attributed to the STP effluent discharge to Beaver Creek. The increases in nutrient concentrations are somewhat ameliorated further downstream as a result of chemical reactions, dilution from tributaries and/or biological uptake. Although the nutrient concentrations within the creek did not exceed drinking water quality guidelines, increased nutrients may be responsible for negative changes in stream invertebrate community structure;
- Bacterial concentrations were fairly consistent along the length of Beaver Creek. Total and faecal coliform bacteria and *E.coli* concentrations in the STP effluent were lower than those measured in the creek both upstream and downstream. The results, coupled with the findings that bacterial concentrations within Beaver Creek were occasionally higher at the uppermost sites in the water shed, indicate that the STP effectively removes much of the microbial content in the effluent, and that other non-point sources of bacteria, including septic tanks, urban runoff, livestock and domestic and wild animals may be a greater contributor to bacteria in the creek; and
- Upgrades to the Fruitvale STP appeared to have been successful in significantly improving the effluent quality, as measured by decreases in ammonia, phosphorus, and microbial concentrations when comparing to 1990 and 1999 levels. These improvements were likely brought about by an increase in the aeration of the lagoons, which enhances the conversion of ammonia into nitrate, as well as the addition of flocculants and RI basins, which appear to have been effective at phosphorus and bacteria removal.

6.3.3.3 *On-going Monitoring Program*

Golder contacted the Village of Fruitvale to obtain information on the monitoring program conducted for the Fruitvale STP. Jason Startup from Public Works indicated that samples of the effluent are collected on a quarterly basis and a groundwater monitoring program is also being conducted quarterly. Groundwater samples are collected at two wells (E234550 and E234551) as part of the groundwater monitoring program. Well E234550 is located upgradient from the STP and well E234551 is located immediately downgradient. The certificates of analysis from CARO Analytical Services (CARO) of the effluent results for 2008 and 2009 were provided to Golder as well as the quarterly groundwater monitoring reports for 2008 and 2009 (ENG Environmental, 2008 and 2009).

The quality of the effluent for 2008-2009 was compared to the 1999 results provided in the Beaver Creek Environmental Impact Assessment (Westcott, 2004) and the key conclusions are presented below:

- Based on the results reviewed, the concentrations of ammonia in the effluent are generally higher and the concentrations of nitrites and nitrates lower than the concentrations in the effluent reported in the Environmental Impact Assessment;
- Total coliforms and fecal coliforms measured in the effluent in 2008-2009 were considerably higher than the concentrations in the effluent measured in 1999; and
- Dissolved and total metals measured in the effluent were below the Guidelines for Canadian Drinking Water Quality (GCDWQ).

The groundwater monitoring data were also reviewed and compared to the GCDWQ. Iron and manganese concentrations exceed the aesthetic guidelines in one of the monitoring wells (E234551) but all the other parameters, including fecal coliforms, were below the GCDWQ.

6.3.3.4 Potential Impact on BFWD Wells

The objective of this section is to assess the potential impacts of the discharge of treated sewage from Fruitvale STP in Beaver Creek on the BFWD water supply wells located approximately 600 m downstream from the STP. In order to assess the potential impacts, Golder gathered background information on the Fruitvale Sewage Treatment Plant, and documented existing effluent, surface water and groundwater quality results at the STP and at the BFWD wells.

The potential contaminants of concern associated with a sewage treatment plant are nutrients and pathogens. The water quality results obtained in 1999 as part of the Beaver Creek Impact Assessment indicated that the STP effluent contained much higher nutrient (nitrogen and phosphorus) concentrations, but lower bacterial levels than background water quality in Beaver Creek, suggesting the STP effectively removes bacteria but does not remove nutrients in sewage to background creek levels. The sample collected in September 1999 approximately 400 m downstream of the effluent showed that the concentrations in ammonia, nitrate, total nitrogen, total phosphorus and orthophosphate increased at the site immediately downstream of the STP effluent. However, the nutrient concentrations within the creek did not exceed drinking water quality guidelines.

Based on the water quality results reviewed for 2008-2009, total coliforms and fecal coliforms in the effluent increased since 1999. However, the groundwater monitoring data provided by ENG Environmental (2008, 2009) indicated that no fecal coliforms were detected in groundwater immediately downgradient from the STP.

Groundwater quality data obtained at the BFWD wells indicated that all the parameters, including nutrients, total coliforms and *E.coli*, are below the GCDWQ. Based on all the water quality results reviewed, the Fruitvale STP does not appear to be currently impacting the BFWD wells. As discussed previously in the GWUDI Assessment section, the BFWD wells are not considered to be under the direct influence of surface water. Even though the capture zone analysis indicated that the 100-day capture zones of the wells intercept Beaver Creek, the water chemistry and the MPA test result indicates that there is sufficient stream bank filtration to likely eliminate any risk of pathogens reaching the wells under the present operating condition. Therefore, the risk of a potential contamination of the BFWD wells caused by the presence of the Fruitvale STP upstream from the wells is considered to be low; however, the potential for contamination still exists and the implementation of a monitoring program at the BFWD wells is recommended, as described in Section 8.3.

6.3.4 Contaminant Inventory for the 100-Day and 1-Year Time of Travel Zone of the BFWD wells

Contaminant inventories within the 100-day and 1-year time-of-travel capture zones were conducted by means of a field reconnaissance. It should be noted that the inventory did not include interviews with private property owners. The inventory also did not include a review of historical site activities.

The 100-day and 1-year capture zones are shown on Figure 3. Other than the presence of residential properties and the Scout Camp, the area within the capture zones is mainly rural forested land. The residential property located immediately west of Well No.2 is within the 1-year capture zone and on the periphery of the 100-day capture zone for Well No.2. The location of the disposal field on this property is unknown, but may be within the 100-day capture zone of Well No.2. Another property falls in the 1-year capture zone of Well No.2. Beaver Creek is intercepted by the 100-day and the 1-year capture zones for all three wells. The septic disposal field of the Scout Camp is located outside the 100-day capture zones of all three wells but within the 1-year capture zones.

Several of the test holes identified on the BC MoE WRA also likely fall within the 1-year capture zones of the wells. It should be noted that the locations of the wells in the WRA database are approximate, therefore, the exact location of the test wells, if still present, is unknown.

7.0 CONCLUSIONS

Based on the results of this assessment, the following conclusions are made:

- The BFWD Wells are located on an alluvial fan and appear to be drawing water from a confined sand and gravel aquifer. Approximately 11 m of silty sediments overly the aquifer and provide some level of protection at the locations of the BFWD wells. Well No.1, Well No.2 and Well No.3 are completed at total depths of 20.7 m, 28.1 m and 26.8 m, respectively. The reported depth to the water table is approximately 2 m to 3 m below the top of casing of the wells;
- There is no evidence of proper surface seals around the wells. However, the wells are located in pumphouses and Well No.1 and Well No.2 are encased within a concrete pad;
- The regional groundwater flow direction in the area of the wells is inferred to be south towards Beaver Creek, with possibly seasonal variations in flow direction, depending on the river stage. The localized hydraulic gradient was calculated to be approximately 0.005 m/m;
- The aquifer transmissivity is estimated to be 175 m^2/day. The hydraulic conductivity (K) of the aquifer is estimated to be in the order of 1 x 10^{-4} m/s (10.3 m/day), assuming the approximate 17 m thickness of the sand and gravel aquifer material in which the wells are completed;
- The 100-day and 1-year time-of-travel capture zones calculated for the wells intersect Beaver Creek. However, because the groundwater flow direction and hydraulic gradient were inferred based on limited data, additional observation wells would be required to be able to determine the exact groundwater flow direction and hydraulic gradient. A steeper hydraulic gradient would shift the capture zones upgradient (i.e away from the creek);
- Based on the historic bacteriological data reviewed, Well No.2 do not contain total coliforms or *E. coli*. No historic bacteriological data were available for Well No.1 and Well No.3 for Golder to review.

- The groundwater and surface water samples have a similar water type (calcium carbonate hydrochemical facies) However, the concentrations of the major ions, as well as conductivity, total dissolved solids, dissolved oxygen and pH measurements indicate a longer residence time for groundwater, suggesting that most of the water supplying the wells comes from a water source located some distance upgradient from the wells;
- Groundwater quality remained at relatively constant concentrations during the water quality monitoring period and could not be correlated with surface water quality fluctuations measured in Beaver Creek for the same period;
- MPA testing conducted on Well No.2 indicated that the risk of surface water contamination was low based on the Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (USEPA, 1992);
- Based on the water quality monitoring program, historical data and the results of MPA testing, Well No.2 is not considered to be under the direct influence of surface water. Even though the capture zone analysis indicated that the 100-day capture zone intercepted Beaver Creek, the water chemistry and the MPA test result indicate a possibly longer travel time between the creek and the wells and sufficient stream bank filtration to likely eliminate any risk of pathogens reaching the wells under the present operating conditions.
- The contaminant inventory indicated that the area within the capture zones is mainly rural forested land. Only one private septic system in the area might be lying within the 100-day capture zone and/or the minimum 30 m setback,. The presence of the septic system and any test holes or old wells potentially still present were identified as potential threats to the BFWD wells.
- Based on the hydrostratigraphy and the water quality information reviewed, and because the BFWD wells are not considered to be under the direct influence of surface water, the risk of potential contamination of the BFWD wells caused by the presence of the Fruitvale STP upstream from the wells is considered to be low.

8.0 RECOMMENDATIONS

The following recommendations are made with regards to the implementation of groundwater protection measures. In addition, Golder recommends the implementation of a Groundwater Monitoring Program which would include water level and water quality monitoring and well performance monitoring and maintenance. Details are provided in the following sections.

8.1 Designation of Groundwater Protection Area

The aquifer that the BFWD water system withdraws from is considered to be confined and comprised of sand and gravel. Because there is no information on the continuity of the silty confining layer overlying the aquifer, the aquifer is still considered to be moderately vulnerable to surface contamination.

A groundwater protection area is an area where land use restrictions are applied as a safety precaution to protect the drinking water supply. Because the aquifer is of limited extent and because potential seasonal fluctuations in the direction of groundwater flow are expected, it is recommended that an aquifer protection approach be considered to delineate the areas where protection measures should be implemented.

The suggested groundwater protection area for the BFWD water supply wells should include, at a minimum, the 1-year capture zones for the wells (Figure 3), but where practical, land use restrictions for the area located hydraulically upgradient from the wells (i.e located north of the wells) should be implemented. No land use that could potentially negatively impact the aquifer water quality should be allowed in these areas.

8.2 Groundwater Protection Measures

The BC MoE has regulations governing the protection of groundwater and drinking water supplies. The following well protection recommendations are based on these Provincial regulations, together with our experience in groundwater protection:

- Well No.3 has never been used since its construction in 2005 and Well No.1 was recently taken out of service due to a decline in production capacity. As per the BC Groundwater Protection Regulation, wells that are not used for 5 years should be deactivated or closed in accordance with Section 6 of the Code of Practice for Construction, Testing, Maintenance, Alteration and Closure of Wells in British Columbia, set out in Appendix A of the Groundwater Protection Regulation. When deactivating a well, the owner of the well must equip the well with a secure well cap and maintain the well in a safe and sanitary condition. When closing a well, the well must be filled throughout its depth with a combination of appropriate sealant and backfill materials.

- Well No.1 and Well No.3 are located inside a masonry pumphouse. A concrete slab surrounds Well No.1. Any cracks in the foundation around the pumphouse and the concrete pad surrounding the well head of Well No.1 that may occur in the future should be repaired immediately to avoid having water infiltrating toward the well head. The building should be kept locked at all time and any openings that could allow rodents or other animals to enter the pumphouse should be permanently blocked. There is no concrete pad around Well No.3 and there is no evidence of the presence of a surface seal. The installation of a surface seal around the wellhead of Well No.3 should be considered unless the BFWD is considering closing Well No.3. Both wells should be equipped with a secure well cap.

- The use or storage of pesticides, herbicides, petroleum hydrocarbons and other harmful chemicals should be discouraged within the 1-year capture zones of the wells. Specifically, the owners of the private residences located in the vicinity of the BFWD wells and the operator of the Scout Camp should be informed of the Groundwater Protection Zone and signage designating the area as a Groundwater Protection Zone should be posted. Information on septic system maintenance, and proper handling and disposal of household and garden chemicals should also be provided to the owner of the private residence and the Scout Camp. The use of heavy machinery on unpaved areas adjacent to the wellheads should be prohibited or, if necessary, should be authorized only if strict procedures are followed. Only well-maintained machinery should be used and machinery should be inspected daily to make sure that there is no leakage of petroleum hydrocarbons on the ground. On-site fuelling or maintenance of the machinery should be prohibited.

- Communication with the Village of Fruitvale should be initiated by the BFWD. The BFWD should be notified by the Village of Fruitvale if unusual operational conditions occur at the Fruitvale Sewage Treatment Plant or if the quarterly effluent or groundwater monitoring results are higher than usual or present anomalies.

8.3 Water Quality Monitoring

A water quality monitoring program should be implemented. Standard potability analyses, including physical parameters (color, turbidity, pH, conductivity), total metals, anions and nutrients, should be conducted, at a minimum, annually for each well in operation. In order to obtain a water sample representative of the aquifer, Golder recommends sampling each well in operation as part of the regular sampling program. This recommended annual potability analysis is in addition to the routinely collected water samples recommended by a Health Officer for bacteriological parameters. For the latter, it is good practice to sample groundwater from both the distribution points and from the wells. It allows for the identification of the source of bacteriological contamination (aquifer or distribution system) when sampling results exceed the applicable guidelines.

Additionally, heterotrophic plate count (HPC) testing should be considered. The HPC testing is recommended on a regular basis, coincident with other bi-weekly bacteriological testing, to establish baseline conditions for ongoing comparison of laboratory analytical results. If elevated HPC concentrations are observed, possible causes for the increase (i.e. higher bacteriological levels in the creek due to Fruitvale STP, failed surface seal, etc.) should be identified and mitigated. It should be noted that no maximum acceptable guideline (MAC) is specified in the drinking water guidelines for HPC bacteria in water supplied by public, semipublic, or private drinking water systems. Instead, increases in HPC concentrations above baseline levels are considered undesirable.

Water monitoring during the spring and MPA testing could not be conducted on Well No.1 and Well No.3 since these wells are currently not in service. It is our understanding that BFWD is considering rehabilitating Well No.1 and placing it back in service if the rehabilitation efforts are successful at increasing the well's specific capacity. Because the general chemistry of Well No.1 is similar to Well No.2 and Well No.1 is located at a greater distance from Beaver Creek than Well No.2, Well No.1 is also not considered to be under the direct influence of surface water. However, if the well is placed back in service and is available for sampling, Golder recommends conducting a microscopic particulate analysis (MPA), and/or testing the well using US Environmental Protection Agency (USEPA) Method 1623 to confirm the low risk of surface water contamination at Well No.1. The intent of both tests is to identify organisms that only occur in surface waters as opposed to groundwater and whose presence in groundwater would indicate that it is under the direct influence of surface water. Method 1623 is a more sensitive test, compared to MPA analysis, for determining the presence of *Giardia* and *Cryptosporidium,* which are organisms that occur in surface water.

Golder also recommends conducting a second MPA test and/or Method 1623 at Well No.2 to confirm the previous results. The BC Draft Guidance Document for determining Ground Water at Risk of Containing Pathogens and Groundwater Under the Direct Influence of Surface Water (2007) stipulates that two or more samples over a period of a year or more might be required to predict future MPA values.

In general, all persons monitoring and sampling the distribution system and the water supply wells should be trained in proper techniques for collecting samples, sample storage, and shipment of samples. Groundwater samples should be submitted to a Canadian Association for Laboratory Accreditation (CALA) certified laboratory for the analyses. Should a specific contaminant of concern be identified as a result of local contamination within the area (i.e. contamination event at the STP), the groundwater sampling frequency and list of parameters should be adjusted accordingly to account for this event.

Analytical data should be compiled within a database and reviewed annually by a qualified professional so that adjustments to the groundwater quality monitoring program can be made, if necessary.

8.4 Well Performance Monitoring and Maintenance

Routine well inspection (monitoring) and maintenance are required in order to prolong the life of a well. Any changes in the water chemistry and operating characteristics of the well should be closely monitored and dealt with promptly, as both the well and pump can deteriorate beyond repair if problems are left unattended. The purpose of the well performance monitoring program is to assess the well efficiency, and determine if well rehabilitation is required to optimize the efficiency of the well. Typically, if the specific capacity of a well decreases by more than 10 to 20 percent, this is indication that a well rehabilitation program may be needed. For non-domestic (municipal) wells completed in sand and gravel aquifers, the typical frequency for major well maintenance is usually every 5 to 10 years. Down-hole video camera inspection should also be completed when a decrease in the well capacity is noted. This can be completed at the same time when down-hole pumping equipment is removed for scheduled inspection. Down-hole video camera inspections were conducted by Golder on Well No.1 and Well No.3 in August 2008. Both screens were found to be heavily plugged and encrusted by calcareous deposits and/or iron and manganese oxides. In order to increase the specific capacity and the well yield of these wells, development and rehabilitation of either Well No.1 or Well No.3 was recommended. A well rehabilitation program should be implemented before the well(s) is placed back in service.

In order to be able to monitor well performance, the static and pumping water levels, pumping rates, and duration of pumping should be recorded on a regular basis for all the wells in operation. The BFWD is already monitoring water consumption and operational data at Well No.2. Every week, the total number of hours and water consumption at Well No.2 is noted on a note pad located inside the pumphouse. In addition, the water level, in percentage, at Well No.2 is recorded (inferred to be percentage of submergence of the pressure transducer installed in wells). However, it should be noted that the recorded values cannot easily be correlated with exact water level measurements because there is no record of the installation of the automatic pressure transducers and the depth of installation is unknown. If either Well No.1 or No.3 is placed in service, installation of a water level monitoring tube (25 mm diameter PVC pipe) from the surface down to the top of the pump is recommended so that a record of static and pumping water levels can be maintained by the operator. This can be accomplished by installing either a permanent pressure transducer/data logger within the PVC monitoring tube or by manually measuring water levels using an electric well sounder. All operational data should be compiled and reviewed annually by a qualified professional.

8.5 Regular Updates to Contaminant Inventory

The contaminant inventory provided for this assessment represents a summary of the land use activities that were observed in the area of the Site during the summer of 2009 and a review of the BC MoE Site Registry system, which identifies those properties for which the MoE holds environmental information from about 1989 to date. It is important to note that land use activities are subject to change. Accordingly, it is recommended that the BFWD carry out regular updates of the contaminant inventory, and assess the potential for impact to each of the BFWD wells. If new potential sources of contamination are identified, additional management strategies may be required.

8.6 Emergency Response and Contingency Planning

The main goal of GWPPs is to prevent the contamination of underground drinking water supplies. Even under the best prevention plans, a scenario that threatens to contaminate the aquifer may occur. When this happens, emergency response plans direct a coordinated and timely response to assure a continued supply of potable water. Many communities have an emergency response plan, however they often do not include specific provisions for the protection of groundwater resources in the event of emergency situations. For example, it may be prudent for emergency response personnel to restrict the use of fire retardant chemicals in sensitive groundwater areas.

In addition to Emergency Response Planning, the BFWD should consider developing a Contingency Plan for the location and provision of an alternative drinking water supply in the event that the existing supply cannot be used. This is important for the BFWD, as Well No.2 is the only well supplying the water system at the present time. The contingency plan should identify short-term alternatives in the event of a minor disruption of the water supply, and long-term alternatives in the event of a complete loss of water supply.

9.0 LIMITATIONS AND USE OF THIS REPORT

This report was prepared for the exclusive use of Beaver Falls Waterworks District and is intended to provide documentation of the hydrogeological assessment of water supply Wells No.1, No.2 and No.3. This report is not meant to represent a legal opinion regarding compliance with applicable laws. Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

The assessment of groundwater conditions presented has been made using historical and technical data collected and information from sources as noted in the report. The methodologies used to conduct the field investigation, to analyze information and for the preparation of a technical report were performed according to current professional standards and practices in the groundwater field. Any chemical analysis, based on either sampling completed as part of field investigations on this assignment, or on water quality information provided by others, is intended to provide a snapshot only of the existing water quality available from the aquifer and only at the locations specified. The spatial and temporal water quality within the aquifer may vary as the aquifer is stressed or impacts occur due to other influences.

Golder has relied in good faith on information provided by third parties noted in this report. We accept no responsibility for any deficiency, misstatements or inaccuracies contained in this report as a result of omissions, misinterpretations or fraudulent acts of others. Furthermore, if new information is discovered during future work, including excavations, borings or other studies, Golder should be requested to provide amendments as required.

10.0 CLOSURE

We trust the foregoing provides the information you need at this time. Should you have any questions or require additional information, please do not hesitate to contact the undersigned.

Report Signature Page

ORIGINAL SIGNED

Genevieve Pomerleau, M.Sc., P.Eng.
Senior Hydrogeologist

ORIGINAL SIGNED

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Senior Hydrogeologist

ORIGINAL SIGNED

Jillian Sacre, M.Sc., P.Geo.
Principal, Senior Reviewer

GP/WGB/JS/gp

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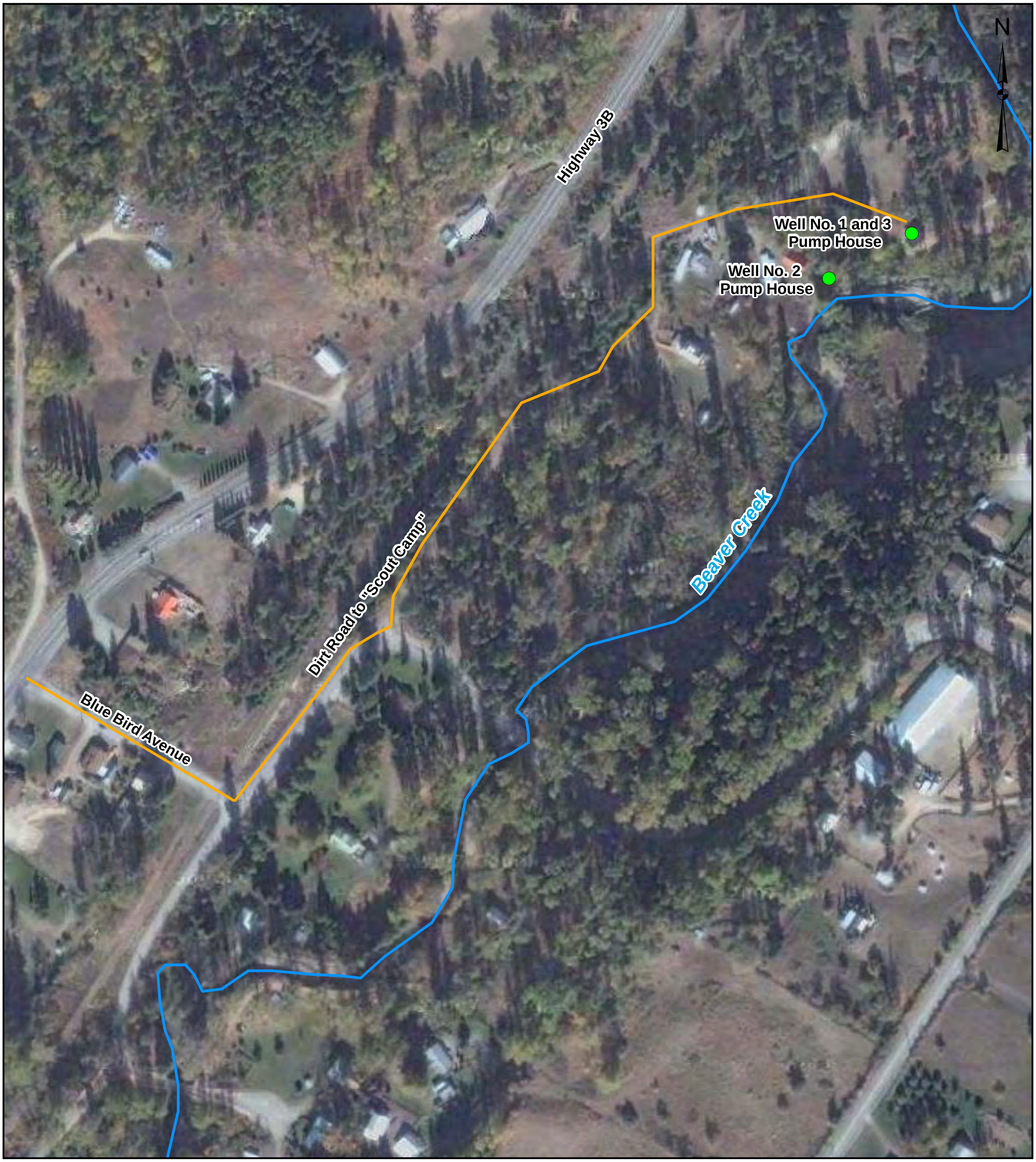

LEGEND

- Pump House
- Water Feature
- Road

60 0 60

SCALE 1:3,000 METRES

REFERENCE

Orthos provided by Google Map.
Datum: NAD 83 Projection: UTM Zone 10

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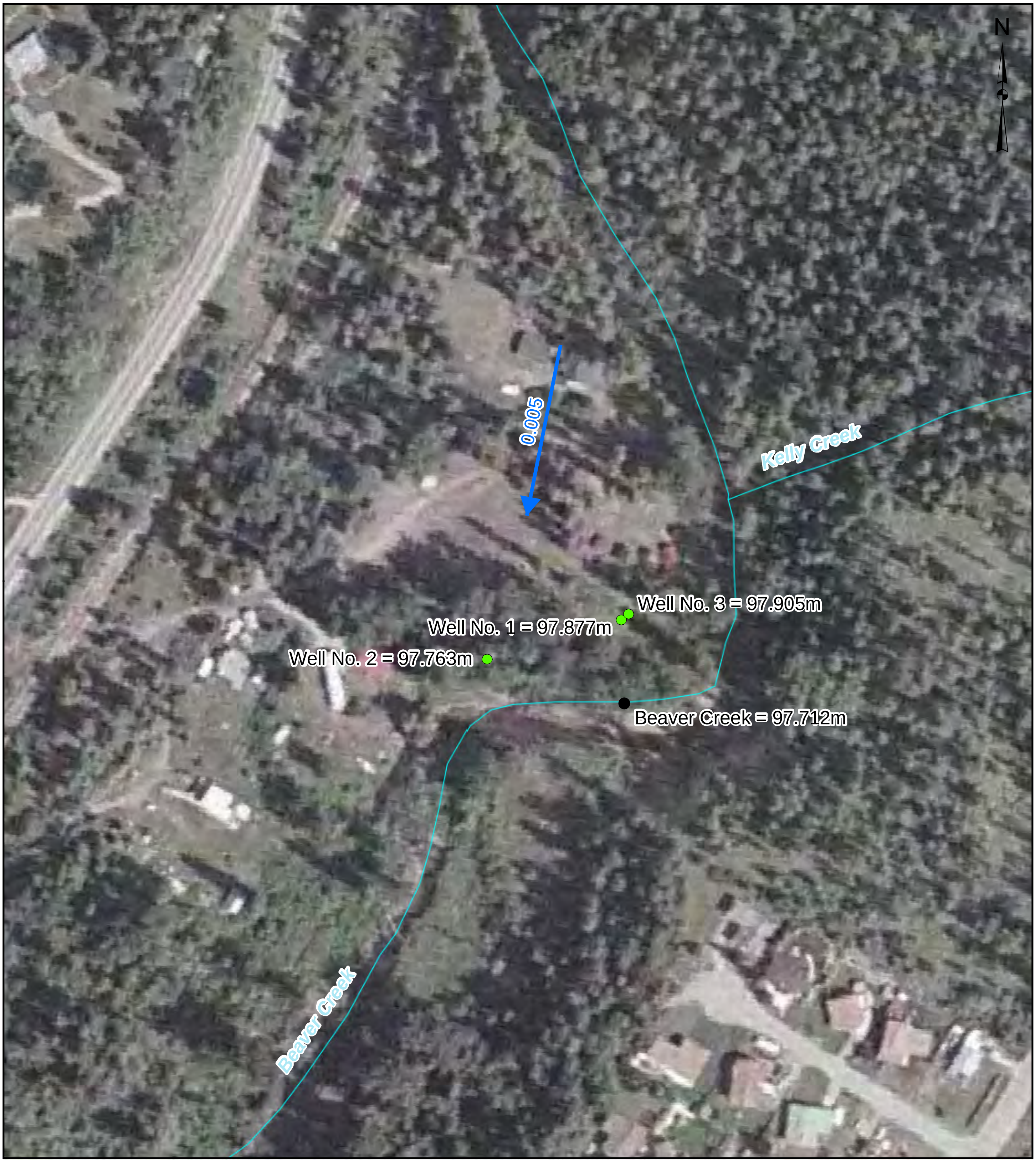
PROJECT
BEAVER FALLS WATERWORKS DISTRICT
PHASE I GROUNDWATER PROTECTION PLAN
MONTROSE, B.C.

TITLE

SITE LOCATION MAP

Golder Associates
Burnaby, B.C.

PROJECT No. 08-1480-0074			SCALE AS SHOWN	REV. 0
DESIGN	GP	13MAY2009	FIGURE 1	
GIS	MCM	13MAY2009		
CHECK				
REVIEW				



LEGEND

- Water Supply Well
- 97.877m Groundwater/Surface Water Elevation (July 21, 2008)
- Groundwater Flow Direction
- 0.005 Hydraulic Gradient (m/m)

40 0 40

SCALE 1:2,000 METRES

PROJECT BEAVER FALLS WATERWORKS DISTRICT
PHASE I GROUNDWATER PROTECTION PLAN
MONTROSE, B.C.

TITLE

GROUNDWATER ELEVATION

Golder Associates
Greater Vancouver Office, B.C.

PROJECT No. 08-1480-0074			PHASE No: 4000
DESIGN	GP	16SEP09	FIGURE 2
GIS	MCM	16SEP09	
CHECK			
REVIEW			

REFERENCE

Orthos provided by WMS (2004)
Datum: NAD 83 Projection: UTM Zone 10

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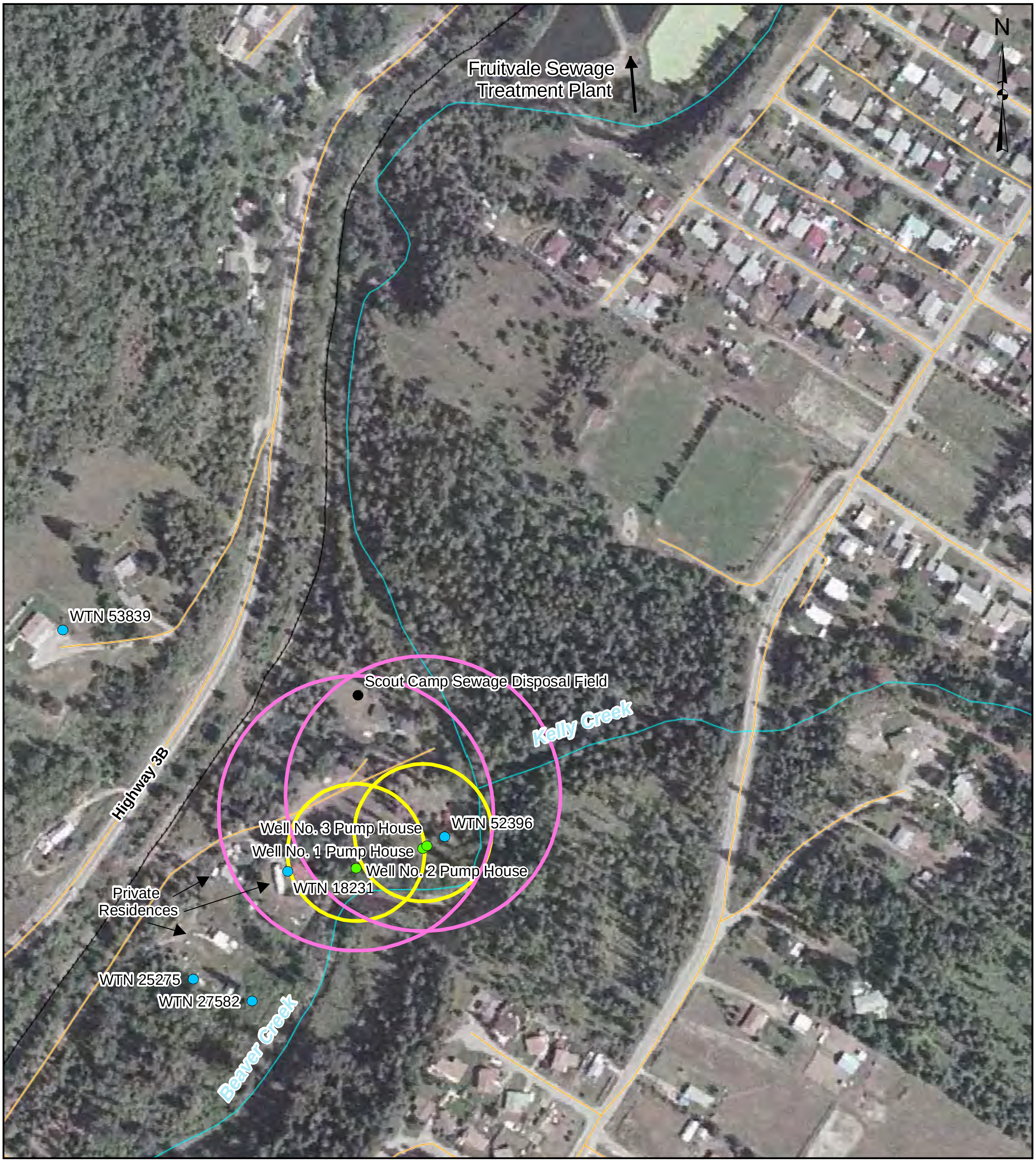

LEGEND

- Well Registered in WRA
- Well No. 1; Well No. 3; Well No. 1 and 3 Pump House; Well No. 2 Pump House
- Scout Camp Sewage Disposal Field
- 1-year Time-of-Travel Capture Zone
- 100-day Time-of-Travel Capture Zone

80 0 80

SCALE 1:4,000 METRES

REFERENCE

Orthos provided by WMS (2004)
Datum: NAD 83 Projection: UTM Zone 10

PROJECT
BEAVER FALLS WATERWORKS DISTRICT
PHASE I GROUNDWATER PROTECTION PLAN
MONTROSE, B.C.

TITLE
TIME-OF-TRAVEL CAPTURE ZONES

Golder Associates
Greater Vancouver Office, B.C.

PROJECT No. 08-1480-0074			PHASE No: 4000
DESIGN	GP	16SEP09	FIGURE 3
GIS	MCM	16SEP09	
CHECK			
REVIEW			

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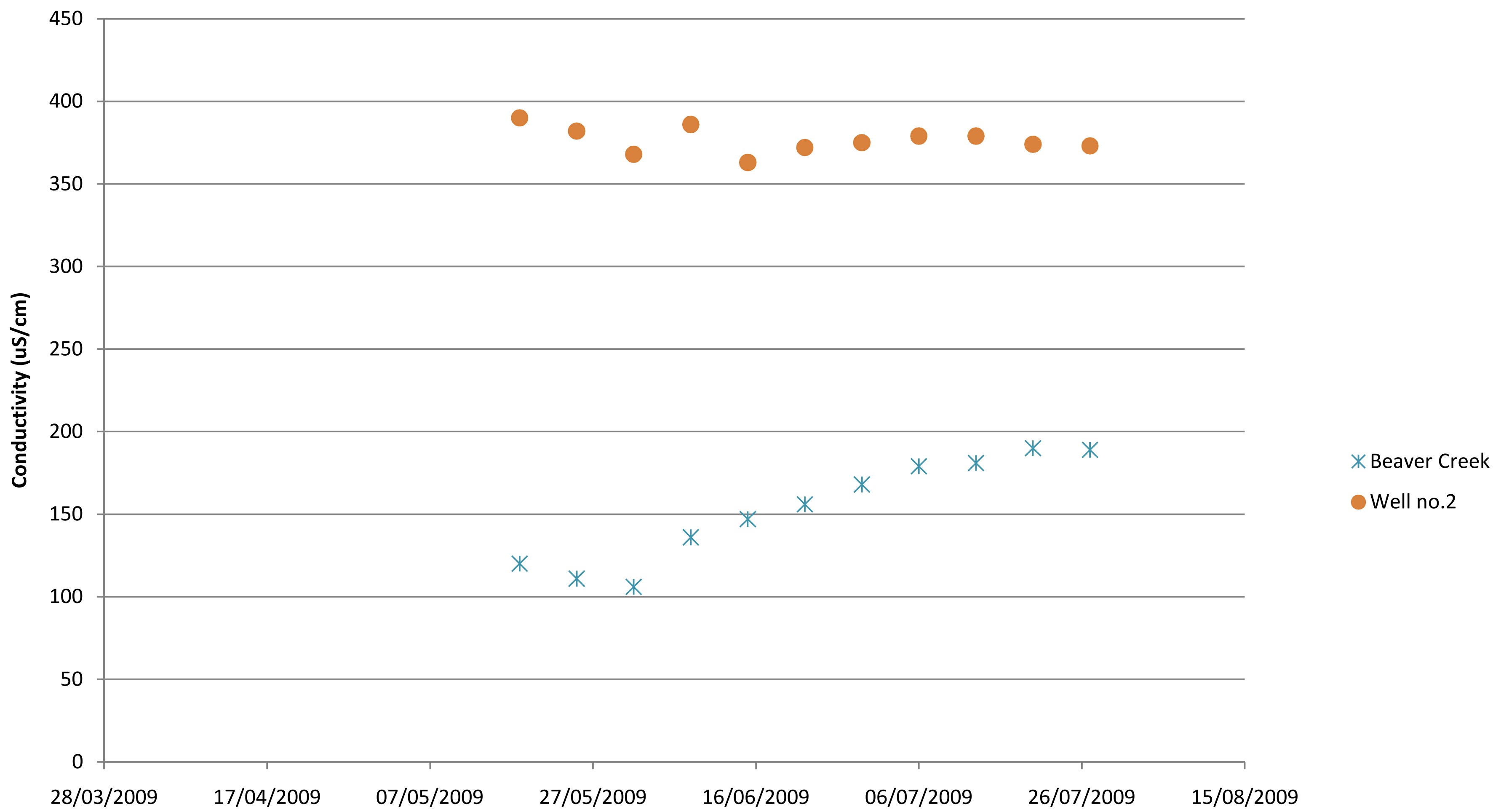


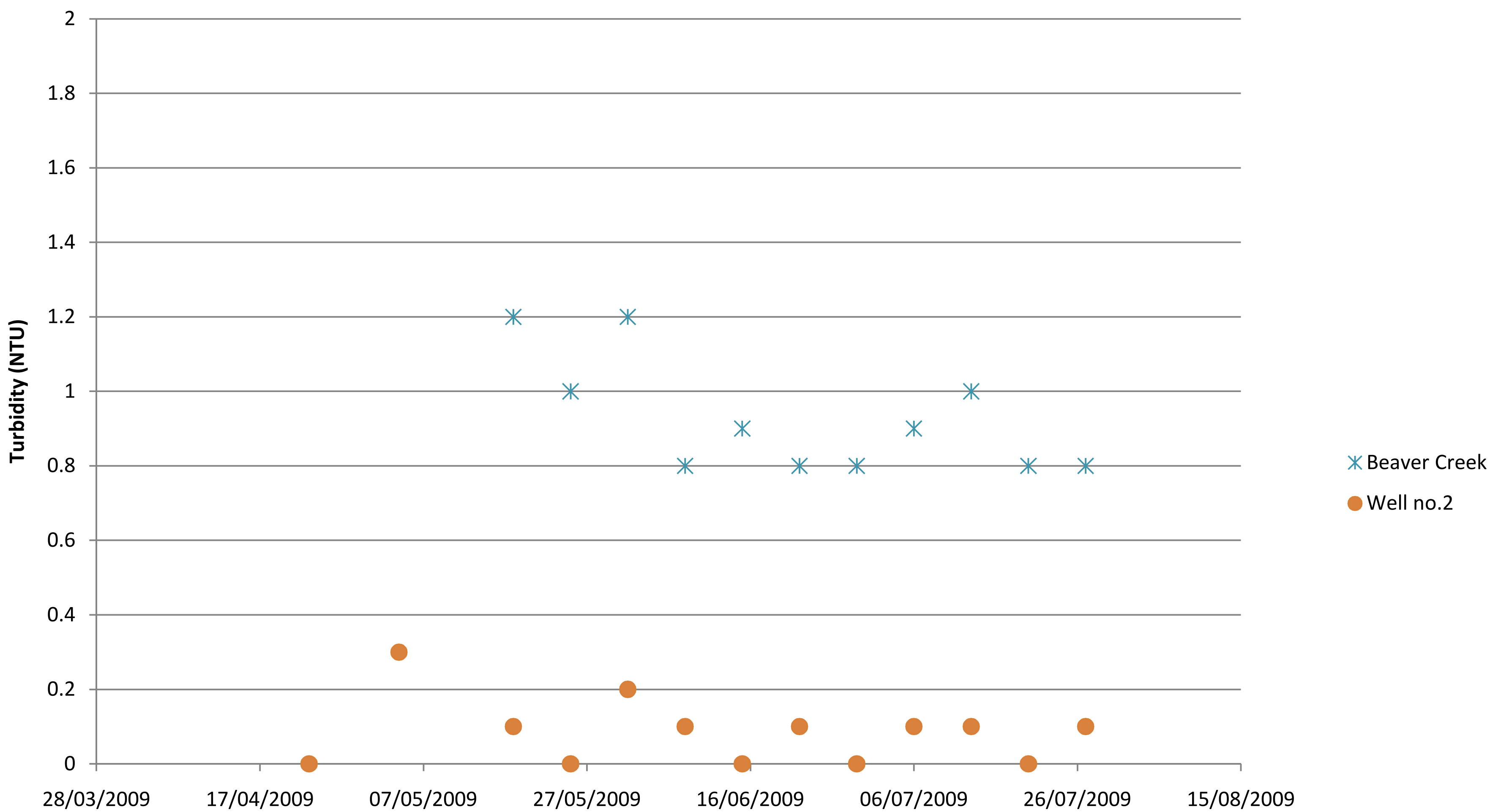
Project No. 08-1480-0074
Drawn: GP
Reviewed: WGB
Date: August 26, 2009

Golder Associates

Comparison of Conductivity Measurements

Beaver Falls Waterworks District, BC

Figure 4



Project No. 08-1480-0074
Drawn: GP
Reviewed: WGB
Date: August 26, 2009

Golder Associates

Comparison of Turbidity Measurements

Beaver Falls Waterworks District, BC

Figure 5

APPENDIX I

Well Logs

0218559

E. LIVINGSTON, P. ENG.
CONSULTING GROUND WATER GEOLOGIST

107-1401 WEST BROADWAY,
VANCOUVER 9, B.C.
TELEPHONE: 738-9232

February 16, 1973.

Well No 1

Associated Engineering Services Ltd.,
1661 West 8th Avenue,
Vancouver 9, B.C.

Attention: Mr. P.J. Abley, P.Eng.

Dear Sir,

This is further to my letter of November 10, 1972 about a water well for Beaver Falls.

The drilling was started on January 16, 1973 by Pacific Pump & Pressure Installations Ltd. The drilling was completed on January 27 at a depth of 68' where the hole reached the bottom of the sand and gravel aquifer. The log of the ten inch diam. hole is as follows:

0	-	24	Compact, very dirty sand & gravel with cobbles
24	-	36	Silty sand and gravel, making water
36	-	68	Gravel with fine, medium and coarse sand and sticky brown silt binder.

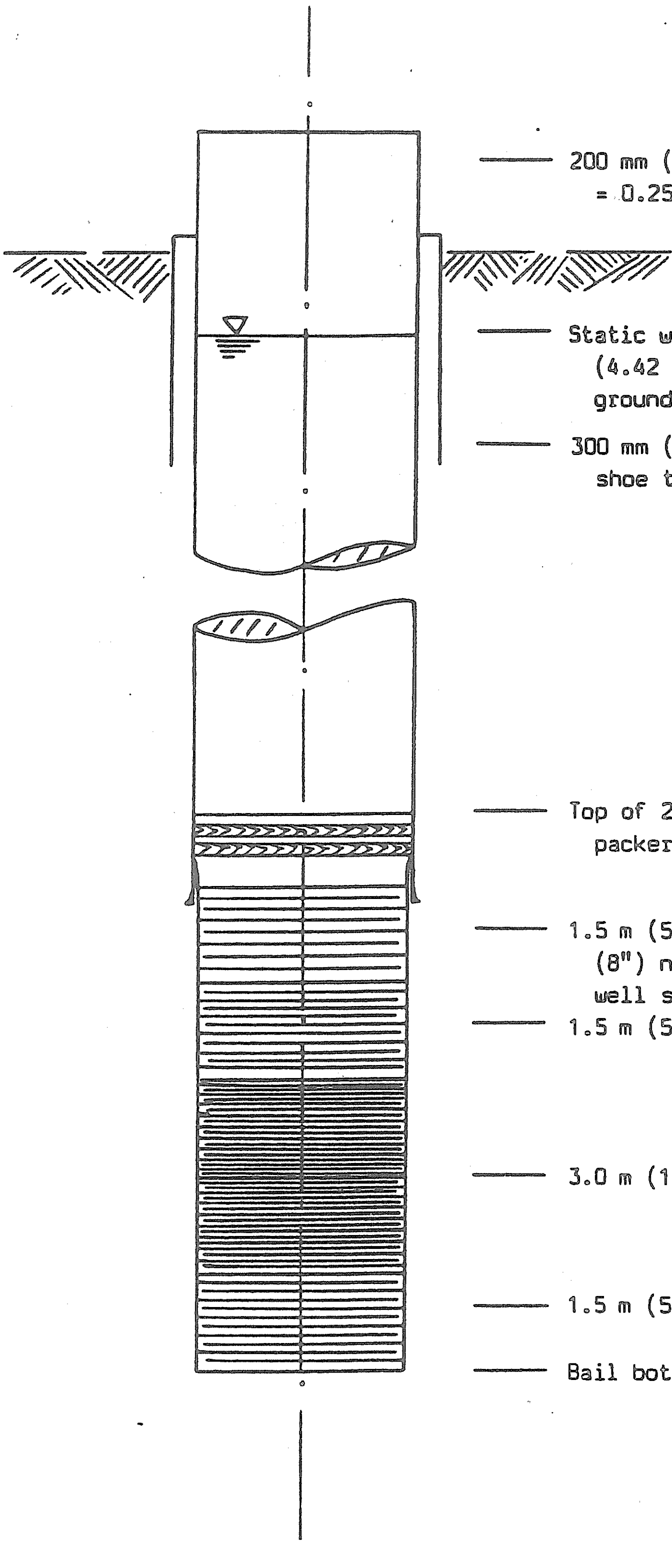
Static level is about 6 ft.

Twelve aquifer samples for the interval 38' through 68' were sent to me in Vancouver for sieve analysis. The data from these analyses are included with this letter. On the basis of these the well was designed with 25 ft. of 8" nominal size well screen as follows:

top 8" x 10"	reducing packer
43' to 53'	.080" slot
53' to 58'	.060 "
58' to 68'	.100" slot
bottom at 68'	

The screens listed above were in stock in Langley and were shipped on January 29 arriving in Castlegar the next morning. The screen was installed on February 1 and development was started by surging in the screen while pumping with a contractors pump at a rate of about 50 gpm. Most of the surging was done in the lower fifteen feet of the screen in order to avoid the possibility of starting caving above the screen.

Cont'd 2



BEAVER FALLS WATERWORKS DISTRICT

FIGURE 2

BEAVER FALLS WATERWORKS DISTRICT
PRODUCTION WELL ~~NO. 3~~ No. 2
WELL CONSTRUCTION DETAILS

Scale: N. T. S.

[Note that all measurements are below ground unless otherwise indicated.]

Ministry of Water, Land and Air Protection
Water, Air & Climate Change Branch

BRITISH COLUMBIA

WELL # 3

WATER WELL RECORD

Date 05/05/26 (YR MO DY)

BCGS MAP ______ WELL No. ______ ELEV ______ Location Accuracy ______

Z ______ E ______ N ______ UTM Date 20__ Well Type ______ Well ID Plate # ______

Owners Name & Address: Beaver Falls Waterworks District

Legal Description & Address: 1600 Scout Road, Fruitvale B.C.

Descriptive Location: Scout Camp - bottom of Bluebird Road

1. TYPE OF WORK 1 ☒ New Well 2 ☐ Reconditioned 3 ☐ Deepened 4 ☐ Abandoned

2. WORK METHOD 1 ☐ Cable tool 2 ☐ Bored 3 ☐ Jetted 4 ☒ Rotary a ☐ mud b ☒ air c ☐ reverse ☐ Other ______

3. WATER WELL USE 1 ☐ Domestic 2 ☒ Municipal 3 ☐ Irrigation 4 ☐ Comm. & Ind. ☐ Other ______

4. DRILLING ADDITIVES None

5. MEASUREMENTS from 1 ☒ ground level 2 ☐ top of casing; casing height above ground level ______ ft.

FROM ft	TO ft	6. WELL LOG DESCRIPTION	SWL ft
0	38	clay gravel	
38	77	sand gravel cobbles	
77	88	gray silty clay gravel	
		- pulled casing back to 76 feet and screened	
		- pump well to determine flow	

7. CONSULTANT ______ Address ______

8. WELL LOCATION SKETCH

110 lb pump off
130 lb pump running

9. CASING: Materials 1 ☒ Steel 2 ☐ Galvanized 3 ☐ Wood 4 ☐ Plastic 5 ☐ Concrete ☐ Other ______

							units
Hole Diameter	10 5/8						ins
Diameter	10						ins
from	0						ft
to	56						ft
Thickness							ins
Weight							lb/ft

Pitless unit ______ ft 1 ☐ above 2 ☐ below ground level
1 ☒ Welded 2 ☐ Cemented 3 ☐ Threaded | 1 ☒ New 2 ☐ Used
Perforations: ______
Shoe(s): 1 10" carbide button
Open hole, from ______ to ______ ft Diameter ______ ins
Grout: ______

10. SCREEN: 1 ☒ Nominal (Telescope) 2 ☐ Pipe Size
Type 1 ☒ Continuous Slot 2 ☐ Perforated 3 ☐ Louvre ☐ Other ______
Material 1 ☒ Stainless Steel 2 ☐ Plastic ☐ Other ______
Set from 76 to 54 ft below ground level

RISER, SCREEN & BLANKS							units
Length	5' 3"	5' 3"	5' 3"	5' 3"			ft
Diam. I D	7"	7"	7"	7"			ins
Slot Size	150	100	.80	50			ins
from	76	71	66	60			ft
to	71	66	60	55			ft

Fittings, top reducing K-packer bottom bail
Gravel Pack total length of screen & packer is 22 feet

11. DEVELOPED BY 1 ☐ Surging 2 ☐ Jetting 3 ☒ Air 4 ☐ Bailing 5 ☐ Pumping ☐ Other ______

12. TEST 1 ☐ Pump 2 ☐ Bail 3 ☐ Air Date ______ (YR MO DY)
Rate ______ USgpm Temp ______ °C SWL before test ______ ft
Water Level ______ ft after test of ______ hrs

☐ DRAWDOWN in ft				☐ RECOVERY in ft			
mins	WL	mins	WL	mins	WL	mins	WL

13. RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
Sub	72 ft	USgpm

14. WATER TYPE: 1 ☒ fresh 2 ☐ salty 3 ☒ clear 4 ☐ cloudy
colour no smell no ; gas 1 ☐ yes 2 ☒ no

15. WATER ANALYSIS: 1 Hardness ______ mg/L 2 Iron ______ mg/L 3 Chloride ______ mg/L 4 pH ______
Field Date ______ Lab Date ______ (YR MO DY)

EMS SITE No. ______

16. FINAL WELL COMPLETION DATA
Well Depth 76 ft Well Yield ______ US gpm
Static Water Level 25 ft Artesian Flow ______ US gpm Pressure Head ______ ft
Back filled ______
Well Head Completion Welded plate

17. DRILLER (PLEASE PRINT) Surname: Woodford First Name: Stan
Signature ______

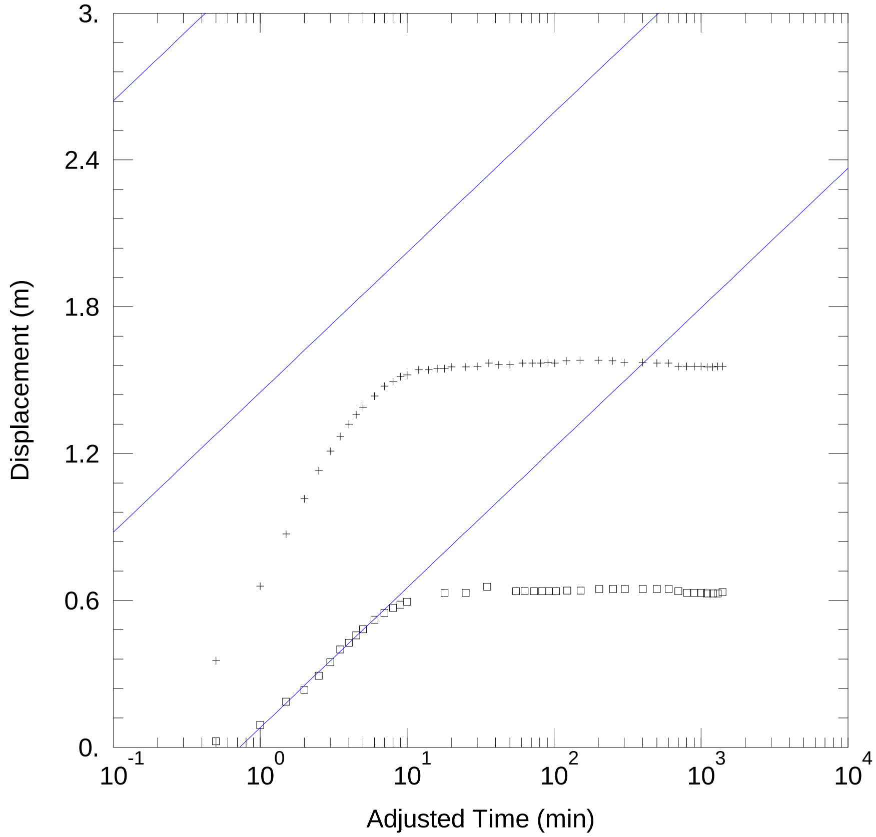
18. CONTRACTOR, Address
OWEN'S DRILLING LTD
BOX 730
CRANBROOK, B.C. V1C 4J5

HARRY CALDWELL

Member, B C G W A ☒ yes ☐ no ;

APPENDIX II

AQTESOLV Type Curves and Output Files



WELL TEST ANALYSIS

Data Set: N:\...\Constant-Rate Pumping Test obs well2.aqt
Date: 09/28/09 Time: 13:28:09

PROJECT INFORMATION

Company: Golder Associates Ltd
Client: Beaver Falls Waterworks Dist.
Project: 08-1480-0045
Location: Montrose, BC
Test Well: Well 3
Test Date: July 21-22, 2008

AQUIFER DATA

Saturated Thickness: 17. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Well 3	0	0

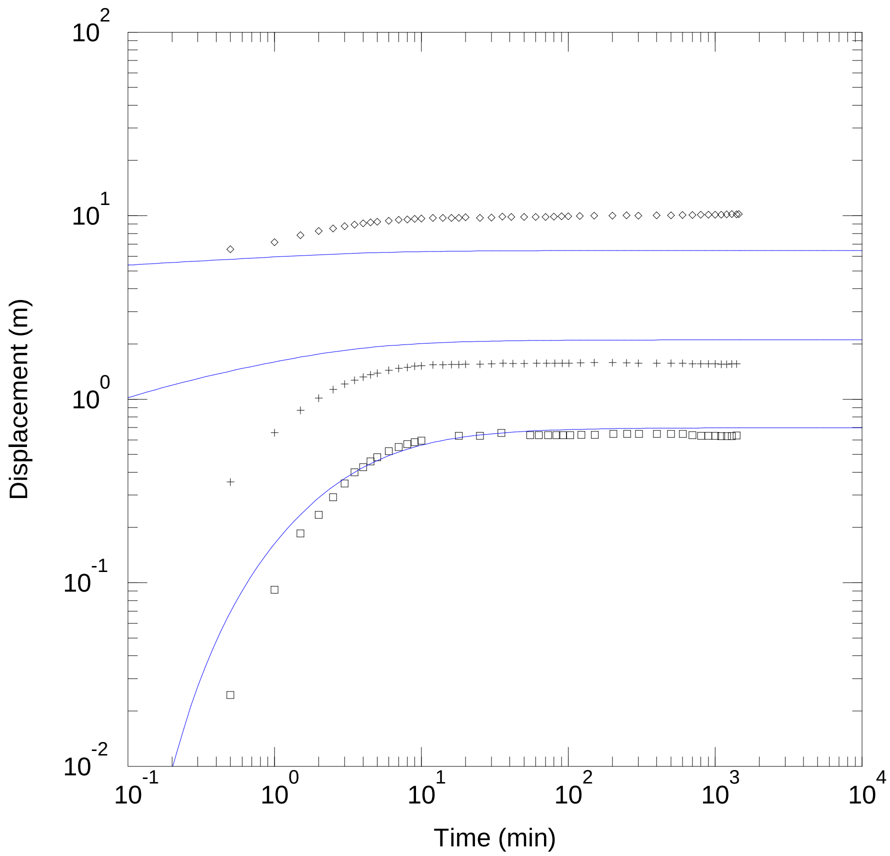
Observation Wells

Well Name	X (m)	Y (m)
◇ Well 3	0	0
+ Well 1	3.1	0
□ Well 2	49	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 174.8 m^2/day S = 8.216E-5



WELL TEST ANALYSIS

Data Set: N:\...\Constant-Rate Pumping Test Theis boundary.aqt
Date: 09/28/09 Time: 13:29:41

PROJECT INFORMATION

Company: Golder Associates Ltd
Client: Beaver Falls Waterworks Dist.
Project: 08-1480-0045
Location: Montrose, BC
Test Well: Well 3
Test Date: July 21-22, 2008

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Well 3	0	0

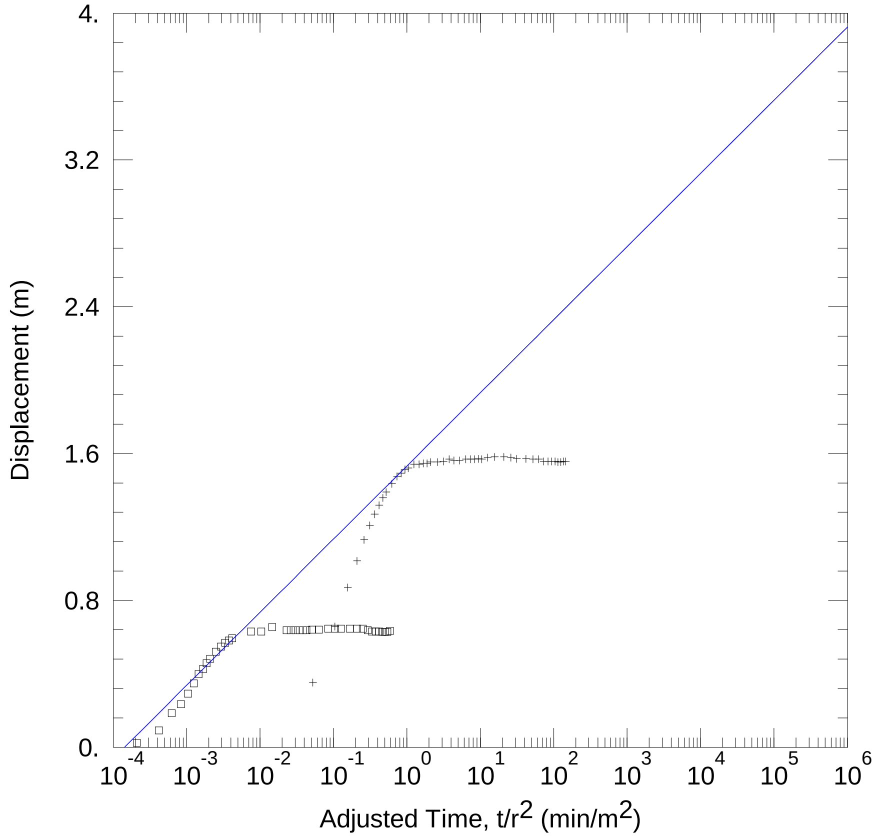
Observation Wells

Well Name	X (m)	Y (m)
◇ Well 3	0	0
+ Well 1	-3.1	0
□ Well 2	-49	-20

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 171.1 m^2/day
S = 7.405E-5
Kz/Kr = 1.
b = 17. m



WELL TEST ANALYSIS

Data Set: N:\...\Constant-Rate Pumping Test Combined.aqt
Date: 09/28/09 Time: 13:25:00

PROJECT INFORMATION

Company: Golder Associates Ltd
Client: Beaver Falls Waterworks Dist.
Project: 08-1480-0045
Location: Montrose, BC
Test Well: Well 3
Test Date: July 21-22, 2008

AQUIFER DATA

Saturated Thickness: 26. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Well 3	0	0

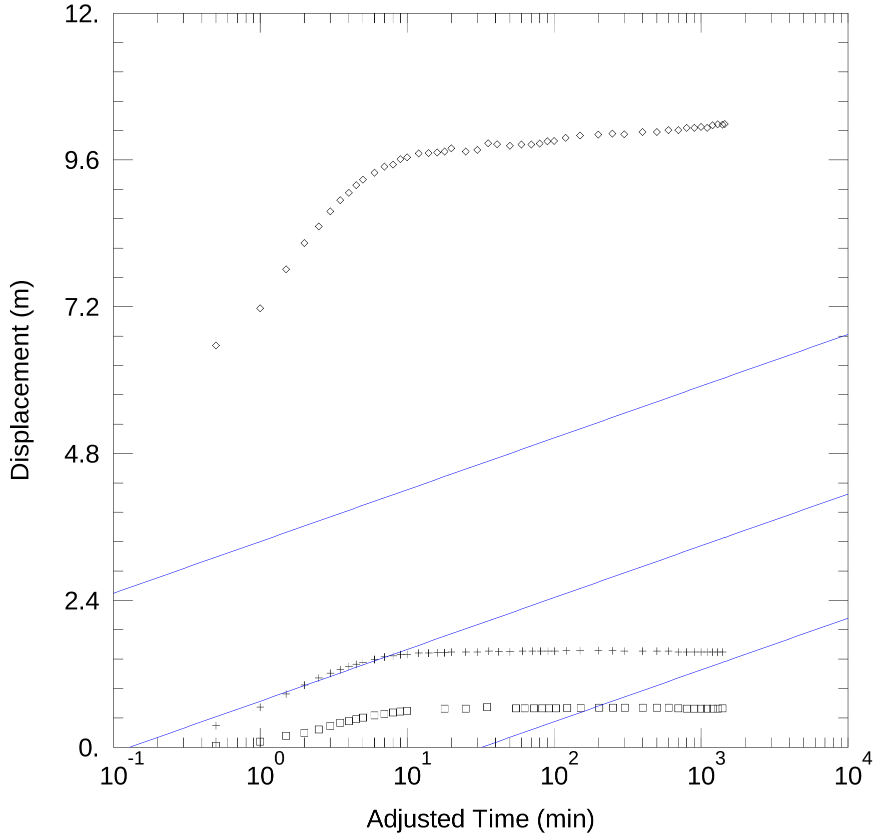
Observation Wells

Well Name	X (m)	Y (m)
◇ Well 3	0	0
+ Well 1	3.1	0
□ Well 2	49	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 250.7 m^2/day S = 5.565E-5



WELL TEST ANALYSIS

Data Set: N:\...\Constant-Rate Pumping Test obs well1.aqt
Date: 09/28/09 Time: 13:28:42

PROJECT INFORMATION

Company: Golder Associates Ltd
Client: Beaver Falls Waterworks Dist.
Project: 08-1480-0045
Location: Montrose, BC
Test Well: Well 3
Test Date: July 21-22, 2008

AQUIFER DATA

Saturated Thickness: 17. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Well 3	0	0

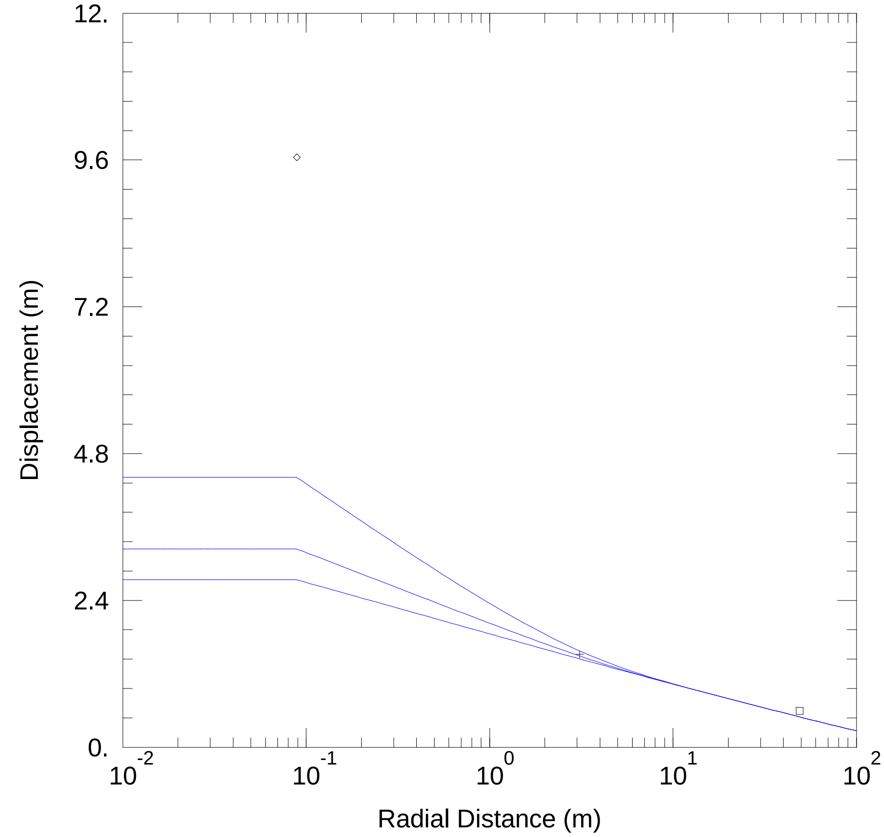
Observation Wells

Well Name	X (m)	Y (m)
◇ Well 3	0	0
+ Well 1	3.1	0
□ Well 2	49	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 118. m^2/day S = 0.002471



WELL TEST ANALYSIS

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PROJECT INFORMATION

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Project: 08-1480-0045
Location: Montrose, BC
Test Well: Well 3
Test Date: July 21-22, 2008

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Well 3	0	0

Observation Wells

Well Name	X (m)	Y (m)
◇ Well 3	0	0
+ Well 1	3.1	0
□ Well 2	49	0

SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 255.5 m^2/day

S = 9.251E-5

Kz/Kr = 1.

b = 17. m

APPENDIX III

Capture Zone - Analytical Solutions

Approximate Time-of-Travel Capture Zones - 100 DAYS

Reference: Ceric, A., and Haitjema, H., 2005. **On Using Simple Time-of-Travel Capture Zone Delineation Methods**. *Ground Water* Vol 43, No. 3 pp 408-412.

Step 1: **Calculate T* (dimensionless time of travel parameter)**

Given

Parameter Description	*Symbol*	*Value*	*Unit*
Pumping rate	Q	0.004	m^3/s
Time-of-Travel Zone Required (100 d)	T	8640000	s
Ambient groundwater flow rate (Qo =kHi)	Qo	8.50E-06	m^2/s per unit width of aquifer
regional gradient	i	0.005	-
hydraulic conductivity	k	1.00E-04	m/s
aquifer thickness	H	17.00	m
porosity	n	0.25	-

Assumptions
- aquifer of inifinite areal extent
- aquifer of constant uniform thickness
- constant effective porosity
- constant isotropic hydraulic conductivity
- steady state conditions

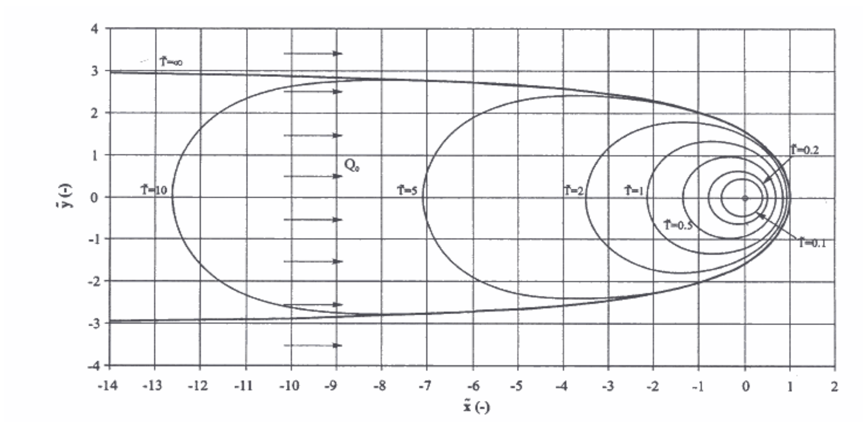
WARNING: INPUT DATA ONLY WHERE BLUE FONT APPEARS

Solution

$$T^* = \frac{2\pi Q_0^2 T}{nHQ} \; or \; \frac{2\pi (kHi)^2 T}{nHQ}$$

where **T*** <0.1 indicates time-of-travel capture zones concentric (circular) around the well
where 0.1< **T*** <1 indicates time-of-travel capture zones which resemble circles but are shifted in the direction of upgradient regional groundwater flow
where **T*** >1 the time-of-travel capture zones are like ellipses and cannot reasonably be approximated by circles

Dimensionless time of travel parameter T* = 0.23 -



Step 2: **If T*<0.1, then calculate Centric Circular Capture Zone**

(this case typically occurs when ambient gw flow is small compared to well pumping rate)

Solution

$$R = 1.1543\sqrt{\frac{QT}{\pi Hn}}$$

where R is the approximate but conservative (15% larger than exact radius by volumetric method alone) fixed-radius capture zone (m)

Approximate conservative fixed-radius R = 58.54 m

If 0.1< T*<1, then calculate Eccentric Circular Capture Zone

(the capture zone circle in this case is shifted upgradient)

Solution

$$L_s = \frac{Q}{2\pi Q_0} \; or \; \frac{Q}{2\pi kHi}$$
$$R^* = 1.161 + \ln(0.39 + T^*)$$
$$R = R^* L_s$$
$$\delta = L_s(0.00278 + 0.652\,T^*)$$

where Ls is the distance from the well to the well's stagnation point (m),
R is the approximate fixed-radius capture zone (m),
δ is the eccentricity (amount of shift) of the circle centre upgradient (m)

Distance from well to well's stagnation point (x at y = 0)	Ls =	74.41	m
Approximate fixed-radius capture zone	R =	51.09	m
Amount of upgradient shift of the circle centre	δ =	11.47	m

R*= 0.69
δ*= 0.15

If T*>1, then calculate Boat-Shaped Capture Zone

(capture zone cannot reasonably be approximated by circle; propose replacement of actual time of travel capture zone by envelope of all capture zones.

Solution

$$L_u^* = T^* + \ln(T^* + e)$$

$$L_u = L_u^* L_s$$

where Lu is the distance from the well to the furthest upgradient point of the time of travel capture zone (m),

$$-x = \frac{-y}{\tan\left(2\pi kHiy / Q\right)}$$

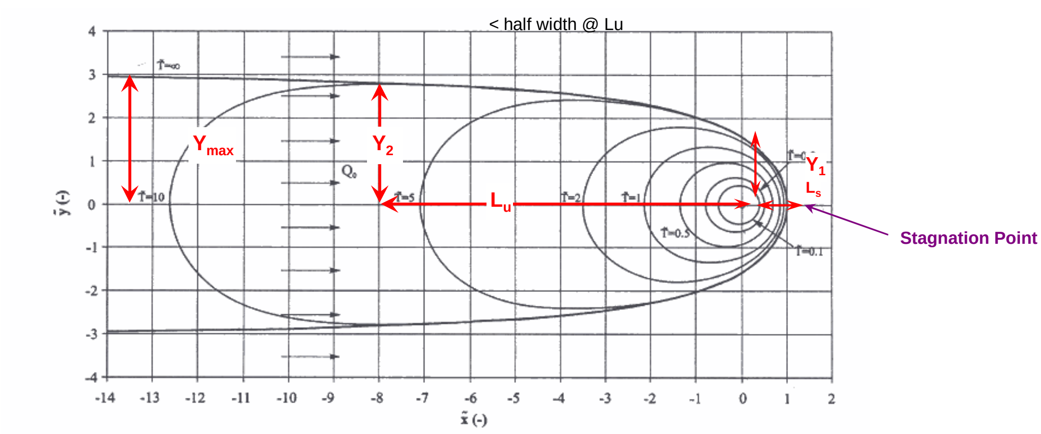
Equation to describe the edge of the **steady-state capture zone** for a confined aquifer when steady state conditions have been reached (Todd 1980; Grubb 1993) where tan(y) in radians

	Lu* =	1.31	-	
Distance to furthest upgradient point of the time of travel capture zone	Lu =	97.79	m	**<WARNING, DOES NOT EQUATE TO X AT 99%Ymax**
Distance to the furthest downgradient point of the time of travel capture zone (Ls) (x at y = 0)	Ls =	74.41	m	< stagnation point
Half width of capture zone at well location (y at x=0)	Y_1 =	116.89	m	< symmetrical about the x-axis
Maximum half width of capture zone (y at -x=infinity)	Y_{max} =	233.78	m	< symmetrical about the x-axis

5% Y_{max}, or	y= 11.69	x =	73.80 m	< downgradient of well (positive side of x axis on figure below)
25% Y_{max}, or	y= 58.44	x =	58.44 m	
50% Y_{max}, or	y= 116.89	x =	0.00 m	< x at origin (see figure below)
60% Y_{max}, or	y= 140.27	x =	-45.58 m	< upgradient of well (negative side of x axis on figure below)
70% Y_{max}, or	y= 163.65	x =	-118.90 m	< upgradient of well (negative side of x axis on figure below)
75% Y_{max}, or	y= 175.33	x =	-175.33 m	< upgradient of well (negative side of x axis on figure below)
80% Y_{max}, or	y= 187.02	x =	-257.42 m	< upgradient of well (negative side of x axis on figure below)
85% Y_{max}, or	y= 198.71	x =	-390.00 m	< upgradient of well (negative side of x axis on figure below)
90% Y_{max}, or	y= 210.40	x =	-647.55 m	< upgradient of well (negative side of x axis on figure below)
95% Y_{max}, or	y= 222.09	x =	-1402.22 m	< upgradient of well (negative side of x axis on figure below)

Calculate half width of time of travel capture zone (y at -x ≈Lu): Use "trial-and-error" approach by changing %Ymax or y below until '-x' ≈ Lu

98.78% Y_{max}, or	Y_2= 230.93	x =	-6022.17 m	< where -x ≈ Lu



Approximate Time-of-Travel Capture Zones - 1 YEAR

Reference: Ceric, A., and Haitjema, H., 2005. **On Using Simple Time-of-Travel Capture Zone Delineation Methods**. *Ground Water* Vol 43, No. 3 pp 408-412.

Step 1: **Calculate T* (dimensionless time of travel parameter)**

Given

Parameter Description	*Symbol*	*Value*	*Unit*
Pumping rate	Q	0.004	m^3/s
Time-of-Travel Zone Required (1 year)	T	31536000	s
Ambient groundwater flow rate (Qo =kHi)	Qo	8.50E-06	m^2/s per unit width of aquifer
regional gradient	i	0.005	-
hydraulic conductivity	k	1.00E-04	m/s
aquifer thickness	H	17	m
porosity	n	0.25	-

Assumptions
- aquifer of inifinite areal extent
- aquifer of constant uniform thickness
- constant effective porosity
- constant isotropic hydraulic conductivity
- steady state conditions

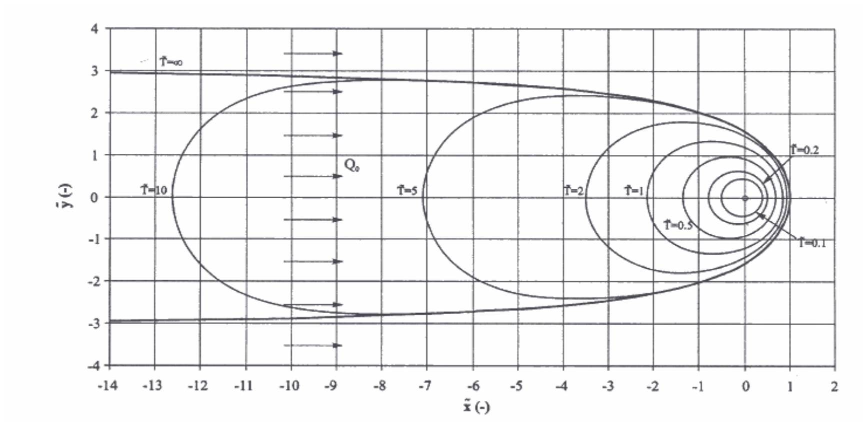
WARNING: INPUT DATA ONLY WHERE BLUE FONT APPEARS

Solution

$$T^* = \frac{2\pi Q_0^2 T}{nHQ} \quad or \quad \frac{2\pi (kHi)^2 T}{nHQ}$$

where **T*** <0.1 indicates time-of-travel capture zones concentric (circular) around the well
where 0.1< **T*** <1 indicates time-of-travel capture zones which resemble circles but are shifted in the direction of upgradient regional groundwater flow
where **T*** >1 the time-of-travel capture zones are like ellipses and cannot reasonably be approximated by circles

Dimensionless time of travel parameter T* = 0.85 -



Step 2: **If T*<0.1, then calculate Centric Circular Capture Zone**

(this case typically occurs when ambient gw flow is small compared to well pumping rate)

Solution

$$R = 1.1543 \sqrt{\frac{QT}{\pi H n}}$$

where R is the approximate but conservative (15% larger than exact radius by volumetric method alone) fixed-radius capture zone (m)

Approximate conservative fixed-radius R = 111.84 m

If 0.1< T*<1, then calculate Eccentric Circular Capture Zone

(the capture zone circle in this case is shifted upgradient)

Solution

$$L_s = \frac{Q}{2\pi Q_0} \quad or \quad \frac{Q}{2\pi kHi}$$
$$R^* = 1.161 + \ln\left(0.39 + T^*\right)$$
$$R = R^* L_s$$
$$\delta = L_s\left(0.00278 + 0.652\, T^*\right)$$

where Ls is the distance from the well to the well's stagnation point (m),
R is the approximate fixed-radius capture zone (m),
δ is the eccentricity (amount of shift) of the circle centre upgradient (m)

Distance from well to well's stagnation point (x at y = 0)	Ls =	74.41	m
Approximate fixed-radius capture zone	R =	102.26	m
Amount of upgradient shift of the circle centre	δ =	41.33	m

R*= 1.37
δ*= 0.56

If T*>1, then calculate Boat-Shaped Capture Zone

(capture zone cannot reasonably be approximated by circle; propose replacement of actual time of travel capture zone by envelope of all capture zones.

Solution

$$L_u^* = T^* + \ln(T^* + e)$$
$$L_u = L_u^* L_s$$

where Lu is the distance from the well to the furthest upgradient point of the time of travel capture zone (m),

$$-x = \frac{-y}{\tan\left(2\pi kHiy / Q\right)}$$

Equation to describe the edge of the **steady-state capture zone** for a confined aquifer when steady state conditions have been reached (Todd 1980; Grubb 1993)
where tan(y) in radians

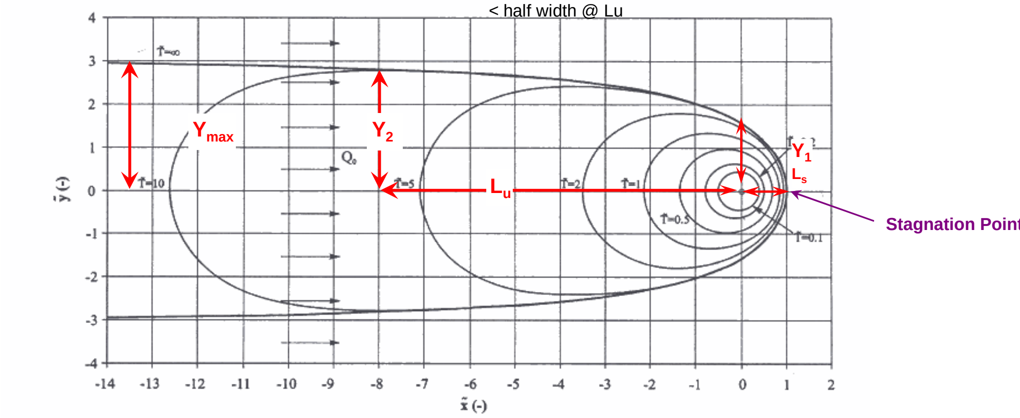
	Lu^* =	2.12	-	
Distance to furthest upgradient point of the time of travel capture zone	Lu =	157.68	m	**<WARNING, DOES NOT EQUATE TO X AT 99%Ymax**
Distance to the furthest downgradient point of the time of travel capture zone (Ls) (x at y = 0)	Ls =	74.41	m	< stagnation point
Half width of capture zone at well location (y at x=0)	Y_1 =	116.89	m	< symmetrical about the x-axis
Maximum half width of capture zone (y at -x=infinity)	Y_{max} =	233.78	m	< symmetrical about the x-axis

5% Y_{max}, or	y=	11.69	x =	73.80	m	< downgradient of well (positive side of x axis on figure below)
25% Y_{max}, or	y=	58.44	x =	58.44	m	
50% Y_{max}, or	y=	116.89	x =	0.00	m	< x at origin (see figure below)
60% Y_{max}, or	y=	140.27	x =	-45.58	m	< upgradient of well (negative side of x axis on figure below)
70% Y_{max}, or	y=	163.65	x =	-118.90	m	< upgradient of well (negative side of x axis on figure below)
75% Y_{max}, or	y=	175.33	x =	-175.33	m	< upgradient of well (negative side of x axis on figure below)
80% Y_{max}, or	y=	187.02	x =	-257.42	m	< upgradient of well (negative side of x axis on figure below)
85% Y_{max}, or	y=	198.71	x =	-390.00	m	< upgradient of well (negative side of x axis on figure below)
90% Y_{max}, or	y=	210.40	x =	-647.55	m	< upgradient of well (negative side of x axis on figure below)
95% Y_{max}, or	y=	222.09	x =	-1402.22	m	< upgradient of well (negative side of x axis on figure below)

Calculate half width of time of travel capture zone (y at -x ≈Lu): Use "trial-and-error" approach by changing %Ymax or y below until '-x' ≈ Lu

99.65% Y_{max}, or	Y_2=	232.96	x =	-21185.96	m	< where -x ≈ Lu

< half width @ Lu



APPENDIX IV

Water Quality Monitoring

Appendix IV
Laboratory Analytical Results - Water
Beaver Falls Waterworks District, BC

Sample ID	Units	RDL[1]	Guidelines for Canadian Drinking Water Quality		Well No.1	Well No. 2	Well No. 2	Well No. 3	Beaver Creek
Date Sampled			MAC[2]	AO/[OG][3]	27-Feb-08	9-May-06	25-May-09	22-Jul-08	22-Jul-08
Matrix					Groundwater	Groundwater	Groundwater	Groundwater	Surface Water
Field Parameters									
Temperature	°C			<15	-	8.5	9.5	9.4	15.7
pH	pH Units	0.1		6.5-8.5	-	6.5	6.8	6.8	7.8
Conductivity	uS/cm	0.1			-	-	-	437	181.2
Dissolved Oxygen	%				-	-	-	23.4	96.1
Radioactivity Parameters									
Gross Alpha	Bq/L	0.18	0.1[4]		-	-	-	**0.25**	-
Gross Beta	Bq/L	0.11	1[4]		-	-	-	0.12	-
Microbiological Parameters									
Background Colonies	CFU/100mL				-	-	5	-	-
Heterotrophic Plate Count	CFU/mL				-	-	2	-	-
Coliforms, Total	CFU/100mL	1	0		-	-	<1	<1	-
E. Coli	CFU/100mL	1	0		-	-	<1	<1	-
General Parameters									
pH	pH Units	0.1		6.5-8.5	-	6.9	7.3	6.9	-
Conductivity (EC)	uS/cm	5			-	378	382	415	196
Aggresiveness Index	-				-	-	11.1	11.1	-
Langelier Index	-	-5			-	-	-0.94	-0.95	-
Colour, True	Colour Units	5		<15	-	<5	<5	<5	-
Alkalinity, Total as CaCO3	mg/L	1			-	107	124	130	81
Carbon, Total Organic	mg/L	0.5	4[6]		-	-	1.3	1.5	-
Chloride	mg/L	0.1		<250	-	32	31.5	39.3	5.74
Cyanide (total)	mg/L	0.01	0.2		-	<0.01	<0.01	<0.01	-
Fluoride	mg/L	0.1	1.5		-	<0.10	<0.10	<0.10	<0.10
Hardness, Total (Total as CaCO3)	mg/L	2.07			-	155	159	165	80
Nitrogen, Ammonia as N	mg/L	0.02			-	<0.02	<0.02	0.05	-
Nitrogen, Nitrate as N	mg/L	0.01	10		-	1.7	1.35	0.954	-
Nitrogen, Nitrate+Nitrite as N	mg/L	0.02			-	1.7	1.35	0.954	-
Nitrogen, Nitrite as N	mg/L	0.01	1		-	<0.01	<0.01	<0.010	-
Nitrogen, Organic	mg/L	0.05			-	0.83	0.17	0.17	-
Nitrogen, Total	mg/L	0.07			-	-	-	1.18	-
Nitrogen, Total Kjeldahl	mg/L	0.05			-	0.1	0.17	0.23	-
Phosphorus, Total	mg/L	0.01			-	<0.3	<0.2	0.01	0.02
Solids, Total Dissolved	mg/L	5		<500	-	251	220	250	70
Sulfate	mg/L	1		<500	-	21	17.3	17.1	10.3
Sulfide	mg/L	0.05		<0.05	-	-	<0.050	<0.050	-
UV Transmittance	%				-	-	94.7	-	-
Turbidity	NTU	0.1	0.3/1.0/0.1[5]		-	0.09	<0.1	0.1	-

Appendix IV
Laboratory Analytical Results - Water
Beaver Falls Waterworks District, BC

Sample ID	Units	RDL[1]	Guidelines for Canadian Drinking Water Quality		Well No.1	Well No. 2	Well No. 2	Well No. 3	Beaver Creek
Date Sampled			MAC[2]	AO/[OG][3]	27-Feb-08	9-May-06	25-May-09	22-Jul-08	22-Jul-08
Matrix					Groundwater	Groundwater	Groundwater	Groundwater	Surface Water
Total Recoverable Metals by ICPMS									
Aluminum	mg/L	0.05		**OG = <0.1/0.2[7]**	<0.005	<0.01	<0.050	<0.050	<0.050
Antimony	mg/L	0.003	**0.006**		<0.001	<0.0005	<0.0010	<0.0030	<0.0030
Arsenic	mg/L	0.005	**0.01**		<0.001	<0.001	<0.0050	<0.0050	<0.0050
Barium	mg/L	0.005	**1**		0.034	0.03	0.0341	0.04	0.017
Beryllium	mg/L	0.002			<0.001	-	<0.0010	<0.0020	<0.0020
Bismuth	mg/L	0.0005			<0.001	-	<0.0010	<0.0005	<0.0005
Boron	mg/L	0.02	**5**		<0.05	<0.1	0.042	0.02	<0.020
Cadmium	mg/L	0.0001	**0.005**		<0.0002	<0.0002	<0.00010	<0.00010	<0.00010
Calcium	mg/L	0.5			51.1	52	52.6	55.8	27.7
Chromium	mg/L	0.015	**0.05**		0.002	<0.002	<0.0050	<0.015	<0.015
Cobalt	mg/L	0.0005			<0.001	-	<0.00050	<0.0005	<0.0005
Copper	mg/L	0.003		**<1.0**	0.003	<0.01	0.0014	<0.0030	<0.0030
Iron	mg/L	0.2		**<0.3**	0.07	<0.03	<0.10	<0.20	0.28
Lead	mg/L	0.001	**0.01**		<0.001	<0.001	<0.0010	<0.0010	<0.0010
Lithium	mg/L	0.002			0.002	-	0.0027	<0.0020	<0.0020
Magnesium	mg/L	0.2			5.97	6.2	6.63	6.24	2.62
Manganese	mg/L	0.005		**<0.05**	**0.48**	<0.002	<0.0020	0.0407	0.0235
Mercury	mg/L	0.0003	**0.001**		<0.02	<0.0002	<0.00050	<0.00030	<0.00030
Molybdenum	mg/L	0.001			0.0016	<0.03	<0.0010	<0.0010	<0.0010
Nickel	mg/L	0.005			0.003	<0.001	<0.0020	<0.005	<0.005
Phosphorus	mg/L	0.2			<0.15		<0.20	<0.20	<0.20
Potassium	mg/L	0.2			2.8	2.3	2.27	2.7	1.12
Selenium	mg/L	0.005	**0.01**		<0.001	0.001	<0.0030	<0.0050	<0.0050
Silicon	mg/L	1			9.8	-	7.2	9	5.5
Silver	mg/L	0.0004			<0.00025	<0.0001	<0.00050	<0.00040	<0.00040
Sodium	mg/L	0.2		**<200**	16.3	14	14	13.8	4.02
Strontium	mg/L	0.005			0.25	-	0.217	0.25	0.125
Tellurium	mg/L	0.003			<0.001	-	<0.0020	<0.0030	<0.0030
Thallium	mg/L	0.0005			<0.0001	-	<0.00020	<0.0005	<0.0005
Thorium	mg/L	0.003			<0.0005	-	-	<0.0030	<0.0030
Tin	mg/L	0.002			<0.001	-	<0.0020	<0.0020	0.0057
Titanium	mg/L	0.1			<0.001	-	<0.050	<0.10	<0.10
Uranium	mg/L	0.0005	**0.02**		<0.0005	0.0004	0.00039	0.0008	<0.0005
Vanadium	mg/L	0.01			<0.001	-	<0.010	<0.010	<0.010
Zinc	mg/L	0.01		**<5.0**	0.016	<0.05	<0.010	0.021	<0.010
Zirconium	mg/L	0.005			<0.01	-	<0.0010	<0.005	<0.005

Notes:

1) RDL = Reported Detection Limit 2) MAC = Maximum Acceptable Concentration 3) AO = Aesthetic Objective, [OG] = Operational Guidance

4) Screening level only. Inferred from guidelines for individual radionuclides.

5) Treated water guideline based on type of treatment: conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration.

6) The recommended guideline for TOC is 4 mg/L for raw drinking water in systems that use chlorination for disinfection.

7) This is an operatinoal guidance designed to apply only to drinking water treatment plants using aluminium-based coagulants. The operational guidance value of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.

Water Quality Monitoring - Well No.2								
Date	Total Coliforms CFU/100mL	E.coli CFU/100 mL	Heterotrophic Plate count CFU/1mL	Lab pH	Conductivity uS/cm	Turbidity NTU	Field Temperature oC	UV Transmittance %
23/04/2009	<1	<1	<1			<0.1		
04/05/2009	<1	<1	1			0.3		
18/05/2009	<1	<1	2	6.50	390	0.1	9.0	97.2
25/05/2009	<1	<1	2	7.30	382	<0.1	9.5	94.7
01/06/2009	<1	<1	1	7.63	368	0.2	9.5	98.1
08/06/2009	<1	<1	<1	7.69	386	0.1	9.0	96.9
10/06/2009					397		8.8	
15/06/2009	<1	<1	<1	7.69	363	<0.1	13.0	96.6
22/06/2009	<1	<1	<1	7.62	372	0.1	8.0	95.7
29/06/2009	<1	<1	<1	7.65	375	<0.1	9.0	98.8
06/07/2009	<1	<1	5	7.58	379	0.1	9.0	99.2
13/07/2009	<1	<1	1	7.74	379	0.1	9.0	97.2
20/07/2009	<1	<1	<1	7.74	374	<0.1	9.0	97.3
27/07/2009	<1	<1	<1	7.77	373	0.1	9.0	97.3

Notes:

Additional field parameters were measured by Golder on June 10 ,2009.

Field pH = 6.89; TDS = 198 ppm; Dissolved Oxygen = 4.77 mg/L; potential oxydo-reduction = 118 mV

Water Quality Monitoring - Beaver Creek						
Date	Total Coliforms CFU/100mL	E.coli CFU/100 mL	Lab pH	Conductivity uS/cm	Turbidity NTU	Field Temperature oC
22/07/2008			NA	196		15.7
18/05/2009			7.00	120	1.2	8.0
25/05/2009			7.40	111	1.0	8.0
01/06/2009			7.87	106	1.2	9.0
08/06/2009			7.51	136	0.8	8.5
10/06/2009				131.7		9.3
15/06/2009			7.99	147	0.9	13.0
22/06/2009			7.94	156	0.8	12.0
29/06/2009			8.01	168	0.8	13.0
06/07/2009			8.04	179	0.9	14.0
13/07/2009	O.G. with	O.G. with	8.07	181	1.0	14.8
20/07/2009			8.08	190	0.8	14.0
27/07/2009			8.10	189	0.8	16.0

Notes:
Water level in Beaver Creek was at its highest at around May 25, 2009.
Water level in Beaver Creek lower on June 1, 2009 than the week before.
O.G. with : overgrown with
Additional field parameters were measured by Golder on June 10 ,2009.
Field pH = 7.56; TDS = 65.9 ppm; Dissolved Oxygen = 11.07 mg/L; potential oxydo-reduction = 93 mV

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Principal Scientist: Peter M. Wallis, Ph.D.

MICROSCOPIC PARTICULATE ANALYSIS REPORT SHEET (GUDI)

CLIENT:	Genevieve Pomerleau Golder Associates 201 Columbia Avenue Castlegar, BC V1N 1A8
TELEPHONE:	(250) 365-0344
FAX:	(250) 365-0988

Date of Sample:	10 June, 2009
Sample Location:	BFWD Well #2
Type:	Raw
Volume Filtered (L):	3830
Temperature (° C):	8.8
pH:	6.89
Conductivity:	397

The methodology used to generate this report conforms to the USEPA Consensus Method for the Microscopic Particulate Analysis. Based on the validation data, the method is fit for its intended use.

Sample Processing Information

Final Pellet Vol. (µL): 10.0

Date Received	Time Received	Customer #	Temp. on Arrival (°C)	Lab ID	Density Medium	Sediment (mL)
11.VI.09	1630	174	8.8	49189	none	0.10

Total Wash (mL)	Concentrated (mL)	G/C Volume (µL)	MPA Volume (µL)	Suspension Vol. (µL)	Equiv. Vol. (L)
1000	1000	30	90	120	3,830

GIARDIA and *CRYPTOSPORIDIUM* RESULTS

***Giardia* cysts/100 L:** 0.00 ***Cryptosporidium* oocysts/100 L:** 0.00

PARTICULATE ANALYSIS RESULTS

Primary Particulates	Total Count	#/380 L (100 US gal.)	Relative Risk Factor
Diatoms:	0	0.00	NS
Other Algae:	2	0.26	NS
Insect/larvae:	0	0.00	NS
Rotifers:	0	0.00	NS
Plant Debris:	29	3.84	R

Relative Risk Factors: EH - extremely heavy
M - moderate H - heavy
R - Rare NS - not significant

Secondary Particulates	Total Count	#/380 L (100 US gal.)
Pollen	31	4
Nematodes	0	0
Crustacea	0	0
Amoebae	0	0
Ciliates/flagellates	0	0
Other	0	0
Large Debris	low	
Fine Debris	iron floc	
Minerals	silica	

CONCLUSION: Based on this sample, the risk of surface water contamination is judged to be low and the risk factor is **0**

Additional Data: Lots of surface water organisms, diatoms in sample submitted.

Analyst:

Peter M. Wallis, Ph.D.

From the EPA Consensus Method:

Risk of Surface Water Contamination
20+ - high risk
10 to 19 - moderate risk
0 to 9 - low risk

Recovery efficiencies for particles are known to be low by this method but are compensated for by filtering a large volume of water. Minimum recovery was measured to be 6.5 +/-1.2% for *Giardia* cysts, 0.5 +/-0.2% for *Cryptosporidium* oocysts and 4.2 +/-2.3% for *Euglena* (algae). Despite the low recovery, the method reliably detected as few as 1 cell/L of groundwater in validation trials with no false positives.

Effective Date: 27/05/2006 Version #: 1.1
Revision Date: 02/01/2007 Document #: HR0013

Note: These results pertain to this sample only.

APPENDIX V

MOE Contaminated Sites Registry Search Result

```
As Of: AUG 30, 2009          BC Online: Site Registry                 09/09/01
                     For: PE92096  GOLDER ASSOCIATES LTD. (KELOWNA)    16:21:04
Folio: 08-1480-0074                                                   Page    1
```

Area Nil Search

As of AUG 30, 2009, no records from Site Registry
fall within 0.5 kilometers of coordinates
Latitude 49 degrees, 6 minutes, 12.9 seconds, and
Longitude 117 degrees, 33 minutes, 16.2 seconds.

You have been charged for this information.

Sites may be revealed by searching with alternate search methods. For example, a site not revealed in an Area search may be revealed by searching with another piece of information such as PID, PIN, address or Crown Lands File Number

APPENDIX VI

BC MoE Water Resources Atlas Search

BRITISH COLUMBIA

WRA Search

Legend

Water - River, Canal, etc. - Colour Themed (1:20,000)

- Canal
- River or Stream - Definite

Water - River, Canal, etc. - Outlined (1:20,000)

- Canal
- River or Stream - Definite

Water - Lake, Reservoir, etc. - Colour Themed (1:20,000)

- Mine - Tailing Pond
- Lake - Definite
- Reservoir - Definite

Water - Lake, Reservoir, etc. - Outlined (1:20,000)

- Mine - Tailing Pond
- Lake - Definite
- Reservoir - Definite

Water - Wetlands - Colour Themed (1:20,000)

- Flooded Land - Inundated
- Marsh
- Swamp

Water - Wetlands - Outlined (1:20,000)

- Flooded Land - Inundated
- Marsh
- Swamp

Water - Ocean - Colour Filled (1:20,000)

0 70 140 m.

Scale: 1:5,000

Datum/Projection: NAD83, Albers Equal Area Conic

Key Map of British Columbia

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 52396

Owner: BEAVER FALLS WATER

Address: SCOUT CAMP

Area: MONTROSE

WELL LOCATION:
KOOTENAY Land District
District Lot: 1236 Plan: 785B Lot: 105
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 082F013112 Well: 5

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Unknown Constru
Diameter: 8.0 inches
Casing drive shoe:
Well Depth: 214 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 1983-07-01 00:00:00.0

Driller: Pacific Pump & Pressure
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 150 (Driller's Estimate) U.S. Gallons per Minute
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 4 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):

Water Utility:
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag:
Material:
Method:
Depth (ft):
Thickness (in):

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size	

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	4	Ft.	sandy tan clay with boulders
From	4	to	12	Ft.	clayey sand and gravel to 25 mm.
From	12	to	26	Ft.	tight, med. and coarse sand, some gravel
From	0	to	0	Ft.	making some water
From	26	to	32	Ft.	coarse sandy gravel, w.b.
From	32	to	38	Ft.	med. and coarse sand with gravel and
From	0	to	0	Ft.	clay binder
From	38	to	44	Ft.	fine and med. sandy gravel
From	44	to	54	Ft.	tight sandy gravel with brown silty clay
From	0	to	0	Ft.	binder
From	54	to	56	Ft.	grey sandy gravel
From	56	to	75	Ft.	grey till
From	75	to	148	Ft.	sticky grey till
From	148	to	176	Ft.	very hard till
From	176	to	196	Ft.	till and boulders
From	196	to	214	Ft.	sticky till, some boulders

Report 1 - Detailed Well Record

Well Tag Number: 18231 Owner: VILLAGE OF FRUITVALE Address: Area: FRUITVALE WELL LOCATION: KOOTENAY Land District District Lot: 1236 Plan: 785B Lot: 105 Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 082F013112 Well: 1 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Other Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 10.0 inches Casing drive shoe: Well Depth: 49.6 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: 49 feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1963-10-01 00:00:00.0 Driller: Western Water Wells Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 200 (Driller's Estimate) Imperial Gallons per Minute Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 9 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Y Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	**to feet**	**Diameter**	**Material**	**Drive Shoe**

GENERAL REMARKS:

LITHOLOGY INFORMATION:

```
From     0 to    18 Ft.   silty sand and gravel -tight
From    18 to    44 Ft.   sands and gravels, clean, fairly well
From     0 to     0 Ft.   sorted
From    44 to  49.6 Ft.   silty sand and gravel
From     0 to  49.6 Ft.   bedrock
From     0 to     0 Ft.
From     0 to     0 Ft.   200 I. GPM
```


- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 25275 Owner: BEAVER FALLS WATER Address: Area: FRUITVALE WELL LOCATION: KOOTENAY Land District District Lot: Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 082F013112 Well: 2 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Well Depth: 58 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1971-08-19 00:00:00.0 Driller: Pacific Pump & Pressure Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 300 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 9 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0 to	2 Ft.	soil and gravel
From	2 to	6 Ft.	rocky gravel
From	6 to	14 Ft.	silt with gravel (20 %)
From	14 to	22 Ft.	silt with gravel (40 %)
From	22 to	31 Ft.	med. to coarse sand and gravel (w.b.)
From	31 to	36 Ft.	med. to crse sand with some fine sand
From	36 to	38 Ft.	sand and gravel, estimated screen size
From	0 to	0 Ft.	.050
From	38 to	41 Ft.	sand and gravel, est. scr. size .040
From	41 to	46 Ft.	sand and gravel, est. scr. size .050
From	46 to	50 Ft.	somewhat compact sand and gravel, w.b.,
From	0 to	0 Ft.	est. scr. size 0.040
From	50 to	58 Ft.	compact sand and gravel (w.b.) est. scr.
From	0 to	0 Ft.	size 0.050
From	0 to	0 Ft.	
From	0 to	0 Ft.	5' slotted casing set in aquifer.

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 27582 Owner: BEAVER FALLS WATER Address: Area: FRUITVALE WELL LOCATION: KOOTENAY Land District District Lot: Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 27): 082F013112 Well: 6 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 10.0 inches Casing drive shoe: Well Depth: 68 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1973-01-31 00:00:00.0 Driller: Pacific Pump & Pressure Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 250 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: 6 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	24	Ft.	compact, very dirty sand and gravel with
From	0	to	0	Ft.	cobbles
From	24	to	36	Ft.	silty sand and gravel making water
From	36	to	68	Ft.	gravel with fine, med. and coarse sand
From	0	to	0	Ft.	and sticky brown silt binder

- Return to Main
- Return to Search Options
- Return to Search Criteria

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 53839 Owner: DAVE BORTNICK Address: Area: FRUITVALE WELL LOCATION: KOOTENAY Land District District Lot: 1236 Plan: 785A Lot: Township: Section: Range: Indian Reserve: Meridian: Block: 51 Quarter: Island: BCGS Number (NAD 27): 082F013112 Well: 4 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Well Use: Domestic Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Well Depth: 200 feet Elevation: 0 feet (ASL) Final Casing Stick Up: inches Well Cap Type: Bedrock Depth: 7 feet Lithology Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Site Info Details: Other Info Flag: Other Info Details:	Construction Date: 1984-08-01 00:00:00.0 Driller: Owen's Drilling Ltd. Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 4 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: Artesian Flow: Artesian Pressure (ft): Static Level: WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Material: Method: Depth (ft): Thickness (in): WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:

Screen from	to feet	Type	Slot Size	
Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
SAYS WATER QUALITY IS HARD, BUT ACCEPTABLE. THE QUANTITY IS APPROX. 4 GPM.

LITHOLOGY INFORMATION:
From 0 to 7 Ft. clay and gravel
From 7 to 200 Ft. bedrock

- Return to Main
- Return to Search Options
- Return to Search Criteria

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