PITEAU ASSOCIATES
GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS

SUITE 300 - 788 COPPING STREET
NORTH VANCOUVER, B.C.
CANADA - V7M 3G6
TEL: (604) 986-8551 / FAX: (604) 985-7286
www.piteau.com

HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN

Prepared for
DISTRICT OF SQUAMISH
ENGINEERING AND PARKS DEPARTMENT

Prepared by
PITEAU ASSOCIATES ENGINEERING LTD.

PROJECT 2841 **MAY 2014**

EXECUTIVE SUMMARY

The Powerhouse Springs Well Field (the Well Field) is the primary source of potable water to the District of Squamish. It is located approximately 5 km east of the Squamish town centre at the western terminus of the Ring Creek lava flow. The Well Field consists of seven production wells supplying groundwater a combined rate of between 130 and 210 L/s. This report represents preliminary investigations undertaken to develop a Well Protection Plan (WPP) for the purpose of protecting this groundwater resource is future generations.

At the outset of this Hydrogeological Assessment, regional information about the nature and extent of the Ring Creek Aquifer (the Aquifer), and its predominant sources of recharge (e.g., incident precipitation or surface water) was very limited. Desktop analyses and field investigations were undertaken, including an inspection of the lava flow and creek channel geology, sampling of groundwater and surface water chemistry, and monitoring of water levels and flow rates in creeks. Our interpretation of these data suggests that the Aquifer extends at least as far as the Skookum Creek/Mamquam River confluence. Most of the water entering the Aquifer originates from Ring and Skookum creeks, and a smaller component is sourced from rainfall and snowmelt that infiltrate the lava flow cap. Total groundwater flow through the Aquifer in the vicinity of the Well Field is estimated to be 800 L/s year over year.

A spreadsheet water balance was developed to quantify recharge from various sources using climate data and stream gauging data collected in this and other studies. A good match was achieved between simulated and measured stream flows and groundwater discharge rates by assuming that roughly one-third of groundwater flowing in the Aquifer originates from incident precipitation, and the remaining two-thirds originate from Skookum and Ring creeks.

A regional scale numerical model was developed to simulate this conceptual model and estimate groundwater travel times to the Well Field. Groundwater travel times between

Ring Creek and the Well Field were estimated to be between nine months and two years, depending on the pathway taken. Estimated travel times between Skookum Creek and the Well Field ranged from three to seven years.

A capture zone is the area over which groundwater is expected to report to a well within a certain time period. Three-month, one-year, and five-year capture zones were defined for the Well Field using the numerical model. These form the basis for defining a Groundwater Protection Area within which aquifer protection measures are implemented.

With reference to the Province's Well Protection Toolkit, the next steps in formulation of a WPP are to:

1. Define the Well Protection Area
2. Identify Potential Contaminants
3. Develop Management Strategies and Contingency Plans
4. Implement, Monitor, and Evaluate the Plan

These are presented in a subsequent document, entitled "Powerhouse Springs Well Protection Plan." This plan was developed in collaboration with various land user groups, stakeholders, and interested members of the public that we hope will continue to serve on a Well Protection Planning Committee. This committee, and the Squamish community at large, play an important role in implementing the WPP and ensuring that it evolves in step with future land uses upgradient of the Well Field.

CONTENTS

CONTENTS (cont'd.)

TABLES

FIGURES

PHOTOS

Photo 1	Outcrop of granitic basement rock on Mamquam FSR (June 5, 2012).
Photo 2	Exposed glaciofluvial sediments on north side of Ring Creek FSR (August 27, 2012).
Photo 3	Paleochannel glaciofluvial sediments at toe of Ring Creek Lava Flow (June 15, 2012).
Photo 4	Looking north to lava flow sequence exposed above Mamquam River from Mamquam FSR (June 15, 2012).
Photo 5	Blocky top surface on upper portion of Ring Creek Lava Flow (June 15, 2012).
Photo 6	Steep blocky lateral flow breccias on south levee of Ring Creek Lava Flow (June 15, 2012).
Photo 7	Confluence of Skookum Creek (viewer's left) and Mamquam River (viewer's right) (June 15, 2012).
Photo 8	Alluvial sediments upstream of confluence of Skookum Creek with Mamquam River (August 17, 2012).
Photo 9	Contact between granitic basement rock (viewer's left) and Ring Creek Lava Flow (viewer's right) at the Upper Mamquam hydroelectric facility (November 7, 2012).
Photo 10	Powerhouse Creek above confluence with Mamquam River (Site 4) (May 24, 2012).
Photo 11	Weakly jointed and massive core of Ring Creek Lava Flow (June 15, 2012).
Photo 12	Highly jointed lava rock pre-dating Ring Creek Lava Flow southeast of confluence of Skookum Creek with Mamquam River (June 15, 2012).

1. INTRODUCTION

1.1 BACKGROUND

The District of Squamish (the District) has developed the Powerhouse Springs Well Field to withdraw water from a paleochannel aquifer that was overridden by the Ring Creek Lava Flow. Seven water supply wells have been constructed where the paleochannel intercepts the Mamquam River valley. The wells were commissioned following approval under the Environmental Assessment Process (EAP), and currently supply groundwater at a combined average annual rate of 130 L/s. One of the requirements of the operating permit was that the District develop a Well Protection Plan (WPP). This WPP will serve as a framework for responsible stewardship of this groundwater resource for current and future water users.

Well protection plans are developed by a committee which has representation from various stakeholders involved with the groundwater resource, government agencies that regulate industrial or resource activity in groundwater recharge areas, and industries active in these areas. This hydrogeological assessment provides technical information so that decisions on what measures should be incorporated in the plan can be made in an informed and quantitative manner.

1.2 SCOPE OF WORK

This program of investigation has been conducted in general accordance with our March 29, 2012 proposal prepared by Piteau and Kerr Wood Leidal Associates Ltd. (KWL). As laid out in the Province’s Well Protection Toolkit, development of a WPP involves several steps, including:

1. Define the Well Protection Area
2. Identify Potential Contaminants
3. Develop Management Strategies and Contingency Plans
4. Implement, Monitor, and Evaluate the Plan

This Hydrogeological Assessment provides the foundation for Step 1 of this process. It has involved a regional-scale study of the Ring Creek aquifer (the Aquifer) and analysis of recharge sources. Based on this information, an aquifer water balance and a numerical model of groundwater flow through the Aquifer were developed. The numerical model was used to define Well Field capture zones, which in turn are used to define a Well Protection Area (referred to as a "Groundwater Protection Zone" in the WPP). Steps 2 and 3 of the well protection planning process identify potential contaminants within the Groundwater Protection Zone, and propose measures to mitigate their risks to groundwater quality. Specific tasks and timelines for implementing, monitoring, and evaluating the plan are provided as part of Step 4. The final product is presented in a separate document entitled "Powerhouse Springs Well Protection Plan."

Further description of the scope of work carried out as part of the Hydrogeological Assessment is provided in the following sections.

1.2.1 Aquifer Characterization and Water Balance

Geologic and hydrologic information were consolidated to define a regional conceptual model of the Aquifer. Sources of information included scientific papers and previous consultant reports, online databases maintained by the Province and various scientific agencies, and interviews with government and stakeholder representatives. In addition, an extensive field investigation program was undertaken, which entailed:

- Reconnoitering of the Ring Creek Lava Flow to assess the structural nature of the rock mass. This information would be used to assess water infiltration potential and the degree of protection provided to the Aquifer by the overlying lava rock mass.
- Performing spot inspections of the Mamquam River, Ring Creek, and Skookum Creek channels to evaluate the likelihood of surface water exfiltration to ground, and their relative importance as sources of water recharge to the Aquifer.
- Collecting samples of groundwater, surface water, and rainwater for analysis of basic anion/cation chemistry and isotopic composition. This would serve to identify likely sources of groundwater recharge and bracket the age of groundwater flowing past the Well Field.

- Performing spot measurements of surface water flows in the vicinity of the Well Field and continuously monitoring creek stage at select locations over a six-month period. This data was used to compare current and historic groundwater discharge rates, and identify effects of pumping on aquifer water levels and spring flows. It was also used to calibrate a spreadsheet water balance and regional-scale numerical model of the Aquifer.

To more quantitatively evaluate sources of aquifer recharge (incident precipitation, exfiltration from surface watercourses), Piteau developed a watershed-scale spreadsheet water balance. This was calibrated using hydrologic data from government and consultant sources and spot measurements of flows in Ring Creek. Climate and geographical data were used to quantify relative runoff and infiltration amounts for portions of the Mamquam River and Ring Creek watersheds in order to obtain a match between predicted and measured surface water and groundwater discharge rates.

1.2.2 Numerical Modelling

Based on the field reconnaissance and water balance assessment, a regional-scale finite difference model was developed to estimate Well Field capture zones for the three-month, one-year, and five-year groundwater time-of-travel scenarios. It also served to validate the conceptual hydrogeological model and quantitative water balance, and test the sensitivity of capture zone configurations to variations in sources of recharge. Additional simulations were performed to assess potential impacts to groundwater flow as a result of the Skookum Run-of-River Power Project.

2. PHYSIOGRAPHY

2.1 SETTING

The study area originates at the Powerhouse Springs Well Field, located approximately 5 km from Squamish Town Centre and immediately above the Atlantic Power generating station on the Mamquam River (Figs. 1 and 2). From here, it extends approximately 12 km westward and 7 km northward along the Ring Creek Lava Flow to the alpine regions of Garibaldi Provincial Park. Ground elevations in the Well Field area average approximately 105m geodetic (m-geod.), and rise to 2,440 m-geod. at the nearby Mamquam Icefield and Garibaldi Nevé. This mountainous area is drained by the Mamquam River, Skookum Creek, and Ring Creek, whose combined watershed area is estimated to be about 320 km^2.

2.2 CLIMATE

The study area is situated in the Coast Mountains and the Islands climate zone, and the Coastal Western Hemlock Biogeoclimatic Zone. Environment Canada’s “Squamish Upper” station (Climate ID 1047672) is located at an elevation of about 46 metres above sea level (m-asl), 23 km northwest of the Well Field. The period of record for this station is 1979 to 2010. Monthly and daily precipitation data have also been collected from the “Squamish Auto” station (Climate ID 10476F0) since 1982, which is located about 8.6 km northwest of the Well Field at an elevation of 52m.

Based on the normalized record for the period of 1971 to 2000, the “Squamish Upper” station receives an average of 2,367mm of precipitation annually, of which 10% falls as snow (Environment Canada, 2012; Table I). The highest monthly average occurs in November (379mm), and the lowest in August (60mm). The average annual temperature at the Squamish Upper Station is 9.0^{o}C.

Squamish’s climate is affected by large-scale oscillations in ocean atmospheric conditions, namely the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The ENSO phenomenon originates in the tropical Pacific and has a cycle of roughly five years. During El Niño events (ENSO’s warm phase), British Columbia experiences warmer temperatures and less precipitation, and during La Niña events (ENSO's cool phase), cooler and wetter conditions prevail (Climate Impacts Group, 2006). Since the 1980's, notable La Niña episodes have been observed in North America in 1988, 1995, 1998, 2007, 2010, and 2011 (National Oceanic and Atmospheric Administration, 2012).

The PDO has a longer cycle (20 to 30 years) and originates in the mid-latitude Pacific. During a positive PDO phase, the west Pacific experiences cooler conditions, and during a negative phase – warmer conditions. The PDO can amplify or dampen the effect of ENSO events, affecting temperature, precipitation, snowpack, and storm patterns.

The cusum plot on Fig. 3 presents the cumulative deviation from the 20-year average of mean monthly precipitation for each month for the period June 1982 to December 2012. A positive slope on this plot indicates a wetter-than-normal period, and a negative slope indicates a drier-than-normal period. An extended drier-than-normal period is noted from 1985 to 1996, over which period there were three extended El Niño events (shaded in orange), and two shorter La Niña events (shaded in blue). A sharp rising trend in the cusum series from 1996 to 1999 indicates a significantly wetter-than-normal period. The longer-term decreasing trend from 1999 to present, interrupted by La Niña occurrences in 2007 and 2010, signals a drier-than-normal period.

2.3 CLIMATE CHANGE

Based on approximately 60 years of climate records, mean annual and mean seasonal temperatures across British Columbia appear to have increased significantly in recent decades (Lemmen et al., 2008; Zhang et al., 2000; Whitfield et al., 2002a). At the same time, the number of El Niño events has increased, and the number of La Niña events has decreased (Trenberth and Hoar, 1996). Some studies suggest that this may be a result of global warming (Fedorov and Philander, 2000); however, there is still considerable uncertainty regarding factors affecting ENSO.

Coastal British Columbia, particularly the South Coast, has experienced less snowfall during the winter, but no obvious change in total precipitation each season (Whitfield and Taylor, 1998). In general, Global Climate Models (GCMs) predict wetter winters and springs throughout most of British Columbia, and drier summers in southern and coastal British Columbia. Regional changes in hydrologic cycles are linked to these temperature and precipitation trends. In coastal British Columbia, such changes include increased winter flows and decreased late summer flows (Whitfield and Taylor, 1998; Whitfield et al., 2002b). Spring freshet in many rivers is also predicted to occur earlier in the year (Zhang et al., 2001).

Other studies indicate that British Columbia glaciers have retreated at unprecedented rates in the last 8,000 years (Lowell, 2000), and most may disappear within the next 100 years. These will significantly impact quantities of stream runoff in the late summer. Local studies by Koch and others (2004) in Garibaldi Provincial Park indicate a dramatic loss of ice and snow and rise in tree line over the 20th century. These conclusions were based on examination of a diverse set of paleo-environmental indicators, such as tree-rings, lake sediments, glacial landforms, and photographs.

2.4 GEOLOGY

The geology of the study area includes basement rock, glaciofluvial outwash sediments and paleochannel, syn- and post-glacial volcanic deposits, and more recent fluvial deposits. The oldest group comprises basement rocks belonging to the Gambier Group and Coast Plutonic Complex. The eroded surface of the granitic rock forms a natural valley which runs from east to west through the study area. Glacial outwash sediments fill the bottom of this bedrock channel, which is truncated by the present day Mamquam River valley just west of the Well Field. These in turn have been overridden by the Ring Creek Lava Flow, which effectively “caps” the sediments filling the bedrock channel. A more detailed description of these four groupings is included in the following sections:

2.4.1 Basement Rock

The basement rock in the study area has been mapped as Late Jurassic rocks of granitic composition (Fig. 4). These rocks are predominantly quartz diorites locally containing numerous dykes and intrusions (Monger, 1993; Mathews, 1958). Outcrops of these rocks were noted on the north side of the upper reaches of Powerhouse Creek, and in the vicinity of the powerhouse and nearby Mamquam River canyon (Photo 1). Structurally complex metamorphosed sedimentary and volcanic strata have also been mapped on

Round Mountain and Mulligan Mountain on the north and south sides of the Ring Creek Lava Flow, respectively (Monger, 1993; Mathews, 1958).

2.4.2 Glaciofluvial Outwash Sediments

The glaciofluvial sediments belong to the southern end of a raised delta unit which extends along the east side of the Squamish River valley. At the time of deposition, the delta was pro-grading westward into a body of water at approximately 122m elevation. These sediments also extend southward across a rock rimmed gap and into the Stawamus basin, indicating that the body of water was drained at that point (Mathews, 1952). The delta was formed by sediments from Mashiter and Ring creeks and the Mamquam River, but since the level of the body of water has dropped, present day drainage courses have progressively incised the delta (Brooks and Friele, 1992).

The glaciofluvial sediments range from silt to boulder sized clasts of dacite and quartz diorite (Photo 2). The thickness of these sediments is estimated to exceed 90m in some places (Mathews, 1952). On Fig. 4, they have been mapped as ice contact, glaciofluvial terrace, glaciofluvial blanket, pro-glacial deltaic, and glaciofluvial veneer (Blais-Stevens, 2008).

In the vicinity of the Well Field, the eroded bedrock channel in which these sediments were deposited is about 250m wide by 45m deep, based on well drilling records and the results of a seismic survey conducted along the power line right-of-way in 1999 (Fig. 5). The width and morphology of the Skookum-Mamquam valley indicate that this was once an important conduit for ice dispersal during the Pleistocene (Mathews, 1958).

2.4.3 Glaciofluvial Paleochannel

It is believed that there is an approximately 100m wide by 6m deep alluvial channel associated with the ancestral Mamquam River on the surface of the glaciofluvial outwash sediments (Brooks and Friele, 1992). The upper portion of the channel is buried by the Ring Creek Lava Flow, and the lower portion is occupied by Powerhouse Creek, a stream misfit for such a large channel. The sediments which comprise this channel would be indistinguishable from the underlying glaciofluvial sediments which are of similar, but older, origin (Photo 3). For the purpose of this study, the entire sequence of glaciofluvial sediments which overlie bedrock is referred to as the Paleochannel.

2.4.4 Ring Creek Lava Flow

The Ring Creek Lava Flow (Lava Flow) extends a distance of about 28 km from Opal Cone located in Garibaldi Park to just east of the Well Field area. It is estimated to have a maximum thickness of 240m and comprise a volume greater than 4 km^3 (Mathews, 1958; Photo 4). The upper portion of the flow is aligned roughly north-south, and the lower portion is aligned east-west. The Lava Flow terminates roughly 250m east of the BC Hydro right-of-way, and at this point is estimated to be about 75m thick. It is believed that the lava followed the contours of the bedrock valley and covered the glaciofluvial outwash sediments and ancestral Mamquam River channel, laterally displacing the Mamquam River to its present position (Mathews, 1958).

Radiocarbon dating of organic materials found in the Mamquam River valley indicates that the Lava Flow is a Late Pleistocene or Early Holocene volcanic feature, deposited about 9,500 years before present (Brooks and Friele, 1992). It is interpreted that the Mamquam River valley was completely deglaciated prior to the eruption of the Lava Flow (Bruno, 2011). The Lava Flow has been mapped as part of the Garibaldi Group., which includes basalt, andesite, dacite, and rhyodacite flows with minor pyroclastic rocks (Bostock, 1963).

Examination of the topographical contours of the Lava Flow indicates that much of the original geometry is preserved in the upper two-thirds of its reach, marked by blocky flow top breccias and steep blocky lateral levees (Fig. 2, Photos 5, 6). Lower portions of the Lava Flow appear to be eroded on top by a possible historic flood event precipitated by blockage of the Mamquam River near Skookum Creek.

Figures 6 and 7 present hydrogeological sections at the lower, middle, and upper elevations of the Lava Flow, as well as along its longitudinal axis. These sections assume a relatively constant thickness of Paleochannel sediments and a constant hydraulic gradient of 0.04. In the central portion of the Lava Flow (Section line D-D’), the levees remain elevated well above the current ground surface. These elevations are indicative of the height the Lava Flow achieved while it was still able to flow. Thickening of the Lava Flow in this area may due to a slow growth rate and increase in viscosity, or to ponding in this area (Bruno, 2011). Blocky lateral, basal, and flow-top breccias would have insulated a molten flowing inner core which fed the leading edge of the pro-grading flow. Once the source of the molten material below Opal Cone was depleted, the Lava Flow “deflated” or drained, leaving elevated lateral levees perched above the collapsed central portion of the Lava Flow.

At Section C-C’, where there is a break in slope of the Lava Flow surface, it is interpreted to be relatively thinner. At this point, the south flowing Skookum Creek meets the west flowing Mamquam River (Photo 7). A minimum 20m thickness of alluvial sediments have been deposited in this area, which consist mostly of dacite clasts eroded from the Skookum Creek canyon upstream (Brooks and Friele, 1992; Photo 8). These sediments are interpreted to overlie older glaciofluvial sediments comprising the Paleochannel.

At Section B-B’, the Lava Flow is bounded by the Mamquam River canyon to the south and Ring Creek to the north. Deep cuts made through this frontal portion of the Lava Flow by the Mamquam River expose relatively widely spaced columns highlighting the massive nature of the core. At the lower Mamquam hydroelectric project impoundment, an exposed contact between the Lava Flow and granitic basement rocks suggests a rise in the bedrock surface and pinching out of Paleochannel sediments (Bruno, 2011; Photo 9). Contrarily, Ring Creek is interpreted to be seated in the glaciofluvial sediments on the north side of the Lava Flow.

2.5 HYDROLOGY

The Lava Flow falls within the catchments of the Ring Creek and Mamquam River watersheds, the latter of which includes the Skookum Creek watershed (Fig. 8). To evaluate relative magnitudes and seasonal variations in surface water discharge in each of these catchments, one flow monitoring site was selected for each catchment based on available discharge data or field accessibility.

The only long-term hydrological station in the project area was on the Mamquam River just above Ring Creek (Fig. 8). This station receives flows from a drainage area of approximately of

277 km^2. Environment Canada operated a flow monitoring station here from 1990 to 2010, and daily and monthly flows are available for most of this 20-year period. The overall average monthly flows for this station were used for the analysis.

Skookum Creek is a tributary of the Mamquam River and the Skookum Creek catchment is thus contained within the Mamquam River catchment. It covers an estimated area of 87 km^2. Four years of stage measurements were collected at 15-minute intervals at a monitoring station located just upstream of the confluence with the Mamquam River by Aquarius (Aquarius, 2010a). This data, plus 34 discharge measurements collected over the same period, were used to develop a stage-discharge curve and calculate a continuous discharge hydrograph for Skookum Creek. Subsequent work by Aquarius generated long-term average monthly flows in Skookum Creek using Monthly Multiple Regression analysis and data collected at several Environment Canada Hydrometric Stations located in similar catchments (Aquarius, 2010b).

The Ring Creek Catchment is the smallest of the three catchments (44 km^2), and a review of the literature did not uncover any previous hydrogeological studies of Ring Creek. The approximate instantaneous discharge of Ring Creek was measured by Piteau above its confluence with Mamquam River (Fig. 2) in August and November 2012.

The highest flows in the Mamquam River (about 40 m^3/s) occur during the spring freshet in May and June. Flows drop to an annual low of less than 15 m^3/s in September, when the winter snowpack has melted and the autumn rains have not yet started. Flows increase in response to heavy rainfall during October and November, and decrease from December through March, when precipitation occurs as snow. In April, flows start to increase with the beginning of the freshet.

The synthesized long-term average monthly flows for Skookum Creek exhibit a pattern similar to the Mamquam River, at about a quarter of the discharge amount. However, small differences are noted during the winter low flow period (10% of Mamquam River flows in February) and during the freshet (38% of Mamquam River flows in June), due to a higher proportion of the catchment area being at a higher elevation where precipitation is temporarily stored as snow.

3. AQUIFER CHARACTERIZATION

3.1 HISTORY OF WELL FIELD DEVELOPMENT

The Well Field consists of seven groundwater production wells (PW-1 to PW-7), all of which are currently in service. These wells supply 90% of the District's water supply, which is augmented by surface water intakes in Mashiter Creek and the Stawamus River. Well locations are shown on Fig. 5, and well construction logs are presented in Appendix A.

The first groundwater production well, PW-4 (formerly PW97-1), was drilled in 1997 under the supervision of Piteau (Piteau, 1998). At this time an observation well (OW97-1) was also constructed. PW-1 (formerly PW99-1) was installed in 1999, with two additional production wells, PW-2 (formerly PW00-2) and PW-3 (formerly PW00-3), installed in 2000 (Piteau, 1999; Piteau, 2000). PW-1 was commissioned in August 2000, and PW-2 and PW-3 were commissioned in June 2002. In 2005, the Well Field was improved by servicing PW-4 and modifying the surface seals at all four wells to meet the Province's Groundwater Protection Regulation (GWPR) requirements (Piteau, 2005).

In 2006, three additional production wells, PW-5 to PW-7, were constructed and tested (Piteau, 2006). In February 2007, PW-6 was re-screened across a shallower interval of the Aquifer, as production from the deeper interval was less than anticipated (Piteau, 2007). These wells were commissioned in 2008. Since then, minor upgrades were conducted in 2012 in light of GWPR requirements, including an above-grade extension of the PW-3 casing, and regrading around OW97-1 to ensure adequate drainage (KWL and Piteau, 2011).

PW-7 is operated almost continuously as the lead production well, with PW-5 and PW-6 also engaged most of the time. PW's 3, 1, 2, and 4 are operated less frequently, mainly at times of higher demand. Limited reservoir capacity requires that the Well Field be operated almost continuously, with PW-7 never off and PW-5 and PW-6 rarely off for more than a few minutes.

All wells are equipped with submersible pumps. The pumps in PW's 1, 5, 6, and 7 are controlled by variable speed drives, while those in the remaining wells operate in on/off mode at fixed rates. The combined flow from the Well Field and individual flows from PW's 4, 5, 6, and 7 are monitored using flow meters that record instantaneous flows. Instantaneous flows for wells PW-1, 2, and 3 are deduced from the combined Well Field flow minus the individual flows recorded at PW's 4, 5, 6, and 7. Based on this data, the average instantaneous flows produced by each well are estimated to be:

	PW-1	**PW-2**	**PW-3**	**PW-4**	**PW-5**	**PW-6**	**PW-7**	**TOTAL**
Equipment:	VFD			FM	VFD, FM	VFD, FM	VFD, FM	
Maximum Instantaneous Pumping Rate (L/s)	95			20	30	30	35	210 L/s
Average Pumping Rate (L/s)	10	10	10	15	25	25	35	130 L/s

Notes: 1. "VFD" indicates Variable Frequency Drive, which allows flow rates to vary in response to demand
2. "FM" indicates that individual well flows are monitored by an individual flow meter

Cumulative measurements of combined Well Field discharge are read on a near daily basis by District staff. Monthly total withdrawal amounts for the last five years (2008 to 2012 inclusive), and average annual withdrawal amounts in units of L/s are summarized below:

	2008	**2009**	**2010**	**2011**	**2012**
January	72	133	-	108	87
February	114	122	122	111	106
March	123	152	121	109	104
April	127	117	123	104	100
May	144	-	130	115	133
June	134	157	134	135	117
July	185	174	147	-	153
August	142	154	149	150	159
September	135	137	132	106	140
October	126	127	117	109	-
November	122	130	118	103	-
December	132	138	122	-	-
Annual	130	140	129	115	122
2008-2012 Average:		**127 L/s**			

Note: "-" indicates insufficient data available

Withdrawal rates over the fall, winter, and spring months (October to April) generally range from 100 to 120 L/s, while those in the summer months (May to September) are higher and peak at about 160 L/s. Over the past five years, annually averaged withdrawal rates have ranged from 115 to 140 L/s, and averaged 127 L/s. For the purposes of our hydrogeological analysis, the average current Well Field withdrawal rate is estimated to be 130 L/s.

3.2 AQUIFER DESCRIPTION

The Aquifer which supplies groundwater to the Well Field comprises the saturated portion of the permeable glaciofluvial sediments occupying the Paleochannel. It is effectively “capped” by the Lava Flow. The Aquifer is interpreted to be unconfined over most of its extent, with minor confinement provided by discontinuous silty horizons.

The Aquifer is estimated to be on the order of 500m wide and 50m deep near the Well Field and as much as 1,500m wide further east where the Lava Flow widens (Fig. 2). The lateral footprint of the Aquifer has been interpreted to underlie the probable core of the Lava Flow, which is bounded on either side by topographic knolls (levees). The extent of the Aquifer in the upstream direction is not known; but it likely extends at least to the confluence of the Mamquam River and Skookum Creek, and possibly higher up to where the Lava Flow narrows (Fig. 2).

3.3 AQUIFER PARAMETERS

Aquifer transmissivity values were determined from Aquifer pumping tests performed on each well shortly following their construction. In January 1998, PW-4 was tested at a maximum rate of 31 L/s. In February 1999, PW-1 was tested at a rate of 60 L/s. PW-2 and PW-3 were tested in 2000 at rates of 84 L/s and 102 L/s, respectively. In May 2006, PW-5, PW-6, and PW-7 were tested at maximum rates of 32 L/s, 29 L/s, and 87 L/s, respectively. During the May 2006 construction program, drawdown measurements recorded at PW-1, PW-6, PW-7, and OW97-1 during starting and stopping of PW-4 were also used to estimate Aquifer transmissivity. PW-6 was subsequently re-screened in a shallower Aquifer zone and was retested at a rate of 62 L/s in 2007.

Pump test water level data were plotted and analyzed using the Cooper-Jacob (1946), Theis Recovery (Theis, 1935), and distance-drawdown methods. The 1999 data were also matched to Neuman (1974) delayed yield type curves for unconfined aquifers.

The following table summarizes the best estimates of Aquifer transmissivity (T) and storativity (S) based on the results of the above-mentioned pumping tests:

PUMPING WELL	**YEAR TESTED**	**PUMPING RATE (L/s)**	**TRANSMISSIVITY (m^2/s)**	**STORATIVITY (unitless)**
PW-1	1999	60	0.015	-
PW-2	2000	84	0.060	0.0017
PW-3	2000	102	0.060	0.0017
PW-4	1998	31	0.015	0.15
PW-4	2006	19	0.019	0.0027
PW-5	2006	32	0.011	0.0045
PW-6	2006	29	0.030	0.000067
PW-6	2007	62	0.016	0.011
PW-7	2006	87	0.023	0.029
Geometric Mean			**0.023**	**0.0043**

Aquifer transmissivity ranges between 1.1 x 10^{-2} and 6.0 x 10^{-2} m^2/s, with a geometric mean value of 2.3 x 10^{-2} m^2/s. Storativity ranges between 6.7 x 10^{-5} and 1.5 x 10^{-1}, with a geometric mean value of 4.3 x 10^{-3}. The relatively high storativity values indicate the Aquifer is either largely unconfined, or experiences a high rate of recharge (or flow through the Aquifer).

3.4 GROUNDWATER CHEMISTRY

3.4.1 Inorganic Analyses

Groundwater samples were been collected from the production wells by Piteau during well testing activities between January 1998 and February 2007. Additional groundwater samples were collected as part of this study in June, August, and November 2012. Tables II and III present a summary of historical and recent analytical results for well water samples. Original lab reports for samples collected as part of this study are included with Appendix B. For these tables, water from Powerhouse Creek was considered to be more representative of groundwater than surface water, since the large majority of its flow originates from spring discharge from the Aquifer. Analytical results for surface and precipitation water samples are summarized in Table IV.

Groundwater in the vicinity of the Well Field can be characterized as very soft with a calcium-sodium bicarbonate-sulphate chemistry. Significant concentrations of chloride were also present (5 mg/L). Most samples had moderate concentrations of total dissolved solids (TDS), typically less than 80 mg/L. Those collected from greater depths (PW-3, PW-6) had higher TDS concentrations (on the order of 120 to 160 mg/L).

Surface water samples collected from the Mamquam River and Skookum and Ring creeks were less mineralized than the groundwater samples (TDS <40 mg/L). They exhibited a calcium bicarbonate chemistry and negligible sodium and chloride (<2.0 and <0.5 mg/L, respectively). Low water temperatures (<10°C in August) and very low concentrations of major ions and trace metals suggest that most of the flow originates from snowmelt and surface runoff at higher elevations.

Relative proportions of major cations and anions in the groundwater and surface water samples are presented graphically on the tri-linear (Piper) plot on Fig. 9. The moderate enrichment of sodium and chloride in the groundwater samples may be attributed to dissolution of mineral facies associated with the basaltic lava flow and/or substantial residence times (years) in the Paleochannel sediments.

All groundwater samples met health-based standards set out in the Guidelines for Canadian Drinking Water Quality (GCDWQ, Health Canada, 2012). Trace metals are present at concentrations well below Maximum Acceptable Concentrations (MACs), including arsenic, which ranges between less than 0.0001 and 0.00087 mg/L (arsenic MAC = 0.010 mg/L). Gross alpha and beta radiation are also well below the GCDWQ objectives. Concentrations of nitrate in groundwater are all less than 0.1 mg/L, indicating no significant anthropogenic effects.

Turbidity levels measured in PW-5 and PW-7 samples ranged from less than 0.10 NTU to 0.37 NTU (Table II, III), which meets the GCDWQ objective that raw source water be less than 1.0 NTU and not exceed 5.0 NTU.

3.4.2 Bacteriological Analyses

Testing for *Escherichia Coli* (*E. coli*) and total coliform bacteria in the raw well water stream is conducted on a weekly basis by the District of Squamish. Results posted on their website[1] indicate only one occurrence of total coliform, and no occurrences of *E. coli* in 2012. No occurrences of total coliform or *E. coli* were observed in 2011 (Vancouver Coastal Health, 2012).

3.4.3 Environmental Isotope Analyses

Stable isotopes deuterium (δ^2H) and oxygen-18 ($\delta^{18}O$), and the radioactive isotope tritium (^3H) have been measured in rainwater, surface water, and groundwater samples collected in June, August, and November 2012.

Concentrations of δ^2H and $\delta^{18}O$ are calculated relative to the standard mean isotopic composition of ocean water (SMOW). These are expressed as per mil (‰) deviations from the SMOW standard, according to the relations:

(1) $$\delta D\% = \frac{\left(\frac{D}{H}\right)sample - \left(\frac{D}{H}\right)SMOW}{\left(\frac{D}{H}\right)SMOW} X\ 1000$$

and

(2) $$\delta 18O\% = \frac{(18O/16O)sample - \left(\frac{18O}{16O}\right)SMOW}{\left(\frac{18O}{16O}\right)SMOW} X\ 1000$$

Waters with less deuterium and ^{18}O than SMOW have negative δD and $\delta^{18}O$ values. Clouds formed from evaporating seawater are generally enriched in lighter water molecules, resulting in relatively depleted (or negative) δD and $\delta^{18}O$ values. This is known as isotopic fractionation. The degree of fractionation in rainwater released from these clouds is affected by ambient air temperature, amount of rain (heavy vs. light rainfall events), the distance travelled over continental landmasses, and altitude.

A local meteoric water line is established by plotting δD and $\delta^{18}O$ values from numerous individual rain events at the same locale and drawing a line of best fit. Groundwater that

---

[1] http://squamish.ca/our-services/water-and-wastewater/water-system/ [accessed Jan 3, 2013]

plots close to the local meteoric water line can be inferred to have not undergone secondary fractionation processes, such as evaporation prior to infiltration, or isotope exchange with minerals underground. It can also be inferred that the groundwater was recharged during the same climate regime (vs. during the last glacial period). For this study, δD and $\delta^{18}O$ data for rainwater samples collected in Victoria[2] were plotted to produce a local meteoric water line (Fig. 10), as well as $\delta^{18}O$ values for water samples collected as part of this investigation.

The $\delta^{18}O$ ratio in surface and groundwater samples ranged from -13.6‰ and -16.0‰ with an average of -14.6‰. The δD composition ranged from -101.5‰ to -113.2‰, with an average of -105.7‰. The rainwater samples were relatively enriched in the heavier isotopes, but compositions varied more widely over the study period ($\delta^{18}O$ between -6.5‰ and -15.6‰, and δ2H between -55.6‰ to -116.5‰). These rainwater results generally lie within the spread of $\delta^{18}O$ and δD data measured at the Victoria station, and may be indicative of air masses of different temperature and latitudinal origin.

The groundwater samples plot close to the surface water samples and above the snowmelt sample on the local meteoric water line, suggesting that the predominant source of recharge to the Aquifer is exfiltrated surface water from Ring or Skookum creeks, and/or precipitation falling at higher elevations over the Lava Flow. A large proportion of the discharge in Ring and Skookum creeks originate from rainfall and snowmelt at higher elevations, which would be relatively depleted in heavier isotopes due to the altitude effect.

Tritium (^{3}H) is a naturally occurring radioactive isotope of hydrogen in the atmosphere, and its concentration in groundwater can be used to approximate its subsurface residence time. Normal background concentrations of tritium in rainwater in the northern hemisphere are between 5 and 10 TU (tritium units); however, this amount increased to levels between 50 and 100 TU in the 1950s as a result of nuclear weapons testing. Since then, concentrations in most regions have fallen back to normal background levels

---

[2] Data provided by Tim Chavez, International Atomic Energy Agency, iaea.org

(Fig. 11). According to Clark & Fritz (1997), ^3H levels in groundwater can be used to approximate mean groundwater residence times:

<0.8 TU	Sub modern – recharged prior to 1952
0.8 to ~ 2 TU	Mixture of sub modern and recent recharge
2 to 8	Modern (< 5- to 10-year residence time)
10 to 20	Residual “bomb” ^3H present
>20 TU	Considerable component of recharge from 1960’s or 1970’s

Tritium concentrations in groundwater samples collected from wells PW-5, PW-7, and Powerhouse Creek ranged from 2.3 to 3.1 TU’s which is indicative of relatively modern groundwater with a short residence time. An approximate groundwater age (a_t) can be calculated using the radioactive decay equation for ^3H:

(3) $$a_t\ {}^3H = a_0\ {}^3He^{-\lambda t}$$

Using tritium’s half-life of 12.43 years, this equation gives:

(4) $$t = -17.93ln\frac{a_t\ {}^3H}{a_0\ {}^3H}$$

For this calculation, an estimate of the initial tritium concentration (a_0) at the time of recharge (t_0) is required. Estimation of t_0 is complicated by the unknown time required for recharge to reach the Aquifer, and the fact that any given recharge “slug” is a composite of recharge from multiple years, rather than just a single year. Assuming that the groundwater is relatively “young” and that atmospheric tritium levels have not changed significantly in the last ten years, we can approximate t_0 using the average of ^3H concentrations measured in rainwater samples (5.5 TU, Fig. 11). Based on equation (4) the age of the groundwater in the Well Field area is about 14 years. This is the approximate time elapsed since this water was introduced into the watershed as precipitation, and not necessarily the time spent in the subsurface. Approximate ages of surface water and snowmelt samples have also been approximated from their tritium concentrations, as listed below:

Source	**Average ^3H Concentration (TU)**	**Approximate Age (years)***
Skookum Creek	3.6	7.4
Ring Creek	3.5	7.8
Mamquam River	3.7	6.9
Snowmelt at 1,300m	4.3	4.2

* Assumes a t_0 of 7.9 TU

If all of the groundwater were sourced from Skookum or Ring creeks, then a simple subtraction of their two ages indicates a subsurface travel time on the order of 6.2 to 6.6 years for this exfiltrated water to reach the Well Field. In either case, the tritium results indicate the groundwater is relatively young, ranging in age from six to 15 years.

3.5 GROUNDWATER FLOWS

3.5.1 Monitored Discharge

The extraordinary groundwater flow that discharges from the Aquifer downgradient of the Well Field appears to occur primarily within the Paleochannel sediments. Some springs were noted above the toe area of the Lava Flow at an elevation of approximately 160 m-geod. Much of this higher elevation flow is interpreted to occur as seepage on specific layers or fractures within the lava.

Piteau measured flows and water levels in nearby watercourses in 1996 and 1997 (Piteau, 1997). These included Site 2 (Powerhouse Creek, just above the Powerhouse Creek bridge crossing), Site 1 (interception ditch on the upslope side of the right-of-way, near tower), Site 3 (further downstream on the same watercourse, above the culvert that crosses the Powerhouse access road), and Site 4 (Powerhouse Creek above the Mamquam River), which are shown on Fig. 5. Creek water levels were measured manually at monthly intervals, and flows were gauged on four occasions between May 1996 and April 1997.

As part of this study, flows at Sites 1, 2, and 3 were measured again in June, August, and November 2012 using a velocity meter and cross-sectional profile measurements. Flows at Site 4 were not measured due to high turbulence in the discharge stream at this location (Photo 10). Water levels were continuously monitored during the June to November period at these same stations, using self-logging pressure transducers.

Historical and recent flow gauging data are summarized in Table V. The measurement error on the flow measurements is considered to be about 20%. Average total spring discharge at the site in 1996-1997 was about 800 L/s. Flows measured at Site 2 and Site 3 comprised approximately 65% of this total flow, and flows measured at Site 2 constituted 60% of the total flow measured at Site 4. Recent flow measurements in 2012 indicate the total flow from the Aquifer to be about 760 L/s, including an average total Well Field withdrawal of 130 L/s. This slight reduction in total flow is not considered to be significant given the margin of error in the flow gauging measurements, and may possibly be a result of drier-than-normal climate trend patterns since 2008 (Fig. 3).

Time-series plots of water levels at each of the stations are presented on Fig. 12. These are compared to total daily precipitation amounts and average daily Well Field withdrawals. The magnitude of water level variation over the 5.5-month period was very slight (less than 10 cm); however, an inverse relationship between water level (and flow rate) and Well Field withdrawal rate is discernible, particularly at Sites 1 and 2, which are closest to the wells. Brief “spikes” in water levels are seen in the hydrographs during heavy rainfall events in mid and late October, which are attributable to runoff.

As a result of Well Field groundwater withdrawals from the Aquifer, flows at Site 2 have dropped by about 30%. At Site 3, they have dropped by about 23%, which includes flow reductions at Site 1. Interpretation of long-term Aquifer water level trends is more difficult, owing to a limited SCADA record of well water levels (data preceding 2011 were not archived), and inherent well losses which mask ambient water level fluctuations in the Aquifer. Currently, there is no recording of water levels in observation well OW97-1. However, the available data set indicates a less than 0.5m variation in static water level at PW-1, both over the past year, and since the well’s construction in 1999 (Fig. 13).

Based on this monitoring data and the relatively small seasonal fluctuations observed in pumping well levels, total aquifer discharge is not expected to vary by more than about 20% over the year. This is attributable to natural damping of seasonal variations in aquifer recharge by aquifer storage.

3.5.2 Aquifer Recharge

Aquifer recharge is interpreted to be from two sources: direct precipitation and leakage from surface watercourses bordering the Lava Flow. Residual permeability in the Lava Flow may include:

- weakly developed columnar joints, such as those exposed along the Mamquam River (Photo 4);
- tension cracks and flow breccia forming the blocky upper surface of the central portion of the Lava Flow (Photo 5); and
- lateral (Photo 6) and basal flow breccias which are inferred to be contiguous and contain some connective porosity.

The most likely pathway for precipitation and snowmelt on the Lava Flow surface to reach the Aquifer is via the marginal levees to the basal flow breccias and then into the underlying Paleochannel (Fig. 6). Direct infiltration downward through the core to the Paleochannel is expected to be less owing to the limited permeability of the weakly jointed lava core (Photo 11).

Of the three surface watercourses, Ring and Skookum creeks are considered to be the most significant contributors to aquifer recharge for the reasons outlined below:

- Along its lower reaches, Ring Creek is seated in glaciofluvial sediments (mapped as Gt and Gb on Fig. 4) that may provide a seepage pathway to the Paleochannel. These are exposed along the north cut of the Ring Creek Forest Service Road (FSR), and consist of a moderately dense assortment of gravel to cobble clasts packed in a fine to coarse sand matrix (Photo 2). Sand deposits were also noted below the Lava Flow sequence on the south bank of Ring Creek downstream of the water sampling/flow monitoring station (Fig. 2).

- Skookum Creek has downcut a steep-sided canyon upstream of the Mamquam River where the Lava Flow (G2d) is in contact with an older volcanic sequence (Gd, Fig. 4). This sequence exhibits tightly spaced, horizontal, and vertical cooling joints which are likely an indication of contact with glacial ice (Photo 12). These joints increase the rocks' residual permeability and potential for erosion and infiltration of surface water. At the Mamquam River confluence, there is a thick (>20m) accumulation of alluvial fan and floodplain sediments, which may directly overlie the Paleochannel and provide a pathway for water to seep from Skookum Creek and Mamquam River into the Aquifer (Figs. 4 and 6).

4. WATER BALANCE

A monthly water balance was developed to quantify groundwater flows through the Aquifer, and to rationalize surface water flows in Ring Creek, Skookum Creek, and the remaining portion of the Mamquam River catchment. Inputs to the water balance include rain and snowmelt. Incident precipitation is routed to evaporation, runoff, snowpack, or infiltration on a monthly basis throughout the year.

4.1 DISCRETIZATION OF CATCHMENT AREAS

Infiltration and runoff rates are dependent upon the recharge surface. For instance, the blocky surface of the Lava Flow will generate low runoff and allow high infiltration. Precipitation onto a glacial surface over the winter months will either be lost to evaporation or sublimation, or accumulate as snowpack for release to the surface water regime in the summer. Native ground will allow some evaporation and some runoff, but most of the precipitation will be routed to infiltration. Some of the infiltration into natural ground will recharge the shallow groundwater regime that eventually reports to the surface water regime downstream in the catchment, and some will be routed to a deeper bedrock groundwater regime.

Each of the surface water catchments was discretized into areas comprised of the three following surface types: lava flow, native ground (below 1,700m elevation), and glacier (native ground above 1,700m). The discretized catchment areas are shown on Fig. 8, and the areas of each surface type within the three catchments are summarized below:

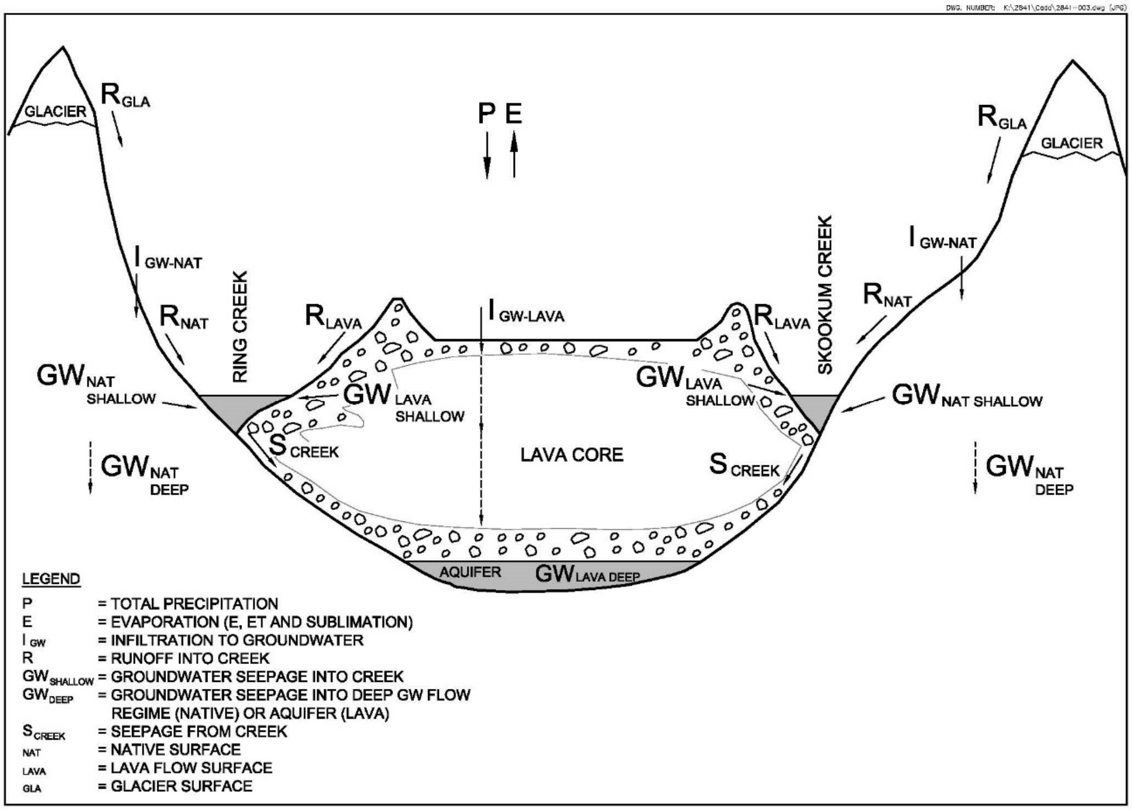
Catchment Area	**Total Watershed Area (km^2)**	**Native Ground (<1,700m) (km^2)**	**Lava Flow (km^2)**	**Glacier (>1,700m) (km^2)**
Mamquam River above Ring Creek	277	235.8	15.8	25.2
Skookum Creek above Mamquam confluence (ROR Gauge)	87	61.3	7.6	18.4
Ring Creek above confluence with Mamquam River	44.3	29.8	11.1	3.3
Aquifer area underneath Ring Creek Lava Flow		0.0	26.9	0.0

Note: Areas determined from surface water catchments based on topography available from NTS 92G10, 11 14, and 15 at a 1:50,000 scale

Unit area monthly balances were developed for each type of surface, and unit rates were then multiplied by the area that each surface represents within the subject catchment. Flows determined for each surface type were summed to estimate the total flows within each river or aquifer catchment. For the purposes of this water balance, it was assumed that the catchment area reporting to the Aquifer is approximately equivalent to the surface water catchments.

4.2 WATER BALANCE COMPONENTS

A description of the water balance components, including total precipitation, evapotranspiration/ sublimation, snowpack/snowmelt, runoff, soil moisture storage, and groundwater recharge/ discharge is presented in this section. Estimated rates for each of these components within each surface type (native, lava, and glacier) are summarized in Tables C-1 to C-3 in Appendix C.
A schematic diagram of these water balance components is shown in below:



Schematic Diagram of Water Balance Components

4.2.1 Temperature and Precipitation

Monthly temperature and precipitation data (rain and snow) for the water balance area were based on climate data recorded at the Squamish Upper climate station between 1971 and 2000, and from the UBC Forestry Climate model. Due to the predominantly orographic precipitation pattern and large elevation difference between the Squamish Upper station (42m) and the mean elevation of the model catchments (over 1,000m), the precipitation measured at the Squamish Upper climate station was not sufficient to sustain the observed flows in the Mamquam River or Skookum Creek.

To determine a more representative average monthly precipitation for each surface, a grid containing mean annual precipitation data (1971-1990) from the UBC Forestry Climate Model was integrated over each of the three surfaces in ArcGIS to determine a mean annual precipitation value for the surface. These values were then prorated according to the monthly precipitation distribution at the Squamish Upper climate station to determine average precipitation for each month and surface.

Similarly, annual precipitation as snow for each surface was determined from the UBC Forestry Climate Model precipitation as snow grid. The proportion of monthly precipitation falling as snow on each of the surfaces was estimated by comparing the proportions of monthly precipitation falling as snow at Environment Canada stations Squamish Upper, Whistler, and Whistler Roundhouse, and prorating the proportions to the surfaces based on approximate mean elevation of the surface, and the elevations of the climate stations. Monthly snow applied to each surface over the year is equal to the annual precipitation as snow calculated for each surface.

Total monthly precipitation and precipitation as rain and snow amounts for the Squamish Upper climate station, as well as those used in the water balance for the lava, native and glacial surfaces, are summarized in Table I.

4.2.2 Evapotranspiration and Sublimation

Potential monthly evaporation (PE) was calculated using the Thornthwaite Method (Dunne and Leopold, 1978), and is presented in Table VI, based on precipitation, temperature and latitude for the Squamish Upper station. Actual evaporation (AE) varies by surface and was set at 50%, 85%, and 95% of the PE for the lava, native, and glacial surfaces, respectively.

Sublimation is a complex process and requires a number of variables for a rigorous determination. In these calculations, additional losses due to sublimation of 6 mm/month are assumed for the native and lava surfaces over the winter months when snowpack is present (November through June). The glacial surface, more exposed to wind and with a longer winter season, is assumed to lose 8 mm/month to sublimation from October through July.

Soils are indicated to be at their moisture holding capacity year round for the native and lava flow surfaces. Actual evaporation from the soil column was therefore not limited by the soil moisture condition in this water balance model.

4.2.3 Snowpack and Snowmelt

Snowpack was accumulated based on the calculated snowfall reduced by sublimation and snowmelt. Snowmelt is responsible for a significant amount of water during the spring months. Although snowmelt can be estimated, the rate will be highly variable and dependent on temperature, cloud cover and precipitation, and is difficult to quantify. For the purposes of this water balance, it was assumed that snow accumulates on the native and lava surfaces from mid-November to mid-May, and that the accumulated snowpack ablates from May to July. On the higher elevation glacier surface, the seasonal snowpack accumulates from mid-October. From November through to March, it is assumed that all precipitation, whether rain or snow, is stored in the snowpack, and from May through August, the seasonal glacial snowpack is gradually reduced as runoff.

4.2.4 Runoff

Runoff was derived from both net ambient precipitation and snowmelt, and was determined with a runoff coefficient multiplied by the net precipitation plus snowmelt. Runoff coefficients for native ground were highest (80%) from April to July when much of the ground would be saturated by snowmelt, and varied between 20% (October) and 70%

(March) for the other months of the year (Table C-1). Runoff from the Lava Flow during the winter months was assumed to be zero; April, May, and June runoff were assumed to equal 5% of ablating snowpack and net ambient precipitation; and July through October runoff was assumed to equal 1% of net ambient precipitation (Table C-2). Glacial runoff was assumed to equal 100% of the net precipitation plus snowmelt, minus evaporation/sublimation and snowpack accumulation (Table C-3).

4.2.5 Soil Moisture Storage

Soil moisture can vary throughout the year in response to surplus and deficit conditions. However, due to the large amounts of precipitation over the catchments for Ring Creek, Skookum Creek and the Mamquam River, soil moisture is assumed to be maintained at a maximum throughout the year. The water holding capacity of the soil was assumed to vary from 150mm in native areas to 10mm on the lava surface. The glacial surface is assumed to have negligible interaction with groundwater, so was not assigned a soil moisture component in this water balance. Any surpluses after evaporation/sublimation were directed to surface runoff.

The monthly moisture surplus or deficit for the Lava Flow and native surfaces was calculated by the equation:

Surplus = ambient precipitation + snowmelt – evaporation – runoff.

Surplus water is available for infiltration to soil moisture, and the soil moisture is increased by the surplus amount up to its water holding capacity. During months with a moisture deficit, water is removed from soil moisture. Any monthly surpluses in excess of the soil water holding capacity are assumed to infiltrate to groundwater.

4.2.6 Groundwater Recharge and Discharge

A key component of the water balance model is the ability to simulate interactions between surface water and groundwater. Infiltration was only allowed when surplus water was available after evaporation, soil moisture requirements and runoff criteria were met. Recharge through the native and lava surfaces occurs each month. As noted above, no infiltration is assumed for the glacial surface. Monthly infiltration rates are shown on the water balance tables for native and lava surfaces, included in Appendix C.

Groundwater recharge for each month was routed into either a shallow or deep groundwater regime for each surface. For the native surface, the proportion of groundwater recharge routed to the shallow groundwater regime was 70%. This water reports to streamflow over the following few months, while water routed to the deep groundwater regime discharges downstream (outside) of the modelled catchment. Monthly discharge from the shallow groundwater flow regime was determined by applying factors that approximate a typical groundwater recession curve. The unit highest groundwater discharge rates were calculated for November and the lowest were calculated for September.

For the Lava Flow surface, the proportion of groundwater recharge routed to the shallow groundwater regime was 90%. This flow was gradually released to streamflow in Skookum Creek, Ring Creek, and the Mamquam River according to the same groundwater recession curve. Monthly groundwater discharge from the shallow flow regime was assumed to be highest in January and lowest in September. The deep groundwater flow regime was allotted 10% of total groundwater recharge, and represents groundwater flows in the basal breccias and paleochannel Aquifer.

4.3 FLOW CALIBRATION

Measured and simulated flows in the Mamquam River, Skookum Creek, and Ring Creek catchments were used to assess the validity of the water balance assumptions. Calibration of the spreadsheet water balance model involved matching the calculated month-to-month discharge hydrographs to those measured for each of the flow gauging stations, and matching flows in the deep groundwater regime below the Lava Flow to those measured in Powerhouse Creek at the Well Field (800 L/s, see Table V).

As discussed in Section 3.4, the Mamquam River catchment is the largest of the three surface water catchments and the data record from the Mamquam flow monitoring station is most complete. Therefore, the water balance calibration began with matching surface water flows measured at the Mamquam gauging station. Shallow and deep groundwater proportions, runoff coefficients, and the rate at which the snowpack ablates for the three surfaces were varied to achieve an approximate match between water balance predicted flows and observed monthly flows (Fig. C-1).

Once a reasonable match was achieved with the Mamquam flows, the same procedure was used to simulate the Skookum flows reported by Aquarius (2010b), without significantly changing the Mamquam River flows. Overall, the water balance slightly overestimates the Skookum Creek flows, particularly in the winter. It is probable that the overall higher elevation of the Skookum Creek catchment allows more precipitation to be stored as snow in the winter than predicted by the water balance. Some of this snow may be lost to the neighbouring catchment to the east due to southwesterly winds blowing from Howe Sound, so would not report to the Skookum Creek.

The Ring Creek flows that were measured by Piteau in August and November 2012 at the water sampling station (Fig. 2) are spot measurements intended to provide an order of magnitude estimate. They are included on the graph (Fig. C-1) to show that the water balance provides a reasonable estimate of Ring Creek flows. A slight overestimation of measured flows in Ring Creek can be attributed to the timing of the spot measurements during periods of relatively low flow (outside of storm events), and possibly water being lost from Ring Creek to the subsurface (i.e., into the Aquifer).

Mean annual runoff and groundwater recharge rates, and monthly unit runoff and groundwater discharge rates from each surface in each catchment are presented in Table C-4.

The water balance was calibrated to flows measured in the Aquifer by varying the percent seepage losses from Ring Creek and Skookum Creek to the Aquifer. Based on the conceptual hydrogeological model, a large proportion of aquifer recharge is interpreted to originate from Ring and Skookum creeks. Contributions from the Mamquam River below the Skookum Creek confluence are assumed to be considerably less. Provisions were made for all three scenarios in the water balance. Seepage from each of the three catchments as a percentage of total monthly flow could be varied on a global basis to achieve a close match with observed surface water and aquifer flows.

Groundwater discharge from the Aquifer is estimated as the sum of average flows pumped from the Well Field and seepage emerging as springs at the toe. The total discharge was estimated to be about 800 L/s, and does not vary significantly over the year (Table C-5). In the calibrated water balance, recharge to the Aquifer comprises 10% of net groundwater recharge to the Lava Flow over the Aquifer footprint, and 5% and 4% of Ring Creek and Skookum Creek flows, respectively (Table C-5). These results were used to define recharge and creek exfiltration rates in the numerical groundwater flow model.

A summary of observed/simulated and water balance calculated flows is presented in Table VII and on Fig. C-1. The monthly variation in seepage losses into the aquifer was between 500 and 1,300 L/s, but due to storage in the aquifer associated with the long residence time, the average discharge flow was calculated to be 800 L/s.

5. CAPTURE ZONE ANALYSIS

The Well Field capture zone provides the physical boundaries for deciding and implementing aquifer protection measures. There are a number of ways to estimate the capture zone, ranging from recharge area calculations to analytical equations to numerical modelling.

5.1 NUMERICAL MODELLING

A small-scale numerical model was developed by Piteau in 1998 to assist in determining the optimal configuration of multiple wells in the Well Field area, and to predict impacts to flows in Powerhouse Creek. As part of this study, a similar model was developed on a more regional scale to determine the capture zone of the seven operating wells, and to estimate groundwater travel times from recharge areas. The following sections outline how the model was constructed and calibrated, and what simulations were performed to improve our understanding of groundwater sources at the larger scale.

5.1.1 Model Configuration and Boundary Conditions

The model covers an approximate 10 km long, 900m wide channel originating at a surface elevation of 820 m-geod. (Section line D-D’ on Fig. 2), and terminating in the Well Field area at a surface elevation of 80 m-geod. The model area comprises the saturated portion of the paleochannel beneath the Lava Flow, whose estimated total surface area is approximately 8.8 km^2.

The model domain was discretized into grid cells measuring 200 x 200m at higher elevations, 100 x 100m to 50 x 50m in mid-elevations, and 25 x 25m in the Well Field area. This finer mesh-size near the wells and spring-fed channels enabled coarse calibration of the model to measured flows and aquifer water levels.

The finite-difference mesh consisted of one layer representing the saturated thickness of the paleochannel Aquifer. For simplicity, a constant aquifer thickness of 40m was used throughout the model. A hydraulic conductivity of 5.7 x 10^{-4} m/s (49.7 m/day) was assigned to most of the model area, which is in agreement with the mean transmissivity estimated from well pumping test data (2.3 x 10^{-2} m^2/s). Above the Skookum-Mamquam confluence, where the Paleochannel is interpreted to be thinner (Fig. 7), and possibly finer-grained, lower hydraulic conductivity values of between 2.6 x 10^{-4} and 3.2 x 10^{-4} m/s were assigned.

Boundary conditions applied to the mesh included constant head, constant flux, drains, wells, and recharge. These boundary conditions were applied at the locations shown on Fig. D-1, and are described below:

<u>Constant flux</u>: Constant flux boundaries were used to simulate exfiltration from surface watercourses, and ambient groundwater flow into the model across the upgradient boundary. Flux boundaries were placed along the lower reaches of Ring Creek and Skookum Creek, where field observations made during this and other investigations support the possibility for surface water losses to the subsurface. Flux rates were set equal to those derived in the water balance.

The constant flux boundary at the top of the model represents groundwater flows originating from recharge at higher elevations. This rate was set equal to one-third of the precipitation-sourced recharge over the Lava Flow footprint (approximately 56 L/s), since approximately one-third of the lava footprint lies outside of the modelled area. The remaining two-thirds of precipitation-sourced aquifer recharge (112 L/s) were applied to the model area as incident recharge.

<u>Constant Head</u>: A constant-head boundary was assigned to the western terminus of the model, where the hanging valley hosting the Paleochannel is truncated by the Mamquam River valley. This head was set to an elevation of 75 m-geod., which is approximately equal to the ground elevation in this area. Flows across this boundary were made to represent limited flows through basement rocks abutting the Paleochannel on the southwest side by assigning low hydraulic conductivities to these cells (5.5 x 10^{-7} m/s).

Drains: Drain boundaries were assigned to mapped groundwater discharge areas, including Powerhouse Creek and the drainage trench adjacent to the Well Field access road. Drain boundaries allow discharge from the model when the water table attains a specified elevation, and applies a conductance term to control flows relative to a head differential. The elevation of these boundaries was set to the approximate invert elevation of these watercourses. The Powerhouse Creek drain was assigned a maximum elevation of 160m, which is where surface flow in the creek was observed to begin during site visits in September and November 2012.

Wells: Well boundaries were used to simulate average withdrawal rates from the seven operating production wells, which are summarized in Section 4.1

5.1.2 Model Calibration

The model was calibrated by adjusting drain node elevations and conductance terms to achieve agreement with estimated cumulative spring discharges across specified reaches, namely Powerhouse Creek between its origin and Site 2, Powerhouse Creek between Site 2 and the Mamquam River (Site 4), and the drainage ditch between its origin and Site 3 (see locations on Fig. 5). This was done for both the pumping and non-pumping scenarios, with reference to best estimates of discharge presented in Table V.

The agreement between observed and simulated flows is presented graphically on Fig. 14. Model-simulated heads were also verified to be in agreement with observed heads by comparing simulated water levels at each well under a no-pumping scenario to static levels measured in February 1999 (PW-4), February/March 2005 (PW-1, PW-2, PW3), and February 2007 (PW-6). Model-simulated drawdowns during pumping were also checked against best estimates of actual drawdowns in the Aquifer (Fig. 14). Actual drawdowns were estimated by pro-rating drawdowns measured at neighbouring wells during individual well pumping tests, relative to the current pumping rates of these individual wells.

5.1.3 Well Capture Zone and Time of Travel Analysis

Groundwater flow lines from each source of recharge (incident rainfall/snowmelt and watercourses) were approximated using MODPATH, MODFLOW®'s particle tracking feature. Particles were placed along each flux boundary and tracked forward in time to obtain the traces shown in red on Fig. D-2. Groundwater travel times to the Well Field were estimated by releasing particles in a circular pattern around each well and tracing them backwards in time. The corresponding travel time boundaries have been overlain in green on Fig. D-2. The "Base" case at the top of the page represents the calibrated model scenario, wherein the rate of recharge from each source is in agreement with the water balance model. Estimated groundwater travel times from Ring Creek to the Well Field are between nine months and two years, and those from Skookum Creek are estimated to be between three and seven years. Actual subsurface residence times may be longer, depending on the time required for seepage from these watercourses to reach the Aquifer.

The sensitivity of the estimated capture zone boundaries to inherent uncertainties in the hydrogeological conceptual model was tested by performing additional simulations representing end-member recharge scenarios:

- The "Rain Only" case presents the scenario wherein all of the recharge to the Aquifer is from vertical infiltration of incident precipitation across the Lava Flow footprint. This would correspond to approximately 32% of water available for groundwater recharge within the Lava Flow footprint reaching the paleochannel Aquifer (vs. 10% estimated in the water balance).

- The "Ring Creek Only" and "Skookum Creek Only" cases assume the Base Case condition of 10% of available surface recharge reaching the Aquifer, and that the remainder of the 800 L/s flowing through the aquifer originates exclusively from either Ring Creek or Skookum Creek.

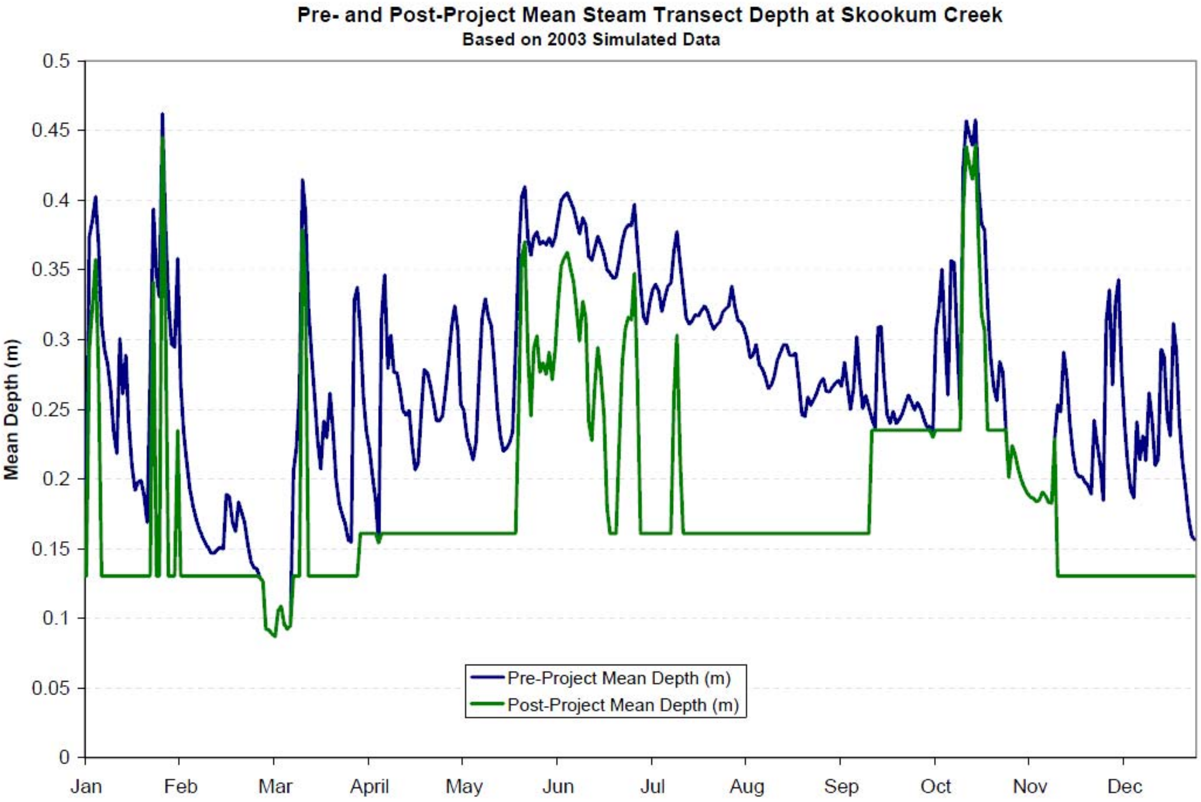
As shown on Fig. D2, the positioning of the time-of-travel boundaries does not change substantially between these scenarios. Hence, capture zones predicted by the “Base Case” will be utilized for aquifer protection planning purposes.

5.1.4 Effects of SPP Water Diversion on Aquifer Water Levels

The Skookum Power Project (SPP) is a run-of-river hydroelectric project located on the lower reaches of Skookum Creek. The project was initiated by Sea to Sky Power Corporation, a subsidiary of Run of River Power Inc., and was recently bought by Concord Green Energy Inc., a member of Concord Pacific Group of companies. The facility is designed to deliver approximately 25 MW to the energy grid. Commercial operation of the facility is planned for the beginning of 2014.

The SPP facility consists of an intake, penstock, powerhouse, and tailrace (Fig. 15), together with access roads and a transmission corridor. Flow from Skookum Creek will be channeled from an intake at an elevation of 805 m-geod. through a 6,300m long penstock to the power plant located at 458 m-asl. Power generated at the plant will be relayed via approximately 20 km of 138 kV transmission line to BC Hydro’s Cheekye substation.

During operations, a maximum of 9.9 m3/s of water will be diverted from Skookum Creek. Diversion rates will comply with minimum instream flow requirements (ISFs) specified in the project’s environmental impact assessment (Barkley Project Group, 2011) to ensure that there is no harmful alteration or destruction of fish habitat. Under an average precipitation scenario, water depths in Skookum Creek between the Intake and the Powerhouse are estimated to vary from 0.15m midwinter to 0.4 to 0.45m during the peak of the freshet and during heavy fall and winter rain events, as shown by the blue line in the figure below:



Comparison of simulated pre-project and post-project mean stream transect depths at Skookum Creek, based on 2003 simulated data, reproduced from Gartner Lee Limited (2008).

During operation of the SPP, water depths in Skookum Creek are expected to be reduced by 8.8 cm on average. Based on our conceptualization that Skookum Creek loses flow to groundwater, this reduction in head in the creek could result in a reduction in aquifer recharge, particularly during the summer months.

Gartner Lee (2008) estimated that the predicted average change in creek level of 8.8 cm would cause a 0.015% decrease in the horizontal hydraulic gradient between the SPP Powerhouse and the Well Field, assuming a baseline hydraulic gradient of 0.044. Multiplying this decrease by a baseline total groundwater discharge of 740 L/s resulted in a potential 0.1 L/s reduction of spring flows at the Well Field. However, this calculation assumes that Skookum Creek and the Mamquam River are in direct hydraulic communication, that is, that the Aquifer water table is at equal elevation with nearby surface water elevations. This differs from our interpretation that these watercourses are perched. It also assumes that flow between the affected reach of Skookum Creek and the Well Field is perfectly horizontal, whereas in reality it is likely to have a downward component in areas of recharge, and an upward component in areas of discharge.

We estimate that a drop in water level in Skookum Creek will cause a decrease in the vertical seepage rate from the creek into the underlying Aquifer. Given the creek's assumed perched condition, the vertical hydraulic gradient can be approximated using:

$$i = \frac{(d+b)}{b} \tag{5}$$

Where:

i	is the vertical hydraulic gradient
d	is the average depth of water in the channel above the channel invert (assume 0.3m)
b	is the average saturated thickness of channel sediments below the channel invert (assume 1.0)

If we assume that b stays approximately the same under the pre- and post-project scenarios, then the percent change in vertical gradient owing to a change in water depth can be estimated using:

$$\Delta i = \frac{d_2 - d_1}{d_1 + b} \times 100 \tag{6}$$

Assuming a pre-project depth of water (d1) of 0.3m and a post-project depth of water (d2) of 0.212m, the change in vertical hydraulic gradient is -6.8%. The downward seepage rate would be further reduced by a corresponding decrease in the wetted perimeter of the channel, which is not accounted for in this calculation. Therefore, we estimate that decrease in average annual groundwater recharge rate from Skookum Creek to be between 10 and 20%. To estimate what impact this might have on Production well water levels, an additional simulation was run with the model, wherein Skookum Creek fluxes in the no-pumping “Base Case” scenario were reduced by 20%. The average resultant head change in wells PW-1 to PW-7 was 0.14m, which is relatively small. Impacts of such a change on individual well productivity will depend on the amount of excess available drawdown in the well. This is the difference between the current average pumping elevation and the lowest tolerable pumping elevation above the pump. If it is less than 0.14m, then pumping rates may need to be decreased to maintain water level above this minimum elevation.

6. GROUNDWATER AT RISK OF CONTAINING PATHOGENS (GARP) ANALYSIS

6.1 TERMS OF REFERENCE

The potential for groundwater produced by the Well Field to be at risk of containing pathogens (GARP) has been assessed with reference to guidance documents developed by the British Columbia Ministry of Health (MOH, 2013). Groundwater that is GARP is defined as groundwater that is likely to be contaminated from any source of pathogens, including sewage effluent, agricultural waste, and surface water that is hydraulically connected to groundwater (GWUDI). A four-stage approach is proposed for evaluating GARP, the first of which is a screening tool that addresses:

i. Water quality (occurrences of total / fecal coliform bacteria or *E. coli,* high turbidity);
ii. Well susceptibility (set back distances from contaminant sources (including viral), well intake depth and position relative to surface water bodies);
iii. Well construction details (compliance with Groundwater Protection Regulation); and
iv. Aquifer type and setting (confined / unconfined, fractured bedrock, karst).

If the Stage 1 Screening Tool determines that the groundwater source is potentially at risk of being GARP, then a vulnerability assessment for each identified risk factor should be carried out to form a decision as to whether the groundwater source is GARP. If the probability of GARP is judged to be medium to high, then the well should be treated, relocated, monitored, and/or a Stage 2 (preliminary) or Stage 3 (advanced) hydrogeological investigation undertaken. If the risk is judged to be low, then a program of long term water quality monitoring (Stage 4) should be implemented.

The purpose of the Stage 2 and 3 investigations is to provide further hydrogeological evidence to determine whether the groundwater source is at low risk of GARP. These studies assess the degree of hydraulic connection with nearby surface waters, the effectiveness of subsurface filtration, and travel times from potential pathogen sources to wells under operating conditions. Elements of a Stage 2 investigation may include a more detailed characterization of site conditions (physiography, geology, wellhead completion, hydrology), an evaluation of groundwater quality, and preliminary estimation of well capture zones, groundwater travel times, etc. Elements of a Stage 3 investigation may include test well drilling, aquifer pumping tests, numerical groundwater flow modelling, Microscopic particulate analyses (MPA), isotope testing, prolonged aquifer monitoring, etc. Once these investigation(s) are complete, a groundwater source that meets the following conditions would be concluded to be at low risk of containing pathogens:

- There is no or little evidence of a hydraulic connection between the groundwater source and nearby source of pathogens;
- If groundwater is hydraulically connected to a source of pathogens, that subsurface filtration or other hydrogeological factors will be effective in minimizing the risk of pathogens, including viruses, from reaching the well(s) under operating conditions;
- The time of travel from a source of pathogens to the well(s) is greater than 100 days (for bacteria and protozoa) and greater than 200 days for viruses (Stage 2) or sufficient to minimize the risk of pathogens reaching the well(s) under operating conditions (Stage 3).

As this Hydrogeological Assessment provides a comprehensive overview of the Aquifer and includes many elements of a Stage 2 and Stage 3 hydrogeological investigation, we consider it appropriate at this time to provide an opinion with respect to GARP. This includes an analysis of Well Field components with respect to the Stage 1 Screening Level Tool, and presentation of additional lines of evidence that ascertain the level of risk.

6.2 GARP EVALUATION

Table VIII presents an evaluation of the Well Field's risk of GARP based on criteria set out in the Stage 1 Screening Tool. Figure 16 presents sections showing approximate intake depths relative to the normal water level in Powerhouse Creek. Based on the Stage 1, the risk that groundwater withdrawn by the well field is GARP is judged to be low. Additional evidence is provided in the following:

- The estimated groundwater travel time from Ring Creek to Well Field, based on numerical model simulations, is between nine months and two years. This is greater than the 200-day benchmark proposed by MOH (2013) for viruses.

- The only known source of enteric viruses upgradient of the Well Field is septic fields at the cluster or rural residences on Ring Creek FSR (Fig. 15). The fastest travel path for viruses to the well field is via Ring Creek or one of its tributaries. As stated above, travel times between Ring Creek and the well field are considered long enough to reduce the risk of viral contamination, based on research available to date.
- Our conceptual hydrogeological model considers Powerhouse Creek to be an expression of groundwater seepage at the toe of the aquifer where it is truncated by the Mamquam River valley. Hence, flows in the creek are expected to be mostly groundwater with a minor component of surface water runoff. This interpretation is supported by the visible correlation between Powerhouse Creek water levels and Well Field withdrawal rates, as shown on Fig. 17. Given the relatively high flow rate of groundwater through this area and natural groundwater discharge to the creek, the potential for surface water in the creek to be drawn back down to the well screens during pumping is negligible.
- The results of an MPA test conducted in June 2012 on raw water collected from the combined Well Field discharge indicate an absence of biological particulates that are indicative of groundwater under the direct influence of surface water (GWUDI). These include *Giardia cysts*, *Cryptosporidium oocysts*, diatoms, algae, insect parts and larvae, and rotifers. The full report provided by Hyperion Research Ltd. is included with Appendix E.
- The consistent absence of bacteria in raw discharge samples collected from the Well Field. Over the period May 2009 to December 2013, there were only three positive results for total coliform (two of which were confirmed laboratory errors, and the third a suspect error) and zero positive results for *E. coli* out of a total of 244 samples tested.

On the basis of the GARP evaluation, the Well Field has been determined to have a low risk of producing water containing pathogens.

7. SUMMARY

1. The Powerhouse Springs Well Field withdraws groundwater from a highly productive unconfined aquifer situated in an ancestral paleochannel buried by the Ring Creek Lava Flow. This channel is filled with permeable sands and gravels of glaciofluvial origin, and is inferred to be up to 50m deep and 1 km wide, and to extend at least 10 km along the axis of the Ring Creek Lava Flow. It is the principle source of drinking water to the District of Squamish and comprises seven production wells withdrawing water at an average rate of 130 L/s.
2. The Well Field is situated in an area of natural groundwater discharge where exposed aquifer sediments are truncated by the Mamquam River valley. Flow gauging of spring-fed watercourses in this area indicate that the discharge rate is about 760 L/s. This is less than the 800 L/s rate estimated in 1997, and may be a result of subsequent drier-than-normal climate trends during recent years.
3. Basic cation/anion water chemistry results indicate that groundwater at the Well Field is moderately mineralized with a calcium-sodium bicarbonate-sulphate chemistry. Relative to surface water in Skookum and Ring creeks, it is slightly enriched in sodium and chloride, which may be attributable to dissolution of minerals in the overlying Ring Creek Lava Flow, or to longer contact times with Paleochannel sediments.
4. Environmental isotope data indicate that groundwater at the Well Field is relatively young in age, with an estimated subsurface residence time of between six and 14 years. These data also indicate that the groundwater is a mix of precipitation water falling on the Lava Flow, and seepage from Ring and Skookum creeks. Seepage from the two creeks is interpreted to represent the most significant recharge source.
5. A spreadsheet water balance model was developed to quantitatively evaluate interactions between groundwater and surface water. A good match was achieved between simulated and measured stream flows and groundwater discharge by assuming that roughly one-third of groundwater recharge originates from infiltrating rainfall and snowmelt, and the remaining two-thirds are contributed by seepage from Skookum and Ring creeks.
6. A numerical groundwater flow model was constructed and calibrated based on the spreadsheet water balance and the regional hydrogeologic conceptual model. This "Base Case" indicates that approximately 43% of the aquifer flow originates as seepage from

Skookum Creek, 26% as seepage from Ring Creek, and 31% from direct precipitation. Groundwater travel times to the Well Field from Ring Creek were estimated to be between nine months and two years, and those from Skookum Creek were estimated to be between three and seven years. Additional simulations indicate that model-estimated travel times do not vary substantially by varying proportions of recharge from precipitation, Ring Creek and Skookum Creek.

7. Three-month, one-year, and five-year capture zones for the Well Field were estimated using the numerical model. These extend approximately 800m, 2.5 km, and 8 km from the Well Field. The model-predicted drop in Well Field water levels owing to diversion of flows by the Skookum Creek Run of River Power project were relatively small, at less than 0.2m.

8. Based on a Screening Level assessment and additional lines of evidence typical of Stage 2 and Stage 3 investigations (model-simulated groundwater travel times, creek and aquifer water level trends, MPA and bacteriological testing, etc.), we determine that groundwater withdrawn by the Well Field is at low risk of containing pathogens (GARP).

Respectfully submitted,

PITEAU ASSOCIATES ENGINEERING LTD.

ORIGINAL SIGNED

Kathy Tixier, P.Eng
Senior Hydrogeologist, Associate

Reviewed by:

ORIGINAL SIGNED

Andrew T. Holmes, P.Eng.
Chief Hydrogeologist, Principal

8. REFERENCES

Aquarius Research and Development, Inc., 2010a. Instream Flow Measurement Program for the Skookum Creek Power Project. Report prepared for Run of River Power Inc., November 24, 46p.

Aquarius Research and Development, Inc., 2010b. Skookum Creek Power Project; Hydrological Analysis. Report prepared for Run of River Power Inc., November 10, 66p.

Blais-Stevens, A., 2008. Surficial geology and landslide inventory of the middle Sea to Sky corridor, British Columbia; Geological Survey of Canada Open File 5323, scale 1:50 000.

Bostock, 1963. “Geology – Squamish (Vancouver, west half map-area), British Columbia.” Geological Survey of Canada, Map 42-1963.

Brooks, G.R., and Friele, P.A., 1992. Bracketing ages for the Formation of the Ring Creek lava Flow, Mount Garibaldi Volcanic Field, Southwestern British Columbia. Can. J. Earth Sci., 29, 2425-2428.

Bruno, Samuel, 2011. Derivation of the Eruption History of the Prehistoric Ring Creek Lava Flow, Southern British Columbia. A thesis presented to the Faculty of Western Washington University in partial fulfillment of the requirements for the degree Master of Science, May, 115p.

Carruthers Forest Solutions Ltd., 2011. Skookum Power Project Forest Resources Assessment. Report prepared for Sea to Sky Power Corporation, May, 23p.

Clark, Ian D., and Fritz, Peter, 1997. Environmental isotopes in hydrogeology: New York, Lewis Publishers, 328p.

Climate Impacts Group, 2006. Impacts of natural climate variability on Pacific Northwest climate; Climate Impacts Group, <http://www.cses.washington.edu/cig/pnwc/clvariability.shtml> and <http://www.cses.washington.edu/cig/pnwc/pnwc.shtml> [accessed December 2012]

Cooper, H.H. and Jacob, C.E., 1946. A generalized graphical method for evaluating formation constants and summarizing well field history. In American Geophysical Union Transactions, Vol. 27, pp. 526-534.

Dunne, T., and Leopold, L., 1978. “Water in Environmental; Planning.” Freeman & Company.

Environment Canada, National Climate Data and Information Archive <http://climate.weatheroffice.gc.ca/Welcome_e.html> [accessed December, 2012]

Fedorov, A.V., Philander, S.G., 2000. "Is El Niño Changing?" Science 288 (5473): 1997-2002.

Gartner Lee Limited, 2008. Skookum Creek Run of River Hydroelectric Project – Groundwater Quantity Technical Assessment. Report prepared for Run of River Power Corp. (Northwest Cascade Power Ltd.), December, 19p.

Health Canada, 2012. Guidelines for Canadian Drinking Water Quality. Prepared by the Federal-Provincial-Territorial Subcommittee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. <http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/2012-sum_guide-res_recom/index-eng.php.> [Accessed December, 2012]

Kerr Wood Leidal Associates and Piteau Associates Engineering Ltd., 2011. Review of Well Head Protection Measures at Powerhouse Springs Well Field, technical memorandum to the District of Squamish, September, 5pp.

Koch, Johannes, Menounos, Brian, Clague, John J., and Osborn, Gerald D., 2004. Environmental Change in Garibaldi Provincial Park, Southern Coast Mountains, British Columbia. Geoscience Canada, Vol 31 No.3, pp. 127-135.

Lemmen, D.S., Warren, F.J., Lacroix, J., and Bush, E., editors, 2008. From Impacts to Adaptation: Canada in a Changing Climate 2007; Government of Canada, Ottawa, ON, 448pp.

Lowell, T.V. 2000. As climate changes, so do glaciers. Proceedings of the National Academy of Science, v.97, no. 4, p.1351-1354.

Mathews, W.H., 1952. Mount Garibaldi, a Supra-Glacial Pleistocene Volcano in South Western British Columbia. American Journal of Science, February, pp. 81-103.

Mathews, W.H., 1958. Geology of the Mount Garibaldi Map-Area, Southwestern British Columbia, Canada: Part II: Geomorphology and Quaternary Volcanic Rocks. Geological Society of America Bulletin 1958:69, no. 2:179-198.

Ministry of Environment, 2012. An Aquifer Classification System for Groundwater Management in British Columbia. <http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/Aq_Classification/Aq_Class.html#class> [Accessed December 2012]

Ministry of Health, 2013. Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) Including Groundwater Under Direct Influence of Surface Water (GWUDI), Version 2, released July 2013, 51pp.

Monger, J.W.H., 1993. Georgia Basin Project – geology of Vancouver map area, British Columbia; in Current Research, Part A; Geological Survey of Canada paper 93-1A, pp. 149-157.

National Oceanic and Atmospheric Administration. United States Department of Commerce. <http://www.publicaffairs.noaa.gov/lanina.html> [Accessed December 2012]

Nelson Environmental Services, 1997. Initial Environmental Assessment Powerhouse (Alava) Creek. Report prepared for Alava Spring Water Company Ltd, February, 10p.

Neuman, S.P., 1974. Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response. In Water Resources Research, Vol. 10, pp. 303-312.

Piteau Associates Engineering Ltd., 1997. Preliminary Assessment of Water Supply Potential – Powerhouse Springs, District of Squamish, B.C. Report prepared for the District of Squamish, May, 16p.

Piteau Associates Engineering Ltd., 1998. Test Well Program – Powerhouse Springs, District of Squamish, B.C." Report prepared for the District of Squamish, March, 23p.

Piteau Associates Engineering Ltd., 1999. Status Report for the Powerhouse Springs Production Well Drilling and Testing Program, District of Squamish, B.C. Report prepared for the District of Squamish, March, 17p.

Piteau Associates Engineering Ltd., 2000. Completion Report, Production Well Construction and Testing Program, Powerhouse Springs, District of Squamish, B.C. Report prepared for the District of Squamish, December, 24p.

Piteau Associates Engineering Ltd., 2005. 2005 Well Redevelopment and Assessment Program, Powerhouse Springs, District of Squamish, B.C. Report prepared for the District of Squamish, June, 19p.

Piteau Associates Engineering Ltd., 2006. Completion Report, Production Well Construction and Testing Program, Powerhouse Springs, District of Squamish, B.C. Report prepared for the District of Squamish, September, 24p.

Piteau Associates Engineering Ltd., 2007. Completion Report, Production Well PW-6 Reconstruction and Testing Program, Powerhouse Springs, District of Squamish, B.C. Report prepared for the District of Squamish, June, 15p.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. In American Geophysical Union Transactions, Vol. 15, pp. 519-524.

Trenberth, Kevin E., Hoar, Timothy J., 1996. "The 1990-1995 El Niño – Southern Oscillation Event: Longest on record". *Geophysical Research Letters* **23** (1), January, pp. 57-60.

UBC Forestry Climate model. Mean Annual Precipitation and Precipitation as Snow (1961-1990) covering British Columbia downloaded as raster files: http://www.genetics.forestry.ubc.ca/cfcg/ClimateBC40/Default.aspx. [Accessed September 2012]

Vancouver Coastal Health, 2012. District of Squamish Waterworks – Inspection Report. March 23. http://www.healthspace.ca/vch. [Accessed January 3, 2013]

Whitfield, P.H., and Taylor, E., 1998. Apparent Recent Changes in Hydrology and Climate of Coastal British Columbia; in Mountains to Sea: Human Interaction with the Hydrologic Cycle, (ed.) Y. Alila; Proceedings of 51st Annual Canadian Water Resources Conference, June 10-12, 1998, Cambridge, Ontario, pp. 22-29.

Whitfield, P.H., Bodtker, K., and Cannon, A.J., 2002a. Recent Variations in Seasonality of Temperature and Precipitation in Canada, 1976-1995; International Journal of Climatology, v. 22, pp. 1617-1644.

Whitfield, P.H., Reynolds, C.J. and Cannon, A.J., 2002b. Modelling Streamflows in Present and Future Climates – Examples from Georgia Basin, British Columbia; Canadian Water Resources Journal, v. 27, no.4, pp. 427-456.

Yates, M.V., Gerba, C.P., and Kelley, L.M., 1985. Virus Persistence in Groundwater. Applied and Environmental Microbiology. 49(4):778-781

Zhang, X., Vincent, L.A., Hogg, W.D., and Niitsoo, A., 2000. Temperature and Precipitation Trends in Canada During the 20th Century; Atmosphere-Ocean, v. 38, no. 3, pp. 395-429.

Zhang, X., Harvey, D.K., Hogg, W.D., and Yuzyk, T.D., 2001. Trends in Canadian Streamflow; Water Resources Research, v. 37, no. 4, pp. 987-998.

TABLES

TABLE I
MONTHLY PRECIPITATION DATA FOR STUDY AREA

	Squamish Upper (El. 46m) 1971 to 2000[1]			Ring Creek Lava Flow[2] (mean Elevation 720m)			Native Ground - Catchment Area below 1700m exclusive of Lava Flow[2] (mean El. 1110m)			Glacier - Catchment Areas above 1700m[2] (mean El. 1900m)			PE [4] (Thornthwaite)
Month	Rain (mm)	Snow (cm)	Total Precip (mm)	Rain (mm)	Snow[3] (mm SWE)	Total Precip (mm)	Rain (mm)	Snow[3] (mm SWE)	Total Precip (mm)	Rain (mm)	Snow[3] (mm SWE)	Total Precip (mm)	(mm)
January	265.7	71.7	337.4	292.5	177.2	469.7	238.3	311.5	549.8	162.2	526.3	688.4	0.6
February	235.3	47.6	282.9	264.2	129.6	393.8	225.5	235.5	461.0	132.4	444.8	577.2	8.6
March	188.9	22.5	211.4	215.6	78.7	294.3	191.4	153.1	344.5	120.2	311.1	431.3	26.2
April	159.2	2.5	161.7	200.1	25.0	225.1	207.5	56.0	263.5	139.0	190.9	329.9	49.3
May	105.8	0.0	105.8	146.1	1.2	147.3	169.6	2.8	172.4	148.4	67.4	215.9	78.3
June	85.8	0.0	85.8	119.4	0.0	119.4	139.8	0.0	139.8	163.1	11.9	175.1	102.1
July	61.1	0.0	61.1	85.1	0.0	85.1	99.6	0.0	99.6	122.9	1.8	124.7	117.2
August	59.6	0.0	59.6	83.0	0.0	83.0	97.1	0.0	97.1	121.2	0.4	121.6	107.3
September	88.2	0.0	88.2	122.8	0.0	122.8	143.7	0.0	143.7	166.1	13.8	180.0	76.3
October	279.0	0.6	279.6	377.8	11.4	389.2	429.1	26.5	455.6	389.2	181.3	570.5	39.4
November	357.5	21.4	378.9	428.5	99.0	527.4	413.9	203.5	617.4	287.3	485.8	773.1	12.2
December	245.2	69.1	314.3	257.6	180.0	437.5	189.9	322.2	512.1	119.6	521.7	641.3	0.0
TOTAL mm	2131.3	235.4	2366.7	2592.5	702.1	3294.6	2545.4	1311.1	3856.5	2071.7	2757.4	4829.1	617.6

H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_THICK.xlsx]TabI-ClimateNormals

Notes:

1. Monthly precipitation based on the average monthly precipitation for the Environment Canada Squamish Upper climate station for the period shown.
2. Total annual precipitation and snow for Ring Creek Lava flow, native ground below 1700m, and glacier above 1700m are derived from the UBC Forestry Climate Model, by integrating (cut/fill analysis in GIS) mean annual precipitation (MAP) and precipitation as snow (PAS) grids from UBC forestry climate model. Monthly precipitation values estimated by prorating Squamish Upper monthly precipitation to each total annual precipitation.
3. Portion of monthly precipitation falling as rain or snow estimated based on data from Squamish Upper, Whistler, and Whistler Roundhouse climate stations, depending on the elevation of interest. Estimated monthly snow (measured as mm SWE) depths must add up to annual Precipitation as Snow for each surface.
4. Evaporation data from Thornthwaite (see TABLE VI).

TABLE II
SUMMARY OF HISTORICAL GROUNDWATER QUILITY RESULTS

		Guidelines for Canadian Drinking Water Quality [2,3]		PW-1	PW-2	PW-3	PW-4		PW-5	PW-6	PW-6	PW-7
				(PW99-1)	(PW00-2)	(PW00-3)	(PW97-1)			(Shallow Screen)	(Deep Screen)	
Date Sampled	**UNIT**	**MAC/IMAC**	**AO**	5-Feb-99	1-Dec-00	29-Nov-00	7-Jan-98	8-Jan-98	18-May-06	15-Feb-07	2-May-06	4-May-06
Physical Tests												
Colour	TCU	-	15	<5	<5	<5	-	<5	<5.0	<5.0	<5.0	<5.0
pH	pH units	-	6.5 to 8.5	6.90	7.63	7.85	6.54	6.43	7.55	7.43	7.61	6.89
Conductivity	µS/cm	-	-	88.0	80.0	162.0	82.0	82.0	68.4	75.0	118.0	75.7
Total Dissolved Solids	mg/L	-	500	81	76	130	78	74	59	67	89	59
Turbidity [4]	NTU	1	0.5	0.20	0.40	0.30	-	<1	0.26	0.22	0.11	0.13
Hardness (as CaCO3)	mg/L	-	-	23.7	23.1	41.3	-	22.1	20.1	22.7	30.8	22.5
UV Transmittance (254nm)	%T	-	-	-	-	-	-	-	-	97.7	-	-
Dissolved Anions												
Alkalinity - Total (as $CaCO_3$)	mg/L	-	-	20.0	20.0	25.0	19.0	18.0	19.3	21.0	24.9	19.5
Bromide	mg/L	-	-	-	-	-	-	-	<0.050	-	>0.050	>0.050
Fluoride	mg/L	1.5	-	0.080	0.120	0.120	-	0.090	0.083	0.060	0.104	0.098
Sulphate	mg/L	-	500	8.00	8.00	20.00	-	8.00	6.98	7.95	15.0	8.30
Chloride	mg/L	-	250	5.50	4.40	17.20	-	4.20	3.82	4.42	10.3	4.45
Dissolved Cations												
Calcium	mg/L	-	-	7.16	7.20	13.20	-	6.70	6.16	9.69	9.63	6.99
Magnesium	mg/L	-	-	1.42	1.24	2.01	-	1.30	1.14	1.29	1.63	1.23
Potassium	mg/L	-	-	1.23	1.31	1.72	-	<2	1.22	1.31	1.55	1.33
Sodium	mg/L	-	200	6.00	4.74	4.74	-	5.00	4.90	4.90	9.40	5.30
Nutrients												
Ammonia Nitrogen (N)	mg/L	-	-	0.03	-	-	-	-	-	-	-	-
Nitrate Nitrogen (N)	mg/L	10	-	<0.1	<0.1	<0.1	-	0.06	<0.10	0.0623	<0.10	<0.10
Nitrite Nitrogen (N)	mg/L	1	-	<0.1	<0.1	<0.1	-	0.06	<0.10	<0.0010	<0.10	<0.10
Bacteriological Tests												
Coliform Bacteria - Total	MPN/100ml	0	-	<1	<1	<1	-	<1	<1	<1	<1	<1
Coliform Bacteria - Fecal	MPN/100ml	-	-	<1	<1	<1	-	<1	<1	<2	<1	<1
Heterotrophic Plate Count	MPN/100ml	-	-	0	-	-	-	-	-	-	-	-
E.Coli	MPN/100ml	0	-	-	-	-	-	-	<1	-	<1	<1
Organic Parameters												
Total Organic Carbon (C)	mg/L	-	-	<0.5	-	-	-	-	<0.50	<0.50	<0.50	<0.50
Metals [5]												
Aluminum	mg/L		0.1	<0.005	0.007	<0.005	-	>0.2	<0.010	<0.050	<0.010	<0.010
Antimony	mg/L	0.006	-	-	-	-	-	-	<0.00050	<0.0025	<0.00050	<0.00050
Arsenic	mg/L	0.010	-	0.0006	0.0006	0.0007	-	0.0006	<0.020	0.00059	0.00087	0.00062
Barium	mg/L	1.0	-	0.002	0.002	0.004	-	<0.01	<0.020	<0.10	<0.020	<0.020
Boron	mg/L	5	-	<0.05	<0.05	0.11	-	<0.1	<0.10	<0.50	<0.10	<0.10
Cadmium	mg/L	0.005	-	<0.0002	<0.0002	<0.0002	-	<0.0002	<0.00020	<0.0010	<0.00020	<0.00020
Chromium	mg/L	0.05	-	<0.001	<0.001	<0.001	-	<0.01	<0.0020	<0.010	<0.0020	<0.0020
Cobalt	mg/L	-	-	-	-	-	-	-	-	-	-	-
Copper	mg/L	-	1.0	0.001	<0.001	<0.001	-	<0.01	<0.0010	<0.0050	<0.0010	<0.0010
Iron (total)	mg/L	-	0.3	<0.03	<0.03	<0.03	-	<0.03	<0.030	<0.030	<0.0010	<0.0010
Iron (dissolved)	mg/L	-	0.3	-	-	-	<0.03	-	-	-	-	-
Lead	mg/L	0.010	-	<0.001	<0.001	<0.001	-	<0.001	<0.0010	<0.0050	<0.0010	<0.0010
Manganese	mg/L	-	0.05	<0.001	<0.001	<0.001	<0.005	<0.005	<0.00020	<0.00020	<0.00020	<0.00020
Mercury	mg/L	0.001	-	<0.00005	<0.00005	<0.00005	-	<0.00005	-	-	-	-
Molybdenum	mg/L	-	-	<0.03	-	-	-	-	-	-	-	-
Nickel	mg/L	-	-	<0.001	-	-	-	-	-	-	-	-
Selenium	mg/L	0.01	-	<0.001	<0.001	<0.001	-	<0.0005	<0.0010	<0.0050	<0.0010	<0.0010
Silver	mg/L	-	-	<0.0001	-	-	-	-	-	-	-	-
Uranium	mg/L	0.02	-	0.00005	0.00003	0.00017	-	-	<0.00010	<0.00050	0.00011	<0.00010
Zinc	mg/L	-	5.0	<0.005	<0.005	<0.005	-	<0.005	<0.050	<0.25	<0.050	<0.050
Radiological Parameters												
Gross Alpha	Bq/L	0.5	-	-	<0.02	0.07±0.03	-	-	0.02	<0.03	<0.020	<0.020
Gross Beta	Bq/L	1.0	-	-	0.02±0.01	0.07±0.01	-	-	0.040	0.020	0.050	0.040
Cation/Anion Difference	%											
Sum Cations	meq/L	-	-	0.77	0.70	1.07	-	-	0.65	0.70	1.06	0.71
Sum Anions	meq/L	-	-	0.65	0.62	1.31	-	-	0.57	0.63	1.01	0.62
Cation/Anion Ratio	ratio	-	-	1.18	1.13	0.82	-	-	1.13	1.10	1.05	1.16
Cation/Anion Difference	%	-	-	8.30	6.29	-9.92	-	-	6.30	5.00	2.60	7.30

H:\Project\2841\Analytical\[Groundwater Chemistry Summary.xlsx]Table_Pre2012_Wells

1. GCDWQ = Guidelines for Canadian Drinking Water Quality (updated August 2012).
2. MAC = Maximum Allowable Concentration; AO = Aesthetic Objective.
3. Average daily source water turbidity levels immediately prior to where the disinfectant is applied should be < 1.0 NTU and not exceed 5.0 NTU for more than 2 days in a 12-month period.
4. All metals values are total unless otherwise indicated.
5. Shading indicates value is outside range specified by GCDWQ.

TABLE III
SUMMARY OF RECENT GROUNDWATER QUALITY RESULTS

		Guidelines for Canadian Drinking Water Quality [2,3]		**Site 2 - Powerhouse Creek**			**PW-5**				**PW-7**		
Date Sampled	**UNIT**	**MAC/IMAC**	**AO/OG**	6-Jun-12	27-Aug-12	7-Nov-12	6-Jun-12	27-Aug-12	27-Aug-12 (Dup)	7-Nov-12	6-Jun-12	27-Aug-12	7-Nov-12
Physical Tests													
Temperature - field measured	°C		≤15	8.5	7.8	6.30	9.2	11.0	11.0	7.0	8.4	7.8	6.9
Colour	TCU	-	15	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
pH	pH units	-	6.5 to 8.5	7.79	8.07	7.46	7.70	7.97	7.86	7.51	7.74	8.40	7.54
pH - field measured	pH units	-	6.5 to 8.5	7.54	7.87	7.79	7.26	6.85	6.85	5.19	7.34	6.89	5.29
Conductivity	µS/cm	-	-	64.2	67.8	59.10	67.9	69.5	69.2	64.9	72.9	81.9	69.8
Conductivity - field measured	µS/cm	-	-	92	57	53	108	55	55	74	168	60	-
Total Dissolved Solids	mg/L	-	500	62	73	7.46	70	68	68	7.51	79	70	8
Turbidity [4]	NTU	1	0.5	0.23	<0.10	0.46	<0.10	<0.10	<0.10	0.37	<0.10	<0.10	0.17
Hardness (as CaCO3)	mg/L	-	-	20.1	20.4	19.80	21.4	21.5	21.4	21.1	23.1	22.8	22.6
UV Transmittance (254nm)	%T	-	-										
Dissolved Anions													
Alkalinity - Total (as $CaCO_3$)	mg/L	-	-	19.8	18.9	17.6	20.8	19.4	19.4	19.9	21.5	20.0	19.8
Bromide	mg/L	-	-										
Fluoride	mg/L	1.5	-	0.08	0.09	0.07	0.088	0.091	0.091	0.080	0.090	0.093	0.082
Sulphate	mg/L	-	500	6.51	6.73	6.32	7.11	7.09	7.18	6.97	8.12	8.11	8.09
Chloride	mg/L	-	250	3.67	3.76	3.55	3.87	3.84	3.89	3.85	4.37	4.33	4.40
Dissolved Cations													
Calcium	mg/L	-	-	6.14	6.23	6.08	6.53	6.55	6.54	6.45	7.06	6.97	6.91
Magnesium	mg/L	-	-	1.16	1.17	1.13	1.24	1.25	1.23	1.22	1.32	1.31	1.30
Potassium	mg/L	-	-	<2.0	1.16	<2.0	<2.0	1.23	1.26	<2.0	<2.0	1.27	3.10
Sodium	mg/L	-	200	4.3	4.5	4.3	4.5	4.8	4.7	4.6	4.9	5.0	5.0
Nutrients													
Nitrate Nitrogen (N)	mg/L	10	-	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Nitrite Nitrogen (N)	mg/L	1	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Dissolved Metals [5]													
Aluminum	mg/L		0.1/0.2	<0.010	<0.010		<0.010	<0.010	<0.010		<0.010	<0.010	
Antimony	mg/L	0.006	-	<0.00050	<0.00050		<0.00050	<0.00050	<0.00050		<0.00050	<0.00050	
Arsenic	mg/L	0.010	-	<0.0010	0.00		<0.0010	0.00	0.00		<0.0010	0.00064	
Barium	mg/L	1.0	-	<0.020	<0.020		<0.020	<0.020	<0.020		<0.020	<0.020	
Boron	mg/L	5	-	<0.10	<0.10		<0.10	<0.10	<0.10		<0.10	<0.10	
Cadmium	mg/L	0.005	-	<0.000050	<0.00020		<0.000050	<0.00020	<0.00020		<0.000050	<0.00020	
Chromium	mg/L	0.05	-	<0.00050	<0.0020		<0.00050	<0.0020	<0.0020		<0.00050	<0.0020	
Cobalt	mg/L	-	-	<0.00050			<0.00050				<0.00050		
Copper	mg/L	-	1.0	<0.0010	<0.0010		0.01	0.01	0.01		0.01	0.00	
Iron (dissolved)	mg/L	-	0.3	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Lead	mg/L	0.010	-	<0.0010	<0.00050		<0.0010	<0.00050	<0.00050		<0.0010	<0.00050	
Manganese	mg/L	-	0.05	<0.010	<0.0020	<0.0050	<0.010	<0.0020	<0.0020	<0.0050	<0.010	<0.0020	<0.0050
Mercury	mg/L	0.001	-	<0.00020	<0.00020		<0.00020	<0.00020	<0.00020		<0.00020	<0.00020	
Molybdenum	mg/L	-	-	<0.0010			<0.0010				<0.0010		
Nickel	mg/L	-	-	<0.0050			<0.0050				<0.0050		
Selenium	mg/L	0.01	-	<0.0010	<0.0010		<0.0010	<0.0010	<0.0010		<0.0010	<0.0010	
Silver	mg/L	-	-	<0.000050			<0.000050				<0.000050		
Strontium	mg/L	-	-										
Thallium	mg/L	-	-	<0.00020			<0.00020				<0.00020		
Tin	mg/L	-	-										
Titanium	mg/L	-	-	<0.050			<0.050				<0.050		
Tungsten	mg/L	-	-										
Uranium	mg/L	0.02	-	<0.00020	<0.00010		<0.00020	<0.00010	<0.00010		<0.00020	<0.00010	
Vanadium	mg/L	-	-	<0.030			<0.030				<0.030		
Zinc	mg/L	-	5.0	<0.0050	<0.050		<0.0050	<0.050	<0.050		<0.0050	<0.050	
Environmental Isotopes													
$\delta^{2}H$-H_2O (Deuterium)	‰	-	-	-101.66	-101.63	-100.82	-102.63	-102.23	-101.61	-102.29	-101.75	-102.56	-102.04
$\delta^{18}O$-H_2O (Oxygen-18)	‰	-	-	-13.56	-14.13	-13.38	-14.12	-14.25	-13.98	-13.62	-14.20	-13.93	-13.51
^{3}H (Tritium)	TU	-	-	2.6			3.1		2.3	2.2	2.6		
Cation/Anion Difference	%												
Sum Cations	meq/L	-	-	6.45E-04	6.33E-04	6.09E-04	6.68E-04	6.70E-04	6.64E-04	6.48E-04	7.10E-04	7.06E-04	7.49E-04
Sum Anions	meq/L	-	-	6.35E-04	6.24E-04	5.84E-04	6.73E-04	6.44E-04	6.47E-04	6.52E-04	7.22E-04	6.90E-04	6.88E-04
Cation/Anion Ratio	ratio	-	-	1.02	1.01	1.04	0.99	1.04	1.03	0.99	0.98	1.02	1.09
Cation/Anion Difference	%	-	-	-2%	-1%	-4%	1%	-4%	-3%	1%	2%	-2%	-8%

H:\Project\2841\Analytical\[Groundwater Chemistry Summary.xlsx]Table_2012_GW

1. GCDWQ = Guidelines for Canadian Drinking Water Quality (updated August 2012).
2. MAC = Maximum Allowable Concentration; AO = Aesthetic Objective; OG = Operational Guideline
3. Average daily source water turbidity levels immediately prior to where the disinfectant is applied should be < 1.0 NTU and not exceed 5.0 NTU for more than 2 days in a 12-month period.
4. Shading indicates value is outside range specified by GCDWQ.

TABLE IV
SUMMARY OF RECENT SURFACE AND PRECIPITATION WATER QUALITY RESULTS

		LOWER SKOOKUM CREEK			LOWER RING CREEK				MAMQUAM RIVER			RAIN AT 100m			RAIN AT 700m			SNOWMELT AT 1300m
Date Sampled	**UNIT**	6-Jun-12	27-Aug-12	7-Nov-12	6-Jun-12	27-Aug-12	7-Nov-12	7-Nov-12 (Dup)	6-Jun-12	27-Aug-12	7-Nov-12	6-Jun-12	27-Aug-12	7-Nov-12	6-Jun-12	27-Aug-12	7-Nov-12	27-Aug-12
Physical Tests																		
Temperature - field measured	°C	5.1	9.8	4.9	6.6	8.8	5.4		5.6	10.1	-			7.9		21.6	6.7	1.8
Colour	TCU	11.10	<5.0	13.40	10.00	<5.0	6.2		9.90	<5.0	10.00					<5.0		<5.0
pH	pH units	7.72	7.05	7.26	7.61	7.86	7.39		7.48	7.93	7.20					5.68		6.37
pH - field measured	pH units	7.30	7.07	6.35	7.38	7.02	7.17		7.28	7.04	5.57			5.82		5.94	7.11	5.15
Conductivity	µS/cm	20.4	19.4	27.30	36.3	29.9	38		24.6	34.0	20.4					2.70		10.2
Conductivity - field measured	µS/cm	20	20	25	39	27	30		29	34	19			19		104	65	9
Total Dissolved Solids	mg/L	24	15		37	36			25	25						<10		15
Turbidity 4	NTU	2.02	3.64	0.87	5.84	12.20	3.98		0.77	2.04	1.46					0.68		0.11
Hardness (as CaCO3)	mg/L	8.7	7.8	11.80	15.2	11.8	16.6		10.8	13.4	9.4					<0.50		1.95
UV Transmittance (254nm)	%T																	
Dissolved Anions																		
Alkalinity - Total (as CaCO$_3$)	mg/L	8.2	6.7	9.3	13.1	9.1	13.1		10.4	11.1	7.7					<2.0		4.40
Bromide	mg/L																	
Fluoride	mg/L	<0.020	<0.020	<0.020	0.021	0.023	0.022		<0.020	<0.020	<0.020					<0.020		<0.020
Sulphate	mg/L	1.46	1.98	2.67	4.89	3.95	5.91		2.15	3.60	1.97					<0.50		<0.50
Chloride	mg/L	<0.50	<0.50	0.55	<0.50	<0.50	<0.50		<0.50	0.93	<0.50					<0.50		<0.50
Dissolved Cations																		
Calcium	mg/L	3.05	2.79	4.15	4.87	3.73	5.37		3.79	4.70	3.32					0.11		0.78
Magnesium	mg/L	0.25	0.20	0.34	0.74	0.59	0.78		0.32	0.41	0.27					<0.10		<0.10
Potassium	mg/L	<2.0	0.26	<2.0	<2.0	0.32	<2.0		<2.0	0.28	<2.0					<0.10		0.49
Sodium	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0		<2.0	<2.0	<2.0					<2.0		<2.0
Nutrients																		
Ammonia Nitrogen (N)	mg/L																	
Nitrate Nitrogen (N)	mg/L	0.03	<0.0050	0.04	0.01	<0.0050	0.04		0.03	0.01	0.03					0.10		0.04
Nitrite Nitrogen (N)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010		<0.0010	<0.0010	<0.0010					<0.0010		<0.0010
Dissolved Metals [5]																		
Aluminum	mg/L	0.06	<0.010		0.07	0.03			0.06	0.01						<0.010		<0.010
Antimony	mg/L	<0.00050	<0.00050		<0.00050	<0.00050			<0.00050	<0.00050						<0.00050		<0.00050
Arsenic	mg/L	<0.0010	<0.00010		<0.0010	0.00			<0.0010	<0.00010						<0.00010		<0.00010
Barium	mg/L	<0.020	<0.020		<0.020	<0.020			<0.020	<0.020						<0.020		<0.020
Boron	mg/L	<0.10	<0.10		<0.10	<0.10			<0.10	<0.10						<0.10		<0.10
Cadmium	mg/L	<0.000050	<0.00020		<0.000050	<0.00020			<0.000050	<0.00020						<0.00020		<0.00020
Chromium	mg/L	<0.00050	<0.0020		<0.00050	<0.0020			<0.00050	<0.0020						<0.0020		<0.0020
Cobalt	mg/L	<0.00050			<0.00050				<0.00050									
Copper	mg/L	<0.0010	<0.0010		0.0017	<0.0010			<0.0010	<0.0010						0.00		<0.0010
Iron (dissolved)	mg/L	0.04	<0.030	<0.030	<0.030	<0.030	<0.030		<0.030	<0.030	0.04					<0.030		<0.030
Lead	mg/L	<0.0010	<0.00050		<0.0010	<0.00050			<0.0010	<0.00050						0.00		<0.00050
Manganese	mg/L	<0.010	<0.0020	<0.0050	<0.010	0.00	<0.0050		<0.010	<0.0020	<0.0050					0.00		<0.0020
Mercury	mg/L	<0.00020	<0.00020		<0.00020	<0.00020			<0.00020	<0.00020						<0.00020		<0.00020
Molybdenum	mg/L	<0.0010			<0.0010				<0.0010									
Nickel	mg/L	<0.0050			<0.0050				<0.0050									
Selenium	mg/L	<0.0010	<0.0010		<0.0010	<0.0010			<0.0010	<0.0010						<0.0010		<0.0010
Silver	mg/L	<0.000050			<0.000050				<0.000050									
Strontium	mg/L																	
Thallium	mg/L	<0.00020			<0.00020				<0.00020									
Tin	mg/L																	
Titanium	mg/L	<0.050			<0.050				<0.050									
Tungsten	mg/L																	
Uranium	mg/L	<0.00020	<0.00010		<0.00020	<0.00010			<0.00020	<0.00010						<0.00010		<0.00010
Vanadium	mg/L	<0.030			<0.030				<0.030									
Zinc	mg/L	<0.0050	<0.050		<0.0050	<0.050			<0.0050	<0.050						0.06		<0.050
Environmental Isotopes																		
$\delta^{2}H-H_2O$ (Deuterium)	‰	-113.16	-107.19	-102.75	-110.51	-107.53	-101.94	-100.37	-109.68	-106.27	-97.94	-55.55	-81.08	-83.63	-116.49	-77.52	-53.55	-111.93
$\delta^{18}O-H_2O$ (Oxygen-18)	‰	-15.69	-14.83	-14.22	-15.98	-14.99	-13.94	-13.98	-14.78	-14.83	-13.70	-6.49	-10.03	-11.44	-15.51	-10.03	-8.07	-15.55
^{3}H (Tritium)	TU	4.3	3.3	3.3	4.8	3.2	2.6		3.7			8.2		2.0	7.5		4.4	4.3
Cation/Anion Difference	%																	
Sum Cations	meq/L	2.26E-04	1.84E-04	2.57E-04	4.40E-04	2.65E-04	4.01E-04		2.68E-04	2.97E-04	3.04E-04					5.44E-05		9.91E-05
Sum Anions	meq/L	1.95E-04	1.76E-04	2.02E-04	3.64E-04	2.65E-04	3.92E-04		2.53E-04	3.23E-04	2.57E-04					6.45E-05		1.00E-04
Cation/Anion Ratio	ratio	1.16	1.04	1.27	1.21	1.00	1.02		1.06	0.92	1.18					0.84		0.99
Cation/Anion Difference	%	-15%	-4%	-24%	-19%	0%	-2%		-6%	8%	-17%					17%		1%

H:\Project\2841\Analytical\[Groundwater Chemistry Summary.xlsx]Table_2012_Surface

1. GCDWQ = Guidelines for Canadian Drinking Water Quality (updated August 2012).
2. MAC = Maximum Allowable Concentration; AO = Aesthetic Objective.
3. Average daily source water turbidity levels immediately prior to where the disinfectant is applied should be < 1.0 NTU and not exceed 5.0 NTU for more than 2 days in a 12-month period.
4. Shading indicates value is outside range specified by GCDWQ.

TABLE V
HISTORICAL AND RECENT STREAMFLOW GAUGING RESULTS NEAR WELL FIELD

Measured Flow (L/s)

Date	Site 1 - Hydro Tower	Site 2A - Main Powerhouse Creek at Bridge	Site 2B - Roadside Ditch Tributary	Site 2 - Powerhouse Creek Total	Site 3 - Above Power Station	Site 4 - Powerhouse Crk at Mamquam	Estimated Groundwater Contribution between Site 2 and Site 4	Estimated Spring Discharge above Site 3	Average Withdrawal from Well Field	Estimated Total Groundwater Flow above Site 3	Estimated Total Groundwater Flow above Site 4
31-May-96	50	490	80	570	N/A			570	0	570	0
30-Oct-96	110	770	N/A	770	*310*			*1080*	0	*0*	*0*
10-Mar-97	38	388	N/A	388	120	809	421	508	0	508	929
24-Apr-97	48	379	80	459	130	656	197	589	0	589	786
BEST ESTIMATE VALUES - NO PUMPING				**400**	**130**	**670**	**270**				**800**
5-Jun-12	14	219	20	238	74			313	120	433	721
17-Aug-12	7	168	21	190	43			233	190	423	704
7-Nov-12	6	223	29	251	68			319	127	446	744
BEST ESTIMATE VALUES - PUMPING				**280**	**100**	**530**	**250**		**130**		**760**

H:\Project\2841\River Discharge\[Creek_Monitoring_Piteau.xlsx]Data Summary

Notes:
1. Values in italics considered to be in error.
2. Values in bold font are best estimates, based on measured values.

TABLE VI

MEAN CLIMATE SUMMARY AND THORNTHWAITE METHOD EVAPORATION CALCULATIONS [1]

MONTH	TOTAL PRECIP. (mm) [2]	SNOW equiv (cm)	AVG. TEMP. [2] (°C)	MONTHLY HEAT INDEX (DELTA I)[3]	LAT. ADJUSTMENT FACTOR			PE [4] (mm)[1]
					40N	**50N**	**49° 53'N**	
January	337.4	71.7	0.2	0.01	0.84	0.71	0.71	0.6
February	282.9	47.6	2.3	0.31	0.83	0.84	0.84	8.6
March	211.4	22.5	5.7	1.22	1.03	0.98	0.98	26.2
April	161.7	2.5	9.0	2.43	1.11	1.14	1.14	49.3
May	105.8	0.0	12.5	3.99	1.24	1.28	1.28	78.3
June	85.8	0.0	15.2	5.36	1.25	1.36	1.36	102.1
July	61.1	0.0	17.7	6.75	1.27	1.33	1.33	117.2
August	59.6	0.0	17.8	6.80	1.18	1.21	1.21	107.3
September	88.2	0.0	14.6	5.04	1.04	1.06	1.060	76.3
October	279.6	0.6	9.1	2.47	0.96	0.90	0.90	39.4
November	378.9	21.4	3.5	0.58	0.83	0.76	0.76	12.2
December	314.3	69.1	-0.1	0.00	0.81	0.68	0.68	0.0
	2366.7	**235.4**	**Average** **9.0**	**Annual Heat Index (I)** **35.0**				**Total** **617.6**

H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_THICK.xlsx]TabVI-ThornthwaiteEvap

Notes:

1. Calculation from "WATER IN ENVIRONMENTAL PLANNING", T. Dunne and L. Leopold, 1978.
2. Average monthly precipitation and temperature data recorded at Squamish Upper climate station between 1971 and 2000 (Environment Canada).
3. Monthly heat index = $(T_m/5)^{1.51}$ where T_m is the average monthly temperature.
4. PE = Potential evaporation = $1.62(10*T_m/I)^a$ where I = Annual Heat Index, and

$$a = 67.5*10^{-8}*I^3-77.1*10^{-6}*I^2+0.01791*I+0.492$$

TABLE VII
SUMMARY OF MEAN ANNUAL AND MONTHLY FLOWS FOR WATER BALANCE CALIBRATION

Month	Mamquam River at Ring Creek - Observed [1] (m^3/s)	Mamquam River at Ring Creek - Calculated with Water Balance (m^3/s)	Skookum Creek above Mamquam - Simulated [2] (m^3/s)	Skookum Creek above Mamquam River - Calculated with Water Balance (m^3/s)	Ring Creek - Observed [3] (m^3/s)	Ring Creek - Calculated with Water Balance (m^3/s)	Aquifer - Observed [4] (m^3/s)	Ring and Skookum Creek Streamflow Losses to Aquifer - Calculated with Water Balance (m^3/s)	Discharge from Aquifer Assuming Average Residence Time > 2 Years [5] (m^3/s)
October	21.6	20.9	6.1	7.1		3.2	0.8	0.7	0.8
November	30.8	30.5	7.7	8.7	2.7	4.6	0.8	0.9	0.8
December	21.5	21.1	3.2	5.7		3.5	0.8	0.7	0.8
January	22.9	22.8	4.4	6.1		3.7	0.8	0.7	0.8
February	17.5	18.1	1.8	4.9		3.1	0.8	0.6	0.8
March	18.1	18.6	2.1	5.0		3.0	0.8	0.6	0.8
April	24.8	25.6	4.0	7.3		3.8	0.8	0.8	0.8
May	36.2	38.2	10.2	13.3		5.3	0.8	1.1	0.8
June	40.4	43.7	15.8	17.7		6.3	0.8	1.3	0.8
July	31.0	32.5	11.2	11.5		4.7	0.8	1.0	0.8
August	19.4	25.4	6.5	7.7	1.9	3.6	0.8	0.8	0.8
September	13.7	12.3	3.5	4.7		1.9	0.8	0.5	0.8
Average Annual Discharge	**24.8**	**25.8**	**6.4**	**8.3**		3.9	0.8	0.8	0.8

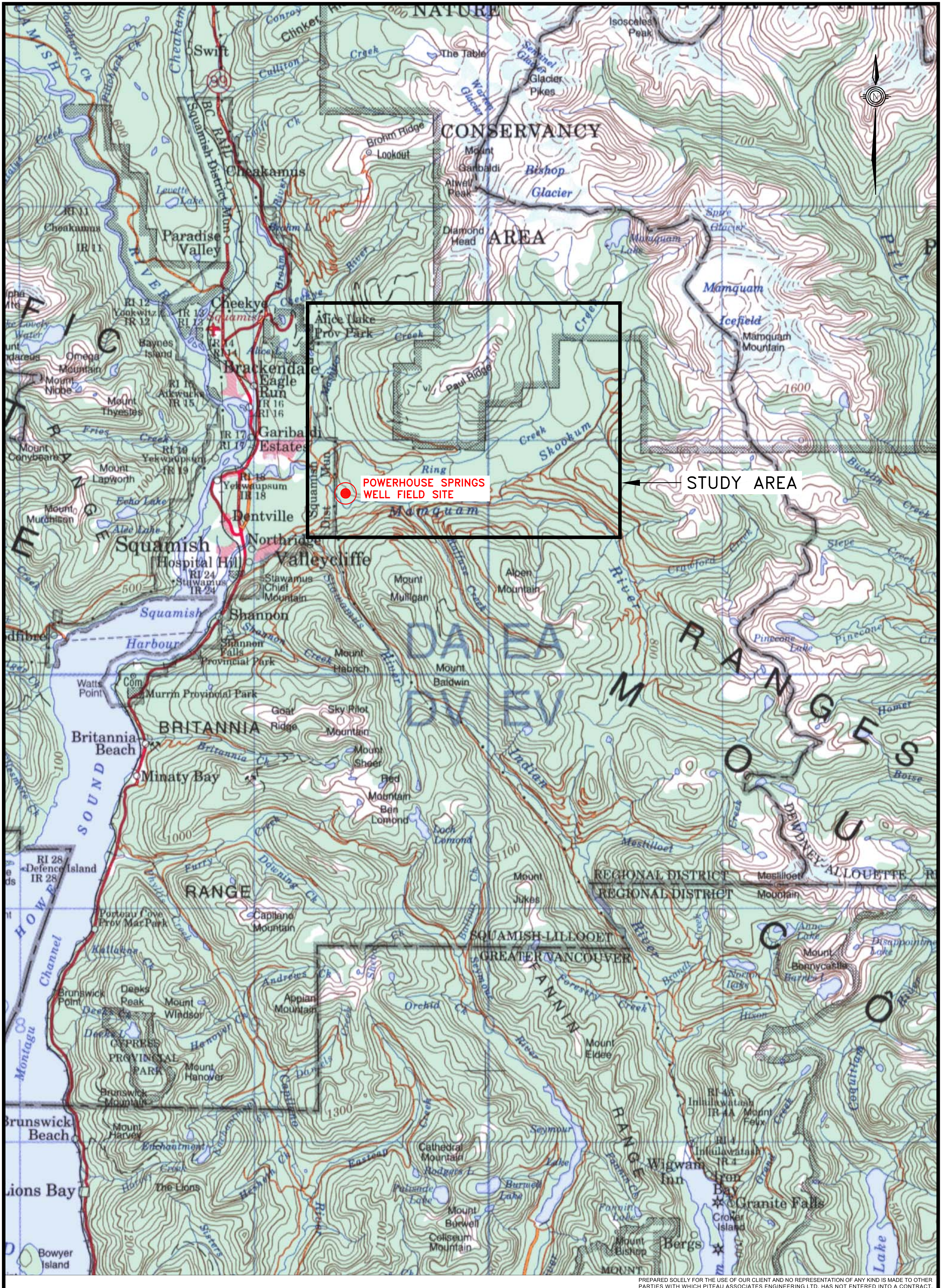
H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_HEAD.xlsx]TABVII-Flow Summary

Notes:

1. Mamquam River at Ring Creek observed mean monthly discharge based on average of 1990-2010 mean monthly discharge values measured by Environment Canada.
2. Simulated Skookum average monthly flows generated by Aquarius by Monthly Multiple Regression analysis and calibrated to flows measured from 2003 to 2010.
3. Ring Creek Flow measured by Piteau at 1-3m^3/s on August 27, 2012, and 2.4-2.9m^3/s on November 7, 2012.
4. Sum of observed Powerhouse Creek flows plus well flows (Table V).
5. Monthly streamflow losses to aquifer were averaged over antecedent period of two years.

FIGURES

DWG. NUMBER: K:\2841\Cadd\2841-006.dwg (Fig 1)



PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ASSOCIATES ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

0 2000 4000 6000 8000 10000m

SCALE 1:150,000

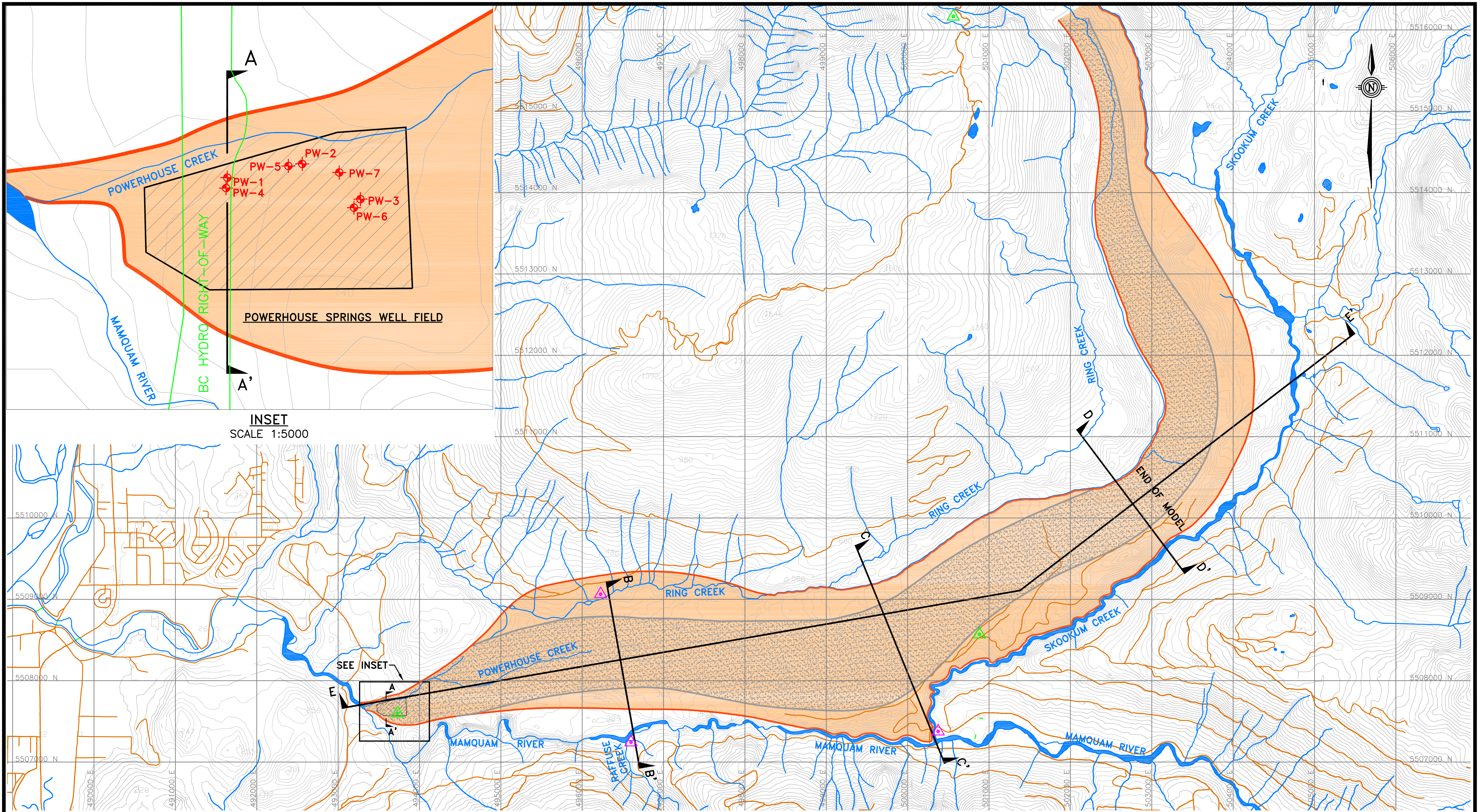
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

STUDY AREA LOCATION

BY:	DATE:
KT/lf	JAN 13
APPROVED:	FIG:
KT	1

DWG. NUMBER: K:\2841\Cadd\2841-005.dwg (Fig 2)



LEGEND

🟧	ESTIMATED EXTENT OF PALEO- CHANNEL SEDIMENTS
▨	ESTIMATED EXTENT OF SATURATED AQUIFER (MODELLED AQUIFER LIMITS)
—	LOGGING ROADS
—	WATERCOURSES
△	SURFACE WATER SAMPLING STATION
△	RAIN/SNOWMELT SAMPLING STATION
⌴	GEOLOGIC SECTION LOCATION

0 400 800 1200 1600 2000m

SCALE 1:45,000

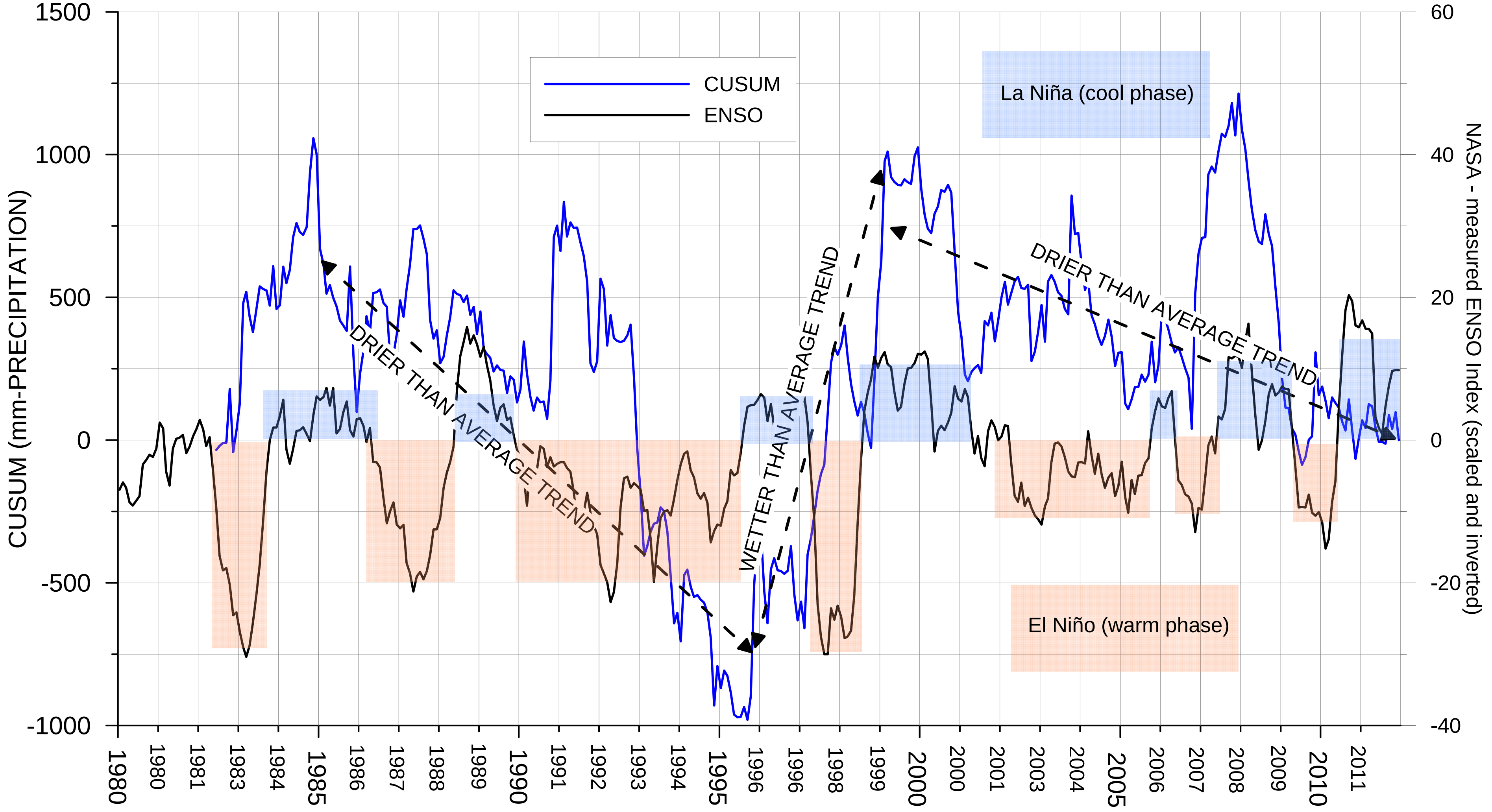
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

STUDY AREA PLAN

BY:	DATE:
KT/lf	JAN 13
APPROVED:	FIG:
KT	2

H:\Project\2841\Water Balance\SquamishAuto_CUSUM.grf



NOTES:
1. PRECIPITATION MEASURED AT ENVIRONMENT CANADA'S SQUAMISH AUTO CLIMATE STATION (EL 52m)
2. ENSO CLIMATE DATA OBTAINED ON-LINE FROM NASA

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

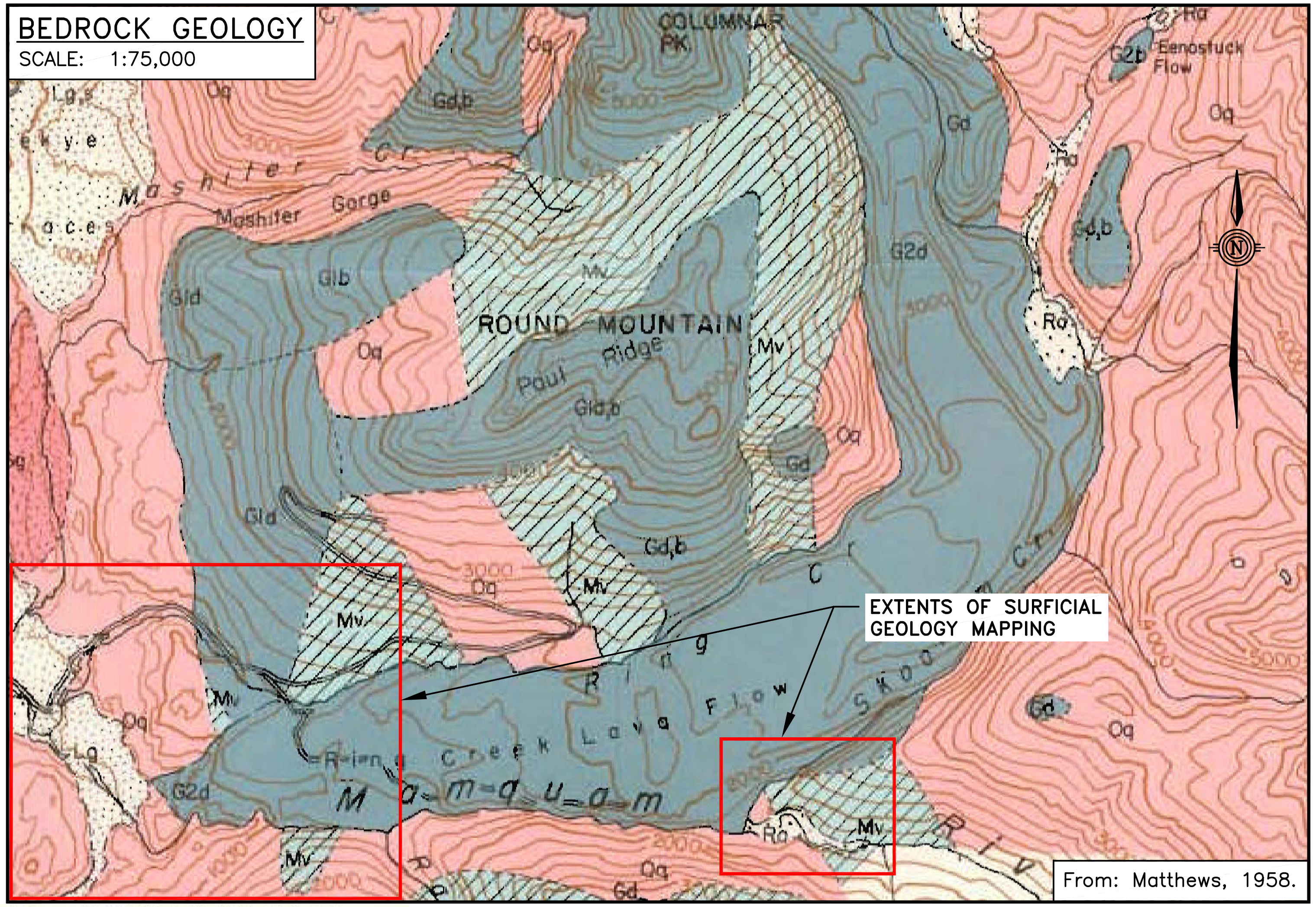
SQUAMISH PRECIPITATION AND CLIMATE TRENDS

BY:	DATE:
JM/KT	JAN 13
APPROVED:	FIG:
KT	3

DWG. NUMBER: K:\2841\Cadd\2841-007.dwg (Fig 4)

BEDROCK GEOLOGY

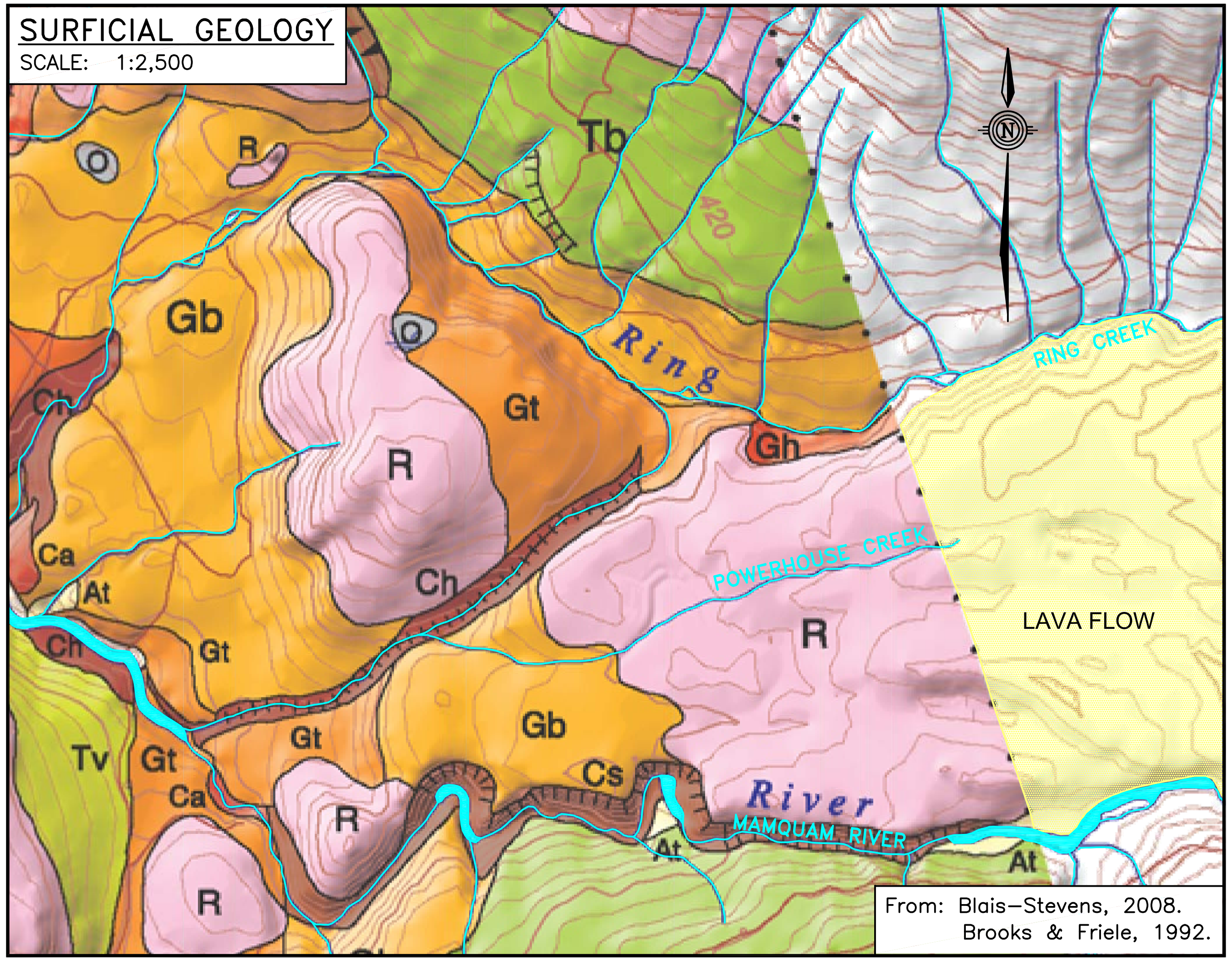
SCALE: 1:75,000



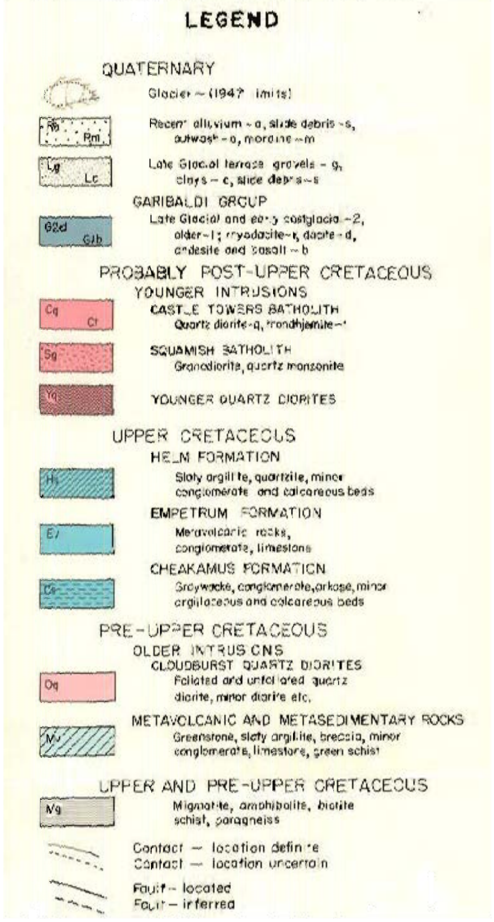
From: Matthews, 1958.

SURFICIAL GEOLOGY

SCALE: 1:2,500



From: Blais–Stevens, 2008.
Brooks & Friele, 1992.



LEGEND

QUATERNARY

Glacier – (1947 limits)

Rb Rm — Recent alluvium – a, slide debris – s, outwash – o, moraine – m

Lg Lc — Late Glacial terrace gravels – g, clays – c, slide debris – s

GARIBALDI GROUP

G2d G1b — Late Glacial and early postglacial – 2, older – 1; rhyodacite – r, dacite – d, andesite and basalt – b

PROBABLY POST-UPPER CRETACEOUS

YOUNGER INTRUSIONS

Cq Ct — CASTLE TOWERS BATHOLITH
Quartz diorite – q, trondhjemite – t

Sg — SQUAMISH BATHOLITH
Granodiorite, quartz monzonite

Yq — YOUNGER QUARTZ DIORITES

UPPER CRETACEOUS

HELM FORMATION

Hs — Slaty argillite, quartzite, minor conglomerate and calcareous beds

EMPETRUM FORMATION

Ev — Metavolcanic rocks, conglomerate, limestone

CHEAKAMUS FORMATION

Cs — Greywacke, conglomerate, arkose, minor argillaceous and calcareous beds

PRE-UPPER CRETACEOUS

OLDER INTRUSIONS

CLOUDBURST QUARTZ DIORITES

Oq — Foliated and unfoliated quartz diorite, minor diorite etc.

METAVOLCANIC AND METASEDIMENTARY ROCKS

Mv — Greenstone, slaty argillite, breccia, minor conglomerate, limestone, green schist

UPPER AND PRE-UPPER CRETACEOUS

Mg — Migmatite, amphibolite, biotite schist, paragneiss

Contact – location definite
Contact – location uncertain

Fault – located
Fault – inferred

LEGEND

PRE–QUATERNARY

R	BEDROCK: sedimentary, low–grade metamorphic, volcanic, and intrusive rocks.

COLLUVIAL DEPOSITS

Ch	Landslide debris: mostly unconsolidated sediments; generally 1 to 10m thick.
Ca	Talus: rubble and block accumulations, 1 to 10m thick; forming aprons and cones.

GLACIAL ENVIRONMENT

Tb	Till blanket: continuous cover with few bedrock outcrops; 1 to 3m thick.
Tv	Till veneer: discontinuous till cover with abundant bedrock outcrops; 1m thick on average.

NON–GLACIAL ENVIRONMENT

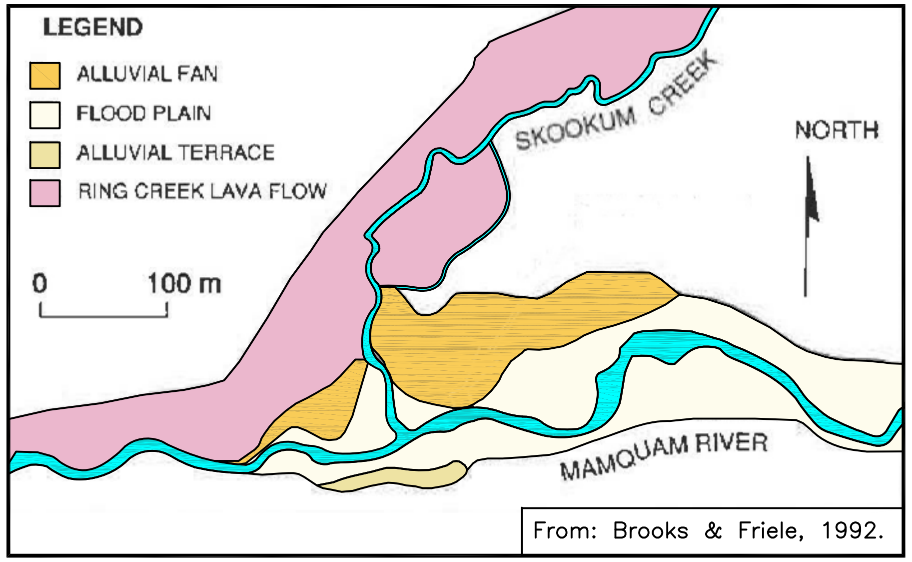
O	ORGANIC DEPOSITS: peat and muck; 1 to 10m thick; forming fens and bogs.

ALLUVIAL (FLUVIAL) DEPOSITS

Ap	Floodplain sediments: sand and silt; 1 to 3m thick; occurring as flat surfaces close to river level; prone to flood.
At	Terrace sediments: stratified sand and gravel; 2 to 10m thick; forming terraces well above flood level.
Af	Fan sediments: poorly sorted sand and gravel; generally 2 to 15m thick; forming fans at the toe of slopes.

GLACIOMARINE DEPOSITS

Gt	Glaciofluvial terrace sediments: sand and gravel; 1 to 10m thick; forming flat surfaces perched well above alluvial deposits.
Gb	Glaciofluvial blanket: sand and gravel; generally 1 to 10m thick; underlying morphology is visible.



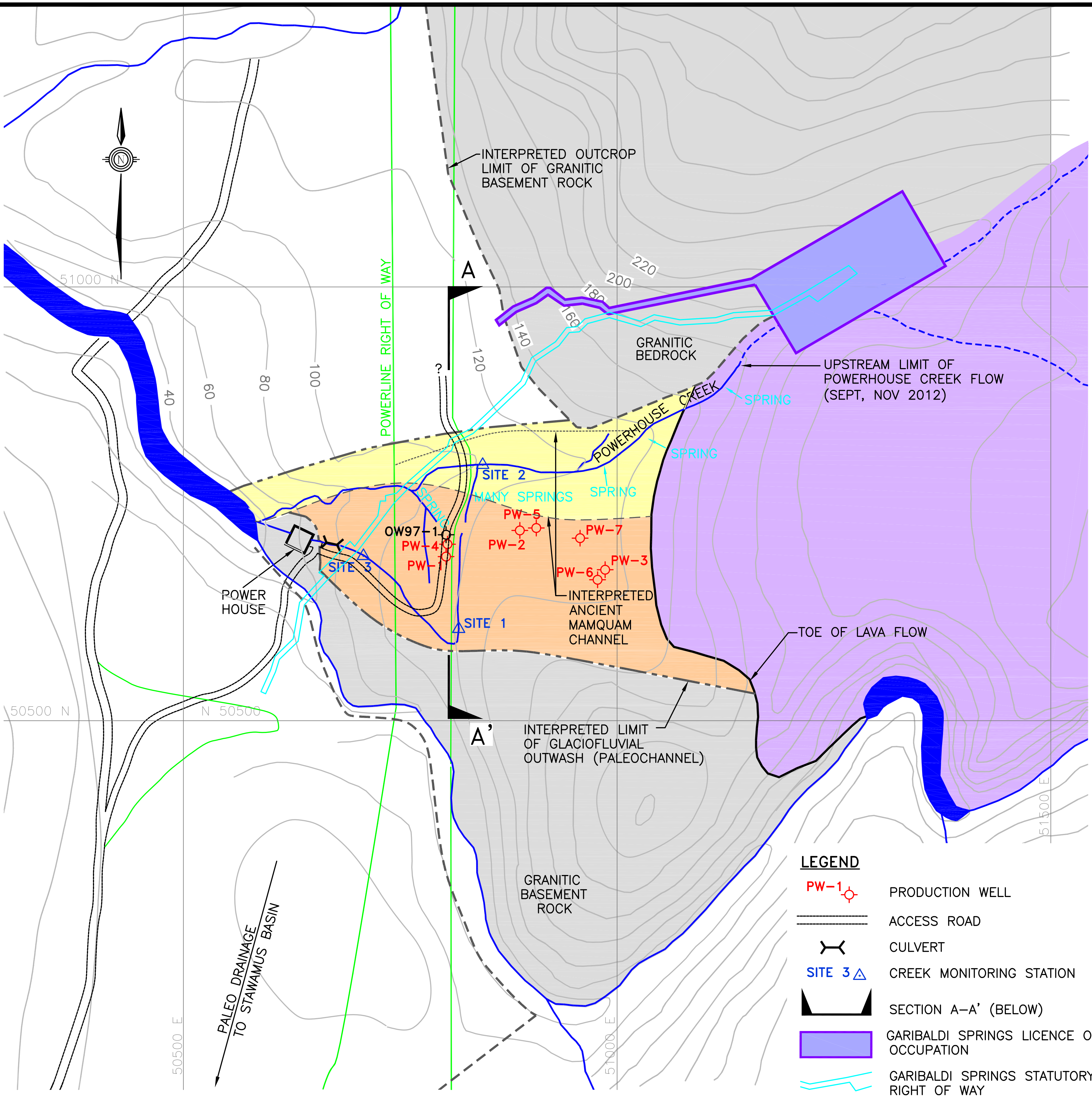
From: Brooks & Friele, 1992.

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

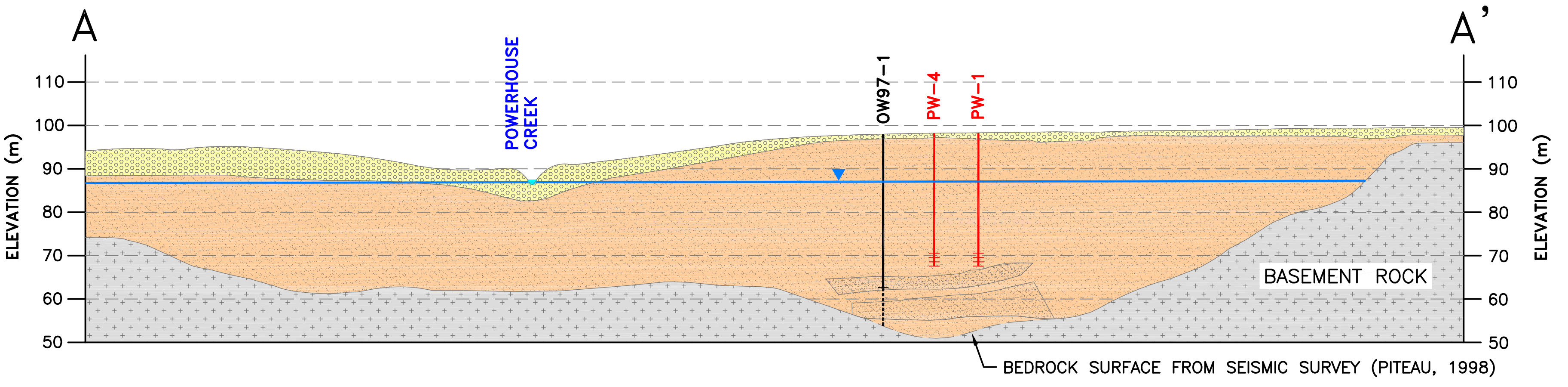
BEDROCK AND SURFICIAL GEOLOGY

BY: ATH/sl
DATE: JAN 13
APPROVED: KT
FIG: 4



NOTE: LOCATIONS ARE APPROXIMATE AND ELEVATIONS ARE BASED ON LOCAL TRIM MAPPING.

SCALE 1:5000



SECTION A–A'

SCALE: 1:1500

NOTE: SECTION ELEVATIONS ARE BASED ON LEVEL SURVEY (ACRES, 1995) AND ARE APPROXIMATELY 10m LOWER THAN SHOWN ON THE ABOVE PLAN.

LEGEND

- ▨ ▨ LAVA ROCK
- ▨ ▨ ALLUVIAL SEDIMENTS
- ▨ GLACIOFLUVIAL SEDIMENTS
- ▨ BASEMENT ROCK
- — INFERRED AQUIFER GROUNDWATER ELEVATION

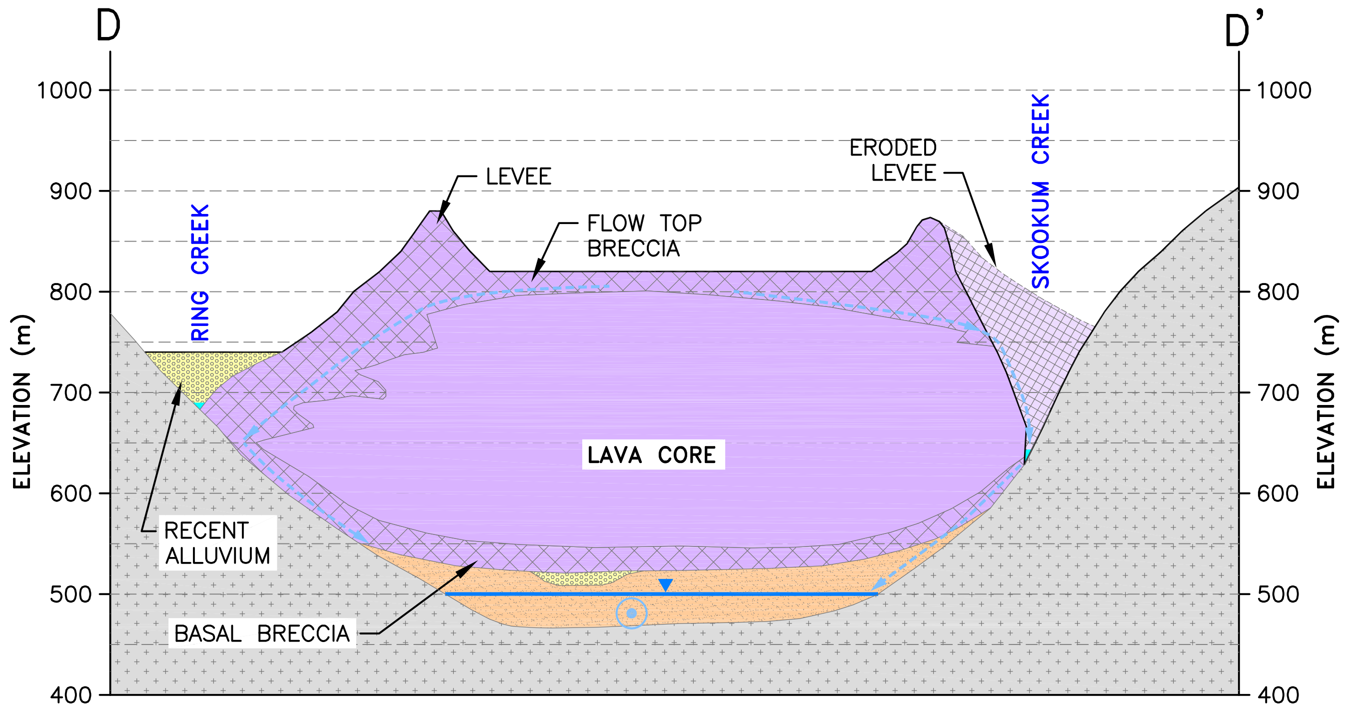
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

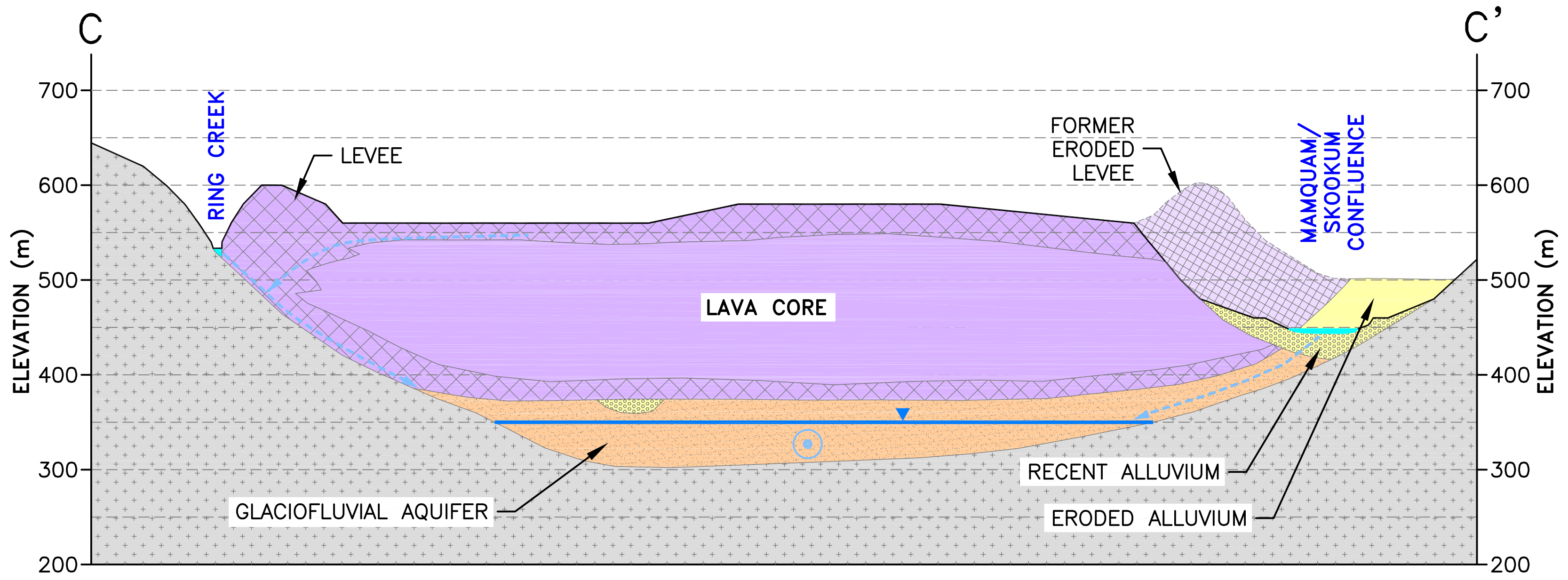
WELL FIELD SITE PLAN AND HYDROGEOLOGIC SECTION A-A'

BY: KT/lf	DATE: JAN 13
APPROVED: KT	FIG: 5

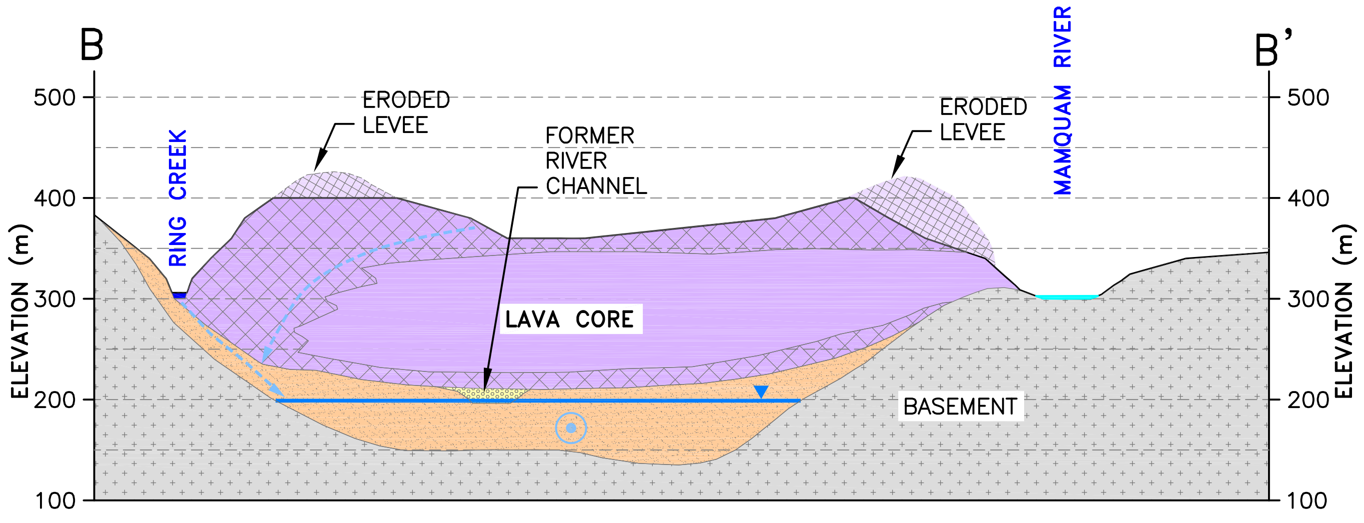
DWG. NUMBER: K:\2841\Cadd\2841-003.dwg (Fig 6)



SECTION D–D'



SECTION C–C'



SECTION B–B'

LEGEND

▨ LAVA ROCK (ERODED/MASSIVE/BRECCIATED)

▨ ALLUVIAL SEDIMENTS (ERODED/RECENT)

▨ GLACIOFLUVIAL SEDIMENTS (ERODED/RECENT)

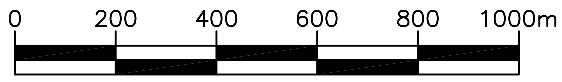
▨ BASEMENT ROCK

▼ INFERRED AQUIFER GROUNDWATER ELEVATION

↓ INFERRED GROUNDWATER RECHARGE PATHWAY

⊙ INFERRED DIRECTION OF GROUNDWATER FLOW (OUT OF PAGE)

NOTE: SEE SECTION LOCATION ON FIG. 2.



SCALE 1:15000

2X VERTICAL EXAGGERATION

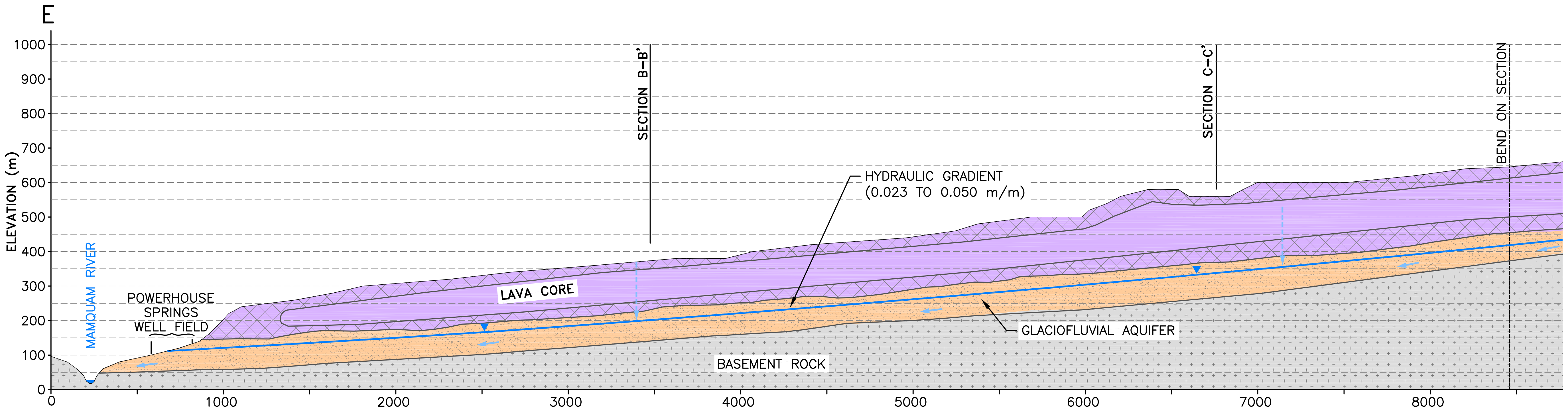
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

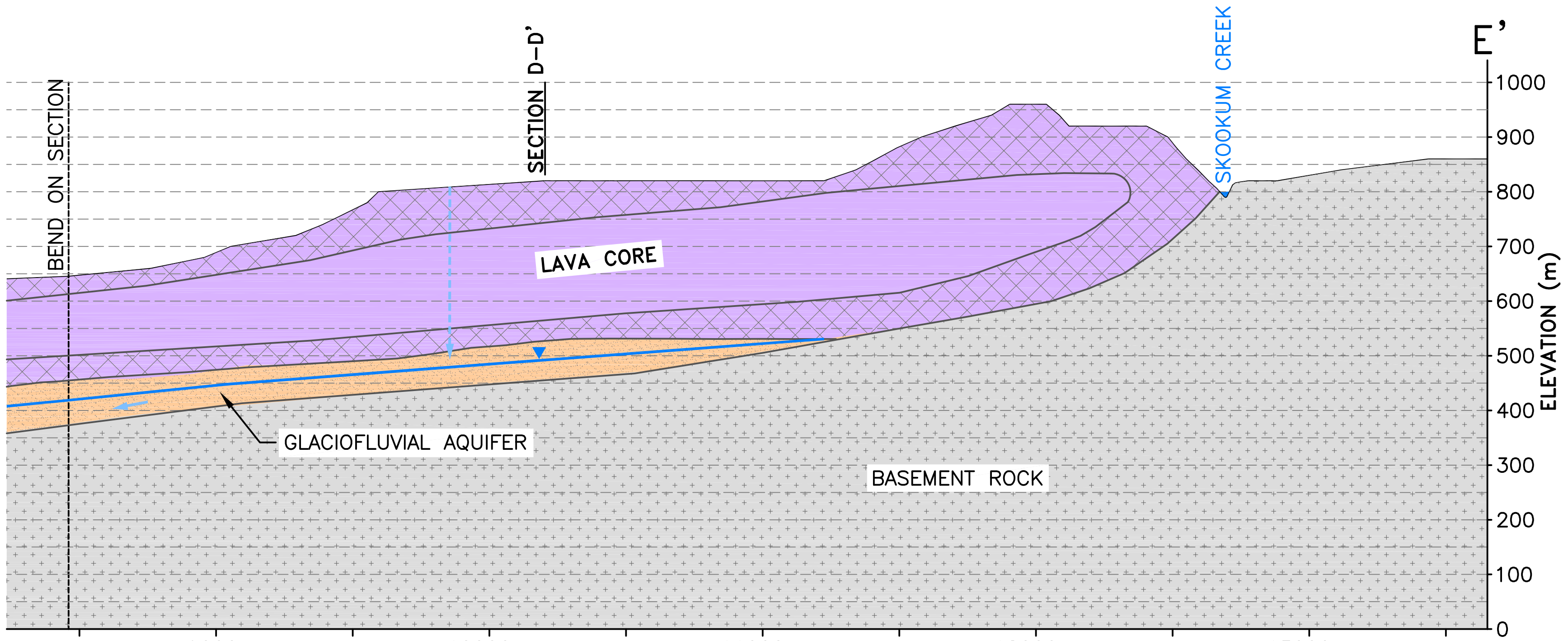
HYDROGEOLOGIC SECTIONS B-B', C-C' AND D-D'

BY: KT/lf
DATE: JAN 13
APPROVED: KT
FIG: 6

DWG. NUMBER: K:\2841\Cadd\2841-003.dwg (Fig 7)



SECTION E–E'



SECTION E–E' (cont.)

NOTE: SEE SECTION LOCATION ON FIG. 2.

LEGEND

- ▨ LAVA ROCK (MASSIVE/BRECCIATED)
- ▨ GLACIOFLUVIAL SEDIMENTS
- ▨ BASEMENT ROCK
- ▼ INFERRED AQUIFER GROUNDWATER ELEVATION
- ⇣ INFERRED GROUNDWATER RECHARGE PATHWAY
- ← INFERRED DIRECTION OF GROUNDWATER FLOW

0 200 400 600 800 1000m

SCALE 1:25000

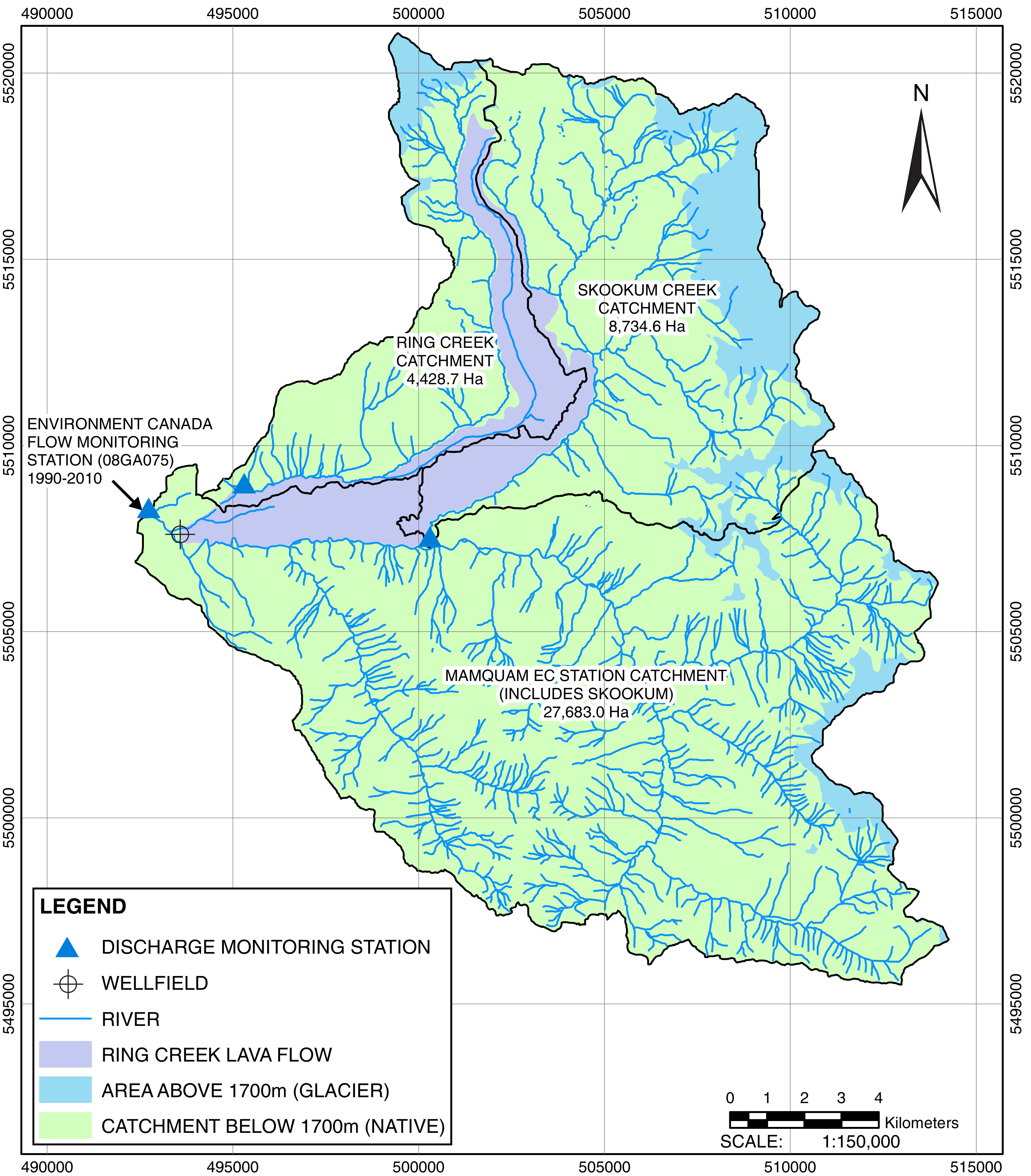
2X VERTICAL EXAGGERATION

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGIC SECTION E-E'

BY: KT/lf
DATE: JAN 13
APPROVED: KT
FIG: 7



DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT
FOR WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

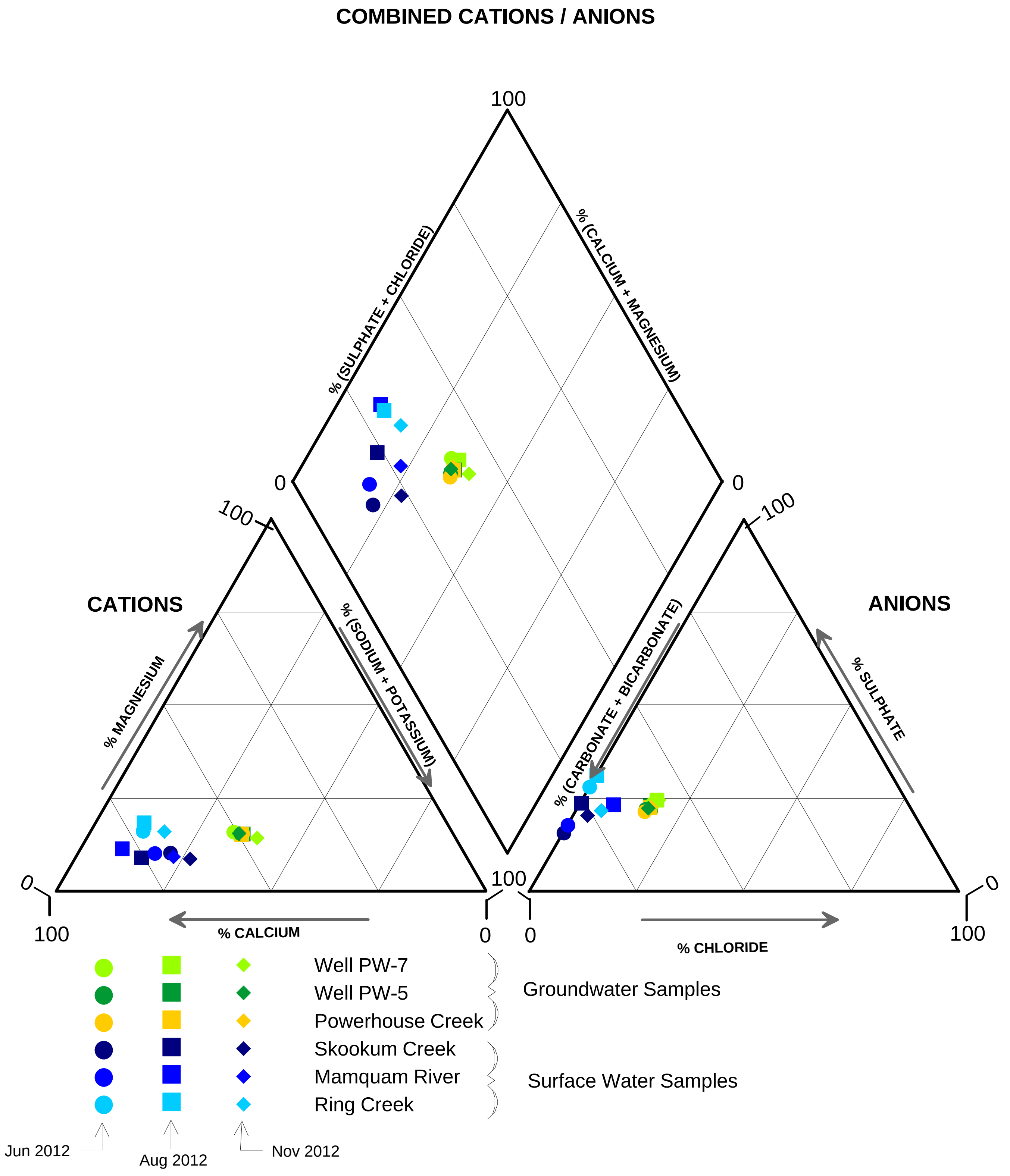
PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

WATERSHED CATCHMENT AREAS

BY: JM	DATE: JAN 13
APPROVED: KT	FIG: 8

H:\Project\2841\ArcMaps\Water_Balance_Catchments.mxd

H:\Project\2841\Analytical\Piper Plots\Piperplot Squamish.grf



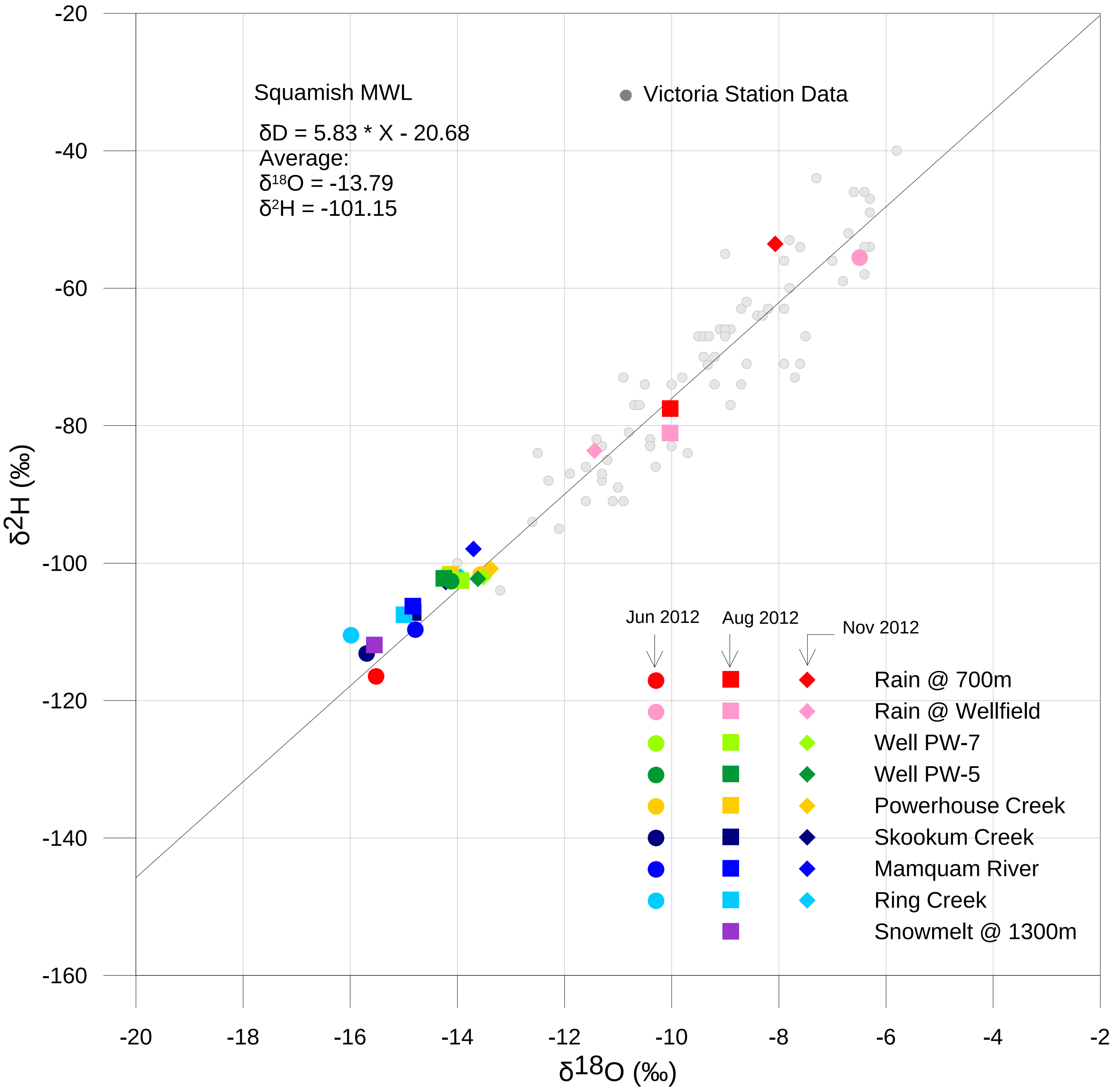
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

PIPER PLOT OF GROUNDWATER AND SURFACE WATER CHEMISTRY

BY: KT / DT	DATE: JAN 13
APPROVED: KT	FIG: 9

H:/Project/2841/Analytical/Isotopic Results/Victoria MWL.grf



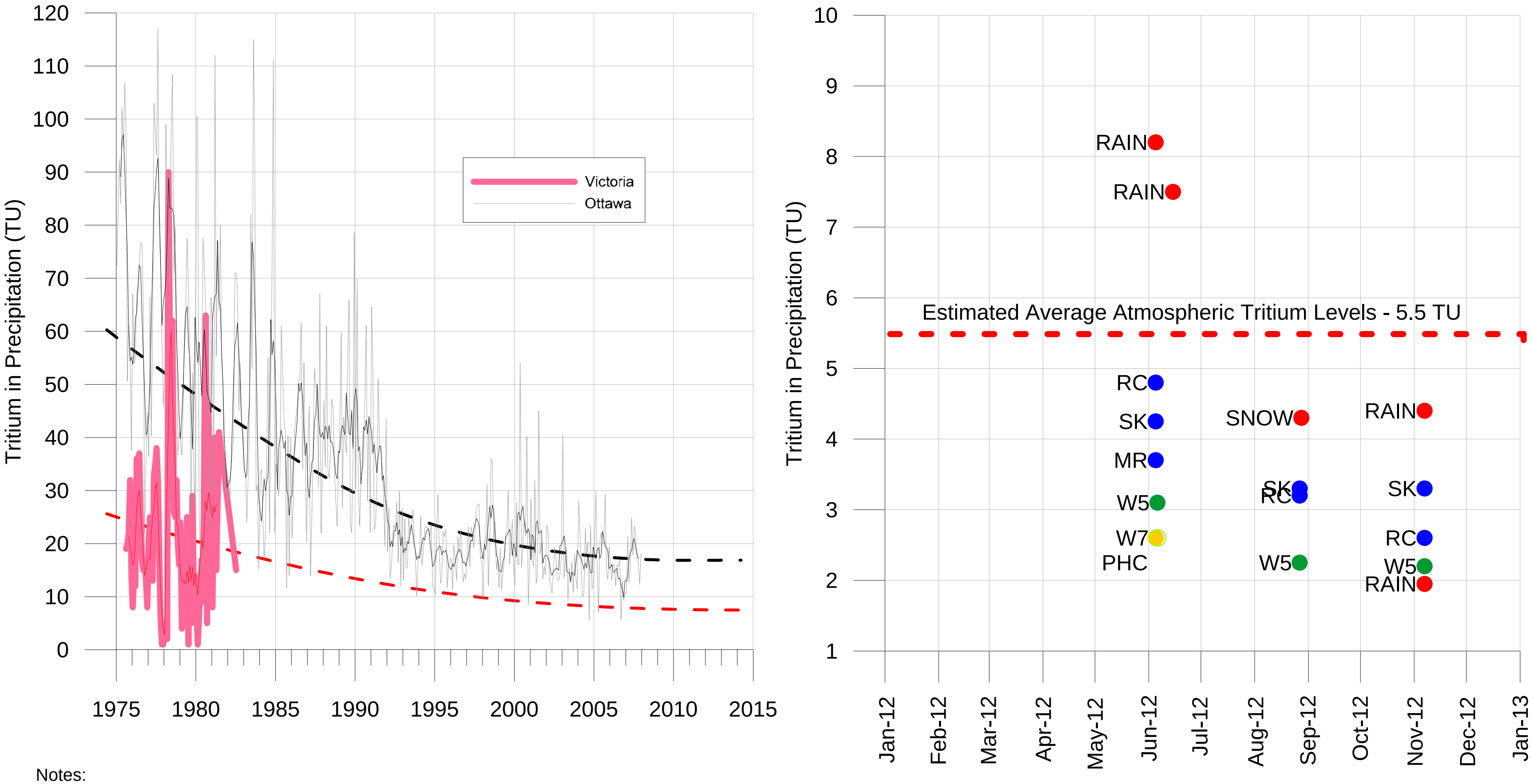
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

δ^{2}H and δ^{18}O IN GROUNDWATER, SURFACE WATER, AND PRECIPITATION

BY: EP
DATE: JAN 13
APPROVED: KT
FIG: 10

H:/Project/2841/Analytical/IsotopicResults/TritiumTrends.grf



Notes:
1. Historic Tritium data for Ottawa and Victoria stations obtained from IAEA archives
2. Current Tritium levels in Squamish area extrapolated from long-term trends and levels measured during this investigtaion.

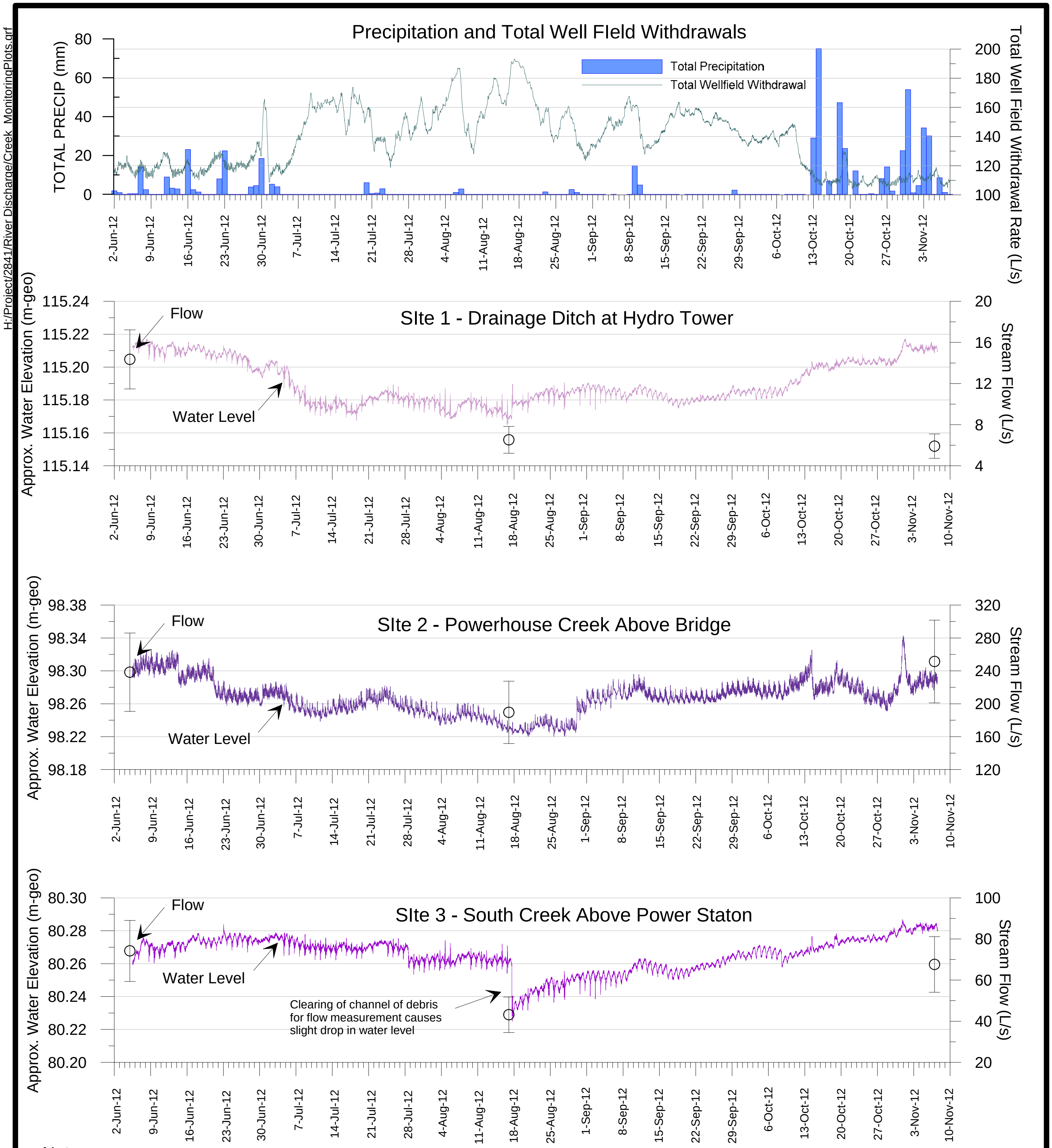
RC = RING CREEK
SK = SKOOKUM CREEK
MR = MAMQUAM RIVER
PHC = POWERHOUSE CREEK
W7 = WELL PW-7
W5 = WELL PW-5

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

TRITIUM CONCENTRATIONS AND TRENDS IN GROUNDWATER, SURFACE WATER AND PRECIPITATION

BY: KT
DATE: JAN 13
APPROVED: KT
FIG: 11



Note:
1. Precipitation measured at Environment Canada's "Squamish Auto" climate station (elevation: 52m)

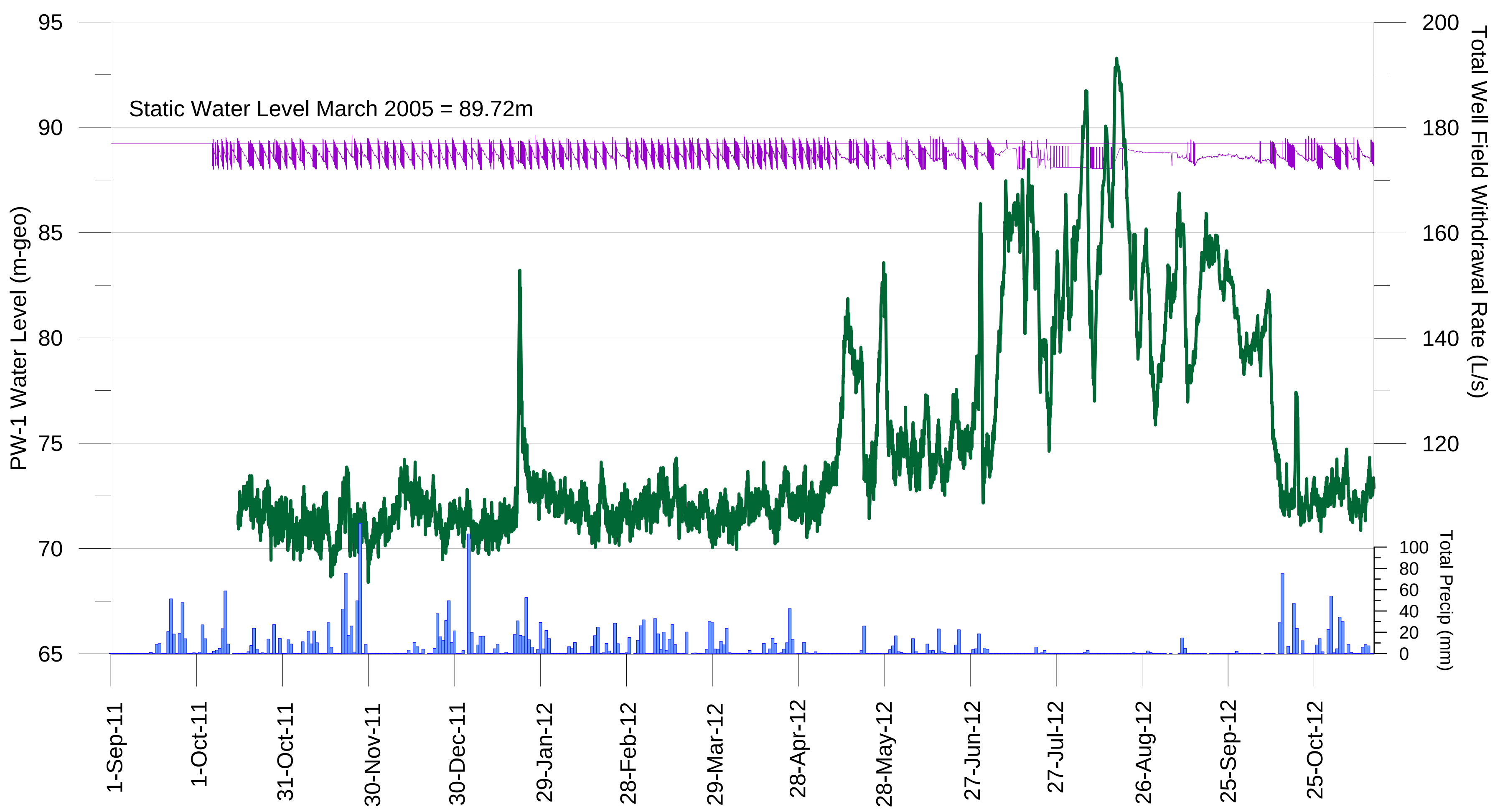
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

SURFACE WATER LEVEL AND DISCHARGE SUMMARY

BY: EP
DATE: JAN 13
APPROVED: KT
FIG: 12

H:/Project/2841/SCADA/WaterLevels_Withdrawals_Precip.grf



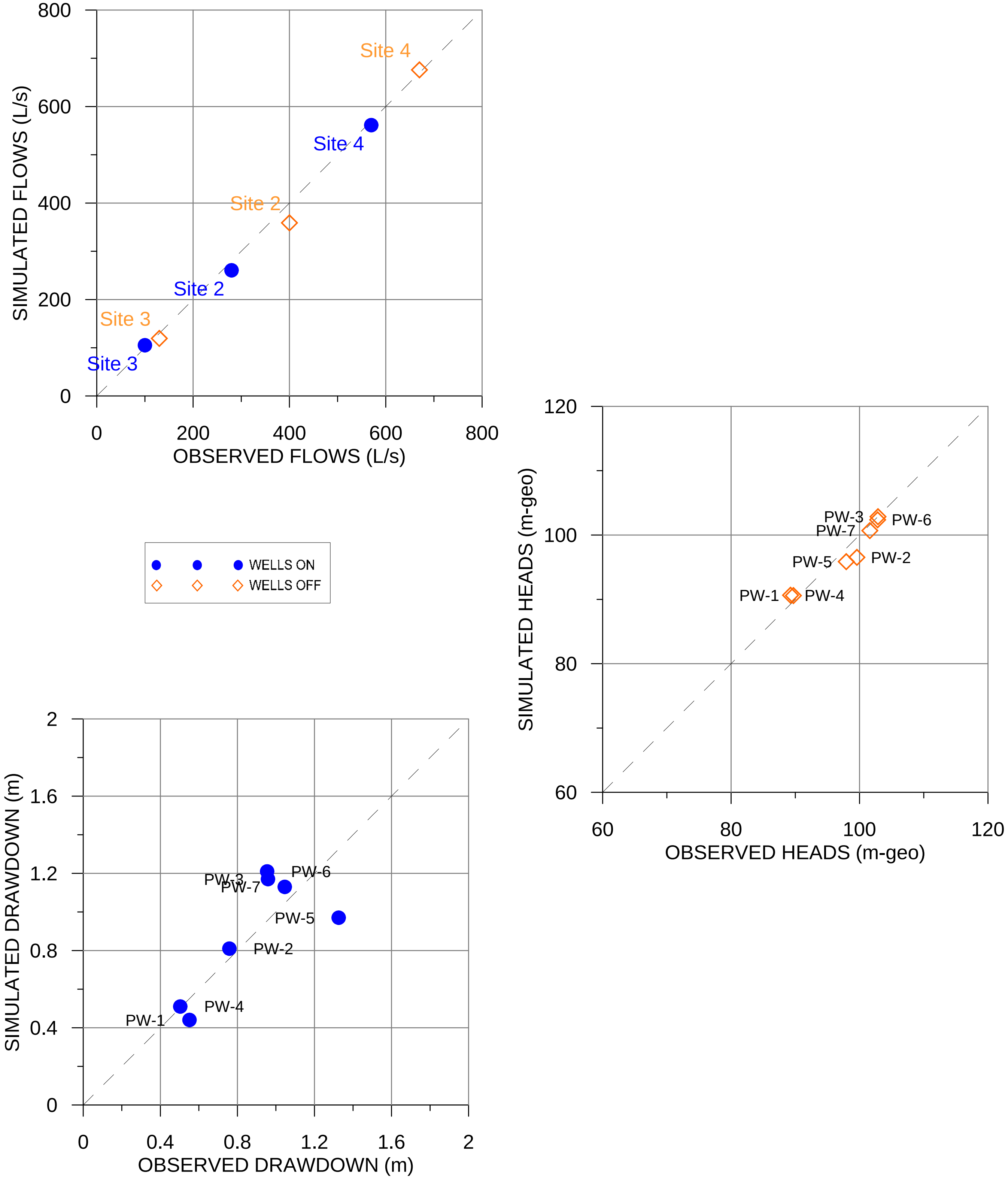
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

ONE-YEAR RECORD OF WELL WATER LEVELS, WELL FIELD WITHDRAWALS, AND PRECIPITATION

BY: KT	DATE: JAN 13
APPROVED: KT	FIG: 13

H:/Project/2841/Vistas/CalibrationPlot.grf



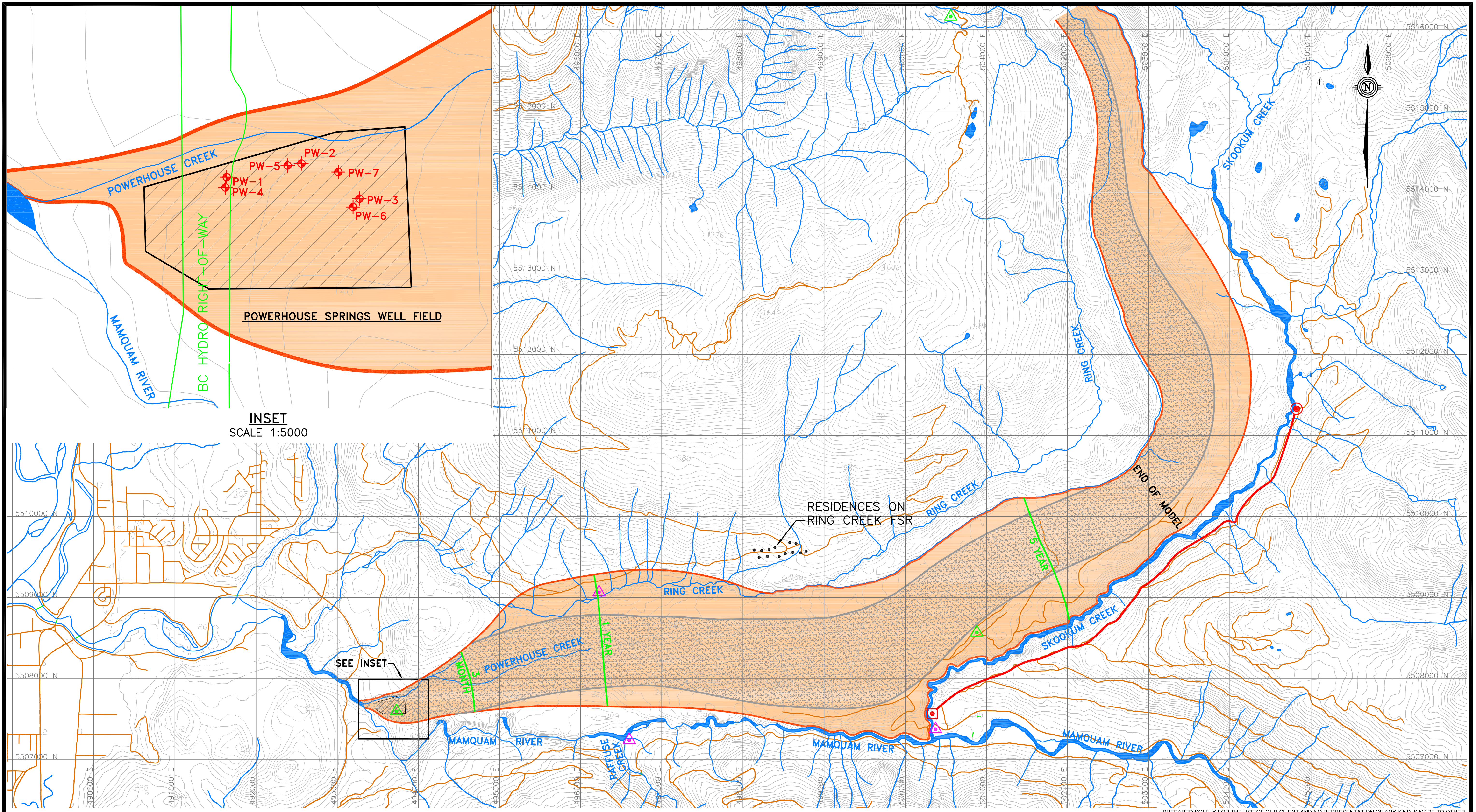
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

NUMERICAL MODEL CALIBRATION RESULTS

BY: JM/KT	DATE: JAN 13
APPROVED: KT	FIG: 14

DWG. NUMBER: K:\2841\Cadd\2841-013.dwg (Fig 15)



PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ASSOCIATES ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

LEGEND

🟧	ESTIMATED EXTENT OF PALEO-CHANNEL SEDIMENTS
▨	ESTIMATED EXTENT OF SATURATED AQUIFER (MODELLED AQUIFER LIMITS)
1 YEAR	ESTIMATED CAPTURE ZONE BOUNDARY FOR GIVEN GROUNDWATER TRAVELTIME
—	LOGGING ROADS
—	WATERCOURSES
△	SURFACE WATER SAMPLING STATION
△	RAIN/SNOWMELT SAMPLING STATION
▣	PLANNED SPP PUMP HOUSE
◉	PLANNED SPP INTAKE
—	PLANNED SPP PENSTOCK ROUTE

0 400 800 1200 1600 2000m

SCALE 1:45,000

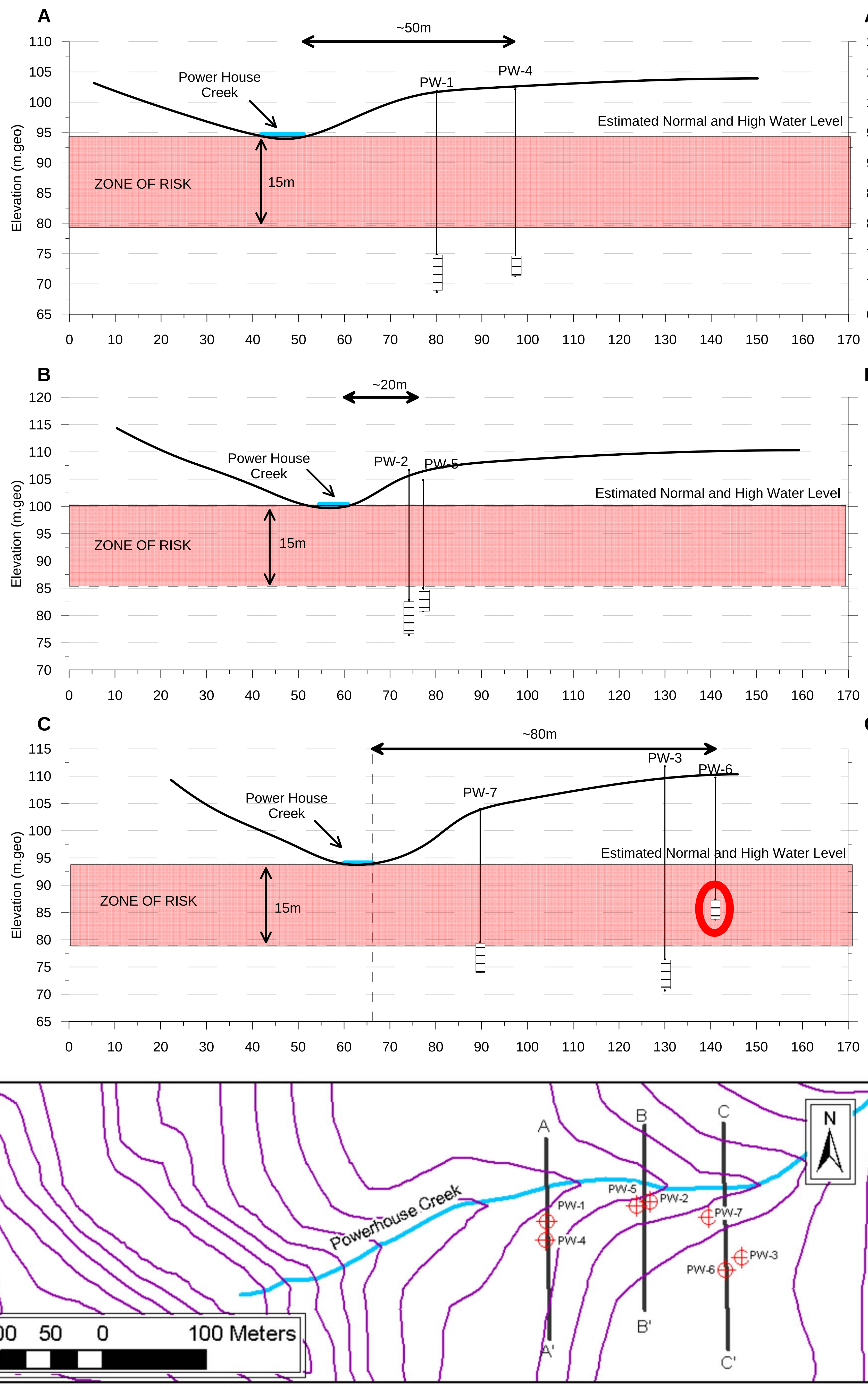
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

WELL FIELD CAPTURE ZONE AND CURRENT LAND USE INFORMATION

BY: KT/lf
DATE: NOV 13
APPROVED: KT
FIG: 15

H:\Project\2841\GARP\GE_Analysis.grf



PREPARED SOLELY FOR THE USE OF OUR CLIENT AND NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ASSOCIATES ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

NOTE: Locations and elevations are approximate.

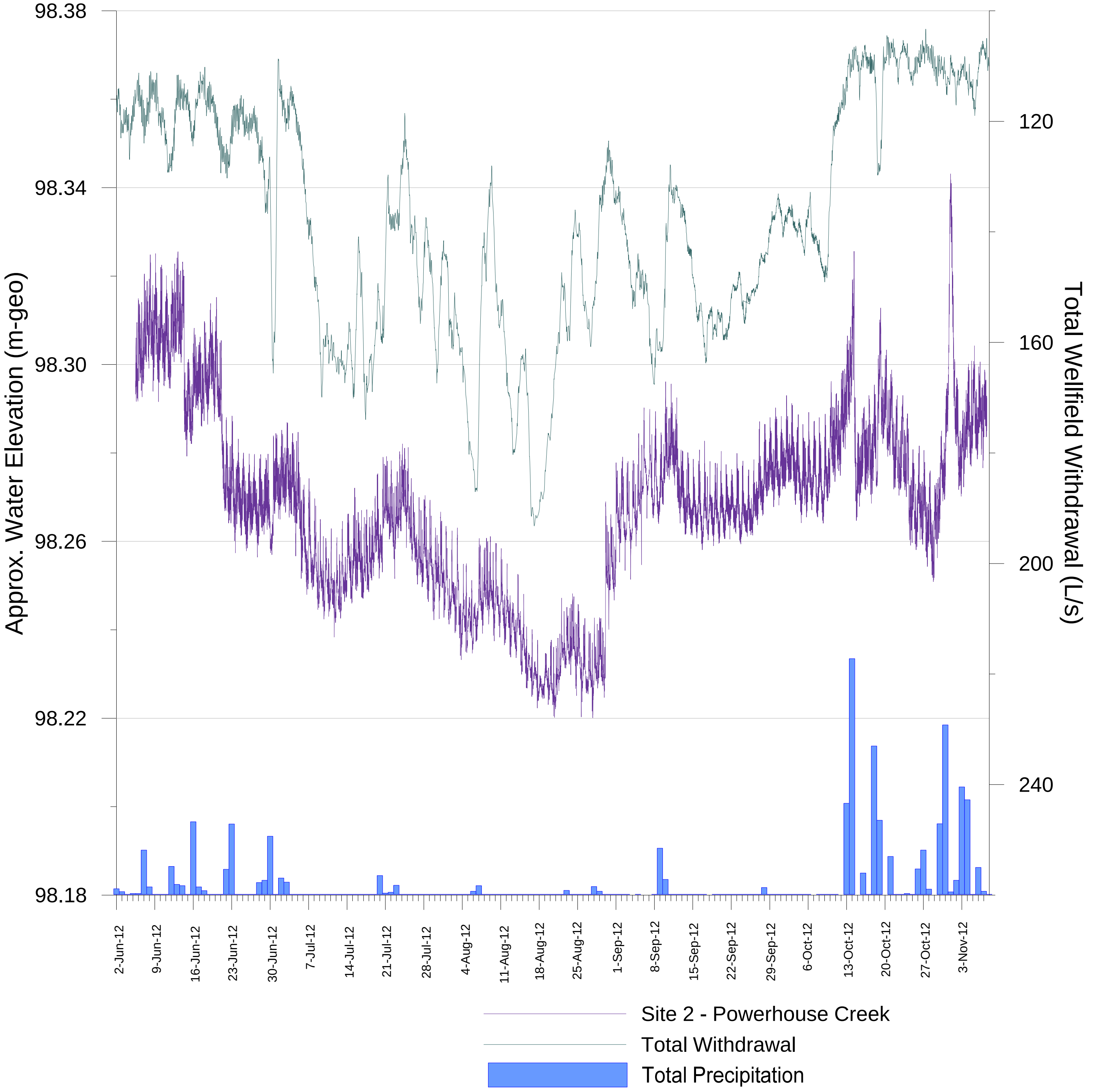
DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR WELL PROTECTION
PLAN, POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

SECTIONS FOR EVALUATING WELL SUSCEPTIBILITY TO GARP

BY: BD	DATE: NOV 13
APPROVED: KCT	FIG: 16

H:/Project/2841/GARP/GARP_CreekLevels&WellWithdrawals.grf



Note:
1. Precipitation measured at Environment Canada's "Squamish Auto" climate station (elevation: 52m)

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

RELATIONSHIP BETWEEN POWERHOUSE CREEK WATER LEVELS AND TOTAL WELL FIELD WITHDRAWALS

BY: KT
DATE: JAN 13
APPROVED: KT
FIG: 17

PHOTOS

Photo 1.
Outcrop of granitic basement rock on Mamquam FSR (June 5, 2012).

Photo 2.
Exposed glaciofluvial sediments on north side of Ring Creek FSR (August 27, 2012).

Photo 3.
Paleochannel glaciofluvial sediments at toe of Ring Creek Lava Flow (June 15, 2012).

Photo 4.
Looking north to thick lava flow sequence exposed above Mamquam River from Mamquam FSR (June 15, 2012).

Photo 5.
Blocky top surface of upper portion of Ring Creek Lava Flow (June 15, 2012).

Photo 6.
Steep blocky lateral flow breccias on south levee of Ring Creek Lava Flow (June 15, 2012).

Photo 7.
Confluence of Skookum Creek (viewer's left) and Mamquam River (viewer's right) (June 15, 2012).

Photo 8.
Alluvial sediments upstream of confluence of Skookum Creek with Mamquam River (August 17, 2012).

Photo 9.
Contact between granitic basement rock (viewer's left) and Ring Creek Lava Flow (viewer's right) at the Upper Mamquam hydroelectric facility (November 7, 2012).

Photo 10.
Powerhouse Creek above confluence with Mamquam River (Site 4) (May 24, 2012).

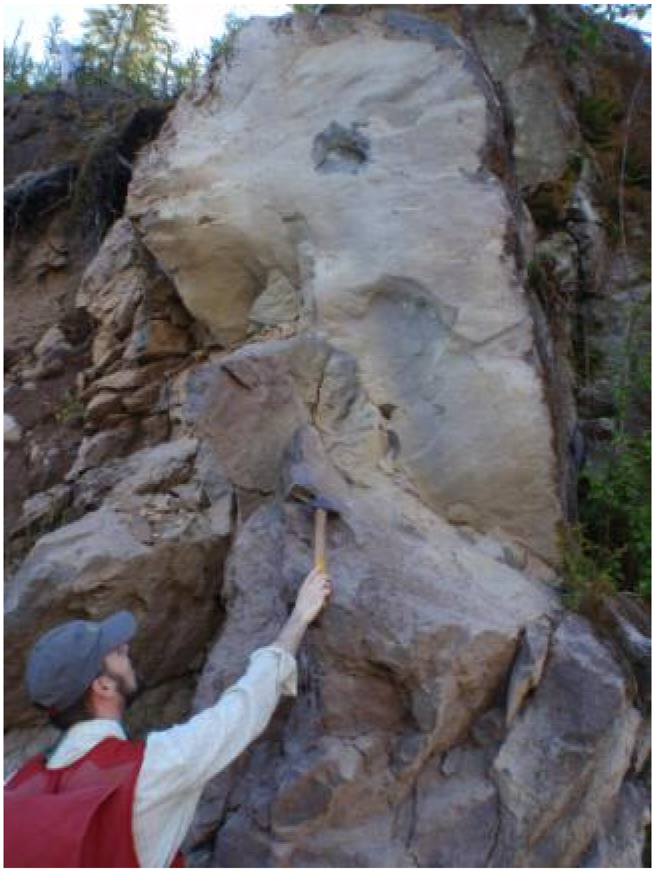


Photo 11.
Weakly jointed and massive core of Ring Creek Lava Flow (June 15, 2012).

Photo 12.
Highly jointed lava rock pre-dating Ring Creek Lava Flow southeast of confluence of Skookum Creek with Mamquam River (June 15, 2012).

APPENDIX A

WELL CONSTRUCTION LOGS

\\hera\project\Project\2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]PW99-01

PW-1

HYDROGEOLOGIC LOG

PURPOSE OF HOLE: PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
DRILLING CONTRACTOR: PERRY'S WELL DRILLING
DATE DRILLED: DECEMBER 17, 1998 TO JANUARY 1999
GROUND ELEVATION: 102.33m-geod.
STEEL CASING STICK UP: 0.58m

WELL I.D. PLATE NU.: 798
WELL TAG NU.: 79159
GROUND ELEVATION: 102.33m-geod.
APPROX. ELEVATION T.O.C.: 102.9m-geod.
DEPTH TO WATER: 12.2m
ELEVATION OF WATER: 90.1m

Depth (m)	Aproximate Elevation (m-geod.)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	
0.0	102.3	*Ground surface*	*Depth*
	99.3	Coarse SAND and GRAVEL, trace fine sand Excavated by backhoe.	3.0
5.0 10.0	89.2	Med-crse SAND and GRAVEL, trace fine sand, some silt to silty, frequent boulders	13.1
15.0	87.7	Water bearing SAND and GRAVEL	14.6
20.0	78.8	Med-crse SAND and GRAVEL, trace fine sand, silty to some silt (layered)	23.5
25.0 30.0	72.3	Med-crse gravelly SAND, some fine sand	30.0
	70.9	Fine-crse SAND, trace to some gravel	31.4
	69.1	Med-crse gravelly SAND, some fine sand	33.2
35.0	68.0	Fine Sand and SILT, some gravel	34.3
40.0 45.0		End of Hole NOTE: Shaded zones are considered to be aquitards, or partially confining layers.	

WELL CONSTRUCTION MATERIALS

500mm surface casing withdrawn after grouting

Bentonite grout

387.4mm I.D. steel casing left with 0.58m stickup

SWL = 12.2m
=90.1m-geod

400mm (333mm I.D.)
TELESCOPIC SCREEN ASSEMBLY

400mm K-Packer

300mm x 400mm telescopic riser

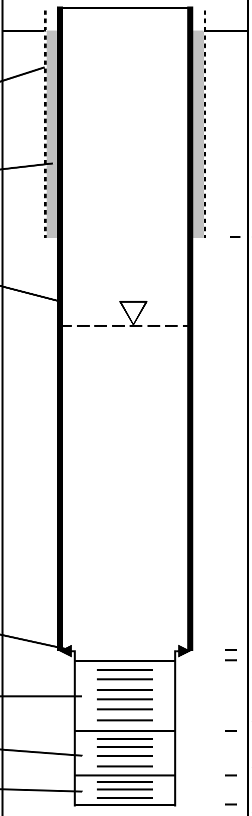
3.05m of 3.7mm slot (0.150")

1.83m of 0.5mm slot (0.020")

1.22m of 3.7mm slot (0.150")

400mm telescopic bail bottom

Well Diagram



Completion Depths (m)

8.7
26.5
27.0
30.1
32.0
33.2

DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-1

BY:	DATE:
ATH/MDP	FEB 99
APPROVED:	FIG:
	A-1

\\hera\project\Project\2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]PW00-02

PW-2

HYDROGEOLOGIC LOG

PURPOSE OF HOLE: PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
DRILLING CONTRACTOR: PERRY'S WELL DRILLING
DATE DRILLED: OCTOBER / NOVEMBER 2000
GROUND ELEVATION: 105.7m-geod.
STEEL CASING STICK UP: 0.65m

WELL I.D. PLATE NU.:
WELL TAG NU.: **83609?**
APPROX. ELEVATION T.O.C.: 106.35m-geod.
DEPTH TO WATER: 6.41m November 27, 2000
ELEVATION OF WATER: 99.94m

Depth (m): 0.0, 5.0, 10.0, 15.0, 20.0, 25.0, 30.0, 35.0, 40.0, 45.0

Depth (m)	Aproximate Elevation (m-geod.)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	
0.0	105.7	*Ground surface*	*Depth*
		Silt, Sand, Gravel (Till), water bearing below 2.4m	9.1
	96.6	Gravelly fine-crse SAND with frequent boulders	15.5
	90.2	Silty SAND and GRAVEL with some cobbles	18.9
	86.8	SAND and GRAVEL with some cobbles and trace silt; some lenses of packed silt	24.4
	81.30	Fine-crse SAND and fine-crse GRAVEL with some cobbles	
	74.80	Fine-crse SAND, trace to some gravel	30.9
	72.20	Fine to medium SAND with trace gravel and silt	33.5
		End of Hole	

NOTE: Shaded zones are considered to be partially confining layers.

WELL CONSTRUCTION MATERIALS

500mm surface casing withdrawn after grouting

Bentonite grout
Static Water Level = 99.94 m-geod..

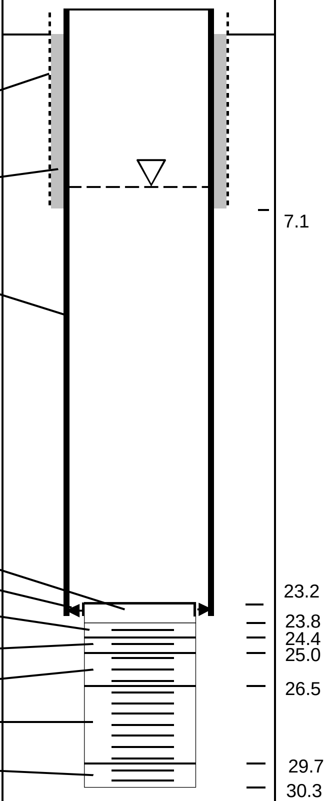
387.4mm I.D. steel casing left with 0.62m stickup

400mm (333mm I.D.)
TELESCOPIC SCREEN ASSEMBLY

0.6m Riser
400mm K-Packer
0.61m of 2.5mm slot (0.100")
0.61m of 4.1mm slot (0.160")
1.52m of 4.6mm slot (0.180")
3.20m of 3.8mm slot (150")
0.61m of 2.5mm slot (0.100")

400mm telescopic bail bottom

Well Diagram



DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-2

BY: ATH/BCM
DATE: DEC 00
APPROVED:
FIG: A-2

\hera\project\Project\2841\Well Records\Well Logs - PW-1 to PW-7.xlsx]PW00-03

PW-3

HYDROGEOLOGIC LOG

PURPOSE OF HOLE: PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
DRILLING CONTRACTOR: PERRY'S WELL DRILLING
DATE CONSTRUCTED: SEPTEMBER / OCTOBER 2000
GROUND ELEVATION: 109.3 m-geod. (approximate)
STEEL CASING STICK UP: 0.62m

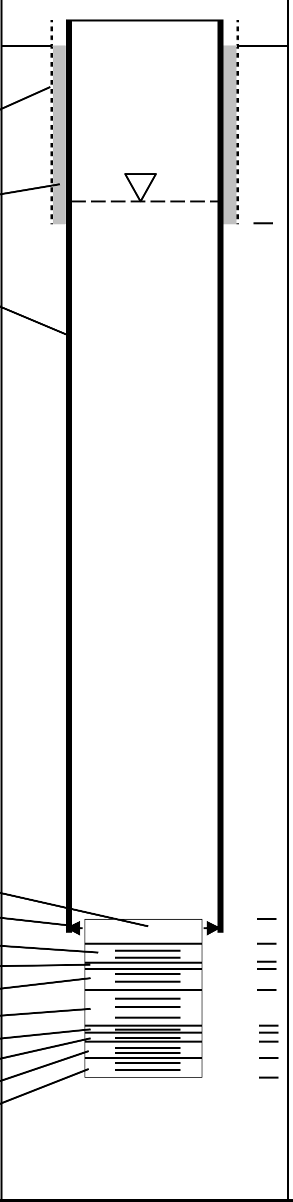
WELL I.D. PLATE NU.:
WELL TAG NU.: 83608 (?)
APPROX. ELEVATION T.O.C.: 109.92 m-geod.
DEPTH TO WATER: 6.63 m November 27, 2000
ELEVATION OF WATER: 103.29 m-geod.

Depth (m)	Aproximate Elevation (m-geod.)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	
0.0	109.3	*Ground surface*	*Depth*
	83.4	Grey, well-graded fine SAND to coarse GRAVEL, some cobbles and boulders, some red particles, sub-angular to sub-rounded clasts, some till layers.	25.9
	82.3	Silty fine to coarse SAND with some gravel	27.0
	74.6	Grey fine-medium SAND, some silt to silty, layered.	34.7
	68.8	Grey well-graded SAND, some fine-coarse gravel.	40.5
	68.2	Well-graded fine SAND to coarse GRAVEL.	41.1
	67.3	Coarse SAND and GRAVEL, v. dense, some fines.	42.0
		End of Hole NOTE: Shaded zones are considered to be partially confining layers.	

WELL CONSTRUCTION MATERIALS

500mm surface casing withdrawn after grouting
Bentonite grout
Static Water Level = 103.29 m-geod.
387.4mm I.D. steel casing left with 0.6m stickup
400mm (333mm I.D.)
TELESCOPIC SCREEN ASSEMBLY
0.6m Riser
400mm K-Packer
1.4m of 2.0mm slot (0.080")
0.3m of 2.5mm slot (0.100")
0.9m of 3.6mm slot (0.140")
1.2m of 1.8mm slot (0.070")
0.3m of 2.5mm slot (0.100")
0.5m of 3.6mm slot (0.140")
0.6m of 2.0mm slot (0.080")
0.6m of 3.6mm slot (0.140")
400mm telescopic bail bottom

Well Diagram



Sample depths (m)

7.0
34.7
35.4
36.7
37.0
37.9
39.2
39.5
39.9
40.5
41.1

DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-3

BY: ATH/MDP
DATE: DEC 00
APPROVED:
FIG: A-3

\\hera\project\Project\2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]PW97-1(1)

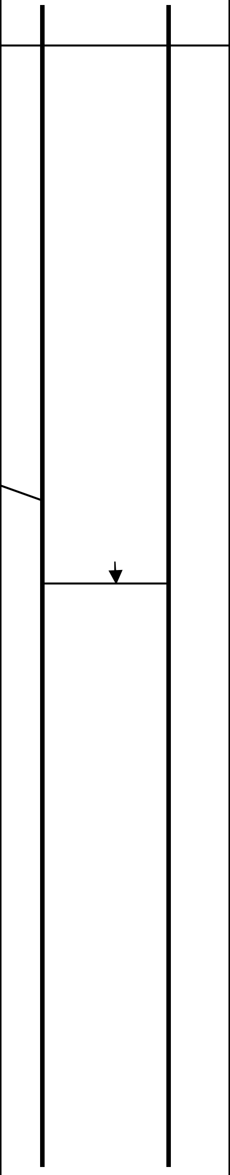
PW-4
(p. 1 of 2)

HYDROGEOLOGIC LOG
PURPOSE OF HOLE: TEST PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
DRILLING CONTRACTOR: PERRY'S WELL DRILLING
DATE DRILLED: DEC 09 - 16, 1997
GROUND ELEVATION (m): 100.00m (estimated from map)

WELL I.D. PLATE NU.:
WELL TAG NU.: 78368
ELEV. TOP OF STEEL CASING: 100.38 m-geod
DEPTH TO WATER (11-DEC-97): 12.84 m-btoc
ELEVATION OF WATER: 87.58 m-geod

Depth (m)	Elev.(m)	**DESCRIPTION OF LITHOLOGY ENCOUNTERED**	**WELL CONSTRUCTION MATERIALS**	**Sample depths (m)**
0.0	100.00	*Ground surface*		
1.0		ROCKS and BOULDERS, grey matrix		
2.0				
3.0		ROCKS and GRAVEL, grey matrix		
4.0	95.43			
5.0	94.36	BOULDER		
6.0				
7.0				
8.0		COBBLES, co. GRAVEL, and co. SAND	203.2mm diam steel casing 0.38m stickup - 35.66m	
9.0				
10.0				
11.0				
12.0	87.81			12.19
13.0	86.28	Grey, med.-co. sandy GRAVEL with tr. f. sand, clasts are subangular to subround		
14.0				
15.0	84.46	Grey, med.-co. SAND with some f.-med. GRAVEL		15.24
16.0		Grey, SAND with some f.-med. gravel		16.15
17.0	83.24			
	82.32	Grey, well graded SAND and GRAVEL		17.37
18.0	81.41	Grey, f.-med. SAND with some co. sand to med. gravel		18.29
19.0	80.49	f.-med. SAND and GRAVEL with some f. sand, clasts are subround to round		19.20
20.0	79.58	f.-med. SAND, some co. sand, tr. f.-med gravel		19.81
21.0	78.66	Grey, f.-med. SAND with some co. sand		21.03
22.0	77.75	f.-med. GRAVEL with some med.-co. sand, trace f. sand, subround to round clasts		21.95
		med. SAND to f. GRAVEL with some f. sand		22.56
23.0	77.14			
		Grey, f.-co. SAND with tr. f. gravel	Note: All elevations are relative to an assumed datum	23.47
24.0	76.23			
				24.38

Well Diagram



DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-4

BY:	DATE:
ATH/MDP	FEB 99
APPROVED:	FIG:
	A-4

\hera\project\Project\2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]PW97-1 (2)

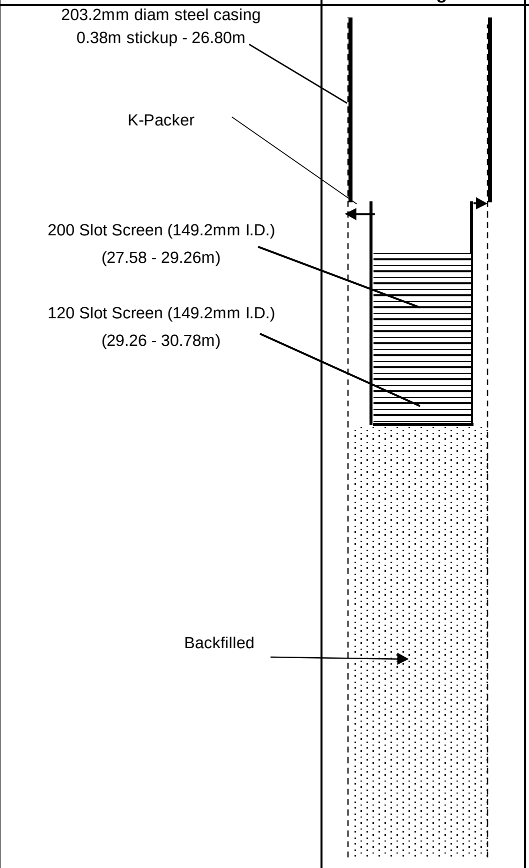
PW-4
(p. 2 of 2)

HYDROGEOLOGIC LOG
PURPOSE OF HOLE: MONITORING WELL
TYPE OF RIG: CABLE TOOL
DRILLING CONTRACTOR: PERRY'S WELL DRILLING
DATE DRILLED: DEC 09 - 16, 1997
GROUND ELEVATION (m): 100.00m (estimated from map)

WELL I.D. PLATE NU.:
WELL TAG NU.: 78368
ELEV. TOP OF STEEL CASING: 100.38 m-geod
DEPTH TO WATER (11-DEC-97): 12.84 m-btoc
ELEVATION OF WATER: 87.58 m-geod

Depth (m)	Elev.(m)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	Sample depths (m)
24.0	76.23		
	75.31	f.-co. SAND with some f. gravel, tr. med. gravel	24.38
25.0		f.-med. GRAVEL with some med. sand, round	
	74.40	to subround clasts	25.30
26.0		Grey, med. SAND and f.-med. GRAVEL with	25.91
	73.79	some med. sand, sand is SA-SR, grav. is SR-R	
27.0	72.87	med. SAND & f-med. GRAVEL, some f.-co. sand	26.82
	72.26	Grey, f.-co. SAND, some f.-med. gravel, R-SR	27.43
28.0		Grey, co. SAND with some f.-med. sand & some	28.04
	71.65	f. gravel	28.65
29.0	71.04	f.-med. SAND & f.-med GRAVEL, some co. sand	
		Grey, co. SAND with some f.-med. sand & some	29.57
30.0	70.13	med. gravel, round to subround, sand is angular	
	69.22	Grey, med.-co. SAND with some f. sand	30.48
31.0		med. SAND with some f. and co. sand and some	
	68.30	f. gravel	31.39
32.0		Grey, uniform f. SAND	32.00
	67.39		
33.0		Grey, f.-med. SAND with some co. SAND to	
	66.17	med. gravel	33.53
34.0		Grey, f.-med. SAND with some f. gravel, tr. med.	34.14
	65.56	gravel	34.75
35.0	64.95	f.-med. SAND with some f. gravel, tr. med. gravel	
		f.-med. SAND with some co. sand to f. gravel, tr.	35.36
36.0	64.34	med. gravel	35.97
	63.73	Well gr. SAND & f. GRAVEL, some med. gravel	36.58
37.0	63.12	f.-med. SAND, some co. sand to fine gravel, SR	37.19
	62.51	Grey, SAND with some f. gravel, tr. med. gravel	
38.0	61.90	Well graded SAND and f.-med. GRAVEL	37.80
	61.29	f.-med. SAND & f.-med. GRAVEL, some co. sand	38.40
39.0		Grey, f. sand with some med. sand and f. gravel,	39.01
	60.38	tr. co. sand, subround to round clasts	
40.0		End of Hole	
41.0			
42.0			
43.0			
44.0			
45.0			
46.0			
47.0			
48.0			

WELL CONSTRUCTION MATERIALS | **Well Diagram**



Note: Shading denotes dense layers with trace clay which are less permeable than other sediments

Note: All elevations are relative to an assumed datum

DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-4

BY: ATH/MDP
DATE: FEB 99
APPROVED:
FIG: A-4

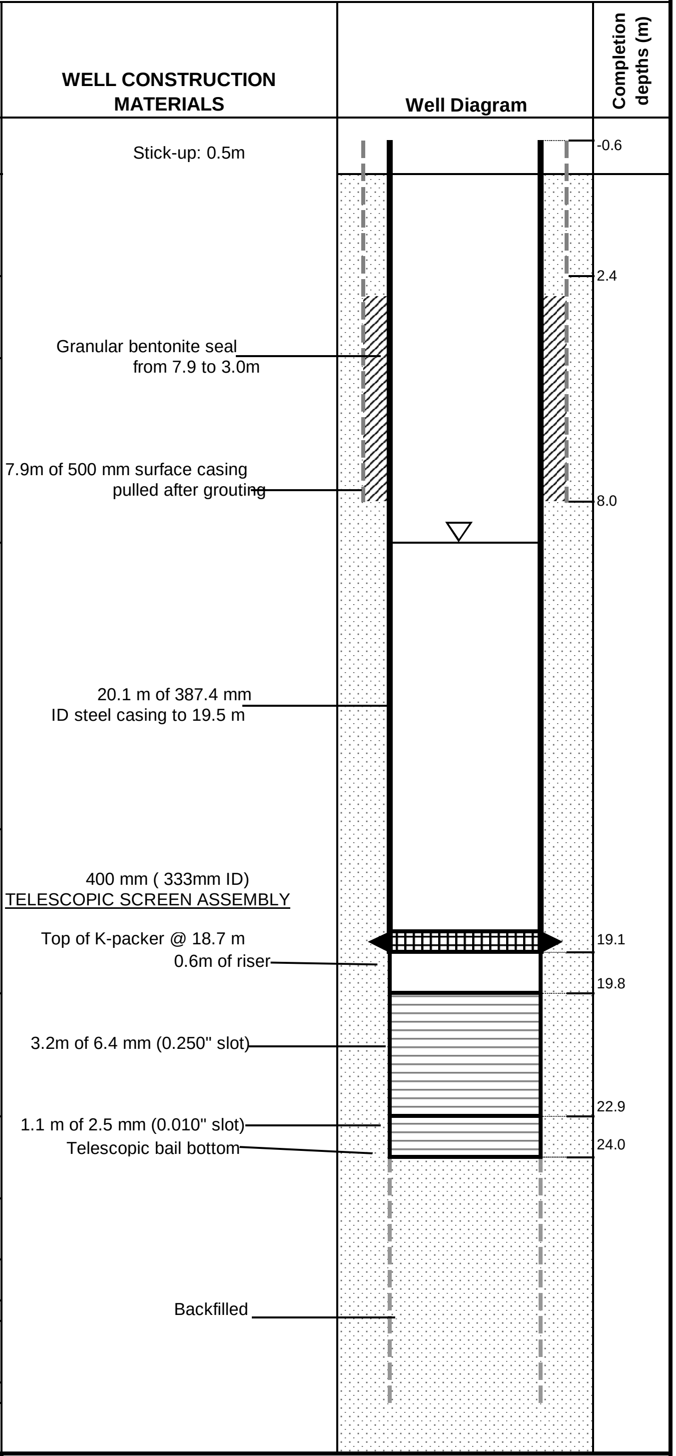
\hera\project\Project\2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]P\

PW-5

HYDROGEOLOGIC LOG
PURPOSE OF HOLE: PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
CONTRACTOR: COLUMBIA WATER WELLS (1986) Ltd.
DATE DRILLED: MAY 02 - 15, 2006
GROUND ELEVATION (m): 105.79

WELL I.D. PLATE NU.: 14957
WELL TAG NU.:
ELEV. TOP OF STEEL CASING: 106.46 m-geod
DEPTH TO WATER WHILE PW-1,2,3,4, PUMPING (17-MAY-06) : 9.1 m-btoc
ELEVATION OF WATER: 97.4 m-geod

Depth (m) ft	m	Elev. (m)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	Depth (m)
		105.8	*Ground surface*	
8	2.4	103.4	Cobble boulder coarse GRAVEL brown rusty wash	2.4
15	4.6	101.2	Coarse GRAVEL, cobbles water	4.6
30	9.1	96.6	GRAVEL, cobbles cleaner	9.1
52	15.8	89.9	Coarse GRAVEL + sand, cobbles grey wash	15.8
65	19.8	86.0	Grey coarse SAND and GRAVEL poor sorting	19.8
75	22.9	82.9	Grey coarse SAND and GRAVEL medium sorting	22.9
81	24.7	81.1	Brown-grey fine to medium SAND, trace gravel	24.7
86	26.2	79.6	Brown-grey medium to coarse SAND + GRAVEL	26.2
90	27.4	78.4	Fine to medium SAND, stones + some cobbles	27.4
92	28.0	77.7	Fine SAND, more fines and silty brown wash	28.0
96	29.3	76.5	Fine SILTY SAND, some coarse sand	29.3
99	30.2	75.6	Fine SILTY SAND, tr. coarse sand to pebbles	30.2
			End of Hole	



DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-5

BY: DRG
DATE: JUL 06
APPROVED:
FIG: A-5

\\hera\project\Project2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]PW-6p1

PW-6
(p. 1of 2)

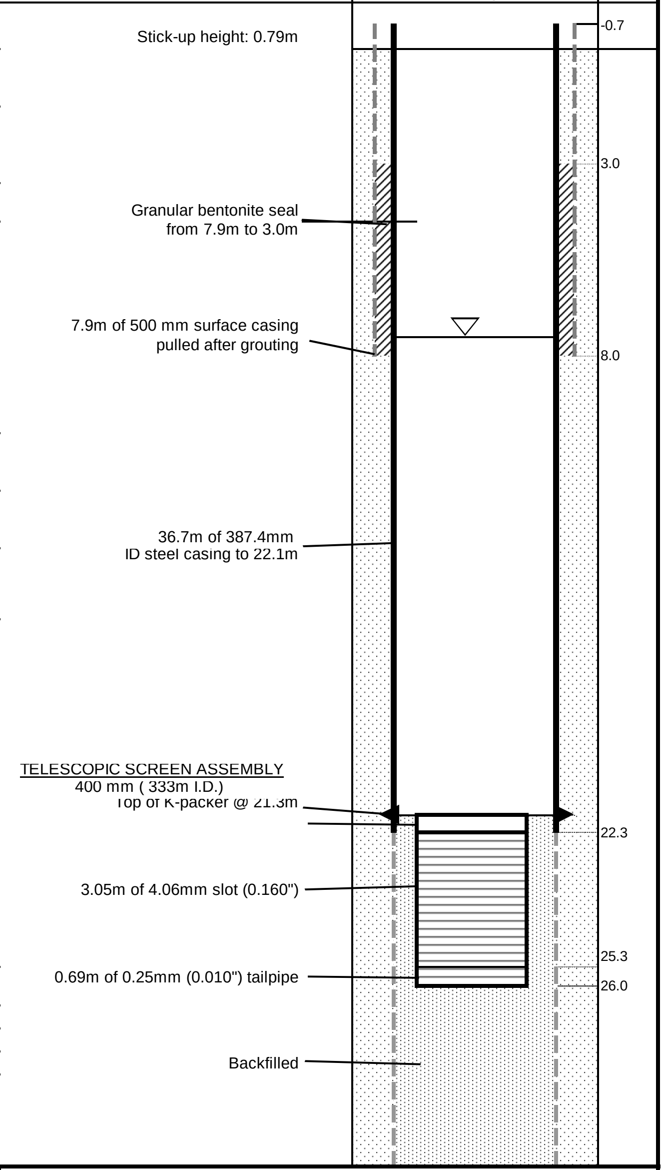
HYDROGEOLOGIC LOG
PURPOSE OF HOLE: PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
CONTRACTOR: COLUMBIA WATER WELLS (1986) Ltd.
DATE DRILLED: MARCH 26 - APRIL 14, 2006
GROUND ELEVATION (m-geod): 108.7 (approximate)

WELL I.D. PLATE NU.: 14955
WELL TAG NU.:
Approximate ELEV. TOP OF STEEL CASING: 109.49 m-geod
DEPTH TO WATER WHILE PUMP TESTING (15-FEB-07): 6.5 m-btoc
Approximate ELEVATION OF WATER: 103.0 m-geod

Depth (m): 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0, 27.0, 28.0, 29.0, 30.0

Elevation (m-geod.)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	
108.7	*Ground surface*	*Depth(m)*
107.5	Cobbly brown SANDY GRAVEL, woody debris	1.2
105.0	Cobbly, boulder GRAVEL	3.7
104.1	Tight coarse GRAVEL TILL, cobbles	4.6
98.6	Coarse GRAVEL + SAND, cobbles, tight	10.1
97.1	Coarse GRAVEL + SAND, cobbles, tight water bearing	11.6
95.9	Coarse GRAVEL + SAND, some cobbles, water bearing	12.8
94.1	Coarse GRAVEL + SAND, cobbles, tight, lt. grey wash	14.6
83.1	Coarse GRAVEL and cobbles with some sand, grey wash	25.6
82.5	Tight GRAVEL + SAND, grey wash	26.2
81.9	Medium - fine gravelly SAND, grey silt wash	26.8
81.3	Fine - coarse SAND, tight, grey silty wash	27.4
80.7	Grey, coarse - fine GRAVEL and SILTY SAND	28.0
	Fine brown SILTY SAND, tight	

WELL CONSTRUCTION MATERIALS | **Well Diagram** | **Completion depths (m-geod.)**



DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-6

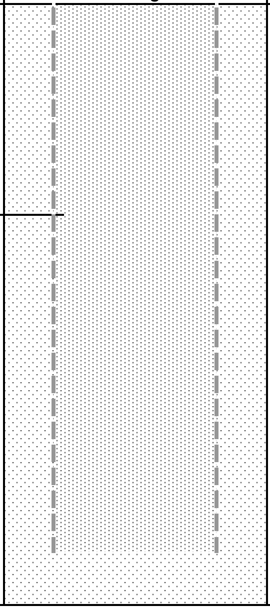
BY:	DATE:
KCT	MAR 07
APPROVED:	FIG:
	A-6

\hera\project\Project\2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]PW-6p2

PW-6
(p. 2 of 2)

HYDROGEOLOGIC LOG
PURPOSE OF HOLE: PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
CONTRACTOR: COLUMBIA WATER WELLS (1986) Ltd.
DATE DRILLED: MARCH 26 - APRIL 14, 2006
GROUND ELEVATION (m-geod): 108.7 (approximate)

WELL I.D. PLATE NU.:	14955	
WELL TAG NU.:		
Approximate ELEV. TOP OF STEEL CASING:	109.49	m-geod
DEPTH TO WATER WHILE PUMP TESTING (15-FEB-07):	6.5	m-btoc
ELEVATION OF WATER:	103.0	m-geod

Depth (m)	Elevation (m-geod.)	DESCRIPTION OF LITHOLOGY ENCOUNTERED		WELL CONSTRUCTION MATERIALS	Well Diagram	Completion depths (m-geod.)
30.0 31.0 32.0 33.0 34.0 35.0	73.6		35.1	Backfilled with Birds-eye Gravel		
36.0 37.0 38.0	70.3	Coarse GRAVEL + SAND, some silty sand, rusty staining	38.1			
39.0	70.0	Grey, fine - coarse SAND, some silt, fine gravel, tight	38.7			
40.0	68.2	Fine - medium SAND, some stones	40.5			
41.0	67.2	Fine SAND, stones, grey silty wash	41.5			
42.0	66.9	Fine SAND and coarse GRAVEL, tight	41.8			
	66.6	Coarse to fine SAND, some stones	42.0			
43.0	65.7	Course SAND and fine GRAVEL, some stones	43.0			
44.0		End of Hole				

DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-6

BY: KCT
DATE: MAR 07
APPROVED:
FIG: **A-6**

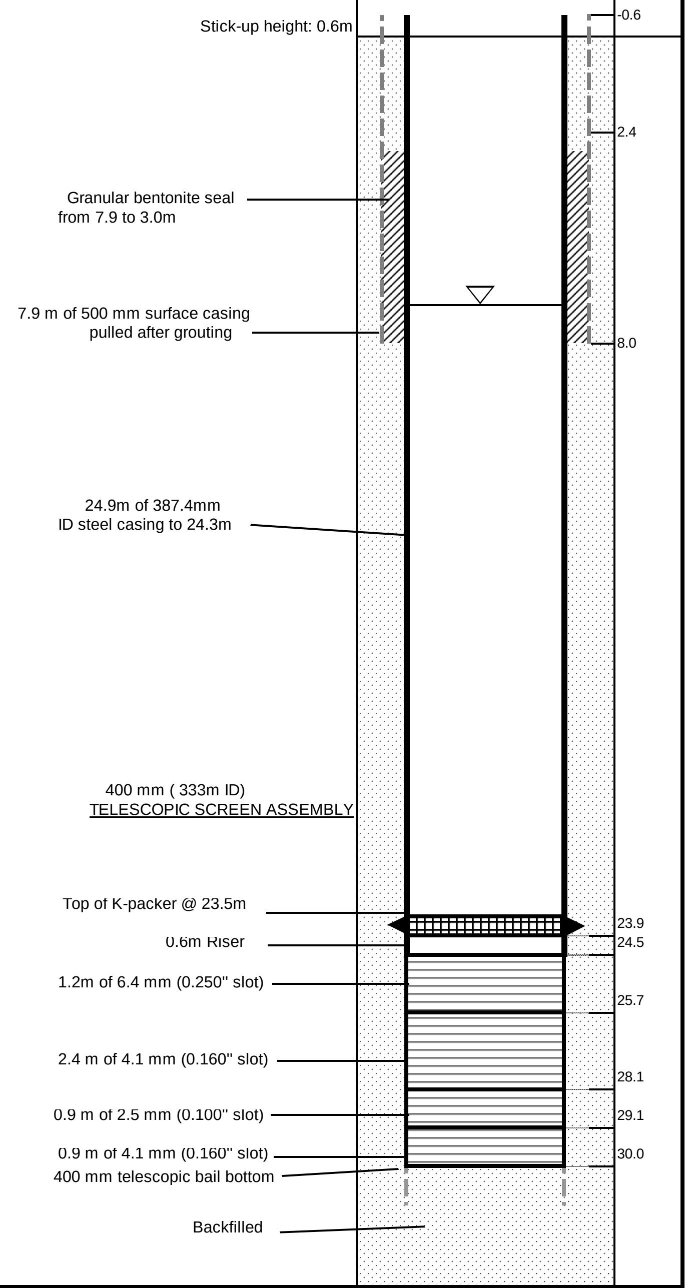
PW-7

HYDROGEOLOGIC LOG
PURPOSE OF HOLE: PRODUCTION WELL
TYPE OF RIG: CABLE TOOL
CONTRACTOR: COLUMBIA WATER WELLS (1986) Ltd.
DATE DRILLED: APRIL 16 - MAY 2, 2006
GROUND ELEVATION (m): 107.5m

WELL I.D. PLATE NU.:	14956	
WELL TAG NU.:		
ELEV. TOP OF STEEL CASING:	108.14	m-geod
DEPTH TO WATER WHILE PW-1,2,3,4 PUMPING (03-MAY-06):	7.1	m-btoc
ELEVATION OF WATER:	101.0	m-geod

Depth (m)	Elev.(m) geod.	DESCRIPTION OF LITHOLOGY ENCOUNTERED	Depth (m)
0.0	107.5	*Ground surface*	
1.0 2.0	105.1	Brown SAND + GRAVEL, some cobbly boulders	2.4
3.0 4.0	102.9	Coarse GRAVEL, some cobbles, some water	4.6
5.0 6.0 7.0	100.2	Coarse GRAVEL + SAND, some cobbles, tight in spots	7.3
8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0	92.0	Coarse GRAVEL with cobbles, some coarse to medium sand	15.5
16.0 17.0 18.0 19.0 20.0	86.8	Coarse GRAVEL with 8-10" cobbles, some medium - fine sand	20.7
21.0 22.0 23.0	83.7	Coarse GRAVEL, cobbles, some coarse sand	23.8
24.0	82.5	Coarse GRAVEL, coarse - fine SAND, 8-10" cobbles, traces of v.f. sand	25.0
25.0	81.9	Coarse GRAVEL and SAND, some cobbles, some fine sand	25.6
26.0 27.0	79.5	Coarse GRAVEL + SAND, some cobbles, tighter, more fine sand	28.0
28.0 29.0	78.5 77.6	Coarse GRAVEL and SAND, 6-10" cobbles, brown wash	29.9
30.0	77.0	Silty coarse GRAVEL, more fine sand, brown wash	30.5
	76.7	Fine - coarse SAND, fine GRAVEL, silty wash	30.8
31.0 32.0 33.0		End of Hole	

WELL CONSTRUCTION MATERIALS | **9** | **Completion depths (m)**



DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-7

BY:	DATE:
DRG	JUL 06
APPROVED:	FIG:
	A-7

\\hera\project\Project\2841\Well Records\Well Logs - PW-1 to PW-7.xlsx]OW97-1(1)

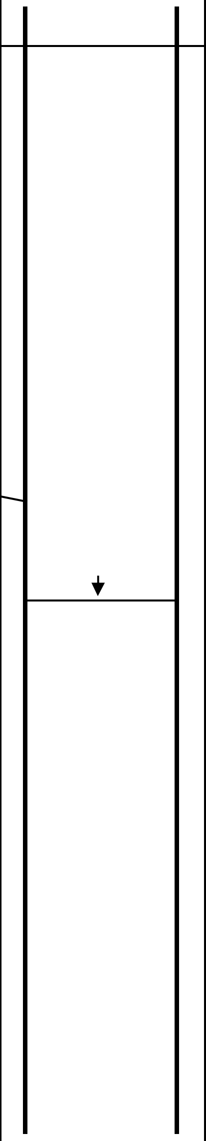
OW97-1
(p.1 of 2)

HYDROGEOLOGIC LOG
PURPOSE OF HOLE: MONITORING WELL
TYPE OF RIG: CABLE TOOL
DRILLING CONTRACTOR: PERRY'S WELL DRILLING
DATE DRILLED: DEC 05 - 09, 1997
GROUND ELEVATION (m): 100.00m (estimated from map)

WELL I.D. PLATE NU.:		
WELL TAG NU.:	78367	
ELEV. TOP OF STEEL CASING:	100.46	m-geod
DEPTH TO WATER (11-DEC-97):	12.63	m-btoc
ELEVATION OF WATER:	87.83	m-geod

Depth (m)	Elev.(m)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	WELL CONSTRUCTION MATERIALS	Sample depths (m)
0.0	100.00	*Ground surface*		
		BOULDERS		
1.0	99.09			
	98.63	Grey, GRAVEL with boulders		
2.0	98.17	BOULDER		
3.0		Grey, coarse GRAVEL		
	96.65			
4.0	96.04	BOULDER		
5.0				
6.0				
7.0				
		Coarse GRAVEL		
8.0				
9.0			152.4mm diam steel casing 0.46m stickup - 35.66m	
10.0				
11.0				
	88.42			11.58
12.0		Grey, GRAVEL with some med.-co. sand, tr. f. sand		
13.0	86.89			
14.0				
		Grey, f.-med. SAND with some co. sand & f. gravel		14.63
15.0				
16.0				
	83.54			
17.0				
		Grey, f.-med. SAND with some co. sand, tr. med. gravel, clasts subround		
18.0				17.98
19.0	81.10			
		Grey, f.-med. SAND with some f.-med. gravel		
20.0	79.88			19.81
		Grey, med. SAND with some f. & co. sand, some medium gravel, clasts subround		20.73
21.0				
	78.66			
22.0		Light grey, f. SAND with some med. sand		21.95
	77.75			
23.0		Grey, f.-med. SAND, trace co. sand to f. gravel		22.86
	76.84			
24.0		Grey, f.-med. SAND, trace co. sand to med. gravel, subround clasts		23.77

Well Diagram



Note: All elevations are relative to an assumed datum

DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF OBSERVATION WELL
OW97-1

BY: IRS	DATE: JAN 98
APPROVED:	FIG: **A-8**

\hera\project\Project\2841\Well Records\[Well Logs - PW-1 to PW-7.xlsx]OW97-1 (2)

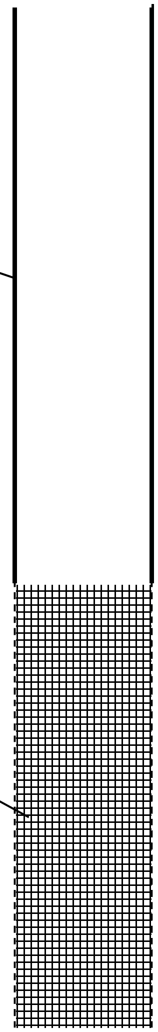
OW97-1
(p.2 of 2)

HYDROGEOLOGIC LOG
PURPOSE OF HOLE: MONITORING WELL
TYPE OF RIG: CABLE TOOL
DRILLING CONTRACTOR: PERRY'S WELL DRILLING
DATE DRILLED: DEC 05 - 09, 1997
GROUND ELEVATION (m): 100.00m

WELL I.D. PLATE NU.:
WELL TAG NU.: 78367
ELEV. TOP OF STEEL CASING: 100.46 m-geod
DEPTH TO WATER (11-DEC-97): 12.63 m-btoc
ELEVATION OF WATER: 87.83 m-geod

Depth (m)	Elev.(m)	DESCRIPTION OF LITHOLOGY ENCOUNTERED	WELL CONSTRUCTION MATERIALS	Sample depths (m)
24.0		Grey, f.-med. SAND, trace co. sand to med. gravel, subround clasts		23.77
25.0				
	74.70			
26.0		Grey, f.-med. SAND, trace f. gravel		
27.0				26.82
	72.57		152.4mm diam steel casing 0.46m stickup - 35.66m	
28.0		Grey, f. SAND to med. GRAVEL, angular to round clasts		28.04
	71.65			
29.0	70.74	Grey, f.-med. SAND, tr. f. gravel		28.96
30.0	69.82	Dark grey, med.-co. SAND with some f. sand, tr. f. gravel		29.87
		Grey, well graded angular SAND		30.48
31.0	69.22			31.09
	68.61	Grey, f.-med. SAND, tr. co. sand and f. gravel		
32.0		Grey, med. SAND with some f. and co. sand & f. gravel		32.00
	67.69			
33.0		Grey, well graded, f. SAND to med. GRAVEL, subround clasts		32.92
	66.47			
34.0		Grey, f.-med. SAND and f.-med. GRAVEL with some co. sand and co. gravel, clasts subround		34.14
	65.25			
35.0		Grey, f.-med. SAND and med. GRAVEL with some co. sand and f. gravel, subround clasts		35.36
	64.34			
36.0		Grey f.-med. SAND with some co. sand to med. gravel		35.97
	63.73			36.58
37.0		Grey, well graded f. SAND to fine GRAVEL, subround clasts	Backfilled with cuttings	
	62.51			
38.0		Med. grey, f.-med. SAND with tr. silt and co. sand		
	61.29			38.71
39.0	60.99	Grey, f.-med. SAND, tr. co. sand & f.-med. grav.		39.01
	60.38	Grey, f.-med. SAND, tr. co. sand-co. gravel, SR		39.62
40.0		Light to med. grey, f.-med. SAND, tr. co. sand		40.54
41.0	58.85			41.15
42.0		Dense SAND		
	57.33			
43.0	57.02	GRAVEL		
44.0		Bedrock		
	55.65			
45.0		End of Hole		
46.0				
47.0				
48.0				

Well Diagram



Note: Shading denotes dense layers with trace clay which are less permeable than other sediments

Note: All elevations are relative to an assumed datum

DISTRICT OF SQUAMISH

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS
SQUAMISH, B.C.

LOG OF PRODUCTION
WELL PW-8

BY:	DATE:
IRS	JAN 98
APPROVED:	FIG:
	A-8

APPENDIX B

LABORATORY ANALYTICAL REPORTS

PITEAU ASSOC. ENGINEERING LTD.
ATTN: Kathy Tixier
215 - 260 West Esplanade
North Vancouver BC V7M 3G7

Date Received: 07-JUN-12
Report Date: 15-JUN-12 18:00 (MT)
Version: FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #: **L1159007**

Project P.O. #: NOT SUBMITTED
Job Reference: 2841
C of C Numbers: 10-251385
Legal Site Desc:

Brent Mack
Account Manager

	Sample ID	L1159007-1	L1159007-2	L1159007-3	L1159007-4	L1159007-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	05-JUN-12	05-JUN-12	05-JUN-12	05-JUN-12	06-JUN-12
	Sampled Time	15:30	16:30	15:00	10:00	08:30
	Client ID	LOWER SKOOKUM CRK	LOWER RING CRK	MAMQUAM RIVER	POWERHOUSE CRK "SITE2"	WELL#7
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	11.1	10.0	9.9	<5.0	<5.0
	Conductivity (uS/cm)	20.4	36.3	24.6	64.2	72.9
	Hardness (as CaCO3) (mg/L)	8.66	15.2	10.8	20.1	23.1
	pH (pH)	7.72	7.61	7.48	7.79	7.74
	Total Dissolved Solids (mg/L)	24	37	25	62	79
	Turbidity (NTU)	2.02	5.84	0.77	0.23	<0.10
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	8.2	13.1	10.4	19.8	21.5
	Chloride (Cl) (mg/L)	<0.50	<0.50	<0.50	3.67	4.37
	Fluoride (F) (mg/L)	<0.020	0.021	<0.020	0.083	0.090
	Nitrate (as N) (mg/L)	0.0297	0.0115	0.0293	0.0506	0.0634
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Sulfate (SO4) (mg/L)	1.46	4.89	2.15	6.51	8.12
Total Metals	Aluminum (Al)-Total (mg/L)	0.163	0.487	0.086	<0.010	<0.010
	Antimony (Sb)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Arsenic (As)-Total (mg/L)	<0.00010	0.00020	<0.00010	0.00054	0.00058
	Barium (Ba)-Total (mg/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Boron (B)-Total (mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10
	Cadmium (Cd)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Calcium (Ca)-Total (mg/L)	3.09	6.32	3.87	6.31	7.22
	Chromium (Cr)-Total (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
	Copper (Cu)-Total (mg/L)	<0.0010	0.0032	<0.0010	<0.0010	0.0083
	Iron (Fe)-Total (mg/L)	0.124	0.264	0.051	<0.030	<0.030
	Lead (Pb)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Magnesium (Mg)-Total (mg/L)	0.28	0.86	0.33	1.21	1.37
	Manganese (Mn)-Total (mg/L)	0.0035	0.0092	<0.0020	<0.0020	<0.0020
	Mercury (Hg)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Potassium (K)-Total (mg/L)	0.20	0.40	0.18	1.18	1.29
	Selenium (Se)-Total (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Sodium (Na)-Total (mg/L)	<2.0	<2.0	<2.0	4.6	5.2
	Uranium (U)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Zinc (Zn)-Total (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Aluminum (Al)-Dissolved (mg/L)	0.059	0.066	0.057	<0.010	<0.010
	Antimony (Sb)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Arsenic (As)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Barium (Ba)-Dissolved (mg/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Beryllium (Be)-Dissolved (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1159007-6
	Description	WATER
	Sampled Date	06-JUN-12
	Sampled Time	08:15
	Client ID	WELL#5
Grouping	**Analyte**	
WATER		
Physical Tests	Colour, True (CU)	<5.0
	Conductivity (uS/cm)	67.9
	Hardness (as CaCO3) (mg/L)	21.4
	pH (pH)	7.70
	Total Dissolved Solids (mg/L)	70
	Turbidity (NTU)	<0.10
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	20.8
	Chloride (Cl) (mg/L)	3.87
	Fluoride (F) (mg/L)	0.088
	Nitrate (as N) (mg/L)	0.0610
	Nitrite (as N) (mg/L)	<0.0010
	Sulfate (SO4) (mg/L)	7.11
Total Metals	Aluminum (Al)-Total (mg/L)	<0.010
	Antimony (Sb)-Total (mg/L)	<0.00050
	Arsenic (As)-Total (mg/L)	0.00055
	Barium (Ba)-Total (mg/L)	<0.020
	Boron (B)-Total (mg/L)	<0.10
	Cadmium (Cd)-Total (mg/L)	<0.00020
	Calcium (Ca)-Total (mg/L)	6.60
	Chromium (Cr)-Total (mg/L)	<0.0020
	Copper (Cu)-Total (mg/L)	0.0067
	Iron (Fe)-Total (mg/L)	<0.030
	Lead (Pb)-Total (mg/L)	<0.00050
	Magnesium (Mg)-Total (mg/L)	1.25
	Manganese (Mn)-Total (mg/L)	<0.0020
	Mercury (Hg)-Total (mg/L)	<0.00020
	Potassium (K)-Total (mg/L)	1.23
	Selenium (Se)-Total (mg/L)	<0.0010
	Sodium (Na)-Total (mg/L)	4.7
	Uranium (U)-Total (mg/L)	<0.00010
	Zinc (Zn)-Total (mg/L)	<0.050
Dissolved Metals	Dissolved Metals Filtration Location	FIELD
	Aluminum (Al)-Dissolved (mg/L)	<0.010
	Antimony (Sb)-Dissolved (mg/L)	<0.00050
	Arsenic (As)-Dissolved (mg/L)	<0.0010
	Barium (Ba)-Dissolved (mg/L)	<0.020
	Beryllium (Be)-Dissolved (mg/L)	<0.0050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1159007-1	L1159007-2	L1159007-3	L1159007-4	L1159007-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	05-JUN-12	05-JUN-12	05-JUN-12	05-JUN-12	06-JUN-12
	Sampled Time	15:30	16:30	15:00	10:00	08:30
	Client ID	LOWER SKOOKUM CRK	LOWER RING CRK	MAMQUAM RIVER	POWERHOUSE CRK "SITE2"	WELL#7
Grouping	**Analyte**					
WATER						
Dissolved Metals	Boron (B)-Dissolved (mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10
	Cadmium (Cd)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Calcium (Ca)-Dissolved (mg/L)	3.05	4.87	3.79	6.14	7.06
	Chromium (Cr)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Cobalt (Co)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Copper (Cu)-Dissolved (mg/L)	<0.0010	0.0017	<0.0010	<0.0010	0.0066
	Iron (Fe)-Dissolved (mg/L)	0.043	<0.030	<0.030	<0.030	<0.030
	Lead (Pb)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Lithium (Li)-Dissolved (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	0.25	0.74	0.32	1.16	1.32
	Manganese (Mn)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Mercury (Hg)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Molybdenum (Mo)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Nickel (Ni)-Dissolved (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Selenium (Se)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Silver (Ag)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Sodium (Na)-Dissolved (mg/L)	<2.0	<2.0	<2.0	4.3	4.9
	Thallium (Tl)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Titanium (Ti)-Dissolved (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Uranium (U)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Vanadium (V)-Dissolved (mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030
	Zinc (Zn)-Dissolved (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1159007-6				
	Description	WATER				
	Sampled Date	06-JUN-12				
	Sampled Time	08:15				
	Client ID	WELL#5				
Grouping	**Analyte**					
WATER						
Dissolved Metals	Boron (B)-Dissolved (mg/L)	<0.10				
	Cadmium (Cd)-Dissolved (mg/L)	<0.000050				
	Calcium (Ca)-Dissolved (mg/L)	6.53				
	Chromium (Cr)-Dissolved (mg/L)	<0.00050				
	Cobalt (Co)-Dissolved (mg/L)	<0.00050				
	Copper (Cu)-Dissolved (mg/L)	0.0056				
	Iron (Fe)-Dissolved (mg/L)	<0.030				
	Lead (Pb)-Dissolved (mg/L)	<0.0010				
	Lithium (Li)-Dissolved (mg/L)	<0.050				
	Magnesium (Mg)-Dissolved (mg/L)	1.24				
	Manganese (Mn)-Dissolved (mg/L)	<0.010				
	Mercury (Hg)-Dissolved (mg/L)	<0.00020				
	Molybdenum (Mo)-Dissolved (mg/L)	<0.0010				
	Nickel (Ni)-Dissolved (mg/L)	<0.0050				
	Selenium (Se)-Dissolved (mg/L)	<0.0010				
	Silver (Ag)-Dissolved (mg/L)	<0.000050				
	Sodium (Na)-Dissolved (mg/L)	4.5				
	Thallium (Tl)-Dissolved (mg/L)	<0.00020				
	Titanium (Ti)-Dissolved (mg/L)	<0.050				
	Uranium (U)-Dissolved (mg/L)	<0.00020				
	Vanadium (V)-Dissolved (mg/L)	<0.030				
	Zinc (Zn)-Dissolved (mg/L)	<0.0050				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SPL	Sample was Preserved at the laboratory - total metals

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1159007-1, -2, -3, -4, -5, -6
Duplicate	Nitrate (as N)	DLM	L1159007-1, -2, -3, -4, -5, -6

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted For Sample Matrix Effects

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

ANIONS-CL-IC-VA	Water	Chloride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-F-IC-VA	Water	Fluoride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-NO2-IC-VA	Water	Nitrite in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

ANIONS-NO3-IC-VA	Water	Nitrate in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ANIONS-SO4-IC-VA	Water	Sulfate by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

COLOUR-TRUE-VA	Water	Colour (True) by Spectrometer	BCMOE Colour Single Wavelength

This analysis is carried out using procedures adapted from British Columbia Environmental Manual "Colour- Single Wavelength." Colour (True Colour) is determined by filtering a sample through a 0.45 micron membrane filter followed by analysis of the filtrate using the platinum-cobalt colourimetric method. Aparent Colour is determined without prior sample filtration. Colour is pH dependent. Unless otherwise indicated, reported colour results pertain to the pH of the sample as received, to within +/- 1 pH unit.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-DIS-CVAFS-VA	Water	Dissolved Mercury in Water by CVAFS	EPA SW-846 3005A & EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by filtration (EPA Method 3005A) and involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry (EPA Method 245.7).

HG-TOT-CVAFS-VA	Water	Total Mercury in Water by CVAFS	EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry (EPA Method 245.7).

MET-DIS-ICP-VA	Water	Dissolved Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma -

Reference Information

optical emission spectrophotometry (EPA Method 6010B).

MET-DIS-LOW-MS-VA Water Dissolved Metals in Water by ICPMS(Low) EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures involves preliminary sample treatment by filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

MET-TOT-ICP-VA Water Total Metals in Water by ICPOES EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-TOT-LOW-MS-VA Water Total Metals in Water by ICPMS(Low) EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

PH-PCT-VA Water pH by Meter (Automated) APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA Water pH by Meter (Automated) APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

TDS-VA Water Total Dissolved Solids by Gravimetric APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	**Laboratory Location**
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

10-251385

Reference Information

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

10- 251385

ALS Environmental

Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Page 1 of 1

Report To Kathy Tixier	**Report Format / Distribution**	**Service Request:**(Rush subject to availability - Contact ALS to confirm TAT)	
Company: Piteau Associates	Standard: ✓ Other (specify):	✓	Regular (Standard Turnaround Times - Business Days)
Contact: Kathy Tixier	Select: PDF ✓ Excel ✓ Digital Fax		Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
Address: 215 - 260 W. Esplanade	Email 1: ktixier@piteau.com		Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
N. Vancouver, B.C.	Email 2: jmancer@piteau.com		Same Day or Weekend Emergency - Contact ALS to confirm TAT
Phone: 604-986-8551 Fax: 604-985-7286		**Analysis Request**	

Invoice To Same as Report ? (circle) [✓ Yes] or No (if No, provide details)	**Client / Project Information**
Copy of Invoice with Report? (circle) Yes or No	Job #: 2841
Company:	PO / AFE:
Contact:	LSD:
Address:	
Phone: Fax:	Quote #:
Lab Work Order # (lab use only) L1159007	**ALS Contact:** B. MACK **Sampler:** KT/JM

(Indicate Filtered or Preserved, **F/P**)

Sample #	**Sample Identification** (This description will appear on the report)	**Date** (dd-mmm-yy) see bottles	**Time** (hh:mm)	**Sample Type**	Full Drinking Water Package	$\delta D / \delta O^{18}$	Tritium ^3H	F/P Dissolved Metals									Number of Containers
	LOWER SKOOKUM CRK	05/JUN/12	15:30	WATER	X	X	X	X									
	LOWER RING CRK	05/JUN/12	16:30	"	X	X	X	X									
	MAMQUAM RIVER	05/JUN/12	15:00	"	✓	X	X	X									
	POWERHOUSE CRK "SITE 2"	05/JUN/12	10:00	"	X	X	X	X									
	WELL #7	06/JUN/12	8:30	"	X	X	X	X									
	WELL #5	06/JUN/12	8:15	"	X	X	X	X									
	RAIN	05/JUN/12	22:00	WATER		X	X										

L1159007-COFC

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

Please log sample times shown on bottle labels

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

PITEAU ASSOC. ENGINEERING LTD.
ATTN: Kathy Tixier
215 - 260 West Esplanade
North Vancouver BC V7M 3G7

Date Received: 07-JUN-12
Report Date: 18-JUN-12 15:57 (MT)
Version: FINAL REV. 2

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #: **L1159007**
Project P.O. #: NOT SUBMITTED
Job Reference: 2841
C of C Numbers: 10-251385
Legal Site Desc:

Comments: ADDITIONAL 18-JUN-12 14:47

18-JUN-12: This report replaces the previously issued 1159007 and includes the removal of Total Metals results, the addition of Dissolved Potassium, and an update to the Sampling Time for all samples.

B Mack

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1159007-1	L1159007-2	L1159007-3	L1159007-4	L1159007-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	06-JUN-12	05-JUN-12	05-JUN-12	05-JUN-12	06-JUN-12
	Sampled Time	14:30	16:00	15:30	11:45	08:45
	Client ID	LOWER SKOOKUM CRK	LOWER RING CRK	MAMQUAM RIVER	POWERHOUSE CRK "SITE2"	WELL#7
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	11.1	10.0	9.9	<5.0	<5.0
	Conductivity (uS/cm)	20.4	36.3	24.6	64.2	72.9
	Hardness (as CaCO3) (mg/L)	8.66	15.2	10.8	20.1	23.1
	pH (pH)	7.72	7.61	7.48	7.79	7.74
	Total Dissolved Solids (mg/L)	24	37	25	62	79
	Turbidity (NTU)	2.02	5.84	0.77	0.23	<0.10
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	8.2	13.1	10.4	19.8	21.5
	Chloride (Cl) (mg/L)	<0.50	<0.50	<0.50	3.67	4.37
	Fluoride (F) (mg/L)	<0.020	0.021	<0.020	0.083	0.090
	Nitrate (as N) (mg/L)	0.0297	0.0115	0.0293	0.0506	0.0634
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Sulfate (SO4) (mg/L)	1.46	4.89	2.15	6.51	8.12
Dissolved Metals	Aluminum (Al)-Dissolved (mg/L)	0.059	0.066	0.057	<0.010	<0.010
	Antimony (Sb)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Arsenic (As)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Barium (Ba)-Dissolved (mg/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Beryllium (Be)-Dissolved (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Boron (B)-Dissolved (mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10
	Cadmium (Cd)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Calcium (Ca)-Dissolved (mg/L)	3.05	4.87	3.79	6.14	7.06
	Chromium (Cr)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Cobalt (Co)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Copper (Cu)-Dissolved (mg/L)	<0.0010	0.0017	<0.0010	<0.0010	0.0066
	Iron (Fe)-Dissolved (mg/L)	0.043	<0.030	<0.030	<0.030	<0.030
	Lead (Pb)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Lithium (Li)-Dissolved (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	0.25	0.74	0.32	1.16	1.32
	Manganese (Mn)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Mercury (Hg)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Molybdenum (Mo)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Nickel (Ni)-Dissolved (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Potassium (K)-Dissolved (mg/L)	<2.0	<2.0	<2.0	<2.0	<2.0
	Selenium (Se)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Silver (Ag)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Sodium (Na)-Dissolved (mg/L)	<2.0	<2.0	<2.0	4.3	4.9
	Thallium (Tl)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Titanium (Ti)-Dissolved (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

	Sample ID	L1159007-6
	Description	WATER
	Sampled Date	06-JUN-12
	Sampled Time	08:30
	Client ID	WELL#5
Grouping	**Analyte**	
WATER		
Physical Tests	Colour, True (CU)	<5.0
	Conductivity (uS/cm)	67.9
	Hardness (as CaCO3) (mg/L)	21.4
	pH (pH)	7.70
	Total Dissolved Solids (mg/L)	70
	Turbidity (NTU)	<0.10
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	20.8
	Chloride (Cl) (mg/L)	3.87
	Fluoride (F) (mg/L)	0.088
	Nitrate (as N) (mg/L)	0.0610
	Nitrite (as N) (mg/L)	<0.0010
	Sulfate (SO4) (mg/L)	7.11
Dissolved Metals	Aluminum (Al)-Dissolved (mg/L)	<0.010
	Antimony (Sb)-Dissolved (mg/L)	<0.00050
	Arsenic (As)-Dissolved (mg/L)	<0.0010
	Barium (Ba)-Dissolved (mg/L)	<0.020
	Beryllium (Be)-Dissolved (mg/L)	<0.0050
	Boron (B)-Dissolved (mg/L)	<0.10
	Cadmium (Cd)-Dissolved (mg/L)	<0.000050
	Calcium (Ca)-Dissolved (mg/L)	6.53
	Chromium (Cr)-Dissolved (mg/L)	<0.00050
	Cobalt (Co)-Dissolved (mg/L)	<0.00050
	Copper (Cu)-Dissolved (mg/L)	0.0056
	Iron (Fe)-Dissolved (mg/L)	<0.030
	Lead (Pb)-Dissolved (mg/L)	<0.0010
	Lithium (Li)-Dissolved (mg/L)	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	1.24
	Manganese (Mn)-Dissolved (mg/L)	<0.010
	Mercury (Hg)-Dissolved (mg/L)	<0.00020
	Molybdenum (Mo)-Dissolved (mg/L)	<0.0010
	Nickel (Ni)-Dissolved (mg/L)	<0.0050
	Potassium (K)-Dissolved (mg/L)	<2.0
	Selenium (Se)-Dissolved (mg/L)	<0.0010
	Silver (Ag)-Dissolved (mg/L)	<0.000050
	Sodium (Na)-Dissolved (mg/L)	4.5
	Thallium (Tl)-Dissolved (mg/L)	<0.00020
	Titanium (Ti)-Dissolved (mg/L)	<0.050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1159007-1	L1159007-2	L1159007-3	L1159007-4	L1159007-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	06-JUN-12	05-JUN-12	05-JUN-12	05-JUN-12	06-JUN-12
	Sampled Time	14:30	16:00	15:30	11:45	08:45
	Client ID	LOWER SKOOKUM CRK	LOWER RING CRK	MAMQUAM RIVER	POWERHOUSE CRK "SITE2"	WELL#7
Grouping	**Analyte**					
WATER						
Dissolved Metals	Uranium (U)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Vanadium (V)-Dissolved (mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030
	Zinc (Zn)-Dissolved (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1159007-6 WATER 06-JUN-12 08:30 WELL#5				
Grouping	**Analyte**					
WATER						
Dissolved Metals	Uranium (U)-Dissolved (mg/L)	<0.00020				
	Vanadium (V)-Dissolved (mg/L)	<0.030				
	Zinc (Zn)-Dissolved (mg/L)	<0.0050				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SPL	Sample was Preserved at the laboratory - total metals

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1159007-1, -2, -3, -4, -5, -6
Duplicate	Nitrate (as N)	DLM	L1159007-1, -2, -3, -4, -5, -6

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted For Sample Matrix Effects

Test Method References:

ALS Test Code | **Matrix** | **Test Description** | **Method Reference****

ALK-COL-VA | Water | Alkalinity by Colourimetric (Automated) | EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

ANIONS-CL-IC-VA | Water | Chloride by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-F-IC-VA | Water | Fluoride by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-NO2-IC-VA | Water | Nitrite in Water by Ion Chromatography | EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

ANIONS-NO3-IC-VA | Water | Nitrate in Water by Ion Chromatography | EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ANIONS-SO4-IC-VA | Water | Sulfate by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

COLOUR-TRUE-VA | Water | Colour (True) by Spectrometer | BCMOE Colour Single Wavelength

This analysis is carried out using procedures adapted from British Columbia Environmental Manual "Colour- Single Wavelength." Colour (True Colour) is determined by filtering a sample through a 0.45 micron membrane filter followed by analysis of the filtrate using the platinum-cobalt colourimetric method. Aparent Colour is determined without prior sample filtration. Colour is pH dependent. Unless otherwise indicated, reported colour results pertain to the pH of the sample as received, to within +/- 1 pH unit.

EC-PCT-VA | Water | Conductivity (Automated) | APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

HARDNESS-CALC-VA | Water | Hardness | APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-DIS-CVAFS-VA | Water | Dissolved Mercury in Water by CVAFS | EPA SW-846 3005A & EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by filtration (EPA Method 3005A) and involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry (EPA Method 245.7).

HG-TOT-CVAFS-VA | Water | Total Mercury in Water by CVAFS | EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry (EPA Method 245.7).

MET-DIS-ICP-VA | Water | Dissolved Metals in Water by ICPOES | EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma -

Reference Information

optical emission spectrophotometry (EPA Method 6010B).

MET-DIS-LOW-MS-VA Water Dissolved Metals in Water by ICPMS(Low) EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures involves preliminary sample treatment by filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

MET-TOT-ICP-VA Water Total Metals in Water by ICPOES EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-TOT-LOW-MS-VA Water Total Metals in Water by ICPMS(Low) EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

PH-PCT-VA Water pH by Meter (Automated) APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA Water pH by Meter (Automated) APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

TDS-VA Water Total Dissolved Solids by Gravimetric APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

10-251385

Reference Information

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

10-251385

ALS Environmental

Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Page 1 of 1

Report To Kathy Tixier
Company: Piteau Associates
Contact: Kathy Tixier
Address: 215 - 260 W. Esplanade
N. Vancouver, B.C.
Phone: 604-986-8551 Fax: 604-985-7286

Report Format / Distribution
Standard: ✓ Other (specify):
Select: PDF ✓ Excel ✓ Digital Fax
Email 1: ktixier@piteau.com
Email 2: jmancer@piteau.com

Service Request:(Rush subject to availability - Contact ALS to confirm TAT)
✓ Regular (Standard Turnaround Times - Business Days)
☐ Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
☐ Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
☐ Same Day or Weekend Emergency - Contact ALS to confirm TAT

Invoice To Same as Report ? (circle) [✓ Yes] or No (if No, provide details)
Copy of Invoice with Report? (circle) Yes or No
Company:
Contact:
Address:
Phone: Fax:

Client / Project Information
Job #: 2841
PO / AFE:
LSD:
Quote #:

Lab Work Order # (lab use only) L1159007
ALS Contact: B. MACK
Sampler: KT/JM

Analysis Request
(Indicate Filtered or Preserved, F/P)

Sample #	**Sample Identification** (This description will appear on the report)	**Date** (dd-mmm-yy) see bottles	**Time** (hh:mm)	**Sample Type**	Full Drinking Water Package	∂D / ∂O^{18}	Tritium ^3H	F P Dissolved Metals									Number of Containers
	LOWER SKOOKUM CRK	05/JUN/12	15:30	WATER	X	X	X	X									
	LOWER RING CRK	05/JUN/12	16:30	"	X	X	X	X									
	MAMQUAM RIVER	05/JUN/12	15:00	"	✓	X	X	X									
	POWERHOUSE CRK "SITE 2"	05/JUN/12	10:00	"	X	X	X	X									
	WELL #7	06/JUN/12	8:30	"	X	X	X	X									
	WELL #5	06/JUN/12	8:15	"	X	X	X	X									
	RAIN	05/JUN/12	22:00	WATER		X	X										

L1159007-COFC

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

Please log sample times shown on bottle labels

Failure to complete all portions of this form may delay analysis..Please fill in this form **LEGIBLY.**

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

PITEAU ASSOC. ENGINEERING LTD.
ATTN: Kathy Tixier
215 - 260 West Esplanade
North Vancouver BC V7M 3G7

Date Received:	17-AUG-12
Report Date:	28-AUG-12 16:49 (MT)
Version:	FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #:	**L1196084**
Project P.O. #:	NOT SUBMITTED
Job Reference:	2841-1
C of C Numbers:	10-207295
Legal Site Desc:	

Comments: For dH2 and dO18 analysis, ALS identified samples L1196084-1 and -2 were sublet to University of Waterloo c/o EILAB C/O Chemistry Stores. Reporting and billing is directed to Piteau Assoicates directly.

B J Mack

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1196084-1	L1196084-2			
	Description	H2O	H2O			
	Sampled Date	17-AUG-12	17-AUG-12			
	Sampled Time	10:30	13:30			
	Client ID	RAIN@100M	RAIN@700M			
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	33.3	<5.0			
	Conductivity (uS/cm)	10.3	2.7			
	Hardness (as CaCO3) (mg/L)	1.95	<0.50			
	pH (pH)	6.21	5.68			
	Total Dissolved Solids (mg/L)	30	<10			
	Turbidity (NTU)	10.4	0.68			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	2.0	<2.0			
	Chloride (Cl) (mg/L)	<0.50	<0.50			
	Fluoride (F) (mg/L)	<0.020	<0.020			
	Nitrate (as N) (mg/L)	<0.0050	0.0997			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Sulfate (SO4) (mg/L)	0.63	<0.50			
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD			
	Aluminum (Al)-Dissolved (mg/L)	0.042	<0.010			
	Antimony (Sb)-Dissolved (mg/L)	<0.00050	<0.00050			
	Arsenic (As)-Dissolved (mg/L)	0.00014	<0.00010			
	Barium (Ba)-Dissolved (mg/L)	<0.020	<0.020			
	Boron (B)-Dissolved (mg/L)	<0.10	<0.10			
	Cadmium (Cd)-Dissolved (mg/L)	<0.00020	<0.00020			
	Calcium (Ca)-Dissolved (mg/L)	0.51	0.11			
	Chromium (Cr)-Dissolved (mg/L)	<0.0020	<0.0020			
	Copper (Cu)-Dissolved (mg/L)	0.0015	0.0030			
	Iron (Fe)-Dissolved (mg/L)	<0.030	<0.030			
	Lead (Pb)-Dissolved (mg/L)	<0.00050	0.00070			
	Magnesium (Mg)-Dissolved (mg/L)	0.17	<0.10			
	Manganese (Mn)-Dissolved (mg/L)	0.0249	0.0039			
	Mercury (Hg)-Dissolved (mg/L)	<0.00020	<0.00020			
	Potassium (K)-Dissolved (mg/L)	1.98	<0.10			
	Selenium (Se)-Dissolved (mg/L)	<0.0010	<0.0010			
	Sodium (Na)-Dissolved (mg/L)	<2.0	<2.0			
	Uranium (U)-Dissolved (mg/L)	<0.00010	<0.00010			
	Zinc (Zn)-Dissolved (mg/L)	<0.050	0.060			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Chloride (Cl)	DLM	L1196084-1, -2
Duplicate	Nitrite (as N)	DLM	L1196084-1, -2
Duplicate	Chloride (Cl)	DLM	L1196084-1, -2
Matrix Spike	Sodium (Na)-Dissolved	MS-B	L1196084-1, -2
Matrix Spike	Manganese (Mn)-Dissolved	MS-B	L1196084-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted For Sample Matrix Effects
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

ANIONS-CL-IC-VA	Water	Chloride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-F-IC-VA	Water	Fluoride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-NO2-IC-VA	Water	Nitrite in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

ANIONS-NO3-IC-VA	Water	Nitrate in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ANIONS-SO4-IC-VA	Water	Sulfate by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

COLOUR-TRUE-VA	Water	Colour (True) by Spectrometer	BCMOE Colour Single Wavelength

This analysis is carried out using procedures adapted from British Columbia Environmental Manual "Colour- Single Wavelength." Colour (True Colour) is determined by filtering a sample through a 0.45 micron membrane filter followed by analysis of the filtrate using the platinum-cobalt colourimetric method. Aparent Colour is determined without prior sample filtration. Colour is pH dependent. Unless otherwise indicated, reported colour results pertain to the pH of the sample as received, to within +/- 1 pH unit.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-DIS-CVAFS-VA	Water	Dissolved Mercury in Water by CVAFS	EPA SW-846 3005A & EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by filtration (EPA Method 3005A) and involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry (EPA Method 245.7).

MET-DIS-ICP-VA	Water	Dissolved Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-DIS-LOW-MS-VA	Water	Dissolved Metals in Water by ICPMS(Low)	EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures involves preliminary sample treatment by filtration (EPA Method 3005A).

Reference Information

Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

PH-MAN-VA	Water	pH by Manual Meter	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

It is recommended that this analysis be conducted in the field.

PH-MAN-VA	Water	pH by Manual Meter	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

10-207295

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

10- 207295

ALS Env

L1196084-COFC

Chain of Custody / Analytical Request Form
Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Page 1 of 1

Report To
Company: Piteau Associates
Contact: Kathy Tixier
Address: 215-260 W. Esplanade
N. Vancouver, B.C
Phone: 604-986-8551 Fax: 604-985-7286

Report Format / Distribution
Standard: ✓ Other (specify):
Select: PDF ✓ Excel ✓ Digital Fax
Email 1: ktixier@piteau.com
Email 2: jmaucer@piteau.com

Service Request: (Rush subject to availability - Contact ALS to confirm TAT)
☑ Regular (Standard Turnaround Times - Business Days)
☐ Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
☐ Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
☐ Same Day or Weekend Emergency - Contact ALS to confirm TAT

Invoice To Same as Report ? (circle) Yes or No (If No, provide details)
Copy of Invoice with Report? (circle) Yes or No
Company:
Contact:
Address:
Phone: Fax:

Client / Project Information
Job #: 2841-1
PO / AFE:
LSD:
Quote #:

Lab Work Order # (lab use only) L1196084

ALS Contact:

Sampler:

Analysis Request
(Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	F/P Full Drinking W. Reg (Dissolved Metals)	δH²/δO¹⁸ *	~~Tritium H³ *~~										Number of Containers
	RAIN @ ~~WELLFIELD~~ 100m	17-AUG-12	10:30	H2O	X	X											3
	RAIN @ 700m	17-AUG-12	13:30	H2O	X	X											4

Short Holding Time
Rush Processing

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

* Isotope analyses to be forwarded to Waterloo, ON Please analyze dissolved metals only, samples field filtered + preserved.

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)
Released by: KT Date: Aug 17'12 Time: 5:00

SHIPMENT RECEPTION (lab use only)
Received by: aw Date: Aug. 17 Time: 17:05 Temperature: 13 °C

SHIPMENT VERIFICATION (lab use only)
Verified by: Date: Time: Observations: Yes / No ? If Yes add SIF

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION WHITE - LABORATORY COPY YELLOW - CLIENT COPY GENF 18.01 Front

PITEAU ASSOC. ENGINEERING LTD.
ATTN: Kathy Tixier
215 - 260 West Esplanade
North Vancouver BC V7M 3G7

Date Received: 28-AUG-12
Report Date: 26-SEP-12 19:42 (MT)
Version: FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #: L1201103
Project P.O. #: NOT SUBMITTED
Job Reference: 2841
C of C Numbers: 10-207294
Legal Site Desc:

Brent Mack
Account Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1201103-1	L1201103-2	L1201103-3	L1201103-4	L1201103-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	27-AUG-12	27-AUG-12	27-AUG-12	27-AUG-12	27-AUG-12
	Sampled Time	09:15	09:00	10:00	10:05	11:00
	Client ID	WELL 7	SITE 2	WELL 5	SITE Z	SKOOKUM
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	<5.0	<5.0	<5.0	<5.0	<5.0
	Conductivity (uS/cm)	81.9	67.8	69.5	69.2	19.4
	Hardness (as CaCO3) (mg/L)	22.8	20.4	21.5	21.4	7.80
	pH (pH)	8.40	8.07	7.97	7.86	7.05
	Total Dissolved Solids (mg/L)	70	73	68	68	15
	Turbidity (NTU)	<0.10	<0.10	<0.10	<0.10	3.64
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	20.0	18.9	19.4	19.4	6.7
	Chloride (Cl) (mg/L)	4.33	3.76	3.84	3.89	<0.50
	Fluoride (F) (mg/L)	0.093	0.087	0.091	0.091	<0.020
	Nitrate (as N) (mg/L)	0.0639	0.0516	0.0615	0.0620	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Sulfate (SO4) (mg/L)	8.11	6.73	7.09	7.18	1.98
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Aluminum (Al)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Antimony (Sb)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Arsenic (As)-Dissolved (mg/L)	0.00064	0.00052	0.00057	0.00055	<0.00010
	Barium (Ba)-Dissolved (mg/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Boron (B)-Dissolved (mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10
	Cadmium (Cd)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Calcium (Ca)-Dissolved (mg/L)	6.97	6.23	6.55	6.54	2.79
	Chromium (Cr)-Dissolved (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
	Copper (Cu)-Dissolved (mg/L)	0.0047	<0.0010	0.0123	0.0128	<0.0010
	Iron (Fe)-Dissolved (mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030
	Lead (Pb)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Magnesium (Mg)-Dissolved (mg/L)	1.31	1.17	1.25	1.23	0.20
	Manganese (Mn)-Dissolved (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
	Mercury (Hg)-Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Potassium (K)-Dissolved (mg/L)	1.27	1.16	1.23	1.26	0.26
	Selenium (Se)-Dissolved (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Sodium (Na)-Dissolved (mg/L)	5.0	4.5	4.8	4.7	<2.0
	Uranium (U)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Zinc (Zn)-Dissolved (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

	Sample ID	L1201103-6	L1201103-7			
	Description	WATER	WATER			
	Sampled Date	27-AUG-12	27-AUG-12			
	Sampled Time	11:50	12:45			
	Client ID	MAMQUAM	RING CK			
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	<5.0	<5.0			
	Conductivity (uS/cm)	34.0	29.9			
	Hardness (as CaCO3) (mg/L)	13.4	11.8			
	pH (pH)	7.93	7.86			
	Total Dissolved Solids (mg/L)	25	36			
	Turbidity (NTU)	2.04	12.2			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	11.1	9.1			
	Chloride (Cl) (mg/L)	0.93	<0.50			
	Fluoride (F) (mg/L)	<0.020	0.023			
	Nitrate (as N) (mg/L)	0.0115	<0.0050			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Sulfate (SO4) (mg/L)	3.60	3.95			
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD			
	Aluminum (Al)-Dissolved (mg/L)	0.011	0.028			
	Antimony (Sb)-Dissolved (mg/L)	<0.00050	<0.00050			
	Arsenic (As)-Dissolved (mg/L)	<0.00010	0.00019			
	Barium (Ba)-Dissolved (mg/L)	<0.020	<0.020			
	Boron (B)-Dissolved (mg/L)	<0.10	<0.10			
	Cadmium (Cd)-Dissolved (mg/L)	<0.00020	<0.00020			
	Calcium (Ca)-Dissolved (mg/L)	4.70	3.73			
	Chromium (Cr)-Dissolved (mg/L)	<0.0020	<0.0020			
	Copper (Cu)-Dissolved (mg/L)	<0.0010	<0.0010			
	Iron (Fe)-Dissolved (mg/L)	<0.030	<0.030			
	Lead (Pb)-Dissolved (mg/L)	<0.00050	<0.00050			
	Magnesium (Mg)-Dissolved (mg/L)	0.41	0.59			
	Manganese (Mn)-Dissolved (mg/L)	<0.0020	0.0030			
	Mercury (Hg)-Dissolved (mg/L)	<0.00020	<0.00020			
	Potassium (K)-Dissolved (mg/L)	0.28	0.32			
	Selenium (Se)-Dissolved (mg/L)	<0.0010	<0.0010			
	Sodium (Na)-Dissolved (mg/L)	<2.0	<2.0			
	Uranium (U)-Dissolved (mg/L)	<0.00010	<0.00010			
	Zinc (Zn)-Dissolved (mg/L)	<0.050	<0.050			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Aluminum (Al)-Dissolved	DLA	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Lead (Pb)-Dissolved	DLA	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Aluminum (Al)-Dissolved	DLA	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Antimony (Sb)-Dissolved	DLA	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Chromium (Cr)-Dissolved	DLA	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Lead (Pb)-Dissolved	DLA	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Selenium (Se)-Dissolved	DLA	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Fluoride (F)	DLM	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Nitrite (as N)	DLM	L1201103-1, -2, -3, -4, -5, -6, -7
Duplicate	Nitrate (as N)	DLM	L1201103-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Manganese (Mn)-Dissolved	MS-B	L1201103-1, -2, -3, -4, -5, -6, -7

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLA	Detection Limit Adjusted For required dilution
DLM	Detection Limit Adjusted For Sample Matrix Effects
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code | **Matrix** | **Test Description** | **Method Reference****

ALK-COL-VA | Water | Alkalinity by Colourimetric (Automated) | EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

ANIONS-CL-IC-VA | Water | Chloride by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-F-IC-VA | Water | Fluoride by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-NO2-IC-VA | Water | Nitrite in Water by Ion Chromatography | EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

ANIONS-NO3-IC-VA | Water | Nitrate in Water by Ion Chromatography | EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ANIONS-SO4-IC-VA | Water | Sulfate by Ion Chromatography | APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

COLOUR-TRUE-VA | Water | Colour (True) by Spectrometer | BCMOE Colour Single Wavelength

This analysis is carried out using procedures adapted from British Columbia Environmental Manual "Colour- Single Wavelength." Colour (True Colour) is determined by filtering a sample through a 0.45 micron membrane filter followed by analysis of the filtrate using the platinum-cobalt colourimetric method. Aparent Colour is determined without prior sample filtration. Colour is pH dependent. Unless otherwise indicated, reported colour results pertain to the pH of the sample as received, to within +/- 1 pH unit.

EC-PCT-VA | Water | Conductivity (Automated) | APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

HARDNESS-CALC-VA | Water | Hardness | APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-DIS-CVAFS-VA | Water | Dissolved Mercury in Water by CVAFS | EPA SW-846 3005A & EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by filtration (EPA Method 3005A) and involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry (EPA Method 245.7).

Dissolved Metals in Water by ICPOES | EPA SW-846 3005A/6010B

Reference Information

MET-DIS-ICP-VA Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-DIS-LOW-MS-VA Water Dissolved Metals in Water by ICPMS(Low) EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures involves preliminary sample treatment by filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

PH-MAN-VA Water pH by Manual Meter APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

It is recommended that this analysis be conducted in the field.

PH-MAN-VA Water pH by Manual Meter APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

It is recommended that this analysis be conducted in the field.

PH-PCT-VA Water pH by Meter (Automated) APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA Water pH by Meter (Automated) APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

TDS-VA Water Total Dissolved Solids by Gravimetric APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	**Laboratory Location**
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

10-207294

Reference Information

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

10- 207294

ALS Environmental

Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Page ____ of ____

Report To
Company: Piteau Associates
Contact: Kathy Tixier
Address: 215-260 W Esplanade
Phone: 604-986-8551 Fax:

Report Format / Distribution
Standard: ✓ Other (specify):
Select: PDF ✓ Excel ✓ Digital Fax
Email 1: ktixier@piteau.com
Email 2: jmancer@piteau.com

Service Request:(Rush subject to availability - Contact ALS to confirm TAT)
✓ Regular (Standard Turnaround Times - Business Days)
Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
Same Day or Weekend Emergency - Contact ALS to confirm TAT

Invoice To Same as Report ? (circle) [✓ Yes] or No (if No, provide details)
Copy of Invoice with Report? (circle) [✓ Yes] or No
Company:
Contact:
Address:
Phone: Fax:

Client / Project Information
Job #: 2841
PO / AFE:
LSD:
Quote #:

Lab Work Order # (lab use only) L1201103

ALS Contact: B. Mack **Sampler:** JM / KT

Analysis Request
(Indicate Filtered or Preserved, F/P)

Sample #	Sam (This descripti report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Full DW Package (Dissolved Metals) F	$\partial D/\partial O^{18}$	Tritium ^3H											Number of Containers
	Well 7	27 aug 12	9:05	Water	X	X												
	Site 2	↓	9:00	↓	X	X												
	Well 5		10:00		X	X	X											
	Site Z		10:05		X	X	X											
	Skookum		10:00		X	X	X											
	Mamquam		11:50		X	X												
	Ring Ck.		12:45		X	X	X											

Short Holding Time
Rush Processing

L1201103-COFC

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commerci

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date:	Time:	Received by:	Date:	Time:	Temperature:	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF
Jen Mancer	Aug 27	18:00	Brittany	Aug. 28	10:22	9.5 °C				

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION
WHITE - LABORATORY COPY YELLOW - CLIENT COPY
GENF 18.01 Front

PITEAU ASSOC. ENGINEERING LTD.
ATTN: Kathy Tixier
215 - 260 West Esplanade
North Vancouver BC V7M 3G7

Date Received:	29-AUG-12
Report Date:	07-SEP-12 16:55 (MT)
Version:	FINAL REV. 2

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #:	**L1201762**
Project P.O. #:	NOT SUBMITTED
Job Reference:	2841-1
C of C Numbers:	10-173223
Legal Site Desc:	

B Mack

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1201762-1				
	Description	H2O				
	Sampled Date	28-AUG-12				
	Sampled Time	14:15				
	Client ID	SNOWMELT@1300M				
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	<5.0				
	Conductivity (uS/cm)	10.2				
	Hardness (as CaCO3) (mg/L)	1.95				
	pH (pH)	6.37				
	Total Dissolved Solids (mg/L)	15				
	Turbidity (NTU)	0.11				
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	4.4				
	Chloride (Cl) (mg/L)	<0.50				
	Fluoride (F) (mg/L)	<0.020				
	Nitrate (as N) (mg/L)	0.0377				
	Nitrite (as N) (mg/L)	<0.0010				
	Sulfate (SO4) (mg/L)	<0.50				
Dissolved Metals	Aluminum (Al)-Dissolved (mg/L)	<0.010				
	Antimony (Sb)-Dissolved (mg/L)	<0.00050				
	Arsenic (As)-Dissolved (mg/L)	<0.00010				
	Barium (Ba)-Dissolved (mg/L)	<0.020				
	Boron (B)-Dissolved (mg/L)	<0.10				
	Cadmium (Cd)-Dissolved (mg/L)	<0.00020				
	Calcium (Ca)-Dissolved (mg/L)	0.78				
	Chromium (Cr)-Dissolved (mg/L)	<0.0020				
	Copper (Cu)-Dissolved (mg/L)	<0.0010				
	Iron (Fe)-Dissolved (mg/L)	<0.030				
	Lead (Pb)-Dissolved (mg/L)	<0.00050				
	Magnesium (Mg)-Dissolved (mg/L)	<0.10				
	Manganese (Mn)-Dissolved (mg/L)	<0.0020				
	Mercury (Hg)-Dissolved (mg/L)	<0.00020				
	Potassium (K)-Dissolved (mg/L)	0.49				
	Selenium (Se)-Dissolved (mg/L)	<0.0010				
	Sodium (Na)-Dissolved (mg/L)	<2.0				
	Uranium (U)-Dissolved (mg/L)	<0.00010				
	Zinc (Zn)-Dissolved (mg/L)	<0.050				

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Aluminum (Al)-Dissolved	DLA	L1201762-1
Duplicate	Lead (Pb)-Dissolved	DLA	L1201762-1
Duplicate	Fluoride (F)	DLM	L1201762-1
Duplicate	Nitrite (as N)	DLM	L1201762-1
Duplicate	Nitrate (as N)	DLM	L1201762-1
Matrix Spike	Manganese (Mn)-Dissolved	MS-B	L1201762-1

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLA	Detection Limit Adjusted For required dilution
DLM	Detection Limit Adjusted For Sample Matrix Effects
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

ANIONS-CL-IC-VA	Water	Chloride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-F-IC-VA	Water	Fluoride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ANIONS-NO2-IC-VA	Water	Nitrite in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

ANIONS-NO3-IC-VA	Water	Nitrate in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ANIONS-SO4-IC-VA	Water	Sulfate by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

COLOUR-TRUE-VA	Water	Colour (True) by Spectrometer	BCMOE Colour Single Wavelength

This analysis is carried out using procedures adapted from British Columbia Environmental Manual "Colour- Single Wavelength." Colour (True Colour) is determined by filtering a sample through a 0.45 micron membrane filter followed by analysis of the filtrate using the platinum-cobalt colourimetric method. Aparent Colour is determined without prior sample filtration. Colour is pH dependent. Unless otherwise indicated, reported colour results pertain to the pH of the sample as received, to within +/- 1 pH unit.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-DIS-CVAFS-VA	Water	Dissolved Mercury in Water by CVAFS	EPA SW-846 3005A & EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by filtration (EPA Method 3005A) and involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry (EPA Method 245.7).

MET-DIS-ICP-VA	Water	Dissolved Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-DIS-LOW-MS-VA	Water	Dissolved Metals in Water by ICPMS(Low)	EPA SW-846 3005A/6020A

Reference Information

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures involves preliminary sample treatment by filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

PH-MAN-VA Water pH by Manual Meter APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

It is recommended that this analysis be conducted in the field.

PH-MAN-VA Water pH by Manual Meter APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

It is recommended that this analysis be conducted in the field.

TDS-VA Water Total Dissolved Solids by Gravimetric APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA Water Turbidity by Meter APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	**Laboratory Location**
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

10-173223

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Short Holding Time

Rush Processing

10-173223

Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878

www.alsglobal.com

Page 1 of 1

Report To Piteau Associates
Company: Kathy Tixier
Contact:
Address: 215-260 W. Esplanade.
N. Vancouver, B.C.
Phone: 604-986-8551 Fax: 604-988-7286

Invoice To Same as Report ? (circle) [✓ Yes] or No (if No, provide details)
Copy of Invoice with Report? (circle) [✓ Yes] or No
Company:
Contact:
Address:
Phone: Fax:

Lab Work Order # (lab use only) L1201762

Report Format / Distribution
Standard: ✓ Other (specify):
Select: PDF ✓ Excel ✓ Digital Fax
Email 1: ktixier@piteau.com
Email 2: jmancer@piteau.com.

Client / Project Information
Job #: 2841-1
PO / AFE:
LSD:
Quote #:

ALS Contact:
Sampler:

Service Request:(Rush subject to availability - Contact ALS to confirm TAT)
✓ Regular (Standard Turnaround Times - Business Days)
☐ Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
☐ Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
☐ Same Day or Weekend Emergency - Contact ALS to confirm TAT

Analysis Request
(Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	F/P Full Drinking Water Pkg (Diss. Metals)	∂H2/∂O18 *	Tritium *										Number of Containers
	Snowmelt @ 1300 m.	28-AUG-12	14:15	H2O	X	X	X										4

L1201762-COFC

RUSH

Priority processing

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

* Isotope Analytes to be forwarded to Waterloo (RUSH on these, if possible) ; Dissolved metals only.

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: KTixier	Date: Aug 29 '12	Time: 9:30 am	Received by:	Date: Aug 29	Time: 13:44	Temperature: 5.2 °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

GENF 18.01 Front

PITEAU ASSOC. ENGINEERING LTD.
ATTN: Kathy Tixier
215 - 260 West Esplanade
North Vancouver BC V7M 3G7

Date Received: 08-NOV-12
Report Date: 27-NOV-12 10:38 (MT)
Version: FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #: L1235264
Project P.O. #: NOT SUBMITTED
Job Reference: 2841
C of C Numbers: 10-251387
Legal Site Desc:

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Grouping	Analyte	L1235264-1	L1235264-2	L1235264-3	L1235264-4	L1235264-5
	Description	H2O	H2O	H2O	H2O	H2O
	Sampled Date	07-NOV-12	07-NOV-12	07-NOV-12	07-NOV-12	07-NOV-12
	Sampled Time	11:00	10:30	15:30	12:30	12:00
	Client ID	MAMQUAM RIV	SKOOKUM CRK	RING CRK	SITE 2	WELL 7
WATER						
Physical Tests	Colour, True (CU)	13.4	10.0	6.2	<5.0	<5.0
	Conductivity (uS/cm)	27.3	20.4	38.0	59.1	69.8
	Hardness (as CaCO3) (mg/L)	11.8	9.38	16.6	19.8	22.6
	pH (pH)	7.26	7.20	7.39	7.46	7.54
	Turbidity (NTU)	0.87	1.46	3.98	0.46	0.17
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	9.3	7.7	13.1	17.6	19.8
	Chloride (Cl) (mg/L)	0.55	<0.50	<0.50	3.55	4.40
	Fluoride (F) (mg/L)	<0.020	<0.020	0.022	0.071	0.082
	Nitrate (as N) (mg/L)	0.0401	0.0313	0.0353	0.0553	0.0666
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	0.0010	<0.0010
	Sulfate (SO4) (mg/L)	2.67	1.97	5.91	6.32	8.09
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	4.15	3.32	5.37	6.08	6.91
	Iron (Fe)-Dissolved (mg/L)	<0.030	0.040	<0.030	<0.030	<0.030
	Magnesium (Mg)-Dissolved (mg/L)	0.34	0.27	0.78	1.13	1.30
	Manganese (Mn)-Dissolved (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Potassium (K)-Dissolved (mg/L)	<2.0	<2.0	<2.0	<2.0	3.1
	Sodium (Na)-Dissolved (mg/L)	<2.0	<2.0	<2.0	4.3	5.0

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1235264-6				
	Description	H2O				
	Sampled Date	07-NOV-12				
	Sampled Time	12:15				
	Client ID	WELL 5				
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	<5.0				
	Conductivity (uS/cm)	64.9				
	Hardness (as CaCO3) (mg/L)	21.1				
	pH (pH)	7.51				
	Turbidity (NTU)	0.37				
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	19.9				
	Chloride (Cl) (mg/L)	3.85				
	Fluoride (F) (mg/L)	0.080				
	Nitrate (as N) (mg/L)	0.0616				
	Nitrite (as N) (mg/L)	<0.0010				
	Sulfate (SO4) (mg/L)	6.97				
Dissolved Metals	Dissolved Metals Filtration Location	FIELD				
	Calcium (Ca)-Dissolved (mg/L)	6.45				
	Iron (Fe)-Dissolved (mg/L)	<0.030				
	Magnesium (Mg)-Dissolved (mg/L)	1.22				
	Manganese (Mn)-Dissolved (mg/L)	<0.0050				
	Potassium (K)-Dissolved (mg/L)	<2.0				
	Sodium (Na)-Dissolved (mg/L)	4.6				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Fluoride (F)	DLM	L1235264-1, -2, -3, -4, -5, -6
Duplicate	Nitrite (as N)	DLM	L1235264-1, -2, -3, -4, -5, -6
Duplicate	Nitrate (as N)	DLM	L1235264-1, -2, -3, -4, -5, -6
Duplicate	Nitrite (as N)	DLM	L1235264-1, -2, -3, -4, -5, -6
Matrix Spike	Calcium (Ca)-Dissolved	MS-B	L1235264-1, -2, -3, -4, -5, -6
Matrix Spike	Magnesium (Mg)-Dissolved	MS-B	L1235264-1, -2, -3, -4, -5, -6
Matrix Spike	Sodium (Na)-Dissolved	MS-B	L1235264-1, -2, -3, -4, -5, -6
Matrix Spike	Calcium (Ca)-Dissolved	MS-B	L1235264-1, -2, -3, -4, -5, -6
Matrix Spike	Manganese (Mn)-Dissolved	MS-B	L1235264-1, -2, -3, -4, -5, -6
Matrix Spike	Manganese (Mn)-Dissolved	MS-B	L1235264-1, -2, -3, -4, -5, -6
Matrix Spike	Calcium (Ca)-Dissolved	MS-B	L1235264-1, -2, -3, -4, -5, -6

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted For Sample Matrix Effects
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

ALS Test Code	Matrix	Test Description	Method Reference**
ANIONS-CL-IC-VA	Water	Chloride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ALS Test Code	Matrix	Test Description	Method Reference**
ANIONS-F-IC-VA	Water	Fluoride by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ALS Test Code	Matrix	Test Description	Method Reference**
ANIONS-NO2-IC-VA	Water	Nitrite in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

ALS Test Code	Matrix	Test Description	Method Reference**
ANIONS-NO3-IC-VA	Water	Nitrate in Water by Ion Chromatography	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ALS Test Code	Matrix	Test Description	Method Reference**
ANIONS-SO4-IC-VA	Water	Sulfate by Ion Chromatography	APHA 4110 B.

This analysis is carried out using procedures adapted from APHA Method 4110 B. "Ion Chromatography with Chemical Suppression of Eluent Conductivity" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography".

ALS Test Code	Matrix	Test Description	Method Reference**
COLOUR-TRUE-VA	Water	Colour (True) by Spectrometer	BCMOE Colour Single Wavelength

This analysis is carried out using procedures adapted from British Columbia Environmental Manual "Colour- Single Wavelength." Colour (True Colour) is determined by filtering a sample through a 0.45 micron membrane filter followed by analysis of the filtrate using the platinum-cobalt colourimetric method. Aparent Colour is determined without prior sample filtration. Colour is pH dependent. Unless otherwise indicated, reported colour results pertain to the pH of the sample as received, to within +/- 1 pH unit.

ALS Test Code	Matrix	Test Description	Method Reference**
EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

ALS Test Code	Matrix	Test Description	Method Reference**
HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in $CaCO_3$ equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

ALS Test Code	Matrix	Test Description	Method Reference**
MET-DIS-ICP-VA	Water	Dissolved Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

ALS Test Code	Matrix	Test Description	Method Reference**
PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

Reference Information

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

10-251387

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

L1235264-COFC

10-251387

Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878

www.alsglobal.com

Page 1 of 1

Report To

Company: Piteau Associates
Contact: Kathy Tixier
Address: 215-260 W. Esplanade
Phone: 604-986-8551 Fax:

Report Format / Distribution

Standard: ✓ Other (specify):
Select: PDF ✓ Excel ✓ Digital Fax
Email 1: ktixier@piteau.com
Email 2: jmaucer@piteau.com

Service Request: (Rush subject to availability - Contact ALS to confirm TAT)

- ✓ Regular (Standard Turnaround Times - Business Days)
- Priority(2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
- Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
- Same Day or Weekend Emergency - Contact ALS to confirm TAT

Invoice To Same as Report ? (circle) [✓ Yes] or No (if No, provide details)
Copy of Invoice with Report? (circle) [✓ Yes] or No

Company:
Contact:
Address:
Phone: Fax:

Client / Project Information

Job #: 2841
PO / AFE:
LSD:
Quote #:

Lab Work Order # (lab use only) L1235264

ALS Contact: B. Mack. **Sampler:** JM / KT

Analysis Request (Indicate Filtered or Preserved, F/P)

Sample #	Sample Identification (This description will appear on the report	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	BASIC DW Packs (Diss. Metals)		∂D/∂O^{18} (waterloo)		Tritium H^3 (waterloo)		Tritium H^3 HOLD						Number of Containers
1	~~Disso~~ Mamquam Riv.	7-NOV-12	11:00	H2O	X		X										3
2	Skookum Crk		10:30		X		X		X								4
3	Ring Crk		15:30		X		X		X								4
4	Site 2		12:30		X		X										3
5	Well 7		12:00		X		X										3
6	Well 5		12:15		X		X		X								4
7	Rain@700m		9:00				X				X						2
8	Rain @ 100 m		11:30				X		X								2
9	SiteX		15:00				X										1

Short Holding Time

Rush Processing

Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details

∂D/∂O^{18} + H^3 analyses @ U of Waterloo, Ask them to HOLD analysis of H^3 on "Rain@700 m" sample

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Tixer	Date: 8-NOV-12	Time: 8:00	Received by: Brit	Date: Nov. 8	Time: 9:40	Temperature: 4.3 °C	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

GENF 18.01 Front

Client: Tixier
Piteau Associates Engineering Ltd.
PO#:

ISO# 2012314
Location:
7 for 18O, 2H, E3H

University of Waterloo
Environmental Isotope Lab

#	Sample	Lab#	$\delta^{18}O$	Result	Repeat	δ^2H	Result	Repeat	E3H	Result	± 1σ	Repeat	± 1σ
			H_2O	VSMOW		H_2O	VSMOW						
1	Lower Skookum Crk	287704	X	-15.72	-15.66	X	-112.93	-113.39	X	4.0	0.5	4.5	0.5
2	Lower Ring Crk	287705	X	-15.98		X	-110.72	-110.30	X	4.8	0.5		
3	Mamquam River	287706	X	-14.68	-14.89	X	-109.78	-109.58	X	3.7	0.5		
4	Powerhouse Crk "Site 2"	287707	X	-13.56		X	-101.87	-101.45	X	2.6	0.4		
5	Well #7	287708	X	-14.20		X	-101.52	-101.97	X	2.6	0.4		
6	Well #5	287709	X	-14.15	-14.09	X	-102.35	-102.91	X	3.1	0.4		
7	Rain	287710	X	-6.61	-6.37	X	-55.70	-55.40	X	8.2	0.7		

Tritium is reported in Tritium Units.
1TU = 3.221 Picocurries/L per IAEA, 2000 Report.
1TU = 0.11919 Becquerels/L per IAEA, 2000 Report.

#	Sample	Lab#	$\delta^{18}O$	Result	Repeat	δ^2H	Result	Repeat	E3H	Result	± 1σ	Repeat	± 1σ
			H_2O	VSMOW		H_2O	VSMOW						
1	Rain @ 700m	288397	X	-15.60	-15.43	X	-116.45	-116.52	X	7.5	0.7		

Tritium is reported in Tritium Units.
1TU = 3.221 Picocurries/L per IAEA, 2000 Report.
1TU = 0.11919 Becquerels/L per IAEA, 2000 Report.

#	Sample	Lab#	$\delta^{18}O$	Result	Repeat	δ^2H	Result	Repeat		pH	onductivity
			H_2O	VSMOW		H_2O	VSMOW				
1	RAIN@100M 17-AUG-12	291277	X	-9.99	-10.07	X	-81.05	-81.11	125ml bottle		
2	RAIN@700M 17-AUG-12	291278	X	-10.09	-9.96	X	-77.46	-77.57	125ml bottle		

#	Sample	Lab#	$\delta^{18}O$	Result	Repeat	δ^2H	Result	Repeat	E3H	Result	± 1σ	Repeat	± 1σ
			H_2O	VSMOW		H_2O	VSMOW						
1	Snowmelt @1300 m	291578	X	-15.52	-15.58	X	-111.73	-112.13	X	4.3	0.5		

#	Sample	Lab#	$\delta^{18}O$	Result	Repeat	δ^2H	Result	Repeat	Result	± 1σ	Repe	± 1σ	E3H	± 1σ
			H_2O	VSMOW		H_2O	VSMOW							
1		291579	X	-14.73	-14.92	X	-107.22	-107.17					X	
2		291580	X	-15.07	-14.92	X	-107.93	-107.14					X	
3		291581	X	-14.83		X	-106.47	-106.06						
4		291582	X	-14.25	-14.01	X	-101.61	-101.64						
5		291583	X	-13.93		X	-102.39	-102.73						
6		291584	X	-14.31	-14.19	X	-102.43	-102.04					X	
7		291585	X	-13.98		X	-101.21	-102.00					X	

#	Sample	Lab#	$\delta^{18}O$	Result	Repeat	δ^2H	Result	Repeat	E3H	Result	± 1σ	Repeat	± 1σ
			H_2O	VSMOW		H_2O	VSMOW						
1	Mamquam River	294004	X	-13.77	-13.63	X	-97.88	-98.00					
2	Skookum Creek	294005	X	-14.22		X	-102.47	-103.03	X	3.3	0.4		
3	Ring Creek	294006	X	-13.94	-13.94	X	-102.19	-101.70	X	2.6	0.3		
4	Site 2	294007	X	-13.41	-13.35	X	-100.59	-101.05					
5	Well 7	294008	X	-13.50	-13.52	X	-101.80	-102.28					
6	Well 5	294009	X	-13.62		X	-102.26	-102.33	X	2.2	0.3		
7	Rain @ 700m	294010	X	-8.07		X	-53.44	-53.67	x	4.4	0.4		
8	Rain @ 100m	294011	X	-11.37	-11.50	X	-83.56	-83.71	X	1.7	0.3	2.2	0.4
9	Site X	294012	X	-13.98		X	-100.65	-100.08					

Rick Heemskerk
uwEILAB Manager
rkhmskrk@uwaterloo.ca
519 888 4567 ext 35838

To Contact uwEILAB:
519 888 4732

APPENDIX C

WATER BALANCE SPREADSHEETS

TABLE C-1

MONTHLY WATER BALANCE TO ESTIMATE GROUNDWATER RECHARGE TO NATIVE SURFACE FLOW BELOW 1700m

MONTH		November	December	January	February	March	April	May	June	July	August	September	October	Total
TOTAL PRECIP (mm) [1]		617.4	512.1	549.8	461.0	344.5	263.5	172.4	139.8	99.6	97.1	143.7	455.6	3856.5
SNOWFALL EQUIVALENT (mm)[1]		203.5	322.2	311.5	235.5	153.1	56.0	2.8	0.0	0.0	0.0	0.0	26.5	1311.1
SNOW ACCUMULATION (mm) [3]		183.3	499.5	805.0	1034.5	1181.6	1157.3	898.9	605.2	302.6			26.5	
POTENTIAL MONTHLY EVAPOTRANSPIRATION [2]		12.2	0.0	0.6	8.6	26.2	49.3	78.3	102.1	117.2	107.3	76.3	39.4	617.6
SUBLIMATION (mm)		6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0					48.0
ACTUAL EVAPOTRANSPIRATION / SUBLIMATION		16.4	6.0	6.5	13.4	28.3	47.9	72.5	92.8	99.6	75.1	64.9	33.5	556.9
NET PRECIPITATION (mm)		601.1	506.1	543.3	447.6	316.2	215.6	99.9	47.0	-0.1	22.0	78.8	422.1	3299.6
RUNOFF (mm) [4]		157.6	98.0	134.1	67.2	122.5	196.6	291.5	272.5	242.0	194.8	47.3	79.1	1903.3
SURPLUS (mm) [5]		286.7	92.0	103.7	150.9	46.5	43.2	66.9	68.1	60.5	129.8	31.5	316.5	1396.3
SOIL MOISTURE (mm) [6]		150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	
GROUNDWATER RECHARGE (mm) [7]		286.7	92.0	103.7	150.9	46.5	43.2	66.9	68.1	60.5	129.8	31.5	316.5	1396.3
SHALLOW GROUNDWATER DISCHARGE (mm) [8]	70%	146.0	125.5	108.8	103.0	76.0	58.6	50.0	46.3	44.9	60.8	48.2	109.2	977.4
DEEP GROUNDWATER DISCHARGE (m	30%	34.4	35.6	35.6	32.1	35.6	34.4	35.6	34.4	35.6	35.6	34.4	35.6	418.9
NET TO STREAMFLOW (mm) [9]		303.6	223.5	242.8	170.3	198.6	255.3	341.5	318.8	286.9	255.6	95.5	188.4	2880.7

H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_THICK.xlsx]C-1 Native

NOTES:

1) Average monthly precipitation interpreted for the native surface (TABLE I). Snow is water equivalent.
2) Potential monthly evapotranspiration (PE) from TABLE I. Average actual monthly evapotranspiration (AET) plus sublimation calculated as PE x 85% plus sublimation.
3) Snow accumulation equals 80% of November snow, all December to March snow, and most of April snow, after sublimation. Sublimation, higher temperatures, and rainfall from April through August reduce ambient snow pack by 6%, 22%, 32%, 50% and 100% for April, May, June, July and August, respectively.
4) November, December, January, and February runoff were assumed to equal 35% / 50% / 55% / 30% of rain amount. March runoff assumed to equal 70% rain amount, while April, May, June and July runoff were assumed to equal 80% of ablating snow pack and net ambient precipitation. August runoff equals 60 % of net precipitation and snowpack ablation and September to October runoff equal 80% and 20% of net precipitation.
5) Monthly deficit or surplus of water (precipitation - evaporation - runoff).
6) Soil moisture balance based on 150mm water holding capacity. Water will infiltrate to groundwater recharge only when soil at water holding capacity. As noted, soil moisture is indicated to be at full water holding capacity twelve months of year.
7) Groundwater recharge equals water surplus that is in excess of that required to maintain soil at its water holding capacity. It is assumed that 70% will go to a shallow groundwater regime that discharges to surface water, and 30% goes to a deeper flow regime that discharges beyond the extent of the catchment.
8) Groundwater discharge equals weighted average of recharge over preceding 12 months (i.e. follows a groundwater flow recession curve).
9) Sum of groundwater discharge plus runoff.

TABLE C-2

MONTHLY WATER BALANCE TO ESTIMATE GROUNDWATER RECHARGE TO RING CREEK LAVA FLOW

MONTH	November	December	January	February	March	April	May	June	July	August	September	October	Total
TOTAL PRECIP (mm) [1]	527.4	437.5	469.7	393.8	294.3	225.1	147.3	119.4	85.1	83.0	122.8	389.2	3294.6
SNOWFALL EQUIVALENT (mm)[1]	99.0	180.0	177.2	129.6	78.7	25.0	1.2	0.0	0.0	0.0	0.0	11.4	702.1
SNOW ACCUMULATION (mm) [3]	13.8	187.8	359.0	482.6	555.3	574.3	455.6	85.1					
POTENTIAL MONTHLY EVAPOTRANSPIRATION [2]	12.2	0.0	0.6	8.6	26.2	49.3	78.3	102.1	117.2	107.3	76.3	39.4	617.6
SUBLIMATION (mm)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0					48.0
ACTUAL EVAPOTRANSPIRATION / SUBLIMATION [2]	12.1	6.0	6.3	10.3	19.1	30.7	45.1	57.0	58.6	53.7	38.2	19.7	356.8
NET PRECIPITATION (mm)	515.4	431.5	463.4	383.5	275.2	194.4	102.2	62.4	26.4	29.3	84.6	369.5	2937.8
RUNOFF (mm) [4]	0.0	0.0	0.0	0.0	0.0	8.8	11.0	21.6	1.1	0.3	0.8	3.7	47.4
SURPLUS (mm) [5]	501.6	257.6	292.2	259.9	202.5	166.7	209.8	411.2	110.4	29.0	83.8	365.8	2890.3
SOIL MOISTURE (mm) [6]	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	
GROUNDWATER RECHARGE (mm) [7]	501.6	257.6	292.2	259.9	202.5	166.7	209.8	411.2	110.4	29.0	83.8	365.8	2890.3
SHALLOW GROUNDWATER DISCHARGE (mm) [8] 90%	278.2	278.1	280.0	262.8	232.5	201.3	190.7	249.0	202.2	141.5	108.6	176.3	2601.3
DEEP GROUNDWATER DISCHARGE TO AQUIFER (mm) 10%	23.8	24.5	24.5	22.2	24.5	23.8	24.5	23.8	24.5	24.5	23.8	24.5	289.0
NET TO STREAMFLOW (mm) [9]	278.2	278.1	280.0	262.8	232.5	210.1	201.8	270.6	203.4	141.8	109.5	180.0	2648.7

H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_THICK.xlsx]C-2 Lava Flow

NOTES:

1) Average monthly precipitation interpreted for the lava flow surface (TABLE I). Snow is water equivalent.

2) Potential monthly evapotranspiration (PE) from TABLE I. Average actual monthly evapotranspiration (AET) plus sublimation calculated as PE x 50% plus sublimation.

3) Snow accumulation equals 20% of November snow, all December to April snow after sublimation, and most of May snow. Sublimation, warmer temperatures and rainfall in May, June and July reduce snow pack by 20%, 80% and 100%.

4) No runoff November through March. April, May, and June runoff were assumed to equal 5% of ablating snow pack and net ambient precipitation. July through October runoff was assumed to equal 1% net ambient precipitation.

5) Monthly deficit or surplus of water (precipitation - evaporation - runoff).

6) Soil moisture balance based on 10mm water holding capacity. Water will infiltrate to groundwater recharge only when soil at water holding capacity. As noted, soil moisture is indicated to be at full water holding capacity twelve months of year.

7) Groundwater recharge equals water surplus that is in excess of that required to maintain soil at its water holding capacity. It is assumed that 90% will go to a shallow groundwater regime that discharges to surface water, and 10% goes to a deeper flow regime that recharges the aquifer below the Ring Creek Lava Flow.

8) Shallow groundwater discharge equals weighted average of recharge over preceding 12 months (i.e., follows a groundwater flow recession curve).

9) Sum of groundwater discharge plus runoff.

TABLE C-3

MONTHLY WATER BALANCE FOR GLACIATED AREAS (ALL AREAS AT ELEVATIONS >1700m)

MONTH	November	December	January	February	March	April	May	June	July	August	September	October	Total
TOTAL PRECIP (mm) [1]	773.1	641.3	688.4	577.2	431.3	329.9	215.9	175.1	124.7	121.6	180.0	570.5	4829.1
SNOWFALL EQUIVALENT (mm)[1]	485.8	521.7	526.3	444.8	311.1	190.9	67.4	11.9	1.8	0.4	13.8	181.3	2757.4
SNOW ACCUMULATION (mm) [3]	744.0	1377.3	2057.2	2618.2	3016.6	3152.6	2493.7	1147.9	455.5	217.1		145.1	
POTENTIAL MONTHLY EVAPOTRANSPIRATION [2]	12.2	0.0	0.6	8.6	26.2	49.3	78.3	102.1	117.2	107.3	76.3	39.4	617.6
SUBLIMATION (mm)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0			8.0	80.0
ACTUAL EVAPOTRAN / SUBLIMATION [2]	19.6	8.0	8.5	16.2	32.9	54.9	82.3	105.0	119.4	102.0	72.5	45.5	666.7
NET PRECIPITATION (mm)	753.5	633.3	679.9	561.0	398.4	275.1	133.5	70.1	5.3	19.7	107.5	525.0	4162.3
RUNOFF (mm) [4]	154.6	0.0	0.0	0.0	0.0	139.0	792.5	1416.0	697.7	258.0	324.6	380.0	4162.3
SURPLUS (mm) [5]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ADDITIONAL GLACIAL MELT (mm) [6]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NET TO STREAMFLOW (mm) [7]	154.6	0.0	0.0	0.0	0.0	139.0	792.5	1416.0	697.7	258.0	324.6	380.0	4162.3

H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_THICK.xlsx]C-3Glacier

NOTES:

1) Average monthly precipitation interpreted for the glacial surface (above 1700m) (TABLE I). Snow is water equivalent.

2) Potential monthly evapotranspiration (PE) from TABLE I. Average actual monthly evapotranspiration (AET) plus sublimation calculated as PE x 95% plus sublimation.

3) Snow accumulation equals 80% of October snow, and assume all precipitation accumulates in the snowpack from November to March, as well 75% of May precipitation and 25% of June's. Snowpack is reduced by monthly evaporation and sublimation over the winter, and dissipates due to warmer temperatures and rainfall from June to September.

4) No runoff November through March. April through October runoff equal to net ambient precipitation and snowmelt.

5) Surplus after evaporation and sublimation, snowpack additions and runoff assumed to be zero, as no interaction between the glacial surface and groundwater regime is assumed in this model.

6) No year-over-year glacial melt is assumed in this water balance.

7) Streamflow is comprised of runoff from rainfall and annual snowpack ablation.

TABLE C-4

MEAN ANNUAL AND MONTHLY WATER BALANCE UNIT RUNOFF AND GROUNDWATER RECHARGE/DISCHARGE RATES

	WELL FIELD			MAMQUAM RIVER			RING CREEK			SKOOKUM CREEK		
	NATIVE GROUND	RING CREEK LAVA FLOW (DEEP GW FLOW ONLY)	GLACIER	NATIVE GROUND	RING CREEK LAVA FLOW	GLACIER	NATIVE GROUND	RING CREEK LAVA FLOW	GLACIER	NATIVE GROUND	RING CREEK LAVA FLOW	GLACIER
AREA (ha)	0.0	2691.8	0.0	23583.9	1579.9	2519.2	2984.4	1111.9	331.7	6131.7	761.5	1842.8
MEAN ANNUAL UNIT RATES (mm/yr)												
NET ANNUAL RUNOFF[1]	1903.3		4162.3	1903.3	47.4	4162.3	1903.3	47.4	4162.3	1903.3	47.4	4162.3
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
NET ANNUAL GW RECHARGE	977.4	289.0	0.0	977.4	2601.3	0.0	977.4	2601.3	0.0	977.4	2601.3	0.0
JANUARY UNIT RATES (mm/mth)												
MONTHLY RUNOFF	134.1		0.0	134.1	0.0	0.0	134.1	0.0	0.0	134.1	0.0	0.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	108.8	24.5	0.0	108.8	280.0	0.0	108.8	280.0	0.0	108.8	280.0	0.0
FEBRUARY UNIT RATES (mm/mth)												
MONTHLY RUNOFF	67.2		0.0	67.2	0.0	0.0	67.2	0.0	0.0	67.2	0.0	0.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	103.0	22.2	0.0	103.0	262.8	0.0	103.0	262.8	0.0	103.0	262.8	0.0
MARCH UNIT RATES (mm/mth)												
MONTHLY RUNOFF	122.5		0.0	122.5	0.0	0.0	122.5	0.0	0.0	122.5	0.0	0.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	76.0	24.5	0.0	76.0	232.5	0.0	76.0	232.5	0.0	76.0	232.5	0.0
APRIL UNIT RATES (mm/mth)												
MONTHLY RUNOFF	196.6		139.0	196.6	8.8	139.0	196.6	8.8	139.0	196.6	8.8	139.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	58.6	23.8	0.0	58.6	201.3	0.0	58.6	201.3	0.0	58.6	201.3	0.0
MAY UNIT RATES (mm/mth)												
MONTHLY RUNOFF	291.5		792.5	291.5	11.0	792.5	291.5	11.0	792.5	291.5	11.0	792.5
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	50.0	24.5	0.0	50.0	190.7	0.0	50.0	190.7	0.0	50.0	190.7	0.0
JUNE UNIT RATES (mm/mth)												
MONTHLY RUNOFF	272.5		1416.0	272.5	21.6	1416.0	272.5	21.6	1416.0	272.5	21.6	1416.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	46.3	23.8	0.0	46.3	249.0	0.0	46.3	249.0	0.0	46.3	249.0	0.0
JULY UNIT RATES (mm/mth)												
MONTHLY RUNOFF	242.0		697.7	242.0	1.1	697.7	242.0	1.1	697.7	242.0	1.1	697.7
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	44.9	24.5	0.0	44.9	202.2	0.0	44.9	202.2	0.0	44.9	202.2	0.0
AUGUST UNIT RATES (mm/mth)												
MONTHLY RUNOFF	194.8		258.0	194.8	0.3	258.0	194.8	0.3	258.0	194.8	0.3	258.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	60.8	24.5	0.0	60.8	141.5	0.0	60.8	141.5	0.0	60.8	141.5	0.0
SEPTEMBER UNIT RATES (mm/mth)												
MONTHLY RUNOFF	47.3		324.6	47.3	0.8	324.6	47.3	0.8	324.6	47.3	0.8	324.6
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	48.2	23.8	0.0	48.2	108.6	0.0	48.2	108.6	0.0	48.2	108.6	0.0
OCTOBER UNIT RATES (mm/mth)												
MONTHLY RUNOFF	79.1		380.0	79.1	3.7	380.0	79.1	3.7	380.0	79.1	3.7	380.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	109.2	24.5	0.0	109.2	176.3	0.0	109.2	176.3	0.0	109.2	176.3	0.0
NOVEMBER UNIT RATES (mm/mth)												
MONTHLY RUNOFF	157.6		154.6	157.6	0.0	154.6	157.6	0.0	154.6	157.6	0.0	154.6
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	146.0	23.8	0.0	146.0	278.2	0.0	146.0	278.2	0.0	146.0	278.2	0.0
DECEMBER UNIT RATES (mm/mth)												
MONTHLY RUNOFF	98.0		0.0	98.0	0.0	0.0	98.0	0.0	0.0	98.0	0.0	0.0
SEEPAGE FROM GLACIER TOE			0.0			0.0			0.0			0.0
GROUNDWATER BASEFLOW CONTRIBUTI	125.5	24.5	0.0	125.5	278.1	0.0	125.5	278.1	0.0	125.5	278.1	0.0

H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_THICK.xlsx]C-4 Monthly Rates

WATER BALANCE SPREADSHEETS

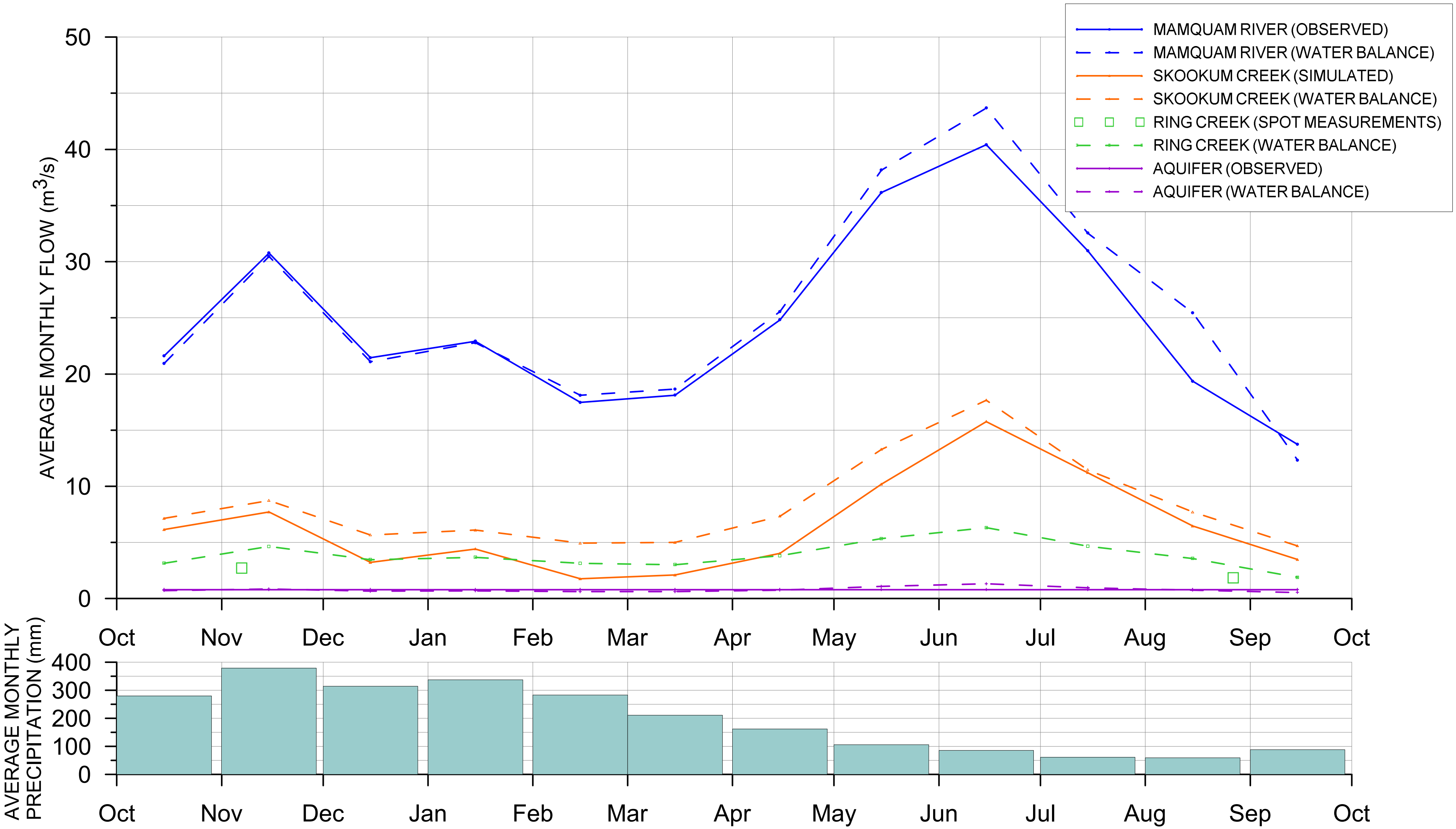
TABLE C-5

CALCULATED MEAN ANNUAL AND MONTHLY FLOWS (L/s)

	WELL FIELD							MAMQUAM RIVER						RING CREEK					SKOOKUM CREEK				
				SEEPAGE TO AQUIFER BENEATH RING CREEK LAVA FLOW							0%						5%					4%	
	NATIVE GROUND	RING CREEK LAVA FLOW (DEEP GW FLOW ONLY)	GLACIER	SEEPAGE FROM SKOOKUM CREEK	SEEPAGE FROM RING CREEK	SEEPAGE FROM MAMQUAM	TOTAL FLOW IN RING CREEK LAVA FLOW AQUIFER	NATIVE GROUND	RING CREEK LAVA FLOW	GLACIER	LOSSES TO AQUIFER BELOW SKOOKUM	LOSSES TO AQUIFER IN SKOOKUM CATCHMENT	TOTAL MAMQUAM	NATIVE GROUND	RING CREEK LAVA FLOW	GLACIER	LOSSES TO AQUIFER	TOTAL RING CREEK	NATIVE GROUND	RING CREEK LAVA FLOW	GLACIER	LOSSES TO AQUIFER	TOTAL SKOOKUM CREEK
MEAN ANNUAL FLOWS (L/s)																							
MEAN ANNUAL RUNOFF	0		0					14234	24	3325				1801	17	438			3701	11	2432		
MEAN TOE DISCHARGE			0					0	0	0				0	0	0			0	0	0		
MEAN ANNUAL GROUNDWATER DISCHAR	0	247	0					7309	1303	0				925	917	0			1900	628	0		
TOTAL MEAN ANNUAL DISCHARGE	0	247	0	347	205	0	799	21543	1327	3325	0	347	25848	2726	934	438	205	3893	5601	640	2432	347	8326
JANUARY FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					11807	0	0				1494	0	0			3070	0	0		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					9576	1652	0				1212	1163	0			2490	796	0		
TOTAL MONTHLY DISCHARGE	0	247	0	254	193	0	694	21383	1652	0	0	254	22781	2706	1163	0	193	3675	5560	796	0	254	6101
FEBRUARY FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					6555	0	0				830	0	0			1704	0	0		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					10042	1716	0				1271	1208	0			2611	827	0		
TOTAL MONTHLY DISCHARGE	0	247	0	206	165	0	618	16597	1716	0	0	206	18107	2100	1208	0	165	3143	4315	827	0	206	4937
MARCH FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					10790	0	0				1365	0	0			2805	0	0		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					6695	1371	0				847	965	0			1741	661	0		
TOTAL MONTHLY DISCHARGE	0	247	0	208	159	0	614	17485	1371	0	0	208	18648	2213	965	0	159	3019	4546	661	0	208	4999
APRIL FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					17892	53	1351				2264	38	178			4652	26	988		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					5333	1227	0				675	863	0			1387	591	0		
TOTAL MONTHLY DISCHARGE	0	247	0	306	201	0	753	23225	1280	1351	0	306	25551	2939	901	178	201	3817	6038	617	988	306	7338
MAY FLOWS (Freshet) (L/s)																							
MEAN MONTHLY RUNOFF	0		0					25664	65	7454				3248	46	981			6672	31	5452		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					4404	1125	0				557	792	0			1145	542	0		
TOTAL MONTHLY DISCHARGE	0	247	0	554	281	0	1082	30068	1190	7454	0	554	38158	3805	838	981	281	5343	7817	574	5452	554	13290
JUNE FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					24798	132	13762				3138	93	1812			6447	64	10067		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					4209	1518	0				533	1068	0			1094	731	0		
TOTAL MONTHLY DISCHARGE	0	247	0	736	332	0	1315	29008	1650	13762	0	736	43683	3671	1161	1812	332	6311	7542	795	10067	736	17668
JULY FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					21311	7	6562				2697	5	864			5541	3	4800		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					3950	1193	0				500	840	0			1027	575	0		
TOTAL MONTHLY DISCHARGE	0	247	0	478	245	0	970	25262	1200	6562	0	478	32545	3197	844	864	245	4660	6568	578	4800	478	11469
AUGUST FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					17150	2	2427				2170	1	319			4459	1	1775		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					5353	835	0				677	588	0			1392	402	0		
TOTAL MONTHLY DISCHARGE	0	247	0	321	188	0	756	22503	837	2427	0	321	25445	2848	589	319	188	3568	5851	403	1775	321	7708
SEPTEMBER FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					4305	5	3155				545	4	415			1119	2	2308		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					4389	662	0				555	466	0			1141	319	0		
TOTAL MONTHLY DISCHARGE	0	247	0	196	99	0	542	8693	667	3155	0	196	12319	1100	470	415	99	1886	2260	322	2308	196	4694
OCTOBER FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					6966	22	3574				882	15	471			1811	11	2614		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					9619	1040	0				1217	732	0			2501	501	0		
TOTAL MONTHLY DISCHARGE	0	247	0	298	166	0	710	16586	1062	3574	0	298	20924	2099	747	471	166	3151	4312	512	2614	298	7141
NOVEMBER FLOWS (L/s)																							
MEAN MONTHLY RUNOFF	0		0					14339	0	1503				1815	0	198			3728	0	1099		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					13288	1696	0				1682	1193	0			3455	817	0		
TOTAL MONTHLY DISCHARGE	0	247	0	364	244	0	855	27627	1696	1503	0	364	30461	3496	1193	198	244	4643	7183	817	1099	364	8735
DECEMBER FLOW (L/s)																							
MEAN MONTHLY RUNOFF	0		0					8627	0	0				1092	0	0			2243	0	0		
MEAN MONTHLY TOE SEEPAGE			0					0	0	0				0	0	0			0	0	0		
GROUNDWATER DISCHARGE	0	247	0					11054	1641	0				1399	1155	0			2874	791	0		
TOTAL MONTHLY DISCHARGE	0	247	0	236	182	0	665	19680	1641	0	0	236	21085	2490	1155	0	182	3463	5117	791	0	236	5671

H:\Project\2841\Water Balance\[2012Dec5_Water_Balance_THICK.xlsx]C-5 Monthly Flows

H:\Project\2841\Water Balance\WBFlowCalibration.grf



NOTES:
1. PRECIPITATION MEASURED AT ENVIRONMENT CANADA'S SQUAMISH UPPER CLIMATE STATION (EL 46m).
2. SEE TABLE VII FOR SOURCES OF OBSERVED AND SIMULATED FLOW MEASUREMENTS.
3. WATER BALANCE FLOWS FOR SKOOKUM AND RING CREEKS ARE NET OF LOSSES TO AQUIFER.

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRINGS, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

WATER BALANCE FLOW CALIBRATION

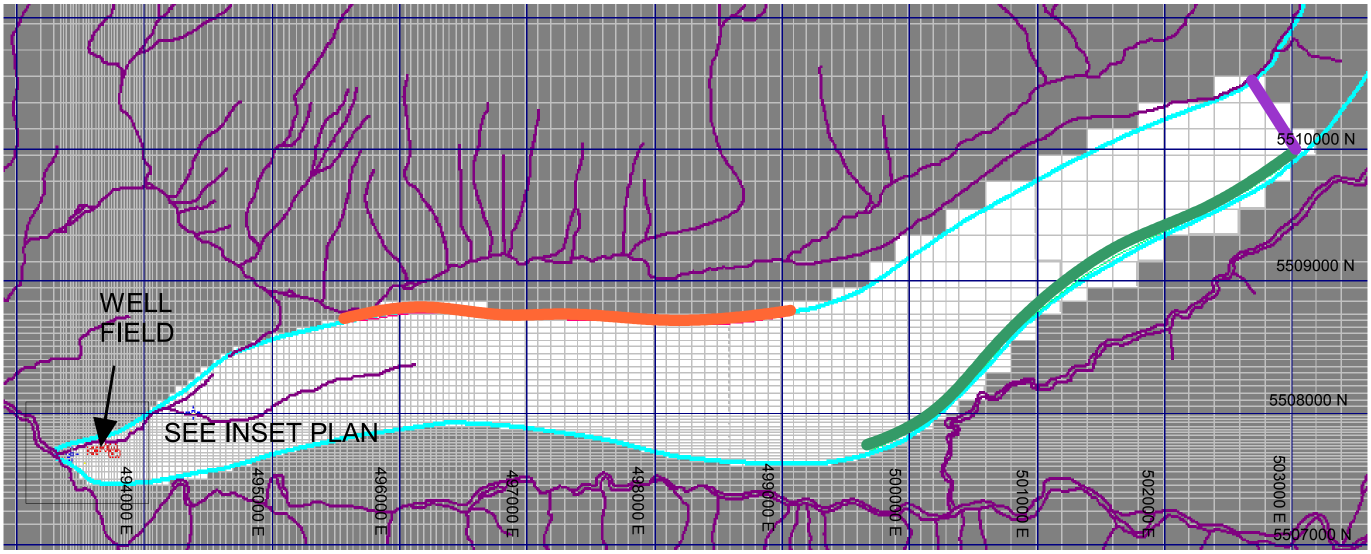
BY: JM
DATE: JAN 13
APPROVED: KT
FIG: C-1

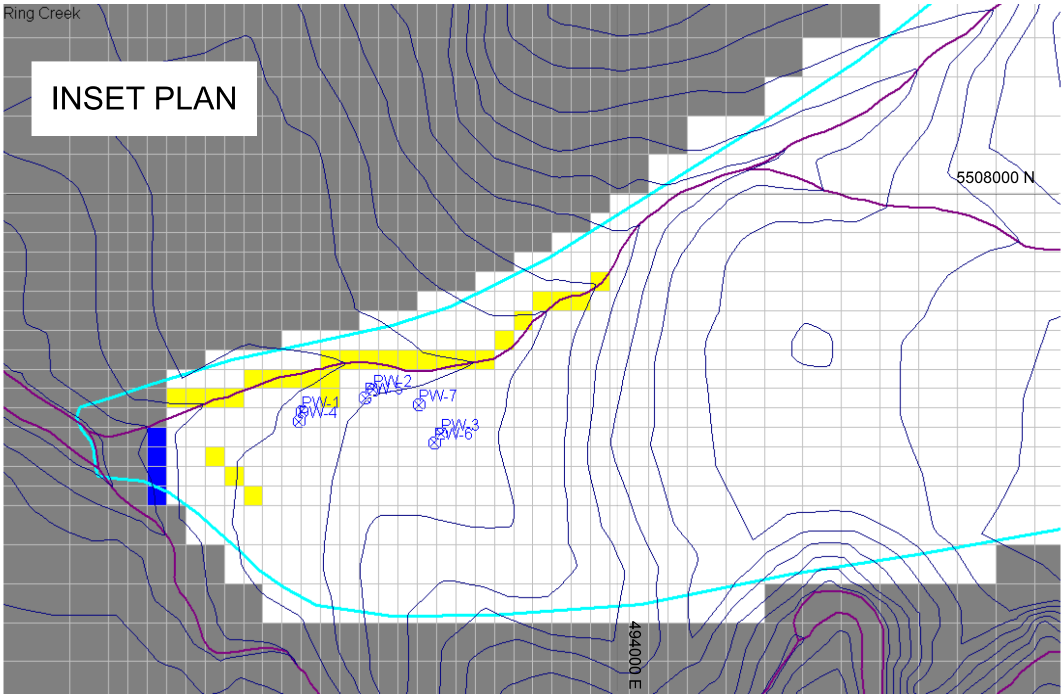
APPENDIX D

MODEL CAPTURE ZONE SIMULATIONS

H:/Project/2841/VISTAS/FigD1 ModelSetup.grf

SCALE ≃ 1 : 57,500





N

SCALE ≃ 1 : 10,000

🟧 SKOOKUM CREEK
🟩 RING CREEK
🟪 UPGRADIENT INFLOW
ANALYTIC ELEMENT CONSTANT FLUX BOUNDARY

— SURFACE WATER COURSE
— TOPOGRAPHIC CONTOUR (20m)

🟨 DRAIN NODES ALONG POWERHOUSE CREEK
🟦 CONSTANT HEAD NODES

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRING, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

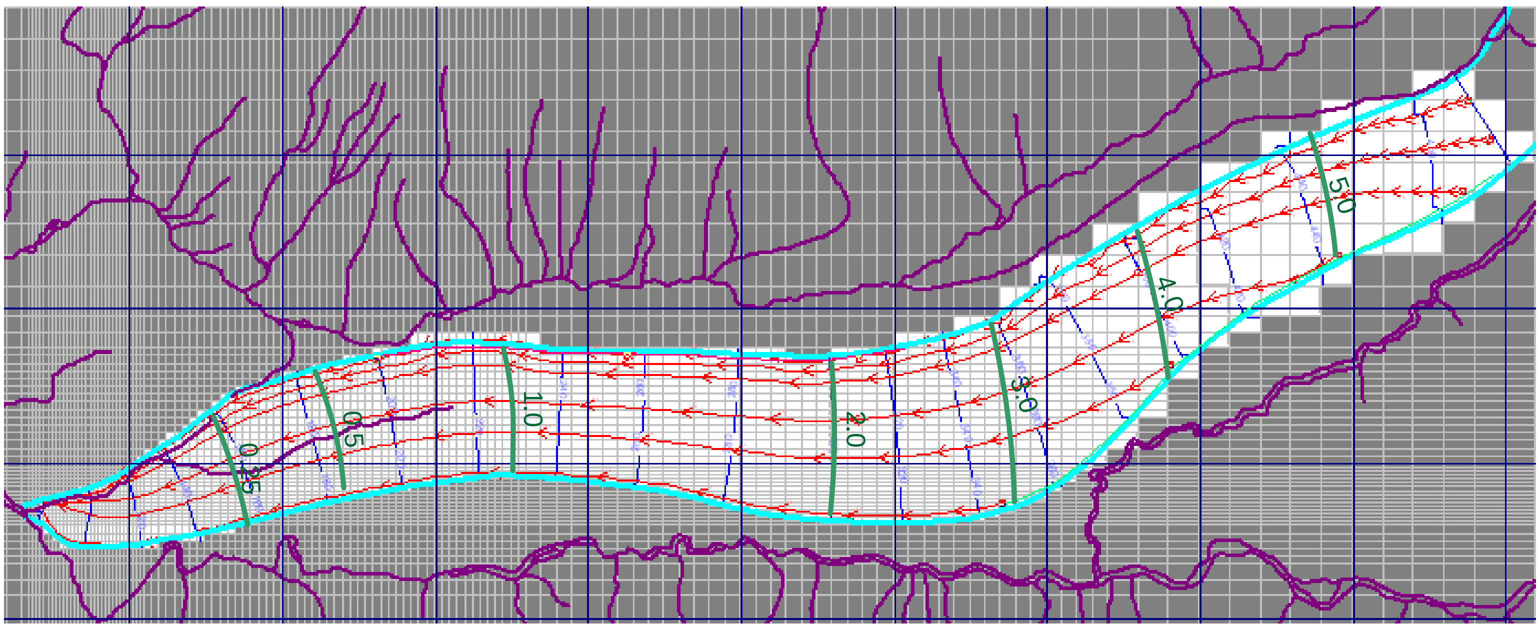
NUMERICAL MODELLING
FINITE DIFFERENCE MESH AND BOUNDARY CONDITIONS

BY: KT/TH
DATE: JAN 13
APPROVED: KT
FIG: D-1

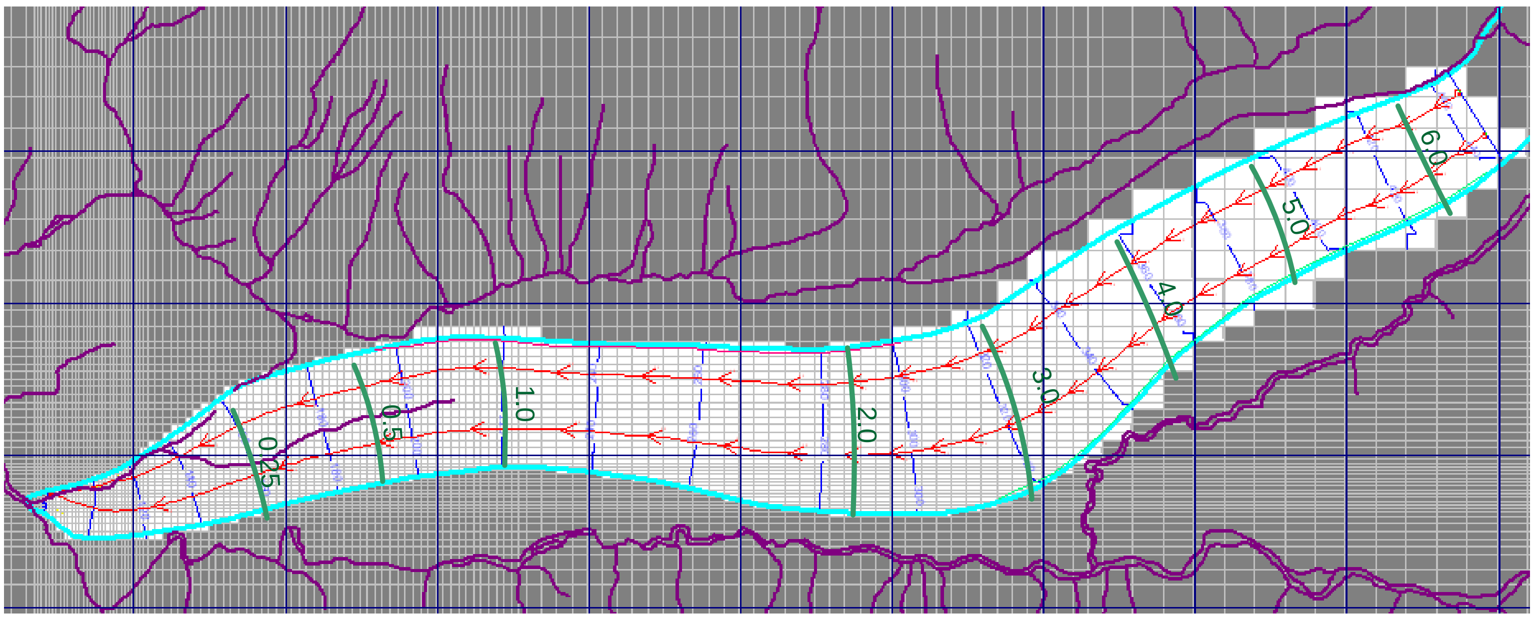
H:/Project/2841/VISTAS/FigD2_ModelPredictions_Fwd.grf

N

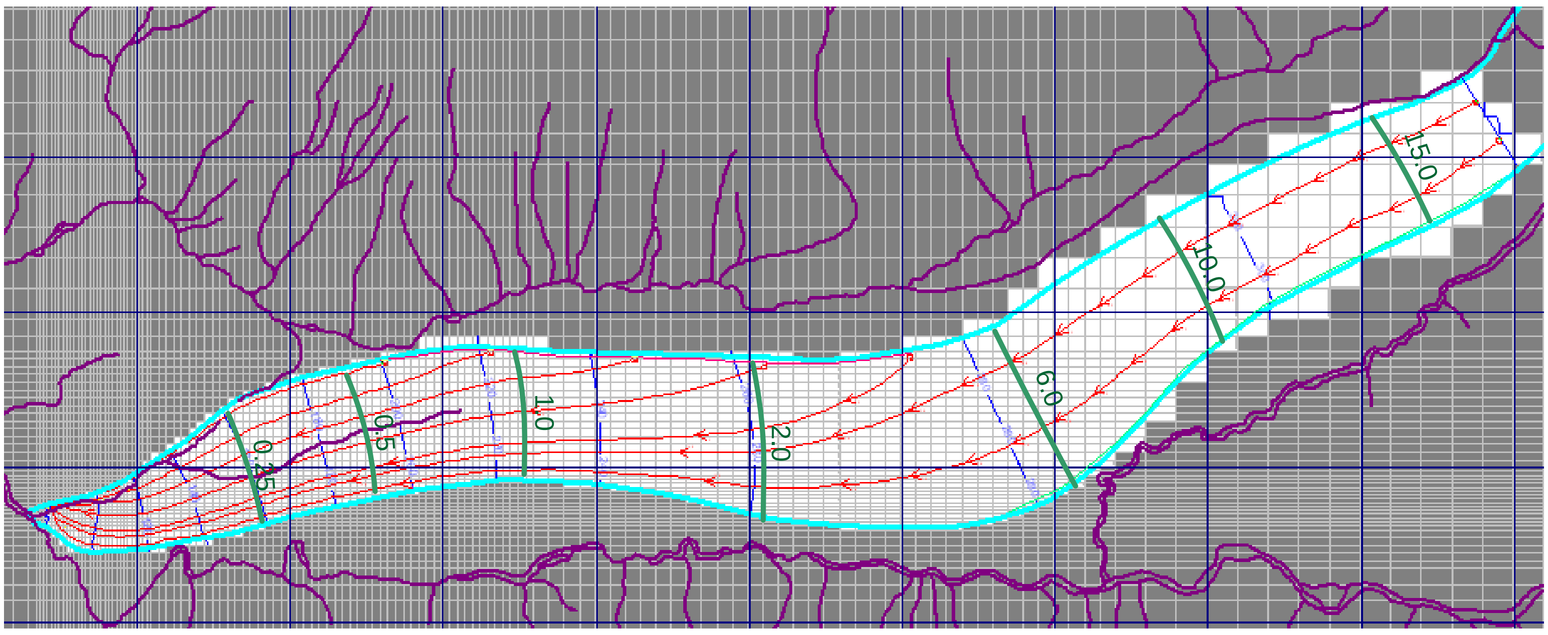
SCALE ≃ 1 : 50,000



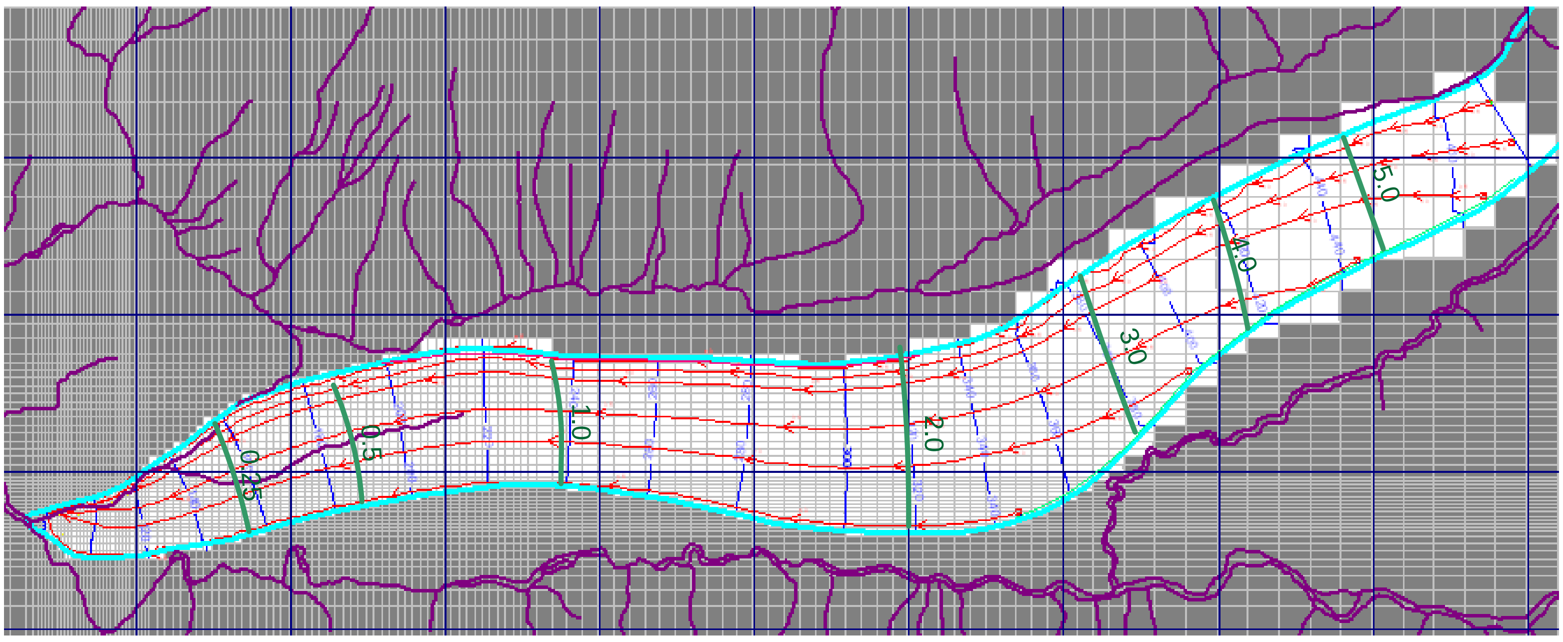
BASE
CASE



RECHARGE
FROM
PRECIPITATION
ONLY



RECHARGE
FROM
PRECIPITATION
+
RING CREEK
ONLY



RECHARGE
FROM
PRECIPITATION
+
SKOOKUM
CREEK
ONLY

2.0 SIMULATED TRAVEL TIMES FROM WELL FIELD

1.0 SIMULATED PARTICLE TRACES

160 SIMULATED EQUIPOTENTIAL LINES (m-geo)

DISTRICT OF SQUAMISH
HYDROGEOLOGICAL ASSESSMENT FOR
WELL PROTECTION PLAN
POWERHOUSE SPRING, SQUAMISH, B.C.

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

NUMERICAL MODELLING SIMULATION RESULTS

BY: KT/TH
DATE: JAN 13
APPROVED: KT
FIG: D-2

APPENDIX E

MICROSCOPIC PARTICULATE ANALYSIS RESULTS

Hyperion Research Ltd.

1008 Allowance Ave. SE,
Medicine Hat, AB T1A 3G8
Tel: (403) 529-0847 Toll Free: (888) 529-0847
Fax: (403) 529-0852 Email: *hyperion@telusplanet.net*
Principal Scientist: Peter M. Wallis, Ph.D.

MICROSCOPIC PARTICULATE ANALYSIS REPORT SHEET (GUDI)

CLIENT: Kathy Tixier
Piteau Associates
215, 260 West Esplanade
North Vancouver, BC
V7M 3G7

TELEPHONE (604) 986-8551
FAX: (604) 985-7286

Date of Sample: 6-Jun-12
Sample Location: Powerhouse Well Field
Type: Raw
Volume Filtered (L) 3648
Temperature (° C)
pH:
Conductivity:

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. Hyperion Research Ltd. is accredited for this analysis by CALA under the ISO/IEC 17025:2005 standard.

Sample Processing Information

Final Pellet Vol. (µL): 40.0

Date Received	Time Received	Customer #	Temp. on Arrival (°C)	Lab ID	Density Medium	Sediment (mL)
8-Jun-12	1010	149	17.5	52305		0.20

Total Wash (mL)	Concentrated (mL)	G/C Volume (µL)	MPA Volume (µL)	Suspension Vol. (µL)	Equiv. Vol. (L)
1000	1000	28	81	109	3,648

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:	0	0.00	NS
Insect/larvae:	0	0.00	NS
Rotifers:	0	0.00	NS
Plant Debris:	0	0.00	NS

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	5	0.7
Nematodes	0	0.0
Crustacea	0	0
Amoebae	0	0
Ciliates/flagellates	0	0
Other	0	0
Large Debris	none	
Fine Debris	iron	
Minerals	silica, clay	

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

Additional Data:

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.

Note: These results pertain to this sample only.