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DISTRICT OF MISSION

HYDROGEOLOGICAL INVESTIGATION FOR GROUNDWATER SUPPLY MIRACLE VALLEY, B.C.

Prepared by

PITEAU ASSOCIATES ENGINEERING LTD.

PROJECT 3131 **APRIL 2012**

EXECUTIVE SUMMARY

Piteau Associates Engineering Ltd. has been retained by the District of Mission to conduct hydrogeologic investigations at the Miracle Valley to explore the feasibility of supplying up to 210 L/s of quality groundwater for municipal water supply. Our investigations have included the construction and testing of two 200mm (8”) diameter test wells – TW11-1 at the south end of Burns Road, and TW12-1 at the north end of Stave Lake Road.

The Miracle Valley Aquifer is a 10 km^2 sand and gravel aquifer that is confined by a thick sequence of clay and sandy till. Primary sources of recharge include exfiltration from watercourses along the east side of the valley and downward infiltration of incident precipitation. Groundwater flow is interpreted to be northward above Hartley Road towards Stave Lake. South of Hartley Road, groundwater flows to the south/southwest and discharges to a number of spring-fed creeks. The results of aquifer pumping tests conducted with TW11-1 and TW12-1 indicate that aquifer sediments are highly permeable, and theoretical short-term yields for larger diameter (12” to 16”) pumping wells constructed in these areas are 124 and 360 L/s, respectively. It therefore appears possible to extract groundwater at 210 L/s from two or more wells at either location.

Groundwater quality measured in water samples collected from TW11-1 is excellent, and the concentrations of all constituents analyzed were within Guidelines for Canadian Drinking Water Quality. However, analyses conducted on shallower and deeper groundwater samples in the vicinity indicate that iron concentrations could exceed aesthetic objectives at horizons in the aquifer. Concentrations of total manganese and lead in groundwater samples collected from TW12-1 slightly exceeded drinking water quality guidelines.

A long-term groundwater withdrawal of 210 L/s in the vicinity of TW11-1 is expected to reduce flows in creeks draining the south portion of the aquifer. As fish habitat is considered to be already compromised along some reaches, obtaining environmental approval could be challenging. In the vicinity of TW12-1, project withdrawals are not expected to impact these creeks, as groundwater flow is interpreted to be northward toward Stave Lake. However, other watercourses may potentially be affected. Groundwater withdrawals of 210 L/s in the vicinity of TW11-1 or TW12-1 are not expected to affect the performance of other wells identified in the near vicinity. This should be verified on a well-to-well basis based on information regarding the well's depth and current use.

In accordance with the British Columbia *Environmental Assessment Act,* an environmental assessment will be required for groundwater extraction projects with an anticipated withdrawal rate exceeding 75 L/s. The scope of assessment should be determined by an environmental consultant, with input from the Environmental Assessment Office, and may include:

- Completing a survey of existing wells and operating springs at potential municipal well sites;
- Establishing a seasonal baseline of flows and water quality in nearby watercourses draining the aquifer;
- Continuation of long-term monitoring of piezometric levels in the aquifer; and/or
- Conducting extended, high-rate (75 to 100 L/s) aquifer pumping test(s) with larger diameter (12 to 16") test production wells, and/or developing a numerical groundwater flow model to estimate aquifer response to project withdrawals.

More specific recommendations have also been provided to examine the water supply prospects in the north end of the Miracle Valley near Stave Lake to investigate the extent of the aquifer in this direction, degree of hydraulic connection with Stave Lake, and ultimately to supply a much greater quantity of groundwater (e.g., 1,000 L/s). These include reviewing any borehole information available for the BC Hydro right-of-way, determining land ownership and reconnoitering the lands to the north of the power line right-of-way to identify possible drilling sites as close as possible to the lake high water level, drilling a test well, and conduct aquifer pumping tests. If results are favourable, additional work would be needed to assess the aquifer capacity in this area in support of an environmental assessment. The scope of these investigations would be generally similar to those described above.

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1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Piteau Associates Engineering Ltd. (Piteau) was retained by the District of Mission (DOM) to conduct hydrogeological investigations in the Miracle Valley (the Valley), located approximately 10 km north of the Mission town centre (Fig. 1). The purpose of this work was to assess whether groundwater supply development in the Valley could be a viable means of meeting future water demand. This would require a source capable of supplying on the order of 18 ML/day (210 L/s) of potable fresh water.

1.2 SCOPE OF WORK

This investigation was conducted between November 2011 and March 2012. Over this period, Piteau carried out the following tasks:

- Reviewing existing information on groundwater extraction and exploration in the Valley (water well records, consulting reports);
- Collecting relevant mapping information (topography, surficial geology, bedrock geology) and spatial (GIS) data;
- Reviewing stereo-paired aerial photographs of the Valley;
- Obtaining information on potential groundwater pollution hazards in the Valley, including a search of the BC Ministry of Environment (BC MOE) Site Registry;
- Selecting two locations for the drilling of test production wells in consultation with the DOM;

- Conducting preparatory steps before drilling, such as obtaining land access permits, checking for underground services, co-ordinating a professional survey to verify lot boundaries, and arranging the construction of drill pads;
- Retaining and supervising a drilling contractor to construct test wells at two locations;
- Retaining and supervising a pump service contractor to conduct aquifer pumping tests with the new test wells;
- Collecting groundwater samples for water quality analyses;
- Retaining an environmental consultant to evaluate aquatic ecosystem components within watercourses and riparian areas that could be potentially impacted by future large-scale groundwater supply development;
- Establishing two surface water monitoring stations, and installing automated monitoring instrumentation at these stations and at the two test wells to obtain a long-term record of water level variations. An electronic copy of these data are provided on a CD included with hardcopies of this report;
- Analyzing relevant hydrogeologic information and analyzing the results of well drilling and testing program to provide statements pertaining to potential groundwater supply development in the Miracle Valley. These statements and our supporting analysis are presented in this report.

2. BACKGROUND INFORMATION

2.1 GEOGRAPHIC SETTING

The Miracle Valley, sometimes referred to as the Upper Hatzic Valley, is located on a topographic bench north of the Hatzic Valley (Fig. 2). It extends from Lagace Creek at its south end to the Stave Lake reservoir at its north end, and is bounded by steep mountainous terrain on the east and west sides. Ground elevations rise abruptly north of Durieu Road from 20 to 100 metres above sea level (m-asl), then continue to rise gradually to 140 m-asl at Hartley Road. Continuing northward, ground elevations decline gradually to about 80 m-asl at Stave Lake.

Land use in the Valley is predominantly forest, followed by rural residential and low-intensity agriculture. At the south end of the Valley, there are two fish hatcheries, one at 35745 Durieu Road, and the other at 12451 Stave Lake Road (Miracle Valley Springs). A rock quarry (Stave Lake Quarry) is located at the north end of the valley at 13361 Stave Lake Road. A BC Hydro power corridor runs southwest to northeast across the north end of the Valley.

2.2 CLIMATE

The nearest climate monitoring station is the Mission West Abbey, located about 8 km southwest of the Valley at an elevation of 221 m-asl. Data released by Environment Canada for the period January 2000 to October 2011 indicate that this station receives 1,808mm of precipitation annually. Average monthly precipitation amounts range from 54mm in July and 274mm in January. Approximately 68% of the total annual precipitation falls between the months of October and March.

2.3 GEOLOGY

Bedrock mapping by Roddick (1965) indicates that the Valley is bounded by Mesozoic and Paleozoic plutonic bedrock (quartz diorite) belonging to the Coast Plutonic Complex.

During the last ice age that began approximately 25,000 years ago, the Fraser Lowland was repeatedly invaded by glaciers from the adjacent Coast Mountains. Sediments deposited by these processes have been extensively mapped by Armstrong (1984, 1990). Periods of glacial advance and retreat brought deposits of till and glaciofluvial sediments, which were overlain by fluvial, marine, and colluvial deposits during non-glacial periods. During the peak of glacial advance approximately 13,000 years ago, glaciers had carved out a U-shaped valley and depressed the land surface by about 80m below current sea level. Marine waters inundated some valleys, leaving thick deposits of glaciomarine clay and silt. During glacial retreat, meltwater channels and shrinking lobes of ice left glaciofluvial and ice contact sands and gravels in some areas. More recently, the Fraser River has deposited finer-grained sands and silts within the floodplain, and other areas have accumulated eolian, lacustrine, bog, and stream sediments.

In the Miracle Valley, patches of peaty sediments have been mapped near the high point of the Valley, and colluvial slope deposits, including landslide fan gravels and rubble, blanket the toe of the south-facing bench (all Salish deposits). These are underlain by a thick sequence of clays and stony silt (Fort Langley Formation) and sandy till (Sumas Drift), which in turn is underlain by glaciofluvial sands and gravels (likely Vashon Drift). The lower-lying Hatzic Valley which borders the Miracle Valley is filled with more recent sands and silts (Fraser River).

The east wall of the Valley is blanketed by thick deposits of alluvial sediments reworked by numerous, mostly ephemeral watercourses (Fig. 3). Vast areas are covered by younger deciduous forest, possibly owing to the instability of these slopes. An extensive alluvial fan abuts the northeast end of the Valley as far as Cascade Creek. On the southeast end of the Valley, the Lagace Creek alluvial fan spills into the northeast corner of the Hatzic Valley.

2.4 SURFACE WATER

Several watercourses drain the east wall of the Valley (Fig. 3). On the north end of the Valley, they report to Cascade Creek (Photo 1), which in turn empties into Stave Lake. In the middle of the Valley, they report to Allan Lake (e.g., MacNab Creek) or to Lagace Creek directly. Some creek channels (e.g., Pattison Creek) show signs of extreme flows and channel erosion during periods of high rainfall/snowmelt (Photo 2). Given the coarse nature of their bed materials, these creeks may lose significant amounts of water to the subsurface upon reaching the valley floor. In late summer, many creeks are dry, and the water level in Allan Lake drops considerably (Photo 3).

Lagace Creek crosses the south end of the Valley (Photo 4) and then picks up flow from several tributaries on the west side, namely Belcharton Creek, Durieu Creek, Oru Creek, and Seux Brook (Photo 4). These creeks are relatively low grade and are interpreted to be largely spring-fed, as flow is relatively constant throughout the year. They are also incised in steep-sided ravines that cut into the topographic bench.

With the exception of Bouchier Creek at the south end and Marino Creek at the north end, there are no significant watercourses draining the west wall of the Valley. This wall is largely outcropping bedrock overlain by a veneer of colluvium and glacial drift. Marino Creek is sourced from spring-fed marshy areas at the foot of the rock quarry, and flows northward to Stave Lake.

A surface water divide exists at the high point in the Valley along Hartley Road. Runoff on the north side of Hartley Road flows towards Stave Lake and runoff on the south side reports to Lagace Creek. A subtle east-west surface water flow divide follows Burns Road. In this part of the Valley, the ground is soggy and poorly drained, owing to fine-textured, clayey soils. Boggy conditions also exist in the low-lying areas at the north end of the Valley (Photo 6).

Recent correspondence with BC Hydro confirms that Stave Lake water levels fluctuate between 75 and 82 m-asl over the year in response to flows released at the Stave Falls dam. This range in lake elevations has not changed since the beginning of the shared period of record (1983).

2.5 MIRACLE VALLEY AQUIFER

The glaciofluvial sands and gravels underlying the Fort Langley clays comprise a deep-confined aquifer known as the Miracle Valley Aquifer (the Aquifer). It has been mapped to cover an area of about 10 km^2, although there are some uncertainties regarding its northern boundary (Fig. 2).

The Aquifer is likely recharged by infiltrating surface runoff from Cascade Creek and ephemeral creeks draining the east wall of the Valley, and by slow infiltration of direct precipitation through the overlying aquitard. Several shallow, perched aquifers have been encountered in small pockets of sandy material within the clay, but these are considered to have limited supply potential owing to their small size and isolation from surface sources of recharge.

Numerous domestic water supply wells have been drilled into the Aquifer, and those that have been registered in the BC MOE's water well database are shown on Fig. 3. The driller estimated yields of these wells are generally greater than 1.5 L/s, which suggests a productive aquifer since most wells are constructed with short screens (less than 2m) extending a short distance (<5m) into the Aquifer. Wells of interest near the south end of the Valley include a well with an estimated yield of 47 L/s, and an artesian well that had at one time flowed at a rate of 16 L/s.

The Aquifer discharges to several springs at the south end of the Valley where topographic bench intercepts the piezometric surface. The springs are indicated by number on Fig. 3 and include:

- A number of spring vents that supply water to the Miracle Springs Hatchery and neighbouring property at 12697 Stave Lake Road (Spring No. 1). These springs are commonly referred to as the Lehmann Springs and at an elevation of about 76 m-asl. The combined flow rate from the springs has been estimated to be about 135 L/s, and is sustained year round[1]. Most of flow is currently licensed for domestic use, bottled water sales, and pond maintenance.
- A series of springs issuing from coarse sediments in the banks Durieu Creek near its headwaters (Spring No. 2). These have been referred to as the Gadlatis Springs, and are at an elevation of about 79 m-asl. Flow from these springs has been estimated to be on the order of 35 L/s[1]. The property owner currently holds spring water diversion licenses for domestic use, irrigation, and pond maintenance.
- Seux Brook is also reported to be sourced from springs near the top of Seux Road (Spring No. 3). Three residents on Seux Road hold licenses to divert spring water for domestic use. A small hatchery at the 35745 Durieu Road diverts flows from the Brook through fish-rearing tanks. Brook flows are highest in November and decrease to about 40 L/s in August[2].

Based on the above, Oru, Seux, Belcharton, and possibly Lagace Creek are interpreted to be largely groundwater-fed, especially along their lower reaches. The toe of the topographic

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[1] Conversations with local residents during site visit by Allan Dakin of Piteau on September 13, 1994.
[2] Conversation with hatchery owner during site visit by Kathy Tixier or Piteau on December 6, 2011.

bench is blanketed by coarse landslide debris, which would provide little resistance to groundwater discharge.

These springs are distinct from springs discharging from fractured bedrock at west margin of the Valley. Fractures and joint sets have been observed in the west wall, which could convey groundwater flow from west to east. One such spring is located at 12699 Stave Lake Road at an elevation of 92 m-asl (above Belcharton Creek near the Miracle Valley Trout Hatchery), and is referred to as the Conroy Spring (Spring No. 4). The other is located on the Marino Creek bed on the north side of the rock quarry above 200 m-asl (Spring No. 5).

2.6 GROUNDWATER QUALITY

Laboratory analyses of a water sample previously collected from the Lehmann springs at the Miracle Valley Trout Hatchery indicate a relatively low degree of mineralization (TDS ~ 60 mg/L). This is unusually low for water originating from a deep confined aquifer, and suggests a relatively low residence time for groundwater in the Aquifer.

Groundwater samples were collected from domestic wells throughout the Valley as part of a Masters' research program (Magwood, 2004). Of the samples collected, approximately 10% had iron and manganese concentrations exceeding aesthetic guidelines of 0.3mg/L and 0.05 mg/L, respectively. Magwood (2004) also noted similarities in water chemistry between groundwater from the Aquifer and the adjacent Hatzic Prairie Aquifer to the south.

A search of the BC MOE Site Registry was conducted to locate potential groundwater pollution hazards in the Valley. The only notable result was a Notice of Independent Remediation Completion submitted for 14042-14100 Stave Lake Road on July 21, 2011. The notice states that a small volume (<700 m^3) of soils potentially impacted by petroleum hydrocarbons were excavated in the vicinity of previously-existing underground fuel storage tanks and disposed of off-site. These soils are considered to impart a low level of risk to groundwater quality owing to their small volume and the fact that any downward migration of contaminants would be impeded by the confining clay layer. The risks associated with current land uses in the Valley are also judged to be low, given the minimal pesticide/herbicide use associated with the main agricultural crop (hay), and the low the density of ground disposal of sewage effluent.

3. SUMMARY OF INVESTIGATIONS

3.1 TEST WELL LOCATION SELECTION

Test well sites were selected at the north and south ends of the Valley to enable aquifer pump testing for evaluation of the potential for constructing future large-capacity production wells. Well locations were selected based on the following criteria:

- Not on private property or on Crown Lands;
- Accessible to truck-mounted well drilling and testing equipment;
- Clear of underground and overhead utilities;
- Near the centre of the Aquifer; and
- Where flowing artesian conditions unlikely to occur.

As over 90% of the lands overlying the Aquifer are privately owned, permits were obtained to locate test wells on Ministry of Transportation and Infrastructure (MOTI) right-of-way. A surveyor was retained to ground-truth cadastral boundaries, and utilities were contacted to verify underground service lines. On-site meetings were also conducted with drilling and site preparation contractors to mark out areas for drill pad construction and vehicular access.

3.2 DRILLING AND TEST WELL CONSTRUCTION

Test wells TW11-1 and 12-1 were drilled using a dual-mode air-rotary drilling rig operated by A&H Well Drilling Ltd. of Chilliwack, BC. The test wells were drilled and cased at a diameter of 200mm (8”), which can accommodate a submersible pump capable of pumping up to 40 L/s.

Logs with lithological information and well construction information are included with Appendices A and B along with results of grain size analyses conducted on formation samples collected from the screen completion zones. A more detailed account of formation conditions encountered and the design of each well are provided in the following sections.

3.2.1 TW11-1

Test well TW11-1 was drilled on the MOTI right-of-way at the south end of Burns Road (Photo 7). A small area adjacent to the road was cleared of vegetation and a gravel drill pad was constructed to facilitate access for the drilling rig and support vehicle. Drilling of the test well began on December 5, 2011 and was completed on December 13, 2011 (Photo 8).

Unconsolidated sediments were encountered from ground surface to a maximum drilled depth of 77.7m. These consisted of sandy overburden to 4.6m, clay to 27.4m, and sand and gravel to 77.7m. The ratio of sand to gravel varied across this latter interval, but was predominantly sand below 63m. At this depth, sediment samples changed colour from a brownish-grey to grey, and the drilling discharge water changed colour from a rusty brown to grey. Drilling was stopped at 77.7m since sediments appeared to be less permeable with depth (fining downward), and since the productivity of the overlying 50m of aquifer sediments was considered more than adequate to ultimately supply groundwater at a rate of 210 L/s.

A 4.8m long section of stainless-steel telescopic well screen with a slot size of 2.03mm (0.080”) was installed in the test well casing and exposed to aquifer sediments between 54.4 and 59.2m. The screen was developed by airlift pumping using compressed air for approximately ten hours, when the rate of sand migration had diminished to acceptable levels. The static water level observed on December 14, 2011, following development of the well was 25.3m below ground level.

3.2.2 TW12-1

Test well TW12-1 was drilled on the MOTI right-of way which extends eastward from the intersection of Rodela and Stave Lake roads (Photo 9). Permission to access the drill site via roadways on the adjacent property to the north was obtained by the landowner.
Well construction began on January 3, 2012, and was completed on January 11, 2012 (Photo 10).

Unconsolidated sediments were encountered from ground surface to a maximum drilled depth of 76.8m. Overburden consisting of silty sand and sandy clay were encountered to a depth of 6.1m, followed by clay to 38.1m. Below the clay, a silty sand transitioned to coarse sand and gravel at 41.1m. This unit extended to the total depth drilled of 76.8m, with some variation in the proportions of sand to gravel. A distinct colour change in the sediments from brownish-grey to grey, and in the drilling discharge water from rusty brown to grey, was observed at about 69m (Photo 11). Drilling was stopped at 76.8m since the productivity of overlying 37m of sand and gravel was judged to be sufficient to meet the targeted extraction rate of 210 L/s.

A 3.1m long section of stainless-steel telescopic well screen with slot size of 2.03mm (0.080”) was installed in the test well casing and exposed to aquifer sediments between 72.6 and 75.7m. The screen was developed by airlift pumping for approximately six hours. The static water level observed on January 17 was 34.6m below ground level

3.3 AQUIFER PUMP TESTING

Precision Service and Pumps Ltd. (Precision) were retained to conduct aquifer pumping tests with TW11-1 and TW11-12 using temporarily installed submersible pumps powered by a diesel generator (Photo 12). In each case, a brief (two-hour) variable-rate pumping test was completed, followed by a 24-hour constant-rate test.

Water levels in the pumped wells were monitored using graduated electric tapes and a self-logging pressure transducer. Groundwater levels in nearby domestic wells were monitored using self-logging pressure transducers. Pumping rates were measured using an orifice plate device, and all pumped water was discharged onto plastic tarps or plywood on the ground before draining to nearby watercourses (Photo 13). Discharge from TW11-1 was released to a watercourse within 30m of the well, and ultimately reported to Oru Creek. Discharge from TW12-1 was released to a watercourse within 15m of the well. This flowed into a large pond on the adjacent property to the north and then into a tributary to Cascade Creek.

Summary tables of manual measurements collected during the pumping tests are included with Appendices C and D. Additional details on the aquifer pump testing program are given in the following sections:

3.3.1 Variable-Rate Testing

Variable-rate tests were conducted to evaluate the performance characteristics of the test wells, and to select a rate for the constant-rate tests. In each case, the test wells were pumped for 30 minutes at incrementally increasing rates while water level drawdown in the well was measured and recorded at frequent intervals.

3.3.2 Constant-Rate Testing

Constant-rate aquifer pumping tests were conducted after the wells had recovered from the variable-rate tests. This involved pumping the wells for 24 hours (1,440 minutes) at a constant rate of 34.7 L/s at TW11-1 and 33.1 L/s at TW12-1. Water level drawdown in the pumped wells was monitored at frequent intervals.

During the test with TW11-1, drawdown was also monitored in a domestic well located approximately 109m north of the pumped well at 12880 Burns Rd, henceforth referred to as OBS11-1. During the test with TW12-1, drawdown was also monitored in a well intended for fire suppression at 14042 Stave Lake Rd, approximately 120m from the pumped well (OBS12-1). Both observation wells are screened near the top of the confined aquifer at total depths of 40.8m and 53.3m, respectively. Driller’s logs for these wells have also been included with Appendices A and B.

When pumping stopped, the recovery of water levels in the pumping wells and observation wells was monitored manually for at least two hours.

Analysis and interpretation of the constant-rate aquifer pumping test data is discussed in Section 4.2.

3.4 GROUNDWATER SAMPLE COLLECTION AND ANALYSES

Samples of drilling discharge water were collected during drilling of TW11-1 and TW12-1 from depths of 77.7 and 78.6m, respectively. The purpose of these samples was to investigate whether the colour change noted in the sediment / drilling discharge samples at 64 and 69m may be indicative of a change in groundwater chemistry and possibly an increase in iron and manganese concentrations at depth. Samples of groundwater were also collected from OBS11-1 to sample groundwater quality near the top of the Aquifer, and as a good-will gesture to the owner for providing access to their well during aquifer pump testing.

Samples of groundwater were also collected from the discharge stream at the end of the constant-rate pumping tests with TW11-1 and TW12-1. All samples were submitted to ALS Environmental's Vancouver laboratory for analysis of basic potability parameters (including physical parameters, anions, nutrients, and metals), total coliform, E. coli bacteria, and radionuclides. Select samples were also tested for volatile organic compounds (VOCs), extractable petroleum hydrocarbons, and/or polycyclic aromatic hydrocarbons (PAHs). These additional analyses were requested to screen for the presence of petroleum hydrocarbons in the Aquifer, particularly at TW12-1, where recent remediation of suspect hydrocarbon-impacted soils had been reported on the adjacent property.

3.5 GROUNDWATER AND SURFACE WATER LEVEL MONITORING

On December 6, 2011, temporary creek gauging stations were established at Durieu and Oru creeks at their culverted crossings of Durieu Road (Photos 14, 15). The purpose of this monitoring was to obtain a qualitative baseline record of flows in these creeks for interpretation of groundwater-surface water relationships. Each station was equipped with a self-logging pressure transducer suspended inside a 2" diameter perforated pipe (stilling tube) that was secured to a length of rebar driven vertically into the creek bed.

No station was installed at the Seux Brook crossing since discharge rates are controlled by the nearby fish hatchery at 35745 Durieu Road. Furthermore, we observed that Seux Brook crosses Seux Road above Durieu Road (rather than crossing Durieu Road east of Seux Road as indicated on Figs. 2 and 3)[3]. Based on a close inspection of recent aerial imagery, we infer that Seux Brook flows eastward from Seux Road to Oru Creek just above Durieu Road, and empties into Oru Creek just above our gauging station. Hence, flows measured at this station are interpreted to be the sum of flows from Oru Creek and Seux Brook.

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[3] Observed during Piteau site visit on December 6, 2011.

Manual flow measurements were conducted at both stations on December 14, 2011 and February 1, 2012. Flow was calculated based on the wetted cross-sectional area of the culvert and average velocities measured using a hand-held current meter.

Piezometric heads in TW11-1 and TW12-1 have been monitored since completion of the aquifer pumping tests using self-logging pressure transducers installed in the wells.

4. ANALYSIS AND INTERPRETATION

4.1 HYDROSTRATIGRAPHY

Sediments encountered in TW11-1 and TW12-1 were consistent with conditions anticipated based on driller's logs for neighbouring domestic wells. The sediment profile can be divided into two major hydrostratigraphic units:

1. Clay and Till (Fort Langley Formation, Sumas Drift): grey, with some fine sand and gravel, and overlain by up to 5m of loamy sand (Salish Sediments). This unit acts as a confining layer to the underlying aquifer and is saturated over most of its thickness.

2. Sand and Gravel (probably Vashon Drift): brown to grey sandy gravel and gravelly sand, moderately graded, with trace silt. This unit hosts the Miracle Valley Aquifer, and appeared to be very permeable, based on the texture of recovered samples and observed airlift yields during drilling and development. The vertical thickness of this unit is greater than 50m at TW11-1 and 35m at TW12-1. The piezometric head elevation at these wells was approximately 3 to 4m above the contact with the overlying clay unit.

Hydrostratigraphic profiles through the aquifer along section lines A-A', B-B' and C-C' are presented on Figs. 4, 5, and 6.

4.2 AQUIFER PROPERTIES

4.2.1 Aquifer Parameters

Drawdown observed during the variable-rate tests with TW11-1 and TW12-1 are plotted against a logarithmic timescale on the upper portions of Figs. E-1 and F-1 included with Appendices E and F. At the end of each test, the drawdown in the pumped well was significantly less than the available drawdown above the pump intake; hence, the maximum possible pumping rates from the installed submersible pumps were chosen for the constant-rate tests.

Drawdown measurements in the pumped well during the constant-rate tests with TW11-1 and TW12-1 are plotted against a logarithmic timescale on Figs. E-2 and F-2. On the same plots, residual drawdown during the recovery interval (after the pump is shut off) is plotted versus the logarithm of the time ratio[4]. Drawdown response measured in the observation wells during the pumping and recovery intervals of the constant-rate tests are plotted versus the logarithm of time in the upper portions of Figs. E-3 and F-3. The lower portions of Figs. E-3 and F-3 present the drawdown response measured in the observation wells in log-log format.

Aquifer transmissivity (T) [5] and storativity (S)[6] values determined from the pumping interval data using the Cooper-Jacob (1946) and Theis methods are summarized in Table I. T and S values calculated from the recovery interval data using the Theis Recovery (1935) method are also shown in Table I. Representative T values of 1.6×10^{-1} for TW11-1 and 1.3×10^{-1} m^2/s for TW12-1 were obtained from the geometric mean of the T values given by each of these methods. Dividing the average T values by 10 times the screen lengths of the wells (as a rough approximation of aquifer thickness contributing to flow, in consideration of partial penetration effects) gives mean hydraulic conductivity (K) values of 3.3×10^{-3} and 4.3×10^{-3} m/s at TW11-1 and TW12-1, respectively.

These K values are comparable to the K values estimated from the grain size distributions of sediment samples collected near the screened intervals of the pumped wells (Figs. A-1, B-1). Using the Hazen (1911) method, these Ks are 1.1×10^{-3} and 5.6×10^{-3} m/s at TW11-1 and TW12-1, respectively.

Representative S values obtained by analysis of the drawdown and recovery trends at the observation wells are 1.9×10^{-3} at TW11-1 and 2.4×10^{-5} at TW12-1. Confined aquifers have relatively small storage coefficients (10^{-5} to 10^{-3}), since the stored water is derived from the compression of aquifer and expansion of water when the hydrostatic pressure (head) is reduced during pumping. Hence, these S values appear to be reasonable.

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[4] Time ratio (t/t') = time since start of test (t) over time since pumping stopped (t')

[5] Transmissivity (T) = the rate that groundwater would flow through a vertical slice of aquifer one metre wide under a hydraulic gradient of one metre per horizontal metre. It is also equivalent to the hydraulic conductivity (K) multiplied by the aquifer thickness (b).

[6] Storativity (S) = the volume of water an aquifer releases from storage per unit surface area of aquifer per unit drop in head.

The semi-log plot on Fig. F-3 indicates a departure from the straight-line drawdown trend at OBS12-1 approximately 700 minutes (11.7 hrs) into the constant-rate test with TW12-1. The cause of this deflection is unknown, but may indicate the interception of an impermeable boundary, such as the west bedrock wall of the Valley. As bedrock does not transmit water as readily as saturated sediments, drawdown would be expected to increase as shown. This departure from the straight-line trend was not apparent at the pumped well (Fig. F-2).

The semi-log plot on Fig. E-3 shows a near-perfect overlap between the drawdown and recovery trends at OBS11-1. This may indicate that groundwater flow upgradient from TW11-1 was adequate to meet the pumping demand and that there was no significant depletion of aquifer storage. There is a slight deflection away from the straight-line near the end of the pumping interval; however, it is uncertain whether this is due to a boundary effect or activation of a nearby well. There is no deflection from the straight-line fit in the drawdown trend at the pumped well (Fig E-2).

Possible boundary effects may be determined with greater certainty by longer duration tests at either location.

4.2.2 Possible Well Yields

The foregoing analysis of confirms that the Aquifer is highly permeable. Yields for larger diameter (12” or 16”) production wells constructed near TW11-1 and TW12-1 can be roughly estimated using the formula:

$$Q = D_{max} \times S_c$$

Where Q is the maximum sustainable flow rate, D_{max} is the maximum allowable drawdown, and S_c is the specific capacity.

For this exercise, the production wells are assumed to be larger diameter wells screened across the same intervals as TW11-1 and TW12-1. The maximum allowable drawdown (D_{max}) was estimated by multiplying the difference between the estimated lowest seasonal aquifer water level and the top of the screened interval by a 70% safety factor. The specific capacity (S_c) was estimated from the projected 100-day specific capacity (Figs. E-2, F-2). This is a conservative estimate of S_c, since wells of larger diameter (and screen length) would have more open area than the test wells. As shown in Table II, the maximum yields for a production well constructed near TW11-1 and TW11-2 are estimated to be on the order of 124 L/s and 360 L/s, respectively. As this is higher than what can generally be achieved using a single well, the desired yield of 210 L/s could potentially be achieved using two or more larger diameter wells (12" or 16") at either location.

Notwithstanding the above, for a groundwater extraction rate of this magnitude to be sustainable, it must:

- Be balanced by available groundwater recharge;
- Not cause environmental harm, especially to aquatic environments (e.g., surface water); nor
- Interfere with other well drawing water from the same aquifer, and connected aquifers to the extent that they are unable to meet existing demands.

These considerations are discussed further in Section 4.5.

4.3 AQUIFER CONCEPTUAL MODEL

4.3.1 Groundwater Flow direction

A hydrostratigraphic profile along the north-south section line A-A' is presented on Fig. 4. At about 92 m-asl, the piezometric surface elevation is highest in the middle portion of the Valley (between TW11-1 and TW12-1). South of TW11-1, the piezometric surface elevation drops rapidly as a result of spring discharge to Durieu and Oru creeks. North of TW12-1, piezometric levels slope gradually toward Stave Lake (max. elevation 82 m-asl).

Based on these findings, we interpret there to be north-south groundwater flow divide in the mid-portion of the Valley, roughly in parallel with the surface water divide. Groundwater flow north of the divide discharges to Stave Lake, Cascade Creek and

Marino Creek, and groundwater flow south of the divide discharges primarily to Belcharton, Durieu, Oru creeks and Seux Brook. Inferred groundwater flow directions are indicated in plan view on Fig. 3.

Figures 5 and 6 present the hydrostratigraphic profile along east-west section lines B-B' and C-C'. On Section C-C', the piezometric surface elevation rises from west to east across the Valley, indicating a westward component of groundwater flow. The locations of major springs along the west and south margins of the Aquifer (at the end of the groundwater flow path) are consistent with this observation. The east walls of the Valley are blanketed with coarse alluvial deposits, which act as effective drains for rainfall runoff and snowmelt. This surface water flows to Lagace Creek, which has downcut a steeply incised ravine downstream of Allan Lake. The section indicates that the Lagace Creek invert elevation is below the relatively thin confining clay unit and is in direct contact with Aquifer sediments. Therefore, there is likely significant infiltration of surface water into the Aquifer, thus elevating piezometric water levels on this side of the Valley.

4.3.2 Aquifer Recharge

Most recharge to the Aquifer is inferred to originate from Lagace Creek and its tributaries on the east side of the Valley, and possibly from runoff along the bedrock walls on the west side of the Valley. This interpretation is based on the following rationale:

- Temporal changes in groundwater and surface water levels between from December 2011 to February 2012 (Fig. 7): Precipitation amounts and ambient atmospheric temperature are shown in the top portion of the figure, and the remaining graphs present time-series of water levels at the Durieu and Oru creek stations, Stave Falls Dam, and test wells TW11-1 and TW12-1.

  As would be expected water levels in Durieu and Oru creeks respond rapidly to heavy precipitation events. A similar response of lesser magnitude is detected in Aquifer water levels at TW11-1. Since the Aquifer is overlain by a thick sequence of clay that would delay groundwater response to recharge events, the response observed is indicative of the Aquifer being recharged directly from surface water. Another possible line of evidence is the steadily rising groundwater levels observed at TW11-1 between the end of December and mid-January. This may be a result of gradually increasing water levels and in Allan Lake and overflows to Lagace Creek, since Allan Lake effectively acts as a storage basin for mountain runoff.

- Rudimentary water balance calculations: Average annual recharge by direct infiltration is estimated to be on the order of 140 L/s, assuming an average annual precipitation of 1,800mm and infiltration rate of 30% across the footprint of the portion of the Aquifer south of the groundwater flow divide. This amount is much smaller than the estimated rate groundwater discharge to Creeks draining the south end of the Aquifer (on the order of 450 L/s, annual average). The difference can only be made up by infiltrating surface runoff along the Valley margins. For example, if 40% of the average annual precipitation falling within the Lagace and Belcharton creek catchments (Fig. 2) outside the Aquifer footprint infiltrates the Aquifer, this would constitute another 280 L/s of recharge.

- The elimination of Stave Lake as a source of recharge to the Aquifer, based on recorded lake water elevations below that of Aquifer piezometric elevations.

4.3.3 Potential Climate Change Impacts

Climate change is expected to impact groundwater resources across BC, owing to changes in both temperature and precipitation trends. Since the 1950's, BC's climate has warmed significantly and precipitation has increased slightly, although there are significant variations from region to region (Walker and Sidneysmith, 2008). Climate change models predict that the Coastal region of BC will experience a reduced snowpack, with more precipitation falling as rain during the winter months. Higher rainfall will result more frequent and higher volume runoff events. Warming temperatures will cause the spring freshet to occur earlier in the year, which in turn could extend the duration of the summer low-flow period and exacerbate limited streamflows in the late summer/early fall.

Shifts in the timing and amount of precipitation and streamflows will affect the amount of water recharging the Aquifer. A major proportion of this recharge is expected to be from exfiltration of surface water from Lagace and other creeks on the east side of the Valley. This rate of “leakage” is expected to vary with the wetted surface area of the creek channel. Aquifer water levels are expected to be highest during periods of high surface flow and lowest during periods of low surface flow, with some time lag. Higher streamflows during the winter months may more quickly top up groundwater levels; however, decreased snow accumulations on the local mountains may significantly shorten this recharge period. Groundwater levels during the summer months will largely follow the rate depletion of this stored water due to pumping withdrawals and groundwater discharge to creeks at the south end of the Aquifer (Belcharton, Durieu, Oru, Seux). If this recession period is lengthened, aquifer water levels may reach lower than average levels in the late summer/early fall, thereby making less water available for withdrawal and fisheries habitat.

Future shifts in the incidence of extreme climate events, are more difficult to predict, and will vary season to season and region to region across BC. Extreme droughts and extreme high rainfall/runoff events are expected to be buffered somewhat by the capacity of the Aquifer to store water, and affect groundwater flow dynamics in the short term.

4.4 AQUIFER WATER QUALITY

Laboratory reports for groundwater chemical analyses with TW11-1 and TW12-1 are summarized in Table III. In general, groundwater sampled from both wells is moderately mineralized (TDS 40 to 80 mg/L) and near neutral in pH. Water chemistry is identified as the calcium-carbonate type, with minor sulphate.

Analyses results for groundwater samples collected during the constant-rate test with TW11-1 are presented in column 1 of Table III. Concentrations of all constituents tested were below maximum allowable concentrations (MACs) and aesthetic objectives (AOs) in the Guidelines for Canadian Drinking Water Quality (GCDWQ, Health Canada). It is noteworthy that total and dissolved iron and manganese concentrations were less than method detection limits.

A sample collected from OBS11-1, screened at a higher elevation than TW11-1, had total iron concentrations exceeding the AOs of 0.1 mg/L and 0.05 mg/L, respectively (column 3). A sample of formation water collected 18m below the screened interval of TW11-1 during drilling (column 4) had detectable concentrations of dissolved iron and manganese. Although the formation water samples cannot be relied upon to be as representative as well water samples, these results suggest that iron and manganese concentrations vary with depth in the Aquifer.

Analyses results for groundwater samples collected during the pumping test with TW12-1 are presented in column 2 of Table III. Concentrations of all constituents tested were below GCDWQ MACs and AOs with the exception of:

- Lead, whose total and dissolved concentrations (both 0.012 mg/L) slightly exceeded the MAC of 0.01 mg/L;
- Manganese, whose total and dissolved concentrations (both 0.08 mg/L) slightly exceeded the AO of 0.05 mg/L.

The province occasionally collects water samples at select groundwater and surface water quality monitoring stations as part of the BC Environmental Monitoring System (EMS). One such station is located 190m northeast of TW12-1, and is screened within the Aquifer at a higher elevation (driller's log in Appendix B). The maximum concentrations of constituents analyzed between December 1992 and September 1993 are tabulated in column 6 of Table III. These also indicate a slight exceedance with respect to total lead (0.014 mg/L), but no detectable dissolved or total manganese. A sample of formation water collected 3.3m below the screened interval of TW12-1 during drilling had a dissolved manganese concentration of 0.04 mg/L (column 5). While the reliability of the EMS data is not proven, they affirm lead concentrations may be a concern in this part of the Aquifer, and that manganese concentrations may be spatially variable. The elevated lead concentrations are most likely the result of dissolution of naturally occurring lead-bearing minerals in the aquifer matrix.

Lead is considered as a cumulative general poison that can affect the central nervous system. Fetuses, infants, children up to six years of age, and pregnant women (because of their fetuses) are the most susceptible to adverse health effects. Presence of any detectable lead in a municipal scale water supply is undesirable, and concentrations above the GCDWQ would need to be reduced to very low levels before the water could be considered suitable for consumption by the general population.

Manganese concentrations exceeding the AO guideline are common in groundwater. This element has a low toxicity, and concentrations are limited to avoid problems resulting from precipitation and staining.

The green sand filtration process can be used to remove both lead and manganese from water and achieve very low residual concentrations. With a design filter capacity of 2 L/s/m^2, a filter area of about 105 m^2 would be needed to treat a flow of 210 L/s. This is equivalent to 40 cylindrical filter vessels with a diameter of 1.8m (6'). Additional detailed testing and system design by a water treatment specialist will be needed to determine actual treatment requirements.

4.5 SAFE AQUIFER YIELD

The results of this investigation show that the maximum achievable rate of groundwater withdrawal from municipal production wells constructed into the Aquifer near TW11-1, TW12-1 (or points in between) is likely greater than the District of Mission's target of 210 L/s. However, for a new groundwater extraction project to be considered sustainable, it will be necessary to demonstrate that it will be balanced by available groundwater recharge, that it will not result in net environmental harm, particularly to aquatic environments (e.g., surface water), and that it will not unduly interfere with other operating wells drawing water from the same Aquifer.

There is only limited data available on water wells drawing from the Aquifer, and the surface water regime in the study area, and further study is thus necessary to support a defensible assessment of the impacts of this groundwater extraction project. In accordance with the British Columbia *Environmental Assessment Act,* the scope of assessment will need to be developed in conjunction with an environmental consultant with input from the Environmental Assessment Office.

Based on the results of this assessment, and Piteau's experience with other environmental assessments for groundwater extraction, it can be anticipated that extraction of up to 210 L/s of groundwater from one or more municipal wells drawing from the Aquifer in the vicinity of TW11-1 (Burns Road) may reduce flows in Seux Brook, Oru, Durieu, and Belcharton creeks, which are fed with groundwater from the Aquifer. Furthermore, limited surface water infiltration along the margins of the Valley during the summer drought period may reduce recharge to the Aquifer during periods of peak groundwater extraction.

An overview assessment of stream, fish, and wildlife resources in the Miracle Valley by Scott Resource Services (SRS, Appendix H) indicates that water use in Belcharton Creek is oversubscribed compared to available flows, and the BC Fisheries Inventory Summary System (FISS) has described this water use and diversion as a constraint for fisheries production. Scott anticipates that Seux Brook and Oru and Durieu creeks have similar hydrological constraints, and concludes that obtaining environmental approvals for a project to withdraw additional water from the Aquifer will be difficult, and would only be granted following adequate:

- modelling to quantity the effect;
- biophysical assessment to determine existing baseline environmental resources; and
- mitigation or compensation to offset the quantified effect on the relevant species.

Socio-economic impacts to holders of water licenses on these watercourses also warrant some consideration. A recent search of the BC MOE on-line Water Resources Atlas[7] indicates several licensed points of diversion on Belcharton, Durieu, and Oru creeks and Seux Brook, most of which are at the springs feeding their headwaters. Most licenses are for domestic purposes at relatively small diversion rates (<0.1 L/s). Greater diversion rates have been approved for maintenance of pond levels (47-142 L/s), some of which support hatchery operations. These may be more susceptible to impacts owing to their greater demand, while domestic license holders may only be impacted if their spring sources were to shift location or dry up altogether.

A preliminary estimate of the steady state drawdown in the piezometric level in the Aquifer resulting from pumping a municipal production wells at the location of TW11-1 at 210 L/s is shown on Fig. 4. This is based on the drawdown observed at OBS11-1 during the aquifer pumping test with TW11-1, projected to 100 days and pro-rated to 210 L/s. Well(s) screened near the top of the Aquifer within 110m of the wells would be expected to experience 1.5m or more of interwell drawdown interference. Based on the driller's log (Appendix A) and static

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[7] Available on-line at http://www.env.gov.bc.ca/wsd/data_searches/wrbc/

water level measurements taken in December 2011, we conservatively estimate there to be 4.8m of available drawdown in OBS11-1, of which less than 1m is expected to be consumed by the installed pump. Hence, it is unlikely that this well would experience a loss in capacity due to interwell drawdown interference. Excluding OBS11-1, there appear to be no registered wells within 110m of TW11-1, and interwell drawdown interference of less than 1.5m is not expected to impact the performance of wells located outside this radius. However, this will need to be verified.

Extraction of up to 210 L/s of groundwater from one or more municipal wells drawing from the Aquifer in the vicinity of TW12-1 (Stave Lake Road) is less likely to significantly affect flows in Seux Brook, Oru, Durieu, and Belcharton creeks, as this location is further away and on the other side of a flow divide. As groundwater flow in this area is toward Stave Lake; a reduction in seepage toward the lake resulting from pumping a new well (or wells) at 210 L/s is not likely to have any significant effects on the lake. However, flows in Marino Creek and a nearby tributary to Cascade Creek, which are both reported by SRS to be fish-bearing reaches could potentially be affected.

A preliminary estimate of the steady-state drawdown resulting from pumping municipal wells at the location of TW12-1 at 210 L/s is shown on Fig. 4. This is based on the drawdown observed at OBS12-1 during the aquifer pumping test with TW12-1, projected to 100 days and pro-rated to 210 L/s. Well(s) screened near the top of the Aquifer within 120m of the wells would be expected to experience 4.1m or more of interwell drawdown interference. At OBS12-1, we conservatively estimate there to be 9.3m of available drawdown, based on the driller’s log (Appendix B) and static water level measurements taken in January 2012. Therefore, there is a low likelihood that this well would experience a loss in capacity due to well interference caused by extracting groundwater from municipal wells at 210 L/s. Wells greater than 300m from the well field would be expected to experience less than 1m of interwell drawdown interference, and are thus even less likely to be affected. Impacts to wells within 300m (the MOE wells database indicates eight) should be done on an individual basis in consideration of their construction and operational characteristics. If well performance were compromised, drilling deeper wells could be considered as a form of mitigation.

5. ADDITIONAL INVESTIGATIONS

5.1 GENERAL RECOMMENATIONS

Depending on which strategy is pursued, additional field investigations and review will be needed to investigate the feasibility of groundwater supply options, to support an environmental assessment. Specific objectives of the work should include providing data to enhance the understanding of aquifer characteristics, assess the relationships between surface water and groundwater, and to inventory operating wells drawing from the Aquifer. The scope of these investigations should be developed in conjunction with an environmental consultant, and possibly with input from the Environmental Assessment Office.

As a minimum, the following investigations are recommended:

- Completing a survey of existing wells and operating springs in the study area to enable assessment of the potential effects that groundwater supply development in the Aquifer may have on them. Through a combination of mail-out questionnaires, door-to-door survey, and/or telephone contacts, the locations, elevations, and characteristics of all wells in the study area should be recorded. At this time, water samples could also be collected from selected wells to confirm groundwater quality in the vicinity of proposed municipal production wells. This would be a prudent next step in the vicinity of TW12-1 to confirm that lead concentrations exceeding the GCDWQ MAC are pervasive in this part of the Aquifer.

- Establishing and monitoring a surface water monitoring network to quantify flows in watercourses draining the southern end of the Aquifer (Oru, Durieu, Belcharton, and Lagace creeks) and establish a seasonal baseline. This would form the basis for assessing potential effects resulting from further groundwater supply development in the Aquifer. Basic inorganic quality could also be monitored. If warranted, flows in other creeks potentially affected by a well field near TW12-1 (e.g., Marino Creek) could also be monitored.

- Continuation of long-term monitoring of piezometric levels in TW11-1 and TW12-1 to determine range of variation, lowest seasonal level, and to provide data needed to better understand sources of recharge.

- Construction and testing of one or more larger diameter (12” to 16”) test production wells and conducting high-rate (75 to 100 L/s) aquifer pumping test(s) over a minimum duration of one week in early autumn, when surface water flows and water levels in the aquifer are lowest. The surface and groundwater monitoring systems described above would be used to measure changes resulting from the test(s). Where permission can be obtained, water levels in a subset of private wells screened in the Aquifer should also be monitored.

- Developing a numerical groundwater flow model to simulate baseline conditions in the Aquifer and the response to groundwater withdrawals in terms of piezometric drawdown, and changes in groundwater inflow to creeks. If needed, the model could also be used to predict well capture zones.

- Preparation of one or more reports to summarize the program and results of work completed during this phase (Phase 2). These would document work completed, provide results of analysis and interpretation, and recommend strategies for sustainable groundwater supply development.

5.2 SPECIFIC RECOMMENDATIONS

Given the potential for surface water impacts to limit the maximum quantity of groundwater available from the south end of the Aquifer (Burns Road area), the District has indicated a preference to examine the water supply prospects in the area between TW12-1 and Stave Lake. If there is sufficient capacity, they are also interested in the possibility of extracting a much higher amount (~1,000 L/s). To this end, determining the extent of the Aquifer, and degree of hydraulic connection with Stave Lake, is now of primary interest.

Specific recommendations aimed at providing additional information in this regard are as follows:

- If available, review logs for any geotechnical boreholes drilled along the SW-NE trending BC Hydro power line right-of-way that crosses the north end of the Miracle Valley to determine what materials may be present in this area.

- Examine land ownership and reconnoiter the lands to the north of the power line right-of-way to identify possible drilling sites as close as possible to the lake high water level, and access routes. To maximize the probability of encountering a thick sequence of aquifer sediments, preference should be given to locations near the centre of the valley.

- After obtaining a temporary access agreement, retain a drilling contractor to drill a test well at a suitable location. The depth of drilling would depend on the soil and groundwater conditions encountered, but a maximum depth of 120m (400') is anticipated. A test well diameter of 200mm (8") is recommended, as this will accommodate a submersible pump capable of pumping at up to 40 L/s from 120m. Soil samples collected during drilling would be analyzed to define grain size distribution, and this data would be used to select appropriate sizes for well screens to be installed in the test well.

- If appropriate, conduct an aquifer pumping test with the test well to facilitate collection of groundwater samples and monitoring of aquifer and well performance. This would involve pumping at rates up to approximately 40 L/s and monitoring water levels in the pumped well and any other wells in the area (e.g., TW12-1). In addition to monitoring physical parameters during pumping, groundwater samples for a complete suite of analyses should be collected.

If the results of the test well drilling and aquifer pump testing program indicate favourable results, additional work would be needed to further assess the feasibility of extracting up to 1,000 L/s, and to provide information that would be needed in support of an environmental assessment. The scope of these investigations would be generally similar to described in Section 5.1. Additionally, if conditions warrant, consideration could also be given to conducting non-invasive geophysical surveys along a line parallel to the lakeshore using seismic refraction to assess the depth to bedrock, and/or the transient electromagnetic (TEM) method to identify potential water-bearing zones based on their electrical conductivity. Coupled with the results of a test well in this area, the survey information could potentially be useful for mapping of the most productive parts of the Aquifer and for targeting high-capacity water supply wells.

6. CONCLUSIONS

Piteau Associates Engineering Ltd. has been retained by the District of Mission to conduct hydrogeologic investigations at the Miracle Valley to explore the feasibility of supplying up to 210 L/s of quality groundwater for municipal water supply. Our investigations have included the construction of two 200mm (8”) diameter test wells conducting aquifer pumping tests with these wells.

The Miracle Valley is underlain by a sand and gravel aquifer that is confined by a thick sequence of clay and sandy till. Spatial and temporal trends in piezometric water levels indicate that primary source of recharge to the Aquifer is likely exfiltration from watercourses along the east side of the valley. Groundwater flow is interpreted to diverge to the north and south at a flow divide at the high point of the Valley (Hartley Road), and a westward component of flow is inferred in the southern portion of the Aquifer. At the southern limit of the Aquifer, watercourses which steeply incise the confining clay unit are predominantly spring-fed.

Aquifer pumping test data indicate that Aquifer sediments are highly permeable, with a hydraulic conductivity estimated to be on the order of 10^{-3} m/s. Theoretical short-term yields for larger diameter pumping wells constructed at or near test well sites TW11-1 and TW12-1 could range between about 124 and 360 L/s, respectively. It therefore appears possible to extract groundwater at 210 L/s from two or more larger diameter (12” to 16”) wells at either location.

Groundwater quality measured in water samples collected from TW11-1 is excellent, with the concentration of all constituents analyzed were within limits recommended in the Guidelines for Canadian Drinking Water Quality. However, analyses conducted on shallower and deeper groundwater samples indicate that iron concentrations could exceed aesthetic objectives at other depth horizons. Concentrations of manganese and lead in groundwater samples collected from TW12-1 slightly exceed acceptable limits. Elevated lead concentrations were also detected at a neighbouring well completed at a shallower depth in the Aquifer.

A long-term groundwater withdrawal of 210 L/s in the vicinity of TW11-1 is expected to reduce flows in creeks draining the south portion of the Aquifer (Belcharton, Oru, Durieu creeks, and Seux Brook). As fish habitat is considered to be already compromised along some reaches, obtaining environmental approval could be challenging. In the vicinity of TW12-1, project withdrawals are not expected to impact these creeks, as groundwater flow is interpreted to be northward toward Stave Lake. However, Marino Creek and a small tributary to Cascade Creek may potentially be affected.

Groundwater withdrawals of 210 L/s in the vicinity of TW11-1 or TW12-1 is not expected to significantly affect the performance of water supply wells identified in the near vicinity. This should be verified on a well to well basis based on information regarding the well's depth and current use.

In accordance with the British Columbia *Environmental Assessment Act,* an environmental assessment will be required for groundwater supply development if the total amount of groundwater to be extracted will exceed 75 L/s. The scope of assessment should be determined by an environmental consultant, with input from the Environmental Assessment Office. This may include:

- Completing a survey of existing wells and operating springs in targeted areas to assess the potential impacts of the project on their supply capacity.
- Monitoring flows and possibly water quality in watercourses draining the southern end of the Aquifer (Oru, Durieu, Belcharton, and Lagace creeks) to establish a seasonal baseline for assessing potential impacts of the project on aquatic life. Monitoring of flows in other watercourses (e.g., Allan Lake and Marino Creek).
- Continuation of long-term monitoring of piezometric levels in TW11-1 and TW12-1 to improve the current conceptual model of groundwater flow dynamics and sources of recharge.
- Conducting extended, high-rate (75 to 100 L/s) aquifer pumping test(s) with larger diameter (12 to 16") test production wells to measure potential effects on creeks and neighbouring wells/springs.
- Developing a numerical groundwater flow model to estimate aquifer response to project withdrawals in terms of piezometric drawdown and changes in groundwater inflow to creeks, and predict well capture zones.

More specific recommendations have also been provided to examine the water supply prospects in the north end of the Aquifer between TW12-1 and Stave Lake to investigate the extent of the Aquifer, degree of hydraulic connection with Stave Lake, and ultimately to supply a much greater quantity of groundwater (1,000 L/s). These recommendations include reviewing any geotechnical drilling information available for the BC Hydro right-of-way, determining land ownership and reconnoitring the lands to the north of the power line right-of-way to identify possible drilling sites as close as possible to the lake high water level, drilling a test well and conduct aquifer pumping tests. If results are favourable, additional work would be needed to assess the safe Aquifer yield in this area in support of an environmental assessment. The scope of these investigations would be generally similar to investigations recommended in the foregoing.

7. LIMITATIONS

This investigation has been conducted using a standard of care consistent with that expected of scientific and engineering professionals undertaking similar work under similar conditions in BC. No warranty is expressed or implied.

This report is prepared for the sole use of the District of Mission. Any use, interpretation, or reliance on this information by any third party is at the sole risk of that party, and Piteau accepts no liability for such unauthorized use.

Respectfully submitted,

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TABLES

TABLE I

SUMMARY OF AQUIFER PARAMETERS ESTIMATED FROM CONSTANT-RATE PUMPING TEST RESULTS

Pumped Well	Date	Pumping Rate (L/s)	Monitoring Point	Radius from Pumped Well (m)	Analysis Method	Transmissivity, T (m^2/s)	Aquifer Thickness, b (m)	Hydraulic Conductivity, K (m/s)	Storativity ( )	Plot
TW11-1	15-Dec-2011	34.7	TW11-1 (pumped well)	0	Cooper-Jacob	6.6E-02			-	E2
					Theis Recovery	2.3E-01			-	E2
			OBS11-1	120	Cooper-Jacob	1.3E-01			1.6E-03	E3
					Theis Recovery	3.8E-01			2.6E-03	E3
					Theis	1.3E-01			1.7E-03	E3
					Representative Mean	**1.6E-01**	**48**	**3.3E-03**	**1.9E-03**	

Pumped Well	Date	Pumping Rate (L/s)	Monitoring Point	Radius from Pumped Well (m)	Analysis Method	Transmissivity, T (m^2/s)	Aquifer Thickness, b (m)	Hydraulic Conductivity, K (m/s)	Storativity ( )	Plot
TW12-1	17-Jan-2012	33.1	TW12-1 (pumped well)	0	Cooper-Jacob	6.6E-02			-	F2
					Theis Recovery	2.3E-01			-	F2
			OBS12-1	109	Cooper-Jacob	1.3E-01			6.6E-06	F3
					Theis Recovery	1.2E-01			2.9E-06	F3
					Theis	1.7E-01			7.5E-04	F3
					Representative Mean	**1.3E-01**	**31**	**4.3E-03**	**2.4E-05**	

TABLE II

ESTIMATED PRODUCTION WELL YIELDS

			South Aquifer TW11-1	North Aquifer TW12-1
	PARAMETER	Unit	Value	Value
A	Static water level	m-bgl	25.3	35.6
B	Depth to top of screened interval	m-bgl	56.4	71.8
C	Allowance for seasonal variance	m	2.0	2.0
D	Available drawdown = *B - A - C*	m	29.1	34.2
E	Safety Factor (SF)		30%	30%
F	Allowance for interwell drawdown interference from other wells	m	0.0	0.0
G	Allowable drawdown (D_{max}) = D x (1-E) - F	m	20.4	23.9
H	Test rate used for analysis	L/s	34.7	33.1
		Igpm	458.0	436.9
		USgpm	550.0	524.6
I	Projected drawdown after 100 days pumping at rate specified in (H)	m	5.70	2.20
J	Projected specific capacity at 100 days = *H / I* (S_c)	L/s/m	6.1	15.0
K	Estimated 100 day safe pumping rate = $D_{max} * S_c$	L/s	124.0	360.2
		Igpm	1,637	4,754
		USgpm	1,966	5,709

Notes:

m-bgl = metres below ground level

A: Static water level measured on Dec 14, 2011

E: For a 30% Factor of Safety, Allowable drawdown = 70% of Available drawdown

Calculations assume not interwell drawdown interference

TABLE III

SUMMARY OF WATER QUALITY ANALYTICAL RESULTS

Column No.:	**Units**	**Canadian Drinking Water Quality Guidelines** [1, 2, 3]		1	2	3	4	5	6
Sample ID:				TW11-1	TW12-1	LANG RESIDENCE[4]	TW11-1, 77.7m	TW12-1, 75.6m	BC EMS WELL[5]
Sample Description:				Well discharge at end of pumping test	Well discharge at end of pumping test	Observation well OBS11-1 water	Formation water collected at 255 ft during drilling of TW11-1	Formation water collected at 258 ft during drilling of TW12-1	EMS water quality monitoring well near TW12-1
Date & Time Sampled:				16-Dec-11 12:00	18-Jan-12 14:30	14-Dec-11 11:45	8-Dec-11 12:00	6-Jan-12 15:00	Dec 1992-Sep 1993
Laboratory COC:				L1096762 COFC	L1105481 COFC	L1096345 COFC	L1093778 COFC	L1102004-1 COFC	EMSR0300
Laboratory ID:				L1096762	L1105481	L1096345	L1093778	L1102004-1	
		MAC/IMAC	AO / OG						
Physical Chemistry									
Hardness (as CaCO3)	mg/L	-	-	55.6	46.3	23.8	75.7	-	20.0
Colour, True	CU	-	≤15	<5.0	<5.0	<5.0	-	-	<5
Conductivity	uS/cm	-	-	122	64.5	59	-	-	53
Field Conductivity	uS/cm	-	-	172	-	300	-	-	6.7
pH	pH	-	6.5-8.5	7.72	7.60	7.51	-	-	-
Field pH	pH	-	6.5-8.5	7.21	-	6.92	-	-	-
Total Dissolved Solids	mg/L	-	≤500	76	41	44	-	-	-
Turbidity	NTU	1		<0.10	0.23	**1.12**	-	-	-
Field Temperature	°C	-	-	6.3	-	7.4	-	-	-
UV Absorbance (254 nm)	Abs/cm-1	-	-	<0.0010	-	0.12	-	-	-
Anions and Nutrients									
Alkalinity, Total (as CaCO3)	mg/L	-	-	49.5	47.3	23	-	-	22.3
Bicarbonate (HCO3)	mg/L	-	-	49.5	-	-	-	-	22.3
Carbonate (CO3)	mg/L	-	-	<2.0	-	-	-	-	-
Hydroxide (OH)	mg/L	-	-	<2.0	-	-	-	-	-
							-	-	-
Bromide (Br)	mg/L	-	-	-	-	-	-	-	-
Chloride (Cl)	mg/L	-	≤250	0.95	0.70	1	-	-	0.90
Fluoride (F)	mg/L	1.5	-	0.031	0.030	<0.020	-	-	<0.1
Sulfate (SO4)	mg/L	-	≤500	9.41	10.7	2	-	-	2.2
Nitrate (as N)	mg/L	10	-	0.204	0.0729	1	-	-	-
Nitrite (as N)	mg/L	3.2	-	<0.0010	<0.0010	<0.0010	-	-	-
Nitrate plus Nitrite (as N)	mg/L	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	-	-	-	-	-	-	-	-
Sulphide (as S)	mg/L	-	≤0.05	<0.020	<0.0020	-	-	-	-
Bacteriological Tests									
Coliform Bacteria - Total	MPN/100mL	0	-	<1	<1	-	-	-	-
E. coli	MPN/100mL	0	-	<1	<1	-	-	-	-
Total Metals									
Aluminum (Al)	mg/L	-	0.1 / 0.2	<0.010	<0.010	<0.010	191	-	0.060
Antimony (Sb)	mg/L	0.006	-	<0.00050	<0.00050	<0.00050	<0.010	-	<0.015
Arsenic (As)	mg/L	0.01	-	0.00090	0.00167	0.00010	**0.092**	-	-
Barium (Ba)	mg/L	1	-	<0.020	<0.020	<0.020	**1.27**	-	<0.001
Boron (B)	mg/L	5	-	<0.10	<0.10	<0.10	<0.0050	-	0.043
Cadmium (Cd)	mg/L	0.005	-	<0.00020	<0.0020	<0.00020	<0.10	-	<0.002
Chromium (Cr)	mg/L	0.05	-	<0.0020	<0.0020	<0.0020	0.0058	-	<0.002
Copper (Cu)	mg/L	-	≤1.0	<0.0010	0.0033	0.0064	0.735	-	0.055
Iron (Fe)	mg/L	-	≤0.3	<0.030	<0.030	0.197	300	-	0.07
Lead (Pb)	mg/L	0.01	-	<0.00050	**0.0120**	<0.00050	**0.125**	-	**0.014**
Manganese (Mn)	mg/L	-	≤ 0.05	<0.0020	0.0798	0.0089	6.62	-	<0.002
Mercury (Hg)	mg/L	0.001	-	<0.00020	<0.00020	<0.00020	0.00046	-	
Selenium (Se)	mg/L	0.01	-	<0.0010	<0.0010	<0.0010	<0.020	-	<0.005
Uranium (U)	mg/L	0.02	-	<0.00010	<0.00010	<0.00010	0.0067	-	
Zinc (Zn)	mg/L	-	≤5.0	<0.050	<0.050	<0.050	0.663	-	0.03

TABLE III

SUMMARY OF WATER QUALITY ANALYTICAL RESULTS

Column No.:	**Units**	**Canadian Drinking Water Quality Guidelines** [1, 2, 3]		1	2	3	4	5	6
Sample ID:				TW11-1	TW12-1	LANG RESIDENCE[4]	TW11-1, 77.7m	TW12-1, 75.6m	BC EMS WELL[5]
Sample Description:				Well discharge at end of pumping test	Well discharge at end of pumping test	Observation well OBS11-1 water	Formation water collected at 255 ft during drilling of TW11-1	Formation water collected at 258 ft during drilling of TW12-1	EMS water quality monitoring well near TW12-1
Date & Time Sampled:				16-Dec-11 12:00	18-Jan-12 14:30	14-Dec-11 11:45	8-Dec-11 12:00	6-Jan-12 15:00	Dec 1992-Sep 1993
Laboratory COC:				L1096762 COFC	L1105481 COFC	L1096345 COFC	L1093778 COFC	L1102004-1 COFC	EMSR0300
Laboratory ID:				L1096762	L1105481	L1096345	L1093778	L1102004-1	
		MAC/IMAC	AO / OG						
Calcium (Ca)	mg/L	-	-	16.1	14.6	7.76	153	-	6.9
Magnesium (Mg)	mg/L	-	-	3.46	2.45	1.07	129	-	0.73
Potassium (K)	mg/L	-	-	0.83	0.87	0.38	-	-	0.6
Sodium (Na)	mg/L	-	≤200	2.5	<2.0	<2.0	19.7	-	2.76
Dissolved Metals									
Aluminum (Al)	mg/L	-	0.1 / 0.2	<0.010	<0.010	-	0.174	-	<0.02
Antimony (Sb)	mg/L	0.006	-	<0.00050	<0.00050	-	**0.00705**	-	<0.015
Arsenic (As)	mg/L	0.01	-	0.00091	0.002	-	0.0051	-	**0.04**
Barium (Ba)	mg/L	1	-	<0.020	<0.020	-	0.021	-	0.002
Boron (B)	mg/L	5	-	<0.10	<0.1	-	<0.10	-	<0.008
Cadmium (Cd)	mg/L	0.005	-	<0.00020	<0.0002	-	<0.000050	-	<0.002
Chromium (Cr)	mg/L	0.05	-	<0.0020	<0.0020	-	<0.00050	-	<0.002
Copper (Cu)	mg/L	-	≤1.0	<0.0010	0.003	-	0.0010	-	0.054
Iron (Fe)	mg/L	-	≤0.3	<0.030	<0.030	-	0.105	<0.03	**0.012**
Lead (Pb)	mg/L	0.01	-	<0.00050	**0.012**	-	<0.0010	-	<0.001
Manganese (Mn)	mg/L	-	≤ 0.05	<0.0020	0.080	-	0.039	0.0361	<0.002
Mercury (Hg)	mg/L	0.001	-	<0.00020	<0.00020	-	<0.00020	-	
Selenium (Se)	mg/L	0.01	-	<0.0010	<0.0010	-	0.0012	-	<0.003
Uranium (U)	mg/L	0.02	-	<0.00010	<0.00010	-	0.00054	-	
Zinc (Zn)	mg/L	-	≤5.0	<0.050	<0.00010	-	<0.0050	-	0.021
Calcium (Ca)	mg/L	-	-	16.5	14.600	-	23.0	-	6.78
Magnesium (Mg)	mg/L	-	-	3.50	2.380	-	4.41	-	0.75
Potassium (K)	mg/L	-	-	0.81	0.860	-	-	-	<0.4
Sodium (Na)	mg/L	-	≤200	2.5	<2.0	-	6.1	-	1.95
Radionuclides									
Gross Alpha	Bq/L	<0.5	-	-	<0.05	-	-	-	-
Gross Beta	Bq/L	<1	-	-	0.05	-	-	-	-
Volatile Organic Compounds							-		
Benzene	mg/L	0.005	-	<.000050	<0.00050	-	-	-	-
Ethylbenzene	mg/L	-	≤0.0024	<.000050	<0.00050	-	-	-	-
Methyl t-butyl ether (MTBE)	mg/L	-	0.015	<.000050	<0.00050	-	-	-	-
Toluene	mg/L	-	-≤0.024	<.000050	<0.00050	-	-	-	-
ortho-Xylene	mg/L	-	-	<.000050	<0.00050	-	-	-	-
meta- & para-Xylene	mg/L	-	-	<.000050	<0.00050	-	-	-	-
Xylenees	mg/L	-	≤ 0.3	<.000075	<0.00075	-	-	-	-
Hydrocarbons									
EPH 10-19	mg/L	-	-	<0.25	<0.25	-	-	-	-
EPH 19-32	mg/L	-	-	<0.25	<0.25	-	-	-	-
LEPH	mg/L	-	-	-	<0.25	-	-	-	-
HEPH	mg/L	-	-	-	<0.25	-	-	-	-
Volatile Hydrocarbons (VH6-10)	mg/L	-	-	-	<0.10	-	-	-	-
VPH (C6-C10)	mg/L	-	-	-	<0.10	-	-	-	-

TABLE III

SUMMARY OF WATER QUALITY ANALYTICAL RESULTS

Column No.:	**Units**	**Canadian Drinking Water Quality Guidelines** [1, 2, 3]		1	2	3	4	5	6
Sample ID:				TW11-1	TW12-1	LANG RESIDENCE[4]	TW11-1, 77.7m	TW12-1, 75.6m	BC EMS WELL[5]
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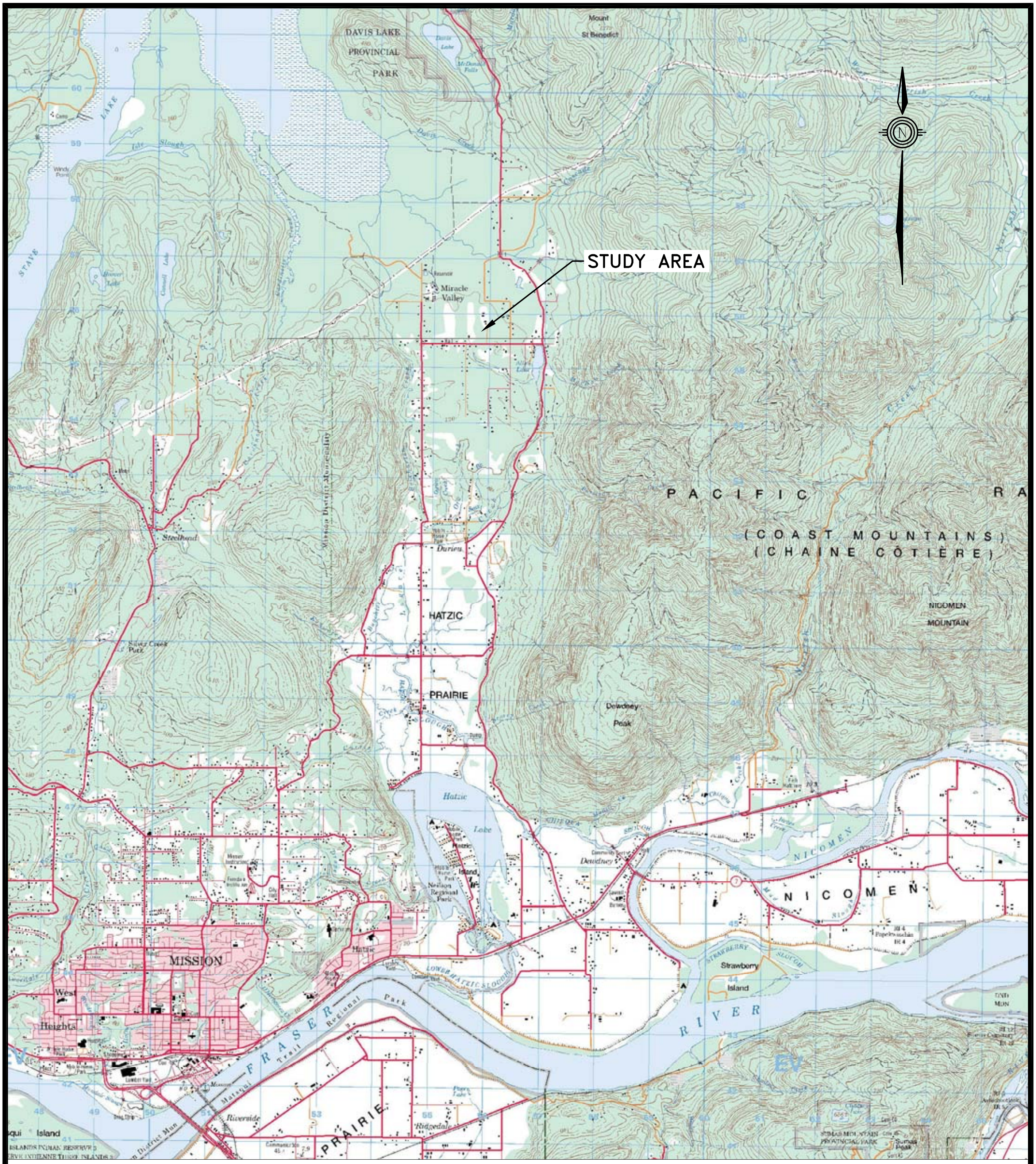
Laboratory COC:				L1096762 COFC	L1105481 COFC	L1096345 COFC	L1093778 COFC	L1102004-1 COFC	EMSR0300
Laboratory ID:				L1096762	L1105481	L1096345	L1093778	L1102004-1	
		MAC/IMAC	AO / OG						
Polycyclic Aromatic Hydrocarbons									
Acenaphthene	mg/L	-	-	-	<0.000050	-	-	-	-
Acenaphthylene	mg/L	-	-	-	<0.000050	-	-	-	-
Acridine	mg/L	-	-	-	<0.000050	-	-	-	-
Anthracene	mg/L	-	-	-	<0.000050	-	-	-	-
Benz(a)anthracene	mg/L	-	-	-	<0.000050	-	-	-	-
Benzo(a)pyrene	mg/L	-	-	-	<0.000010	-	-	-	-
Benzo(b)fluoranthene	mg/L	-	-	-	<0.000050	-	-	-	-
Benzo(g,h,i)perylene	mg/L	-	-	-	<0.000050	-	-	-	-
Benzo(k)fluoranthene	mg/L	-	-	-	<0.000050	-	-	-	-
Chrysene	mg/L	-	-	-	<0.000050	-	-	-	-
Dibenz(a,h)anthracene	mg/L	-	-	-	<0.000050	-	-	-	-
Fluoranthene	mg/L	-	-	-	<0.000050	-	-	-	-
Fluorene	mg/L	-	-	-	<0.000050	-	-	-	-
Indeno(1,2,3-c,d)pyrene	mg/L	-	-	-	<0.000050	-	-	-	-
Naphthalene	mg/L	-	-	-	<0.000050	-	-	-	-
Phenanthrene	mg/L	-	-	-	<0.000050	-	-	-	-
Pyrene	mg/L	-	-	-	<0.000050	-	-	-	-
Quinoline	mg/L	-	-	-	<0.000050	-	-	-	-

Notes:

1. IMAC/MAC Interim and maximum allowable concentration; AO - Aesthetic objective; OG - Operational guidance value; Health Canada, May 2008.
2. AO is for sulphide as H_2S
3. **Bold** and underlined cells denotes concentration exceeding IMAC/MAC or AO, respectively.
4. Sample obtained from domestic well at 12880 Burns Rd, used as an observation well during pumping test with TW11-1.
5. BC Environmental Monitoring System historical statistics report for water well ID EMSR0300, located approx. 190m NE of TW12-1, 44m deep.
   Values given are histoical maximum values measured between Dec 1992 and Sep 1993.

FIGURES

DWG. NUMBER: K:\3131\Cadd\3131-005.dwg (Fig 1)



0 1000 2000 3000 4000 5000m

SCALE 1:100,000

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HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY, MIRACLE
VALLEY, MISSION, BC

STUDY AREA LOCATION

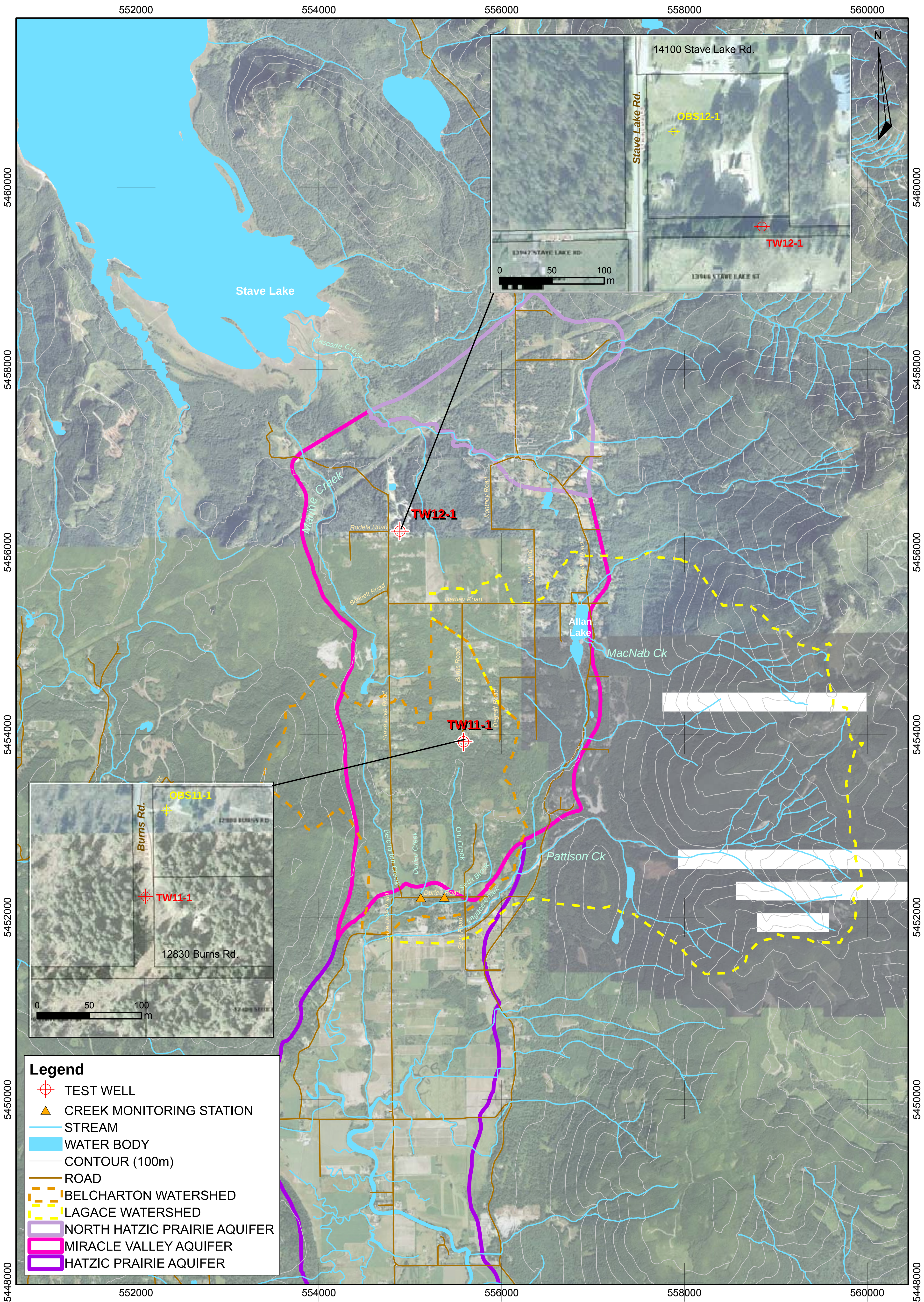
BY: KT/lf

DATE: APR 12

APPROVED: KT

FIG: 1

H:\Project\3131\ArcGIS\Arcmaps\Reports\Fig 2 - Area Plan.mxd



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0 250 500 750 1,000
m

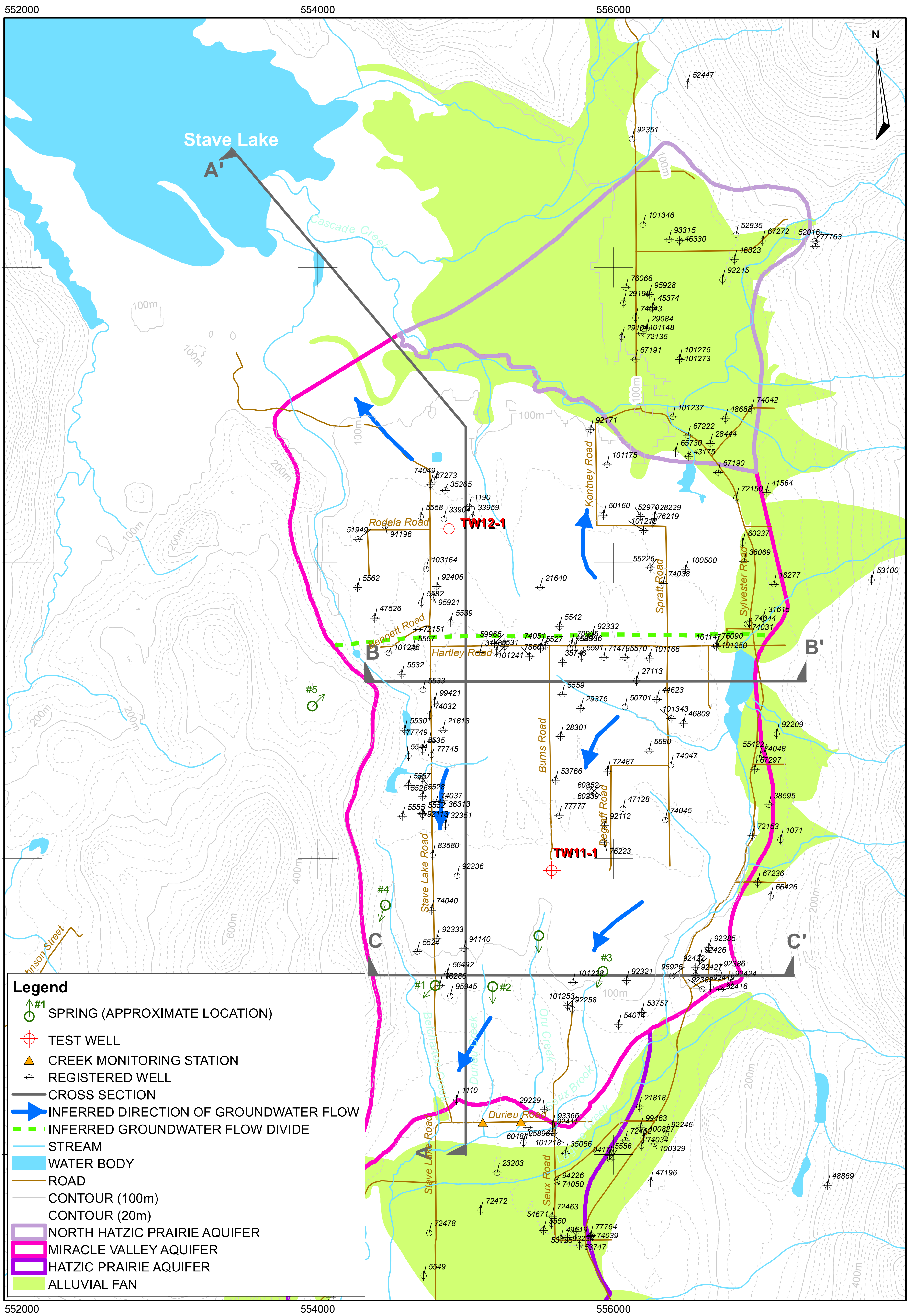
SCALE: 1:40,000

HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, B.C.

AREA PLAN

BY: MLS
DATE: APR 12
APPROVED: KT
FIG: 2

H:\Project\3131\ArcGIS\Arcmaps\Reports\Fig 3 - Area Plan With Work Details.mxd



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0 250 500 750 1,000
m

SCALE: 1:25,000

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FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, B.C.

AREA HYDROGEOLOGY PLAN

BY: MLS	DATE: APR 12
APPROVED: KT	FIG: 3

DWG. NUMBER: K:\3131\Cadd\3131-003.dwg (Fig 4)

SECTION A-A'

LEGEND

DRILLED WELL SHOWING WATER ELEVATION AND BCMOE WELL TAG NO.

PIEZOMETRIC ELEVATION

GEOLOGICAL BOUNDARY

PREDICTED DRAWDOWN OF PIEZOMETRIC SURFACE AT 210 L/S

INFERRED DIRECTION OF GROUNDWATER FLOW

SPRINGS

G	GRAVEL
S	SAND
SI	SILT
CL	CLAY
T	TILL
HP	HARDPAN

(LOWER CASE INDICATES MINOR COMPONENT)

NOTE:

SEE LOCATION OF SECTION ON FIG.2

0 100 200 300 400 500m

HORIZONTAL SCALE 1:12500

VERTICAL EXAGGERATION 12.5x

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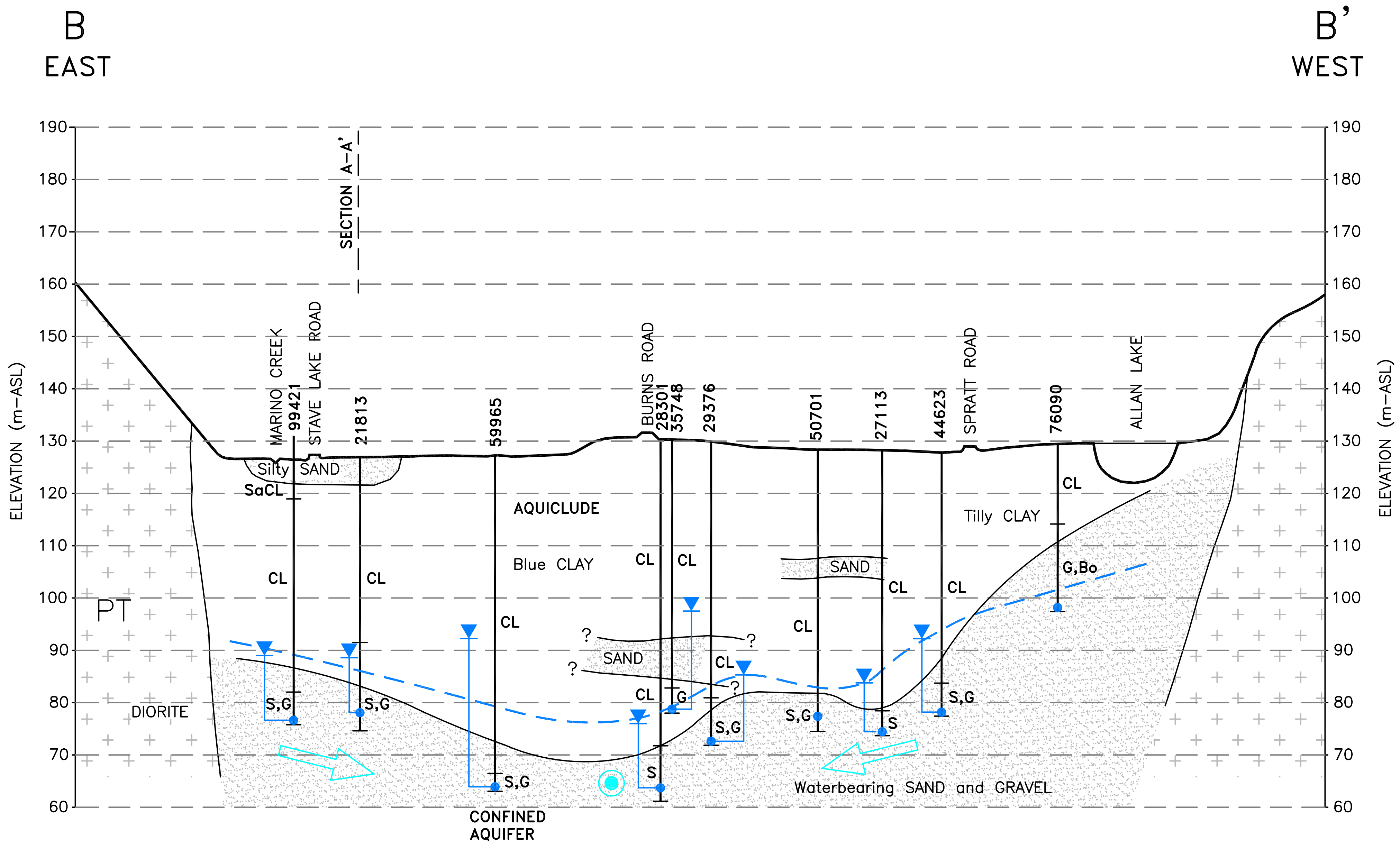
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, B.C.

HYDROGEOLOGICAL
SECTION A-A'

BY: DJT/sl
DATE: APR 12
APPROVED: KT
FIG: 4

DWG. NUMBER: K:\3131\Cadd\3131-002.dwg (Fig 5)



SECTION B–B'

LEGEND

DRILLED WELL SHOWING WATER ELEVATION AND BCMOE WELL TAG NO.

PIEZOMETRIC ELEVATION

GEOLOGICAL BOUNDARY

INFERRED DIRECTION OF GROUNDWATER FLOW PARALLEL TO SECTION

INFERRED DIRECTION OF GROUNDWATER FLOW OUT OF SECTION TO SOUTH

G	GRAVEL
S	SAND
SI	SILT
CL	CLAY
T	TILL
HP	HARDPAN

(LOWER CASE INDICATES MINOR COMPONENT)

0 100 200 300 400 500m

HORIZONTAL SCALE 1:12500
VERTICAL EXAGGERATION 12.5x

NOTE:

SEE LOCATION OF SECTION ON FIG.2

DISTRICT OF MISSION

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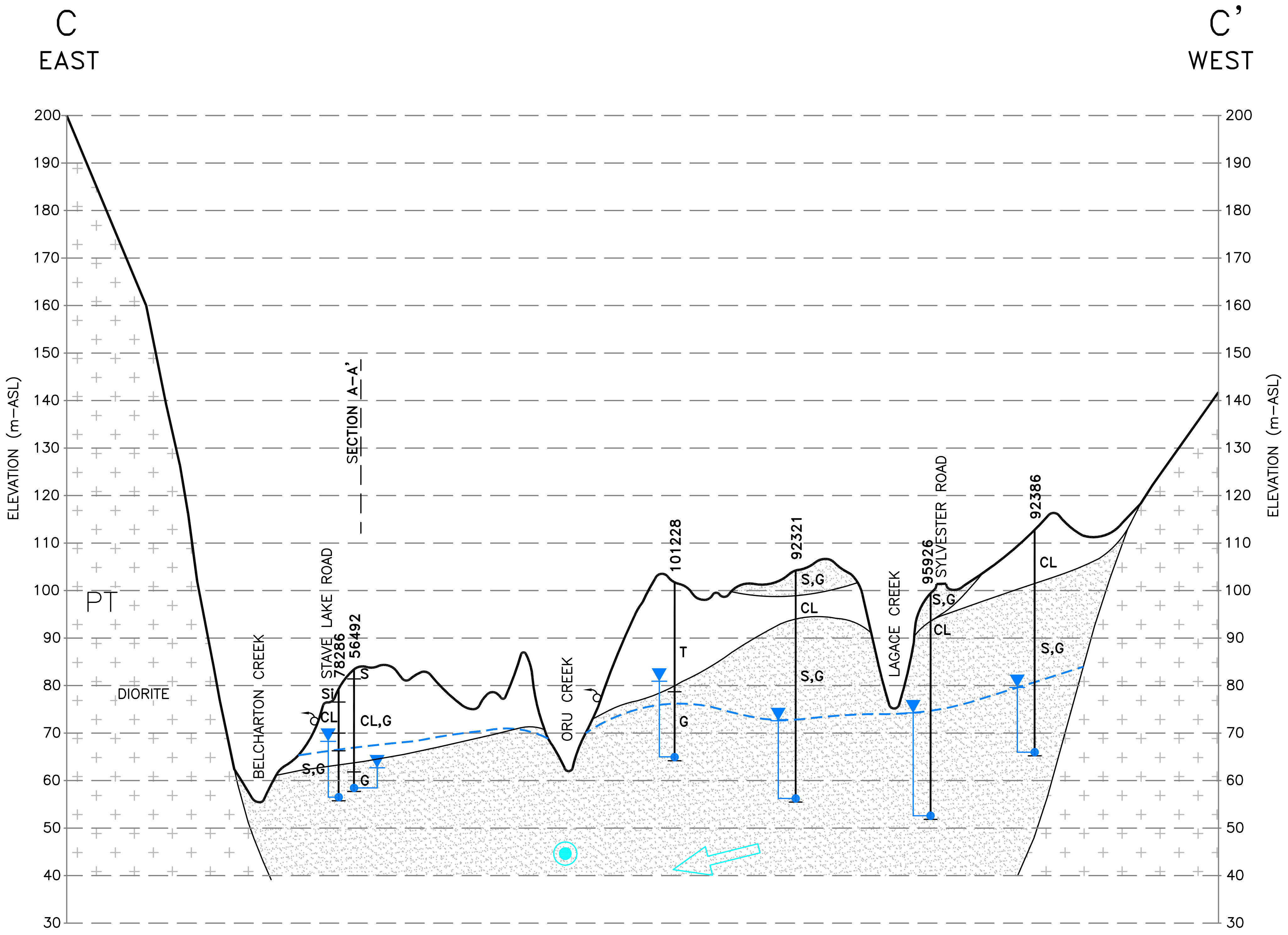
HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, B.C.

HYDROGEOLOGICAL
SECTION B-B'

BY: DJT/sl
DATE: APR 12
APPROVED: KT
FIG: 5

DWG. NUMBER: K:\3131\Cadd\3131-004.dwg (Fig 6)



SECTION C–C'

LEGEND

DRILLED WELL SHOWING WATER ELEVATION AND BCMOE WELL TAG NO.

PIEZOMETRIC ELEVATION

GEOLOGICAL BOUNDARY

INFERRED DIRECTION OF GROUNDWATER FLOW PARALLEL TO SECTION

INFERRED DIRECTION OF GROUNDWATER FLOW OUT OF SECTION TO SOUTH

SPRINGS

G	GRAVEL
S	SAND
SI	SILT
CL	CLAY
T	TILL
HP	HARDPAN

(LOWER CASE INDICATES MINOR COMPONENT)

0 100 200 300 400 500m

HORIZONTAL SCALE 1:12500

VERTICAL EXAGGERATION 12.5x

NOTE:

SEE LOCATION OF SECTION ON FIG.2

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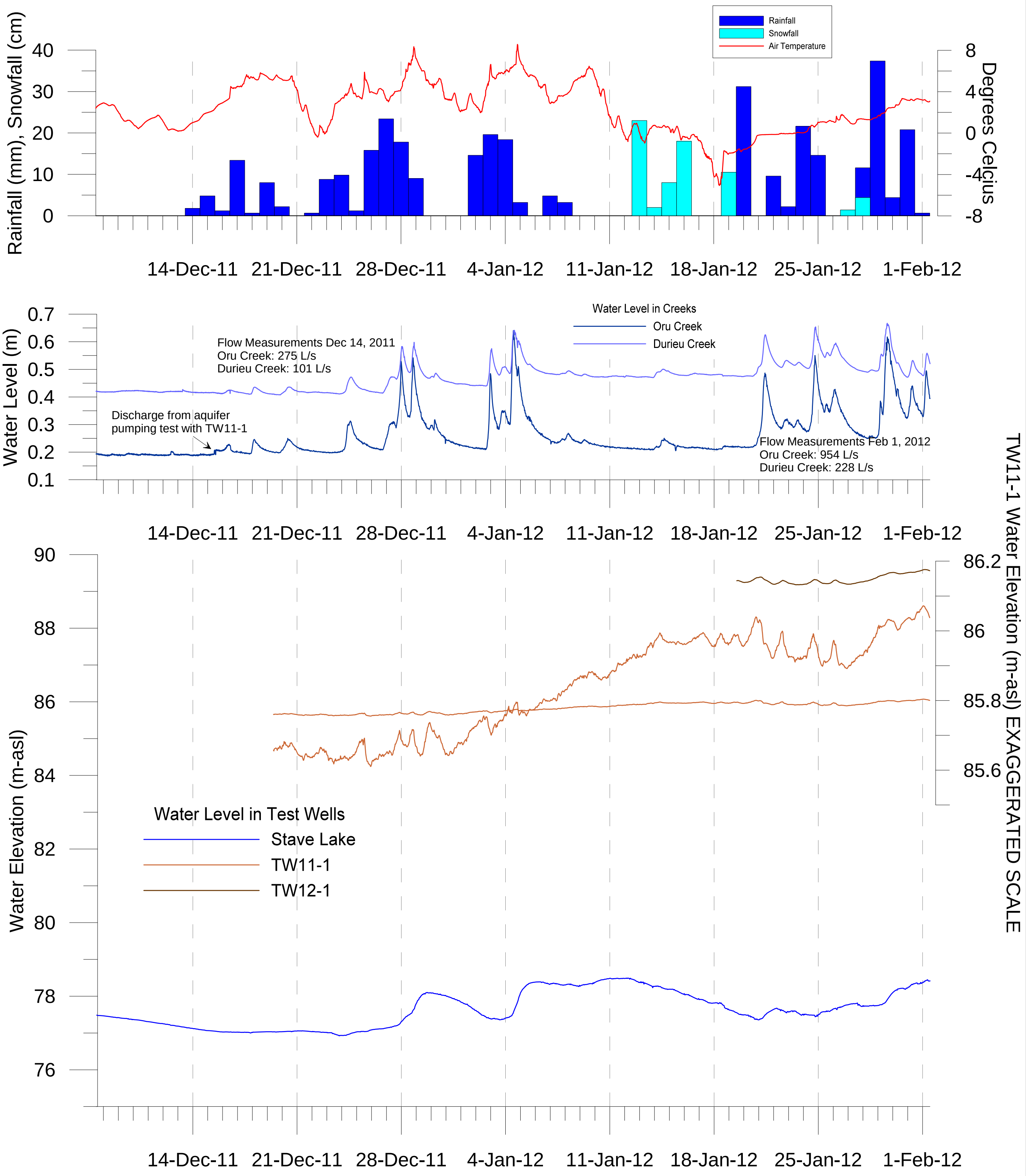
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, B.C.

HYDROGEOLOGICAL
SECTION C-C'

BY: DJT/sl
DATE: APR 12
APPROVED: KT
FIG: 6

H:\Project\3131\Climate\Water Levels.grf



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HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, BC

GROUND AND SURFACE
WATER LEVELS AND
CLIMATE PATTERNS

BY: RS

DATE: APR 12

APPROVED: KT

FIG: 7

PHOTOS

FILE: P:/Photos/3131/Feb-2012-Report_Photos

Photo 1.
Cascade Creek near Kontney Road looking east, October 13, 2011.

Photo 2.
Pattison Creek at Sylvester Road looking west, October 13, 2011.

FILE: P:/Photos/3131/Feb-2012-Report_Photos

Photo 3.
Low water level in Allan Lake, October 13, 2011. Creek entering lake on north end is dry.

Photo 4.
Lagace Creek at Farms Road looking east, October 13, 2011.

Photo 5.
Oru Creek on north side of Durieu Road, December 6, 2011.

Photo 6.
Marshy area along Kontney Road near Cascade Creek, October 13, 2011.

Photo 7.
Location of test well TW11-1 at south terminus of Burns Road, February 1, 2012.

Photo 8.
Drilling TW11-1 on December 6, 2011, with 20ft lengths of 8 inch well casing in foreground.

Photo 9.
Location of test well TW12-1 adjacent to 14042 Stave Lake Road, February 1, 2012.

Photo 10.
Drill rig and support truck at TW12-1, January 6, 2012.

FILE: P:/Photos/3131/Feb-2012-Report_Photos

Photo 11.
Colour change in sediment samples from greyish-brown (210') to grey (234') at TW12-1, January 6, 2012.

Photo 12.
Equipment configuration at well head during pumping tests with TW11-1, December 14, 2011.

FILE: P:/Photos/3131/Feb-2012-Report_Photos

Photo 13.
Orifice plate for measuring of well discharge rate during pumping tests with TW11-1, December 14, 2011.

Photo 14.
Durieu Creek gauging station at Durieu Road, December 6, 2011. Stilling tube is at outlet of culvert.

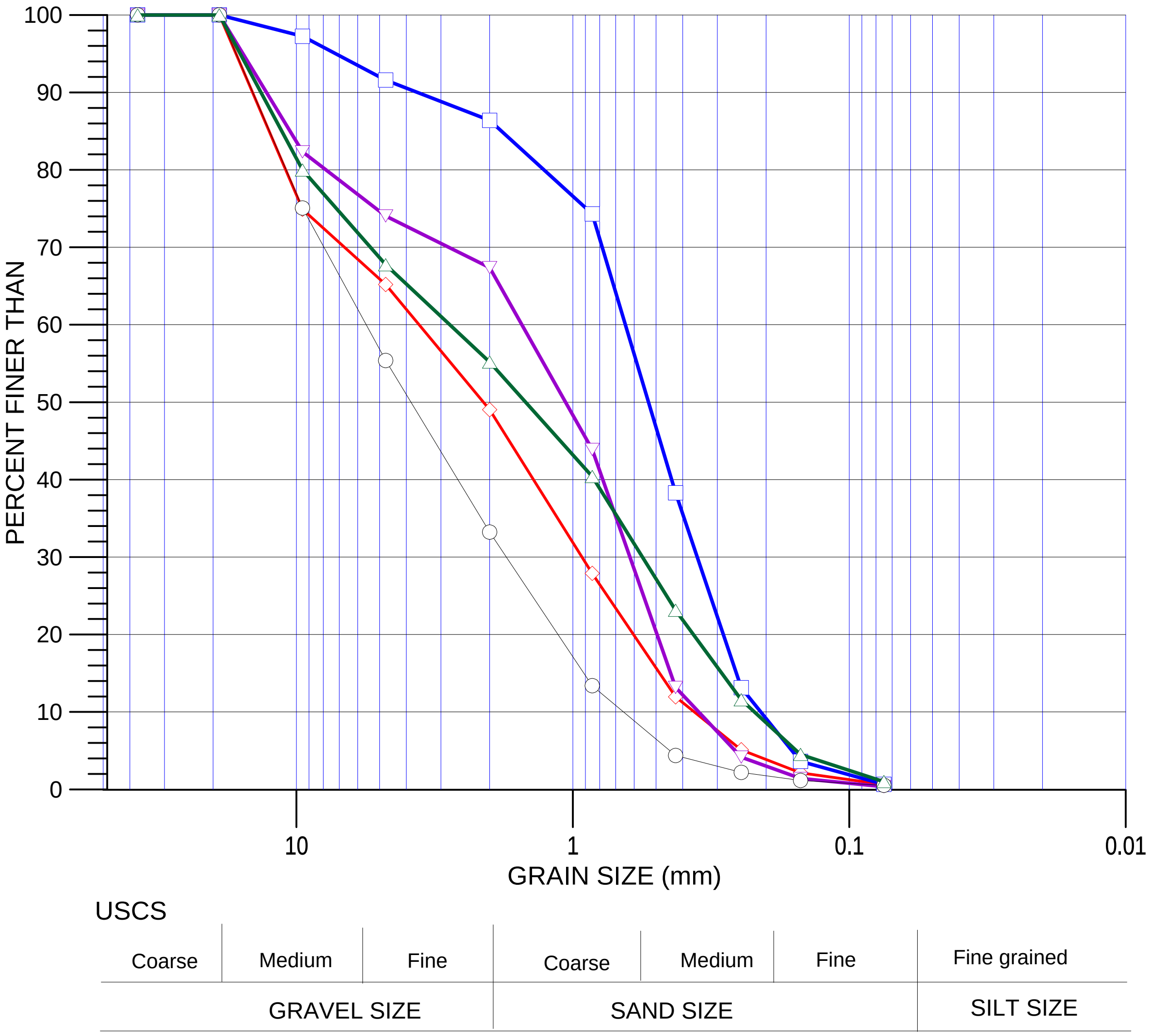
Photo 15.
Oru Creek gauging station at Durieu Road, February 1, 2012. Stilling tube is at inlet of culvert in background.

APPENDIX A

TW11-1 LOG AND GRAIN SIZE ANALYSES RESULTS
PUMPING TEST OBSERVATION WELL LOG

H:\Project\3131\Well Design\Burns Rd Well\Grain Size Plot.grf

UNIFIED SOIL CLASSIFICATION SYSTEM (1992)



HAZEN (1911) APPROXIMATION:

60.4-61.0m; $K = 1.4 \times 10^{-3}$ m/s
61.0-59.7m; $K = 4.8 \times 10^{-4}$ m/s
59.7-58.5m; $K = 1.3 \times 10^{-3}$ m/s
58.5-57.3m; $K = 4.4 \times 10^{-3}$ m/s
57.3-56.1m; $K = 5.3 \times 10^{-4}$ m/s

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HYDROGEOLOGIC ASSESSMENT
FOR GROUNDWATER SUPPLY
MIRACLE VALLEY, MISSION, B.C.

GRAIN SIZE DISTRIBUTION
AT WELL TW11-1

BY: RS
DATE: MAR 12
APPROVED:
FIG: A-1

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

Test Well: TW11-1

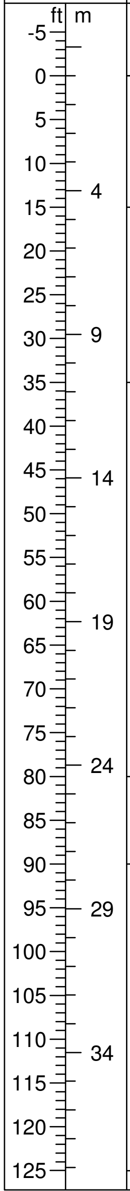
Page 1 of 2

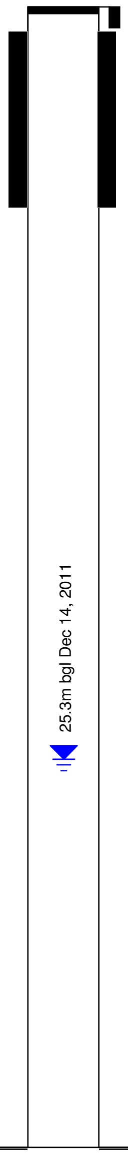
Date Drilled: Dec 5 - 13, 2011

Location: Burns Rd, Miracle Valley BC
Easting: 555578
Northing: 5453915
Elevation: 110 maSL

Client: District of Mission
Project Number: 3131
Logged By: R. Segovia
Borehole Diameter: 203 mm

Depth Below Ground Surface	Elevation (maSL)	Lithologic Description	Depth (mbg)	Lithology	Remarks	Constructed Well
		Ground Surface				
		SAND WITH CLAY Brown medium sand with clay, trace gravel	4.6		Surface Completion: 0.91 m stick-up with locking cap Surface Seal: 305 mm surface casing installed to 6.1 m and removed during installation of bentonite seal	
		GRAVELLY CLAY Grey gravelly clay, some silt Wet below 5.3m	10.7			
		CLAY Grey clay, some silt	24.4			
		SANDY CLAY Grey sandy clay, some gravel	27.4			
		SAND AND GRAVEL Brown medium to coarse sand and gravel, well graded	38.1			





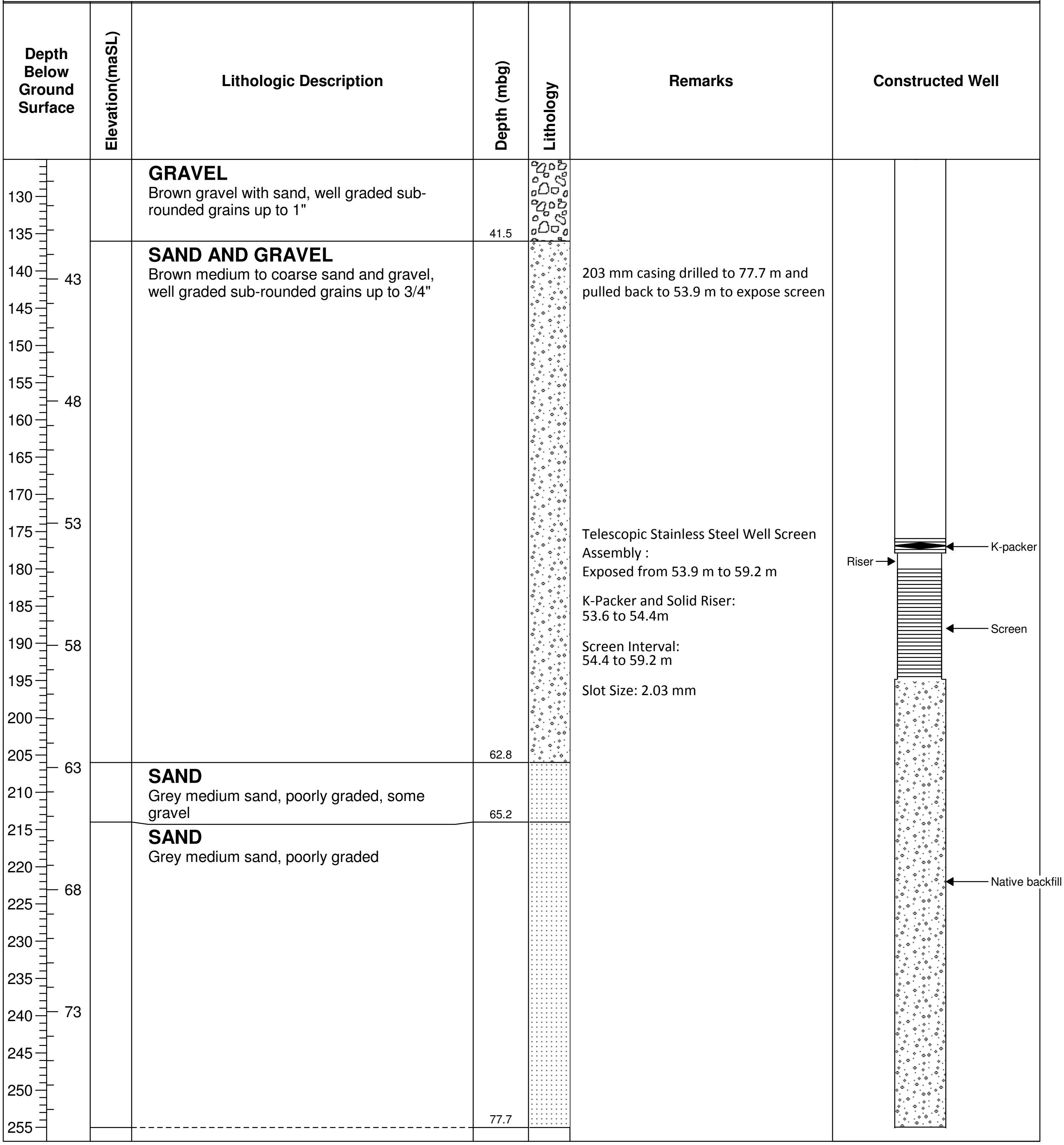
Well Plate I.D: 33361

Drilling Company: A&H Drilling
Drilling Method: Dual Rotary

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

Test Well: TW11-1
Project Number: 3131
Location: Burns Rd, Miracle Valley BC

Page 2 of 2



GRAVEL
Brown gravel with sand, well graded sub-rounded grains up to 1"

SAND AND GRAVEL
Brown medium to coarse sand and gravel, well graded sub-rounded grains up to 3/4"

SAND
Grey medium sand, poorly graded, some gravel

SAND
Grey medium sand, poorly graded

203 mm casing drilled to 77.7 m and pulled back to 53.9 m to expose screen

Telescopic Stainless Steel Well Screen Assembly :
Exposed from 53.9 m to 59.2 m

K-Packer and Solid Riser:
53.6 to 54.4m

Screen Interval:
54.4 to 59.2 m

Slot Size: 2.03 mm

TW11-1 OBS Well

FIELD DRILLING CONTRACTORS LTD

[illegible]
Aldergrove, BC V4W 2V1

[illegible]
Fax: (604)857-2267

WATER WELL RECORD

OWNER: ENGH, LEONARD
DATE. NOVEMBER 29, 2005
ADDRESS: 5236 BOX 1
HEDLEY, BC V0X 1K0
PHONE: 604-826-3633
SITE ADDRESS: 12880 BURNS ROAD
MISSION, BC

Date Begun: NOVEMBER 23, 2005
Date Completed: NOVEMBER 28, 2005
Hole Diameter: 6 Inch
Surface casing:
Dia: 8 18 Feet
Drive shoe: yes
MEASUREMENTS FROM GROUND LEVEL:
Stick-Up: 3 Feet
Bottom of Casing: 129'6" Feet
Hole Depth: 134 Feet
Open Hole: From: Feet
To: Feet
SCREENS:
Number of Screens: 1
Slot Size:
Slot 30 Slot
Slot Slot
Screen Length: 4 Feet
8 Inch
Top at: 127 Feet Inch
Bottom At: 134 Feet Inch

K. Packer: YES Riser: 2FT
B. Bottom: YES
WELL COMPLETION:
Rate: 20 GPM
Pump Setting: 125 Feet
Static Water Level: Feet
Develop: 1 Hours

FROM	TO	WELL LOG DESCRIPTION
0	20	SAND AND CLAY
20	105	CLAY WITH GRAVEL
105	135	W.B. SAND AND GRAVEL

SITE LEGAL DESCRIPTION:

WELL I.D.
11545

Rig No: 5
Rotary: YES
Cable:
Driller: LARRY FIELD
Helper: STEVE JANZEN

NAME: ENGH, LEONARD
JOB NUMBER: 2923-5

APPENDIX B

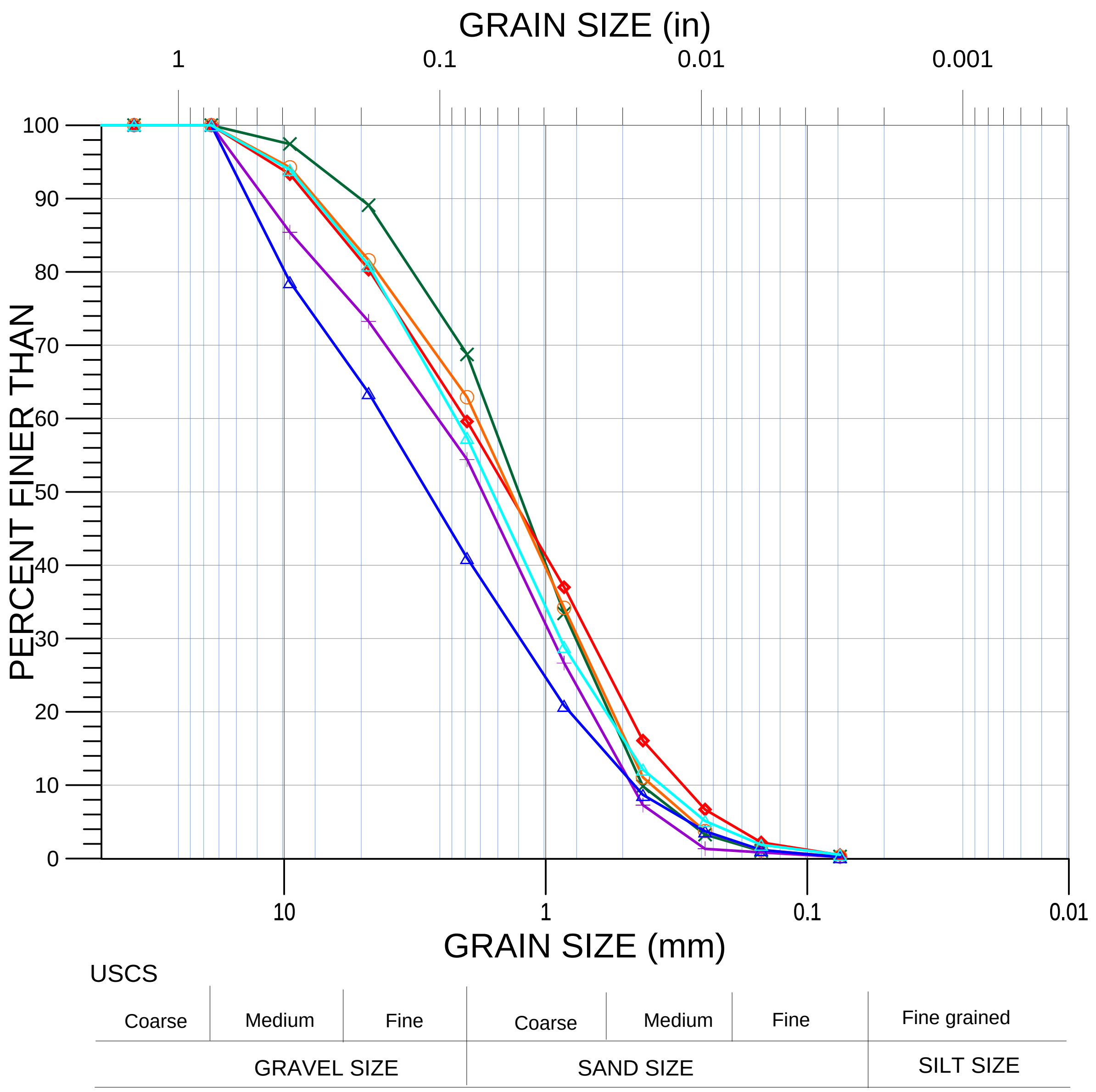
TW012-1 LOG AND GRAIN SIZE ANALYSES RESULTS

PUMPING TEST OBSERVATION WELL LOG

PROVINCIAL EMS WELL LOG

H:\Project\3131\Well Design\StaveLkRd Well\Grain Size Plot.grf

UNIFIED SOIL CLASSIFICATION SYSTEM (1992)



HAZEN (1911) APPROXIMATION:

71.3-71.9m; K = 5.6 x 10^{-3} m/s
71.9-72.5m; K = 6.2 x 10^{-3} m/s
72.5-73.8m; K = 6.2 x 10^{-3} m/s
73.8-74.4m; K = 5.8 x 10^{-3} m/s
74.4-75.0m; K = 5.3 x 10^{-3} m/s
75.0-75.6m; K = 5.9 x 10^{-3} m/s

DISTRICT OF MISSION

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGIC ASSESSMENT
FOR GROUDNWATER SUPPLY
MIRACLE VALLEY, MISSION, B.C.

GRAIN SIZE DISTRIBUTION
WELL TW12-1

BY: MLS
DATE: MAR 12
APPROVED:
FIG: B-1

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

Test Well: TW12-1

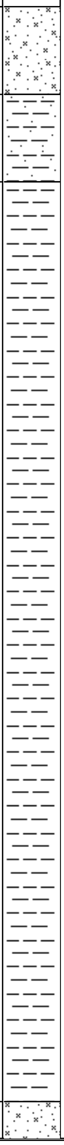
Page 1 of 2

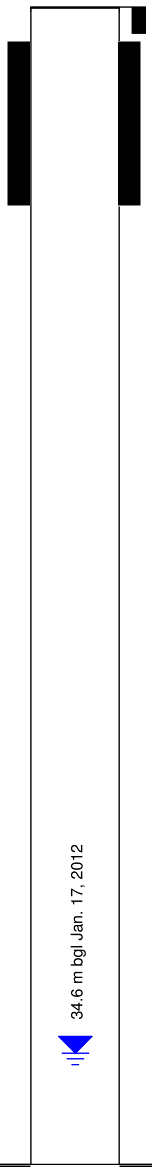
Date Drilled: JAN 3-11 2012

Location: Stave Lk Rd, Miracle Valley BC
Easting: 554897
Northing: 5456251
Elevation: 129 maSL

Client: District of Mission
Project Number: 3131
Logged By: K. Tixier
Borehole Diameter: 203 mm

Depth Below Ground Surface	Elevation (maSL)	Lithologic Description	Depth (mbg)	Lithology	Remarks	Constructed Well
ft / m		Ground Surface			Surface Completion: 1.0m stick-up with locking cap	
		SILTY SAND Brown silty fine to coarse sand, some clay, some subangular gravel	3.0		Surface Seal: 305 mm surface casing installed to 6.1 m and removed during installation of bentonite seal.	
		SANDY CLAY Light brown sandy clay, some subangular gravel	6.1			
		CLAY Grey clay with fine sand, trace rounded gravel, increasing fine sand and gravel content with depth	38.1			





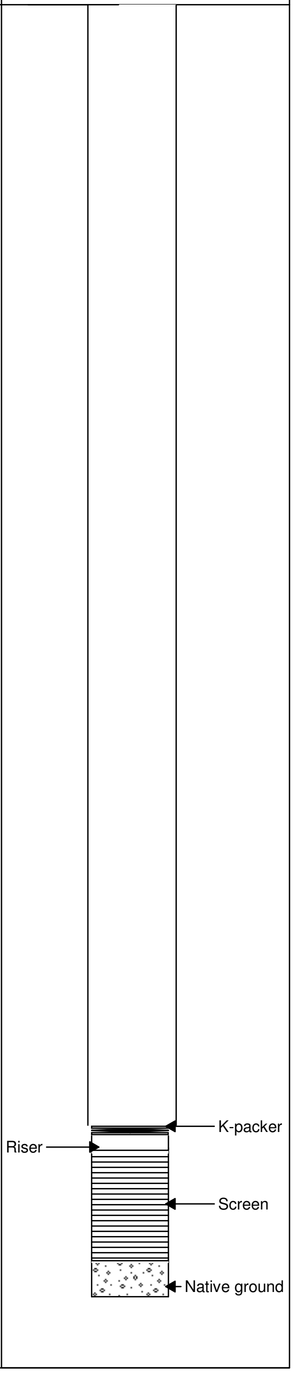
Well Plate I.D: 33369

Drilling Company: A&H Drilling
Drilling Method: Dual Rotary

Depth Below Ground Surface	
132	
137	
142	43
147	
152	
157	48
162	
167	
172	53
177	
182	
187	
192	58
197	
202	
207	63
212	
217	
222	68
227	
232	
237	
242	73
247	
252	
257	78

Elevation(maSL)	Lithologic Description	Depth (mbg)	Lithology	Remarks
	SILTY SAND Brown silty fine to medium sand, with subrounded gravel	41.1		
	SAND AND GRAVEL Brown-grey coarse sand and angular to rounded gravel, trace silt	64.6		203mm casing drilled to 76.8m and pulled back to 72.3m to expose screen
	SAND Brown-grey medium to coarse sand with subrounded gravel	68.6		
	GRAVELLY SAND Grey gravelly coarse sand Colour change in water from brown to grey at 68m	75.6		Telescopic Stainless Steel Well Screen Assembly: Exposed from 71.8 to 75.7m K-Packer and Solid Riser: 71.8 to 72.6m Screen Interval: 72.6 to 75.7m Slot Size: 2.03 mm
	SAND Grey sand with gravel, fining down to end of hole, trace silt	76.8		
	End of Hole			

Constructed Well



BRITISH COLUMBIA

TW 12-1
Obs well

Report 1 - Detailed Well Record

Well Tag Number: 33904

Owner: MIRACLE VALLEY CENTR

Address: MIRACLE VALLEY

Area:

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: Lot: A
Township: 18 Section: 36 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G029421 Well: 11

Class of Well:
Subclass of Well:
Orientation of Well:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Unknown Constru
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 175 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:

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

Construction Date: 1975-12-01 00:00:00.0

Driller: A. & H. Construction
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 60 (Driller's Estimate) Gallons per Minute (U.S./Imperial)
Development Method:
Pump Test Info Flag:
Artesian Flow:
Artesian Pressure (ft):
Static Level: 116 feet

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

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

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

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

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:

LITHOLOGY INFORMATION:

From	0	to	20	Ft.	Clay
From	120	to	139	Ft.	Till and clay
From	130	to	175	Ft.	Sand and gravel

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

BRITISH COLUMBIA

BC EMS Monitoring Well

Report 1 - Detailed Well Record

Well Tag Number: 1190

Owner: RON ROSS

Address: 14100 STAVE LAKE RD.

Area: MISSION

WELL LOCATION:
NEW WESTMINSTER Land District
District Lot: Plan: 8404 Lot:
Township: 18 Section: 36 Range:
Indian Reserve: Meridian: Block:
Quarter:
Island:
BCGS Number (NAD 27): 092G029421 Well: 14

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well:
Status of Well: New
Well Use: Water Supply System
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Casing drive shoe:
Well Depth: 143.5 feet
Elevation: 0 feet (ASL)
Final Casing Stick Up: inches
Well Cap Type:
Bedrock Depth: feet
Lithology Info Flag: N
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

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

Construction Date: 1901-01-01 00:00:00.0

Driller: Unknown
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Development Method:
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 92 feet

WATER QUALITY:
Character:
Colour:
Odour:
Well Disinfected: N
EMS ID: E217927
Water Chemistry Info Flag: Y
Field Chemistry Info Flag:
Site Info (SEAM): Y

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

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

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

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe

GENERAL REMARKS:
MIRACLE VALLEY REHABILITATION CENTRE

LITHOLOGY INFORMATION:

- Return to Main
- Return to Search Options

APPENDIX C

DATA SUMMARY FOR AQUIFER TESTING WITH TW11-1

TABLE C-1
SUMMARY OF MANUAL DATA DURING VARIABLE-RATE PUMPING TEST WITH TW11-1

Date 2011	Clock Time (h:m:s)	Elapsed Time, t (min)	Water Levels				Pumping Rate			Comments
			Depth bTOC		Drawdown					
			(ft)	(m)	(ft)	(m)	(USgpm)	(Igpm)	(L/s)	
14-Dec			82.89	25.265						**STEP #1**
	14:00	0	82.89							OBS WELL - 97.55 FT
		0.5	86.71	26.429	3.820	1.164	160	133	10.1	
		1	87.15	26.563	4.260	1.298				
		1.5	87.52	26.676	4.630	1.411	160	133	10.1	
		2	87.52	26.676	4.630	1.411				WATER CLEAR
		2.5	87.52	26.676	4.630	1.411	160	133	10.1	
		3	87.53	26.679	4.640	1.414				22.5 IN AT ORIFICE
		3.5	87.53	26.679	4.640	1.414	160	133	10.1	
		4	87.53	26.679	4.640	1.414				WATER CLEAR
		4.5	87.54	26.682	4.650	1.417	160	133	10.1	
	14:05	5	87.54	26.682	4.650	1.417				22.5 IN AT ORIFICE
		6	87.54	26.682	4.650	1.417	160	133	10.1	
		7	87.54	26.682	4.650	1.417				WATER CLEAR
		8	87.54	26.682	4.650	1.417	160	133	10.1	34.6 USGPF
		9	87.54	26.682	4.650	1.417				
	14:10	10	87.54	26.682	4.650	1.417	160	133	10.1	
		12	87.55	26.685	4.660	1.420				22.5 IN AT ORIFICE
		14	87.55	26.685	4.660	1.420	160	133	10.1	WATER CLEAR
		16	87.55	26.685	4.660	1.420				
		18	87.55				160	133	10.1	22.5 IN AT ORIFICE
	14:20	20	87.55	26.685	4.660	1.420				OBS WELL 97.62 FT
		25	87.61	26.704	4.720	1.439	160	133	10.1	
	14:30	30	87.61	26.704	4.720	1.439				CHANGED PLATE TO 5 IN
										SHUT DOWN DUE TO GENERATOR
										PROBLEMS STEP CONTINUE NEXT DAY
										STEP #2 - DEC 15, 2011
15-Dec	8:50	0	83.00	25.298	0.110	0.034				OBS WELL - 97.69 FT
		0.5	87.85	26.777	4.960	1.512	176	147	11.1	
		1								VALVING
		1.5	92.66	28.243	9.770	2.978	338	282	21.3	
		2	92.75	28.270	9.860	3.005				WATER CLEAR
		2.5	92.79	28.282	9.900	3.018	338	282	21.3	
		3	92.80	28.285	9.910	3.021				6 IN AT ORIFICE
		3.5	92.82	28.292	9.930	3.027	338	282	21.3	
		4	92.82	28.292	9.930	3.027				
		4.5	92.84	28.298	9.950	3.033	338	282	21.3	WATER CLEAR
	8:55	5	92.86	28.304	9.970	3.039				
		6	92.87	28.307	9.980	3.042	338	282	21.3	
		7	92.89	28.313	10.000	3.048				
		8	92.89	28.313	10.000	3.048	338	282	21.3	
		9	92.89	28.313	10.000	3.048				PH 7.07 - TEMP 11.0°C
	9:00	10	92.90	28.316	10.010	3.051	338	282	21.3	COND. 1010
		12	92.90	28.316	10.010	3.051				TDS 520
		14	92.90				338	282	21.3	
		16	92.91							WATER CLEAR
		18	92.92	28.322	10.030	3.057	338	282	21.3	
	9:10	20	92.93	28.325	10.040	3.060				OBS WELL 97.85 FT
		25	92.92	28.322	10.030	3.057	338	282	21.3	
	9:20	30	92.92	28.322	10.030	3.057				

TABLE C-1
SUMMARY OF MANUAL DATA DURING VARIABLE-RATE PUMPING TEST WITH TW11-1

Date 2011	Clock Time (h:m:s)	Elapsed Time, t (min)	Water Levels				Pumping Rate			Comments
			Depth bTOC		Drawdown					
			(ft)	(m)	(ft)	(m)	(USgpm)	(Igpm)	(L/s)	
										STEP #3
		30.5								VALVING
		31	97.46				472	393	29.7	
		31.5	97.49	29.715	14.600	4.450				
		32	97.52	29.724	14.630	4.459	470	392	29.6	
		32.5	97.51	29.721	14.620	4.456				
		33	97.52	29.724	14.630	4.459	470	392	29.6	13 IN AT ORIFICE
		33.5	97.53	29.727	14.640	4.462				
		34	97.56	29.736	14.670	4.471	470	392	29.6	WATER CLEAR
		34.5								
	9:25	35	97.55				470	392	29.6	
		36	97.56	29.736	14.670	4.471				
		37	97.57	29.739	14.680	4.474	470	392	29.6	
		38	97.58	29.742	14.690	4.478				WATER CLEAR
		39	97.58	29.742	14.690	4.478	470	392	29.6	13 IN AT ORIFICE
	9:30	40	97.59	29.745	14.700	4.481				
		42	97.60	29.748	14.710	4.484	470	392	29.6	13 IN AT ORIFICE
		44	97.62	29.755	14.730	4.490				
		46	97.62	29.755	14.730	4.490	470	392	29.6	OBS WELL 97.90 FT
		48	97.62							PH 8.22
	9:40	50	97.65	29.764	14.760	4.499	470	392	29.6	COND 1033
		55	97.67							TDS 520
	9:50	60	97.68	29.773	14.790	4.508	470	392	29.6	TEMP 8.1°C
										STEP #4
		60.5								VALVING
		61	100.42	30.608	17.530	5.343	548	457	34.5	
		61.5	100.42							WATER CLEAR
		62	100.45	30.617	17.560	5.352	550	458	34.7	17.5 IN AT ORIFICE
		62.5	100.45	30.617	17.560	5.352				
		63	100.45	30.617	17.560	5.352	550	458	34.7	
		63.5	100.46	30.620	17.570	5.355				17.5 IN AT ORIFICE
		64	100.47	30.623	17.580	5.358	550	458	34.7	
		64.5	100.48	30.626	17.590	5.361				WATER CLEAR
	9:55	65	100.49	30.629	17.600	5.364	550	458	34.7	
		66	100.52	30.638	17.630	5.374				
		67	100.55	30.648	17.660	5.383	550	458	34.7	17.5 IN AT ORIFICE
		68	100.55	30.648	17.660	5.383				
		69	100.56	30.651	17.670	5.386	550	458	34.7	WATER CLEAR
	10:00	70	100.56	30.651	17.670	5.386				
		72	100.57	30.654	17.680	5.389	550	458	34.7	
		74	100.57	30.654	17.680	5.389				PH - 7.96
		76	100.56	30.651	17.670	5.386	550	458	34.7	COND - 899, TEMP 7.4°C
		78	100.58	30.657	17.690	5.392				TDS - 440
	10:10	80	100.57	30.654	17.680	5.389	550	458	34.7	OBS WELL 97.98 FT
		85	100.64	30.675	17.750	5.410				
	10:20	90	100.65	30.678	17.760	5.413	550	458	34.7	
										RECOVERY
		90.5	83.40	25.420	0.510	0.155				
		91	83.30	25.390	0.410	0.125				
		91.5	83.25	25.375	0.360	0.110				
		92	83.23	25.369	0.340	0.104				
		92.5	83.20	25.359	0.310	0.094				
		93	83.16	25.347	0.270	0.082				
		93.5	83.15	25.344	0.260	0.079				
		94	83.15	25.344	0.260	0.079				
		94.5	83.15	25.344	0.260	0.079				
	10:25	95	83.14	25.341	0.250	0.076				
		96	83.13	25.338	0.240	0.073				
	10:27	97	83.13	25.338	0.240	0.073				
	10:32	102	83.11	25.332	0.220	0.067				
	10:44	114	83.01	25.301	0.120	0.037				
	11:20	150	83.03	25.308	0.140	0.043				END RECOVERY

TABLE C-2
SUMMARY OF MANUAL DATA DURING CONSTANT-RATE PUMPING TEST WITH TW11-1

Date 2011	Clock Time (h:m:s)	Elapsed Time, t (min)	Water Levels				Pumping Rate			Comments
			Depth bTOC		Drawdown					
			(ft)	(m)	(ft)	(m)	(USgpm)	(Igpm)	(L/s)	
15-Dec	**11:30**	0	83.04	25.311	0.000	0.000				**STATIC**
		0.5								OBS WELL 97.76 FT
		1	93.75	28.575	10.710	3.264				VALVING
		1.5	95.32	29.054	12.280	3.743				
		2	97.71	29.782	14.670	4.471	527	439	33.2	
		2.5	100.00	30.480	16.960	5.169				WATER BROWNISH COLOUR
		3	100.15	30.526	17.110	5.215	550	458	34.7	
		3.5	100.17	30.532	17.130	5.221				WATER CLEAR
		4	100.23	30.550	17.190	5.240	549	457	34.6	
		4.5	100.25	30.556	17.210	5.246				17.5 IN AT ORIFICE
	11:35	5	100.26	30.559	17.220	5.249	549	457	34.6	
		6	100.30	30.571	17.260	5.261				
		7	100.36	30.590	17.320	5.279				
		8	100.35	30.587	17.310	5.276				
		9	100.36	30.590	17.320	5.279	549	457	34.6	
	11:40	10	100.37	30.593	17.330	5.282				
		12	100.41	30.605	17.370	5.294				
		14	100.44	30.614	17.400	5.304	549	457	34.6	WATER CLEAR
		16	100.45	30.617	17.410	5.307				17.5 IN AT ORIFICE
		18	100.46	30.620	17.420	5.310				
	11:50	20								WATER CLEAR
		25	100.48	30.626	17.440	5.316	549	457	34.6	
	12:00	30	100.52	30.638	17.480	5.328				
		35	100.52	30.638	17.480	5.328	549	457	34.6	
	12:10	40	100.55	30.648	17.510	5.337				
	12:20	50	100.59	30.660	17.550	5.349	548	457	34.5	
	12:30	60	100.61	30.666	17.570	5.355				OBS WELL 98.01 FT
	12:40	70	100.61	30.666	17.570	5.355				
	12:50	80	100.60	30.663	17.560	5.352	549	457	34.6	
	13:00	90	100.61	30.666	17.570	5.355				
	13:10	100	100.66	30.681	17.620	5.371	548	457	34.5	
	13:30	120	100.69	30.690	17.650	5.380				PH - 7.9, COND - 345, TDS-480
	13:50	140	100.68	30.687	17.640	5.377	549	457	34.6	TEMP - 6.8°C
	14:10	160	100.72	30.699	17.680	5.389				OBS WELL 98.05 FT
	14:30	180	100.75	30.709	17.710	5.398				PH - 5.88, COND - 314, TDS-680
	14:50	200	100.75	30.709	17.710	5.398	548	457	34.5	TEMP - 6.7°C
	15:40	250	100.74	30.706	17.700	5.395	548	457	34.5	OBS WELL 98.08 FT
	16:30	300	100.77	30.715	17.730	5.404				PH-5.8, TDS-243, COND.-124, TEMP 6.9°C
	17:20	350	100.86	30.742	17.820	5.432	550	458	34.7	17.5 IN AT ORIFICE, TWEAKED VFD
	18:10	400	100.89	30.751	17.850	5.441				OBS WELL 98.06 FT
	19:00	450	100.92	30.760	17.880	5.450				PH-5.57, COND- 570, TDS-270, TEMP 6.0°C
	19:50	500	100.92	30.760	17.880	5.450	550	458	34.7	
	20:40	550	100.92	30.760	17.880	5.450				
	21:30	600	100.93	30.763	17.890	5.453				TEMP 6.0°C, PH-5.26, COND-1080, TDS-542
	22:20	650	100.94	30.767	17.900	5.456	549	457	34.6	OBS WELL - 97.17 FT
	23:10	700	100.94							17.5 IN AT ORIFICE
16-Dec	0:00	750	100.93							**DEC 16, 11** - WATER CLEAR
	0:50	800	100.92	30.760	17.880	5.450				TEMP 6.0°C, PH-5.46 TDS-582
	1:40	850	100.91	30.757	17.870	5.447				17.5 IN AT ORIFICE
	2:30	900	100.92	30.760	17.880	5.450				TEMP 6.0°C, PH-5.29, COND-531, TDS-468
	3:20	950	100.94	30.767	17.900	5.456				OBS WELL - 98.19 FT
	4:10	1000	100.94	30.767	17.900	5.456				
	5:00	1050	100.94	30.767	17.900	5.456				PH-7.05, COND-592, TDS-341, TEMP 6.3°C
	5:50	1100	100.92				550	458	34.7	17.5 IN AT ORIFICE
	6:40	1150	100.92	30.760	17.880	5.450	551	459	34.7	OBS WELL 98.2 FT
	7:30	1200	100.91	30.757	17.870	5.447				PH-7.05, COND-216, TDS-111, TEMP 6.9°C
	8:20	1250	100.90	30.754	17.860	5.444	550	458	34.7	17.5 IN AT ORIFICE
	9:10	1300	100.91	30.757	17.870	5.447	550	458	34.7	OBS WELL 98.25 FT
	10:00	1350	100.91	30.757	17.870	5.447				PH-7.21, COND-172, TDS-159, TEMP 9.9°C
	10:50	1400	100.92	30.760	17.880	5.450				17.5 IN AT ORIFICE
	11:30	1440								OBS WELL 98.23 FT
										RECOVERY
		1440.5	83.40	25.420	0.360	0.110				
		1441	83.52	25.457	0.480	0.146				
		1441.5	83.48	25.445	0.440	0.134				
		1442	83.43	25.429	0.390	0.119				
		1442.5	83.42	25.426	0.380	0.116				
		1443	83.38	25.414	0.340	0.104				
		1443.5	83.40	25.420	0.360	0.110				
		1444	83.38	25.414	0.340	0.104				
		1444.5								
	11:35	1445	83.37	25.411	0.330	0.101				
		1446	83.41							
		1447	83.42	25.426	0.380	0.116				
		1448	83.40	25.420	0.360	0.110				
		1449	83.40	25.420	0.360	0.110				
	11:40	1450	83.39	25.417	0.350	0.107				
	11:51	1461	83.35							
	12:02	1472	83.30	25.390	0.260	0.079				
	12:15	1485	83.30	25.390	0.260	0.079				OBS WELL 98.31 FT AT 12:45
	13:30	1500	83.27	25.381	0.230	0.070				**END RECOVERY**

APPENDIX D

DATA SUMMARY FOR AQUIFER TESTING WITH TW12-1

TABLE D-1
SUMMARY OF MANUAL DATA DURING VARIABLE-RATE PUMPING TEST WITH TW12-1

Date 2012	Clock Time (h:m:s)	Elapsed Time, t (min)	Water Levels				Pumping Rate			Comments
			Depth bTOC		Drawdown					
			(ft)	(m)	(ft)	(m)	(USgpm)	(Igpm)	(L/s)	
17-Jan	**10:30**	0	116.61	35.543	0.000	0.000				**STEP #1**
		0.5	117.45							6 IN AT ORIFICE = 161 USGPM
		1								
		1.5	127.30	38.801	10.690	3.258	116	97	7.3	WATER AT ORIFICE
		2								VALVE BACK
		2.5	118.10	35.997	1.490	0.454	143	119	9.0	VFD UP
		3	118.00	35.966	1.390	0.424	144	120	9.1	VALVE BACK
		3.5								
		4	118.10	35.997	1.490	0.454	163	136	10.3	
		4.5								
	10:35	5	118.10	35.997	1.490	0.454				WATER VERY BROWN
		6	118.10	35.997	1.490	0.454				
		7	118.10	35.997	1.490	0.454				
		8	118.10	35.997	1.490	0.454				
		9	118.10	35.997	1.490	0.454				
	10:40	10	118.10	35.997	1.490	0.454				
		12	118.10	35.997	1.490	0.454				
		14	118.13	36.006	1.520	0.463	166	139	10.5	6.5 IN AT ORIFICE
		16	118.15	36.012	1.540	0.469	167	139	10.5	
		18	118.15	36.012	1.540	0.469	166	139	10.5	
	10:50	20	118.15	36.012	1.540	0.469	167	139	10.5	
		25	118.15	36.012	1.540	0.469	169	140	10.6	VALVED BACK TO MAINTAIN FLOW
	11:00	30	118.15	36.012	1.540	0.469	167	139	10.5	105.84 USGPF
										STEP #2 - VALVE UP
		30.5	118.63	36.158	2.020	0.616				
		31	119.05	36.286	2.440	0.744	234	195	14.7	22 IN AT ORIFICE
		31.5	119.23	36.341	2.620	0.799	275	229	17.3	VALVE UP
		32	119.35	36.378	2.740	0.835	288	240	18.1	VFD UP
		32.5	119.51	36.427	2.900	0.884				
		33					325	271	20.5	
		33.5	119.95	36.561	3.340	1.018	305	254	19.2	VALVE BACK
		34	119.75	36.500	3.140	0.957				
		34.5	119.75	36.500	3.140	0.957	305	254	19.2	20.5 IN AT ORIFICE
	11:05	35	119.76	36.503	3.150	0.960	312	260	19.7	VALVE UP
		36	119.70	36.485	3.090	0.942	315	262	19.8	
		37	119.87	36.536	3.260	0.994				22 IN AT ORIFICE
		38	119.87	36.536	3.260	0.994	315	262	19.8	WATER CLEAR
		39	119.97	36.567	3.360	1.024	315	262	19.8	22 IN AT ORIFICE
	11:10	40	119.87	36.536	3.260	0.994	316	263	19.9	COLD OUT SIDE
		42	119.87	36.536	3.260	0.994	315	263	19.9	
		44	119.88	36.539	3.270	0.997				
		46	119.88	36.539	3.270	0.997				
		48	119.88	36.539	3.270	0.997				22 IN AT ORIFICE
	11:20	50	119.88	36.539	3.270	0.997				
		55	119.88	36.539	3.270	0.997	315	263	19.8	
	11:30	60	119.95	36.561	3.340	1.018	316	263	19.9	CHANGE TO 5 IN PLATE
										STEP #3 - VALVE UP
		60.5	120.35	36.683	3.740	1.140	340	283	21.4	449 USGPM
		61								13 IN AT ORIFICE
		61.5	121.45	37.018	4.840	1.475	443	369	27.9	VFD UP
		62	121.49	37.030	4.880	1.487	443	369	27.9	
		62.5	121.56	37.051	4.950	1.509	443	369	27.9	VALVE UP
		63	121.60	37.064	4.990	1.521	445	371	28.0	
		63.5	121.70	37.094	5.090	1.551				ADJUSTING VALVE
		64								
		64.5								
	11:35	65	121.70	37.094	5.090	1.551	451	376	28.4	11 IN AT ORIFICE
		66	121.70	37.094	5.090	1.551				VALVE UP
		67	121.79	37.122	5.180	1.579	461	384	29.0	
		68								VALVE UP 13 IN AT ORIFICE
		69	122.22	37.253	5.610	1.710	490	409	30.9	
	11:40	70	122.25	37.262	5.640	1.719	490	408	30.9	WATER CLEAR
		72	122.25	37.262	5.640	1.719	490	408	30.9	
		74	122.25	37.262	5.640	1.719				13 IN. AT ORIFICE
		76	122.28	37.271	5.670	1.728	490	408	30.9	
		78	122.30	37.277	5.690	1.734				
	11:50	80	122.30	37.277	5.690	1.734				
		85	122.30	37.277	5.690	1.734	488	407	30.7	
	12:00	90	122.30	37.277	5.690	1.734				80.32 USGPF
										STEP #4 - VALVE UP
		90.5								16.5 IN AT ORIFICE
		91								
		91.5								
		92	123.10	37.521	6.490	1.978	549	457	34.6	VALVE UP
		92.5	123.12	37.527	6.510	1.984				16 IN AT ORIFICE
		93	123.15	37.536	6.540	1.993				VALVE UP
		93.5								
		94	123.15	37.536	6.540	1.993				
		94.5	123.18	37.545	6.570	2.003				WATER CLEAR

TABLE D-1
SUMMARY OF MANUAL DATA DURING VARIABLE-RATE PUMPING TEST WITH TW12-1

Date 2012	Clock Time (h:m:s)	Elapsed Time, t (min)	Water Levels				Pumping Rate			Comments
			Depth bTOC		Drawdown					
			(ft)	(m)	(ft)	(m)	(USgpm)	(Igpm)	(L/s)	
	12:05	95	123.18	37.545	6.570	2.003	550	459	34.7	
		96	123.18	37.545	6.570	2.003				
		97	123.18	37.545	6.570	2.003				VALVE UP
		98	123.25	37.567	6.640	2.024	557	464	35.1	17 IN MAXED ON PUMP
		99	123.33	37.591	6.720	2.048				
	12:10	100	123.33	37.591	6.720	2.048				
		102	123.33	37.591	6.720	2.048				
		104	123.28	37.576	6.670	2.033				
		106	123.28	37.576	6.670	2.033				µs 120, PPM 60, PH 8.79, TEMP 6.6ºC
		108	123.34	37.594	6.730	2.051	555	462	35.0	
	12:20	110	123.33	37.591	6.720	2.048				
		115	123.35	37.597	6.740	2.054	557	464	35.1	
	12:30	120	123.35	37.597	6.740	2.054	557	464	35.1	76.11 USGPF
										RECOVERY
		120.5	117.36	35.771	0.750	0.229				
		121	116.99	35.659	0.380	0.116				
		121.5	116.99	35.659	0.380	0.116				
		122	116.97	35.652	0.360	0.110				
		122.5	116.95	35.646	0.340	0.104				
		123	116.93	35.640	0.320	0.098				
		123.5	116.91	35.634	0.300	0.091				
		124	116.90	35.631	0.290	0.088				
		124.5	116.89	35.628	0.280	0.085				
	12:35	125	116.85	35.616	0.240	0.073				
		126	116.85	35.616	0.240	0.073				
		127	116.85	35.616	0.240	0.073				
		128	116.83	35.610	0.220	0.067				
		129	116.83	35.610	0.220	0.067				
	12:40	130	116.82	35.607	0.210	0.064				
		132								
		134	116.78	35.595	0.170	0.052				
		136								
		138	116.77	35.591	0.160	0.049				
	12:50	140								
		145								
	13:00	150	116.75	35.585	0.140	0.043				**END RECOVERY**

TABLE D-2
SUMMARY OF MANUAL DATA DURING CONSTANT-RATE PUMPING TEST WITH TW12-1

Date 2012	Clock Time (h:m:s)	Elapsed Time, t (min)	Water Levels				Pumping Rate			Comments
			Depth bTOC		Drawdown					
			(ft)	(m)	(ft)	(m)	(USgpm)	(Igpm)	(L/s)	
17-Jan	**14:30**	0	116.72	35.576	0.000	0.000				**STATIC**
		0.5	123.00	37.490	6.280	1.914				WATER AT ORIFICE
		1	123.01	37.493	6.290	1.917				WATER BROWN
		1.5	123.08	37.515	6.360	1.939	565	471	35.6	
		2	123.19	37.548	6.470	1.972				
		2.5	123.13	37.530	6.410	1.954	565	471	35.6	
		3	123.19	37.548	6.470	1.972				
		3.5	123.21	37.554	6.490	1.978				
		4	123.25	37.567	6.530	1.990	565	471	35.6	
		4.5	123.28	37.576	6.560	1.999				
	14:35	5	123.23	37.561	6.510	1.984	550	458	34.7	CHECK ORIFICE
		6	123.23	37.561	6.510	1.984				WATER FROZEN IN PIZO.
		7								
		8	123.23	37.561	6.510	1.984				FIX PIZO. TUBE
		9	123.27	37.573	6.550	1.996				
	14:40	10	123.21	37.554	6.490	1.978				
		12	123.18	37.545	6.460	1.969	575	479	36.2	ADJUST VALVE DOWN
		14	123.18	37.545	6.460	1.969				PIZO TUBE FROZEN
		16	123.20	37.551	6.480	1.975				CLEAN OUT
		18	123.09	37.518	6.370	1.942				
	14:50	20	122.91	37.463	6.190	1.887	530	442	33.4	20.5 IN. AT ORIFICE
		25	123.00	37.490	6.280	1.914				
	15:01	31	123.00	37.490	6.280	1.914	527	439	33.2	18.5 IN. AT ORIFICE
		35	122.95	37.475	6.230	1.899	529	441	33.3	18 IN. AT ORIFICE
	15:10	40	122.95	37.475	6.230	1.899	529	441	33.3	
	15:20	50	122.95	37.475	6.230	1.899	527	439	33.2	
	15:30	60	123.03	37.500	6.310	1.923	525	437	33.1	18 IN. AT ORIFICE
	15:40	70	123.05	37.506	6.330	1.929	526	438	33.1	
	15:50	80	123.05	37.506	6.330	1.929	527	439	33.2	18 IN. AT ORIFICE
	15:60	90	123.09	37.518	6.370	1.942	524	437	33.0	
	16:10	100	123.10	37.521	6.380	1.945	525	437	33.1	18 IN. AT ORIFICE
	16:30	120	123.12	37.527	6.400	1.951	526	438	33.1	
	16:50	140	123.10	37.521	6.380	1.945	526	438	33.1	
	17:10	160	123.10	37.521	6.380	1.945	526	438	33.1	18 IN. AT ORIFICE
	17:30	180	123.15	37.536	6.430	1.960				PH 8.95, EC 1003, TDS 498 PPM
	17:50	200	123.20	37.551	6.480	1.975	525	437	33.1	SNOWING, COLD OUT,
	18:40	250	123.15	37.536	6.430	1.960				WATER NOT POOLING ANYWERE
	19:30	300	123.28	37.576	6.560	1.999	526	438	33.1	WATER SAMPLE TAKEN
	20:20	350	123.31	37.585	6.590	2.009				TDS 2000 PPM, PH 8.86, EC 3999, TEMP 1.2ºC
	21:10	400	123.30	37.582	6.580	2.006	524	437	33.0	
	22:00	450	123.31	37.585	6.590	2.009				TDS 1343, PH 9.00, EC 2322, TEMP 0.2ºC
	22:50	500	123.30	37.582	6.580	2.006	525	437	33.1	
	23:40	550	123.31	37.585	6.590	2.009	525	437	33.1	WATER SAMPLE #2
18-Jan	0:30	600	123.32	37.588	6.600	2.012	524	437	33.0	**18-Jan-12**
	1:20	650	123.33	37.591	6.610	2.015	524	437	33.0	TDS 1658, PH 9.12, EC 2638, TEMP. 0.9ºC
	2:10	700	123.35	37.597	6.630	2.021				
	3:00	750	123.40	37.612	6.680	2.036	526	438	33.1	TDS 847, PH 9.05, EC 1942, TEMP 1.3ºC
	3:50	800	123.42	37.618	6.700	2.042	525	437	33.1	
	4:40	850	123.42	37.618	6.700	2.042	525	437	33.1	TDS 836, PH 9.13, EC 1389, TEMP 2.7ºC
	5:30	900	123.39	37.609	6.670	2.033	524	437	33.0	WATER SAMPLE #3
	6:20	950	123.42	37.618	6.700	2.042	524	437	33.0	TDS 1061, PH 8.5, ECD 1681, TEMP 2.7ºC
	7:10	1000	123.38	37.606	6.660	2.030	526	438	33.1	
	8:00	1050	123.38	37.606	6.660	2.030	528	440	33.3	18 IN. AT ORIFICE - SNOWING
	8:50	1100	123.37	37.603	6.650	2.027	526	438	33.1	TDS 1051, PH 8.65, EC 1545, TEMP 2.4ºC
	9:40	1150	123.35	37.597	6.630	2.021	524	437	33.0	WATER SAMPLE #3
	10:30	1200	123.36	37.600	6.640	2.024	525	437	33.1	TDS 442, PH 7.55, EC 801, TEMP 0.7ºC
	11:20	1250	123.40	37.612	6.680	2.036	526	438	33.1	ALS WATER SAMPLES
	12:10	1300	123.36	37.600	6.640	2.024	524	437	33.0	TDS 80, PH 8.96, EC 225, TEMP 0.8
	13:00	1350	123.35	37.597	6.630	2.021	526	438	33.1	18 IN. AT ORIFICE
	13:50	1400	123.42	37.618	6.700	2.042	524	437	33.0	
	14:30	1440	123.36	37.600	6.640	2.024				

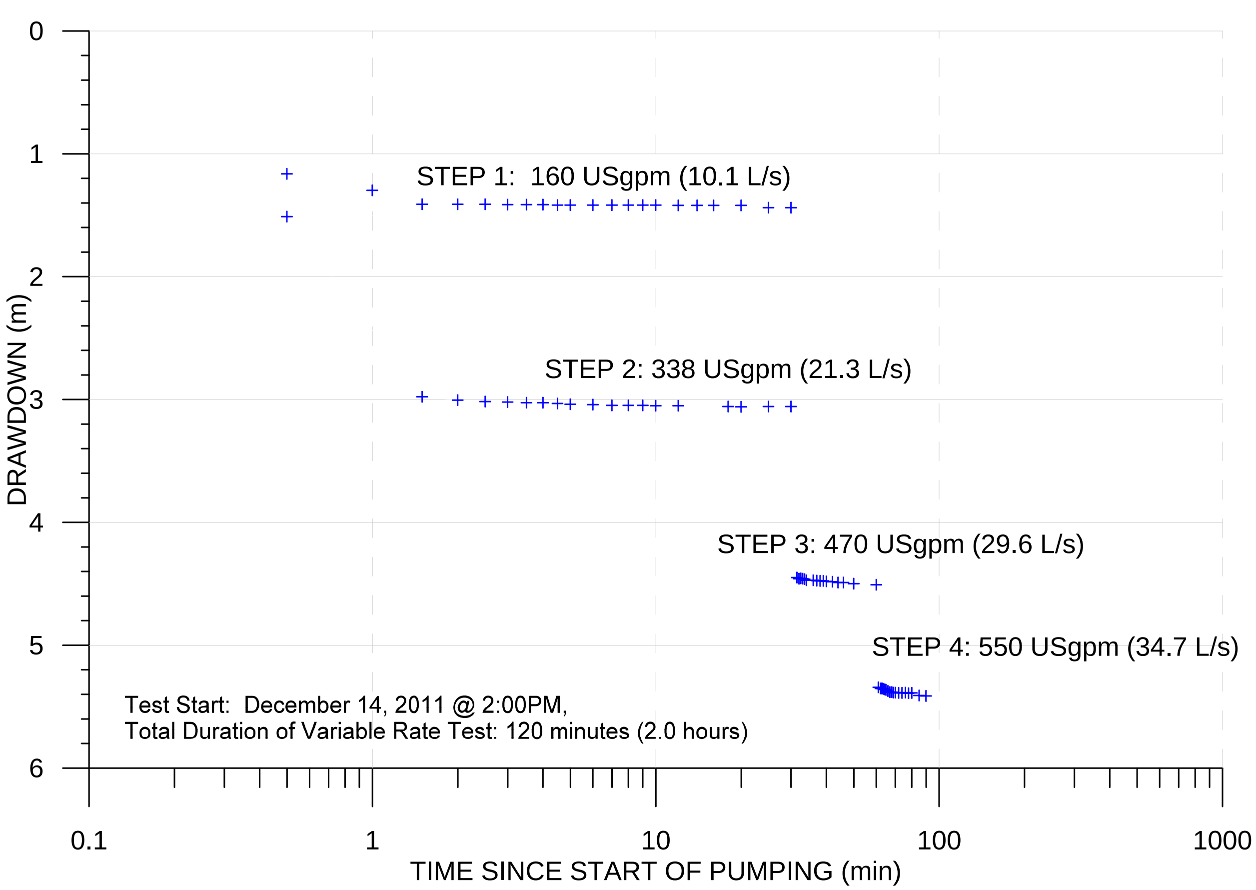
TABLE D-2
SUMMARY OF MANUAL DATA DURING CONSTANT-RATE PUMPING TEST WITH TW12-1

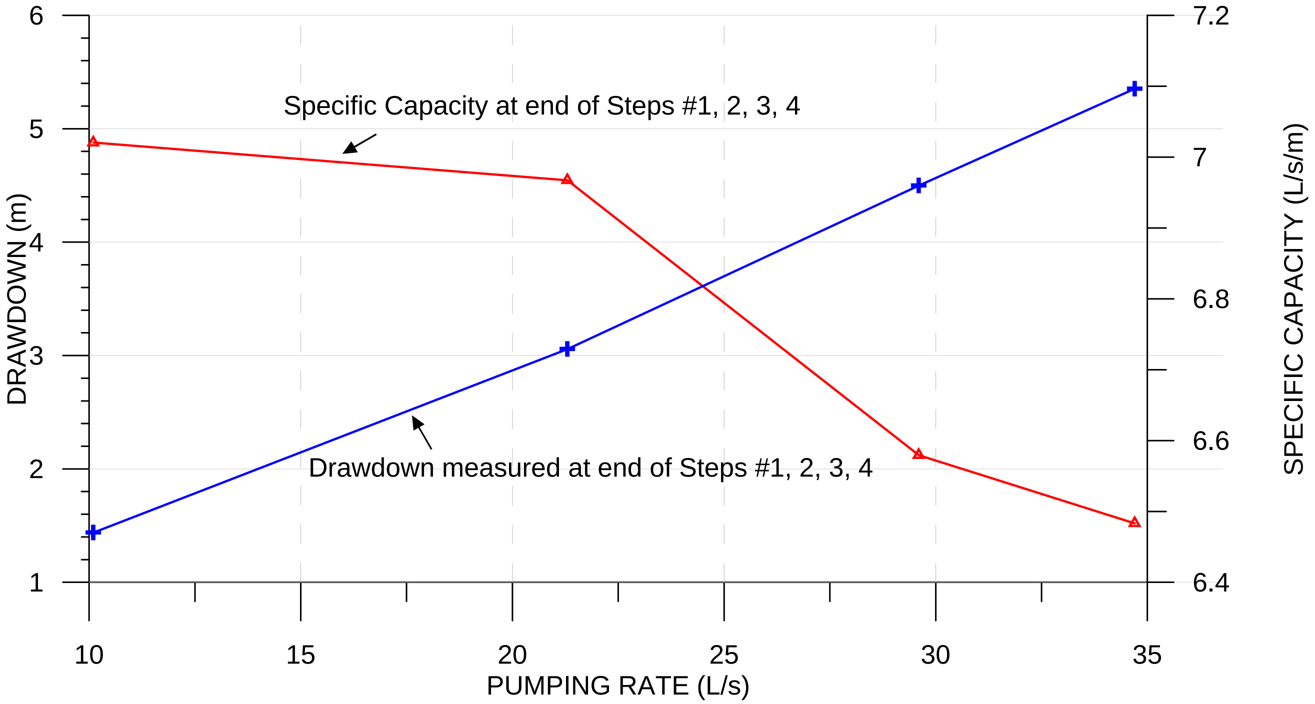
Date 2012	Clock Time (h:m:s)	Elapsed Time, t (min)	Water Levels				Pumping Rate			Comments
			Depth bTOC		Drawdown					
			(ft)	(m)	(ft)	(m)	(USgpm)	(Igpm)	(L/s)	
										RECOVERY
		1440.5	117.35	35.768	0.630	0.192	0	0	0.0	
		1441	117.30	35.753	0.580	0.177				
		1441.5	117.29	35.750	0.570	0.174				
		1442	117.27	35.744	0.550	0.168				
		1442.5	117.25	35.738	0.530	0.162				
		1443	117.22	35.729	0.500	0.152				
		1443.5	117.21	35.726	0.490	0.149				
		1444	117.20	35.723	0.480	0.146				
		1444.5	117.19	35.720	0.470	0.143				
	14:35	1445	117.18	35.716	0.460	0.140				
		1446	117.17	35.713	0.450	0.137				
		1447	117.15	35.707	0.430	0.131				
		1448	117.17	35.713	0.450	0.137				
		1449	117.16	35.710	0.440	0.134				
	14:40	1450	117.15	35.707	0.430	0.131				
		1452	117.13	35.701	0.410	0.125				
		1454	117.12	35.698	0.400	0.122				
		1456	117.10	35.692	0.380	0.116				
		1458	117.09	35.689	0.370	0.113				
	14:50	1460	117.08	35.686	0.360	0.110				
		1465	117.06	35.680	0.340	0.104				
	15:00	1470	117.05	35.677	0.330	0.101				
		1475	117.04	35.674	0.320	0.098				
	15:10	1480	117.02	35.668	0.300	0.091				
	15:20	1490	117.00	35.662	0.280	0.085				
	15:30	1500	116.99	35.659	0.270	0.082				
	15:40	1510	116.97	35.652	0.250	0.076				
	15:55	1525	116.96	35.649	0.240	0.073				
	16:10	1540	116.95	35.646	0.230	0.070				
	16:30	1560	116.95	35.646	0.230	0.070				END RECOVERY

APPENDIX E

GRAPHICAL ANALYSIS OF VARIABLE- AND CONSTANT-RATE TESTS WITH TW11-1

H:\Project\3131\Pumping Tests\BurnsRd\TW11-1 STEP TEST.grf





DISTRICT OF MISSION

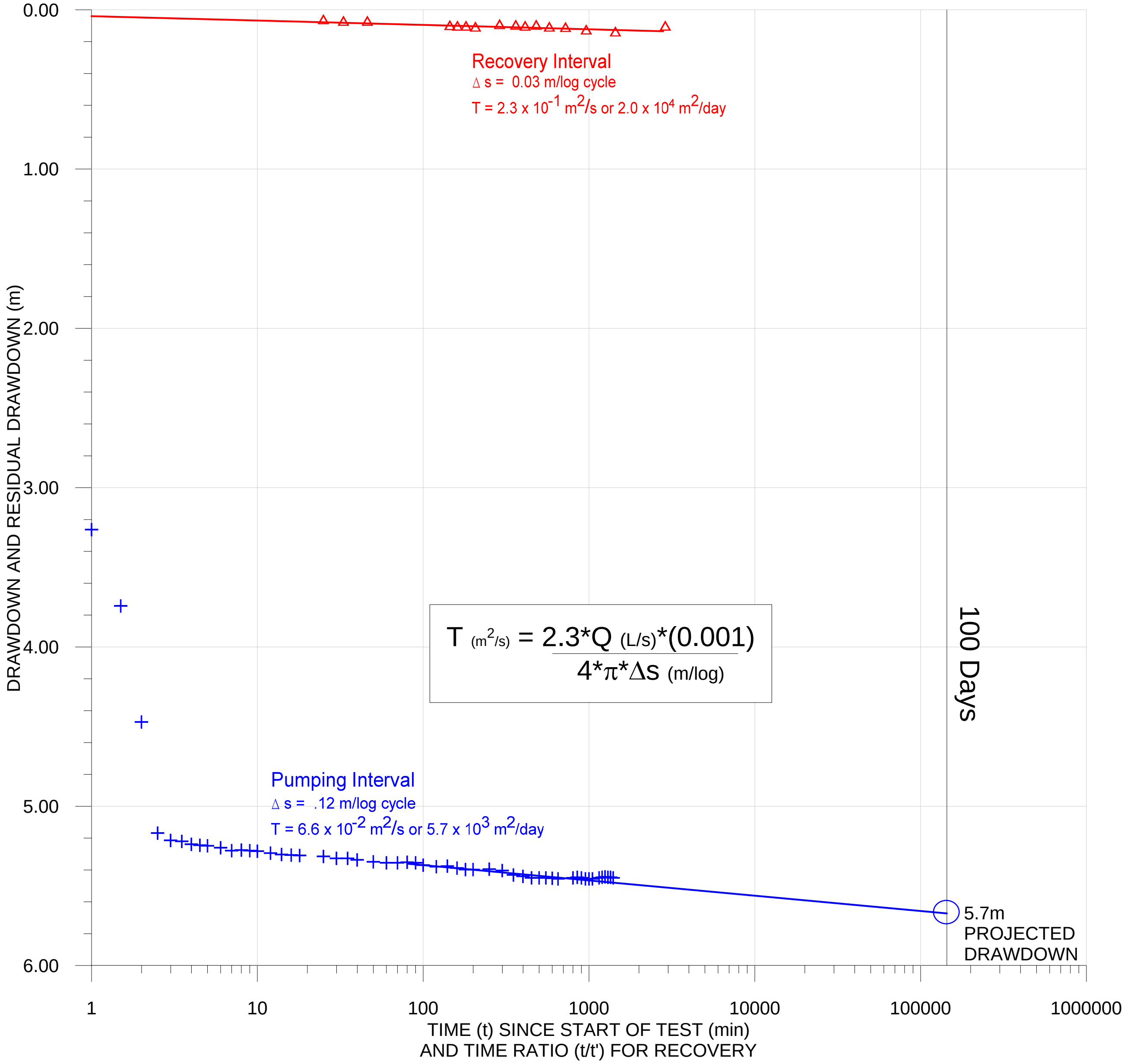
PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, BC

DRAWDOWN IN PUMPED
WELL DURING VARIABLE-
RATE TEST WITH TW11-1

BY: RS
DATE: MAR 12
APPROVED:
FIG: E-1

H:\Project\3131\Pumping Tests\BurnsRd\TW11-1 CONSTANT RATE.grf



Test Start: Dec 15, 2012 @ 11:30am
Test Duration: 24 hours (1440 mins)
Test Pumping Rate: 34.7 L/s (550 USgpm)
Pre-test Static Water Level: 25.3 m BTOC
Distance from Top of Screen to Static Water Level = 29 m

Note: t/t' is the total elapsed time since pumping started (t)
divided by the time allowed for recovery once pumping has stopped (t')

DISTRICT OF MISSION

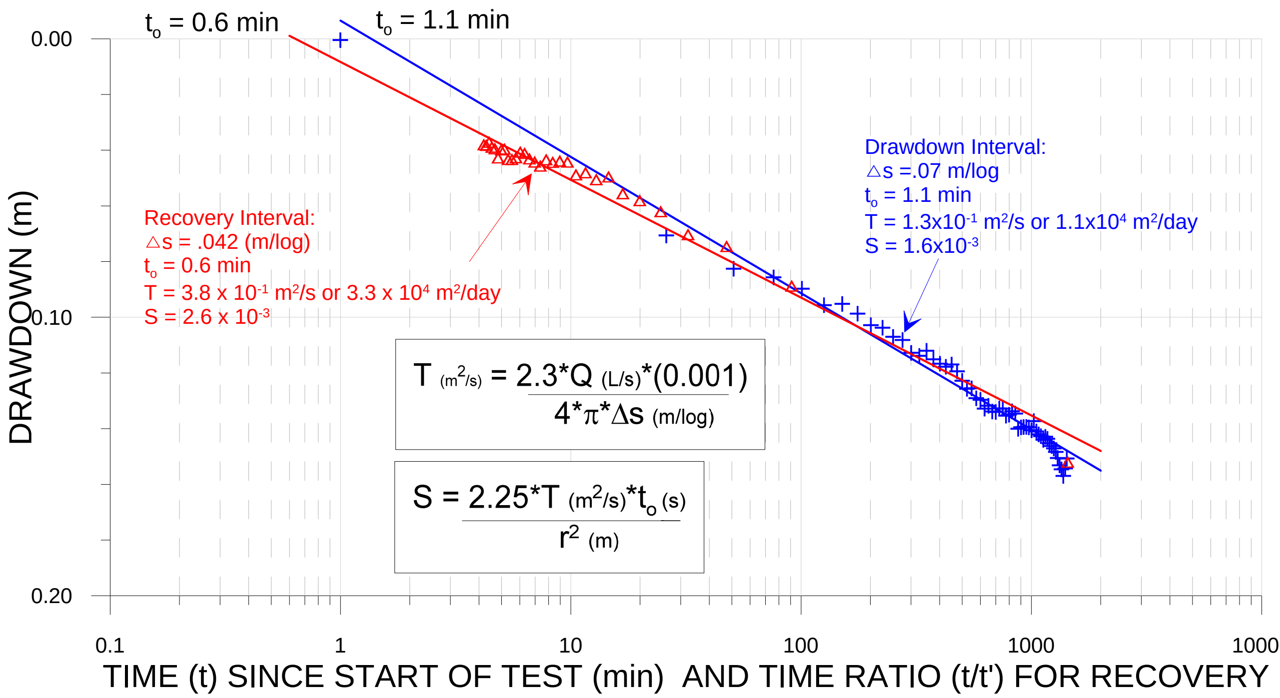
PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, BC

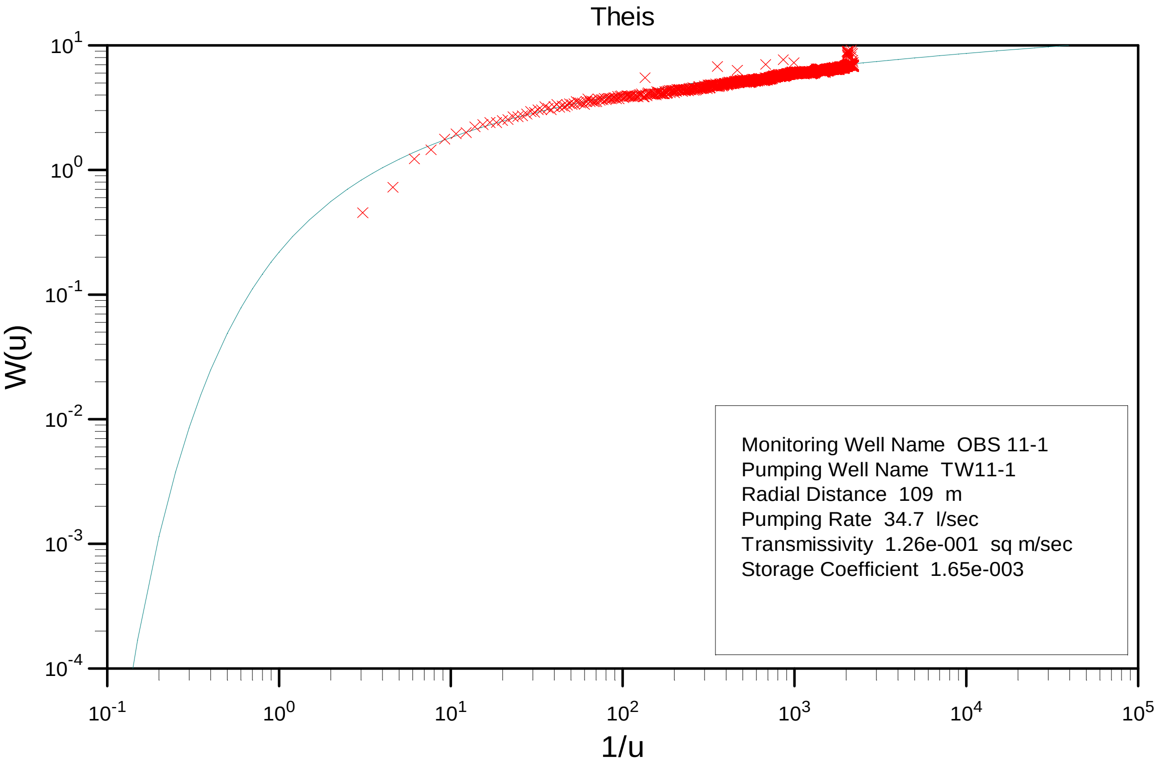
DRAWDOWN IN PUMPED
WELL DURING CONSTANT-
RATE TEST WITH TW11-1

BY: RS
DATE: MAR 12
APPROVED:
FIG: E-2

H:\Project\3131\Pumping Tests\BurnsRd\OBS11-1 DRAWDOWN ANALYSIS.grf



Test Start: Dec 15, 2012 @ 11:30am
Test Duration: 24 hours (1440 mins)
Test Pumping Rate: 34.7 L/s (550 USgpm)



Monitoring Well Name OBS 11-1
Pumping Well Name TW11-1
Radial Distance 109 m
Pumping Rate 34.7 l/sec
Transmissivity 1.26e-001 sq m/sec
Storage Coefficient 1.65e-003

DISTRICT OF MISSION

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GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, BC

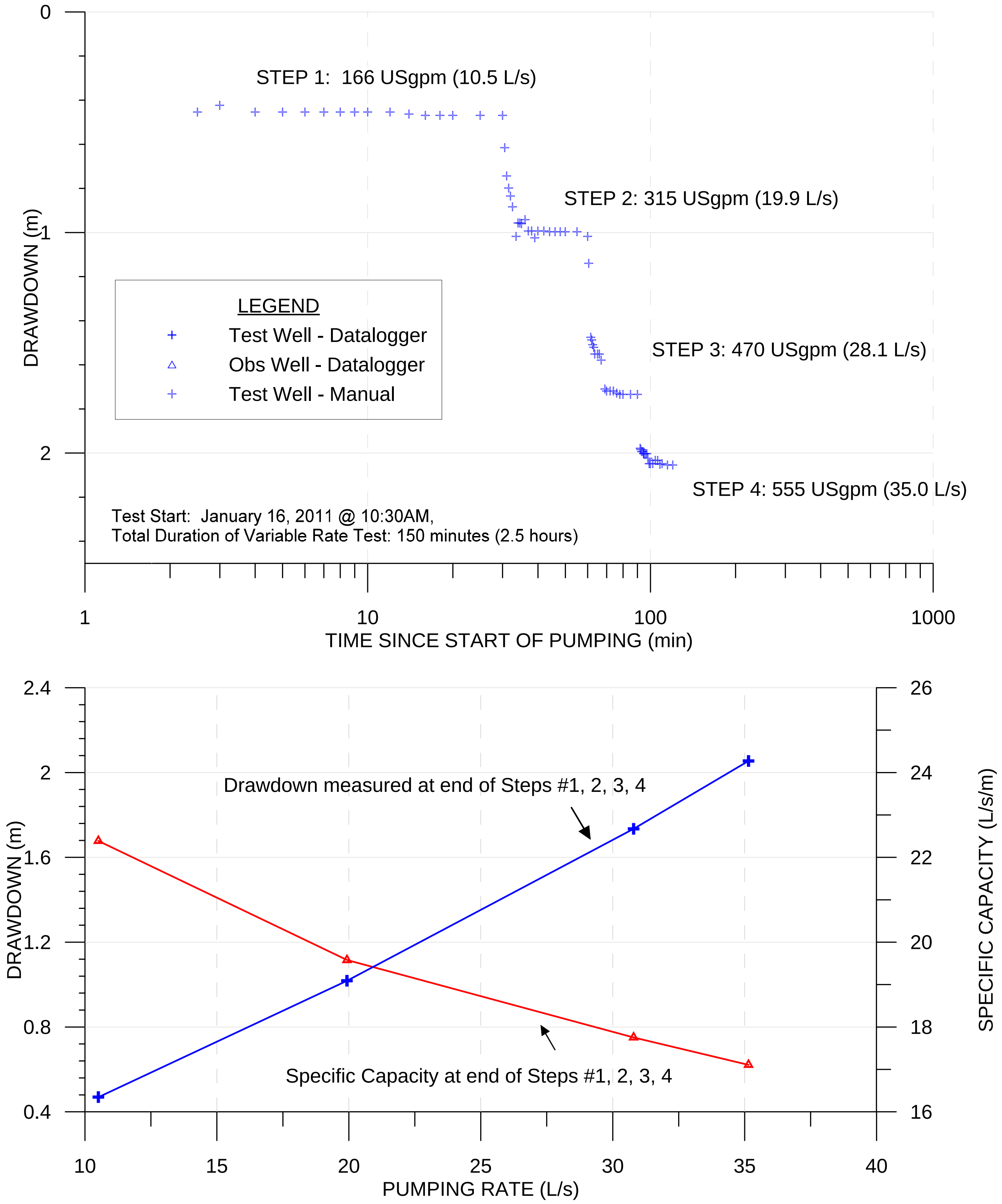
DRAWDOWN IN OBS11-1
DURING CONSTANT-
RATE TEST WITH TW11-1

BY: RS
DATE: MAR 12
APPROVED:
FIG: E-3

APPENDIX F

GRAPHICAL ANALYSIS OF VARIABLE- AND CONSTANT-RATE TESTS WITH TW12-1

H:\Project\3131\Pumping Tests\StaveLkRd\TW12-1 STEP TEST.grf



DISTRICT OF MISSION

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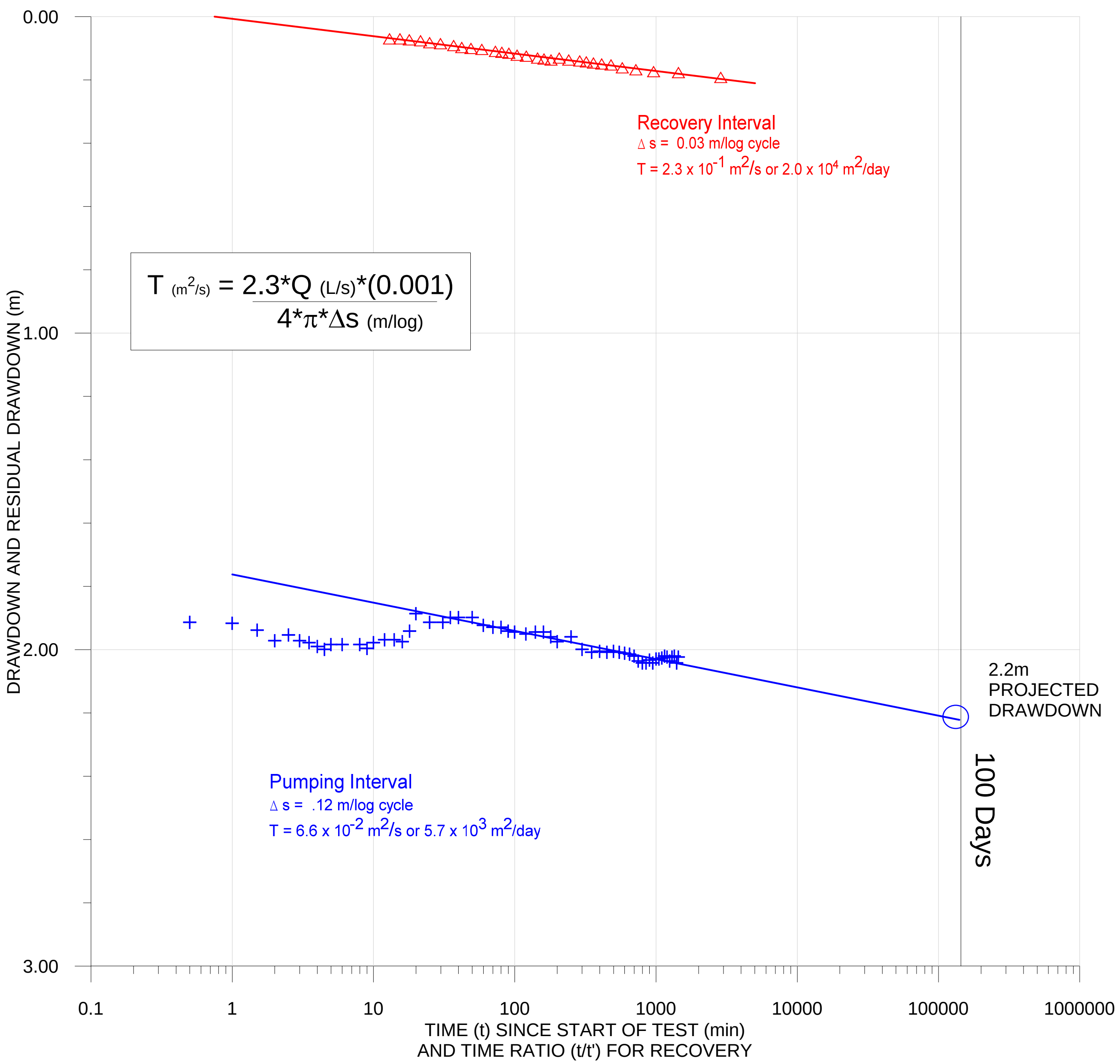
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, BC

DRAWDOWN IN PUMPING
WELL DURING VARIABLE-
RATE TEST WITH TW12-1

BY: MLS
DATE: MAR 12
APPROVED:
FIG: F-1

H:\Project\3131\Pumping Tests\StaveLkRd\TW12-1 CONSTANT RATE.grf



Test Start: Jan 17, 2012 @ 14:30pm
Test Duration: 24 hours (1440 mins)
Test Pumping Rate: 33.1 L/s (526 USgpm)
Pre-test Static Water Level: 35.6 m BTOC
Distance from Top of Screen to Static Water Level = 36.1 m

Note: t/t' is the total elapsed time since pumping started (t)
divided by the time allowed for recovery once pumping has stopped (t')

DISTRICT OF MISSION

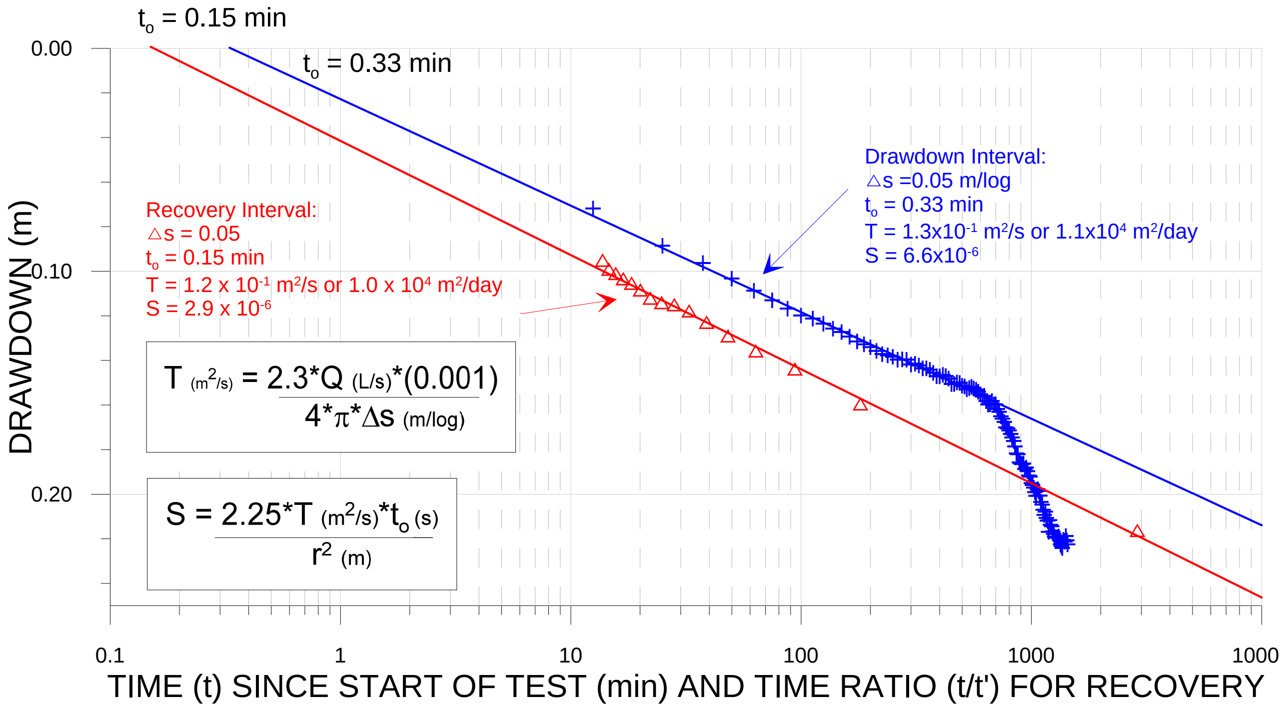
PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

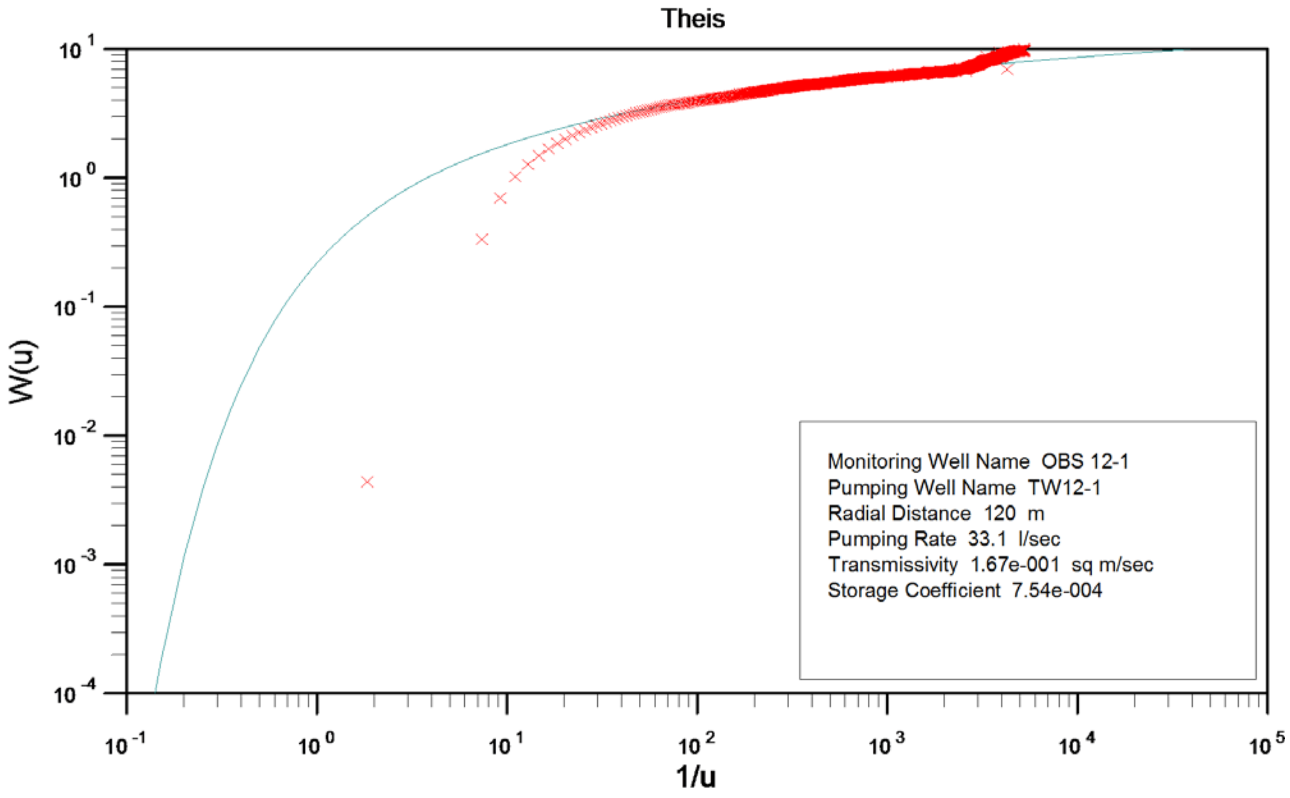
HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, BC

DRAWDOWN IN PUMPING
WELL DURING CONSTANT-
RATE TEST WITH TW12-1

BY: MLS
DATE: MAR 12
APPROVED:
FIG: F-2

H:\Project\3131\Pumping Tests\Stave Lk Rd\OBS12-1 CONSTANT RATE.grf





Monitoring Well Name OBS 12-1
Pumping Well Name TW12-1
Radial Distance 120 m
Pumping Rate 33.1 l/sec
Transmissivity 1.67e-001 sq m/sec
Storage Coefficient 7.54e-004

DISTRICT OF MISSION

PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS

HYDROGEOLOGICAL ASSESSMENT
FOR WATER SUPPLY,
MIRACLE VALLEY, MISSION, BC

DRAWDOWN IN OBS12-1
DURING CONSTANT-RATE
TEST WITH TW12-1

BY: MLS
DATE: MAR 12
APPROVED:
FIG: F-3

APPENDIX G

LABORATORY ANALYSES REPORTS

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

Date Received: 15-DEC-11
Report Date: 23-DEC-11 15:09 (MT)
Version: FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #: L1096345

Project P.O. #: NOT SUBMITTED
Job Reference: 3131
C of C Numbers:
Legal Site Desc:

Mack

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1096345-1				
	Description	WATER				
	Sampled Date	14-DEC-11				
	Sampled Time	11:45				
	Client ID	LANG RESIDENCE				
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	<5.0				
	Conductivity (uS/cm)	58.8				
	Hardness (as CaCO3) (mg/L)	23.8				
	pH (pH)	7.51				
	Total Dissolved Solids (mg/L)	44				
	Turbidity (NTU)	1.12				
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	23.3				
	Chloride (Cl) (mg/L)	1.21				
	Fluoride (F) (mg/L)	<0.020				
	Nitrate (as N) (mg/L)	0.613				
	Nitrite (as N) (mg/L)	<0.0010				
	Sulfate (SO4) (mg/L)	2.39				
Total Metals	Aluminum (Al)-Total (mg/L)	<0.010				
	Antimony (Sb)-Total (mg/L)	<0.00050				
	Arsenic (As)-Total (mg/L)	0.00010				
	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)	7.76				
	Chromium (Cr)-Total (mg/L)	<0.0020				
	Copper (Cu)-Total (mg/L)	0.0064				
	Iron (Fe)-Total (mg/L)	0.197				
	Lead (Pb)-Total (mg/L)	<0.00050				
	Magnesium (Mg)-Total (mg/L)	1.07				
	Manganese (Mn)-Total (mg/L)	0.0089				
	Mercury (Hg)-Total (mg/L)	<0.00020				
	Potassium (K)-Total (mg/L)	0.38				
	Selenium (Se)-Total (mg/L)	<0.0010				
	Sodium (Na)-Total (mg/L)	<2.0				
	Uranium (U)-Total (mg/L)	<0.00010				
	Zinc (Zn)-Total (mg/L)	<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	Chloride (Cl)	DLM	L1096345-1
Duplicate	Fluoride (F)	DLM	L1096345-1
Duplicate	Nitrite (as N)	DLM	L1096345-1
Matrix Spike	Mercury (Hg)-Total	MS-B	L1096345-1

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)	APHA 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-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-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).

Reference Information

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:

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.

Request Form

COC #

Page 1 of

L1096345-COFC

Report To

Company: Piteau Associates Engineering Ltd.
Contact: Kathy Tixier
Address: 215-260 West Esplanade

Phone: 604-986-8551 Fax: 604-985-7286

☑ Standard ☐ Other
☑ PDF ☑ Excel ☐ Digital ☐ Fax
Email 1: ktixier@piteau.com
Email 2:
Email 3:

Service Requested (Rush for routine analysis subject to availability)
● Regular (Standard Turnaround Times - Business Days)
○ Priority (2-4 Business Days) - 50% Surcharge - Contact ALS to Confirm TAT
○ Emergency (1-2 Bus. Days) - 100% Surcharge - Contact ALS to Confirm TAT
○ Same Day or Weekend Emergency - Contact ALS to Confirm TAT

Invoice To Same as Report ? ☑ Yes ☐ No
Hardcopy of Invoice with Report? ☑ Yes ☐ No
Company:
Contact:
Address:
Phone: Fax:

Client / Project Information
Job #: 3131
PO / AFE:
LSD:

Quote #:

Lab Work Order # (lab use only) L1096345

ALS Contact:
Sampler:

Analysis Request

Please indicate below Filtered, Preserved or both (F, P, F/P)

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	FULL Potability Package	Total metals (p)	General
	Lang Residence	14-Dec-11	11:45	water	x	x	x

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

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 provided on a separate Excel tab.
Also provided on another Excel tab are the ALS location addresses, phone numbers and sample container / preservation / holding time table for common analyses.

SHIPMENT RELEASE (client use)
Released by: KT
Date (dd-mmm-yy): 15-DEC-11
Time (hh-mm): 11:00 am.

SHIPMENT RECEPTION (lab use only)
Received by: HD
Date: 15-Dec-11
Time: 16:50
Temperature: 9 °C

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

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

Date Received: 08-DEC-11
Report Date: 14-DEC-11 15:38 (MT)
Version: FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #: L1093778

Project P.O. #: NOT SUBMITTED
Job Reference: 3131
C of C Numbers: 10-195225
Legal Site Desc:

B J Mack

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1093778-1				
	Description	WATER				
	Sampled Date	08-DEC-11				
	Sampled Time	12:00				
	Client ID	W255				
Grouping	**Analyte**					
WATER						
Physical Tests	Hardness (as CaCO3) (mg/L)	75.7				
Total Metals	Aluminum (Al)-Total (mg/L)	191				
	Antimony (Sb)-Total (mg/L)	<0.010 DLA				
	Arsenic (As)-Total (mg/L)	0.092				
	Barium (Ba)-Total (mg/L)	1.27				
	Beryllium (Be)-Total (mg/L)	<0.0050				
	Boron (B)-Total (mg/L)	<0.10				
	Cadmium (Cd)-Total (mg/L)	0.0058				
	Calcium (Ca)-Total (mg/L)	153				
	Chromium (Cr)-Total (mg/L)	0.388				
	Cobalt (Co)-Total (mg/L)	0.190				
	Copper (Cu)-Total (mg/L)	0.735				
	Iron (Fe)-Total (mg/L)	300				
	Lead (Pb)-Total (mg/L)	0.125				
	Lithium (Li)-Total (mg/L)	0.118				
	Magnesium (Mg)-Total (mg/L)	129				
	Manganese (Mn)-Total (mg/L)	6.62				
	Mercury (Hg)-Total (mg/L)	0.00046				
	Molybdenum (Mo)-Total (mg/L)	0.029				
	Nickel (Ni)-Total (mg/L)	0.62				
	Selenium (Se)-Total (mg/L)	<0.020 DLA				
	Silver (Ag)-Total (mg/L)	0.0016				
	Sodium (Na)-Total (mg/L)	19.7				
	Thallium (Tl)-Total (mg/L)	<0.0040 DLA				
	Titanium (Ti)-Total (mg/L)	10.2				
	Uranium (U)-Total (mg/L)	0.0067				
	Vanadium (V)-Total (mg/L)	0.528				
	Zinc (Zn)-Total (mg/L)	0.663				
Dissolved Metals	Aluminum (Al)-Dissolved (mg/L)	0.174				
	Antimony (Sb)-Dissolved (mg/L)	0.00705				
	Arsenic (As)-Dissolved (mg/L)	0.0051				
	Barium (Ba)-Dissolved (mg/L)	0.021				
	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)	23.0				
	Chromium (Cr)-Dissolved (mg/L)	<0.00050				

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

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1093778-1
	Description	WATER
	Sampled Date	08-DEC-11
	Sampled Time	12:00
	Client ID	W255
Grouping	**Analyte**	
WATER		
Dissolved Metals	Cobalt (Co)-Dissolved (mg/L)	<0.00050
	Copper (Cu)-Dissolved (mg/L)	0.0010
	Iron (Fe)-Dissolved (mg/L)	0.105
	Lead (Pb)-Dissolved (mg/L)	<0.0010
	Lithium (Li)-Dissolved (mg/L)	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	4.41
	Manganese (Mn)-Dissolved (mg/L)	0.039
	Mercury (Hg)-Dissolved (mg/L)	<0.00020
	Molybdenum (Mo)-Dissolved (mg/L)	0.0142
	Nickel (Ni)-Dissolved (mg/L)	0.0075
	Selenium (Se)-Dissolved (mg/L)	0.0012
	Silver (Ag)-Dissolved (mg/L)	<0.000050
	Sodium (Na)-Dissolved (mg/L)	6.1
	Thallium (Tl)-Dissolved (mg/L)	<0.00020
	Titanium (Ti)-Dissolved (mg/L)	<0.050
	Uranium (U)-Dissolved (mg/L)	0.00054
	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 Individual Parameters Listed:

Qualifier	Description
DLA	Detection Limit Adjusted For required dilution

Test Method References:

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 CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

ALS Test Code	Matrix	Test Description	Method Reference**
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).

ALS Test Code	Matrix	Test Description	Method Reference**
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).

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**
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).

ALS Test Code	Matrix	Test Description	Method Reference**
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).

ALS Test Code	Matrix	Test Description	Method Reference**
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).

** 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:

10-195225

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- 195225

ALS Environmental

L1093778-COFC

Page 1 of 1

Report To	**Report Format / Distribution**
Company: Piteau Associates	Standard: ✓ Other (specify):
Contact: Kathy Tixtier	Select: PDF ✓ Excel Digital Fax
Address: 215 - 360 Esplanade ave	Email 1: rsegovia@piteau.com
N. Vancouver BC	Email 2: ktixtier@piteau.com
Phone: 604 986-8551 Fax:	
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 #: 3131
Company:	PO / AFE:
Contact:	LSD:
Address:	
Phone: Fax:	Quote #:
Lab Work Order # (lab use only) L1093778	**ALS Contact:** Brent M. **Sampler:** Ricardo

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

No (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**	Dissolved & Total METALS												Number of Containers
	W255	08-DEC-11	12:00	Water	✓												

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

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: R. Segovia	Date: DEC 8/11	Time: 2:30pm	Received by: BP	Date: Dec. 8/11	Time: 14:36	Temperature: 12.8 °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:	16-DEC-11
Report Date:	28-DEC-11 15:26 (MT)
Version:	FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #:	**L1096762**
Project P.O. #:	NOT SUBMITTED
Job Reference:	3131
C of C Numbers:	10-196045
Legal Site Desc:	

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1096762-1
	Description	WATER
	Sampled Date	16-DEC-11
	Sampled Time	12:00
	Client ID	MV2011-1
Grouping	**Analyte**	
WATER		
Physical Tests	UV Absorbance (254 nm) (Abs/cm-1)	<0.0010
	Colour, True (CU)	<5.0
	Conductivity (uS/cm)	122
	Hardness (as CaCO3) (mg/L)	55.6
	pH (pH)	7.72
	Total Dissolved Solids (mg/L)	76
	Turbidity (NTU)	<0.10
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	49.5
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<2.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<2.0
	Alkalinity, Total (as CaCO3) (mg/L)	49.5
	Chloride (Cl) (mg/L)	0.95
	Fluoride (F) (mg/L)	0.031
	Nitrate (as N) (mg/L)	0.204
	Nitrite (as N) (mg/L)	<0.0010
	Sulfate (SO4) (mg/L)	9.41
	Sulphide as S (mg/L)	<0.020
Bacteriological Tests	E. coli (MPN/100mL)	<1
	Coliform Bacteria - Total (MPN/100mL)	<1
Total Metals	Aluminum (Al)-Total (mg/L)	<0.010
	Antimony (Sb)-Total (mg/L)	<0.00050
	Arsenic (As)-Total (mg/L)	0.00090
	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)	16.1
	Chromium (Cr)-Total (mg/L)	<0.0020
	Copper (Cu)-Total (mg/L)	<0.0010
	Iron (Fe)-Total (mg/L)	<0.030
	Lead (Pb)-Total (mg/L)	<0.00050
	Magnesium (Mg)-Total (mg/L)	3.46
	Manganese (Mn)-Total (mg/L)	<0.0020
	Mercury (Hg)-Total (mg/L)	<0.00020
	Potassium (K)-Total (mg/L)	0.83
	Selenium (Se)-Total (mg/L)	<0.0010
	Sodium (Na)-Total (mg/L)	2.5

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1096762-1 WATER 16-DEC-11 12:00 MV2011-1				
Grouping	**Analyte**					
WATER						
Total Metals	Uranium (U)-Total (mg/L)	<0.00010				
	Zinc (Zn)-Total (mg/L)	<0.050				
Dissolved Metals	Aluminum (Al)-Dissolved (mg/L)	<0.010				
	Antimony (Sb)-Dissolved (mg/L)	<0.00050				
	Arsenic (As)-Dissolved (mg/L)	0.00091				
	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)	16.5				
	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)	3.50				
	Manganese (Mn)-Dissolved (mg/L)	<0.0020				
	Mercury (Hg)-Dissolved (mg/L)	<0.00020				
	Potassium (K)-Dissolved (mg/L)	0.81				
	Selenium (Se)-Dissolved (mg/L)	<0.0010				
	Sodium (Na)-Dissolved (mg/L)	2.5				
	Uranium (U)-Dissolved (mg/L)	<0.00010				
	Zinc (Zn)-Dissolved (mg/L)	<0.050				
Volatile Organic Compounds	Benzene (mg/L)	<0.00050				
	Ethylbenzene (mg/L)	<0.00050				
	Methyl t-butyl ether (MTBE) (mg/L)	<0.00050				
	Toluene (mg/L)	<0.00050				
	ortho-Xylene (mg/L)	<0.00050				
	meta- & para-Xylene (mg/L)	<0.00050				
	Xylenes (mg/L)	<0.00075				
	Surrogate: 4-Bromofluorobenzene (SS) (%)	102.7				
	Surrogate: 1,4-Difluorobenzene (SS) (%)	99.5				
Hydrocarbons	EPH10-19 (mg/L)	<0.25				
	EPH19-32 (mg/L)	<0.25				

Reference Information

Test Method References:

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

ALK-SCR-VA — Water — Alkalinity by colour or titration — EPA 310.2 OR APHA 2320

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.
OR
This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

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.

ECOLI-COLI-HLTH-VA — Water — E.coli by Colilert — APHA METHOD 9223

This analysis is carried out using procedures adapted from APHA Method 9223 "Enzyme Substrate Coliform Test". E. coli and Total Coliform are determined simultaneously. The sample is mixed with a mixture hydrolyzable substrates and then sealed in a multi-well packet. The packet is incubated for 18 or 24 hours and then the number of wells exhibiting a positive response are counted. The final result is obtained by comparing the positive responses to a probability table.

EPH-SF-FID-VA — Water — EPH in Water by GCFID — BCMOE EPH GCFID

This analysis is carried out in accordance with the British Columbia Ministry of Environment, Lands and Parks (BCMELP) Analytical Method for Contaminated Sites "Extractable Petroleum Hydrocarbons in Water by GC/FID" (Version 2.1, July 1999). The procedure involves extraction of the entire water sample with dichloromethane. The extract is then solvent exchanged to toluene and analysed by capillary column gas chromatography with flame ionization detection (GC/FID). EPH results include Polycyclic Aromatic Hydrocarbons (PAH) and are therefore not equivalent to Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH).

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 - optical emission spectrophotometry (EPA Method 6010B).

Reference Information

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.

S2-T-COL-VA Water Total Sulphide by Colorimetric APHA 4500-S2 Sulphide

This analysis is carried out using procedures adapted from APHA Method 4500-S2 "Sulphide". Sulphide is determined using the methlyene blue colourimetric method.

TCOLI-COLI-HLTH-VA Water Total coliform by Colilert APHA METHOD 9223

This analysis is carried out using procedures adapted from APHA Method 9223 "Enzyme Substrate Coliform Test". E. coli and Total Coliform are determined simultaneously. The sample is mixed with a mixture hydrolyzable substrates and then sealed in a multi-well packet. The packet is incubated for 18 or 24 hours and then the number of wells exhibiting a positive response are counted. The final result is quantified by a statistical estimation of bacteria density (most probable number).

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.

UV-ABS-VA Water UV Absorbance by Spectrometry APHA 5910B UV ABSORPTION METHOD

This analysis is carried out using procedures adapted from APHA Method 5910B "Ultraviolet Absorption Method" and Method 415.3 "Determination of Total Organic Carbon and Specific UV Absorbance at 254nm in Source Water and Drinking Water", published by the United States Environmental Protection Agency (EPA). The sample is filtered through a 0.45um filter and measured for absorbance in a quartz cell at 254nm and reported as absorbance per cm (i.e. cm-1). The analysis is carried out without pH adjustment. Alternatively, results can be reported as % Transmittance (over one cm) where the absorbance result is converted to % Transmittance by the following calculation: %T = 100(10 to the power of -A).

VOC7-HSMS-VA Water BTEX/MTBE/Styrene by Headspace GCMS EPA8260B, 5021

The water sample, with added reagents, is heated in a sealed vial to equilibrium. The headspace from the vial is transfered into a gas chromatograph. Target compound concentrations are measured using mass spectrometry detection.

VOC7/VOC-SURR-MS-VA Water VOC7 and/or VOC Surrogates for Waters EPA8260B, 5021

XYLENES-CALC-VA Water Sum of Xylene Isomer Concentrations CALCULATION

Calculation of Total Xylenes

Total Xylenes is the sum of the concentrations of the ortho, meta, and para Xylene isomers. Results below detection limit (DL) are treated as zero. The DL for Total Xylenes is set to a value no less than the square root of the sum of the squares of the DLs of the individual Xylenes.

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

Reference Information

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:

10-196045

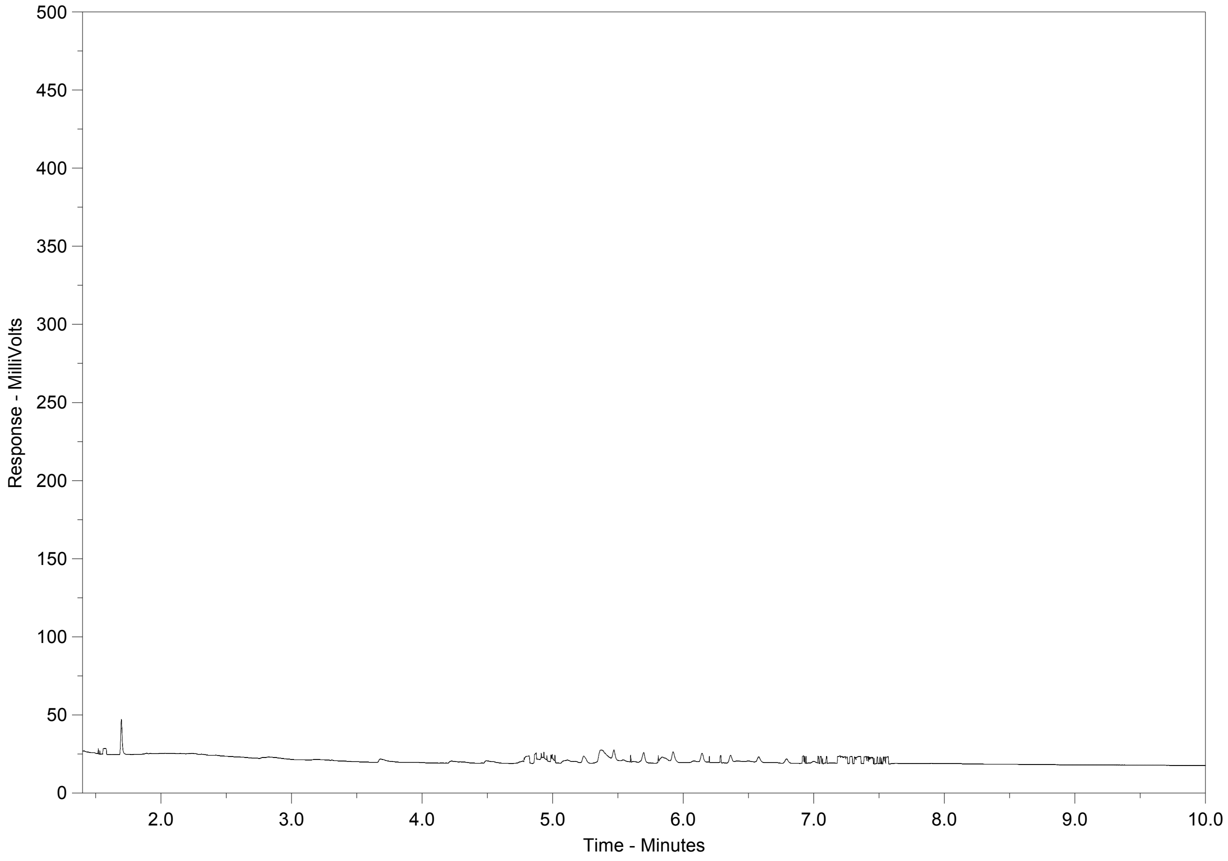
GLOSSARY OF REPORT TERMS

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.

Hydrocarbon Distribution Report

ALS Sample ID: L1096762-1
Client Sample ID: MV2011-1



nC10	nC19	nC32
174°C 346°F	330°C 626°F	467°C 873°F

←— Gasoline —→ ←———— Motor Oils / Lube Oils / Grease ————→
←———— Diesel / Jet Fuels ————→

The EPH Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample. For further interpretation, a current library of reference products is available on www.alsglobal.com or upon request.

The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and three n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at the left.

A "-L-" in the sample ID denotes a low level sample. A "-S-" denotes a silica gel cleaned sample.

10- 196045

ALS Environmental

Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878

www.alsglobal.com

Page ____ of ____

Report To Kathy Tixier
Company: Piteau Associates
Contact: Ricardo Segovia
Address: 215 - 360 W. Esplanade
North Vancouver BC
Phone: 604-986-8551 Fax:

Report Format / Distribution
Standard: ✓ Other (specify):
Select: [✓ PDF] Excel Digital Fax
Email 1: rsegovia@piteau.com
Email 2: ktixier@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 #: 3131
PO / AFE: —
LSD: —
Quote #:

Lab Work Order # (lab use only) L1096762

ALS Contact: BRENT MACK **Sampler:** R S

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	General	Micro Bi	Metals (not Filtered) P	PAH/EPH/LEPH/ HEPH/F2-F4/Acid H	VOC (BTEX)	Sulphide								Number of Containers
	MV2011-1	16-DEC-11	12:00	Water	✓	✓	✓	✓	✓	✓								10

L1096762-COFC

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

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: R. Segovia	Date: Dec 16/11	Time: 3:10 pm	Received by: Dcu	Date: 16 Dec 11	Time: 15.18	Temperature: 5.3 °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

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

Date Received: 06-JAN-12
Report Date: 09-JAN-12 13:26 (MT)
Version: FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #: L1102004

Project P.O. #: NOT SUBMITTED
Job Reference: 03131
C of C Numbers: 10-196263
Legal Site Desc:

B J Mack

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1102004-1				
	Description	WATER				
	Sampled Date	01-JAN-12				
	Sampled Time	15:00				
	Client ID	TW-01-SL-01				
Grouping	**Analyte**					
WATER						
Physical Tests	Total Suspended Solids (mg/L)	34.9				
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.030				
	Manganese (Mn)-Dissolved (mg/L)	0.0361				

Reference Information

Test Method References:

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**
TSS-VA	Water	Total Suspended Solids by Gravimetric	APHA 2540 D - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Suspended Solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

** 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:

10-196263

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.

10-196263

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 Ltd

Contact: Kathy Tixier / Martin Stewart

Address: 215 - 260 West Esplanade,
North Vancouver

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: mstewart@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 #: 03131

PO / AFE:

LSD:

Quote #:

Lab Work Order # (lab use only) L1102004

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	~~TDS~~ TSS	Diss. Fe, Mn											Number of Containers
	TW-01-SL-01	01-Jan-12	3:00	water	✓	✓											

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

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: 08/Jan/12	Time: 16:35	Temperature: 17.1 °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:	18-JAN-12
Report Date:	25-JAN-12 13:24 (MT)
Version:	FINAL

Client Phone: 604-986-8551

Certificate of Analysis

Lab Work Order #:	**L1105481**
Project P.O. #:	NOT SUBMITTED
Job Reference:	3131
C of C Numbers:	10-196227
Legal Site Desc:	

B J Mack

Brent Mack
Account Manager

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

	Sample ID	L1105481-1				
	Description	WATER				
	Sampled Date	18-JAN-12				
	Sampled Time	14:30				
	Client ID	TW12-1				
Grouping	**Analyte**					
WATER						
Physical Tests	Colour, True (CU)	<5.0				
	Conductivity (uS/cm)	64.5				
	Hardness (as CaCO3) (mg/L)	46.3				
	pH (pH)	7.60				
	Total Dissolved Solids (mg/L)	41				
	Turbidity (NTU)	0.23				
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	47.3				
	Chloride (Cl) (mg/L)	0.70				
	Fluoride (F) (mg/L)	0.030				
	Nitrate (as N) (mg/L)	0.0729				
	Nitrite (as N) (mg/L)	<0.0010				
	Sulfate (SO4) (mg/L)	10.7				
	Sulphide as S (mg/L)	<0.0020				
Bacteriological Tests	E. coli (MPN/100mL)	<1				
	Coliform Bacteria - Total (MPN/100mL)	<1				
Total Metals	Aluminum (Al)-Total (mg/L)	<0.010				
	Antimony (Sb)-Total (mg/L)	<0.00050				
	Arsenic (As)-Total (mg/L)	0.00167				
	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)	14.6				
	Chromium (Cr)-Total (mg/L)	<0.0020				
	Copper (Cu)-Total (mg/L)	0.0033				
	Iron (Fe)-Total (mg/L)	<0.030				
	Lead (Pb)-Total (mg/L)	0.0120				
	Magnesium (Mg)-Total (mg/L)	2.45				
	Manganese (Mn)-Total (mg/L)	0.0798				
	Mercury (Hg)-Total (mg/L)	<0.00020				
	Potassium (K)-Total (mg/L)	0.87				
	Selenium (Se)-Total (mg/L)	<0.0010				
	Sodium (Na)-Total (mg/L)	<2.0				
	Uranium (U)-Total (mg/L)	<0.00010				
	Zinc (Zn)-Total (mg/L)	<0.050				
Dissolved Metals	Aluminum (Al)-Dissolved (mg/L)	<0.010				
	Antimony (Sb)-Dissolved (mg/L)	<0.00050				

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1105481-1
	Description	WATER
	Sampled Date	18-JAN-12
	Sampled Time	14:30
	Client ID	TW12-1
Grouping	**Analyte**	
WATER		
Dissolved Metals	Arsenic (As)-Dissolved (mg/L)	0.00181
	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)	14.6
	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)	0.00114
	Magnesium (Mg)-Dissolved (mg/L)	2.38
	Manganese (Mn)-Dissolved (mg/L)	0.0764
	Mercury (Hg)-Dissolved (mg/L)	<0.00020
	Potassium (K)-Dissolved (mg/L)	0.86
	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
Volatile Organic Compounds	Benzene (mg/L)	<0.00050
	Ethylbenzene (mg/L)	<0.00050
	Methyl t-butyl ether (MTBE) (mg/L)	<0.00050
	Styrene (mg/L)	<0.00050
	Toluene (mg/L)	<0.00050
	ortho-Xylene (mg/L)	<0.00050
	meta- & para-Xylene (mg/L)	<0.00050
	Xylenes (mg/L)	<0.00075
	Surrogate: 4-Bromofluorobenzene (SS) (%)	93.9
	Surrogate: 1,4-Difluorobenzene (SS) (%)	99.0
Hydrocarbons	EPH10-19 (mg/L)	<0.25
	EPH19-32 (mg/L)	<0.25
	LEPH (mg/L)	<0.25
	HEPH (mg/L)	<0.25
	Volatile Hydrocarbons (VH6-10) (mg/L)	<0.10
	VPH (C6-C10) (mg/L)	<0.10
	Surrogate: 3,4-Dichlorotoluene (SS) (%)	102.2
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/L)	<0.000050
	Acenaphthylene (mg/L)	<0.000050

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1105481-1				
	Description	WATER				
	Sampled Date	18-JAN-12				
	Sampled Time	14:30				
	Client ID	TW12-1				
Grouping	**Analyte**					
WATER						
Polycyclic Aromatic Hydrocarbons	Acridine (mg/L)	<0.000050				
	Anthracene (mg/L)	<0.000050				
	Benz(a)anthracene (mg/L)	<0.000050				
	Benzo(a)pyrene (mg/L)	<0.000010				
	Benzo(b)fluoranthene (mg/L)	<0.000050				
	Benzo(g,h,i)perylene (mg/L)	<0.000050				
	Benzo(k)fluoranthene (mg/L)	<0.000050				
	Chrysene (mg/L)	<0.000050				
	Dibenz(a,h)anthracene (mg/L)	<0.000050				
	Fluoranthene (mg/L)	<0.000050				
	Fluorene (mg/L)	<0.000050				
	Indeno(1,2,3-c,d)pyrene (mg/L)	<0.000050				
	Naphthalene (mg/L)	<0.000050				
	Phenanthrene (mg/L)	<0.000050				
	Pyrene (mg/L)	<0.000050				
	Quinoline (mg/L)	<0.000050				
	Surrogate: Acenaphthene d10 (%)	93.4				
	Surrogate: Acridine d9 (%)	103.6				
	Surrogate: Chrysene d12 (%)	94.9				
	Surrogate: Naphthalene d8 (%)	93.8				
	Surrogate: Phenanthrene d10 (%)	71.8				

Reference Information

Test Method References:

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

ECOLI-COLI-HLTH-VA	Water	E.coli by Colilert	APHA METHOD 9223

This analysis is carried out using procedures adapted from APHA Method 9223 "Enzyme Substrate Coliform Test". E. coli and Total Coliform are determined simultaneously. The sample is mixed with a mixture hydrolyzable substrates and then sealed in a multi-well packet. The packet is incubated for 18 or 24 hours and then the number of wells exhibiting a positive response are counted. The final result is obtained by comparing the positive responses to a probability table.

EPH-SF-FID-VA	Water	EPH in Water by GCFID	BCMOE EPH GCFID

This analysis is carried out in accordance with the British Columbia Ministry of Environment, Lands and Parks (BCMELP) Analytical Method for Contaminated Sites "Extractable Petroleum Hydrocarbons in Water by GC/FID" (Version 2.1, July 1999). The procedure involves extraction of the entire water sample with dichloromethane. The extract is then solvent exchanged to toluene and analysed by capillary column gas chromatography with flame ionization detection (GC/FID). EPH results include Polycyclic Aromatic Hydrocarbons (PAH) and are therefore not equivalent to Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH).

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).

LEPH/HEPH-CALC-VA	Water	LEPHs and HEPHs	BC MOE LABORATORY MANUAL (2005)

Light and Heavy Extractable Petroleum Hydrocarbons in water. These results are determined according to the British Columbia Ministry of Environment, Lands, and Parks Analytical Method for Contaminated Sites "Calculation of Light and Heavy Extractable Petroleum Hydrocarbons in Solids or Water". According to this method, LEPH and HEPH are calculated by subtracting selected Polycyclic Aromatic Hydrocarbon results from Extractable Petroleum Hydrocarbon results. To calculate LEPH, the individual results for Acenaphthene, Acridine, Anthracene, Fluorene, Naphthalene and Phenanthrene are subtracted from EPH(C10-19). To calculate HEPH, the individual results for Benz(a)anthracene, Benzo(a)pyrene, Fluoranthene, and Pyrene are subtracted from EPH(C19-32). Analysis of Extractable Petroleum Hydrocarbons adheres to all prescribed elements of the BCMELP method "Extractable Petroleum Hydrocarbons in Water by GC/FID" (Version 2.1, July 20, 1999).

Reference Information

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). 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).

PAH-SF-MS-VA Water PAH in Water by GCMS EPA 3510, 8270

The entire water sample is extracted with dichloromethane, prior to analysis by gas chromatography with mass spectrometric detection (GC/MS). Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

PAH-SURR-MS-VA Water PAH Surrogates for Waters EPA 3510, 8270

Analysed as per the corresponding PAH test method. Known quantities of surrogate compounds are added prior to analysis to each sample to demonstrate analytical accuracy.

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.

S2-L-T-COL-VA Water Total Sulphide Low Level by Colorimetric APHA 4500-S2 Sulphide

This analysis is carried out using procedures adapted from APHA Method 4500-S2 "Sulphide". Sulphide is determined using the methlyene blue colourimetric method.

TCOLI-COLI-HLTH-VA Water Total coliform by Colilert APHA METHOD 9223

This analysis is carried out using procedures adapted from APHA Method 9223 "Enzyme Substrate Coliform Test". E. coli and Total Coliform are determined simultaneously. The sample is mixed with a mixture hydrolyzable substrates and then sealed in a multi-well packet. The packet is incubated for 18 or 24 hours and then the number of wells exhibiting a positive response are counted. The final result is quantified by a statistical estimation of bacteria density (most probable number).

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.

VH-HSFID-VA Water VH in Water by Headspace GCFID B.C. MIN. OF ENV. LAB. MAN. (2009)

The water sample, with added reagents, is heated in a sealed vial to equilibrium. The headspace from the vial is transfered into a gas chromatograph. Compounds eluting between n-hexane and n-decane are measured and summed together using flame-ionization detection.

VH-SURR-FID-VA Water VH Surrogates for Waters B.C. MIN. OF ENV. LAB. MAN. (2009)

Reference Information

VOC7-HSMS-VA	Water	BTEX/MTBE/Styrene by Headspace GCMS	EPA8260B, 5021

The water sample, with added reagents, is heated in a sealed vial to equilibrium. The headspace from the vial is transfered into a gas chromatograph. Target compound concentrations are measured using mass spectrometry detection.

VOC7/VOC-SURR-MS-VA	Water	VOC7 and/or VOC Surrogates for Waters	EPA8260B, 5021
VPH-CALC-VA	Water	VPH is VH minus select aromatics	BC MOE LABORATORY MANUAL (2005)

These results are determined according to the British Columbia Ministry of Environment Analytical Method for Contaminated Sites "Calculation of Volatile Petroleum Hydrocarbons in Solids or Water". The concentrations of specific Monocyclic Aromatic Hydrocarbons (Benzene, Toluene, Ethylbenzene, Xylenes and, in solids, Styrene) are subtracted from the collective concentration of Volatile Hydrocarbons (VH) that elute between n-hexane (nC6) and n-decane (nC10).

XYLENES-CALC-VA	Water	Sum of Xylene Isomer Concentrations	CALCULATION

Calculation of Total Xylenes

Total Xylenes is the sum of the concentrations of the ortho, meta, and para Xylene isomers. Results below detection limit (DL) are treated as zero. The DL for Total Xylenes is set to a value no less than the square root of the sum of the squares of the DLs of the individual Xylenes.

** 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:

10-196227

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.

SRC Group # 2012-702

Jan 25, 2012

SRC ANALYTICAL

422 Downey Road
Saskatoon, Saskatchewan, Canada
S7N 4N1
(306) 933-6932 or 1-800-240-8808

ALS Laboratory Group
8081 Lougheed Hwy
Burnaby, BC V5A 1W9
Attn: Brent Mack

Date Samples Received: Jan-20-2012 Client P.O.: L1105481

This is a final report.

Organics results have been authorized by Pat Moser, Supervisor

ICP results have been authorized by Keith Gipman, Supervisor

Inorganics and Radiochemistry results have been authorized by Jeff Zimmer, Supervisor

SLOWPOKE-2 results have been authorized by Dave Chorney

---

* Test methods and data are validated by the laboratory's Quality Assurance Program.

* Routine methods follow recognized procedures from sources such as

- Standard Methods for the Examination of Water and Wastewater APHA AWWA WEF
- Environment Canada
- US EPA
- CANMET

* The results reported relate only to the test samples as provided by the client.

* Samples will be kept for 30 days after the final report is sent. Please contact the lab if you have any special requirements.

* Additional information is available upon request.

SRC Group # 2012-702

Jan 25, 2012

SRC ANALYTICAL

422 Downey Road
Saskatoon, Saskatchewan, Canada
S7N 4N1
(306) 933-6932 or 1-800-240-8808

ALS Laboratory Group
8081 Lougheed Hwy
Burnaby, BC V5A 1W9
Attn: Brent Mack

Date Samples Received: Jan-20-2012

Client P.O.: L1105481

2903 **01/18/2012 L1105481-1 TW12-1 *WATER***

Analyte	Units	2903
Radio Chemistry		
Gross alpha	Bq/L	<0.05
Gross beta	Bq/L	0.05

Symbol of "<" means "less than". This indicates that it was not detected at level stated above.

SRC ANALYTICAL

422 Downey Road
Saskatoon, Saskatchewan, Canada
S7N 4N1
(306) 933-6932 or 1-800-240-8808

Jan 25, 2012

Quality Control Report

Brent Mack
ALS Laboratory Group
8081 Lougheed Hwy
Burnaby, BC V5A 1W9

This report was generated for samples included in SRC Group # 2012-702

Reference Materials and Standards:

A reference material of known concentration is used whenever possible as either a control sample or control standard and analyzed with each batch of samples. These "QC" results are used to assess the performance of the method and must be within clearly defined limits; otherwise corrective action is required.

QC Analysis	**Units**	**Target Value**	**Obtained Value**
Gross Alpha	Bq/L	14.6	13.9
Gross Alpha	Bq	1.9	1.5
Gross Beta	Bq/L	12.4	12.5
Gross Beta	Bq	1.98	1.91

Duplicates:

Duplicates are used to assess problems with precision and help ensure that samples within a given batch were processed appropriately. The difference between duplicates must be within strict limits, otherwise corrective action is required. Please note, the duplicate(s) in this report are duplicates analyzed within a given batch of test samples and may not be from this specific group of samples.

Duplicate Analysis	**Units**	**First Result**	**Second Result**
Gross alpha	Bq/L	<0.12	<0.12
Gross beta	Bq/L	0.06	0.05

Spikes and/or Surrogates:

Samples spiked with a known quantity of the analyte of interest or a surrogate which is a known quantity of a compound which behaves in a similar manner to the analyte of interest, are used to assess problems with the sample processing or sample matrix. The recovery must be within clearly defined limits when the quantity of spike is comparable to the sample concentration.

Spike Analysis	**Percent Recovery**	
Gross Alpha	153	*(1)
Gross Beta	90	

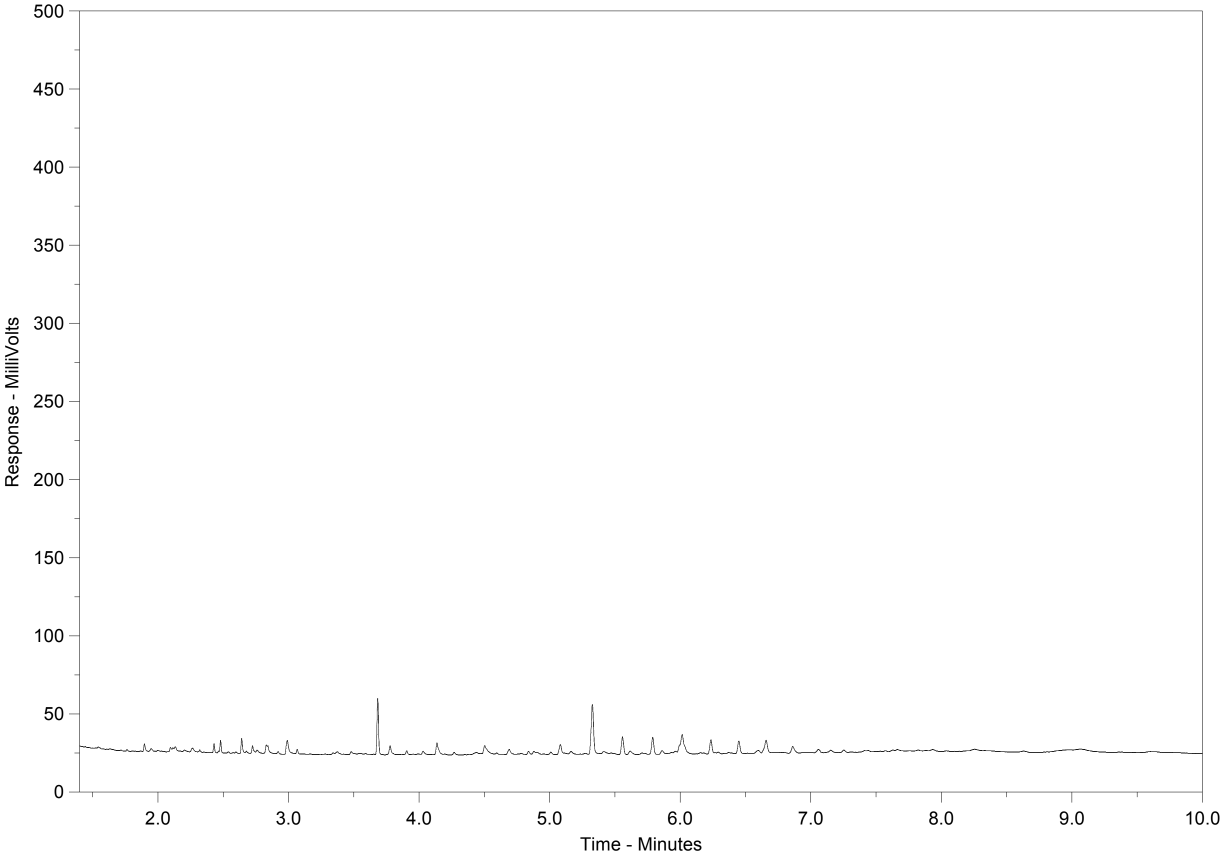
*(1) The percent recovery for Gross alpha in the spiked sample was just outside the laboratory's specified limits of 50 - 150% recovery. The data was reviewed and additional quality control measures in the same batch were within specified limits.

Overall, there were no other indications of problems with the analysis and the results were considered acceptable.

Roxane Ortmann - Quality Assurance
Supervisor

Hydrocarbon Distribution Report

ALS Sample ID: L1105481-1
Client Sample ID: TW12-1



nC10	nC19	nC32
174°C 346°F	330°C 626°F	467°C 873°F

← Gasoline → ← Motor Oils / Lube Oils / Grease →
← Diesel / Jet Fuels →

The EPH Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample. For further interpretation, a current library of reference products is available on www.alsglobal.com or upon request.

The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products, and three n-alkane hydrocarbon marker compounds. Retention times may vary between samples by as much as 0.5 minutes.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the response scale at the left.

A "-L-" in the sample ID denotes a low level sample. A "-S-" denotes a silica gel cleaned sample.

10- 196227

ALS Environmental

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

Page ____ of ____

Report To KATHY TIXIER
Company: PITEAU ASSOCIATES
Contact:
Address: 215 - 360 W Esplanade
North Van BC
Phone: 604 Fax:

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

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Copy of Invoice with Report? (circle) Yes or No
Company:
Contact:
Address:
Phone: Fax:

Client / Project Information
Job #: 3131
PO / AFE:
LSD:
Quote #:

Lab Work Order # (lab use only) L1105481

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	General	Tot Metal (P)	Bacteria (P)	Diss Metal (F P)	Sulphide (P)	PAH/EPH/LEPH/HEPH/F2-F4/HERB (P)	VOC (BTEX) (P)	Gross Alpha (P)	ON HOLD				Number of Containers
	TW12-1	18 JAN 12	2:30	Water	1	1	1	1	1	1	1	1	3				

L1105481-COFC

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

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: R. Segovia	Date: JAN 18	Time: 4:30	Received by: DEAN	Date: 18 Jan 12	Time: 16:51	Temperature: 6.8 °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

Report ID: **EMSR0300**
Report Time: **2012- 02- 14 03:31**
Requested by:

Environmental Monitoring System
Historical Statistics Report

Selection Criteria

EMS ID: **E217927**
Region:
Permit ID:
Office:
Establishing Agency:
Location Type:
Monitoring Group:
Collection Start Date/Time From **1950-01-01 00:00**
Collection Start Date/Time To: **2012-02-14 23:59**
Specific Month:
Sample State:
Sample Descriptor:
Study:
Parameter Code:
Data Index:
QA Index:
Watershed:
Eco Region:

Order by

Office Code: **Y**
Parameter Code: **Y**
Location Type: **N**
Sample State Code: **N**

Report ID: **EMSR0300**
Report Time: **2012- 02- 14 03:31**
Requested by:

Environmental Monitoring System
Historical Statistics Report

Monitoring Location: E217927 **Name:** FVGMP STAVE LAKE ROAD, MISSION **Location Type:** WELL
Office: LOWER MAINLAND **No. Samples:** 2
Establishing Agency: WMB-Groundwater **First Collection Date:** 1992-12-08
Watershed Code: **Most Recent Collection Date:** 1993-09-01
Latitude: 049:15:27 **Longitude:** 122:14:37

Sample State	Sample Desc.	Parameter	Units	Maximum		Minimum	Mean	Median	Standard Deviation	Latest Date	Total Obs.	Used Obs.
FW	GE	0002 Color True	Col.unit	5.00000	<	5.00000		5.00000		1993-09-01	2	0
FW	GE	0004 pH	pH units	6.70000		6.70000	6.70000	6.70000	0.00000	1993-09-01	2	2
FW	GE	0007 Residue: Filterable 1.0u	mg/L	50.00000		45.00000	47.50000	47.50000	3.53553	1993-09-01	2	2
FW	GE	0011 Specific Conductance	uS/cm	53.00000		52.00000	52.50000	52.50000	0.70711	1993-09-01	2	2
FW	GE	0015 Turbidity	NTU	0.60000		0.60000	0.60000	0.60000	0.00000	1992-12-08	1	1
FW	GE	0101 Alkalinity Phen. 8.3	mg/L	0.50000	<	0.50000		0.50000		1993-09-01	2	0
FW	GE	0102 Alkalinity Total 4.5	mg/L	22.30000		20.60000	21.45000	21.45000	1.20208	1993-09-01	2	2
FW	GE	0107 Hardness Total (Total)	mg/L	20.20000		19.20000	19.70000	19.70000	0.70711	1993-09-01	2	2
FW	GE	0112 Nitrogen Organic-Total	mg/L	0.04000		0.04000	0.04000	0.04000	0.00000	1992-12-08	1	1
FW	GE	0150 Bicarbonate Alkalinity	mg/L	22.30000		20.60000	21.45000	21.45000	1.20208	1993-09-01	2	2
FW	GE	1104 Chloride Dissolved	mg/L	0.90000		0.70000	0.80000	0.80000	0.14142	1993-09-01	2	2
FW	GE	1106 Fluoride Dissolved	mg/L	0.10000	<	0.10000		0.10000		1993-09-01	2	0
FW	GE	1107 Hardness Total (Dissolve	mg/L	20.00000		19.80000	19.90000	19.90000	0.14142	1993-09-01	2	2
FW	GE	1108 Nitrogen Ammonia Dissolv	mg/L	0.00600	<	0.00500	0.00600	0.00550	0.00000	1993-09-01	2	1
FW	GE	1109 Nitrate(NO3) + Nitrite(N	mg/L	0.36000		0.31000	0.33500	0.33500	0.03536	1993-09-01	2	2
FW	GE	1110 Nitrate (NO3) Dissolved	mg/L	0.36000		0.31000	0.33500	0.33500	0.03536	1993-09-01	2	2
FW	GE	1111 Nitrogen - Nitrite Disso	mg/L	0.00500	<	0.00500		0.00500		1993-09-01	2	0
FW	GE	1113 Nitrogen (Kjeldahl) Tota	mg/L	0.04	<	0.04		0.04		1992-12-08	1	0
FW	GE	1114 Nitrogen Total Dissolved	mg/L	0.31		0.31	0.31	0.31	0.00	1992-12-08	1	1
FW	GE	1121 Sulfate Dissolved	mg/L	2.20000		2.00000	2.10000	2.10000	0.14142	1993-09-01	2	2
FW	GE	AG-D Silver Dissolved	mg/L	0.01000	<	0.01000		0.01000		1993-09-01	2	0
FW	GE	AG-T Silver Total	mg/L	0.03000	<	0.01000		0.02000		1993-09-01	2	0
FW	GE	AL-D Aluminum Dissolved	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	AL-T Aluminum Total	mg/L	0.06000	<	0.02000		0.04000		1993-09-01	2	0
FW	GE	AS-D Arsenic Dissolved	mg/L	0.04000	<	0.00100	0.04000	0.02050	0.00000	1993-09-01	2	1
FW	GE	AS-T Arsenic Total	mg/L	0.00	<	0.00		0.00		1993-09-01	2	0
FW	GE	B--D Boron Dissolved	mg/L	0.00800	<	0.00800		0.00800		1993-09-01	2	0
FW	GE	B--T Boron Total	mg/L	0.043	<	0.040	0.043	0.042	0.000	1993-09-01	2	1
FW	GE	BA-D Barium Dissolved	mg/L	0.00200	<	0.00100	0.00200	0.00150	0.00000	1993-09-01	2	1
FW	GE	BA-T Barium Total	mg/L	0.00100	<	0.00100		0.00100		1993-09-01	2	0

Outliers are not included, and results less than or greater than
detection limits have been excluded in Mean and Standard Deviation.

Report ID: **EMSR0300**
Report Time: **2012- 02- 14 03:31**
Requested by:

Environmental Monitoring System
Historical Statistics Report

Monitoring Location: E217927 **Name:** FVGMP STAVE LAKE ROAD, MISSION **Location Type:** WELL
Office: LOWER MAINLAND **No. Samples:** 2
Establishing Agency: WMB-Groundwater **First Collection Date:** 1992-12-08
Watershed Code: **Most Recent Collection Date:** 1993-09-01
Latitude: 049:15:27 **Longitude:** 122:14:37

Sample		Parameter		Units	Maximum		Minimum	Mean	Median	Standard Deviation	Latest Date	Total Obs.	Used Obs.
State	Desc.												
FW	GE	BE-D	Beryllium Dissolved	mg/L	0.00100	<	0.00100		0.00100		1993-09-01	2	0
FW	GE	BE-T	Beryllium Total	mg/L	0.00100	<	0.00100		0.00100		1993-09-01	2	0
FW	GE	BI-D	Bismuth Dissolved	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	BI-T	Bismuth Total	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	CA-D	Calcium Dissolved	mg/L	6.78000		6.70000	6.74000	6.74000	0.05657	1993-09-01	2	2
FW	GE	CA-T	Calcium Total	mg/L	6.90000		6.53000	6.71500	6.71500	0.26163	1993-09-01	2	2
FW	GE	CD-D	Cadmium Dissolved	mg/L	0.00200	<	0.00200		0.00200		1993-09-01	2	0
FW	GE	CD-T	Cadmium Total	mg/L	0.00200	<	0.00200		0.00200		1993-09-01	2	0
FW	GE	CO-D	Cobalt Dissolved	mg/L	0.00300	<	0.00300		0.00300		1993-09-01	2	0
FW	GE	CO-T	Cobalt Total	mg/L	0.00400	<	0.00300		0.00350		1993-09-01	2	0
FW	GE	CR-D	Chromium Dissolved	mg/L	0.00200	<	0.00200		0.00200		1993-09-01	2	0
FW	GE	CR-T	Chromium Total	mg/L	0.00200	<	0.00200		0.00200		1993-09-01	2	0
FW	GE	CU-D	Copper Dissolved	mg/L	0.05400		0.00300	0.02850	0.02850	0.03606	1993-09-01	2	2
FW	GE	CU-T	Copper Total	mg/L	0.05500		0.00800	0.03150	0.03150	0.03323	1993-09-01	2	2
FW	GE	FE-D	Iron Dissolved	mg/L	0.01200	<	0.00300		0.00750		1993-09-01	2	0
FW	GE	FE-T	Iron Total	mg/L	0.07000	<	0.02300		0.04650		1993-09-01	2	0
FW	GE	K--D	Potassium Dissolved	mg/L	0.40000	<	0.40000		0.40000		1993-09-01	2	0
FW	GE	K--T	Potassium Total	mg/L	0.60000	<	0.40000	0.60000	0.50000	0.00000	1993-09-01	2	1
FW	GE	MG-D	Magnesium Dissolved	mg/L	0.75000		0.75000	0.75000	0.75000	0.00000	1993-09-01	2	2
FW	GE	MG-T	Magnesium Total	mg/L	0.73000		0.71000	0.72000	0.72000	0.01414	1993-09-01	2	2
FW	GE	MN-D	Manganese Dissolved	mg/L	0.00200	<	0.00200		0.00200		1993-09-01	2	0
FW	GE	MN-T	Manganese Total	mg/L	0.00200	<	0.00200		0.00200		1993-09-01	2	0
FW	GE	MO-D	Molybdenum Dissolved	mg/L	0.02000	<	0.00400	0.02000	0.01200	0.00000	1993-09-01	2	1
FW	GE	MO-T	Molybdenum Total	mg/L	0.00400	<	0.00400		0.00400		1993-09-01	2	0
FW	GE	NA-D	Sodium Dissolved	mg/L	1.95000		1.90000	1.92500	1.92500	0.03536	1993-09-01	2	2
FW	GE	NA-T	Sodium Total	mg/L	2.76000		1.80000	2.28000	2.28000	0.67882	1993-09-01	2	2
FW	GE	NI-D	Nickel Dissolved	mg/L	0.00800	<	0.00800		0.00800		1993-09-01	2	0
FW	GE	NI-T	Nickel Total	mg/L	0.01000	<	0.01000		0.01000		1993-09-01	2	0
FW	GE	P--D	Phosphorus Total Dissolv	mg/L	0.04000	<	0.04000		0.04000		1993-09-01	2	0
FW	GE	P--T	Phosphorus Total	mg/L	0.04000	<	0.04000		0.04000		1993-09-01	2	0

Outliers are not included, and results less than or greater than
detection limits have been excluded in Mean and Standard Deviation.

Report ID: **EMSR0300**
Report Time: **2012- 02- 14 03:31**
Requested by:

Environmental Monitoring System
Historical Statistics Report

Monitoring Location: E217927 **Name:** FVGMP STAVE LAKE ROAD, MISSION **Location Type:** WELL

Office: LOWER MAINLAND **No. Samples:** 2

Establishing Agency: WMB-Groundwater **First Collection Date:** 1992-12-08

Watershed Code: **Most Recent Collection Date:** 1993-09-01

Latitude: 049:15:27 **Longitude:** 122:14:37

Sample State	Sample Desc.	Parameter		Units	Maximum		Minimum	Mean	Median	Standard Deviation	Latest Date	Total Obs.	Used Obs.
FW	GE	PB-D	Lead Dissolved	mg/L	0.001	<	0.001		0.001		1993-09-01	2	0
FW	GE	PB-T	Lead Total	mg/L	0.014	<	0.001	0.014	0.008	0.000	1993-09-01	2	1
FW	GE	S--D	Sulfur Dissolved	mg/L	0.82000		0.73000	0.77500	0.77500	0.06364	1993-09-01	2	2
FW	GE	S--T	Sulfur Total	mg/L	0.80000		0.78000	0.79000	0.79000	0.01414	1993-09-01	2	2
FW	GE	SB-D	Antimony Dissolved	mg/L	0.01500	<	0.01500		0.01500		1993-09-01	2	0
FW	GE	SB-T	Antimony Total	mg/L	0.01500	<	0.01500		0.01500		1993-09-01	2	0
FW	GE	SE-D	Selenium Dissolved	mg/L	0.03000	<	0.03000		0.03000		1993-09-01	2	0
FW	GE	SE-T	Selenium Total	mg/L	0.00500	<	0.00500		0.00500		1993-09-01	2	0
FW	GE	SI-D	Silicon Dissolved	mg/L	6.53000		6.15000	6.34000	6.34000	0.26870	1993-09-01	2	2
FW	GE	SI-T	Silicon Total	mg/L	6.32000		6.00000	6.16000	6.16000	0.22627	1993-09-01	2	2
FW	GE	SN-D	Tin Dissolved	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	SN-T	Tin Total	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	SR-D	Strontium Dissolved	mg/L	0.02200		0.02200	0.02200	0.02200	0.00000	1993-09-01	2	2
FW	GE	SR-T	Strontium Total	mg/L	0.02400		0.02100	0.02250	0.02250	0.00212	1993-09-01	2	2
FW	GE	TE-D	Tellerium Dissolved	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	TE-T	Tellurium Total	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	TI-D	Titanium Dissolved	mg/L	0.00300	<	0.00300		0.00300		1993-09-01	2	0
FW	GE	TI-T	Titanium Total	mg/L	0.00300	<	0.00300		0.00300		1993-09-01	2	0
FW	GE	TL-D	Thallium Dissolved	mg/L	0.02000	<	0.02000		0.02000		1993-09-01	2	0
FW	GE	TL-T	Thallium Total	mg/L	0.03000	<	0.02000		0.02500		1993-09-01	2	0
FW	GE	V--D	Vanadium Dissolved	mg/L	0.00300	<	0.00300		0.00300		1993-09-01	2	0
FW	GE	V--T	Vanadium Total	mg/L	0.00300	<	0.00300		0.00300		1993-09-01	2	0
FW	GE	ZN-D	Zinc Dissolved	mg/L	0.02100	<	0.00000	0.01550	0.01000	0.00778	1993-09-01	3	2
FW	GE	ZN-T	Zinc Total	mg/L	0.03000		0.01100	0.02050	0.02050	0.01344	1993-09-01	2	2
FW	GE	ZR-D	Zirconium Dissolved	mg/L	0.00300	<	0.00300		0.00300		1993-09-01	2	0
FW	GE	ZR-T	Zirconium Total	mg/L	0.00300	<	0.00300		0.00300		1993-09-01	2	0

Outliers are not included, and results less than or greater than
detection limits have been excluded in Mean and Standard Deviation.

APPENDIX H

SCOTT RESEARCH SERVICES INC. REPORT

SCOTT RESOURCE SERVICES INC.
Environmental Consultants
31856 Silverdale Avenue, Mission, BC V2V 2K9
Tel: (604) 820-1415 Fax: (604) 820-1621
mission@scottres.ca www.scottres.ca

March 26, 2012

Our file: 822.04
Your file: 3131

Ms. Kathy C. Tixier, *P. Eng.*
Senior Hydrogeologist
Piteau Associates Engineering Ltd.
#215 – 260 W. Esplanade
North Vancouver, BC, V7M 3G7

Re: Overview environmental assessment of stream, fish and wildlife habitat resources in the vicinity of a proposed groundwater development in the Miracle Valley, north of Hatzic Lake, B.C.

1.0 INTRODUCTION

Per the request of Piteau Associates Engineering Ltd. (Piteau), Scott Resource Services Inc. (SRS) has prepared an overview level environmental assessment of stream, fish and wildlife resources in the Miracle Valley north of Hatzic Lake, B.C. (Attachment 1). The Miracle Valley aquifer is being investigated as a potential source of municipal water supply.

SRS's overview environmental assessment methodology included background research and brief ground-truthing assessments of the watercourses in the area to determine potential impacts to the creeks and associated fish and wildlife habitats.

Specifically, a detailed review of creeks located in the southern part of the aquifer, including Lagace Creek, Belcharton Creek, Durieu Creek, Oru Creek and Seux Brook, and the northern part of the aquifer, including Marino Creek and an unnamed tributary to Cascade Creek was conducted (Attachment 2).

The review identified watercourse attributes and fish habitats that could be potentially affected by groundwater extraction from the aquifer. A review of aquatic species at risk within the area was also conducted.

SRS further provides potential ecological and fish habitat implications associated with a reduction in seasonal water flows.

2.0 METHODS

An electronic search of the Ministry of Environment's (MOE) Fisheries Inventory Summary System (FISS) and the Fraser Valley Regional District's Habitat Atlas (FVHA) was conducted. A search for species at risk was conducted through the British Columbia Conservation Data Centre (BCCDC). In addition, a review of SRS's archives for projects conducted in the vicinity of the aquifer and background information pertaining to the area was gathered.

A brief field reconnaissance was also completed.

3.0 WATERCOURSE & BIOPHYSICAL ASSESSMENT

3.1 Biophysical assessment

Four watercourses in the southern region of the aquifer, Belcharton Creek, Durieu Creek, Oru Creek and Seux Brook, were identified by Piteau as having the potential to be negatively affected by groundwater extraction. All of these watercourses are tributaries to Lagace Creek which drains to Hatzic Lake, which in turn drains to the Fraser River. In addition, sections of the northern region of the aquifer, including Marino Creek and an unnamed tributary to Cascade Creek were identified as streams that may be negatively affected by groundwater extraction in the area. Streams in the northern region of the aquifer drain into Stave Lake. An annotated orthophotograph showing the general location of these watercourses is included in Attachment 2.

Magwood (2004) found that in 2000 most of the land in Miracle Valley was forested (74%), while some was residential (16%) and agricultural (7%) and the remainder (3%) was for other uses (ex. roads, wetlands).

The Miracle Valley aquifer is a sand and gravel aquifer that is recharged from water infiltration sourced from the overlying creeks and precipitation (Piteau, 2007; PHCL, 2003). The aquifer is confined (overlain by a low permeability layer) and the depth to the top of the aquifer is approximately 38 m (PHCL, 2003). Research by Piteau (2007) indicates that flow to Belcharton, Durieu, Oru and Seux are predominantly sourced by groundwater discharge. Hydrographs of Lagace and Belcharton Creek indicate that the average stream flows in the area are highest from November to January and are lowest from June to September (Rood and Hamilton, 1995).

3.2 Fish and fish habitat

3.2.1 Lagace Creek

Lagace Creek is the main creek entering Hatzic Lake with a drainage area of approximately 32 km^2 (Rood and Hamilton, 1995). From FISS records, Lagace Creek is known to support populations of cutthroat trout (*Onchorhynchus clarki*), rainbow trout and steelhead trout (*O. mykiss*), coho salmon (*O. kisutch)*, chum salmon (*O. keta*), three-spined stickleback (*Gasterosteus spp.*), lamprey (*Lampetra spp.*) and sculpin (*Cottus spp.*). A 1999 report by

Fisheries and Oceans Canada (DFO) indicated that rearing potential is good in Lagace Creek and its tributaries.

In August and September of 2005, SRS conducted a fish salvage in Lagace Creek, and reported findings of cutthroat trout, rainbow trout, coho salmon, three-spined stickleback, lamprey and sculpin. In particular there were large numbers of coho salmon (9,343 individuals), rainbow trout (1,011 individuals) and sculpin (2,693 individuals) that were salvaged and relocated during this period. There are no reported physical barriers between Lagace Creek and the four tributaries in the south. All the southern streams – Belcharton, Durieu, Oru and Seux are low gradient and fish-bearing (Scott, 2011).

Lagace Creek is diked for 4 km upstream of Hatzic Lake. It is subject to active gravel and debris extraction and dredging for flood and erosion protection. Low gradient reaches within the Hatzic – Miracle Valley area are subject to aggradation, due to landslide and other hillslope instabilities in the headwater reaches.

Previous studies have suggested that domestic wells in the area and extraction of water for agricultural irrigation have altered the hydrology of the creek and its tributaries (DFO, 1999; NHC, 2005).

3.2.1.1 Belcharton Creek

Belcharton Creek is known to support populations of coho and chum salmon and has been identified as high quality rearing habitat. It is also reported to support populations of cutthroat trout (DFO, 1999). This finding is further supported by the FVHA that has delineated Belcharton Creek as fish bearing habitat. The first kilometre of Belcharton Creek (from its confluence with Lagace Creek), is reported to be one of the largest habitat contributors for salmonid spawning to the Hatzic Lake system (DFO, 1999).

Belcharton Creek has been identified as a major spawning location for both chum salmon and coho salmon (FISS, 2011). Chum salmon migration to Belcharton Creek typically begins in early October with spawning occurring from mid-October to late December. Coho salmon migration to Belcharton Creek typically begins in early November with spawning occurring between mid-November to as late as January.

SRS has completed assessments in Belcharton Creek, and has found a year-round population of coho salmon in various life stages (Scott, 2011; SRS, 2005). Belcharton Creek has also been identified as important cutthroat trout habitat (DFO, 1999).

Precision Identification Biological Consultants (PIBC) classified Belcharton Creek as an endangered stream in 1998. Belcharton was reported to have water quality problems, impacts from logging and “other impacts” (i.e. agricultural/ urban impacts, anthropogenic barriers and cumulative effects of these impacts). Historic records indicate that Belcharton Creek has suffered from poor water extraction management and 1995 records indicate that the summer water extraction from Belcharton Creek was extreme with water licenses amounting to two times the mean August flow for the creek (Rood and Hamilton; 1995).

There are also reports that baseflows in Belcharton Creek were altered due to an active rock quarry operation located near the headwaters of the creek (DFO, 1999).

3.2.1.2 Durieu Creek, Oru Creek and Seux Brook

A search of FISS did not return any records for Durieu Creek, Oru Creek or Seux Brook. However, both Durieu and Oru Creek were delineated as fish bearing habitat on the FVHA. Seux Brook was classified as having unknown fish presence on the FVHA.

A 1999 DFO report classified Durieu Creek as important coho salmon habitat (DFO, 1999). Given the low gradient habitat and the lack of physical barriers between Lagace Creek and its tributaries, there is a high likelihood that coho salmon, chum salmon and cutthroat trout are present in all three streams. All streams are located in close proximity to one another (within 1.5 km) and have very similar stream gradients and adjoining riparian vegetation; thus the stream hydrology of Durieu, Oru and Seux are likely similar to that of Belcharton Creek. However, confirmation of this finding would require additional and more extensive ground-truthing.

PIBC (1998) classified Durieu Creek, Oru Creek and Seux Brook as threatened streams due to agricultural and urban habitat impacts.

3.2.2 Marino Creek

Marino Creek is predominantly spring fed and flows north into Stave Lake. According to the FVHA the creek is fish bearing from its headwaters to Stave Lake. The low gradient reaches of the creek would provide good habitat for cutthroat and rainbow trout. Stave Lake is a non-anadromous lake.

According to Madrone Environmental Services Ltd. (MES) there are currently two water licenses on Marino Creek including one that is held by the active rock quarry (as referenced under Belcharton Creek).

3.2.3 Cascade Creek

Cascade Creek is a large tributary to Stave Lake. From FISS records, Cascade Creek is known to support populations of cutthroat trout, rainbow trout, kokanee salmon (*Oncorhynchus nerka),* Dolly Varden char (*Salvelinus malma malma*) and sculpin.

Golder Associates Ltd. (2008), classified Cascade Creek as a “fairly wide and low gradient stream” that has been subject to channel erosion and destabilization. SRS used satellite imagery to estimate the average channel width to be 20 m in the vicinity of the project area. PIBC’s study (1998) classified Cascade Creek as an endangered stream. Cascade Creek was reported to have been impacted by riparian removal, effects of urbanization and “other impacts”.

3.2.3.1 Tributary to Cascade Creek

According to the FVHA, the tributary to Cascade Creek is delineated as fish bearing habitat on the northern end of the stream and is delineated as having unknown fish presence on the southern end of the stream.

The tributary is low gradient and fish-bearing in the area highlighted by Piteau as a stream of interest. Given the lack of physical barriers between Cascade Creek and the tributary, the tributary is considered by default to be a fish bearing stream reach with a strong likelihood that salmonids (trout and char) are present.

3.3 Wildlife and Species at Risk

A search of the BCCDC map indicated that Pacific water shrew (*Sorex bendirii*) (PWS) was observed in 2000 in the Miracle Valley area in close proximity to Lagace Creek and its tributaries. There was also a sighting in 1992 just north of Cascade Creek, near Stave Lake. PWS are usually associated with riparian areas of moist forests and are found within one kilometre of a water body (Bianchini, 2010). PWS are endangered and red-listed by the province (BCCDC, 2012). The riparian area overlying the Miracle Valley Aquifer is considered suitable habitat for PWS.

In addition, a search of BCCDC revealed that red-legged frog (*Rana aurora*) was observed in 2006 in the Miracle Valley area within the high water mark of Lagace Creek. Critical habitat for the species include temporary and permanent breeding ponds and the species is red-listed by the province.

Multiple sightings of terrestrial Oregon Forestsnail (*Allogona townsendiana*) in 2005 and 2006 were reported within the area (BCCDC, 2012).

Although there were no recorded observations, the area overlying the Miracle Valley Aquifer was also identified by BCCDC as suitable habitat for Emma's dancer (*Argia emma*), a species of dragonfly that breeds in riffle habitats of streams. This species is of special concern (blue-listed) in the province.

The area would also provide suitable habitat for Pacific waterleaf (*Hydrophyllum tenuipes*), a plant that has been red-listed by the BCCDC (2012). This species is typically found in lowland moist forests and streambanks (Bianchini, 2010).

4.0 CONCLUSIONS

All of the southern streams are predominantly sourced by groundwater discharge (Piteau, 1994). Groundwater aquifers in the area tend to recharge during the fall and winter rains. Current sources of groundwater recharge also include water from streams (Piteau, 2007; PPHCL, 2003). Habitat quality for fish and other aquatic species is often dependent on a supply of cold and clean groundwater (FVRD, 2010).

SRS's overview investigation of existing literature and known habitat constraints suggests that existing and historic diversion for waterworks, irrigation or industrial use have had an effect on Belcharton Creek, and evidence suggests that use of the water is over-subscribed compared to the estimated available flows (Magwood, 2004). Summer water use in Belcharton Creek has been rated as extreme and FISS has described this water use and diversion as a constraint for fisheries production.

SRS anticipates that Seux Brook, Oru Creek and Durieu Creek would have similar hydrological constraints as Belcharton Creek.

Drawdowns in the water supply to the streams has the potential to affect surface water availability which can be a major hazard to fish and aquatic species especially when it comes to maintaining minimal flows over spawning beds within a creek. While peak water flows in the winter would to a large degree mitigate the potential effects on salmon eggs and alevins in the gravel, there are significant risks associated with drawdowns and the effect on available rearing habitat for coho salmon and trout fry and smolts. There is also significant risk of trout redd de-watering in late spring.

Maintaining baseflows in the creek is also important for access to off-channel habitat that may only be accessible during high flows (Douglas, 2006). Reductions in groundwater can also influence the thermal refuge for fish by causing earlier cooling and ice formation in streams in the winter months and faster warming in the summer months. Extremes in temperature can also increase fish mortality and stress and decrease the carry capacity of the habitat (Douglas, 2006).

Reductions in groundwater volume can influence water quality by reducing the supply of nutrients to streams. Groundwater extraction can also reduce the amount of water available for riparian vegetation which can have negative ecological effects on the streams (Douglas, 2006). Hancock (2002) found that groundwater extraction lowers the residence time of water in the hyporheic layer (located between the surface water and groundwater aquifer) and can influence biological activity. The effect of groundwater extraction on riparian vegetation would be very difficult to quantify.

Given the existing effects of reduced baseflow within Belcharton Creek, and presumed similar effects in Seux Brook, Durieu Creek and Oru Creek, SRS anticipates that obtaining environmental approvals to withdraw additional water from the Miracle Valley aquifer will be difficult, and would only be granted following adequate:

- modeling to quantify the effect;
- biophysical assessments to determine existing baseline environmental resources; and,
- mitigation or compensation to offset the quantified effect on the relevant species.

Based on SRS's experience with the Bevan Wells project in Abbotsford, it is probable that the proposed water withdrawals would be of sufficient enough size to trigger a requirement for the project to be reviewed under the British Columbia Environmental Assessment Act (BCEAA). Since the works have the potential to affect fish habitat, DFO would be a Federal Authority with jurisdiction.

Unless adequate mitigation could be developed, it seems unlikely that DFO would approve a harmful alteration disruption or destruction (HADD) of fish habitat in Belcharton Creek due to the important habitat available for coho salmon. Were DFO to grant approval for a HADD, then that would require an Authorization per Section 35(2) of the federal *Fisheries Act*. The requirement for DFO to issue an Authorization is an automatic trigger for the project to be screened through the auspices of the *Canadian Environmental Assessment Act* (CEAA).

It is difficult to ascertain what mitigation might be required at this preliminary stage of the investigation, but concepts associated with water withdrawals and reservoir storage during periods of the year when recharge is high and creek flows are high may be acceptable to the environmental regulatory agencies. Another alternative might be to augment stream flows with water transported from other drainages or surface reservoirs to offset effects associated with the withdrawals from the confined aquifer. Feasibility of such a mitigatory approach would have to be reviewed by the owner and proponent as alternate water supply systems may prove to be more practical.

In closing, there is going to be a significant environmental regulatory review process involved with any proposed groundwater extraction in the Miracle Valley. Efforts by the owner's project team to satisfy the regulatory review would also be substantial, because it is unlikely that DFO would support a groundwater withdrawal that significantly reduces existing baseflows, since these baseflows already appear to be below historic levels. Perhaps a water management strategy for the entire valley could be developed to mitigate effects and at the same time allow for additional water extraction.

5.0 RECOMMENDATIONS

- Undertake stream modeling to determine peak and base flows within the affected streams in the Miracle Valley.

- Investigate the feasibility of developing a water supply design configuration that withdraws water and stores water when recharge is high and stream discharge is high, avoiding withdrawals during low water periods.

- Consider augmenting flow to streams during low water periods as a mitigatory measure.

- Concurrent with advancement of the project to a conceptual or preliminary design (and decision to seek project environmental approvals), undertake a comprehensive baseline investigation of fish populations and species at risk populations (predominantly aquatic) within the project area.

6.0 CLOSURE

I trust this is the information you require at this time. If you have any questions please do not hesitate to phone the undersigned to discuss the contents of this overview environmental assessment.

Regards,

SCOTT RESOURCE SERVICES INC.

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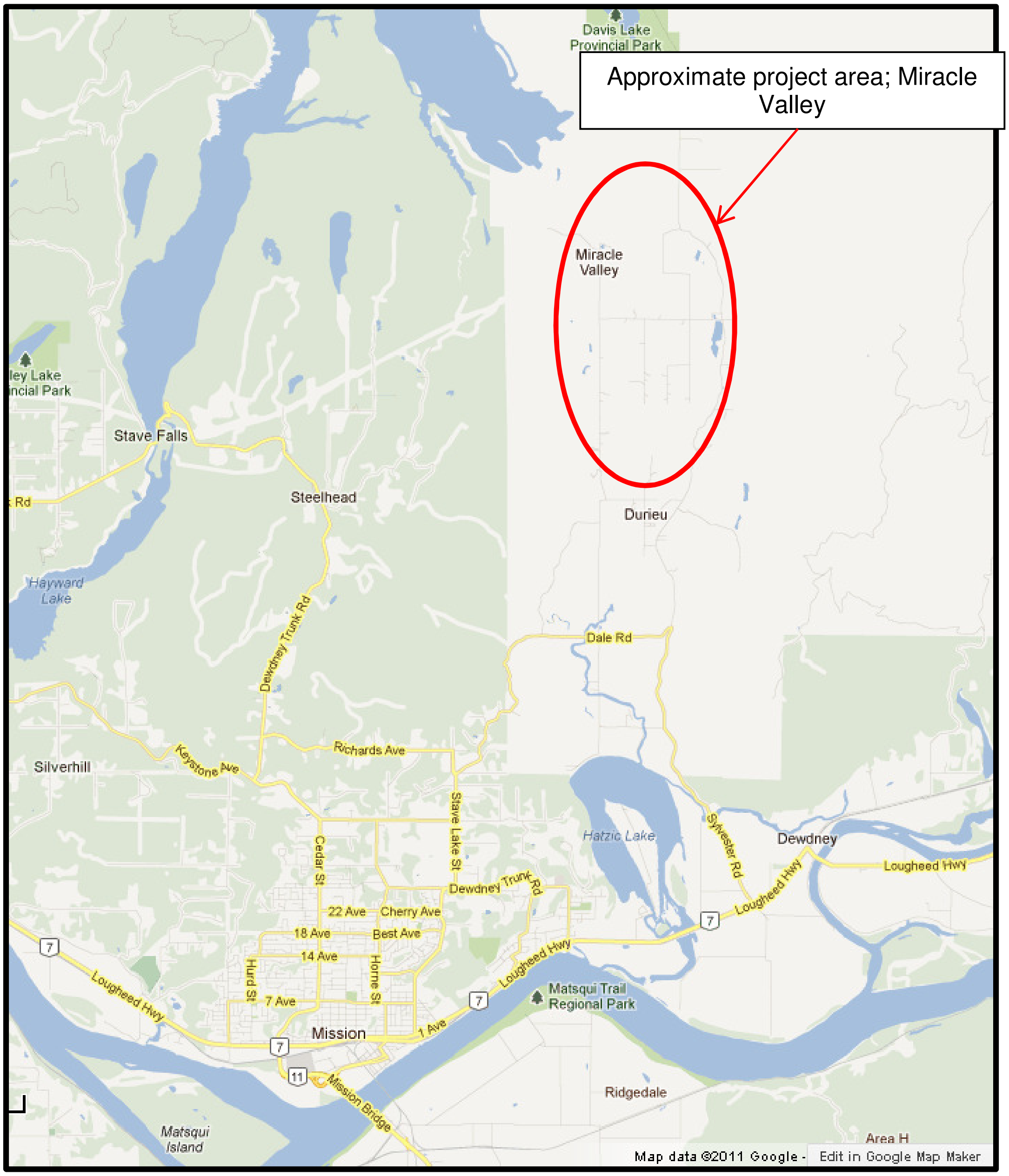
Attachment 1

Site location map



Attachment 2

Annotated orthophotograph