
MEMORANDUM

TO: Ian Chadwick, EHD Engineering Ltd.

E-MAIL: ehdconsulting@shaw.ca

FROM: Dennis Lowen LHC Project: 1818

DATE: December 10, 2018

RE: Follow-up Analyses of Potential Pumping Impacts and Sustainability Regarding the Clinton Bottling Plant Well (Well ID #39845), Clinton, B.C.

OF PAGES: 10

Message:

In their review of the Water License Application the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) has raised questions about the well water supply sustainability and potential impact on surface and groundwaters. Specific questions regarding the LHC well evaluation have also been posed. Following from a meeting at EHD Engineering Ltd. offices with MFLNRORD staff on Sept. 6, 2018 data gaps were identified and the need for further analyses determined. Additional analyses of impacts and sustainability for the proposed well water abstraction are provided herein.

Pumping Test - Well #39845

In Attachment 1 a larger scale view of the plotted pumping test water levels is presented from the November 2015 pumping test. The well was pumped at three different rates; 300 USgpm = 0 - 2 minutes; 170 USgpm = 2 - 300 minutes and 200 USgpm = from 300 - 4320 minutes (3 days). The data after 300 minutes plots on a straight line, as expected in an "ideal" aquifer (Ref. *Groundwater and Wells*, 2nd ed., Driscoll, G Johnson Division, 1986). Minor departures from the straight line are observed and are accounted for by the +/- 1 cm. measuring accuracy and minor variations in flow rate.

The slope of the drawdown curve becomes steeper between 100 and 300 minutes and this is interpreted to be a "boundary condition". The boundary may be the upper edge of the aquifer (south of the well) where the sand/gravel aquifer contacts the surrounding bedrock aquifer which has a lower transmissivity. The boundary condition is accounted for in the well capacity calculation in that the drawdown slope after 300 minutes was used to calculate the long-term well capacity. The pumping test meets or exceeds provincial guidelines for well testing and there is no need to pump the well again.

A copy of the water level recovery graph for Well #39845 and two Observation Wells is provided as Attachment 2. The extension of the recovery curves to the zero residual drawdown level provides an intercept values slightly greater than 1.0. This indicates complete recovery will occur and the aquifer has not been de-watered (Driscoll, 6. 1986). The aquifer was also tested previously at this site with Well #41015 (Well 41015 Assessment Report, EHD Consulting Ltd., October 2015). The water level recovery in that test was also almost ideal.

The water well long-term well capacity has been calculated by the MOE 1999 method resulting in a rate of 2,750 m³/d (504 USgpm). An alternative analysis has been undertaken utilizing the Groundwater Evaluation Guideline, Alberta Environment, February 5, 2003 (Farvolden Method). The "20 years yield" is calculated as follows:

$$Q_{20} = (0.68) T \quad HA \times (0.7)$$

Where: HA = Available head
Q₂₀ = Sustained 20-year yield
T = Aquifer Transmissivity
0.7 = Safety factor

$$Q_{20} = 0.68 \times 626 \times 7.17 \times 0.7$$

$$Q_{20} = 2,137 \text{ m}^3/\text{d}$$

Comparing this to the BC MOE capacity of 2,750 m³/d and it appears that the Alberta methodology is more conservative. In any case, the proposed withdrawal rate for the well is 927 m³/d and this rate is less than half of the capacity of the well.

Aquifer Recharge

The LHC July 2018 Memo provided an estimate of total aquifer recharge. Recharge from infiltration of precipitation was estimated at 10% of total precipitation. The 10% estimate is conservative in our opinion. Several studies can be cited to corroborate this opinion:

1. State of Understanding of the Hydrogeology of the Grand Forks Aquifer; Wei, M.; Allen, D.; Carmichael, V.; Ronneseth, K., BC Ministry of Environment, SFU, 2010.
 - Representative value of 27% of precipitation 135/510 mm/year was determined.
 - Also noted was the irrigation return flow of 22 - 25% of irrigated water.
 - Recharge modelled using HELP code (USEPA) within an Unsat Suite (Waterloo Hydrogeologic Inc., 1997) and climate data.
2. Groundwater in the Cowichan Watershed Lapsevic, P. et al. (MFLNRORD), Draft Final Report, April 2014.
 - Similar confined aquifer (#0178) to Clinton estimated recharge = 15% of precipitation.
3. Results of Coupled Groundwater - Surface Water Model of the Cowichan Valley Watershed, Foster, S. B., Allen, D. M., SFU, June 2015.
 - Aquifer recharge average estimated at 17% of precipitation.
4. Water Budget Project - RDN Phase 1, Vancouver Island, Waterline Resources Inc., Vancouver, B.C., June 2013.
 - Twenty-eight aquifer water budgets were formulated. All aquifers types were included; bedrock, unconsolidated, confined and unconfined.
 - Mountain Block Recharge (MBR) was significant in all the aquifers and the main component of recharge in most.
 - Aquifer recharge rates were calculated from 7% to 16% of precipitation using a modified USGS methodology.
5. Water Budget Project, RDN Phase 1, Gabriola, DeCourcy & Mudge Islands), SRK Consulting, 2013.
 - Groundwater recharge rates were found to range between 10 and 25% of annual precipitation.
6. Preliminary Conceptual Models and Water Budget Methodologies for Aquifers in B.C., BC Ministry of Environment, Hy-Geo Consulting (A.P. Kohut), March 31, 2014.
 - Many Water Budget Case studies from around B.C. are included in this report.
 - Recharge rates up to 80% of annual precipitation are noted.

Considering the research, we have reviewed from around BC, our estimate of recharge from precipitation: R = 10% of annual precipitation is justified.

Climate Data

The LHC, July 2018, Memo quotes 350 mm. as the average annual precipitation in Clinton. This precipitation rate was sourced from online information at weatherspark.com which used Clinton weather station data, data from nearby weather stations and a MERRA-2 computer model. Also, precipitation data is available from the Loon Lake (17 km South of Clinton) Environment Canada weather station. This station has data from 1970 - 1989 with annual precipitation ranging from 207 to 422 mm/year.

Additionally, the iMap BC Interactive Map provides hydrometric data for the Clinton area. The Cut-Off Valley Creek hydrometric station (08LF037) has associated data available including mean monthly precipitation values that indicate a mean annual precipitation of 431.6 mm. And finally, the weather stations indicate precipitation measured in the local valleys and precipitation will be higher in the higher elevations of the surrounding mountains.

Area of Potential Groundwater Recharge

The LHC, July 2018, Memo provided a preliminary estimate of the area that can contribute to groundwater recharge. The proposed area includes the surface of the mapped aquifer plus the surrounding highlands that generate Mountain Block Recharge. This area estimate, of 215 km², has been refined and the area boundaries are depicted in Attachments 3A, 3B and 3C. The total contributing area is as follows:

Aquifer area	-	4.1 Km ²	Attachment #3A
North & South Component	-	15.7 Km ²	Attachment #3A
West component	-	127.1 Km ²	Attachment #3B
South Lakes	-	43.5 Km ²	Attachment #3C
Total	-	<u>190.4 Km²</u>	

In conclusion, our original rough estimate of the potential recharge area of 215 km² was reasonable. The recharge volume calculated using the estimated area will not change significantly using the revised area (190.4 km²).

An independent analysis of the groundwater recharge for the Aquifer 0921 has been completed by Hy-Geo Consulting (Dec. 5 Letter Report). The Hy-Geo analysis confirms that the LHC estimates are reasonable.

Kala Geosciences Ltd. Well Report

Ref.: Letter to B. Jones - Proposed Subdivision - Lillooet, B.C., DL 876, Thompson Nicola R.D., Proof of Domestic Water, August 10, 2013

Subsequent to our meeting with MFLNRORD staff, in September, we obtained a Well Report for the bedrock well (Tag #107809). This water well is located just south and upslope of the subject aquifer. This 48.77 m. deep well was completed in fractured bedrock with a flow of 50 USgpm (3.15 L/s) during development. The well data supports our theory of a potential for significant MBR contributing to flow in the subject aquifer as follows:

- The well geology log shows sand & gravel lying directly over the bedrock. Therefore, a good hydraulic connection between the rock aquifer and sand/gravel aquifer is likely.
- The well water level is close to the level in the nearby sand/gravel wells.
- The water quality is highly mineralized (TDS = 2390) as is water from sand/gravel aquifer.
- The well flow rate indicates that significant volumes of water are moving through the bedrock.
- The bedrock and sand/gravel aquifer form an integrated aquifer system.

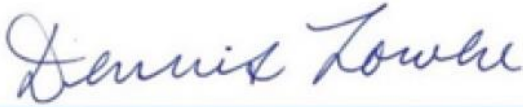
Groundwater Seepage into Duck Lake

Surface water impacts have been addressed in the LHC July 2018 Memo. In this regard groundwater flow into or out of the Duck Lake through the Lake's bottom sediments has been considered. The hydraulic conductivity of lake bottom sediments (sand, silt, clay) has been estimated at $K = 0.0001$ m/d. This K value is derived from the B.C. Government Water Stewardship Branch "K" value estimator provided by K. Ronneseth. We took a median value for clayey-silt (0.001) and silt-sand-clay (0.00001). See the datasheet provided as Attachment 4.

If you have any questions or require any further information, please contact the undersigned by e-mail: dl@lowenhc.ca or phone: 250 595 0624.

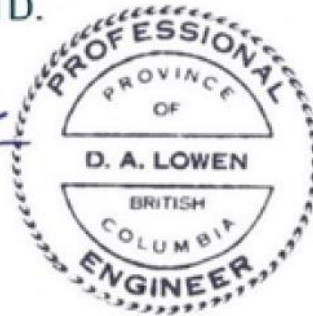
Best regards,

LOWEN HYDROGEOLOGY CONSULTING LTD.

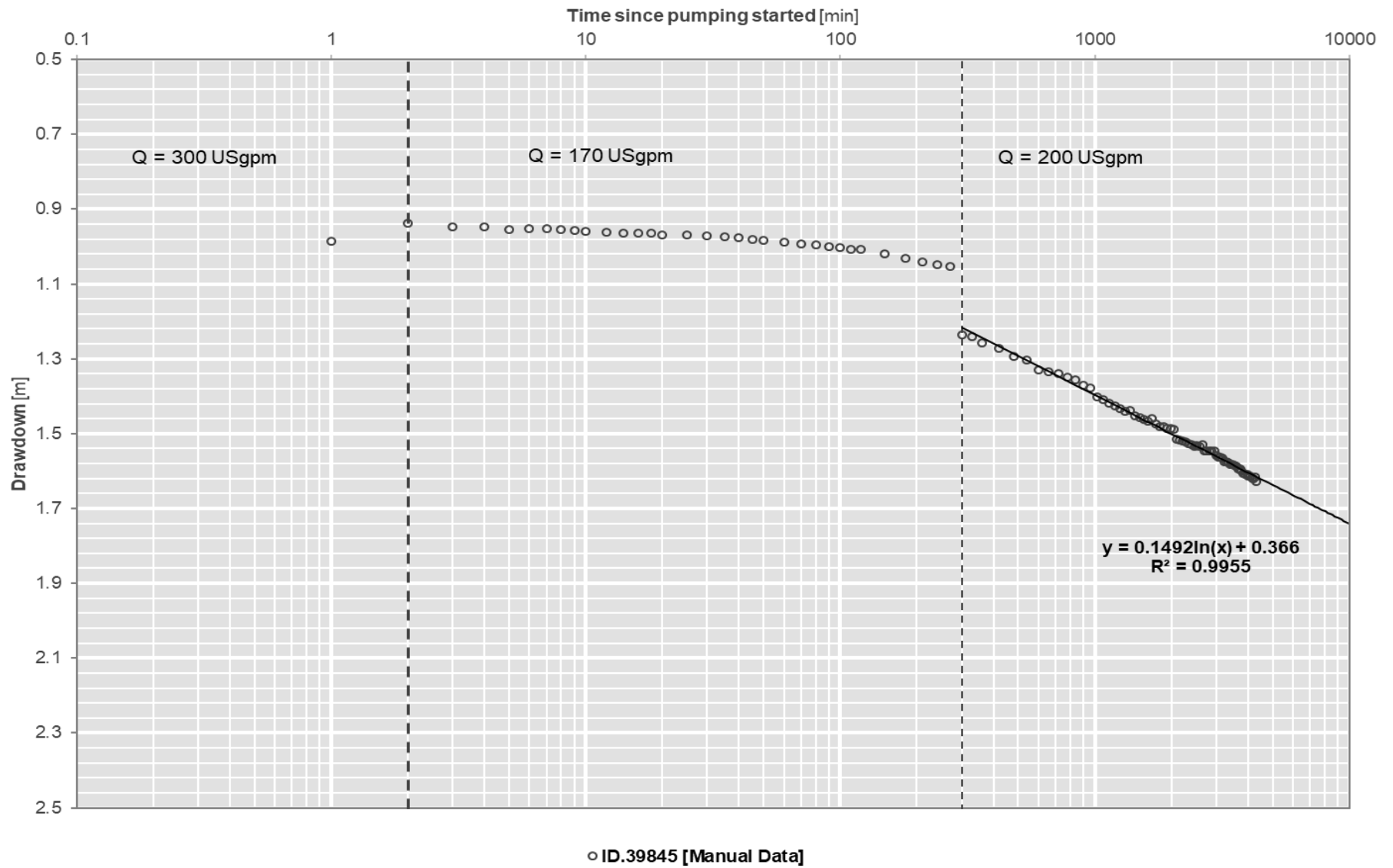


Dennis A. Lowen, P. Eng. P. Geo.

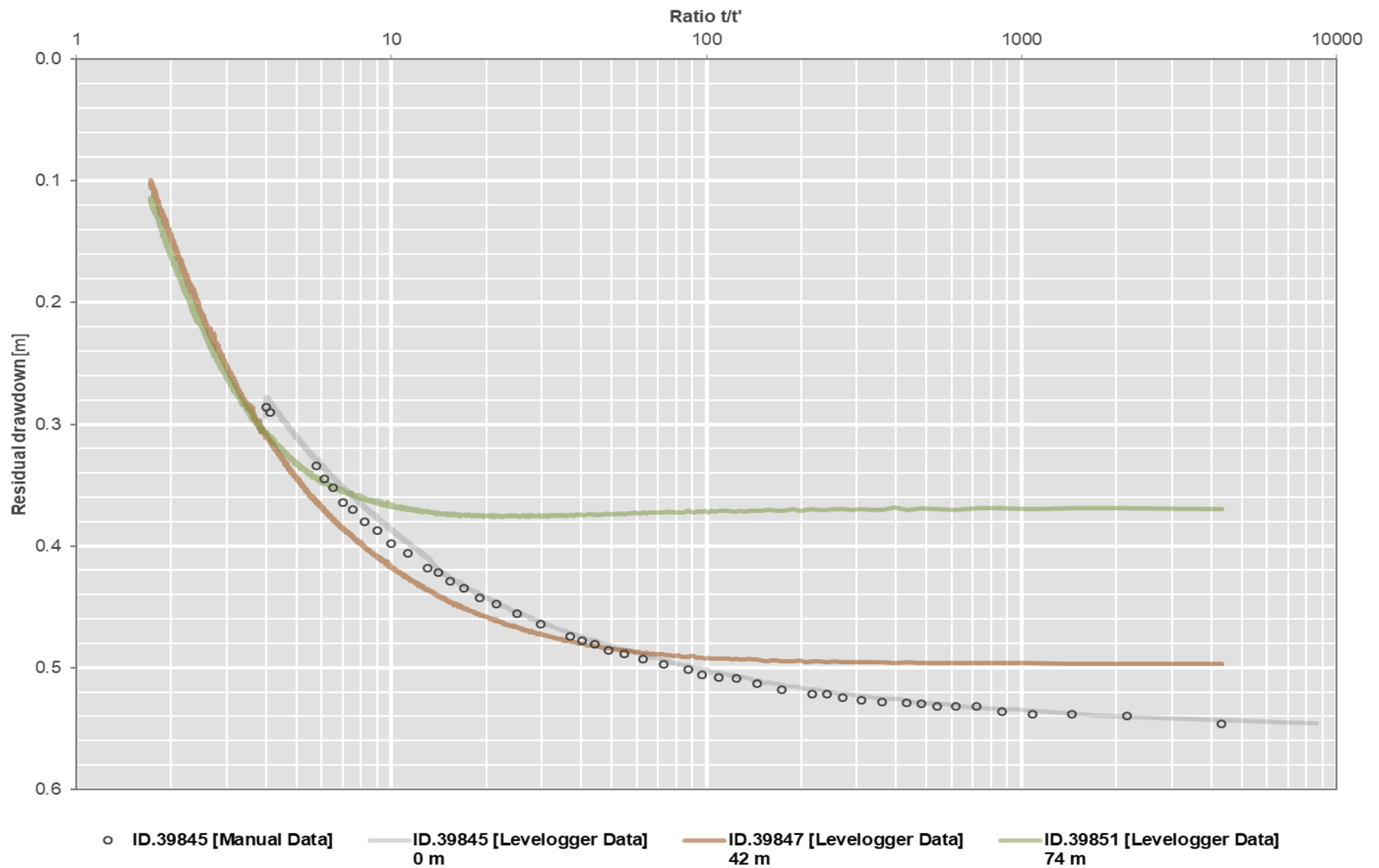
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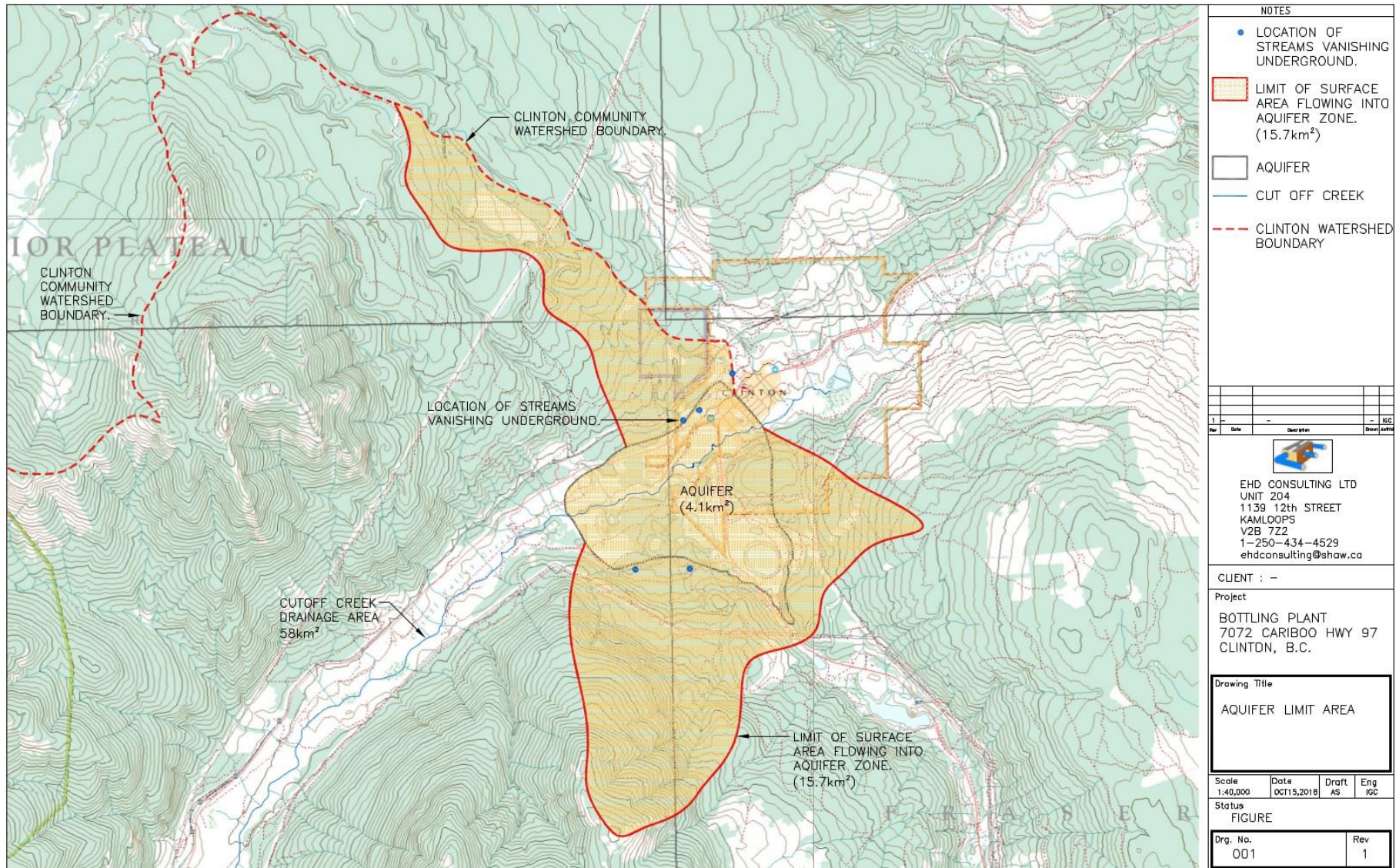
Attachment 1



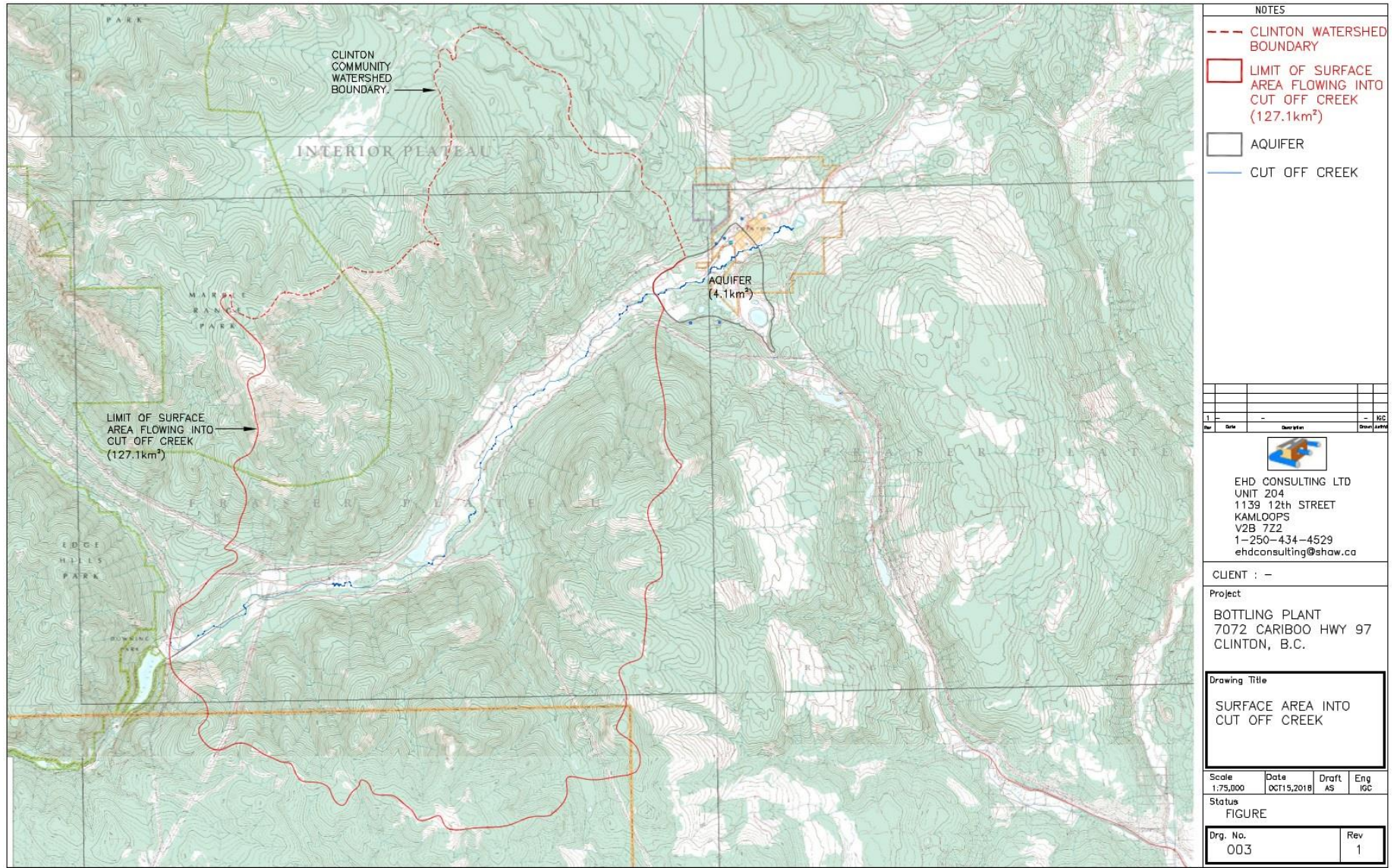
Attachment 2



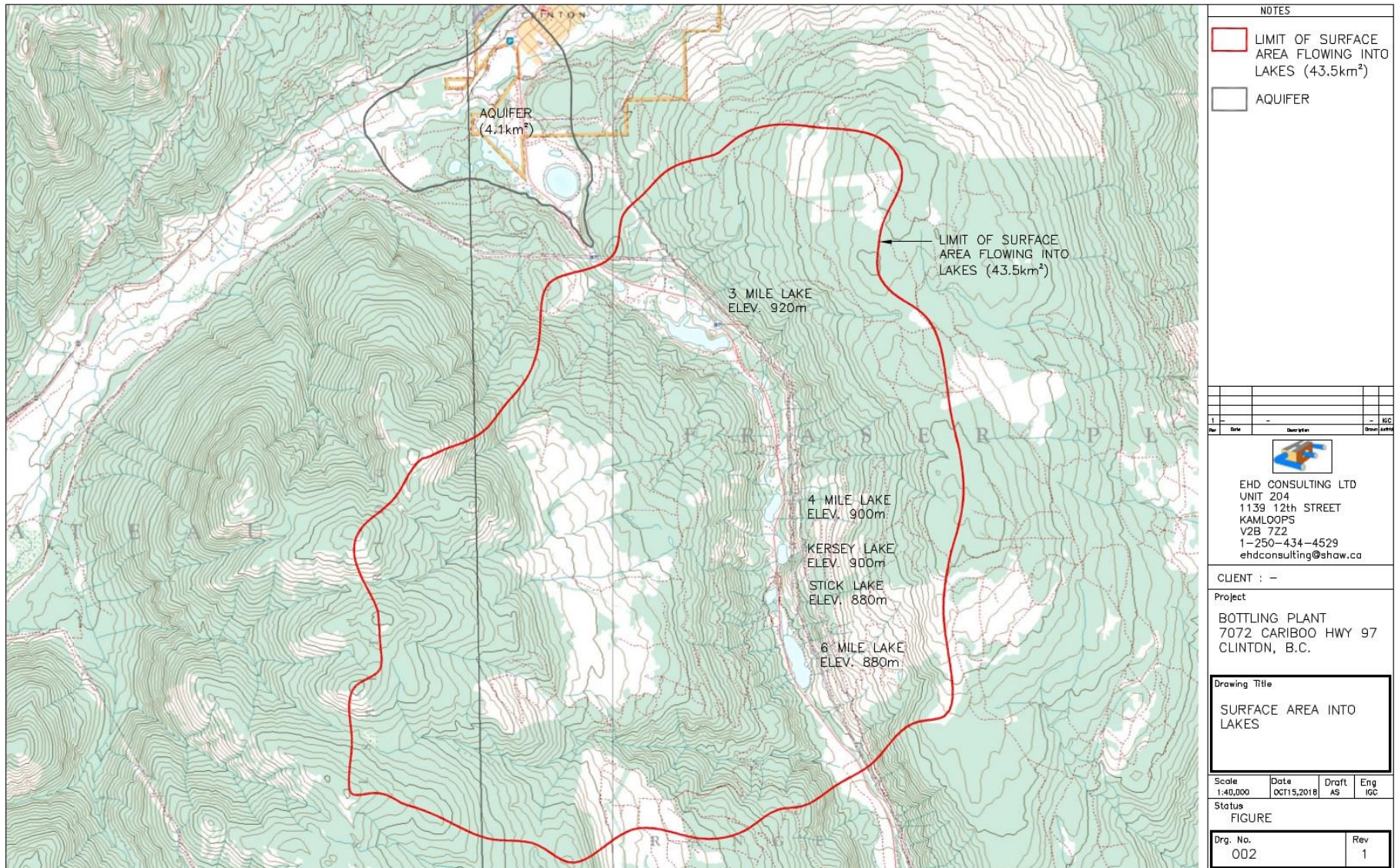
Attachment 3A



Attachment 3B



Attachment 3C



Attachment 4

Hydraulic Conductivity				
Materials	AVI Code	AVI 'K' (m/d)	Our Code	Our 'K' (m/d)
gravel	A	1000	A	1000.000000
coarse sand *			B	100.000000
gravel & sand			B	100.000000
gravel, sand			B	100.000000
sand & gravel *			B	100.000000
sand, gravel *			B	100.000000
sandy gravel			B	100.000000
gravel, sand, silt *			C	10.000000
gravelly sand			C	10.000000
medium sand			C	10.000000
sand	B	10	C	10.000000
fine sand *			D	1.000000
fine sand, gravel *			D	1.000000
silty gravel			D	1.000000
silty sand	C	1	D	1.000000
silty sand & gravel *			D	1.000000
very fine sand			D	1.000000
gravelly silt			E	0.100000
clayey gravel			E	0.100000
clayey sand			E	0.100000
clayey sand & gravel			E	0.100000
sandy gravelly silt			E	0.100000
sandy silt			E	0.100000
silt	D	0.1	E	0.100000
clayey silt			F	0.001000
gravelly till			F	0.001000
sandy gravelly till			F	0.001000
sandy till			F	0.001000
clayey till	G	0.00001	G	0.000010
silt, gravel, clay			G	0.000010
silt, sand, clay	G	0.00001	G	0.000010
silty sand, gravel, clay			G	0.000010
till/hardpan			G	0.000010
clay	H	0.000001	H	0.000001
gravelly clay			H	0.000001
sandy clay			H	0.000001
silty clay			H	0.000001