
MEMORANDUM

TO: Ian Chadwick, EHD Engineering Ltd.

E-MAIL: ehdconsulting@shaw.ca

FROM: Dennis Lowen LHC Project: 1818

DATE: July 11, 2018

RE: Request for information from FLNRO regarding Crystal Clinton Bottling Plant Well

OF PAGES: 15

Message:

In their review of the Water License Application the BC Ministry of Forests, Lands and Resource Operations (FLNRO) and residents have raised concerns about the well water supply sustainability and potential impact on surface and groundwaters. An assessment of impacts and sustainability for the proposed well water abstraction is provided herein.

Firstly, our well testing methodology meets the requirements of the document "Guidance for Technical Assessment Requirements in Support of an Application for Groundwater Use in BC", 2016. Our testing and analysis has exceeded the guideline minimums in several critical aspects including; length of pumping test (72-hours vs. 24-hours), test pumping rate greater than the proposed long-term pumping rate and number of observation wells (4). Ample data was collected to make the analysis and conclusions presented. The subject well can produce the volume of water required with acceptable impacts to existing wells or surface water bodies.

Water Supply Sustainability

The subject well (Well ID #39845) is completed in the mapped Aquifer #0921. The aquifer was mapped by W. S. Hodge in 2000 with assistance from LHC. The aquifer is fan shaped, located SW of Clinton and covers 4.1 Km² in area. The aquifer mapping worksheet is attached at Attachment 1A. A summary of Aquifer features are as follows:

Table 1

Aquifer No. 0921 - Classification - IIIC	
Aquifer Material	Sand and Gravel
Demand	Low
Productivity	Moderate
Vulnerability	Low
Quality Concerns	None
Quantity Concerns	None
Type of Water Use	Domestic
Confined or Unconfined	Confined

The IIC Aquifer Classification denotes a lightly development, low vulnerability aquifer. The assessment of low vulnerability (to contamination from surface sources) has been made because the aquifer is protected by an overlying layer of impermeable clay and/or till. The clay or till layer was absent at the subject well site but this is an isolated occurrence as most well records indicated a thick confining layer overlying the aquifer water bearing layer. It is common for a confined aquifer to have some "windows" where the confining layer is absent.

Aquifer #0921 is recharged (replenished) by precipitation (rainfall and snow) via several different routes:

- By infiltration of precipitation falling directly on top of the aquifer.
- From mountain side creeks that flow to the edge of the aquifer then infiltrate into the soils (see Attachment 1B).
- From upward flow of groundwater originating in the underlying fractured bedrock (Mountain Block Recharge). The well water TDS of 882 mg/L indicates bedrock recharge.

An approximate annual recharge volume can be calculated as follows:

Direct Infiltration

Total Precipitation (m.) X % Precipitation Infiltrates X Area (m²)

$$0.350 \times 0.10 \times 4,100,000 = 143,500 \text{ m}^3/\text{year}$$

Mountain Side Runoff

The aquifer recharge attributed to runoff from the upslope mountain terrain has been estimated by examining well records near the upslope boundary. Groundwater flow at the boundary was estimated using the standard Darcy flow equation:

Q = T I L Q - Flow (m³/d)
 T - Aquifer transmissivity
 L - Length of aquifer section

Q = 30 (0.012) 15,000 Q = 5400m³/day or 1,971,000m³/year

Mountain Block Recharge

The mountainous area surrounding Aquifer 0921 with potential for providing recharge is approximately 215 km² (see Attachment 1C). These highlands receive at least 350 mm. of precipitation yearly and an estimated 10% of this infiltrates rock fractures. The estimated bedrock recharge is then:

$$0.1 \times 0.350 \text{ m.} \times 215,000,000 \text{ m}^2 = 7,525,000 \text{ m}^3/\text{yr.}$$

We estimate 50% of this flow recharges Aquifer 0921 and 50% joins the deeper bedrock flow system likely moving northeast in the Bonaparte Watershed. Therefore, we estimate mountain block recharge to Aquifer 0921 as:

$$0.5 \times 7,525,000 = 3,762,500 \text{ m}^3/\text{year}$$

Total Estimated Aquifer Recharge

Direct Infiltration	-	143,500
Upslope Runoff Infiltration	-	1,971,000
Mountain Block Recharge	-	3,762.500
Total Recharge	-	<u>5,877,000 m³/year</u>

Water Volume Balance

The proposed well production is approximately 200 USgpm (12.6 L/s) or 397,929 m³/year. This represents $\frac{397,926}{5,877,000} \times 100 = 6.8\%$ of the aquifer flow. Considering the low overall demand on the aquifer this is a sustainable scenario.

Climate Change Consideration

Climate change is occurring and is being studied in B.C. and globally. We have referred to; BC MOE Reporting, Indicators of Climate Change for BC, 2016 update. In general, it is becoming warmer and wetter in SW British Columbia. This trend is expected to continue. Annual average precipitation increased by 17%. Therefore, in the long-term precipitation is increasing by $17 / 113 = 0.15$ percent per year.

In the study area, Aquifer 0921 and upslope watershed region, the potential area contribution to aquifer recharge is 215,000,000 m². Total annual precipitation on this area is 350 mm x 215,000,000 = 75,000,000 m³. Considering that this water volume is expected to increase on average 0.15 percent per year that equates to 112,500 m³ of water. Therefore, every 4 years the annual water budget is increasing by a greater amount than the proposed discharge (397,926 m³/yr.). This is another fact supporting the sustainability of the proposed groundwater abstraction.

Long Term Water Level Monitoring in Aquifer 0921

The Province (Ministry of Environment) established a groundwater observation well in aquifer 0921 in 1967. The Well (OW 080) is located on the east side of Highway 97 adjacent to Salt Lake. The water level monitoring summary for this observation water well is provided in Attachment 2A. Overall, the aquifer water levels have been stable for the past 40 years ranging between 4.6 - 5.2 m. below ground. The annual (2017 - 2018) chart with historical median data indicates water levels are highest between February - July and at minimum levels August through to January. The higher levels correlate with the spring frechette and early summer rainfall. Rainfall in Clinton is highest in June and July. Considering the above the subject well test, carried out in late November 2015, occurred at a time of minimum recharge to the aquifer. Therefore, the well yield estimate from the test is conservative.

Well long-term Capacity and Proposed Pumping

As seen in the LHC report (2015) the calculated well capacity is 504 USgpm (2,750 m³/d). It is proposed that the well be pumped at approximately 200 USgpm (1,090 m³/d) or 40% of the well capacity. Pumping the well at significantly less than the well and aquifer capacity will help ensure sustainability over the long-term.

Aquifer Water Levels Drawdown Impacts

The proposed groundwater pumping will lower aquifer water levels in the vicinity of the well. The magnitude of this impact can be determined from analysis of the pumping test data. A distance - drawdown graph is provided in Attachment 3. The graph presents the 200 USgpm pumping test drawdown and extrapolated impact at 100 days.

From the graph, water level drawdown can be determined for any point within the drawdown cone. The graph indicates impact at 100 days of pumping is less than 1.0 m. at a 100 m. offset from the pumping well. This indicates impacts will be acceptable at any neighbouring wells. The nearest neighbouring well is located 294 m. north of the proposed production well.

Surface Water Impacts

The main creek in the study area is Cutoff Valley Creek located 1005 m. north of the proposed pumping well. Water wells along the creek indicate the aquifer is confined near the creek. Well 109358, located 140 m. north of the creek, encountered an 18.3 m. thick till layer between elevations 908 and 889 m. The creek elevation next to this well is 903 m. indicating the creek is cut into the confining layer. The aquifer water level is also at 898 m. Therefore, the aquifer is not recharging the river at this point. Considering the impermeable barrier between the creek and the aquifer plus very small aquifer water level change due to pumping (0.4 m. maximum, see Attachment 4) no measurable impact on the creek is expected.

Duck Lake situated 50 m. west of the proposed pumping well, has also been considered. During the November 2015 pumping test, the lake was frozen, so water level monitoring was not possible. However, during pumping at the test well, at the same site, lake levels were measured during the 3-day test at 85 USgpm in June 2015. The lake level did not respond to the pumping.

Approximate elevations (from GPS and Google Earth) indicate the groundwater level at the proposed production well is slightly higher than the Duck Lake surface water level. This relationship was also confirmed with more accurate surveys during the June 2015 well testing. The lake is fed by groundwater or it can be inferred that the lake is an expression of the groundwater table. Lowering the water table beneath the lake could impact the lake level. The estimated 100-day drawdown beneath the lake ranges from 0.6 to 1.0 m. (see Attachment 4) considering the 550 m. length of the lake.

Considering the worst-case scenario if the well pumping reversed the groundwater flow from Aquifer to Lake to Aquifer infiltration induced through the lake bottom. The sand-silt-clay lake sediments have a hydraulic conductivity of $K = 0.0001$ m/d.

Considering the 100,000 m² lake area it would lose $Q = K \cdot i \cdot A \Rightarrow 0.0001 \times 1 \times 100,000 = 10$ m³/d. The loss of that water could be made up by diverting water from the well to the lake, if necessary. A small flow of 10-50 m³/d could maintain the lake level. Lake levels should be monitored to determine if this strategy is warranted.

Geology/Cross-Section

A cross-section has been constructed to better illustrate the relationship between the subject well, aquifer 0921 and the local creek (Cutoff Valley Creek). The cross-section location plan is attached as Attachment 4A and the cross-section as Attachment 4B. The section begins just above the aquifer boundary and trends to the North crossing the creek and a short distance up the north side of the Creek Valley. The section illustrates the separation of the creek from the aquifer and that in this section the creek is not fed by the aquifer. The creek is at higher elevation than the aquifer.

A small drawdown impact in the aquifer (along the creek) of less than 0.5 m. (Attachment 3) cannot have a measurable impact on the creek flow. A thick confining layer separates the creek and aquifer flowpaths.

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,



Dennis A. Lowen, P. Eng., P. Geo.
DL/hr

Attachment 1A

AQUIFER CLASSIFICATION WORK SHEET

DATE: February 13 and March 30, 2007.

AQUIFER MAPPER: William S. Hodge, P. Geo.

AQUIFER LOCATION: Clinton, BC.

AQUIFER NUMBER: 921.

NTS MAP SHEET: 092P/4

BCGS TRIM MAP: 092P.003.

CLASSIFICATION: IIIC

RANKING VALUE: 8

Aquifer Size:

4.6 km².

Aquifer Boundaries:

This unconsolidated aquifer was delineated based on well log lithology and topography. Because the aquifer is associated with a low degree of certainty a dashed line has been used to define all boundaries.

Geologic Formation (overlying):

Well records indicate that clay or till overlies the entire unconsolidated aquifer.

Geologic Formation (aquifer):

Glaciofluvial or glaciolacustrine deposits.

Major Aquifer System Type:

4b. Confined sand and gravel aquifer of glacial origin (glaciofluvial or glaciolacustrine).

Confined / Partially Confined / Unconfined:

Confined.

Attachment 1A

Vulnerability:

Low. The vulnerability of this unconsolidated aquifer is considered low. The few well records available indicate that clay or till overlies the entire aquifer. Thickness of confining material ranges between 6.1 and 150.0 m (20.0 and 492.0 ft). The average, median and geometric mean thickness of confining material has been determined as 73.9, 71.3 and 30.0 m (242.5, 234.0 and 98.6 ft). Confining material appears much thicker at lower elevation towards the centre of the Clinton townsite.

Productivity:

Moderate. The productivity of this unconsolidated aquifer is considered as *moderate*. Reported estimated well yields range between 0.25 and 3.1+ L/s (4.0 and 50+ USgpm). The average, median and geometric mean estimated well yields have been determined as 1.2, 0.63, and 0.70 L/s (18.5, 10.0 and 11.1 USgpm) respectively. All wells appear to be completed open-ended without designed well screens. If wells were completed with designed well screens productivity would undoubtedly improve (improved efficiency). Examination of lithology suggests this could be a very productive aquifer. Although wells located in the area of productive well 092P.002.4.4.2 #2 have been reported as dry, it appears if the drilling contractor had continued drilling deeper; a productive confined aquifer would have been encountered. Reported well yields are based on short-term air tests and are not considered as reliable as long-term pumping tests.

Depth to Water Table:

Shallow. Reported groundwater levels range between 0 (ground level) and 47.2 m (155.0 ft.) below ground level. The average, median and geometric mean depth to groundwater is 20.2, 16.8 and 3.5 m (66.2, 55.0 and 11.6 ft.) respectively. As groundwater levels vary seasonally, these measurements likely do not represent local water table conditions throughout the year.

Direction of Groundwater Flow:

There is insufficient data to determine the direction of groundwater flow. Groundwater is anticipated to follow the topographic gradient from high elevation to low elevation.

Recharge:

Wells are recharged from the infiltration of precipitation (rain and snow).

Domestic Well Density:

Low. There are 0.76 domestic wells per km² reported. There may be more wells in this aquifer than indicated.

Attachment 1A

Type of Well Use:

Domestic and MoE long-term observation well (note *Comments).

Reliance on Source:

Well water is the only reported source of water for domestic use.

Conflicts Between Users:

None documented.

Quantity Concerns (type, source, level of concern):

None documented.

Quality Concerns (type, source, level of concern):

None documented.

***Comments:**

For the purpose of standardization and to achieve all objectives of the aquifer mapping program, the document *Guide to Using the BC Aquifer Classification Maps* (Berardinucci and Ronneseth, 2002) was referenced in the preparation of this worksheet.

*Observation Well No. 80 was obtained from the Federal Government by the MoE in the late 1960's or early 1970's. The well was equipped with an F-68 type chart recorder and groundwater level information has been collected continuously since the early 1970's by the Ministry of Environment (MoE). Pumping interference from neighboring wells was noted on the data in the 1980's

In January 2004, this monitoring equipment was replaced with a Thalamedes data logger by Regional MoE staff in Kamloops.

The well was last sampled for water quality information in 2005. Further information on this well is available from Regional MoE staff Laurie Lyons at 371-6280 or Laurie.Lyons@gov.bc.ca

References:

Berardinucci J. and K. Ronneseth, 2002. *Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater*. BC Ministry of Water, Land and Air Protection, Water, Air and Climate Change Branch, Water Protection Section.

Attachment 1A

AQUIFER CLASSIFICATION AND RANKING**AQUIFER LOCATION:** Clinton, BC.**AQUIFER NUMBER:** 921.

CLASSIFICATION: IIIC**RANKING VALUE:** 8

Classification Component:**Level of Development:** Low. Low level of demand in relation to moderate aquifer productivity.**Level of Vulnerability:** Low level of vulnerability to surface contamination.**Ranking Component:****Ranking Value**

Productivity:	2
Vulnerability:	1
Size:	2
Demand:	1*
Type of Use:	2
Quality Concerns:	0
Quantity Concerns:	0
<u>Total =</u>	8

* Demand is based on domestic well density, number and type of wells, and general knowledge of well use and land use in the area. Demand assumes that the reported well capacity is the amount of water used, which can be misleading. The reported well capacity can be higher than actual use.

Number of water wells = 4

Attachment 1A

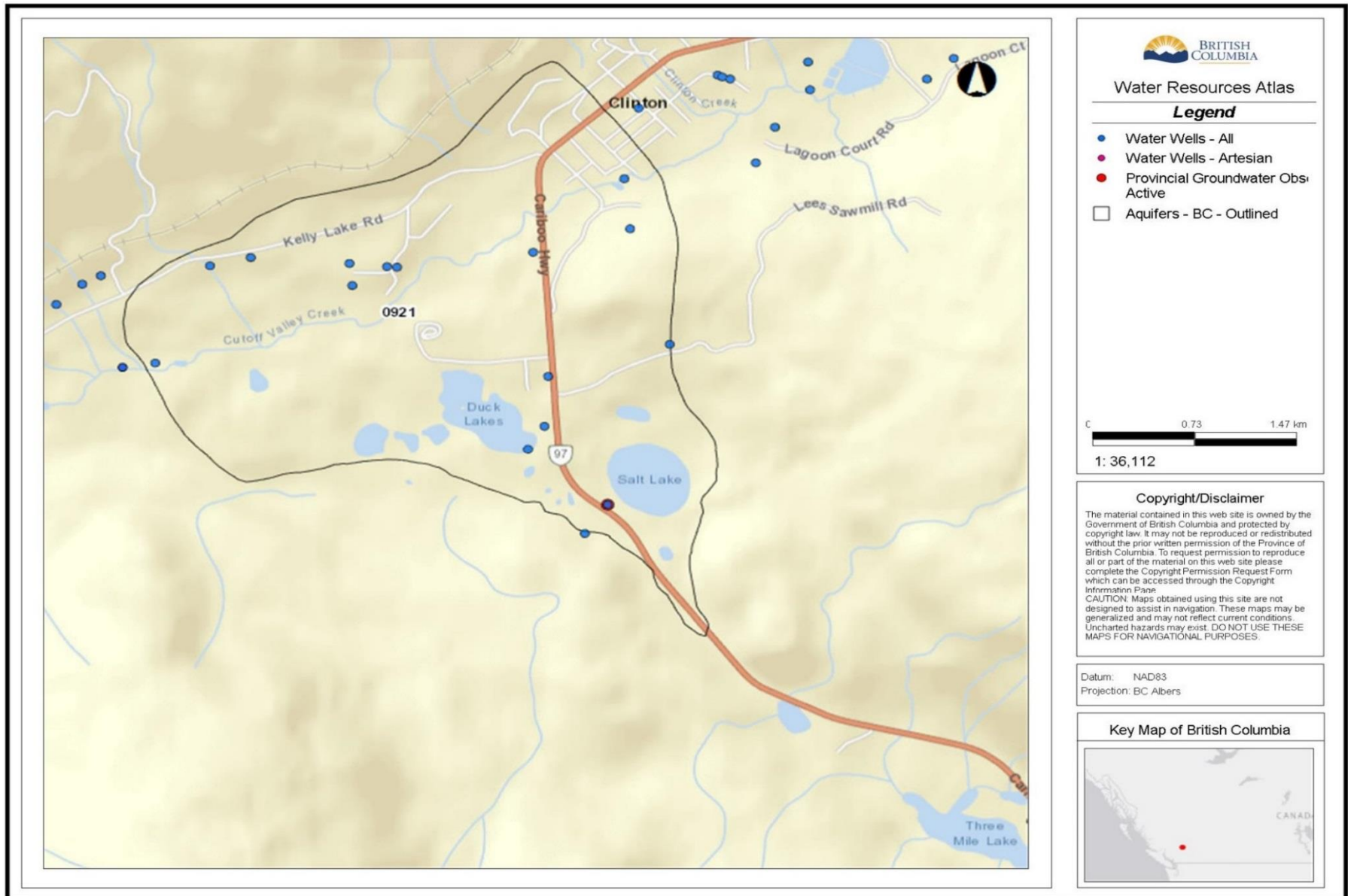
Statistical Analyses of Well Data = Aquifer 921

	Well Depth		Depth to Water		Depth to Bedrock		Reported Est. Well Yield		Est. Thickness of Confining Materials	
	m	ft	m	ft	m	ft	L/s	USgpm	m	ft
Number of Wells	4	4	4	4	unk	unk	4	4	4	4
Maximum	151.2	496.0	0.0	0.0	unk	unk	3.1+	50.0+	147.8	482.0
Minimum	9.1	30.0	47.2	155.0	unk	unk	0.25	4.0	6.1	20.0
Average	79.6	261.3	20.2	66.2	unk	unk	1.2	18.5	73.9	242.5
Median	79.0	259.5	16.8	55.0	unk	unk	0.63	10.0	71.3	234.0
Geometric Mean	41.7	136.7	3.5	11.6	unk	unk	0.70	11.1	30.0	98.6

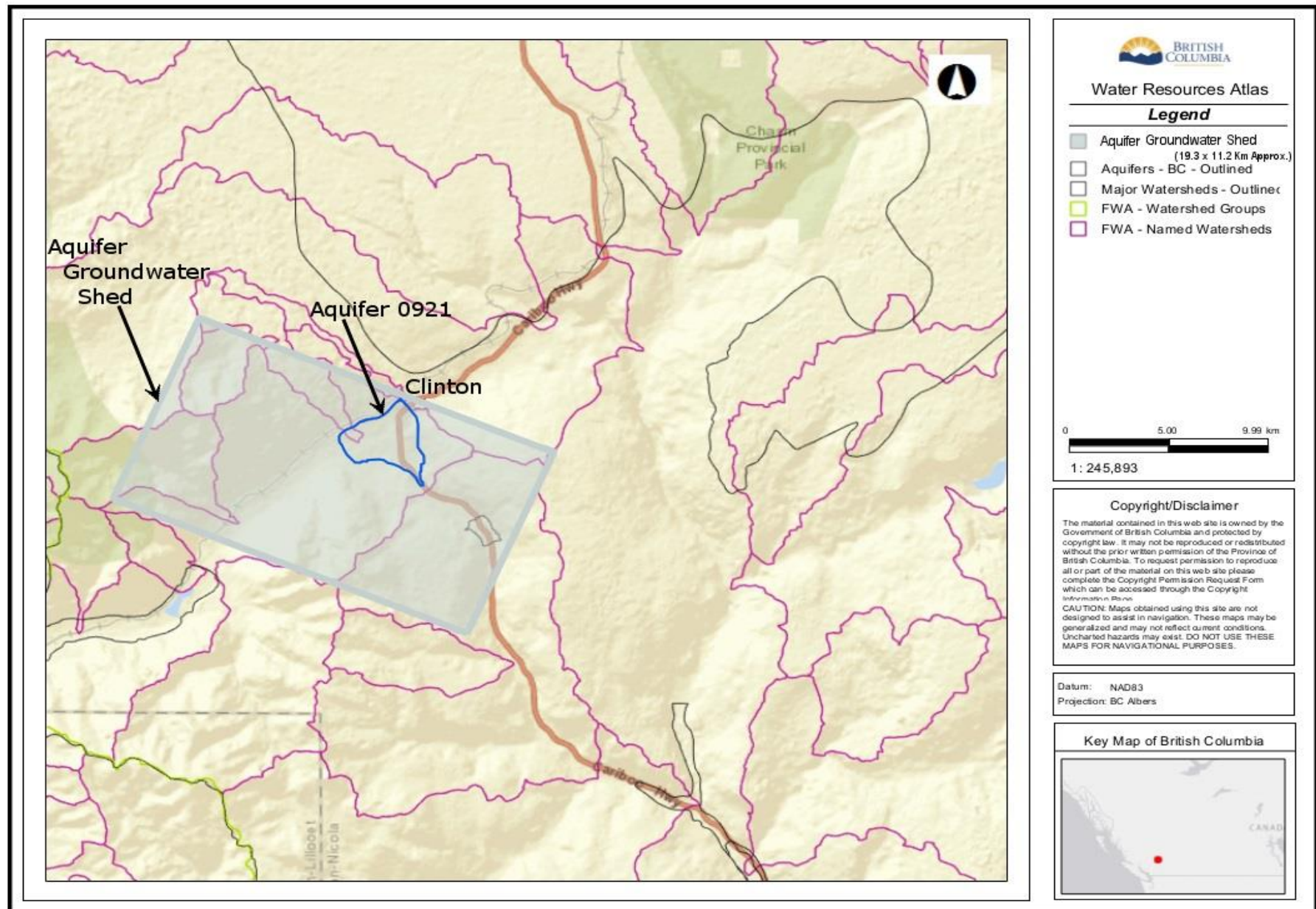
unk = not reported

- = insufficient data

Attachment 1B

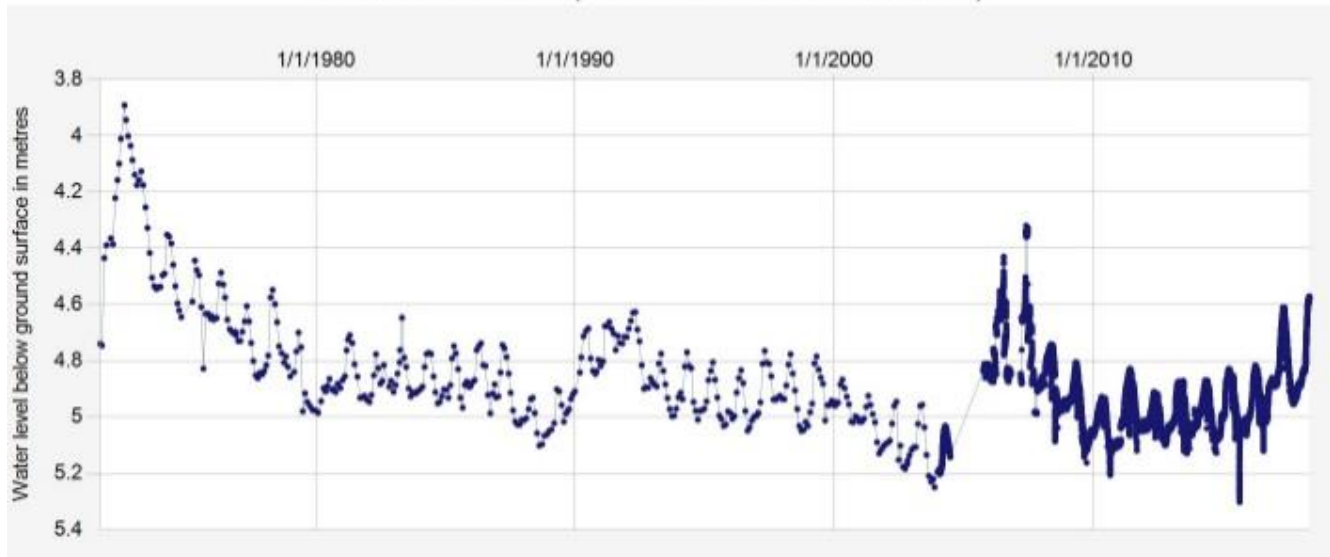


Attachment 1C



Attachment 2

OBS WELL 80 - CLINTON (RODEO GROUNDS CARIBOO HWY 97N)

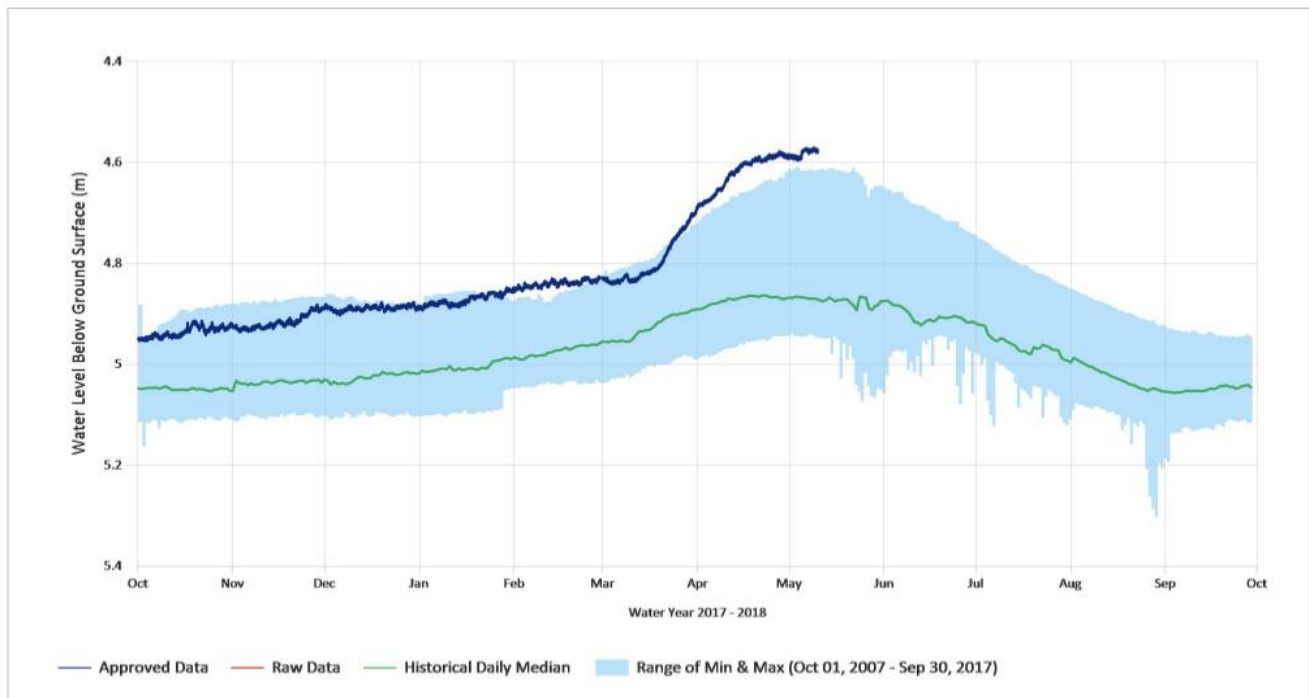


Groundwater Level Statistics Chart

Plot created: June 28, 2018 03:29

OW080: OBS WELL 80 - CLINTON (RODEO GROUNDS CARIBOO HWY 97N)

Latitude: 51.071945 Longitude: -121.585038



The statistics (median/min/max) are based on the previous 10 years of available data prior to the current Water Year

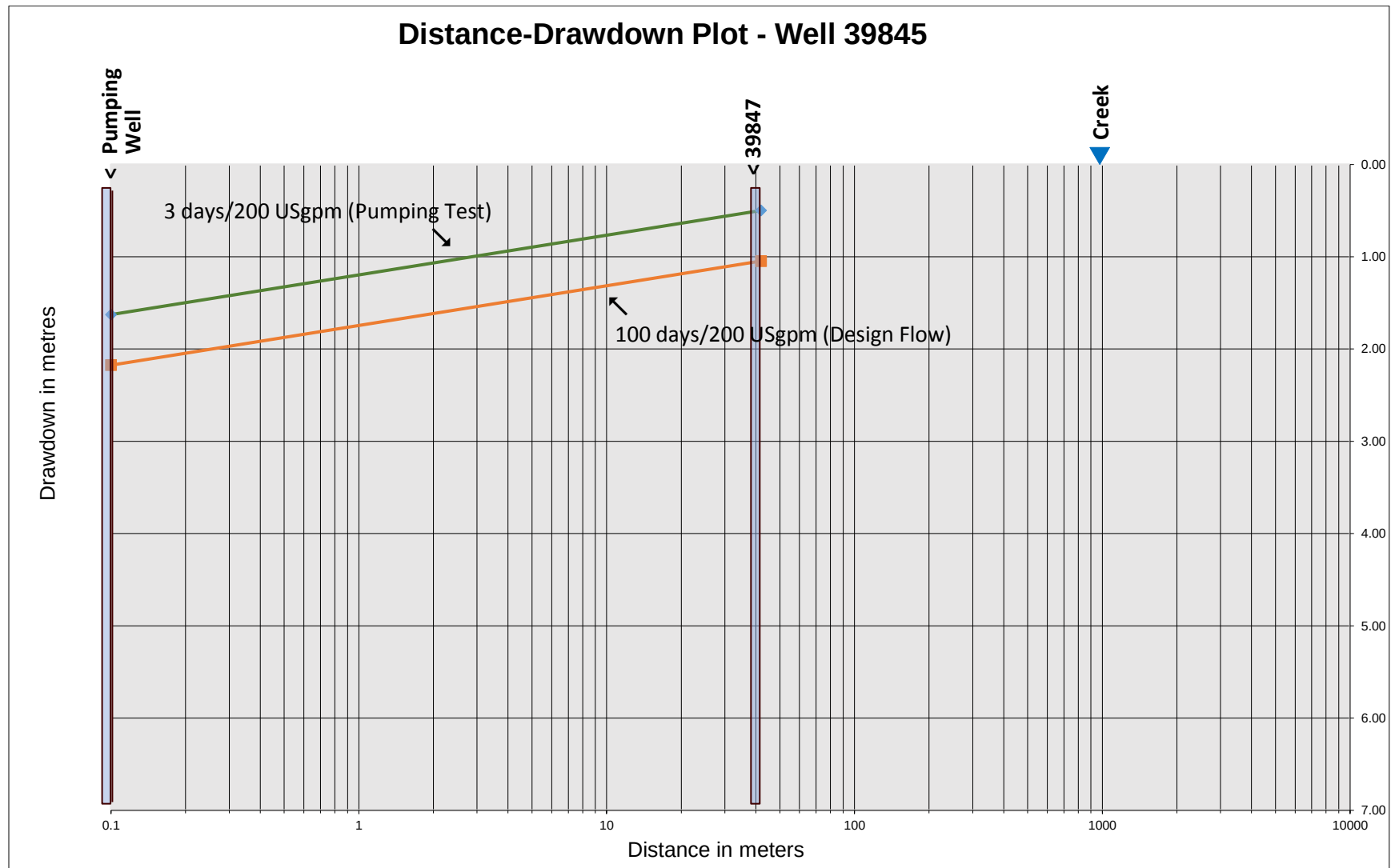
Data last appended: May 10, 2018 07:00 UTC-08:00

The statistics (median/min/max) are only displayed for wells with at least two years of data

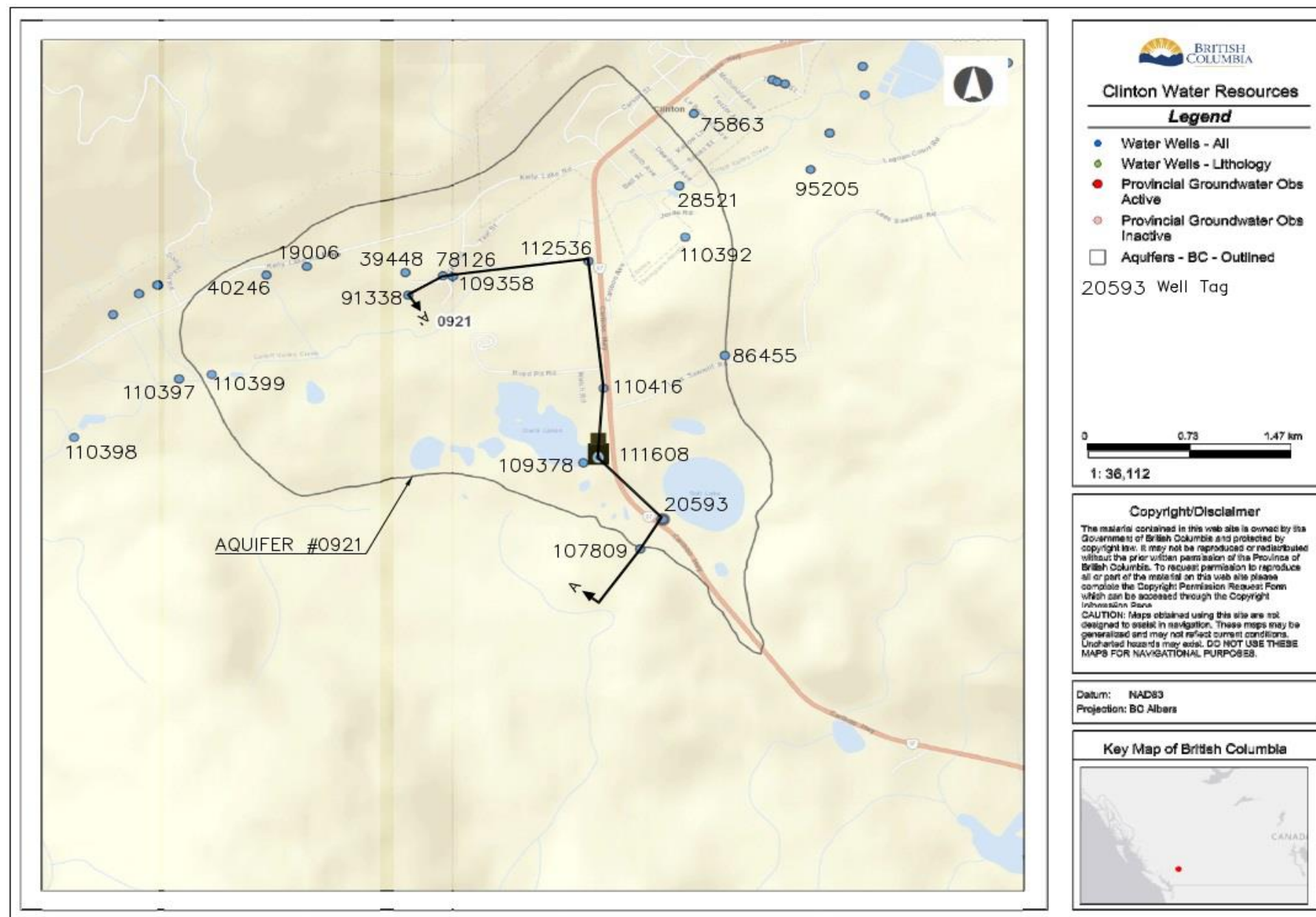
The Groundwater Level Statistics Chart is only available for Active Wells

Status: Active

Attachment 3



Attachment 4A



Attachment 4A

