

EHD Consulting Ltd.
#204-1139 12th Street
Kamloops, BC
V2B 7Z2

03 July 2015

Clinton Hongyang Zhengong International Investment Inc.
Attn: Jane Wang
7029 Cariboo Highway
PO Box 10
Clinton, BC V0K 1K0

Dear Mrs. Wang

Re: Well 41015 Assessment – Proposed Mineral Water Bottling Facility, Clinton, BC

1.0 INTRODUCTION

EHD Consulting Ltd. (EHD) was retained by Clinton Hongyang Zhengong International Investment Inc. (the 'Owner') to assess the sustainable yield of a water well (Well 41015) completed at 7072 Walch Road in Clinton, BC (the 'Site'). The Owner is proposing to develop a mineral water bottling facility at the Site on the basis of using groundwater discharged from Well 41015 as source water.

The scope of work for this well assessment generally included the following tasks:

- A visual review of the Site;
- A review of available background information, including well records and well testing information;
- Pumping tests at Well 41015:
 - 6-hr step test
 - 72-hr constant discharge test
 - 73-hr recovery monitoring test
- Installation and monitoring of a staff gauge at the largest water body of the Duck Lakes, immediately West of the Site;
- Collection and analysis of sample from the Well 41015 groundwater discharge;
- Review and interpretation of pumping test data; and
- Preparation of this report.

2.0 BACKGROUND

Well 41015 completion and preliminary testing is described in the following sections.

2.1 Well 41015 Completion

During August 2014, Well 41015 was drilled and completed by Weston Water Wells Ltd. of Lone Butte, BC (Weston). A Well Construction Report for Well 41015 is presented in Appendix A. A summary of the Well Construction Report is provided in Table 1.

Table 1 – Well 41015 Completion Summary

Completion Date	06 August 2014
Completion Depth	20.4 m bg (67 ft bg)
Casing Diameter	150 mm diameter (6 inch)
Aquifer Material Description	Medium Size Gravel
Surface Seal	38 mm (1.5 inches) thick bentonite seal to 5.2 m bg (17 ft bg)
Screen Type	Telescoping, stainless steel, continuous slot
Screen Slot Opening Size	0.76 mm or 30/1000 inches (30 slot)
Screen Depth Interval	19.0 m bg – 20.4 m bg (slotted interval 19.2 m bg – 20.4 m bg)
Well Yield Estimate*	60 lgpm (72 US gpm)

Notes:

m bg – metres below grade

ft bg – feet below grade

US gpm – US gallons per minute

* - Drillers' estimate based on air lifting

2.2 Maximum Transmitting Capacity - Well 41015 Screen

The maximum transmitting capacity of a well screen is based on the manufacturer's recommended groundwater entrance velocity and the well screen dimensions and design. The well screen maximum transmitting capacity is calculated by multiplying the following:

1. Maximum water entrance velocity;
2. Well screen open area (based on slot size, screen diameter and screen construction materials);
and
3. Well screen length.

In accordance with manufacturer's recommendations and the literature on well screens, the entrance velocity of groundwater transmitted through a well screen should be limited to less than 0.3 m/s or 0.1 ft/s (Driscoll, 2003; Krusemann and de Ridder, 2000). Entrance velocities greater than 0.3 m/s result in elevated friction losses and increased potential for encrustation and calcification.

The open area of a well screen is based on the screen type, material properties (i.e., gauge and reinforcement), diameter and slot size. Although well screen open area estimates are provided in the literature on well design (Driscoll, 2003), a more accurate method is to review screen information directly from the manufacturer. Consequently, EHD contacted Weston to confirm the Well 41015 screen manufacturer. Weston procured the Well 41015 screen from Langley Welding & Machine Shop Ltd. of Langley, BC (Langley Welding). EHD contacted Langley Welding and confirmed that they typically

provide Weston with a 60 wire gauge, stainless steel screen manufactured to Johnson Screens® specifications. Langley Welding also confirmed that the screens are manufactured such that the slotted section is 1.2 m in length. A 30 slot, telescoping screen manufactured to Johnson Screens® specifications has an open area of 0.0982 m²/m (46.4 in²/ft) (Bilfinger Water Technologies, 2014).

Based on the open area (0.0982 m²/m), slotted section length (1.2 m) and the maximum entrance velocity (0.3 m/s), the maximum transmitting capacity of the Well 41015 screen is 3.5 L/s (55 US gpm).

2.3 Well 41015 Preliminary Testing

Between December 2014 and January 2015, Kala Geosciences Ltd. of Kamloops BC (Kala) assessed Well 41015 as a potential source of mineral water. The results of Kala's assessment were presented in their 26 January 2015 letter report entitled *"Preliminary Water Well Evaluation as Mineral Water Source - WIN41015 7029 Cariboo Hwy, Clinton, BC – Lot 3, Plan KAP68363, District Lot 1060, PID: 024-938-734 – Report of Findings."*

Kala's assessment generally included:

- A review of well completion details;
- An 8-hr constant discharge test at a pumping rate of 50 US gpm;
- A recovery test of unknown duration;
- Collection and analysis of a sample of groundwater discharge;
- Analysis of pumping test and groundwater quality data; and
- Report preparation.

Based on their assessment Kala concluded that:

- The long term yield (interpreted by EHD as the sustainable yield) was likely greater than 50 US gpm, but that a 24-hr constant discharge test would be required for confirmation.
- Groundwater discharged from Well 41015 was an unsuitable source of mineral water due to concentrations of total dissolved solids (1,180 mg/L), sulphate (511 mg/L), total manganese (0.558 mg/L) and dissolved manganese (0.538 mg/L) in the sample collected by Kala.

3.0 SITE DESCRIPTION AND PHYSIOGRAPHY

The Site is located immediately West of Highway 97, within the Village of Clinton boundaries. Access to the Site from Highway 97 is provided by Boyd Pit Road and Walch Road. Properties to the North include a sawmill, a lumber storage facility, and a storage yard for an auto repair facility (Jim Walch Repairs). The largest water body of Duck Lakes is located immediately West of the Site. A future wood processing facility, also registered to the Owner, is located to the South. A septic field for the future wood processing facility is approximately 60 m South-southeast of Well 41015. The Site location and surrounding properties are presented in Figure 1.

The Site is situated on a glacial terrace at the juncture of two valleys. One of the valleys (oriented South to North and containing Highway 97) terminates into Cut Off Valley (oriented East to West). The glacial terrace appears to have been modified with glaciofluvial deposits originating from the valley to the South. The Village of Clinton is generally centered about Cut Off Valley, East of intersection of the two valleys. A vertically-exaggerated Google Earth image is presented in Photo 1, attached.

Local geomorphology within the glaciofluvial fan is generally hummocky with kettle lakes (i.e., Duck Lakes and Salt Lake). The fan generally slopes down from the Southeast to the Northwest. To the North, the fan boundary consists of the South wall of Cut Off Valley.

EHD queried the iMapBC online GIS database, maintained by the British Columbia government's DataBC. Based on iMapBC, bedrock in the vicinity of the Site is classified as sedimentary rocks of the Cache Creek Complex.

4.0 BCWRA WATER WELL INFORMATION

The BC Water Resources Atlas (BCWRA) is an online database of registered water wells in British Columbia. The BCWRA is maintained by the BC Ministry of Environment's Water Stewardship Division. Prior to 2005, water well registration was voluntary. Registration of water wells in British Columbia is now mandatory as per the *Groundwater Protection Regulation* (Province of British Columbia, 2005). Consequently, the BCWRA does not represent a complete database of all water wells in British Columbia.

EHD queried the BCWRA for well records within a 1 kilometre radius of the Site centroid. A total of 4 well records were returned for the search area. The well records and a map presenting the location of each well are provided in Appendix B. A summary of the well records is provided in Table 2.

Table 2 – BCWRA Water Well Search Summary Information

Well Tag Number	20593	86455	107809	109378
Well ID Number	12813	11365	38346	41015
Owner	Ministry of Environment	L'Heureux	Jones	Clinton Hongyang Zhengong International
Year Constructed	1967	2006	2013	2014
Well Subclass	Unknown	Domestic	Domestic	Domestic
Diameter (mm)	150	150	150	150
Aquifer Material	Clean Fine Sand	Sand, Gravel	Rock	Gravel
Static Water Level (m)	3.66	19.2	32.9	9.4
Depth (m)	15.2	35.8	35.4	20.4
Well Yield (US gpm)*	5	50	50	72

Notes:

* - Driller's well yield based on visual observation.

NR – Not Reported

EHD notes that Well 41015 has been entered into the BCWRA database.

5.0 BCWRA AQUIFER INFORMATION

In addition to water well logs, the BCWRA database contains mapping from the BC Aquifer Classification System (Berardinucci and Ronneseth, 2002). Based on a query of the BCWRA, the Site is located within a mapped aquifer. An aquifer location map is presented in Appendix C. The aquifer is fan-shaped, with its major axis oriented Southeast to Northwest. The aquifer increases in width from Southeast to Northwest. Nearby Duck Lakes and Salt Lake are located within the aquifer footprint. Table 3 provides a summary of the BCWRA aquifer information.

Table 3 – BCWRA Aquifer Information

Area	4.1 km ²
Aquifer Number	0921
Aquifer Materials	Sand and Gravel
Aquifer Classification	IIIC
Demand	Low
Productivity	Moderate
Vulnerability	Low
Aquifer Ranking Value	8
Descriptive Location	Clinton
Quality Concerns	None
Quantity Concerns	None
Type of Water Use	Domestic

The IIIC aquifer classification denotes a lightly developed, low vulnerability aquifer. The aquifer ranking value is a score between 5 (least at risk) and 21 (most at risk). The ranking value is based on the aquifer's productivity, vulnerability, size, demand, water use type and known or documented water quality and quantity concerns.

6.0 PUMPING TEST METHODOLOGY

Between 5 and 6 June 2015, Ingram Well and Pump Service of Quesnel, BC (IWPS) mobilized to the site to complete a series of pumping tests. IWPS completed the following mobilization tasks:

- Disconnected and removed the Owner's pump and drop pipe assembly from Well 41015;
- Installed a Franklin pump and 7.5 horsepower motor assembly Well 41015;
- Installed 75 mm diameter drop pipe from the wellhead to approximately 3.0 m (10 ft) below grade. The drop pipe was reduced to 50 mm diameter from 3.0 m below the top of the well casing to the top of the pump. The pump was installed such that the intake was set at 18.0 m (59 ft) below the top of the well casing;
- Installed 25 mm PVC sounding tube to a depth of 16.0 m below the top of the well casing;

- Installed a 75 mm diameter cast iron pipe spool at the wellhead, complete with a gate valve, a pressure valve, a calibrated in-line flow meter, twin hose bibs, and a 75 mm diameter discharge hose adapter;
- Installed 75 mm diameter discharge hose to discharge on the marsh-like shore of nearby Duck Lake (i.e., approximately 60 m West-southwest of Well 41015. The hose was positioned to discharge into a 50 US gallon drum; and
- On 6 June 2015, measured a static water level of 10.07 m below the top of the well casing. The static water level was measured using an electronic water level meter.

Photographs of the well and discharge location are presented in Photos 2 through 4, attached.

On 6 June 2015, EHD mobilized to the Site and completed the following tasks in preparation for the pumping tests:

- Installed a staff gauge within the largest water body of Duck Lakes;
- Programmed and installed a data-logging pressure transducer (Solinst Levellogger™) within Well 41015 to record total pressure (i.e., water pressure and barometric pressure) and *in situ* temperature at the sampling rates and durations presented in Table 4; and
- Programmed and installed a data-logging barometric pressure transducer (Solinst Barologger™) at Well 41015 to record barometric pressure above the groundwater column at the well. The Barologger™ was programmed to record measurements at the sampling rates and durations presented in Table 4.

Table 4 – Pressure Transducer Sampling Rates and Durations

Sampling Rate	Start	End	Duration
5 Minutes	8:00 am 5 June 2015	6:00 am 6 June 2015	22 Hours
1 Second	6:00 am 6 June 2015	10:00 am 6 June 2015	4 Hours
2 Minutes	10:00 am 6 June 2015	6:00 am 9 June 2015	68 Hours
1 Second	6:00 am 9 June 2015	10:00 am 9 June 2015	4 Hours
2 Minutes	10:00 am 9 June 2015	10 am 15 June 2015	5 Days

The sampling rates and durations were intended to record water level data at more frequent periods near the beginning and end of the 72-hr constant discharge test and near the beginning of the recovery test.

At 9:00 am on 5 June 2015, IWPS completed a 6-hr step test which included pumping Well 41015 for 1-hr consecutive periods at successively increasing pumping rates (i.e., 60, 65, 70, 75, 80 and 85 US gpm). Throughout the step test, IWPS measured water levels using an electronic water level meter. The discharge rate was measured using the in-line calibrated flow meter. The step test was completed at 3:00 pm on 6 June 2015, and the water level in Well 41015 was allowed to recover overnight.

At 8:55 am on 6 June 2015, IWPS measured the static water level at Well 41015 to be 10.10 m below the top of the well casing. At 9:00 am on 6 June 2015, IWPS turned on the pump at Well 41015 to begin the

72-hr constant discharge test at a pumping rate of 85 US gpm. IWPS measured water levels using an electronic water level meter at regular intervals throughout the 72-hr constant discharge test.

EHD acknowledges that the step test pumping rates and constant discharge test rate exceeded the maximum transmitting capacity of the well screen. The test pumping rate was chosen to achieve drawdown magnitudes sufficient to estimate aquifer transmissivity.

During the constant discharge test, field water quality parameters were measured using a YSI 556 multi-probe system (MPS) and a HACH 2100Q turbidimeter. EHD programmed and installed the YSI 556 MPS to record groundwater discharge quality (i.e., pH, temperature, specific conductance, oxidation reduction potential (ORP) and dissolved oxygen) at 5-minute intervals. Flow from one of the hose bibs was directed, using LPDE tubing, into a flow through cell containing the YSI 556 MPS probe sensors. At regular intervals during the constant discharge test, EHD and IWPS collected samples of the groundwater discharge from the flow through cell in order to measure turbidity using a HACH 2100Q turbidimeter. Calibration records for both the YSI 556 MPS and HACH 2100Q turbidimeter are presented in Appendix D.

On 9 June 2015, EHD completed a location and elevation survey of Well 41015 and the Duck Lakes staff gauge using a total station. Elevations were calculated relative to a local datum. The elevation of the local datum was arbitrarily defined as 100.00 m. The location of the local datum station is presented on Figure 2.

On 10 June 2015 at 8:50 am, and after approximately 4,310 minutes of pumping Well 41015, IWPS collected a sample of the groundwater discharge and submitted the sample for Full Potability and UV Transmittance analyses at ALS Environmental, in Kamloops, BC.

On 13 June 2015 at 10:00 am, EHD visited the Site to retrieve the pressure transducers from Well 41015. Based on the retrieval time and the end of the constant discharge test, the pressure transducers recorded recovering water levels for a total duration of 73 hours.

7.0 PUMPING TEST RESULTS

The following pumping test results are presented in Appendix E:

- Groundwater and Surface Water Elevations – 6 June 2015 to 11 June 2015 (Table and Graph);
- Step Test Curve;
- Constant Discharge Test Drawdown Curves;
- Recovery Monitoring Results Curves;
- Field Groundwater Quality Results Curves; and
- ALS Environmental Analytical Report – Well 41015 Discharge Sample.

Electronic data recorded by the pressure transducers exhibited considerable scatter (i.e., approximately 0.04 m in magnitude) during the constant discharge test. To better interpret the constant discharge test electronic data, EHD averaged/smoothed the data as follows:

- 0 – 60 minutes of pumping – plotted average value over 39 seconds
- 60 – 500 minutes of pumping – plotted average value over 10 minutes
- 500 – 4,320 minutes of pumping – plotted average value over 78 minutes

The above averaging periods were arbitrarily selected based on trial and error.

Field groundwater discharge quality parameters recorded at the nearest measurement interval to collecting the 10 June 2015 groundwater sample from Well 41015 are presented in Table 5.

Table 5 – Well #2 Groundwater Discharge Sample Field Parameters

<u>Time Measured</u>	<u>Parameter</u>	<u>Value</u>
10 June 2015 at 8:47 am	Temperature (°C)	8.62
	Specific Conductance (µS/cm)	1,516
	pH (pH Units)	7.34
	Dissolved Oxygen (mg/L)	0.01
	Oxidation Reduction Potential (mV)	-47.4
10 June 2015 at 9:00 am	Turbidity* (NTU)	0.04

Notes

°C – degrees Celsius

µS/cm – microsiemens per centimetre

mg/L – milligrams per litre

mV – millivolts

NTU – nephelometric turbidity units

Well 41015 groundwater discharge sample was collected on 10 June 2015 at 8:50 am

The laboratory analytical results for the Well 41015 groundwater discharge sample were compared to the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2014). The majority of the *Guidelines for Canadian Drinking Water Quality* (GCDWQ) are reported as a maximum acceptable concentration (MAC) or an aesthetic objective (AO). All reported parameter values met the guidelines, with the exception of the following:

- Hardness - as CaCO₃ (812 mg/L) exceeded the AO (500 mg/L);
- Total suspended solids (1,000 mg/L) exceeded the AO (500 mg/L);
- Turbidity (0.15 NTU) exceeded the guideline for water treated with membrane filtration (0.1 NTU). The GCDWQ for turbidity applies to treated surface water and groundwater under the direct influence of surface water. Although this well assessment may provide some information regarding the source of groundwater discharged from Well 41015, it is not intended to be a conclusive study regarding whether Well 41015 is under the direct influence of surface water. Consequently, Well 41015 was assumed to be under the direct influence of surface water for the purpose of comparing the discharge sample turbidity against the GCDWQ; and
- Total manganese (0.536 mg/L) exceeded the AO (0.05 mg/L).

8.0 PUMPING TEST INTERPRETATION

The step test, constant discharge test and recovery were interpreted using the method presented in Table 6. The assumptions, equations and procedures for each of the methods presented in Table 6 are presented in Appendix F.

Table 6 – Pumping Test Interpretation Methods

Interpretation Method	Data Set
Schafer's Method for Estimating Casing Storage Effects at a Pumped Well	- Step Test - Constant Discharge Test
Hantush-Bierschenk Method	- Step Test
Jacob's Method (Drawdown at a Pumped Well)	- Constant Discharge Test
Theis Recovery (Pumped Well)	- Recovery after Constant Discharge Test
25-Year Safe Sustainable Yield	- Constant Discharge Test - Recovery after Constant Discharge Test

8.1 Casing Storage Effects

The initial removal of groundwater stored within the well casing can affect the drawdown data observed in a pumping well. Schafer's method can be used to determine the duration of this effect (i.e., from the start of pumping to the critical time at which drawdown in a pumped well is not affected by casing storage). Schafer's critical times were calculated to be less than 0.5 minutes for both the step test and constant discharge test.

8.2 Step Test

Step tests are performed for the following purposes:

- 1.) To estimate a suitable discharge rate for a constant discharge test; and
- 2.) To estimate baseline well efficiency (calculated using estimated linear and non-linear head loss coefficients).

Step test drawdown data was analyzed using the Hantush-Bierschenk method described in Appendix F. The Hantush-Bierschenk method curve, presented in Appendix G, was observed to have a negative slope. Theoretically, the curve should have a positive slope. Consequently, linear and non-linear head loss coefficients could not be estimated from both the manual and electronic step test drawdown data from Well 41015. The negatively-sloped curve is considered to be the result of error introduced by

- the accuracy of the equipment used to measure water levels (i.e., 0.01 m for the water level meter and 0.05 m for the pressure transducer); and
- relatively low incremental drawdown values (i.e., less than 0.01 m) for each step.

These relatively low drawdown values are within the same order of magnitude as the pressure transducer detection limits.

8.3 Aquifer Transmissivity

Transmissivity is a measure of an aquifer's ability to transmit groundwater. Units of transmissivity are expressed as area over time. The larger an aquifer's transmissivity, the more rapidly groundwater is transmitted through the aquifer.

Transmissivity of the aquifer at Well 41015 was calculated at each well using the methods presented in Table 6 and Appendix F. Transmissivity values calculated during the constant discharge test and recovery monitoring are presented in Table 7.

Table 7 – Aquifer Transmissivity Values

<u>Test</u>	<u>Data Set</u>	<u>Period</u>	<u>Transmissivity (m²/day)</u>
Constant Discharge Test	Manual	Between 1,700 and 4,320 minutes of pumping	464
	Pressure Transducer	Between 1,000 and 4,140 minutes of pumping	465
Recovery Monitoring	Manual	Could not be determined	N/A
	Pressure Transducer	Between t/t' values of 4 and 2	474

Notes

m²/day – square metres per day

CDT – Constant Discharge Test

REC – Recovery Test

EHD notes that the constant discharge test periods presented in Table 7 are greater than the critical times presented in Section 9.1. Consequently, these periods are considered to be unaffected by casing storage. EHD also notes that the transmissivity values presented in Table 7 meet the mathematical criteria for each applicable interpretation method (see Table 6 and Appendix F).

A value of aquifer transmissivity could not be calculated from the manually-measured recovery data due to the fact that these measurements did not continue to an extent at which a straight line could be projected in the semi-log residual drawdown vs. ratio t/t' plot (Appendix D).

The calculated transmissivity values presented in Table 7 are generally consistent. Consequently, the geometric mean of these values (468 m²/day) is considered to be representative of the aquifer's transmissivity.

Trends in drawdown data collected during constant discharge tests and recovery can provide information regarding aquifer boundaries. Aquifer boundaries are either positive recharge boundaries or negative recharge boundaries. Positive recharge boundaries provide additional recharge to the aquifer from a source more transmissive than the aquifer, thereby short-circuiting flow to the aquifer. Examples of positive recharge boundaries include surface water bodies hydraulically connected to the

aquifer, and other, more transmissive, aquifers. Negative recharge boundaries indicate a feature that is preventing recharge to the aquifer (i.e., features that bound the aquifer). No evidence of positive recharge boundaries or negative recharge boundaries was observed in the drawdown data.

8.4 Aquifer Specific Yield

Aquifer specific yield is defined as the volume of groundwater that an unconfined aquifer, or bedrock aquifer, releases from pore space (fractures in bedrock) per unit decline in the head of the water table (Kruseman and de Ridder, 2000).

Constant discharge test drawdown data from an observation well (i.e., non-pumped well) is required to calculate an aquifer's specific yield. No observation wells were monitored during the constant discharge test. Consequently, the specific yield of the aquifer at Well 41015 was not calculated.

8.5 Aquifer Conceptual Model

Based on the well construction report, the aquifer at Well 41015 is unconfined glaciofluvial sand and gravel. Based on the field groundwater quality parameters recorded during the constant discharge test, the aquifer is recharged by source groundwater observed to be:

- Slightly alkaline (i.e., pH values between 7 and 8)
- Reducing (i.e., negative ORP values, ranging between 6.3 mV and -65.8 mV);
- Highly conductive (i.e., specific conductance ranging between 1,516 $\mu\text{S}/\text{cm}$ and 1,646 $\mu\text{S}/\text{cm}$); and
- Low oxygen (i.e., dissolved oxygen concentrations ranging between 0 mg/L and 0.82 mg/L).

Based on the above, the aquifer at Well 41015 is likely recharged by bedrock, adjacent to the glaciofluvial deposits on all sides but the North. Consequently, groundwater flow within the aquifer is inferred to be North, towards Cut Off Valley.

8.6 Well Sustainable Yield

Based on the 25-year safe sustainable yield method, the well would be capable of providing a flow of up to 450 US gpm. However, the sustainable yield of Well 41015 is limited to the well screen maximum transmitting capacity of 3.5 L/s (55 US gpm).

Typically, the sustainable yield of a well is estimated based on a fall or winter pumping test based on the assumption that water levels are lowest during these seasons. However, the Well 41015 static water level does not greatly fluctuate based on the fact that the static water level reported by Kala during December 2014 (10.20 m below top of casing) was only 0.10 m lower than the static water level measured by IWPS during June 2015 (10.07 m below top of casing).

8.7 Potential for Groundwater and Surface Water Interactions

Based on the observation that there are no streams recharging or discharging from the kettle lakes within the glaciofluvial terrace, the kettle lakes are likely recharged by groundwater. This inference is supported by the fact that the 06 June 2015 static water elevation at Well 41015 was greater than the 06 June 2015 surface water elevation at the Duck Lake staff gauge. Although no positive recharge boundaries were observed during the constant discharge test, continual pumping from Well 41015 may result in groundwater/surface water interactions based on the following:

- Specific conductance decreased throughout the constant discharge test. Typically, surface water exhibits smaller values of specific conductance than groundwater; and
- The groundwater elevation at Well 41015 was drawn below the surface water level at the Duck Lakes staff gauge.

It is unlikely that pumping Well 41015 at 55 US gpm will affect domestic groundwater extraction from the aquifer at other wells within the BCWRA mapped aquifer (i.e., wells on other properties) based on the following:

- The maximum drawdown observed during the constant discharge test was relatively small (0.31 m) and drawdown at any nearby wells completed in the same aquifer would theoretically be less than this amount;
- The transmissivity of the pumped aquifer is relatively large (468 m²/day); and
- The distance from Well 41015 to the nearest mapped well (Well ID 20593) is generally large (i.e., approximately 400 m Southeast of Well 41015).

9.0 RECOMMENDATIONS

The Well 41015 sustainable yield is limited to the maximum transmitting capacity of the well screen (3.5 L/s or 55 US gpm). Well 41015 should not be pumped at a rate greater than 3.5 L/s due to the increased friction loss and potential for encrustation. Turbulent flow across the well screen will encourage manganese precipitation, resulting in decreasing efficiency and flow. Further, increased manganese precipitation will result in more frequent servicing and rehabilitation of Well 41015.

Although linear and non-linear head loss coefficients could not be estimated based on the June 2015 step test, further step testing of Well 41015 is not required at this time. This is due to the fact that the pumping rates required to produce interpretable drawdown values would exceed the maximum transmitting capacity of the well screen. Rather, pumping water levels in the well should be continually monitored throughout operation of the bottled water facility to monitor well performance.

The aquifer could provide flows up to 450 US gpm if a larger well(s) is installed. However, this estimate must be confirmed by subjecting any new well(s) to a pumping test specified by a qualified professional. Considering the potential yield, any new well(s) should be designed and constructed by a qualified professional. Further, any new well(s) should be subjected to an aquifer test that considers, at a

minimum, potential surface water interaction with the Duck Lakes, well interference and potential sources of contamination within the pumping zone of influence.

The suitability of groundwater discharged from Well 41015 for use as source water for the proposed bottling plant, as well as treatment requirements, is beyond the scope of this assessment. However, EHD reviewed and provided treatment options in a 03 July 2015 report entitled *“Water Treatment Requirements for proposed Mineral Water Bottling Plant at 7072 Cariboo Highway 97, Clinton BC, Well 41015.”*

Based on the potential for groundwater discharged from Well 41015 to be influenced by surface water, and the potential for septic field discharge in the vicinity of Well 41015, groundwater extracted from Well 41015 is potentially at risk of containing pathogens. To address this risk, EHD notes that ultra-violet treatment/disinfection was included as a treatment requirement in the 03 July 2015 letter.

10.0 CLOSURE

This report has been prepared on the basis of site observations and pumping test data collected at the time of the assessment by EHD. This report has been prepared for the exclusive use of Clinton Hongyang Zhengong International Investment Inc. and the approving bodies to which they are applying for development. EHD is not responsible for any reliance on this report by a third party.

Sincerely,

EHD Consulting Ltd.
Engineer of Record:

Reviewed by:

Matt Sarkor, P.Eng.
Hydrogeologist

Ian Chadwick, P.Eng., MICE, CEng
Owner, Principal

Attachments:

Photos 1 through 4

Figure 1 – Site Location Plan

Figure 2 – Well Location Plan

Appendix A – Well Construction Report (Well 41015)

Appendix B – BCWRA Water Well Map & Detailed Well Records

Appendix C – BCWRA Aquifer Map

Appendix D – Calibration Records – Field Water Quality Instruments

Appendix E – Pumping Test Results

Appendix F – Pumping Test Interpretation Methods

Appendix G – Hantush-Biershenk Curve

11.0 REFERENCES

- BC Ministry of Environment - Water Stewardship Division, *"Appendix 5 – Guidelines for Groundwater Reports in Support of a CPCN"*, 2010
- BC Ministry of Environment – Water Stewardship Division, *"British Columbia Water Resources Atlas"*, http://www.env.gov.bc.ca/wsd/data_searches/wrbc/
- Berardinucci and Ronneseth, *"Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater"*, British Columbia Ministry of Water, Land and Air Protection, 2002
- Bilfinger Water Technologies, *"Johnson Screens Stainless Steel Well Screens and Accessories"*, Bilfinger Water Technologies Inc., 2014.
- Driscoll, *"Groundwater and Wells – Second Edition"*, Johnson Screens, 2003
- Health Canada – Federal-Provincial-Territorial Committee on Drinking Water, *"Guidelines for Canadian Drinking Water Quality"*, 2012
- Kruseman and de Ridder, *"Analysis and Evaluation of Pumping Test Data – Second Edition"*, International Institute for Land Reclamation and Improvement, 2000.
- Province of British Columbia, *"Groundwater Protection Regulation"*, 2009.
- Province of British Columbia – DataBC, *"iMapBC"*, <http://maps.gov.bc.ca/ess/sv/imapbc>

PHOTOGRAPHS

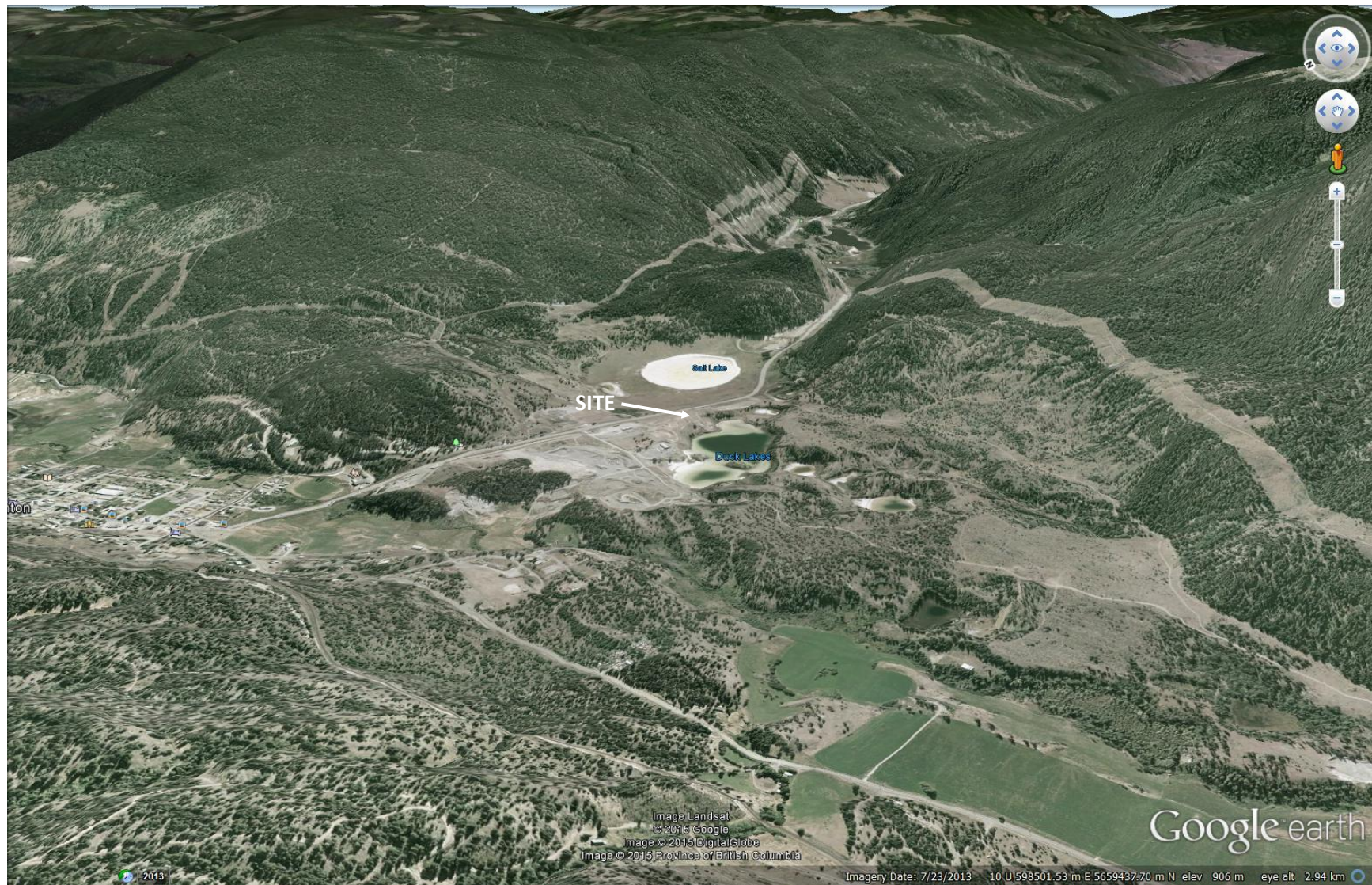


Photo 1 – Google Earth 2x Vertical Exaggeration Image – Facing Southeast



Photo 2 – Well 41015 – Facing West



Photo 3 – Well 41015 – Facing South



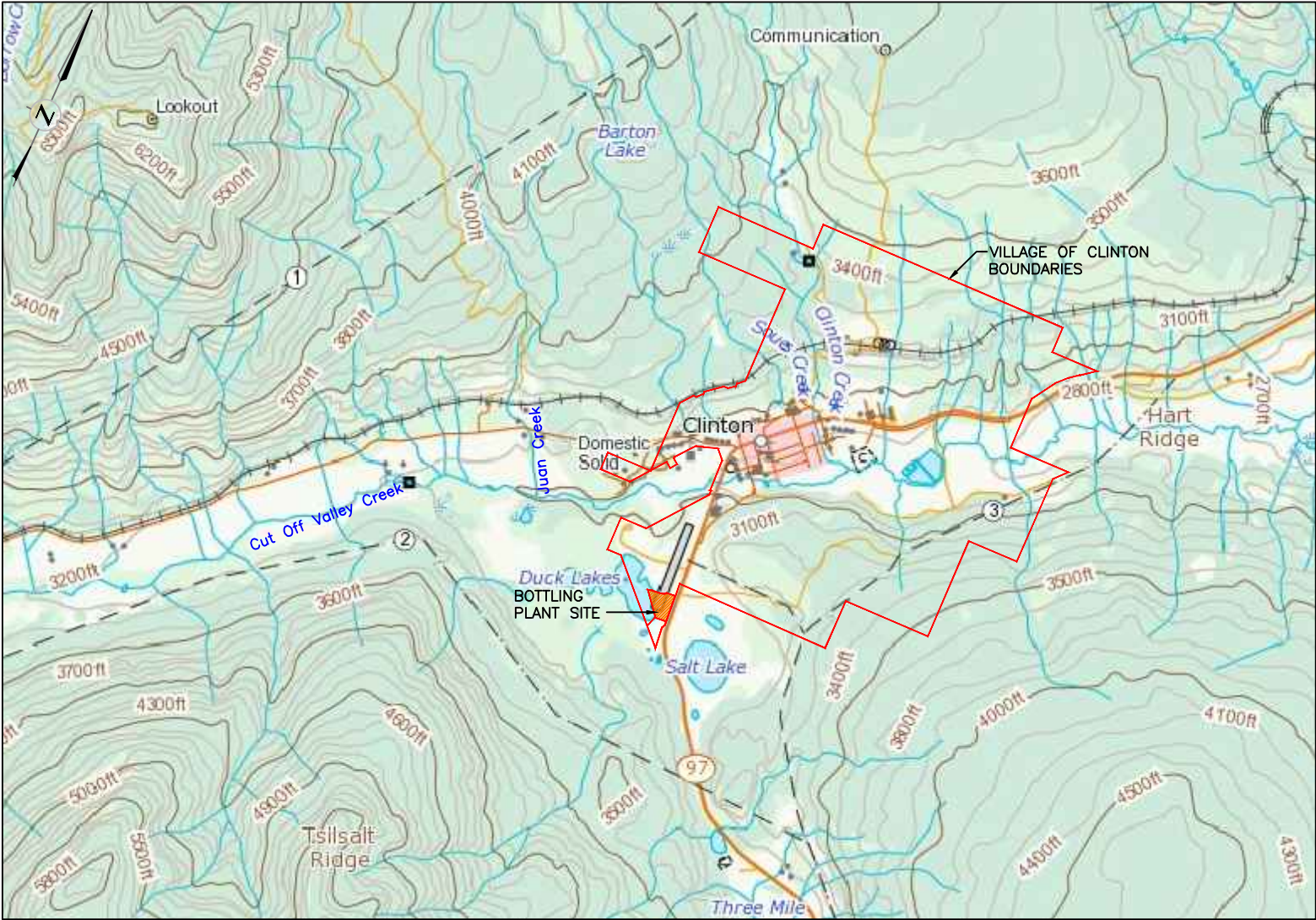
Photo 4 – Pumping Test Discharge Point – Facing Southwest

FIGURES

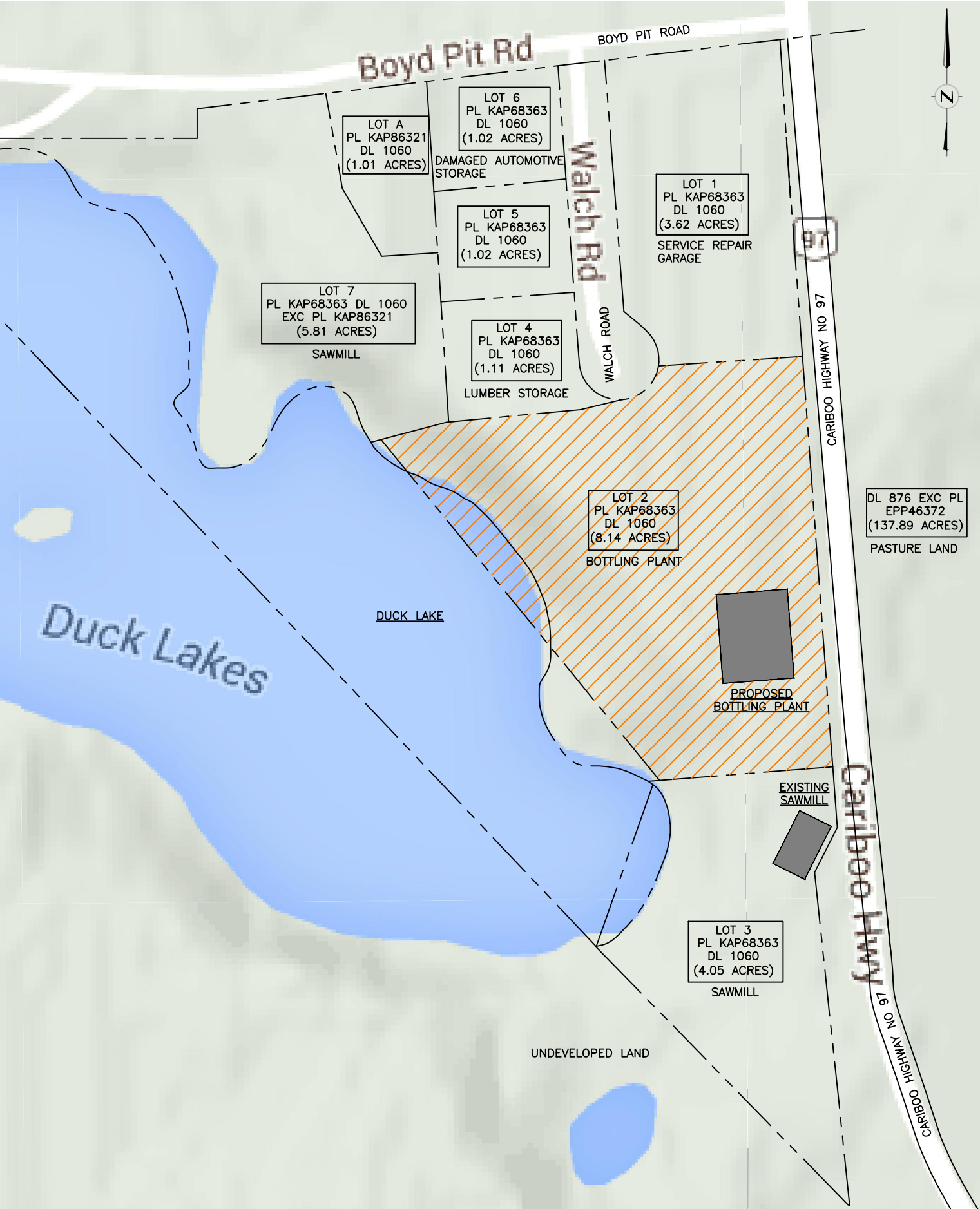


FIGURE 2
WELL LOCATION PLAN
SCALE: 1:2000

908/15
7072 WALCH ROAD
WELL 41015 ASSESSMENT
CLINTON, B.C.



SITE LOCATION PLAN
SCALE: 1:50000



ENLARGED SITE PLAN
SCALE: 1:2500

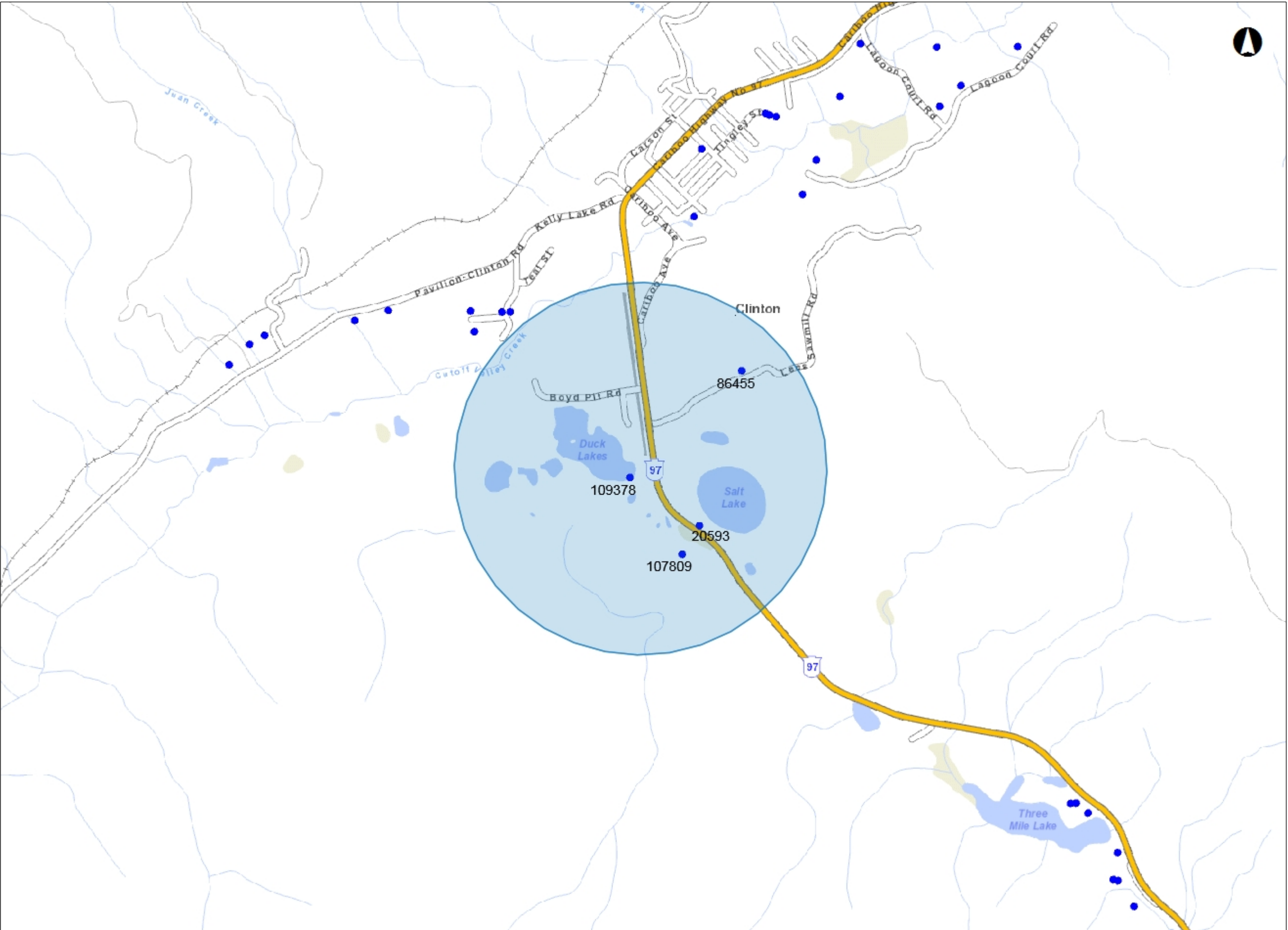
FIGURE 1

APPENDIX A

WELL CONSTRUCTION REPORT (WELL 41015)

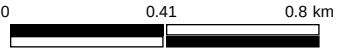
APPENDIX B

BCWRA WATER WELL MAP & DETAILED WELL RECORDS



Legend

- Artesian Wells
- Water Wells
- Water Wells - Lithology
- TileCache



1: 20,000

Copyright/Disclaimer

The material contained in this web site is owned by the Government of British Columbia and protected by copyright law. It may not be reproduced or redistributed without the prior written permission of the Province of British Columbia. To request permission to reproduce all or part of the material on this web site please complete the Copyright Permission Request Form which can be accessed through the Copyright Information Page.

CAUTION: Maps obtained using this site are not designed to assist in navigation. These maps may be generalized and may not reflect current conditions. Uncharted hazards may exist. DO NOT USE THESE MAPS FOR NAVIGATIONAL PURPOSES.

Datum: NAD83
Projection: NAD_1983_BC_Environment_Albers

Key Map of British Columbia





Report 1 - Detailed Well Record

Well Tag Number: 107809 Owner: JONES Address: 7062 97 HIGHWAY SOUTH Area: WELL LOCATION: Land District District Lot: 876 Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 83): 092P003313 Well: Class of Well: Water supply Subclass of Well: Domestic Orientation of Well: Vertical Status of Well: New Licence General Status: UNLICENSED Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Diameter: inches Casing drive shoe: N Y Well Depth: 116 feet Elevation: feet (ASL) Final Casing Stick Up: 18 inches Well Cap Type: welded plate Bedrock Depth: 28 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: 2013-05-21 00:00:00 Driller: J. R. Drilling Central Ltd. Partnership Well Identification Plate Number: 38346 Plate Attached By: DRILLER Where Plate Attached: casing PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 50 (Driller's Estimate) U.S. Gallons per Minute Development Method: Air lifting Pump Test Info Flag: N Artesian Flow: Artesian Pressure (ft): Static Level: 108 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: Water Chemistry Info Flag: N Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: Y Material: Bentonite clay Method: Poured Depth (ft): 20 feet Thickness (in): 1 inches Liner from To: feet WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:																				
<table><tr><td>Screen from</td><td>to feet</td><td>Type</td><td colspan="2">Slot Size</td></tr><tr><td>Casing from</td><td>to feet</td><td>Diameter</td><td>Material</td><td>Drive Shoe</td></tr><tr><td>0</td><td>116</td><td>6</td><td>Steel</td><td>Y</td></tr><tr><td>0</td><td>20</td><td>8</td><td>null</td><td>N</td></tr></table>	Screen from	to feet	Type	Slot Size		Casing from	to feet	Diameter	Material	Drive Shoe	0	116	6	Steel	Y	0	20	8	null	N	
Screen from	to feet	Type	Slot Size																		
Casing from	to feet	Diameter	Material	Drive Shoe																	
0	116	6	Steel	Y																	
0	20	8	null	N																	
GENERAL REMARKS: set pump at shoe 116 feet below ground level. WELL RECORD ENTERED THROUGH EWELLS. PAPER COPY OF RECORD HAS SINCE BEEN SUBMITTED. LITHOLOGY INFORMATION: From 0 to 10 Ft. Medium sand & gravel brown From 10 to 28 Ft. Medium shale bebrock brown From 28 to 82 Ft. Hard fractured bedrock & basalt layers first sign of moisture @ 35' bgl grey From 82 to 130 Ft. Hard soft bedrock dry black From 130 to 160 Ft. Very hard fractured bedrock grey																					

- [Return to Main](#)
- [Return to Search Options](#)
- [Return to Search Criteria](#)

Information Disclaimer

The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

Inserted from <http://a100.gov.bc.ca/pub/wells/wellsreport1.do?wellTagNumber=107809>



Report 1 - Detailed Well Record

<div>Well Tag Number: 109378</div> <div>Owner: CLINTON HONGYANG ZHENGHAN INTERNATIONAL</div> <div>Address: 7029 CARIBOO HIGHWAY</div> <div>Area: CLINTON</div> <div>WELL LOCATION:</div> <div>LILLOOET Land District</div> <div>District Lot: Plan: Lot:</div> <div>Township: Section: Range:</div> <div>Indian Reserve: Meridian: Block:</div> <div>Quarter:</div> <div>Island:</div> <div>BCGS Number (NAD 83): 092P003331 Well:</div> <div>Class of Well: Water supply</div> <div>Subclass of Well: Domestic</div> <div>Orientation of Well: Vertical</div> <div>Status of Well: New</div> <div>Licence General Status: UNLICENSED</div> <div>Well Use: Private Domestic</div> <div>Observation Well Number:</div> <div>Observation Well Status:</div> <div>Construction Method:</div> <div>Diameter: 6 inches</div> <div>Casing drive shoe: Y</div> <div>Well Depth: 67 feet</div> <div>Elevation: 2997 feet (ASL)</div> <div>Final Casing Stick Up: 18 inches</div> <div>Well Cap Type: WELL CAP</div> <div>Bedrock Depth: feet</div> <div>Lithology Info Flag: Y</div> <div>File Info Flag: N</div> <div>Sieve Info Flag: N</div> <div>Screen Info Flag: Y</div> <div>Site Info Details:</div> <div>Other Info Flag:</div> <div>Other Info Details:</div>	<div>Construction Date: 2014-08-05 00:00:00</div> <div>Driller: Weston Water Wells</div> <div>Well Identification Plate Number: 41015</div> <div>Plate Attached By:</div> <div>Where Plate Attached: CASING STICK UP</div> <div>PRODUCTION DATA AT TIME OF DRILLING:</div> <div>Well Yield: 72 (Driller's Estimate) U.S. Gallons per Minute</div> <div>Development Method: Air lifting</div> <div>Pump Test Info Flag: N</div> <div>Artesian Flow:</div> <div>Artesian Pressure (ft):</div> <div>Static Level: 31 feet</div> <div>WATER QUALITY:</div> <div>Character:</div> <div>Colour:</div> <div>Odour:</div> <div>Well Disinfected: Y</div> <div>EMS ID:</div> <div>Water Chemistry Info Flag: N</div> <div>Field Chemistry Info Flag:</div> <div>Site Info (SEAM):</div> <div>Water Utility:</div> <div>Water Supply System Name:</div> <div>Water Supply System Well Name:</div> <div>SURFACE SEAL:</div> <div>Flag: Y</div> <div>Material: Bentonite clay</div> <div>Method: Poured</div> <div>Depth (ft): 17 feet</div> <div>Thickness (in): 1.5 inches</div> <div>Liner from To: feet</div> <div>WELL CLOSURE INFORMATION:</div> <div>Reason For Closure:</div> <div>Method of Closure:</div> <div>Closure Sealant Material:</div> <div>Closure Backfill Material:</div> <div>Details of Closure:</div>										
<table><tr><td>Screen from</td><td>to feet</td><td>Type</td><td>Slot Size</td></tr><tr><td>62.33</td><td>67</td><td></td><td>30</td></tr></table>	Screen from	to feet	Type	Slot Size	62.33	67		30			
Screen from	to feet	Type	Slot Size								
62.33	67		30								
<table><tr><td>Casing from</td><td>to feet</td><td>Diameter</td><td>Material</td><td>Drive Shoe</td></tr><tr><td>0</td><td>64.58</td><td>6</td><td>Steel</td><td>Y</td></tr></table>	Casing from	to feet	Diameter	Material	Drive Shoe	0	64.58	6	Steel	Y	
Casing from	to feet	Diameter	Material	Drive Shoe							
0	64.58	6	Steel	Y							
<div>GENERAL REMARKS:</div> <div>LITHOLOGY INFORMATION:</div> <div>From 0 to 62 Ft. SAND & SMALL GRAVEL</div> <div>From 62 to 68 Ft. MEDIUM SIZE GRAVEL</div> <div>From 68 to 70 Ft. HEAVY SAND</div>											

- [Return to Main](#)
- [Return to Search Options](#)
- [Return to Search Criteria](#)

Information Disclaimer

The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

Inserted from <<http://a100.gov.bc.ca/pub/wells/wellsreport1.do?wellTagNumber=109378>>



Report 1 - Detailed Well Record

Well Tag Number: 20593 Owner: Ministry of Environment Address: CROWN LAND Area: WELL LOCATION: LILLOOET Land District District Lot: Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 83): 092P003313 Well: 1 Class of Well: Subclass of Well: Orientation of Well: Status of Well: New Licence General Status: UNLICENSED Well Use: Observation Well Observation Well Number: 80 Observation Well Status: Active Construction Method: Drilled Diameter: 6.0 inches Casing drive shoe: Well Depth: 50 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: 1967-04-01 00:00:00 Driller: Miller's Drilling & Welding Well Identification Plate Number: 12813 Plate Attached By: Laurie Lyons Where Plate Attached: Well casing PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 5 (Driller's Estimate) Gallons per Minute (U.S./Imperial) Development Method: Pump Test Info Flag: N Artesian Flow: Artesian Pressure (ft): Static Level: 12 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: N EMS ID: 1401070 Water Chemistry Info Flag: 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: OLD OBS WELL # WR-47-67 LITHOLOGY INFORMATION: From 0 to 20 Ft. loose br. clay mixed with crse. sand, From 0 to 0 Ft. some cobbles or small boulders From 20 to 50 Ft. clean fine sand, dark grey with scatter- From 0 to 0 Ft. ed mica and red rock, average size about From 0 to 0 Ft. 1/16" From 0 to 0 Ft. water started at 28'	

- [Return to Main](#)
- [Return to Search Options](#)
- [Return to Search Criteria](#)

Information Disclaimer

The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

Inserted from <<http://a100.gov.bc.ca/pub/wells/wellsreport1.do?wellTagNumber=20593>>



Report 1 - Detailed Well Record

Well Tag Number: 86455 Owner: L'HEUREUX Address: 7058 CARIBOO WAY Area: CLINTON WELL LOCATION: LILLOOET Land District District Lot: 915 Plan: 15161 Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island: BCGS Number (NAD 83): 092P003331 Well: 1 Class of Well: Water supply Subclass of Well: Domestic Orientation of Well: Vertical Status of Well: New Licence General Status: UNLICENSED Well Use: Private Domestic Observation Well Number: Observation Well Status: Construction Method: Diameter: inches Casing drive shoe: Y Well Depth: 117.6 feet Elevation: feet (ASL) Final Casing Stick Up: 24 inches Well Cap Type: WELDED 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: 2006-06-05 00:00:00 Driller: Weston Water Wells Well Identification Plate Number: 11365 Plate Attached By: JERRY WESTON Where Plate Attached: CASING STICK UP PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 50 (Driller's Estimate) U.S. Gallons per Minute Development Method: Air lifting Pump Test Info Flag: N Artesian Flow: Artesian Pressure (ft): Static Level: 63 feet WATER QUALITY: Character: Colour: Odour: Well Disinfected: Y EMS ID: Water Chemistry Info Flag: N Field Chemistry Info Flag: Site Info (SEAM): Water Utility: Water Supply System Name: Water Supply System Well Name: SURFACE SEAL: Flag: N Material: Bentonite clay Method: Poured Depth (ft): 15 feet Thickness (in): 1 inches Liner from To: feet WELL CLOSURE INFORMATION: Reason For Closure: Method of Closure: Closure Sealant Material: Closure Backfill Material: Details of Closure:										
<table><tr><td>Screen from</td><td>to feet</td><td>Type</td><td colspan="2">Slot Size</td></tr><tr><td>114</td><td>117.5</td><td></td><td colspan="2">20</td></tr></table>	Screen from	to feet	Type	Slot Size		114	117.5		20		
Screen from	to feet	Type	Slot Size								
114	117.5		20								
<table><tr><td>Casing from</td><td>to feet</td><td>Diameter</td><td>Material</td><td>Drive Shoe</td></tr><tr><td>0</td><td>114</td><td>6</td><td>Steel</td><td>Y</td></tr></table>	Casing from	to feet	Diameter	Material	Drive Shoe	0	114	6	Steel	Y	
Casing from	to feet	Diameter	Material	Drive Shoe							
0	114	6	Steel	Y							
GENERAL REMARKS: REC PUMP SETTING 110' LITHOLOGY INFORMATION: From 0 to 18 Ft. From 18 to 70 Ft. SAND, GRAVEL From 70 to 110 Ft. SILTY SAND grey From 110 to 118 Ft. SAND, GRAVEL 50 U.S. Gallons per Minute CLEAN											

- [Return to Main](#)
- [Return to Search Options](#)
- [Return to Search Criteria](#)

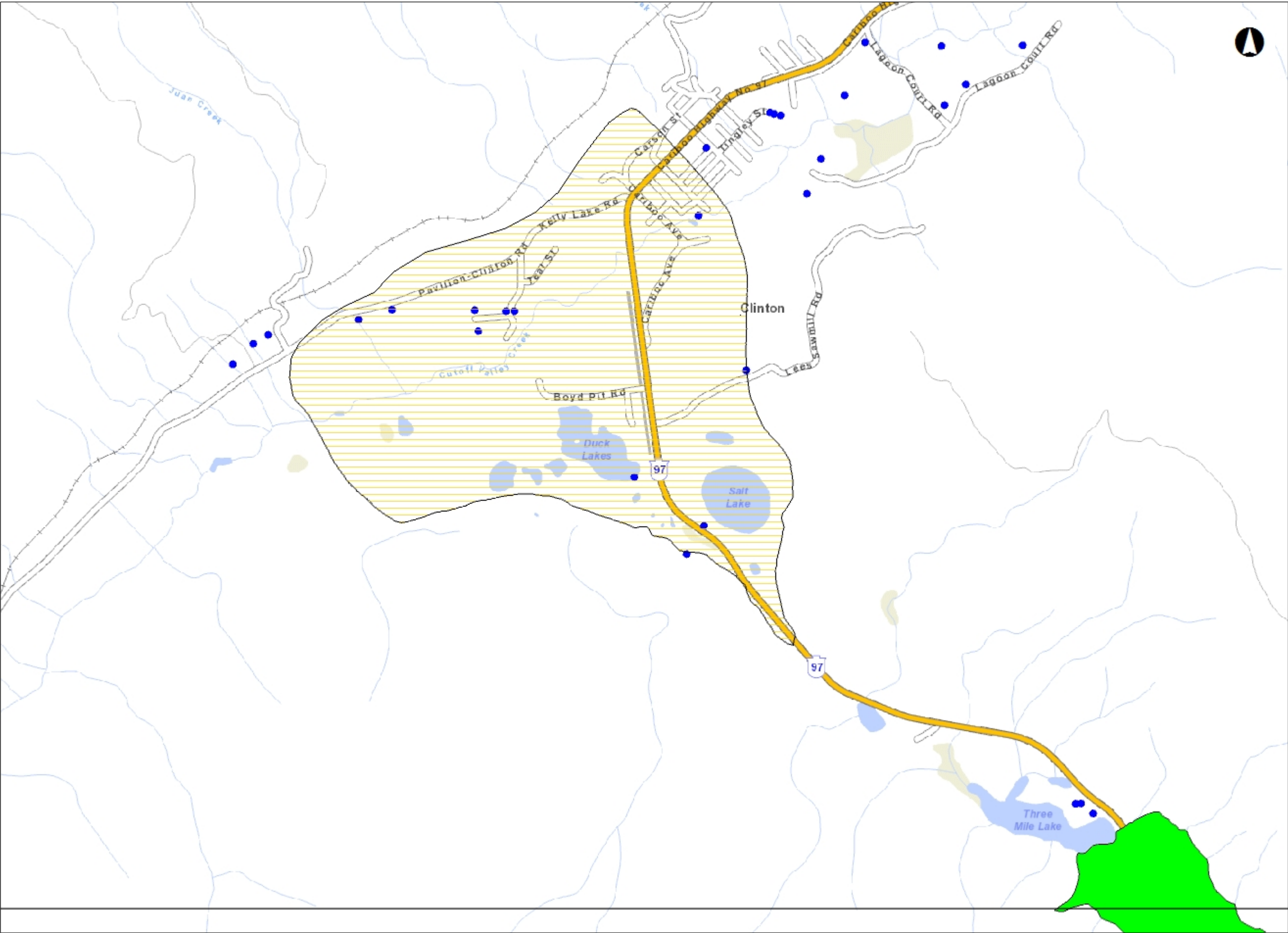
Information Disclaimer

The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

Inserted from <<http://a100.gov.bc.ca/pub/wells/wellsreport1.do?wellTagNumber=86455>>

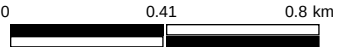
APPENDIX C

BCWRA AQUIFER MAP



Legend

- ☐ Aquifer Boundary - Outlined
- ☐ Aquifer Productivity - Colour
PRODUCTIVITY_CODE
- ☐ Bedrock High Productivity
- ☐ Bedrock Low Productivity
- ☐ Bedrock Moderate Productivity
- ☐ Unconsolidated High Productivity
- ☐ Unconsolidated Low Productivity
- ☐ Unconsolidated Moderate Productivity
- ☐ Artesian Wells
- ☐ Water Wells
- ☐ Water Wells - Lithology
- ☐ TileCache



1: 20,000

Copyright/Disclaimer

The material contained in this web site is owned by the Government of British Columbia and protected by copyright law. It may not be reproduced or redistributed without the prior written permission of the Province of British Columbia. To request permission to reproduce all or part of the material on this web site please complete the Copyright Permission Request Form which can be accessed through the Copyright Information Page.

CAUTION: Maps obtained using this site are not designed to assist in navigation. These maps may be generalized and may not reflect current conditions. Uncharted hazards may exist. DO NOT USE THESE MAPS FOR NAVIGATIONAL PURPOSES.

Datum: NAD83
Projection: NAD_1983_BC_Environment_Albers

Key Map of British Columbia



APPENDIX D

CALIBRATION RECORDS - FIELD WATER QUALITY MONITORING INSTRUMENTS

INSTRUMENT CALIBRATION REPORT



Pine Environmental Services, LLC.

3470 Gardner Court
Burnaby, BC V5G 3K4
Toll-free: (877) 678-8383

Pine Environmental Services, Inc.

Instrument ID R9397
Description YSI 556
Calibrated 6/2/2015 2:21:20PM

Manufacturer YSI
Model Number 556
Serial Number/ Lot 07H102076
Number
Location British Columbia
Department

State Certified
Status Pass
Temp °C 20.48
Humidity % 56

Calibration Specifications

Group # 1
Group Name PH
Stated Accy Pct of Reading

Range Acc % 0.0000
Reading Acc % 3.0000
Plus/Minus 0.00

<u>Nom In Val / In Val</u>	<u>In Type</u>	<u>Out Val</u>	<u>Out Type</u>	<u>Fnd As</u>	<u>Lft As</u>	<u>Dev%</u>	<u>Pass/Fail</u>
7.00 / 7.00	PH	7.00	PH	7.00	7.00	0.00%	Pass
4.00 / 4.00	PH	4.00	PH	4.00	4.00	0.00%	Pass
10.00 / 10.00	PH	10.00	PH	9.99	9.99	-0.10%	Pass

Group # 2
Group Name Conductivity
Stated Accy Pct of Reading

Range Acc % 0.0000
Reading Acc % 3.0000
Plus/Minus 0.000

<u>Nom In Val / In Val</u>	<u>In Type</u>	<u>Out Val</u>	<u>Out Type</u>	<u>Fnd As</u>	<u>Lft As</u>	<u>Dev%</u>	<u>Pass/Fail</u>
1.413 / 1.413	ms/cm	1.413	ms/cm	1.413	1.413	0.00%	Pass

Group # 3
Group Name Redox (ORP)
Stated Accy Pct of Reading

Range Acc % 0.0000
Reading Acc % 3.0000
Plus/Minus 0.00

<u>Nom In Val / In Val</u>	<u>In Type</u>	<u>Out Val</u>	<u>Out Type</u>	<u>Fnd As</u>	<u>Lft As</u>	<u>Dev%</u>	<u>Pass/Fail</u>
240.00 / 240.00	mv	240.00	mv	240.00	240.00	0.00%	Pass

Group # 4
Group Name Dissolved Oxygen Span
Stated Accy Pct of Reading

Range Acc % 0.0000
Reading Acc % 3.0000
Plus/Minus 0.00

<u>Nom In Val / In Val</u>	<u>In Type</u>	<u>Out Val</u>	<u>Out Type</u>	<u>Fnd As</u>	<u>Lft As</u>	<u>Dev%</u>	<u>Pass/Fail</u>
100.00 / 100.00	%	100.00	%	99.90	99.90	-0.10%	Pass



INSTRUMENT CALIBRATION REPORT

Pine Environmental Services, LLC.

3470 Gardner Court
Burnaby, BC V5G 3K4
Toll-free: (877) 678-8383

Pine Environmental Services, Inc.

Instrument ID R9397
Description YSI 556
Calibrated 6/2/2015 2:21:20PM

<u>Test Instruments Used During the Calibration</u>					(As Of Cal Entry Date)
<u>Test Standard ID</u>	<u>Description</u>	<u>Manufacturer</u>	<u>Model Number</u>	<u>Serial Number / Lot Number</u>	<u>Next Cal Date / Last Cal Date / Expiration Date / Opened Date</u>
BC_EC-1.413M	1.413mS/cm -	Aurical	3-1413-8	11412	12/15/2015
S/CM_11412	Conductivity Standard				
BC_ORP240MV	BC - ORP 240 mV -	Hanna	HI 7021L	7872	7/30/2019
	Calibrating Buffer				
BC_PH10.00	PH 10.00 - Calibrating	Aurical	2-1000B-8	11597	5/15/2016
	Buffer				
BC_PH4.00_115	PH 4.00 - Calibrating	Aurical	2-0400R-8	11582	4/8/2016
82	Buffer				
BC_PH7.00_115	BC - PH 7.00	Aurical	2-0700Y-8	11576	4/1/2016
76	Calibrating Buffer				

<u>Sensor Information</u>			
<u>Sensor Type</u>	<u>Manufacturer</u>	<u>Serial Number</u>	<u>Date Installed</u>

Notes about this calibration

Dissolved oxygen sensor reading in sodium sulfite:0.07 mg/L

Calibration Result Calibration Successful
Who Calibrated Val Eftenaru

All instruments are calibrated by Pine Environmental Services, LLC. according to the manufacturer's specifications, but it is the customer's responsibility to calibrate and maintain this unit in accordance with the manufacturer's specifications and/or the customer's own specific needs.

**Notify Pine Environmental Services, LLC. of any defect within 24 hours of receipt of equipment
Please call 866-960-7463 for Technical Assistance**



INSTRUMENT CALIBRATION REPORT

Pine Environmental Services, LLC.

3470 Gardner Court
Burnaby, BC V5G 3K4
Toll-free: (877) 678-8383

Pine Environmental Services, Inc.

Instrument ID 20403
Description HACH 2100Q
Calibrated 6/3/2015 2:17:52PM

Manufacturer HACH
Model Number 2100Q
Serial Number/ Lot Number 11110C014573
Location British Columbia
Department

State Certified
Status Pass
Temp °C 21
Humidity % 55

Calibration Specifications

Group # 1
Group Name Turbidity
Stated Accy Pct of Reading

Range Acc % 0.0000
Reading Acc % 3.0000
Plus/Minus 0.50

<u>Nom In Val / In Val</u>	<u>In Type</u>	<u>Out Val</u>	<u>Out Type</u>	<u>Fnd As</u>	<u>Lft As</u>	<u>Dev%</u>	<u>Pass/Fail</u>
20.00 / 20.00	NTU	20.00	NTU	20.10	20.10	0.50%	Pass
100.00 / 100.00	NTU	100.00	NTU	98.20	98.20	-1.80%	Pass
800.00 / 800.00	NTU	800.00	NTU	802.00	802.00	0.25%	Pass

Test Instruments Used During the Calibration

(As Of Cal Entry Date)

<u>Test Standard ID</u>	<u>Description</u>	<u>Manufacturer</u>	<u>Model Number</u>	<u>Serial Number / Lot Number</u>	<u>Last Cal Date / Opened Date</u>	<u>Next Cal Date / Expiration Date</u>
BC_100NTU_A 4083	Turbidity Standard 100 NTU	HACH	2684901	A4083		6/30/2015
BC_20NTU_A4 128	Turbidity Standard 20 NTU	HACH	2684801	A4128		8/30/2015
BC_800NTU_A 4121A	Turbidity Standard 800 NTU	HACH	2660501	A4121A		8/30/2015

Sensor Information

<u>Sensor Type</u>	<u>Manufacturer</u>	<u>Serial Number</u>	<u>Date Installed</u>
--------------------	---------------------	----------------------	-----------------------

Notes about this calibration

Calibration Result Calibration Successful
Who Calibrated Val Eftenaru

INSTRUMENT CALIBRATION REPORT



Pine Environmental Services, LLC.

3470 Gardner Court
Burnaby, BC V5G 3K4
Toll-free: (877) 678-8383

Pine Environmental Services, Inc.

Instrument ID 20403

Description HACH 2100Q

Calibrated 6/3/2015 2:17:52PM

All instruments are calibrated by Pine Environmental Services, LLC. according to the manufacturer's specifications, but it is the customer's responsibility to calibrate and maintain this unit in accordance with the manufacturer's specifications and/or the customer's own specific needs.

Notify Pine Environmental Services, LLC. of any defect within 24 hours of receipt of equipment
Please call 866-960-7463 for Technical Assistance

APPENDIX E

PUMPING TEST RESULTS

Clinton Hongyang Zhengong International Investment Inc.
Groundwater and Surface Water Elevations - 6 June 2015 to 10 June 2015

Station ID	Date / Time	Time Note	Top of Measurement Point Elevation (m rtld)	Depth to Water Measurement (m btoc)	Water Elevation (m rtld)
Well 41015	06-Jun-2015, 9:00 AM	Prior to Step Test	96.70	10.070	86.631
Well 41015	07-Jun-2015, 9:00 AM	Prior to CDT	96.70	10.100	86.601
Well 41015	08-Jun-2015, 8:20 AM	During CDT	96.70	10.320	86.381
Well 41015	09-Jun-2015, 7:40 AM	During CDT	96.70	10.371	86.330
Well 41015	10-Jun-2015, 7:40 AM	Near End of CDT	96.70	10.404	86.297
Duck Lake SG	06-Jun-2015, 8:00 AM	Prior to Step Test	87.42	0.801	86.617
Duck Lake SG	07-Jun-2015, 9:00 AM	Prior to CDT	87.42	0.803	86.615
Duck Lake SG	08-Jun-2015, 8:20 AM	During CDT	87.42	0.803	86.615
Duck Lake SG	09-Jun-2015, 7:40 AM	During CDT	87.42	0.804	86.614
Duck Lake SG	10-Jun-2015, 7:40 AM	Near End of CDT	87.42	0.805	86.613

Notes:

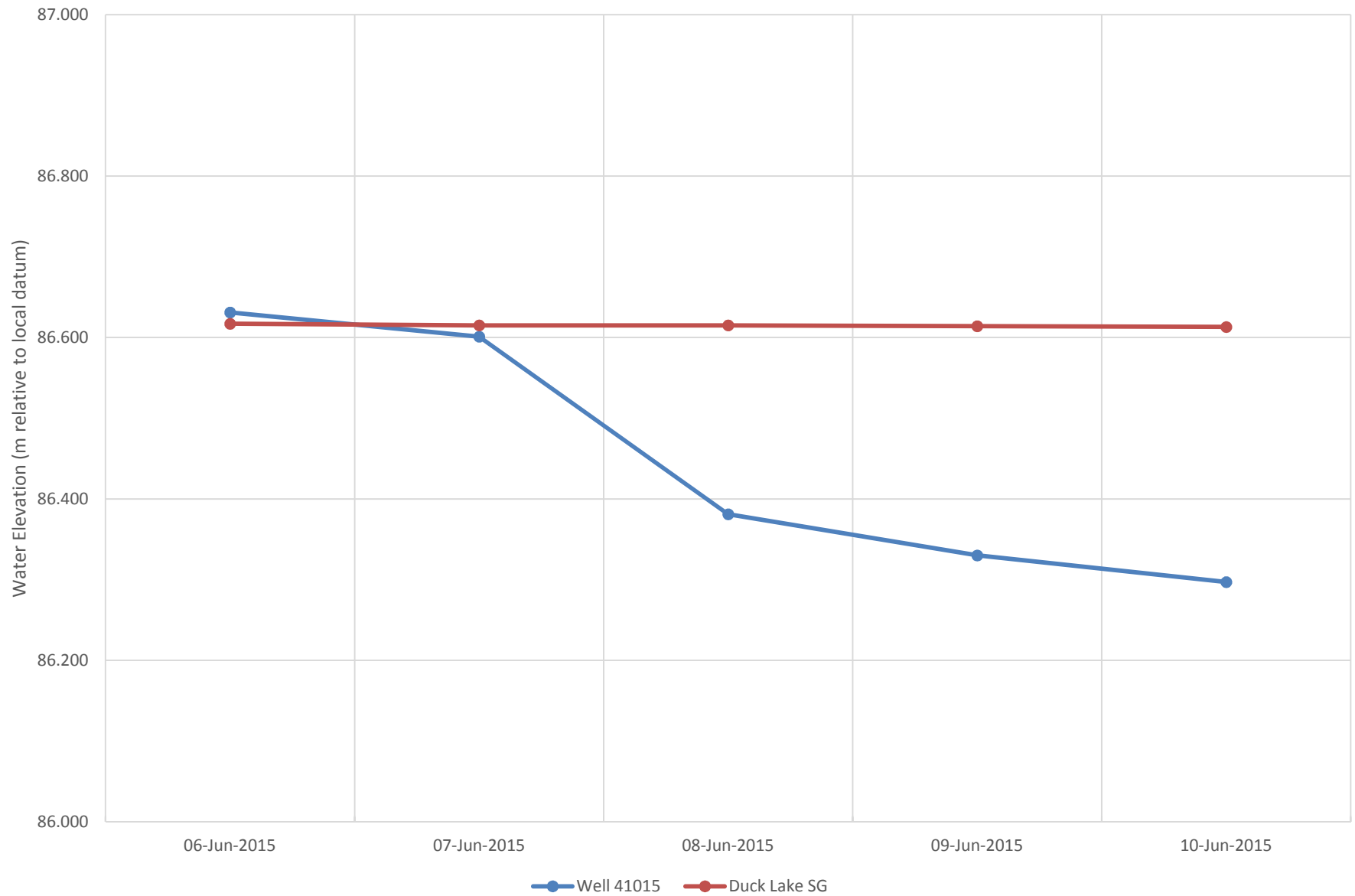
m rtld = metres relative to local datum

m btoc = metres below top of casing

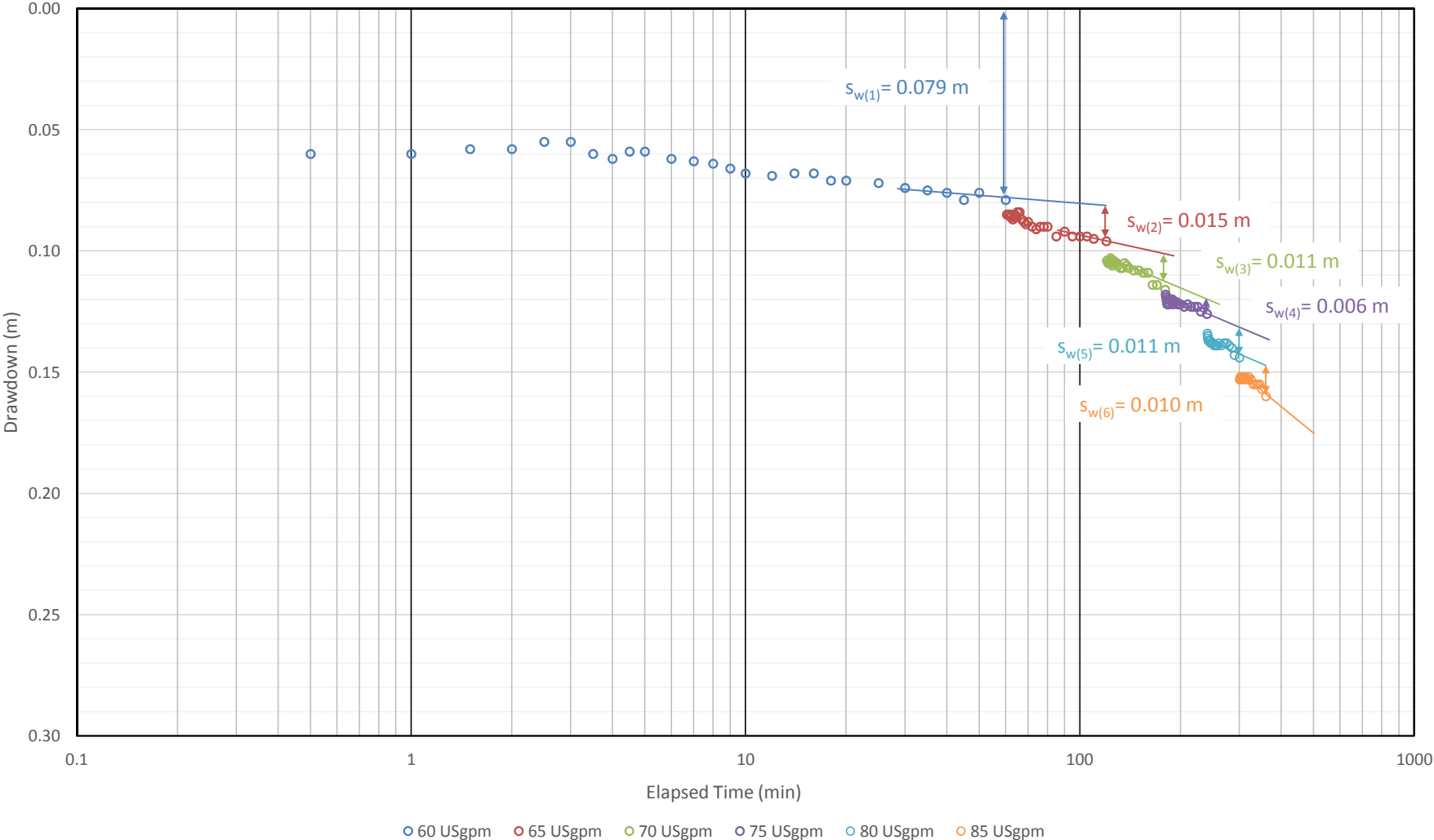
CDT = Constant Discharge Test

Water Elevation = Top of Measurement Point Elevation - Depth to Water Measurement

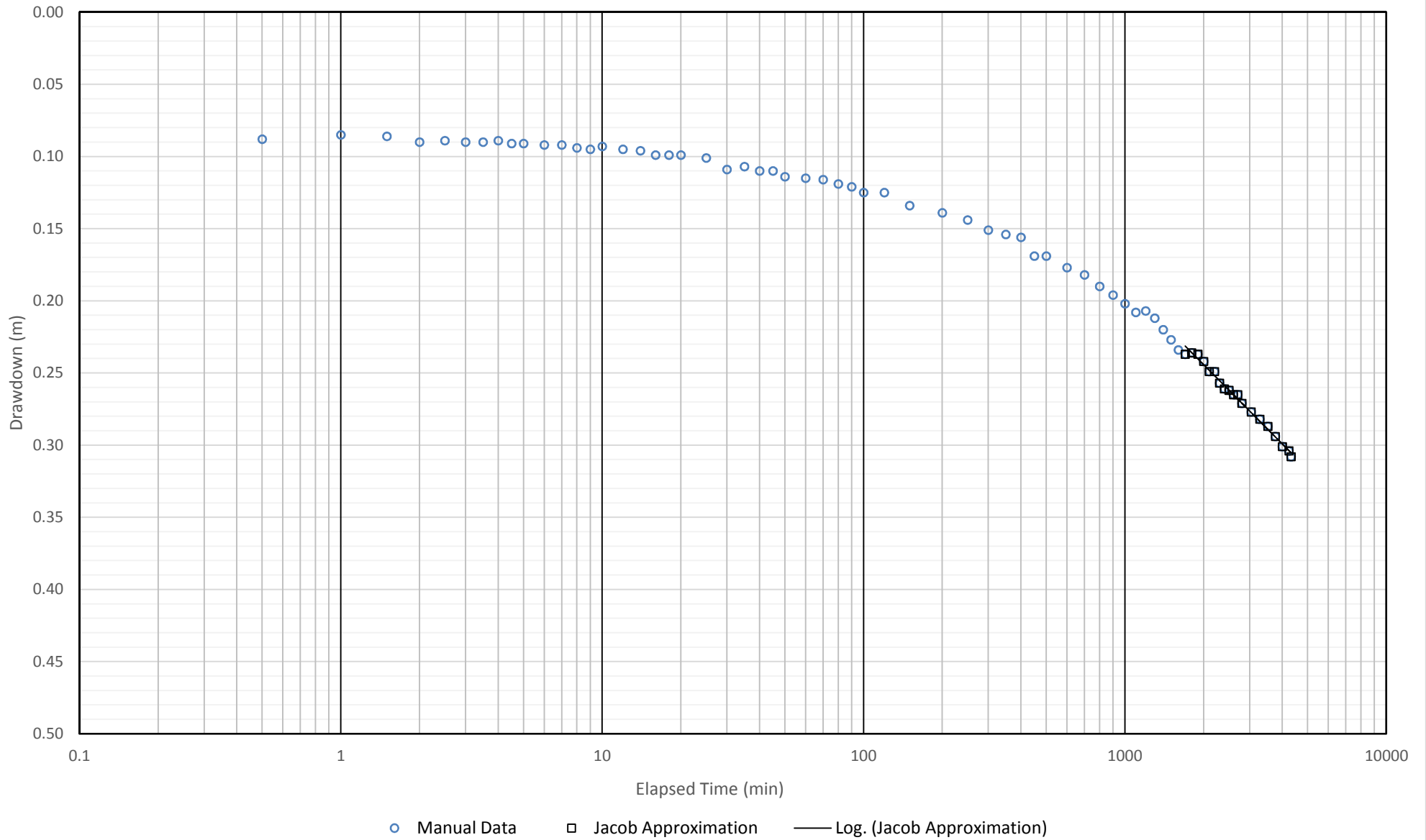
Clinton Hongyang Zhengong International Investment Inc.
Groundwater and Surface Water Elevations - 6 June 2015 to 10 June 2015



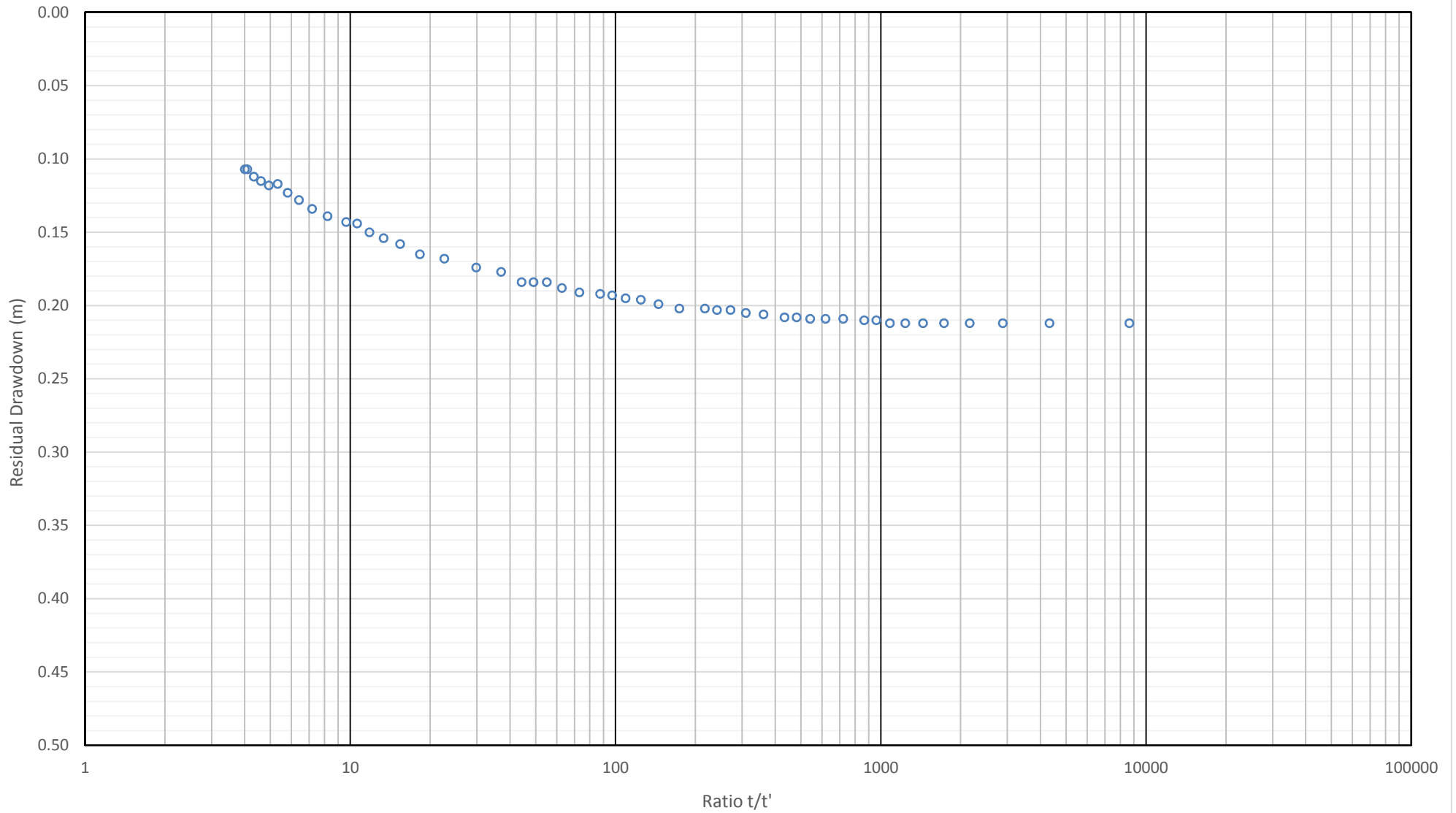
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Step Test Drawdown Chart



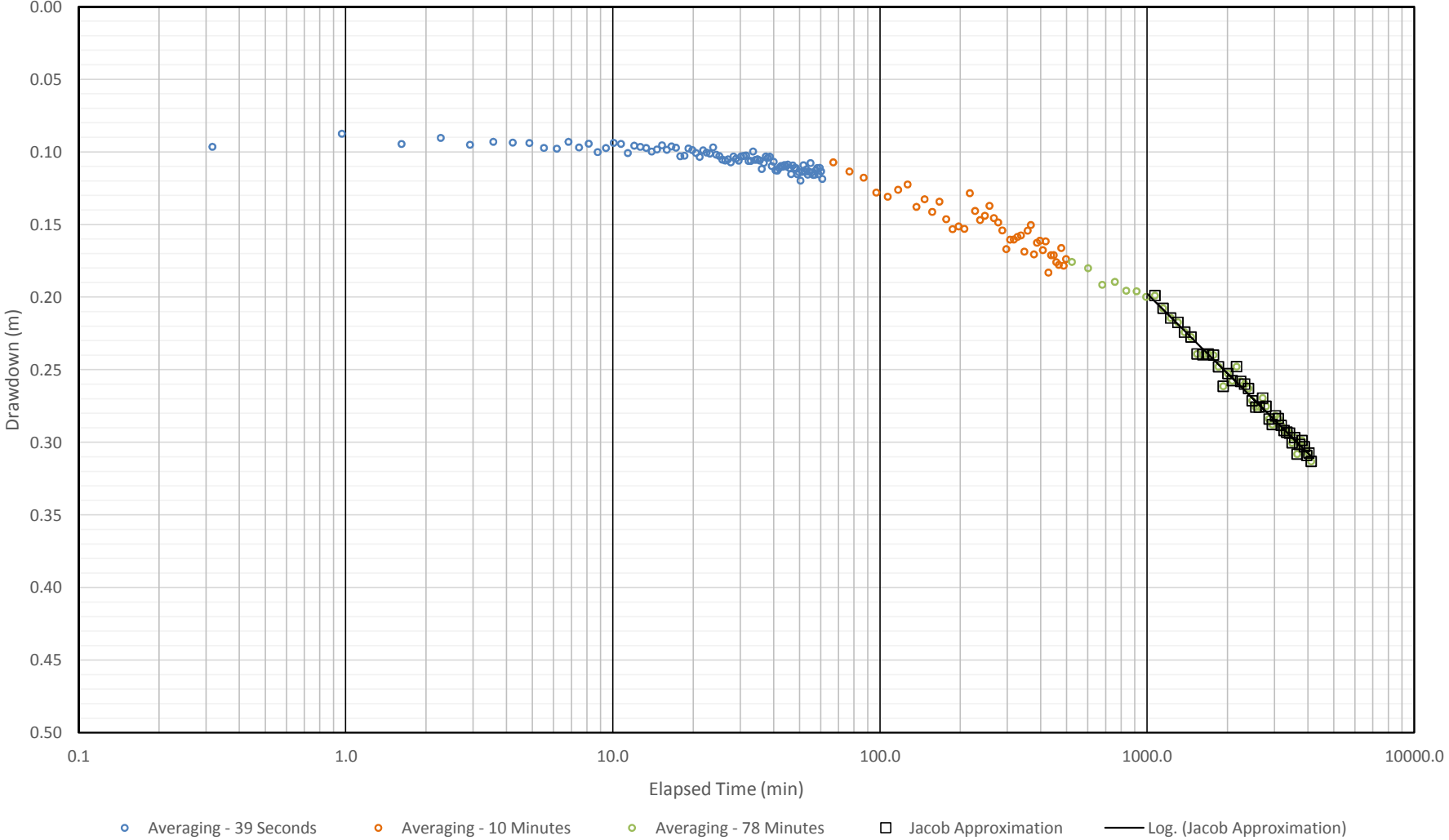
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test Drawdown Chart - Manual Data



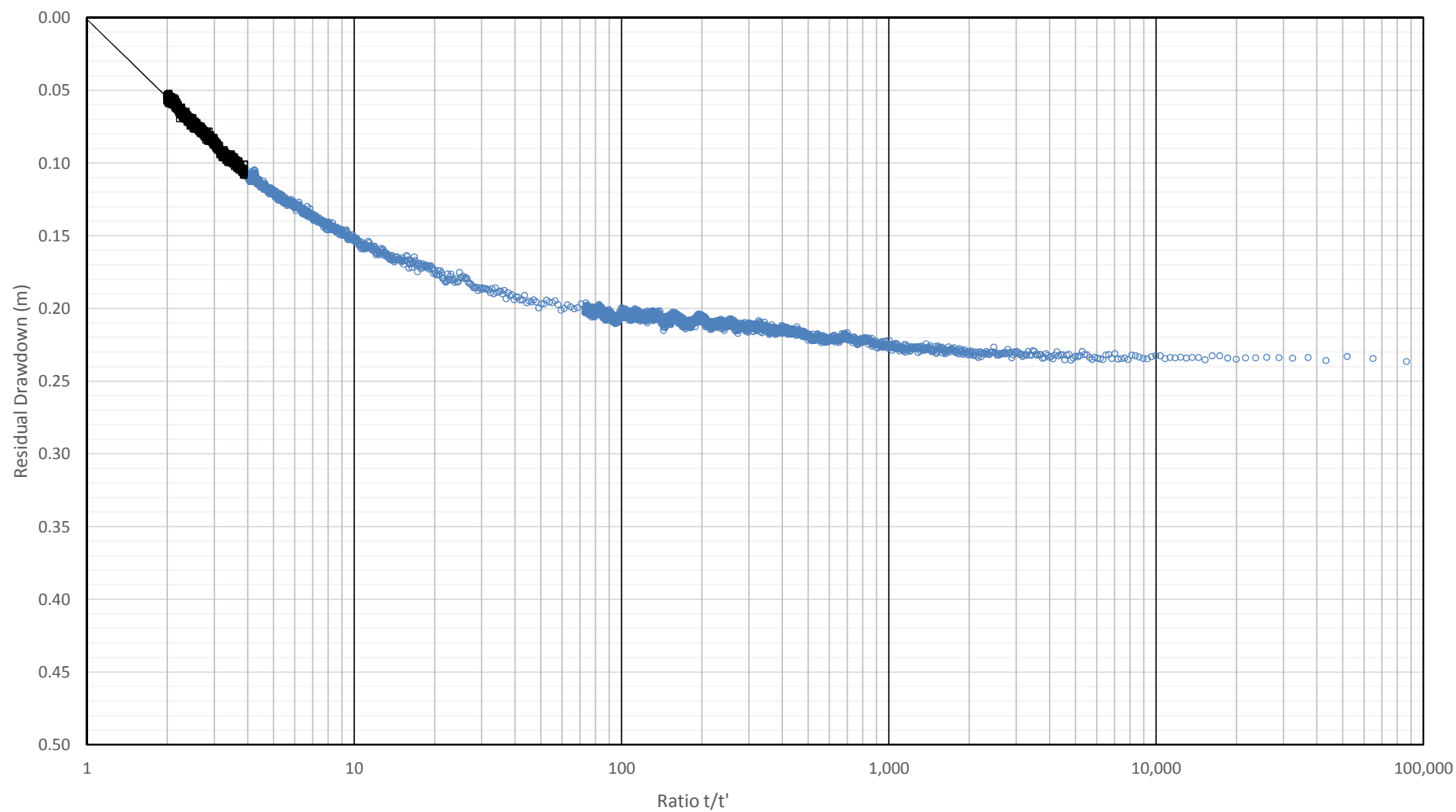
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Recovery Chart - Manual Data



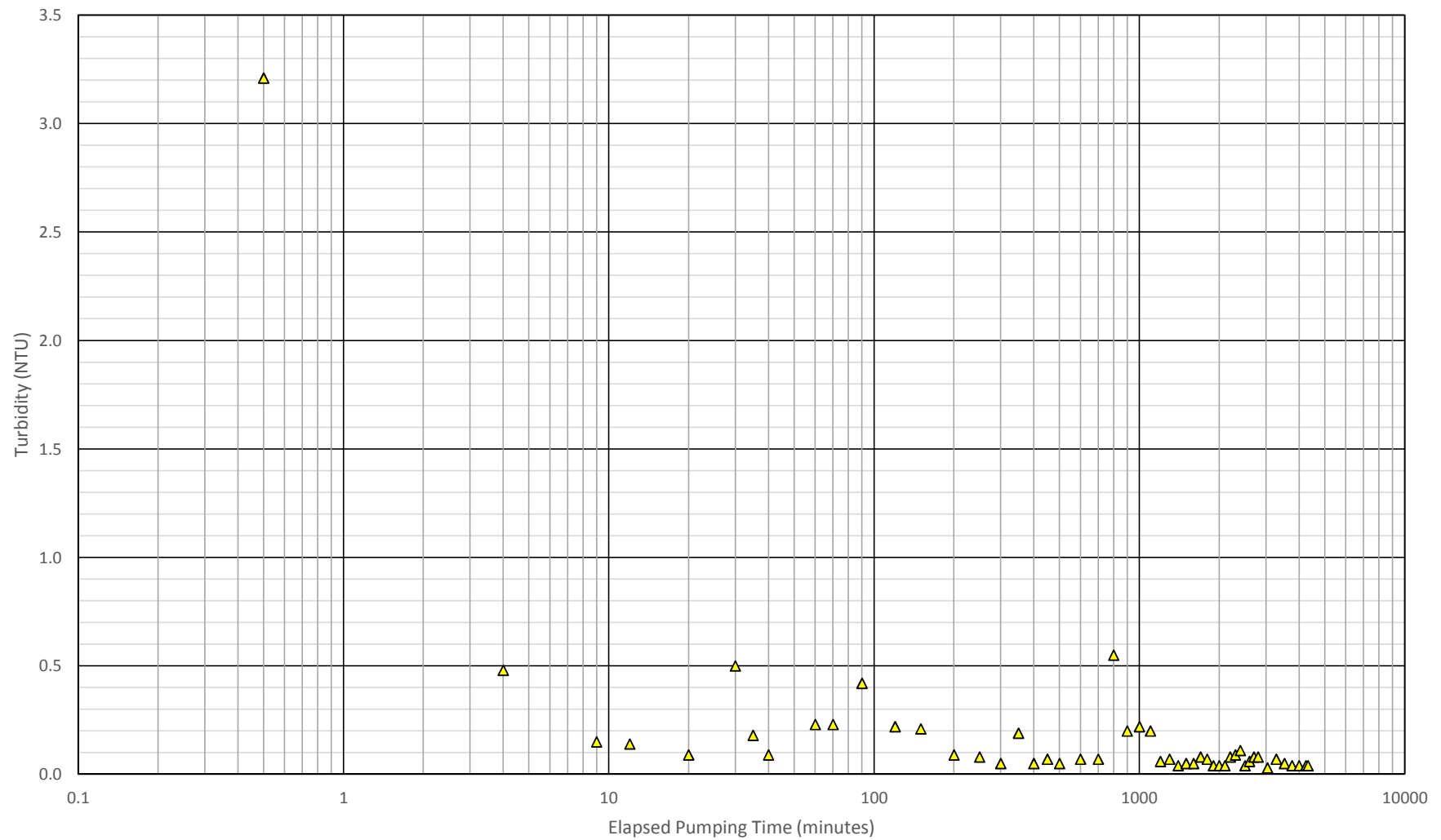
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test Drawdown Chart - Electronic Data



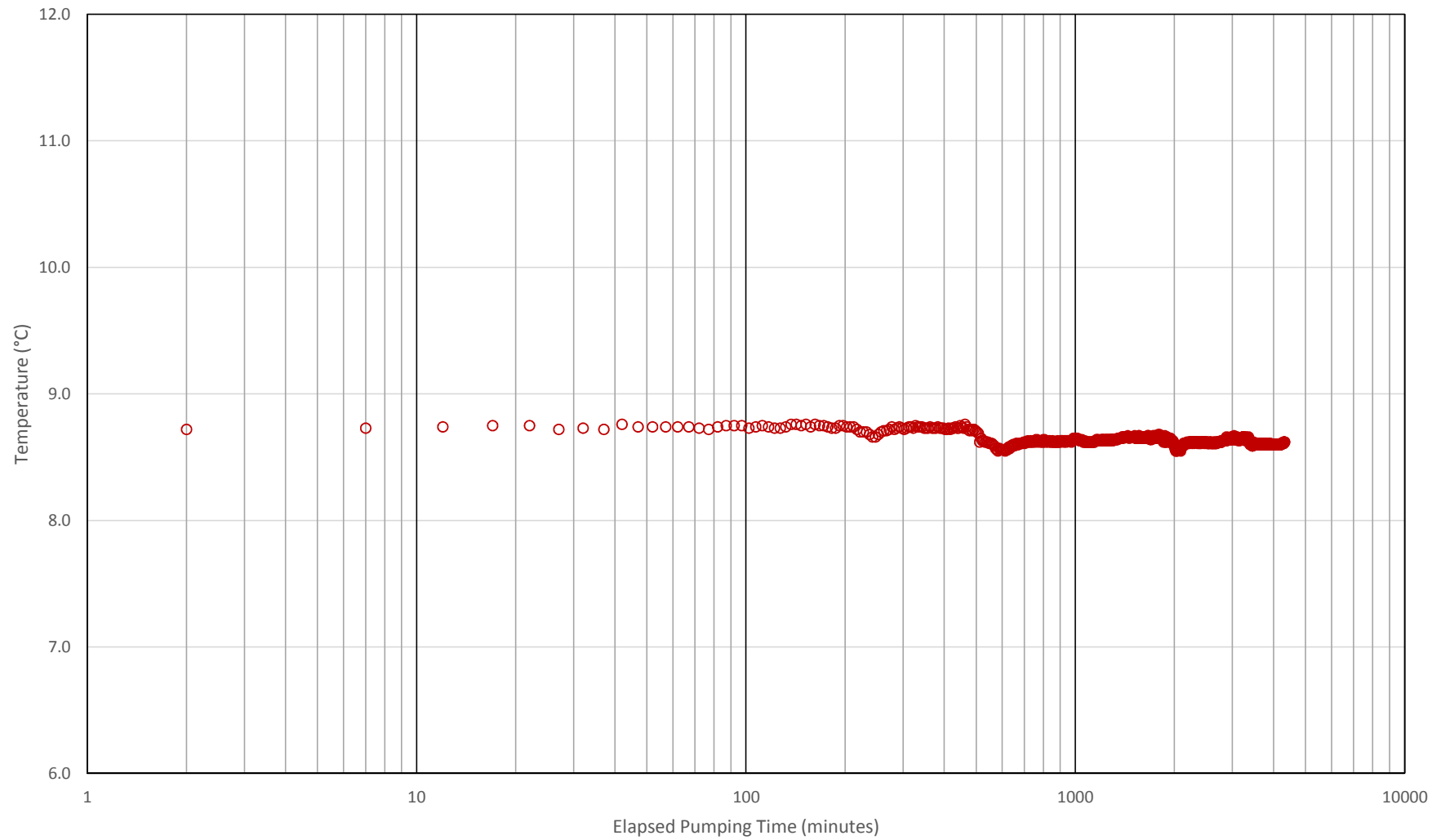
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Recovery Chart - Electronic Data



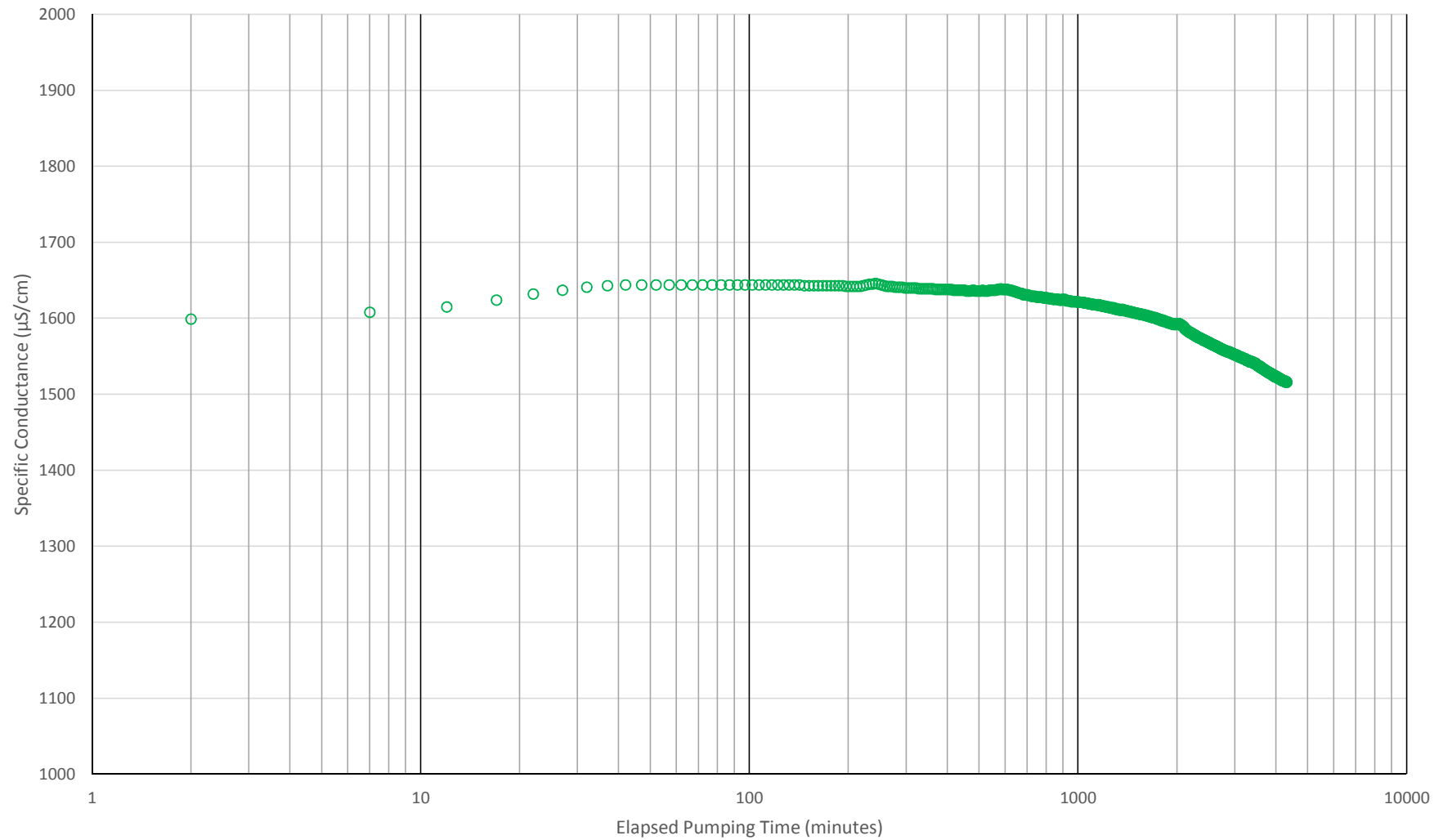
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test - Discharge Turbidity (°C)



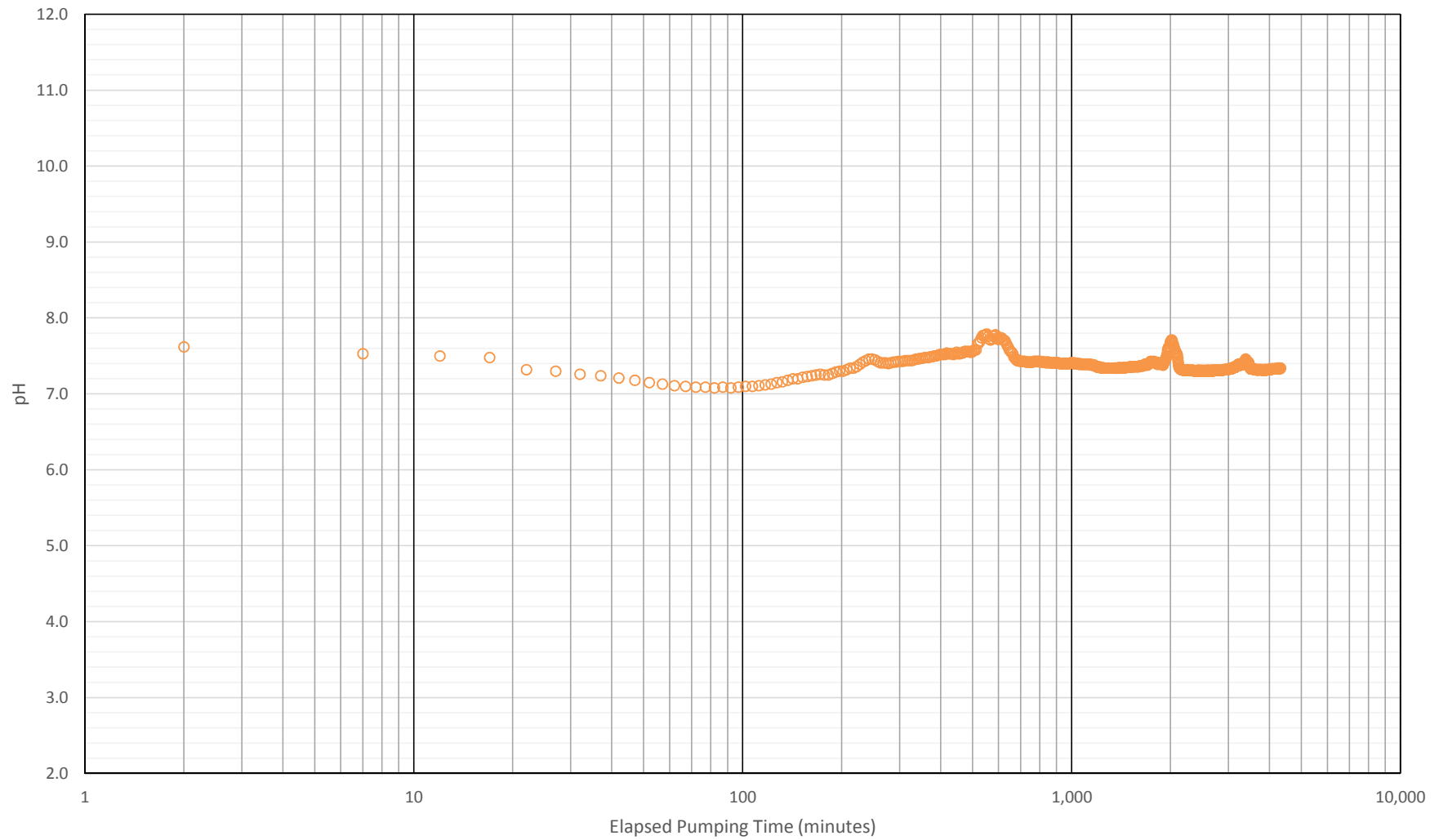
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test - Discharge Temperature (°C)



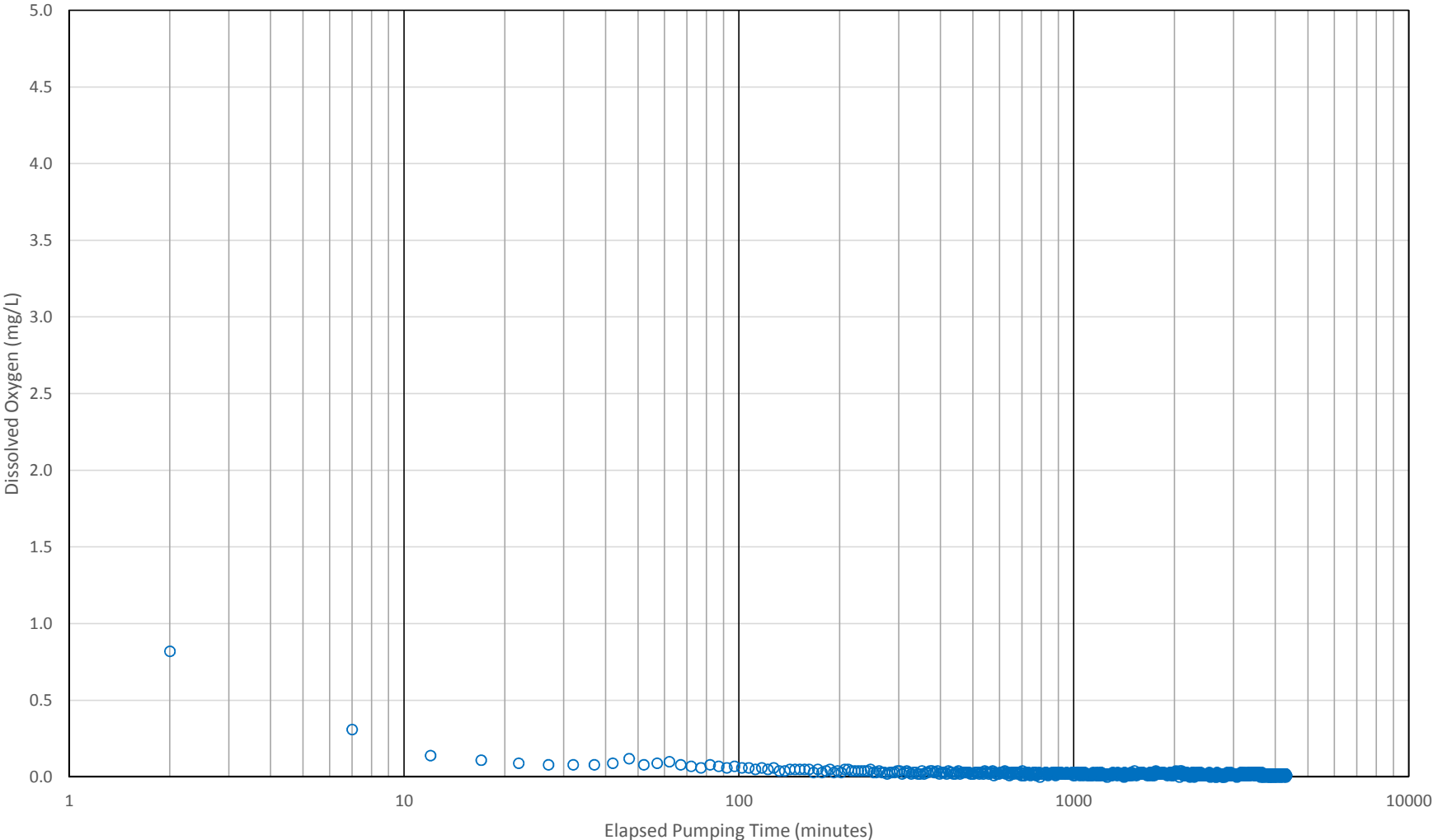
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test - Discharge Specific Conductance ($\mu\text{S}/\text{cm}$)



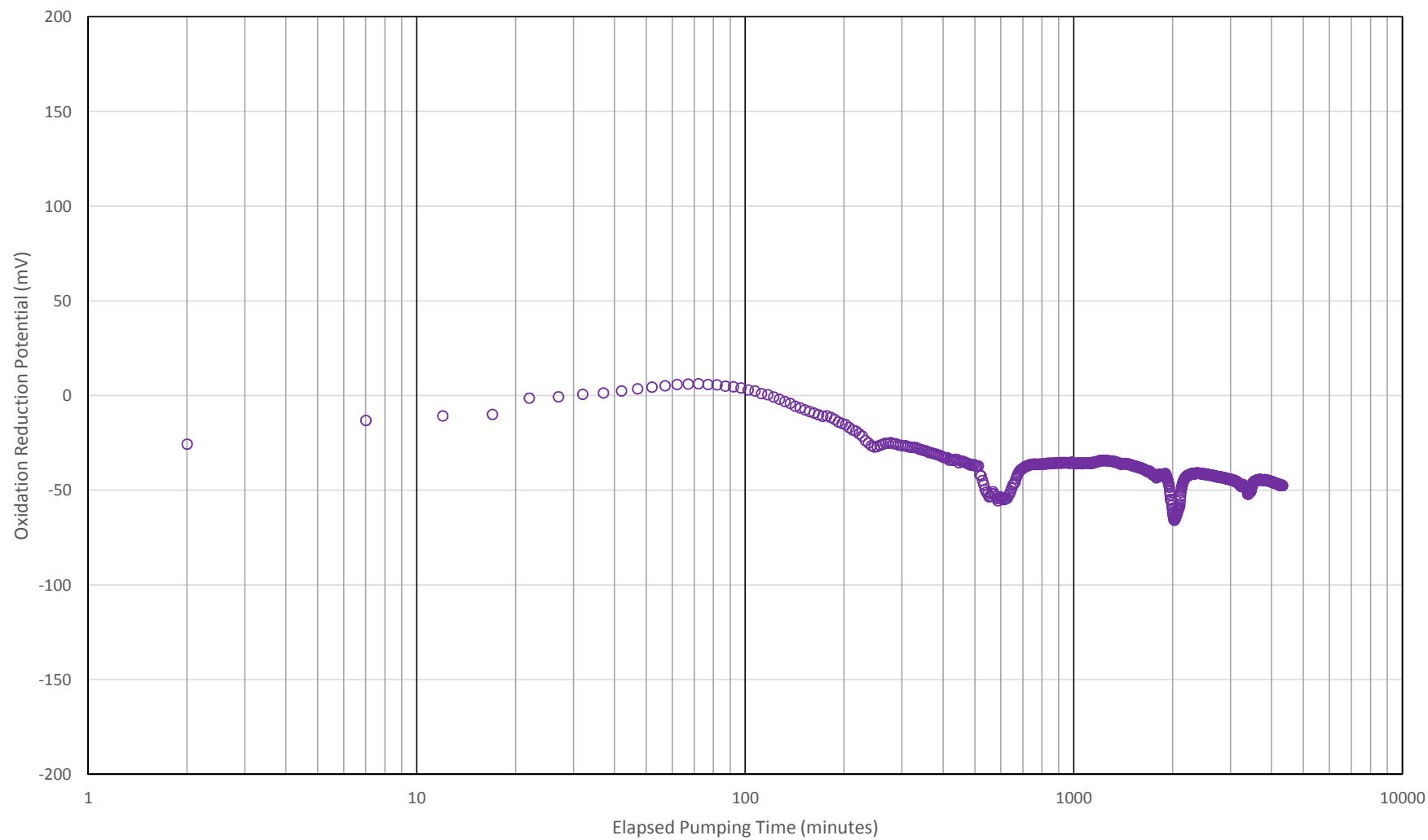
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test - Discharge pH



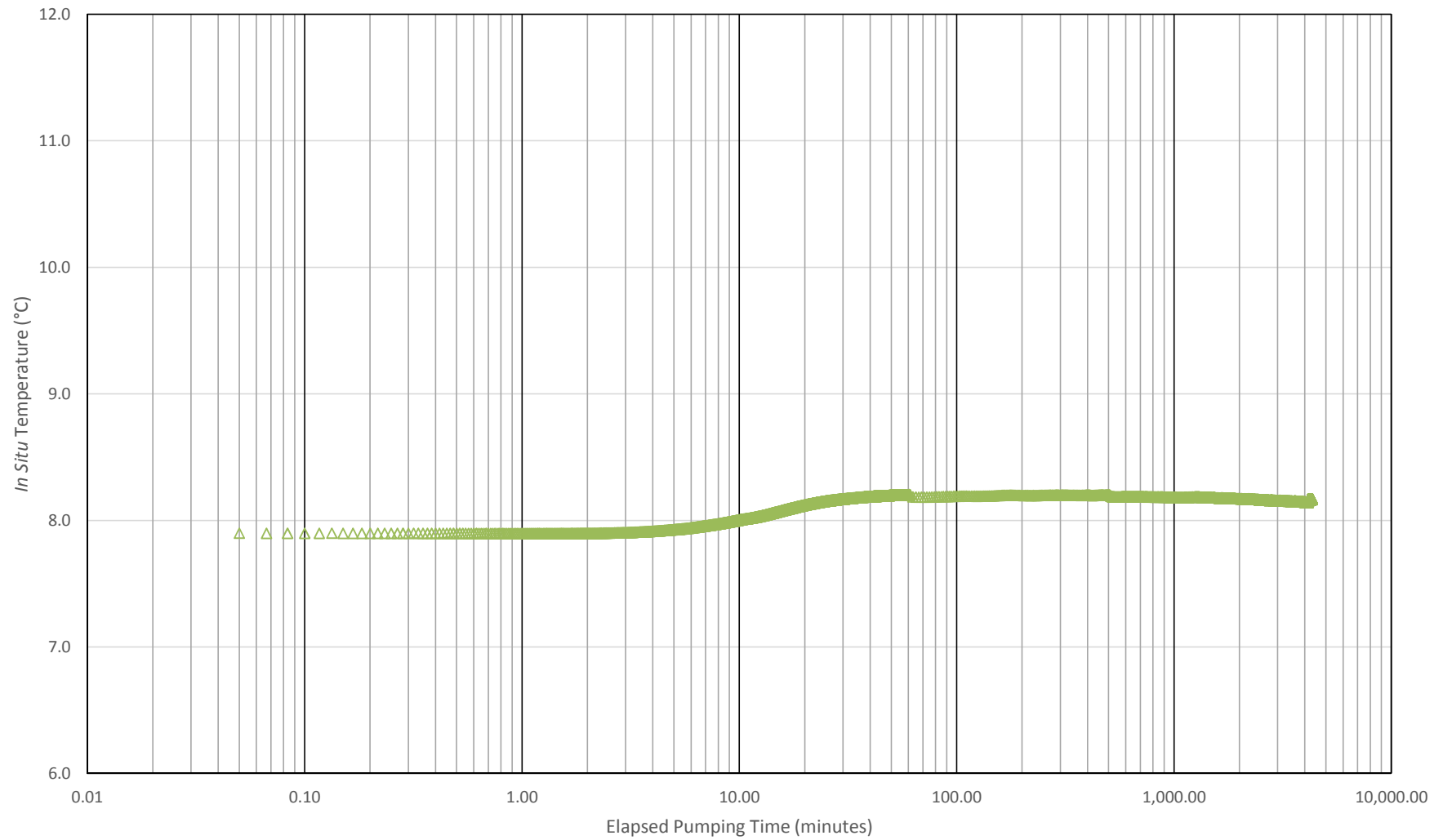
Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test - Discharge Dissolved Oxygen (mg/L)



Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test -Discharge Oxidation Reduction Potential (mV)



Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Constant Discharge Test - *In Situ* Temperature (°C)





CASH CLIENT - KAMLOOPS
EHD Consulting Ltd.
Unit 204-1139 12th Street
Kamloops BC V2B7Z2
ATTN: Matt Sarkor

Date: 17-JUN-15
PO No.:
WO No.: L1624676
Project Ref: 908/15
Sample ID: 41015
Sampled By:
Date Collected: 10-JUN-15
Lab Sample ID: L1624676-1
Matrix: Water

PAGE 1 of 3

Test Description	Result	Qualifier	Units of Measure	CDWQG MAC	Aesthetic Objective	Date Analyzed
Physical Tests						
Colour, True	<5.0		CU			12-JUN-15
Conductivity	1550		uS/cm			15-JUN-15
Hardness (as CaCO ₃)	812		mg/L		500	15-JUN-15
pH	8.50		pH		6.5-8.5	15-JUN-15
Total Suspended Solids	<3.0		mg/L			12-JUN-15
Total Dissolved Solids	1000		mg/L		500	15-JUN-15
Transmittance, UV (254 nm)	94.6		% T			12-JUN-15
Turbidity *	0.15		NTU	0.1		12-JUN-15
Anions and Nutrients						
Alkalinity, Total (as CaCO ₃)	480		mg/L			15-JUN-15
Chloride (Cl)	81.0		mg/L		250	12-JUN-15
Fluoride (F)	0.24		mg/L	1.5		12-JUN-15
Nitrate (as N)	0.332		mg/L	10		12-JUN-15
Nitrite (as N)	0.0170		mg/L	1		12-JUN-15
Sulfate (SO ₄)	425		mg/L		500	12-JUN-15
Bacteriological Tests						
E. coli	<1		CFU/100mL	0		10-JUN-15
Background colonies	<1		CFU/100mL			10-JUN-15
Coliform Bacteria - Total	<1		CFU/100mL	0		10-JUN-15
Total Metals						
Aluminum (Al)-Total	<0.010		mg/L		0.1	14-JUN-15
Antimony (Sb)-Total	<0.00050		mg/L	0.006		14-JUN-15
Arsenic (As)-Total	0.00107		mg/L	0.01		14-JUN-15
Barium (Ba)-Total	<0.020		mg/L	1		14-JUN-15
Boron (B)-Total	<0.10		mg/L	5		14-JUN-15
Cadmium (Cd)-Total	<0.00020		mg/L	0.005		14-JUN-15
Calcium (Ca)-Total	64.2		mg/L			14-JUN-15
Chromium (Cr)-Total	<0.0020		mg/L	0.05		14-JUN-15
Copper (Cu)-Total	<0.0010		mg/L		1.0	14-JUN-15
Iron (Fe)-Total	<0.030		mg/L		0.3	14-JUN-15
Lead (Pb)-Total	<0.00050		mg/L	0.01		14-JUN-15
Magnesium (Mg)-Total	158		mg/L			14-JUN-15
Manganese (Mn)-Total	0.536		mg/L		0.05	14-JUN-15
Mercury (Hg)-Total	<0.00020		mg/L	0.001		12-JUN-15
Potassium (K)-Total	5.86		mg/L			14-JUN-15
Selenium (Se)-Total	0.0053		mg/L	0.05		14-JUN-15
Sodium (Na)-Total	38.0		mg/L		200	14-JUN-15
Uranium (U)-Total	0.00330		mg/L	0.02		14-JUN-15
Zinc (Zn)-Total	<0.050		mg/L		5.0	14-JUN-15

ADDRESS: 1445 McGill Rd, Unit 2B, Kamloops BC, V2C 6K7 | Phone: +1 250 372 3588 | Fax: +1 250 372 3670

ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company



CASH CLIENT - KAMLOOPS
EHD Consulting Ltd.
Unit 204-1139 12th Street
Kamloops BC V2B7Z2
ATTN: Matt Sarkor

Date: 17-JUN-15
PO No.:
WO No.: L1624676
Project Ref: 908/15
Sample ID: 41015
Sampled By:
Date Collected: 10-JUN-15
Lab Sample ID: L1624676-1
Matrix: Water

PAGE 2 of 3

Test Description	Result	Qualifier	Units of Measure	CDWQG MAC	Aesthetic Objective	Date Analyzed
CDWQG = Health Canada Guideline Limits updated OCTOBER 2014 * CDWQG for Nitrate+Nitrite-N is the limit for nitrate only. If present as Nitrate then the limit is 10mg/L < or N.D. = less than detection limit. * Turbidity guideline based on membrane filtration. For guidelines on conventional treatment and slow sand or diatomaceous earth filtration please see Summary Table of Guidelines for Canadian Drinking Water Quality - A blank entry designates no known limit. - A shaded value in the Results column exceeds CDWQG MAC and/ or Aesthetic Objective. - In British Columbia the acceptable limits for drinking water refer to the Guidelines for Canadian Drinking Water Quality for all chemical, physical and radiological parameters. For microbiological parameters, the BC Drinking Water Protection Regulation has an immediate reporting standard of no detectable fecal coliform bacteria or Escherichia coli per 100 mL, which is represented on the report as a result of 0 or <1 MPN/100 mL of 0 or <1 CFU/100 mL.						
Approved by  Amanda Lampreau Account Manager						

ADDRESS: 1445 McGill Rd, Unit 2B, Kamloops BC, V2C 6K7 | Phone: +1 250 372 3588 | Fax: +1 250 372 3670
ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company

Guidelines & Objectives

Health Canada MAC Health Related Criteria Limits

Nitrate/Nitrite-N*	Criteria limit is 10 mg/L (1.0 mg/L if present as all Nitrite-N). High concentrations may contribute to blue baby syndrome in infants.
Lead*	A cumulative body poison, uncommon in naturally occurring hard waters.
Fluoride*	Present in fluoridated water supplies at 0.8 mg/L to reduce dental caries. Elevated levels causes fluorosis (mottling of teeth).
Total Coliforms*	Criteria is 0 CFU/100mL. Adverse health effects.
E. Coli*	Criteria is 0 CFU/100 mL. Certain E. Coli bacteria can be life threatening.

*Health Canada Canadian Drinking Water Quality Guidelines (MAC limit)

Aesthetic Objective Concentration Levels

Alkalinity	Acid neutralizing capacity. Usually a measure of carbonate and bicarbonates and calculated and reported as calcium carbonate.
Balance	Quality control parameter ratioing cations to anions
Bicarbonate	See Alkalinity. Report as the anion HCO ₃ -1
Carbonate	See Alkalinity. Reported at the anion CO ₃ -2
Calcium	See Hardness. Common major cation of water chemistry.
Chloride	Common major anion of water chemistry.
Conductance	Physical test measuring water salinity (dissolved ions or solids)
Hardness	Classical measure or capacity of water to precipitate soap (chiefly calcium and magnesium ions). Causes scaling tendency in water if carbonates/bicarbonates are present (if >200 mg/L). For drinking water purposes waters with results <200 mg/L are considered acceptable, results >200 mg/L are considered poor but can be tolerated. Results >500 mg/L are unacceptable.
Hydroxide	See alkalinity
Magnesium	See hardness. Common major cation of water chemistry. Elevated levels (>125 mg/L) may exert a cathartic or diuretic action.
pH	Measure of water acidity/alkalinity. Normal range is 7.0-8.5.
Potassium	Common major cation of water chemistry.
Sodium	Common major cation of water chemistry. Measure of salinity (saltiness).
Sulphate	Common major anion of water chemistry. Elevated levels may exert a cathartic or diuretic action.
Total Dissolved Solids	A measure of water salinity.
Iron	Causes staining to laundry and porcelain and astringent taste. Oxidizes to red-brown precipitate on exposure to air.
Manganese	Elevated levels may cause staining of laundry and porcelain.
Heterotrophic	
Plate Count	Criteria is 500 cfu/mL Measure of heterotrophic bacteria present.

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.

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

mg/L - unit of concentration based on volume, parts per million.

< - Less than.

D.L. - The reporting limit.

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.



APPENDIX F

PUMPING TEST INTERPRETATION METHODS

PUMPING TEST INTERPRETATION METHODS

SCHAFER'S METHOD (FOR ESTIMATING CASING STORAGE EFFECTS AT A PUMPED WELL)

In the early stages of a step test or constant discharge test, drawdown observed in a pumped well is typically affected by groundwater stored within the well casing. When the well is pumped, groundwater within the casing is removed first. Consequently, using early-stage drawdown data affected by well storage can yield erroneous calculations of aquifer properties (i.e., if the interpretation methods expressly neglect consideration of well casing storage).

Schafer's Method¹ can be used to identify the critical time at which casing storage effects become negligible. Schafer's Method is characterized by the following equation for drawdown data collected from a pumped well:

$$t_c = \frac{0.017(d_c^2 - d_p^2)}{Q/s}$$

Where:

t_c = time when casing storage effect becomes negligible, in minutes (min)

d_c = inside diameter of well casing, in millimetres (mm)

d_p = outside diameter of pump column pipe, in millimetres (mm)

Q/s = specific capacity of the well in m³/day/m of drawdown at time t_c .

The critical time in the above equation is determined iteratively, using a set of drawdown, elapsed pumping time and pumping rate data. Values of t_c are calculated and compared to t (elapsed time, in minutes). The time at which t_c is equal to t is considered to be the critical time.

¹ Driscoll, *Groundwater and Wells*, (Minnesota, United States of America, Johnson Screens, 2003), 233-235.

PUMPING TEST INTERPRETATION METHODS

HANTUSH-BIERSCHENK METHOD (FOR A STEP DRAWDOWN TEST)

A step drawdown test consists of pumping a well at successively increasing pumping rates over equal time periods. The Hantush-Bierschenk Method¹ is a method for interpreting linear and non-linear head losses from a step drawdown test. These head loss coefficients are an indicator of the well design and efficiency. Head losses within an ideal well, when subjected to pumping, will be comprised solely of linear head losses. The Hantush-Bierschenk method is expressed by the following equation:

$$s_{w(n)} = \sum_{i=1}^n \Delta Q_i B(r_{ew}, t - t_i) + C Q_n^2$$

Where:

$s_{w(n)}$ = total drawdown in the well during the n^{th} step at time t , in metres (m)

t_i = time at which the i^{th} step begins ($t_1 = 0$), in days (d)

Q_i = constant discharge during the i^{th} step of that preceding the n^{th} step, in cubic metres per day (m^3/day)

$B(r_{ew}, t - t_i) = B_1(r_{w,t}) + B_2$ = linear loss coefficient sum, dimensionless

B_2 = linear well-loss coefficient, dimensionless

r_w = actual radius of the well, in metres (m)

r_{ew} = effective radius of the well, in metres (m)

Q_n = constant discharge during the n^{th} step

$\Delta Q_i = Q_i - Q_{i-1}$ = discharge increment beginning at time t_i , in cubic metres per day (m^3/day)

$B_1(r_{w,t})$ = linear aquifer-loss coefficient, dimensionless

C = non-linear well-loss coefficient, dimensionless

t = pumping time, in days (d)

The Hantush-Bierschenk method is based on the following assumptions and conditions:

- The aquifer is confined, leaky or unconfined;
- The aquifer has a seemingly infinite areal extent;
- The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;
- Prior to pumping, the piezometric surface is horizontal (or nearly so) over the area that will be influenced by the test;
- The aquifer is pumped step-wise at increased discharge rates;
- The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow;
- The water removed from storage is discharged instantaneously with decline of head;
- The diameter of the well is small (i.e., the storage in the well can be neglected);
- Flow to the well is in an unsteady state;
- The values of u are small ($u < 0.01$), i.e., r is small and t is sufficiently large;
- The flow to the well is in an unsteady state; and
- The non-linear well losses are appreciable and vary according to the expression CQ^2 .

To determine head loss coefficients from a step test using the Hantush-Bierschenk method, a semi-log plot of drawdown (linear y-axis) versus time (logarithmic x-axis) is prepared. Increments of s_w are determined by extrapolating the drawdown curve from the end of the preceding pumping step to the end of succeeding pumping step. After each value of $s_{w(n)}$ is determined, an arithmetic plot of $s_{w(n)}/Q_n$ versus Q_n is prepared. The points should plot on a straight line, with values of $s_{w(n)}/Q_n$ increasing linearly with increasing values of Q_n . The slope of the straight line is equal to C (i.e., non-linear well-loss coefficient), while the y-axis intercept is equal to B (i.e., the linear head loss coefficient sum).

¹ Kruseman and de Ridder, *Analysis and Evaluation of Pumping Test Data (Second Edition)*, (Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement, 2000), 201-205.

PUMPING TEST INTERPRETATION METHODS

JACOB'S METHOD (DRAWDOWN AT A PUMPED WELL)

Jacob's Method¹, also known as the Modified Nonequilibrium Equation², is a method for interpreting aquifer transmissivity from pumping test data collected during unsteady-state groundwater flow to a well pumped at a constant rate. Unsteady-state groundwater flow is characterized by increasing drawdown in a pumped aquifer (i.e., drawdown differences with time are not negligible). Jacob's Method is characterized by the following equations for drawdown data collected from a pumped well³:

$$s = \frac{2.30Q}{4\pi KD} \log \frac{2.25KDt}{r_c^2 S} \qquad u = \frac{r_c^2 S}{4KDt}$$

Where:

s = Drawdown at Pumped Well, in metres (m)

Q = Constant Pumping Rate, in cubic metres per day (m³/d)

K = Aquifer Hydraulic Conductivity, in metres per day (m/d)

D = Aquifer Thickness, in metres (m)

KD = Aquifer Transmissivity, in square metres per day (m²/d)

t = Elapsed Time Since Pumping Started, in days (d)

r_c = Casing Radius of Pumped Well, in metres (m)

S = Aquifer Storativity, dimensionless

The above are based on the following assumptions and conditions⁴:

- The aquifer is confined;
- The aquifer has a seemingly infinite areal extent;
- The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;
- Prior to pumping, the piezometric surface is horizontal (or nearly so) over the area that will be influenced by the test;
- The aquifer is pumped at a constant discharge rate;
- The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow;
- The water removed from storage is discharged instantaneously with decline of head;
- The diameter of the well is small (i.e., the storage in the well can be neglected)
- Flow to the well is in an unsteady state;
- The values of u are small (u < 0.01), i.e., r is small and t is sufficiently large; and
- $t > \frac{25r_c^2}{KD}$, where r_c is the radius of the pumped well's casing.

To use Jacob's Method on drawdown data from a pumped well, a semi-log plot of drawdown (linear y-axis) versus time (logarithmic x-axis) is prepared. A straight line is plotted through the data. The slope of the line over one logarithmic cycle (Δs) is determined. From the slope (Δs), transmissivity is determined as follows:

$$KD = \frac{2.30Q}{4\pi \Delta s}$$

Storativity (S) cannot be determined, using Jacob's Method, solely from drawdown data collected at a pumped well.

¹ Kruseman and de Ridder, *Analysis and Evaluation of Pumping Test Data (Second Edition)*, (Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement, 2000), 65-70.

² Driscoll, *Groundwater and Wells*, (Minnesota, United States of America, Johnson Screens, 2003), 219-223.

³ Kruseman and de Ridder, *Analysis and Evaluation of Pumping Test Data (Second Edition)*, (Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement, 2000), 62, 65.

⁴ Kruseman and de Ridder, *Analysis and Evaluation of Pumping Test Data (Second Edition)*, (Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement, 2000), 55, 56, 65-67, 223-225.

THEIS RECOVERY METHOD (FOR RECOVERY MEASURED AT A PUMPED WELL)

Theis' Recovery Method¹, is a method for interpreting aquifer transmissivity from recovery data collected from a pumped well immediately after the well is pumped at a constant rate. Calculation of aquifer transmissivity from recovery data (i.e., residual drawdown or the difference between the recovered water level and the static water level measured at the beginning of the constant discharge test) provides a means of confirming the transmissivity value calculated from the constant discharge test. Theis' Recovery Method is characterized by the following equation for residual drawdown data collected from a pumped well:

$$s' = \frac{Q}{4\pi KD} \left(\ln \frac{4KDt}{r^2 S} - \ln \frac{4KDt'}{r^2 S'} \right)$$

Where:

s = Drawdown at Observation Well, in metres (m)	t = Elapsed Time Since Pumping Started, in days (d)
Q = Constant Pumping Rate, in cubic metres per day (m ³ /d)	t' = Elapsed Time Since Pumping Stopped, in days (d)
K = Aquifer Hydraulic Conductivity, in metres per day (m/d)	r = Distance from Pumped Well, in metres (m)
D = Aquifer Thickness, in metres (m)	S = Aquifer Storativity during pumping, dimensionless
KD = Aquifer Transmissivity, in square metres per day (m ² /d)	S' = Aquifer Storativity during recovery, dimensionless

The above are based on the following assumptions and conditions:

- The aquifer is confined;
- The aquifer has a seemingly infinite areal extent;
- The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;
- Prior to pumping, the piezometric surface is horizontal (or nearly so) over the area that will be influenced by the test;
- The aquifer is pumped at a constant discharge rate;
- The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow;
- The water removed from storage is discharged instantaneously with decline of head;
- Flow to the well is in an unsteady state;
- Pumping time $t_p > 25r_c^2/KD$ (where r_c = radius of the well casing);
- $t' > 25r_c^2/KD$;
- The aquifer is confined, leaky or unconfined. For leaky aquifers, the sum of the pumping and recovery times should be $t_p + t' \leq L^2 S / 20KD$ or $t_p + t' \leq cS/20$; where:
 - L = leakage factor ($\sqrt{KDc}$) in metres (m)
 - c = hydraulic resistance of the aquifer (D'/K') in days (d)
 - D' = saturated thickness of the aquitard in metres (m)
 - K' = hydraulic conductivity of the aquitard for vertical flow in metres per day (m/d)
 - S = aquifer storativity
- For unconfined aquifers, only late-time recovery data can be used.
- $u < 0.01$, $t_p > (25r_w^2 S)/KD$ (where r_w = actual radius of the well); and
- $u' < 0.01$, i.e., $t' > (25r_w^2 S)/KD$.

To use Theis' Recovery Method on residual drawdown data from a pumped well, a semi-log plot of residual drawdown (linear y-axis) versus time ratio t/t' (logarithmic x-axis) is prepared. A straight line is plotted through the data. The slope of the line over one logarithmic cycle ($\Delta s'$) is determined. Assuming that aquifer Storativity during pumping is equal to aquifer Storativity during recovery, transmissivity is determined from the slope ($\Delta s'$) as follows:

$$KD = \frac{2.30Q}{4\pi \Delta s'}$$

¹ Kruseman and de Ridder, *Analysis and Evaluation of Pumping Test Data (Second Edition)*, (Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement, 2000), 232-233.

PUMPING TEST INTERPRETATION METHODS

25-YEAR SAFE SUSTAINABLE YIELD CALCULATION

The method for calculating the 25-year safe sustainable yield for a well is based on the following assumptions:

- The well is pumped continuously over the typical life-span of the well;
- The typical life-span for a well is 25 years; and
- The specific capacity, immediately after well casing storage effects are negligible, is constant.

Based on the above, the 25-year safe sustainable yield is iteratively estimated using multiple Jacob Approximation straight-line projections based on the following constants:

- 25-year pumping period;
- Specific capacity of the well immediately after well casing storage effects are negligible;
- Aquifer transmissivity; and
- Safe available drawdown. The safe available drawdown is equal to 70 % of the total available drawdown. The total available drawdown is calculated as follows for different well completion scenarios:
 - o *Well completed in bedrock* – the difference between the static water level (i.e., water level measured prior to pumping) and the top of the uppermost bedrock fracture.
 - o *Well completed in a confined aquifer* – the difference between the static water level and the top of the confining layer.
 - o *Well completed in an unconfined aquifer* – the difference between the static water level and the top of the pump intake.

The 25-year safe sustainable yield is equal to the pumping rate used in the above projections that results in a drawdown equal to the safe available drawdown.

The 25-year safe sustainable yield method should also consider:

- Well interference;
- Aquifer mining;
- Surface water interactions; and
- Sea water encroachment.

Further, sustainable yield estimated using the 25-year safe sustainable yield shall not be greater than the well screen maximum transmitting capacity or the rate at which the well was pumped during the constant discharge test.

APPENDIX G

HANTUSH-BIERSCHENCK CURVE

Clinton Hongyang Zhengong International Investment Inc.
Well 41015 Step Test Interpretation - Hantush-Bierschenk Method

