ELANCO ENTERPRISES LTD. Our File: 201

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July 25, 2015

Regional District of Nanaimo
Water Utilities Section
6300 Hammond Bay Road
Nanaimo, B.C.
V9T 6N2

Attention: Gerald St. Pierre, P. Eng, PMP, Project Engineer.

Dear Sirs:

Re: Assessment of Groundwater Supply Potential for Whisky Creek Water Service Area, Hilliers, B.C.

As requested, I have conducted a hydrogeological assessment of the area on, and around, the Whisky Creek water service area located south of Highway 4 in the Hilliers area, west of Qualicum Beach, BC (the Service Area). This report provides a summary of the work carried out and sets out my findings relating to the search for a groundwater source that has the potential to replace the surface water source which currently supplies the Service Area.

Background

The existing water supply system abstracts water from Crocker Creek through an infiltration gallery. According to Koers & Associated Engineering Ltd. (Koers, 2014), this water is treated by dosing with a polymer and passing it through a pressurized sand filter, followed by chlorination, before delivering it to the supply system. As a requirement for the operating permit issued by the Vancouver Island Health Authority (VIHA), the operator is to upgrade the system to achieve an improved capacity to remove microbiological pathogens, in accordance with the VIHA's policy 3.3 and the BC Drinking Water Treatment Objectives. The options being considered for achieving this objective are:

1) Develop a groundwater source and

2) Install a higher level surface water treatment system.

Terms of Reference

In April 2015, Elanco Enterprises Ltd. (Elanco) was retained by the Regional District of Nanaimo (RDN) to carry out a hydrogeological assessment of the area to determine if a groundwater source was feasible, the scope of which is set out in the attached Appendix A.

The work carried out by Elanco included:

- Reviewing and collating relevant information on geology, soils and groundwater, with an emphasis on surficial sediment aquifers, especially in areas located on and west and northwest of the Service Area. This included preparation of hydrogeological profiles in selected areas, identifying groundwater recharge areas and potential sources of contamination, determining groundwater quality and delineating groundwater discharge areas (such as springs and stream inflows).

- Making site visits on May 6th, 2015 and June 22nd, 2015, and communicating with representatives from Fyfe Well Drilling and Pump Systems Ltd. and Red Williams Well Drilling Ltd. While in the field, relevant geological features were mapped and water from accessible springs and creeks was collected for in-field analyses of indicator geochemical parameters, such as: pH, electrical conductivity, temperature and redox.
- Delineating areas where suitable groundwater sources could be developed and carrying out preliminary water balances to assess potential long term sustainability of identified aquifers.

Water Supply Requirement

According to Koers (2014), the Service Area serves a population of about 300 who reside in 123 households. Water consumption ranges from 41.8 m^3/day in winter to about 210 m^3/day at the peak of summer. This represents a range of 0.48 L/s to 2.43 L/s (6.4 to 32.2 Igpm), as set out on Table I in this report.

Physical Setting and Drainage

The irregular shaped Service Area is located south of the Alberni Highway (Hwy 4) and is accessed via Poplar Way. The area is located on undulating land that predominantly rises upwards towards the south. The Crocker Creek water intake is located at the east end of Herbert Street at an elevation of about 123 metres above mean sea level (m-asl) (see Figs. 1 and 2).

The Service Area is drained on both east and west sides by tributaries of Whisky Creek, Crocker Creek being one of them (see Fig. 1). As is indicated later in this report, the base flows in the major Whisky Creek tributaries are sustained by groundwater flowing from an unconfined aquifer located in the south and west of the Service Area.

Surficial Geology

The regional geology map indicates that the Service Area is underlain by marine and glaciomarine sediments (Unit 12a and 12c on Fig. 1). Unit 12a is comprised of sand and sandy gravel (see Photo 1). which are generally underlain by clay. Unit 12c is relatively thin (less than 2m thick) and comprises stony gravel, sand, silt, clay and gravelly loam. South and west of the Service Area there is an extensive glaciofluvial deposit. This deposit is comprised of sand and gravel, with lenses of glacial till. Unit 8 is in the form of hummocky (kame) knob-and-kettle ridged deposits, which were formed when glaciers melted in the area. Further south, there are kame terrace and kame delta deposits Unit 9a).

Water Wells

GW Solutions Inc. (2012) have provided information on the regional hydrogeology and higher yielding wells. There is only one record of a well located in the Service Area (see Well 13336 on Fig. 2.) This 15.2m deep well was constructed before 1950 and other than knowing the depth to bedrock (7.9m) there no other information on the well (see listing on Table II). As the well was apparently never commissioned and given it is geological setting, it is unlikely that this well had a yield greater than about 0.3 litres per second (L/s)

In the greater area, locations of about 50 wells are indicated on the regional well map presented on Fig. 2, and. of these, eight are shallow dug wells. This inventory was based initially on well records listed in the BC Ministry of Environment's wells (MOE) database and has since been supplemented by well logs provided by a local well drilling contractor (see wells on Fig. 3). This is likely still not a complete record of all wells in the area, as government reporting on well construction is voluntary in BC. A summary of depth, yield and elevation information on most of the documented wells is provided on Table II.

The results of this review led to the following observations:

- Of the 33 well records for drilled well summarized on Table II, none confirmed a "dry hole".
- The estimated yields ranged from 0.01 to 3.8 (L/s). This compares with the 2.4L/s peak summer demand required for the Service Area.
- The median and average yields were respectively 0.6 and 1.0 L/s.
- The higher yields were all from wells constructed in the hummocky kame deposits (Unit 8 on Fig. 1)
- Well depths ranged from 4.3 to 110m, but the median was only 14m
- Median depths to static water level (SWL) ranged from 0.9m to 19.8m, and the median was 7.6m.
- Only eight wells encountered bedrock. In each case the record indicates it was shale bedrock.

A dug well located on a property on the south side of Fyfe Road was considered as a potential water supply for the Service Area (see location on Fig. 2) as it had high yield potential. However, when learned that this well is about 6m deep and is situated in an area where surface water is present, this well was not pump tested, as the water from this well clearly would be considered GWUDI.

Aquifers and Groundwater Flow Systems

As indicated earlier, the glaciofluvial deposits form the most productive aquifer in the area, and this helps sustain base flows in the many tributaries of Whisky Creek, including Crocker Creek.

Using lithologic information from selected well logs, two hydrogeologic sections were constructed. These are the southwest to northeast Section A-A', presented on Fig. 5 and the east-west to Section B-B', presented on Fig. 6. Both sections are drawn through hummocky kame deposits (Unit 8) which gradually thin out from about 30m in the southwest to about 2m in the north east. This moderately permeable sand and gravel unit is underlain by shale bedrock, as is confirmed by the few wells that have fully penetrated the unit. Most of the wells were drilled for domestic water supplies and there was no reason to fully penetrate the aquifer.

The western portion of Section B-B' is constructed through wells drilled on each lot in a residential subdivision. As can be seen, the well yields ranged from 0.5 to 1.3 L/s, with the higher yields coming from the deeper two of the seven wells. The other two wells located along this section had progressively lower yields with increased distance to the east. This trend was taken into account when selecting a test well site for the Service Area.

The saturated thickness in the south and western areas of the two sections is about 10m and hydraulic gradients are about 0.015. Assuming an average aquifer hydraulic conductivity of 4 x 10^{-4} m/s the calculated flux is about 6 L/s/100m of aquifer width.

The approximate 150m width of the groundwater discharge zone that feeds Crocker Creek is indicated on Fig. 5. This suggests that the base flow in Crocker Creek will be about 9 L/s, which is well above the Service Area peak usage of 2.4 L/s.

Potential for Constructing a Water Supply Well to Supply the Service Area

The nearest potential groundwater development areas (Area 1 and Area 2) to the existing service intake are located southeast (up gradient) of the Crocker Creek discharge area indicated on Figs. 2, 3 and 7. As they are located on crown land (see Fig. 2), it is possible that the RDN can get permission to locate a well on the property. For example, access to a proposed test site (in Area 1) appears feasible if permission can be obtained to pass through privately owned land located west of the crown land (see access road on Fig 3 and Photo 2.

As the lithology and permeability of the sediments in this target area are likely quite variable, it is recommended that a test drilling program be carried out, and a budget for at least two test holes be considered. If groundwater investigation in the nearest area (see Area No. 1 on Fig. 2) does not prove to be viable, then consideration could be given to exploring for a water source in development Area No. 2, which is located further west on crown land.

As there is always degree of uncertainty when selecting a site for groundwater exploration, the use of geophysical techniques can sometimes be considered to reduce the risk. Consideration was given to recommending the use of resistivity imaging to profile the base of the aquifer. This technique involves profiling using instruments on the ground surface to pass an electrical current into the ground and monitoring responses, so that depths lithological boundaries can be estimated (see information in Appendix B). The estimated cost of running a resistivity survey is in the range $6,000 to $8,000. This compares with an estimated $3,000 cost for drilling casing to a depth of 25m and assessing the potential for completing the hole as a production well or for an additional cost of $2,500 completing the hole as a monitoring well. As the chance of successfully constructing a production well using, the first test hole is reasonably good, the use of geophysics is likely not warranted at this site.

Water Quality

Inorganic water quality parameters in the analyses of Crocker Creek source water suggest that the water has a relatively low (100 mg/L) total dissolved solids concentration (TDS). Most of the inorganic parameters tested easily met Canadian Drinking Water Quality criteria (see data in Appendix C). The exception was aluminum for one sample, and total hardness (too low).

Similarly, water analyses for a community well located at Westurne Heights also indicate a low TDS and excellent water quality (see table in Appendix C). This suggests that a well located at the suggested development site will have a similar quality to these two sets of analyses.

Samples collected from a community well located on Melrose Terrace (see Fig. 2), had higher hardness concentrations and elevated iron and manganese concentrations. (see Appendix C) As this well is located in a hydrogeologically different area, this type of water quality is not anticipated at the proposed development site.

The estimated extent of the typical new production well capture zone is indicated on Fig. 7. In this example, the capture zone is currently undeveloped, and as there is likely a significant thickness of unsaturated sediments above the water table, the chance of the well being contaminated is relatively remote.

The water pumped from the well will not be considered groundwater under the direct influence of surface water (GWUDI).

Summary and Conclusions

1. Glaciofluvial aquifer located south east of the current Service area water intake has the potential for supplying the community needs from one or possibly two wells located on Crown land..
2. The nearest proposed development site is located approximately 0.5 Km from the existing water intake and is located on crown land. Routing for a potential pipeline could either follow a road right of way or have an easement to pass directly through privately owned land.
3. There is a relatively high chance of developing a water source capable of yielding up to 2.4 L/s from one well, and an even higher chance from two wells.
4. The water pumped from the proposed development site will very likely meet the Canadian Drinking Water Quality standards for all parameters.

Limitations.

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

I trust that this is sufficient for you present purposes.

Yours truly,

Elanco Enterprises Ltd.

PROFESSIONAL
PROVINCE OF
R. A. DAKIN
7665
BRITISH COLUMBIA
ENGINEER

R. Allan Dakin, FEC, P. Eng.
Senior Groundwater Engineer

References

GW Solutions Inc. August 2012. Whisky Creek Groundwater Supply Assessment. Report prepared for the Regional District of Nanaimo, 11pp

Koers & Associates Engineering Ltd, September 2014. Whisky Creek Service Area – Water Treatment Options. Report prepared for the Regional District of Nanaimo. 23pp.

Koers & Associates Engineering Ltd, January 2014. Westurne Heights Water System Assessment. Report prepared for the Regional District of Nanaimo.

Photographs

Photo. 1 Exposed sands and gravel – typical of the type found in the test well area.

Photo. 2 Recommended site for a test well on Crown Land Property.

Tables

Table I

Whisky Creek Water Supply System Demend

Parameter units -->	System demand m^3/d/hld	 m^3/d	 L/s	 Igpm	 Usgpm
Population	300				
Number of households	123				
Winter and fall - min	0.34	41.8	0.48	6.4	7.7
Winter and fall - max	0.59	72.6	0.84	11.1	13.4
Summer	1.71	210	2.43	32.2	38.6

Notes:

1) Water demand information from Koers & Associates Engineering Ltd. 2014

Table II
Information on local area water wells

Address	WTN	Construction		Depth (metres) to:						Elevation (m-asl)							Yield
		Year	Type	Top of Aquifer	SWL	Water Strike	Bottom of Aquifer	Bedrock surface	Bottom of Hole	Ground	Top of Aquifer	SWL	Water Strike	Bottom of Aquifer	Bedrock surface	Bottom of Hole	L/s
Albernei Highway - No. 4	13051	<1950	na	7.3	8.8	7.3	8.8	8.8	9.4	140	132.7	131.2	132.7	131.2	131.2	130.6	na
Burbank Road	13184	<1950	na	na	9.1	9.1	na	na	10.4	130	na	120.9	120.9	na	na	119.6	na
Albernei Highway - No. 4	13217	<1950	na	na	9.1	9.1	na	na	10.4	129	na	119.9	119.9	na	na	118.6	na
Albernei Highway - No. 4	13270	<1950	D4	na	10.1	na	na	na	10.7	138	na	127.9	na	na	na	127.3	na
Albernei Highway - No. 4	13306	<1950	D3	na	0.9	na	na	na	4.3	119	na	118.1	na	na	na	114.7	na
Albernei Highway - No. 4	13313	<1950	D4	na	4.3	na	na	na	4.9	119	na	114.7	na	na	na	114.1	na
Albernei Highway - No. 4	13336	<1950	D8	na	na	na	7.9	7.9	15.2	120	na	na	na	112.1	112.1	104.8	na
Albernei Highway - No. 4	13363	<1950	D4	na	10.1	na	na	na	10.7	120	na	109.9	na	na	na	109.3	na
Albernei Highway - No. 4	13365	<1950	na	6.1	7.0	na	na	na	7.9	128	121.9	121.0	na	na	na	120.1	na
Melrose Road	27360	1972	Dr	na	6.1	12.2	na	11.3	30.5	115	na	108.9	102.8	na	103.7	84.5	0.9
Melrose Road	43043	1979	D6	na	4.6	na	na	15.2	68.6	120	na	115.4	na	na	104.8	51.4	0.1
907 Chatsworth Rd (Big Country Auto)	43966	1979	D6	na	6.1	6.1	na	na	18.3	144	na	137.9	137.9	na	na	125.7	0.6
Albernei Highway - No. 4	44700	1980	D6	na	11.3	na	na	na	17.4	130	na	118.7	na	na	na	112.6	0.3
Chatsworth Road	46373	1980	D6	15.2	15.2	18.3	na	na	26.8	144	128.8	128.8	125.7	na	na	117.2	0.4
3681 Tralee Road	50473	1982	D6	6.1	6.1	6.1	13.7	13.7	13.7	152	145.9	145.9	145.9	138.3	138.3	138.3	0.3
Chatsworth Rd (1191 Waltz Road)	506i0	1982	D6	8.8	na	8.8	na	na	11.9	170	161.2	na	161.2	na	na	158.1	1.9
Malcolm Road @ Chatsworth	54234	1984	D6	na	9.1	na	na	na	18.3	146	na	136.9	na	na	na	127.7	0.3
Albernei Highway - Service Stn	55283	1985	D6	4.6	3.7	4.6	na	na	13.7	135	130.4	131.3	130.4	na	na	121.3	2.2
Melrose Road (iron issue)	60285	1993	D6	5.5	2.3	3.0	14.3	na	16.8	135	129.5	132.7	132.0	120.7	na	118.2	3.8
Melrose Road	60508	1994	D6	18.9	18.9	19.8	29.0	33.2	33.2	137	118.1	118.1	117.2	108.0	103.8	103.8	2.2
Albernei Highway - No. 4	82056	na	D6	na	na	na	na	9.1	103.6	114	na	na	na	na	104.9	10.4	0.01
3514 Brittain Boulevard	87312	1983	D6	na	1.5	na	na	7.9	109.7	113	na	111.5	na	na	105.1	3.3	na
Melrose Road - **RDN utility**	93890	na	D6	na	19.2	na	26.2	na	29.3	140	na	120.8	na	113.8	na	110.7	na
Melrose Road	100291	1994	Dr	10.7	4.3	10.7	13.4	na	14.3	133	122.3	128.7	122.3	119.6	na	118.7	1.9
3679 Melrose Road	110000	2014	D6	8.5	7.9	8.5	14.0	na	14.6	120	111.5	112.1	111.5	106.0	na	105.4	0.4

Table II
Information on local area water wells

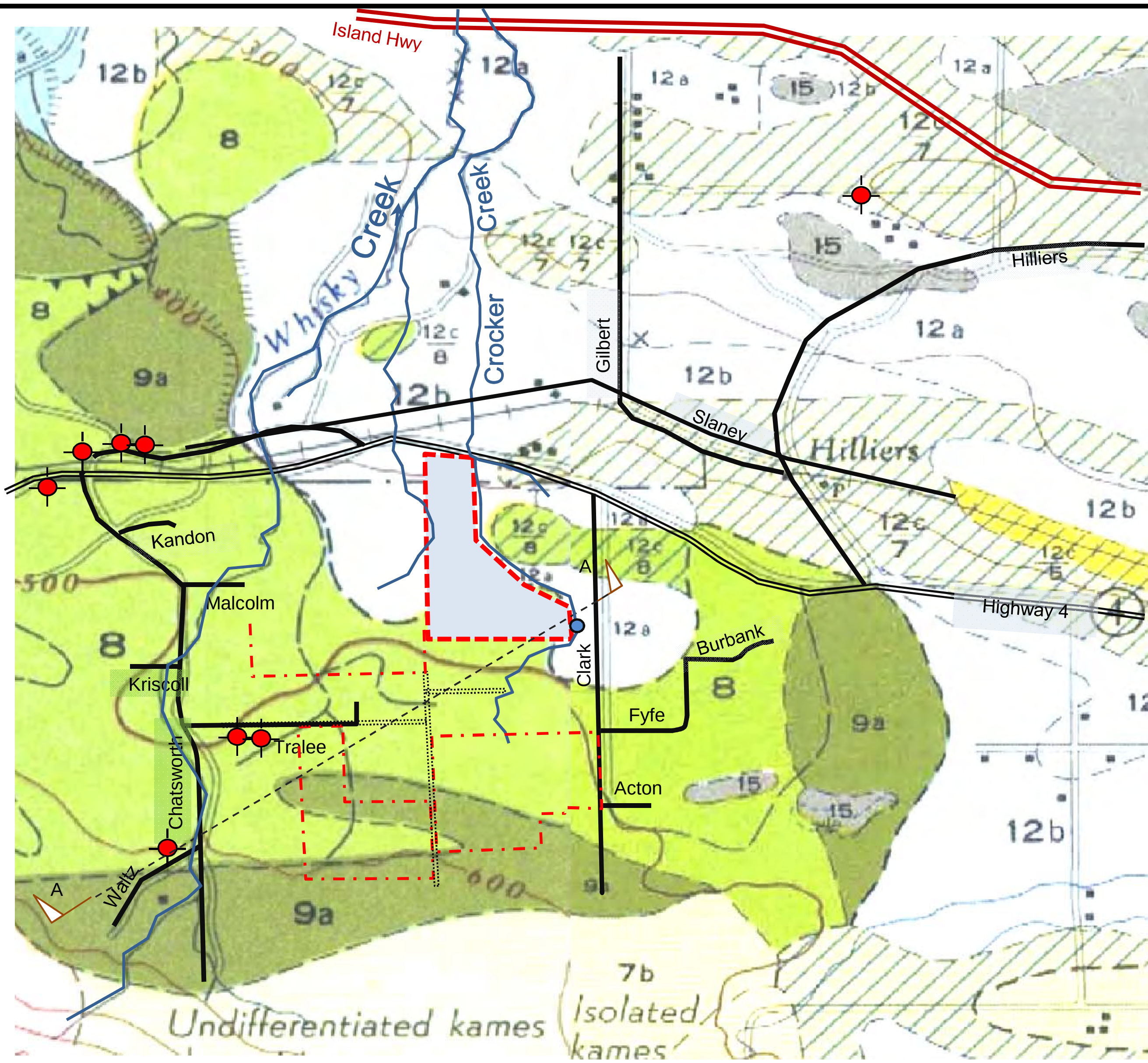
Address	WTN	Construction		Depth (metres) to:						Elevation (m-asl)							Yield
		Year	Type	Top of Aquifer	SWL	Water Strike	Bottom of Aquifer	Bedrock surface	Bottom of Hole	Ground	Top of Aquifer	SWL	Water Strike	Bottom of Aquifer	Bedrock surface	Bottom of Hole	L/s
Tralee Road - Lot 1	na	1996	D6	5.5	7.0	5.5	10.5	na	11.6	160	154.5	153.0	154.5	149.5	na	148.4	0.6
Tralee Road - Lot 2	na	1996	D6	7.3	5.0	7.3	13.6	na	14.0	161	153.7	156.0	153.7	147.4	na	147.0	0.5
Tralee Road - Lot 3	na	1996	D6	6.7	4.3	7.3	12.0	na	12.2	161	154.3	156.7	153.7	149.0	na	148.8	0.4
Tralee Road - Lot 4	na	1996	D6	9.8	9.4	9.8	19.7	na	19.7	160	150.2	150.6	150.2	140.3	na	140.3	1.3
Tralee Road - Lot 5	na	1996	D6	12.8	8.8	12.8	17.1	na	17.1	160	147.2	151.2	147.2	142.9	na	142.9	1.3
Tralee Road - Lot 6	na	1996	D6	9.4	7.6	9.4	13.7	na	13.7	159	149.6	151.4	149.6	145.3	na	145.3	0.6
Tralee Road - Lot 7	na	1996	D6	7.6	8.8	8.5	10.2	na	11.4	159	151.4	150.2	150.5	148.8	na	147.6	0.6
Tralee Road - Lot A	na	2003	D6	7.9	na	8.5	11.0	na	11.0	155	147.1	na	146.5	144.0	na	144.0	0.6
Minimum				4.6	0.9	3.0	7.9	7.9	4.3	113	111.5	109	102.8	106.0		3.3	0.01
Median				7.8	7.6	8.5	13.6	10.2	14.0	137	146.5	129	137.9	139.3		119.6	0.6
Average				8.8	7.8	9.2	14.7	13.4	22.3	138	139.5	130	136.5	132.3		116.1	1.0
Maximum				18.9	19.2	19.8	29.0	33.2	109.7	170	161.2	157	161.2	149.5		158.1	3.8

otes:
1) Data based on logs available on the BC Ministry of Environment wells data base and other sources.
2) See locations of wells on Figs. 2 and 3
3) Ground elevations estimated from Google Earth mapping.
SWL = static water level recorded soon after well construction
WTN = Well tag number assigned by BC MOE.

DRAFT

Well Construction Type
na = No information
Dr = drill hole diam not indicated (likely 6-inch diam)
D4, D6, D8 = Drilled hole with 4, 6 and 8-inch diameter.

Figures



Scale (1:30,000)

0 400 800m

Legend

PLEISTOCENE AND RECENT

SALISH SEDIMENTS

16 — SHORE, DELTAIC AND FLUVIAL DEPOSITS: gravel, sand, silt, clay, peat; 16a, alluvial fan deposits

CAPILANO SEDIMENTS (12,13)

13 — TERRACED FLUVIAL DEPOSITS: 13a, Deltaic deposits: gravel and sand commonly underlain by silt and clay; 13b, Channel and floodplain deposits: gravel, sand, minor silt; in Alberni Valley includes estuarine deposits with lenses of clay (shown only where more that 5 feet thick); 13c, Alluvial fan deposits: poorly sorted gravel and silt

12a,b 12c — MARINE DEPOSITS (INCLUDING GLACIO-MARINE): 12a, silt, clay, stony clay; 12b, sand, sandy gravel, generally underlain by clay — Thickness few inches to 30 feet; 12c, Marine veneer complex: varied stony gravel, gravel, sand, silt, clay, stony loam; discontinuous in bedrock areas — Thickness generally less than 5 feet

14 15 — 14. LANDSLIDE AND TALUS DEPOSITS: blocks and rubble; 15. UPLAND SWAMP DEPOS peat and muck

Whisky Creek water Service area

Crocker Creek water supply source

Well with reported >1 L/s yield.

8 9 — GLACIO-FLUVIAL DEPOSITS: gravel, sand, lenses of till; 8. Hummocky (kame), knob-and-kettle, and ridged deposits; 8a, esker deposits; 9. Terrace and pitted-terrace deposits; 9a, kame terrace and kame delta deposits; 9b, ice-contact alluvial fan deposits

7 — GROUND MORAINE DEPOSITS: till, lenses of gravel, sand, and silt; 7a, sandy till west side of Alberni Valley; 7b, slope complex of till, alluvium, and colluvium

QUADRA SEDIMENTS (3-5)

5 — Sand, minor gravel; in part covered by remnants of till

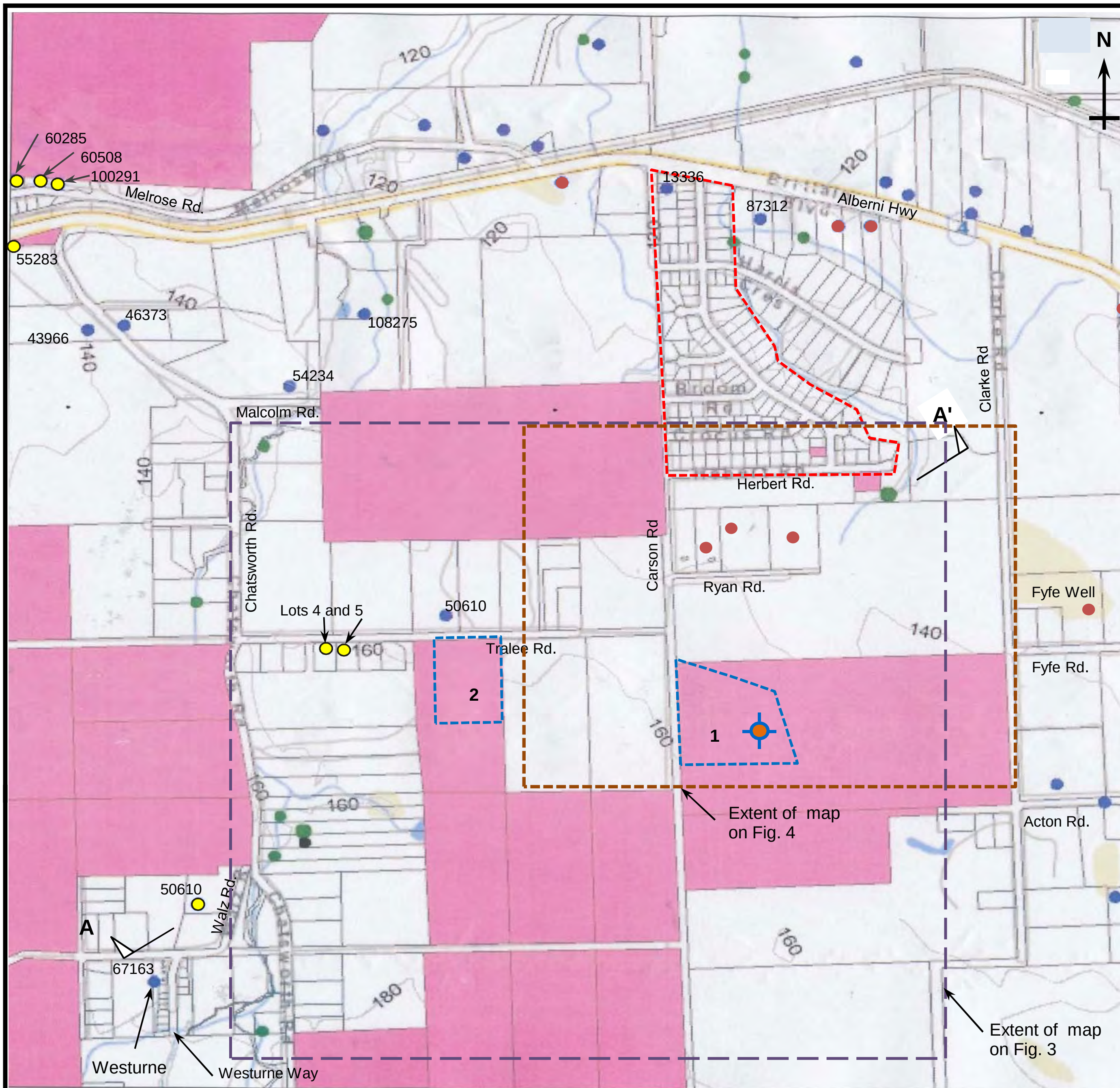
A

NOTES
1) Adapted from Geological Survey of Canada 1:63,000 scale Maps No.1111A & 1112A
2) See Hydrogeological Section A-A' on Fig.4

REGIONAL DISTRICT OF NANAIMO

ELANCO ENTERPRISES LTD.
Victoria, B.C. (250 744-1357)

WHISKY CREEK WATER SERVICE AREA- GROUNDWATER FEASABILITY STUDY, HILLIERS, B.C.	**SURFICIAL GEOLOGY MAP**	Drawn:	Date Jul. 2015
		Approved:	Fig. **1**



Legend

Proposed test well site
Drilled well.
Dug well.
Drilled well with reported yield greater than 1 L/s.

1 Proposed groundwater investigation Area 1

A Hydrogeologic Section (see Fig. 4)

Points of surface water diversion
STATUS
Active Application
Active Application and Licence
Inactive
Active Licence

Crown land

Whisky Creek water Service area

Scale (1:15,000)
0 200 400m

NOTES
1) Base map with well locations is from BC MOE web site.
2) The numbers posted at the well locations are well tag numbers (WTN). See information on drilled wells on Table I.

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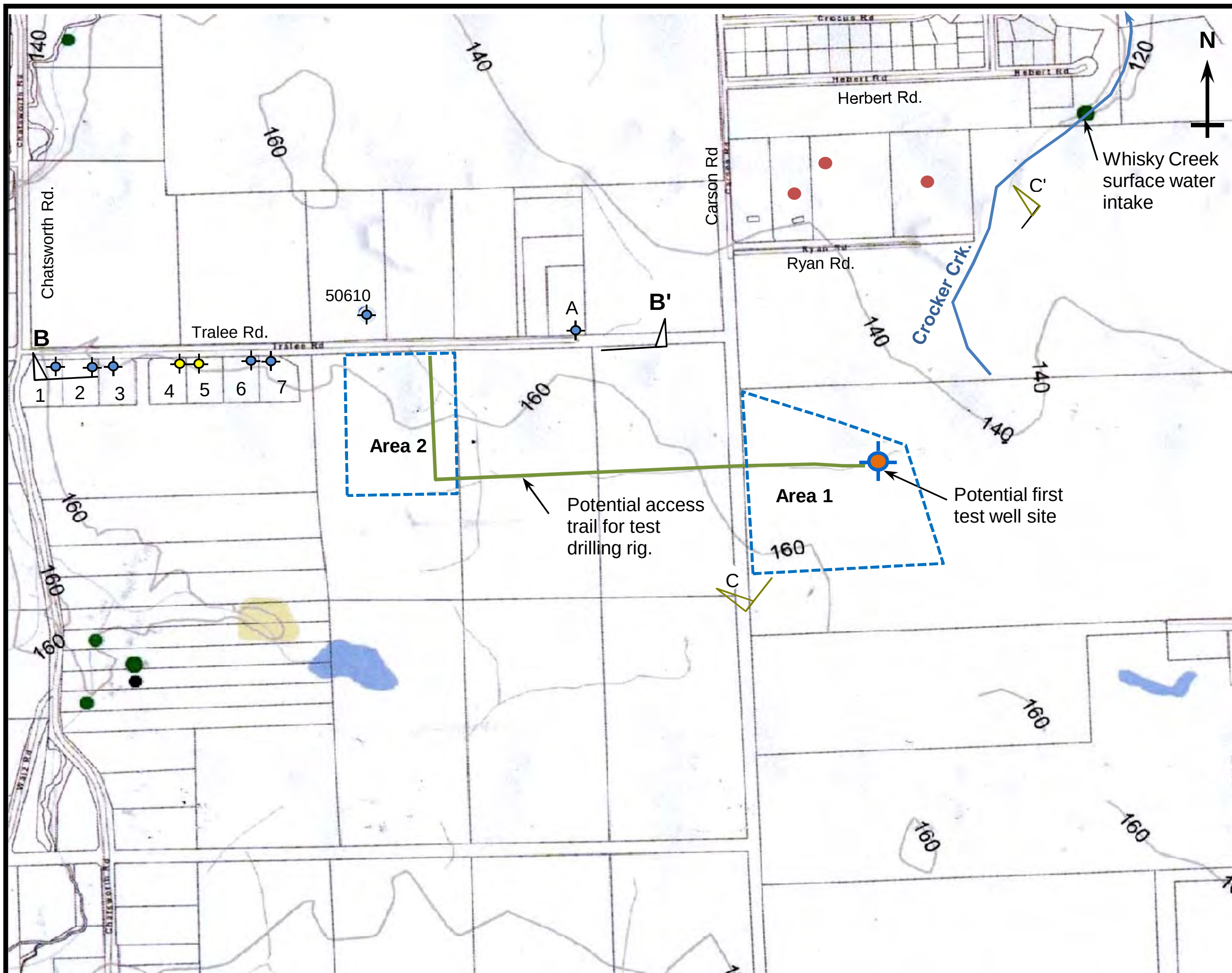
WHISKY CREEK WATER SERVICE AREA- GROUNDWATER FEASABILITY STUDY, HILLIERS, B.C.	**REGIONAL WELL LOCATION MAP**	Drawn:	Date Jul. 2015
		Approved:	Fig. **2**

JOB NUMBER: 201



Scale (1:10,000)

0 200 400m

Legend

B Hydrogeologic Section (see Figs 5 and 7)

Drilled well.

Dug well.

See Note. 1

Drilled well with reported yield greater than 1 L/s.

1 Proposed groundwater investigation Area 1

Points of surface water diversion

STATUS

- Active Application
- Active Application and Licence
- Inactive
- Active Licence

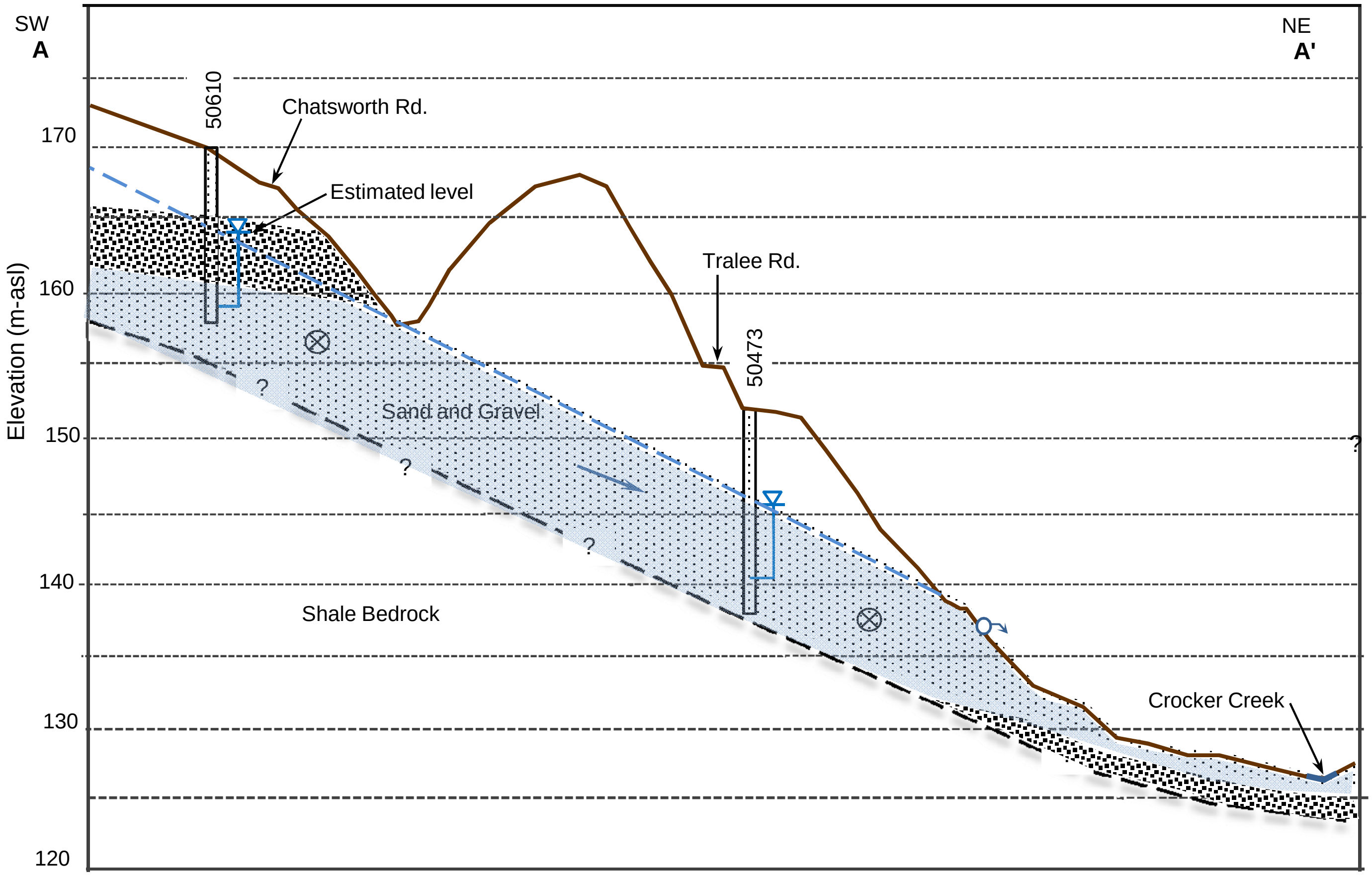
NOTES

1) With the exception of one well (WTN 50610) none of these wells are located on the MOE web based map .

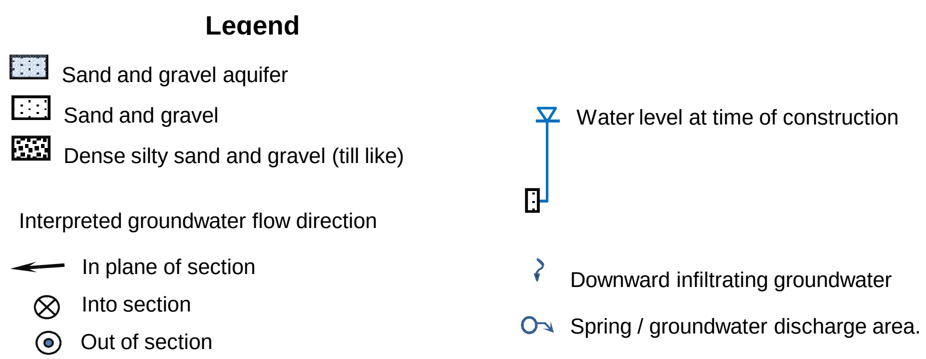
REGIONAL DISTRICT OF NANAIMO	***ELANCO ENTERPRISES LTD.*** ***Victoria, B.C. (250 744-1357)***

WHISKY CREEK WATER SERVICE AREA- GROUNDWATER FEASABILITY STUDY, HILLIERS, B.C.	MAP OF STUDY AREA	Drawn:	Date Jul. 2015
		Approved:	Fig. 3

File:2600 \ 201 Figures 3 Tralee map 27/07/2015 11:39 AM



Estimated flow in the section =	0.05	L/s/m
	5.2	L/s/100m
Gradient =	0.013	
Thickness =	10	m
Hydraulic conductivity =	0.0004	m/s



Horizontal Scale (1:15,000)

0 200 400m

Vertical exaggeration = 30

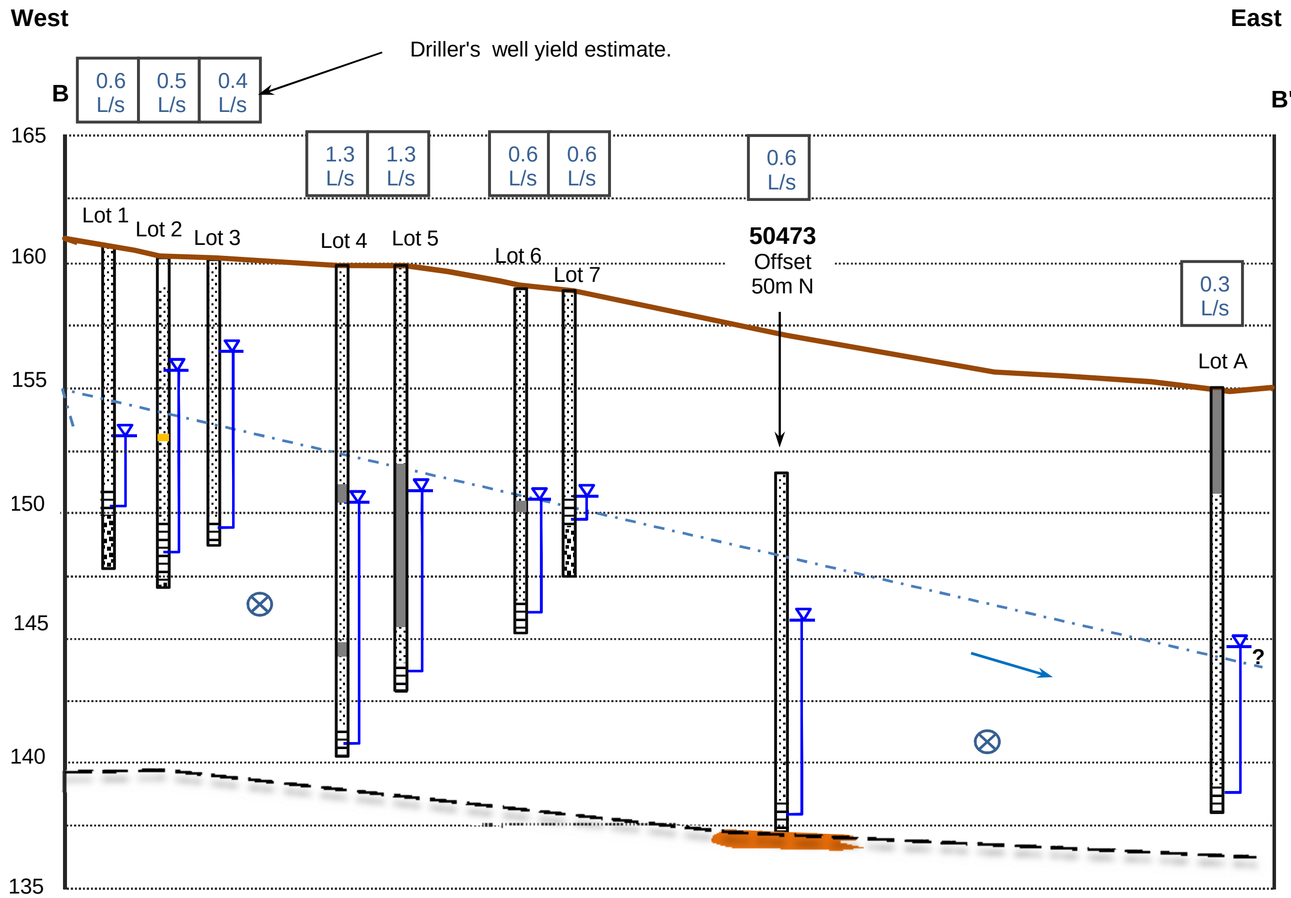
NOTES

1) See location of section on Figs. 2 and 3 and information on wells on Table I.

REGIONAL DISTRICT OF NANAIMO	***ELANCO ENTERPRISES LTD.*** ***Victoria, B.C. (250 744-1357)***

WHISKY CREEK WATER SERVICE AREA- GROUNDWATER FEASABILITY STUDY, HILLIERS, B.C.	**HYDROGEOLOGICAL SECTION A - A'**	Drawn:	Date Jul. 2015
		Approved:	Fig. **4**

JOB NUMBER: 201



Estimated flow in the section = 0.06 L/s/m

6.4 L/s/100m

Gradient = 0.016

Thickness = 10 m

Hydraulic conductivity = 0.0004 m/s

Legend

- Permeable sediments (Sand and gravel, with some silt zones)
- Low permeability (till like) sediments
- Clay and dense silt
- Peat.
- Shale bedrock

SWL

Well screen

Interpreted groundwater flow direction

- In plane of section
- Into section
- Out of section

Interpreted water table

NOTES

1) See location of section on Fig. 3 and summary of information on wells in Table II.

2) SWL = static water level at the time of construction.

Horiz. scale (1:5,000)

0 80 160m

Vertical exaggeration = 16.7

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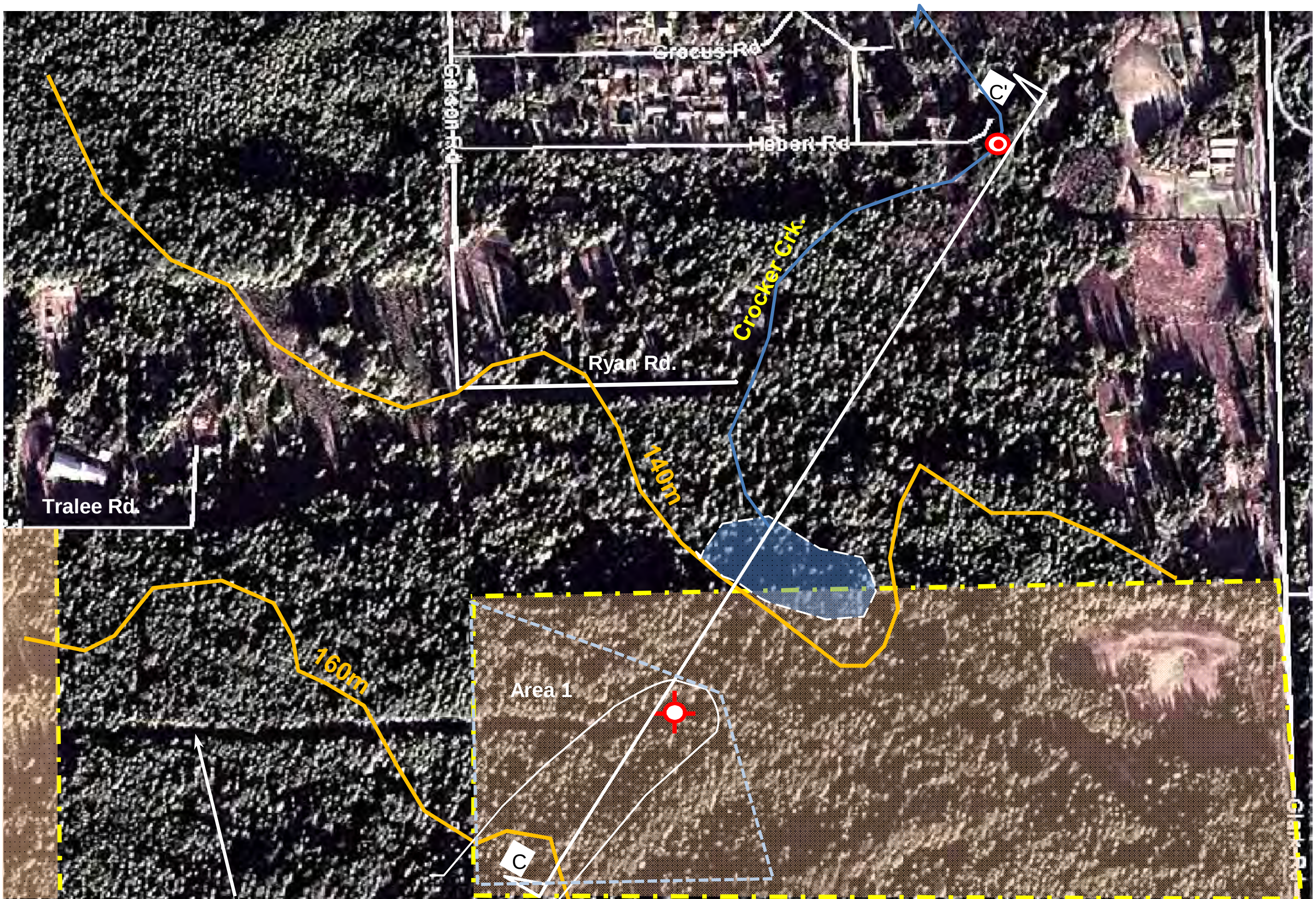
WHISKY CREEK WATER SERVICE AREA- GROUNDWATER FEASABILITY STUDY, HILLIERS, B.C.	**HYDROGEOLOGICAL SECTION B - B'**	Drawn:	Date Jul. 2015
		Approved:	Fig. **5**

JOB NUMBER: 201



Potential access trail for test drilling rig.

Legend

- Proposed test well site
- Hydrogeologic Section (see Fig 7)
- Groundwater discharge area that supplies Crocker Creek.
- Whisky Creek surface water intake
- 1 Proposed groundwater investigation Area 1

Scale (1:7,000)

0 100 200m

NOTES

1) Base map from Google Earth 2015 view.

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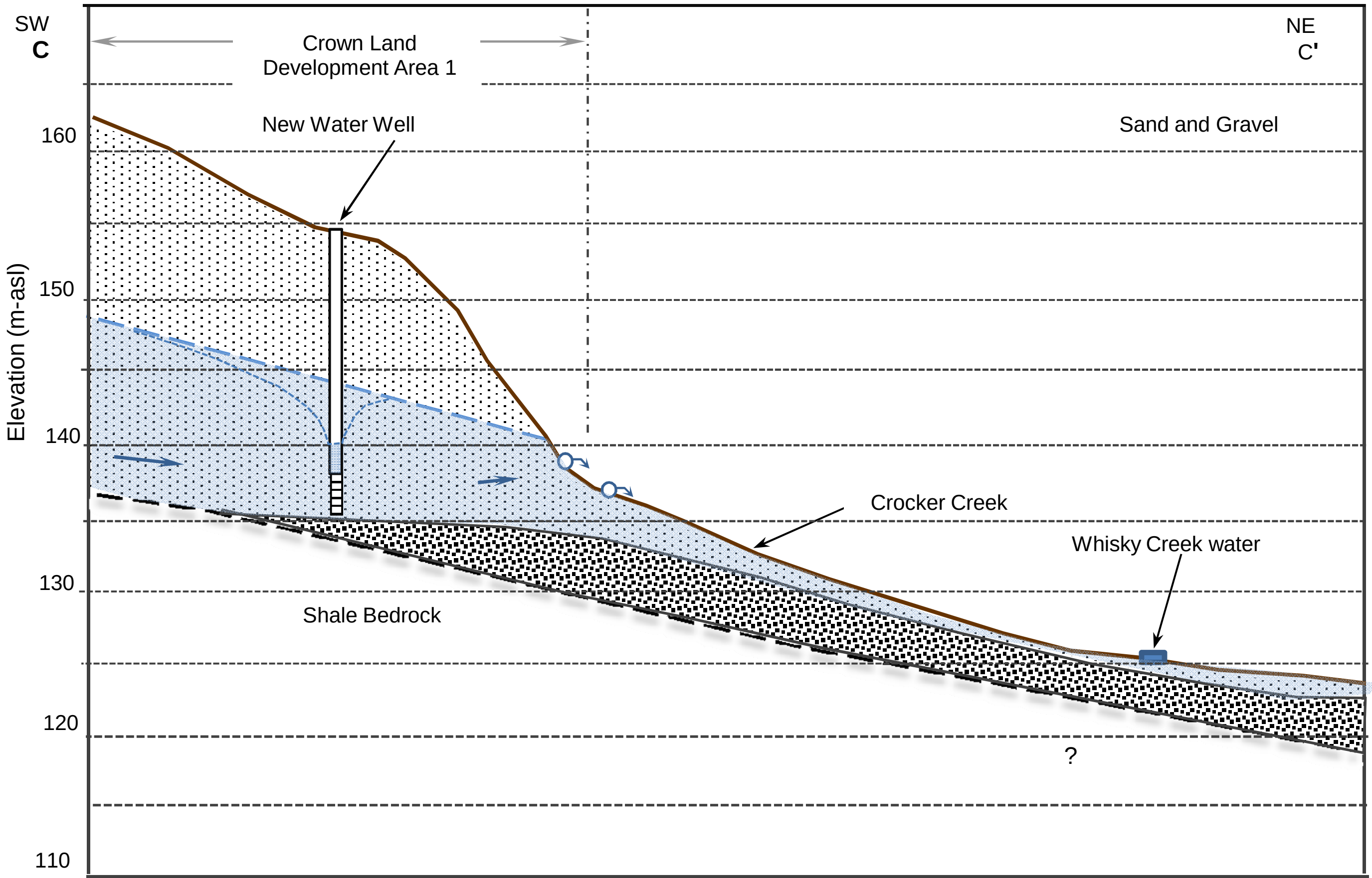
WHISKY CREEK WATER SERVICE AREA- GROUNDWATER FEASABILITY STUDY, HILLIERS, B.C.	**MAP OF AREA SHOWING POTENTIAL TEST WELL**	Drawn:	Date Jul. 2015
		Approved:	Fig. **6**

File:2600 \ 201 Figures 6 Google map 27/07/2015 11:39 AM

JOB NUMBER : 201



Legend

Interpreted aquifer unit

Sand and gravel

Dense silty sand and gravel (till like)

Interpreted groundwater flow direction

In plane of section

Into section

Out of section

Water level at time of construction

Downward infiltrating groundwater

Spring / groundwater discharge area.

Scale (1:7,000)

0 100 200m

Vertical exaggeration = 14

NOTES
1) See location of section on Figs. 2 and 3 and information on wells on Table I.

REGIONAL DISTRICT OF NANAIMO	***ELANCO ENTERPRISES LTD.*** ***Victoria, B.C. (250 744-1357)***

WHISKY CREEK WATER SERVICE AREA- GROUNDWATER FEASABILITY STUDY, HILLIERS, B.C.	**HYDROGEOLOGICAL SECTION C - C'**	Drawn:	Date May. 2015
		Approved:	Fig. **7**

File:2600 \ 201 Figures 7 Sect C 27/07/2015 11:39 AM

Appendix A

Study Terms of Reference

Whiskey Creek Water Service Area

Groundwater Feasibility Study – Scope

Currently, the Whiskey Creek Water Service Area (WCWSA) is supplied via surface water extraction from Crocker Creek. This water source is prone to high turbidity and colour spikes during spring run-off and significant rainfall events. A Surface Water Treatment Options report, completed by Koers & Associates Engineering Ltd. in 2014 (see Attachment A), has determined that substantial treatment costs will need to be incurred in order to meet the Island Health 4-3-2-1 Drinking Water Treatment for Surface Water Policy.

As such, the RDN is interesting in determining whether groundwater supply is a feasible option for the WCWSA. A Groundwater Supply Assessment was completed by GW Solutions Inc. in 2012 (see Attachment B), but a more detailed investigation is warranted now that the costs of treating the existing surface water supply are better understood.

The Groundwater Feasibility study should include, but may not be limited to:

- Detailed investigation of the hydrogeology of the area and identification of potential groundwater sources.
- Investigation of existing wells in the area as potential drinking water sources. This would include a pump test and potability analysis of the nearby well owned by Glen Fyfe.
- A recommendation on whether or not groundwater is a feasible drinking water supply for the WCWSA.
- A recommendation on locations to drill wells for potential drinking water sources.
    - The recommended well sites should be located such that there are no concerns related to the direct influence of surface water (GWUDI).

Study Limitations

1. The Island Health 2015 Operating Permit for the WCWSA requires that a groundwater feasibility study be completed by July 31st, 2015 (see Attachment C).
2. The RDN has set aside a preliminary budget of $10,000 for this study.

Appendix B

Information on Geophysical Systems that could be used for Groundwater Source Exploration

Resistivity profiling or imaging is a method for investigating the subsurface by measuring the capacity of earth materials to pass electrical current. On land or overwater, this technique is effective in detecting boundaries between materials that have contrasting electrical resistivities. Clays and water saturated materials are generally electrically conductive and contrast sharply with more electrically resistive materials such as gravels, glacial till, bedrock, or frozen ground.

Resistivity exploration can be carried out to depths that range from a few metres to several hundred metres under favourable conditions. Historically, recording of resistivity information was carried out using only four electrodes and one of the standard geometric arrays. The advantage of resistivity imaging is that by exploiting the ability to redundantly sample very large numbers of electrode combinations, a detailed resistivity image of the subsurface is developed. Instead of simple layering information, resistivity imaging can resolve small and irregular anomalies even in areas of complex subsurface geometry.

The method is based on generation of an artificial electric field in the earth by introduction of current through metal electrodes. Utilising one of a large variety of standard array configurations, a voltage is measured across two electrodes. This voltage, together with the current value and a constant based on the array geometry, yields an apparent resistivity reading of the underlying geological layering.

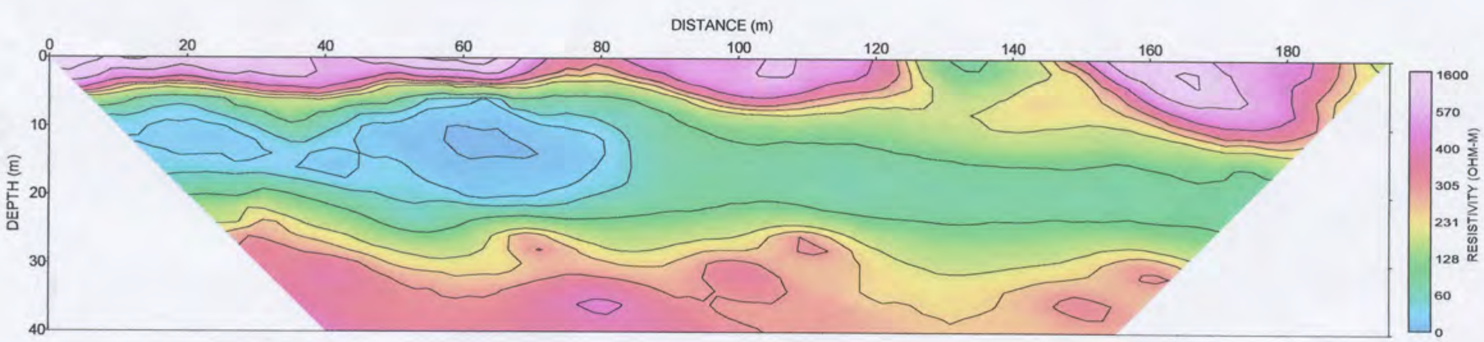
In field operation, the metal electrodes are inserted into the ground at the required separation along the section to be profiled. Wider electrode spacings result in deeper penetration. Intelligent nodes are then connected to the electrodes that allow each to be in either standby, current or potential measuring modes. These nodes are controlled by an automatic multi-electrode switching system that steps through the programmed combination of electrodes. A number of companies offer this instrumentation, some of which include the capability to measure the induced polarisation effect as well.

The data processing is carried out using a package such as RES2DINV. This package uses a finite difference modeling approach to calculate the resistivity values that best fit the observed data. An iterative least-squares method progressively increases the fit for each run of the forward code. The resulting profile is the best estimate of the true resistivity section and is displayed in colour contour format in ohm-metres for interpretation.

Utilising multiple surface electrodes and a multi-electrode switching system that automatically selects electrode arrangements, surveys can be carried out rapidly and accurately.

<u>Applications</u>

- Groundwater exploration
- Monitoring landfill leachate plumes
- Saline intrusion
- Mineral prospecting
- Industrial minerals exploration
- Subsurface void detection
- Permafrost investigations
- Placer exploration
- Geologic mapping



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Appendix C

Water Quality from Representative Water Supply Systems.

REGIONAL DISTRICT OF NANAIMO

Whiskey Creek Surface Water Analysis Results

3474 Hebert Road (Crocker Creek)

Canadian Drinking Water Guidelines Package

water SMART

CDWG=Canadian Drinking Water Guidelines
MAC=Maximum Acceptable Concentration
OG= Operational Guidance Value
AO=Aesthetic Objective

Red font indicates non-compliance with Canadian Drinking Water Guidelines

Parameters	Water Quality Guidelines			26-Feb	26-Oct	16-Oct	17-Oct	4-Nov	
	Units	CDWG		2008	2011	2012	2013	2014	
Total Ammonia (N)	mg/L					<0.01	<0.02	<0.02	
Color-Apparent	CU			11	20	83	41	120	
Conductivity	uS/cm			89.7	90.2	91	94	84	
Corrosivity				-1.79					
TDS	mg/L	≤500	AO	66	100	72	52	78	
TOC	mg/L			3.1					
TON	mg/L			0.14					
Total Phosphate	mg/L			<0.02					
Hardness ($CaCO_3$)	mg/L	80-100	AO	31	21	43	44	42	
pH	pH units	6.5-8.5	AO	7.32	7.6	7.3	7	7	
Turbidity	NTU's	5	AO	<0.5	<0.5	1	2.2	1.3	
Alkalinity	mg/L			30	40	40	42	36	
Chloride	mg/L	250	AO	6.2	2	2.3	2.6	3	
Fluoride	mg/L	1.5	MAC	<1.0	<0.1	0.08	<0.05	0.05	
Sulfate	mg/L	500	AO	<2.0	1.1	2.2	1.1	1.5	
Nitrate	mg/L	10	MAC	<0.1	0.03	0.19	0.07	0.13	
Nitrite	mg/L	1		<0.1	<0.01	<0.05	<0.05	0.07	
T-Aluminum	mg/L	0.100	OG	0.224	0.021	0.083	0.128	0.145	
T-Antimony	mg/L		MAC	<0.0002	<0.0002	<0.0001	<0.0002	<0.0001	
T-Arsenic	mg/L	0.010	MAC	<0.0002	<0.0002	0.00015	0.0002	0.0002	
T-Barium	mg/L	1.0	MAC	0.001	<0.001	0.00143	0.002	0.00098	
T-Beryllium	mg/L			<0.0001	<0.00004	<0.00005	<0.00004	<0.00005	
T-Bismuth	mg/L			<0.0005	<0.001	<0.0001	<0.0010	<0.0001	
T-Boron	mg/L	5.0	MAC	0.004	<0.005	0.003	<0.005	0.004	
T-Cadmium	mg/L	0.005	MAC	<0.00001	<0.00001	0.00002	<0.00001	<0.00001	
T-Calcium	mg/L			8.1	11.4	11.7	11.5	11.9	
T-Chromium	mg/L	0.05	MAC	<0.0005	<0.0004	0.0007	0.0005	0.0009	
T-Cobalt	mg/L			0.0002	0.00002	<0.0001	0.00012	<0.0001	
T-Copper	mg/L	≤1.0	AO	0.001	0.001	0.0044	0.003	0.0112	
T-Iron	mg/L	≤0.3	AO	<0.1	0.047	0.158	0.201	0.227	
T-Lead	mg/L	0.010	MAC	0.0002	0.0006	0.0005	0.0005	0.0006	
T-Lithium	mg/L			<0.001	<0.001	<0.0005	<0.001	<0.0005	
T-Magnesium	mg/L		AO	2.5	3.58	3.43	3.64	3.02	
T-Manganese	mg/L	≤0.05	AO	0.006	<0.005	0.0172	0.031	0.015	
T-Mercury	mg/L	0.001	MAC	<0.0001	<0.00001	<0.0001	<0.00001	<0.00001	
T-Molybdenum	mg/L			<0.001	0.0001	0.00026	0.0001	0.00014	
T-Nickel	mg/L			<0.0005	<0.001	0.0002	<0.001	0.0003	
T-Phosphorus	mg/L				<0.01				
T-Potassium	mg/L			<0.4	<0.1	0.2	0.24	0.1	
T-Selenium	mg/L	0.01	MAC	<0.0002	<0.0006	<0.0001	<0.0006	0.0001	
T-Silicon				6.53	8.07	9.23	8.54	8.44	
T-Silver	mg/L			<0.00001	<0.00001	<0.00001	<0.00001	<0.00005	
T-Sodium	mg/L	≤200	AO	4.9	2.93	2.9	4.62	2.9	
T-Strontium	mg/L			0.02	0.023	0.0243	0.027	0.0261	
T-Sulphur	mg/L			0.4					
T-Thallium	mg/L			0.0014	<0.00001	<0.00001	<0.00001	<0.00001	
T-Tin	mg/L			<0.001	<0.0001	0.0004	<0.0001	0.0004	
T-Titanium	mg/L			0.0014	0.003	0.0049	0.0074	0.0052	
T-Uranium	mg/L	0.02	MAC		<0.0004	<0.00001	<0.0004	<0.00001	
T-Vanadium	mg/L			0.0021	0.0015	0.0029	0.0024	0.0026	
T-Zinc	mg/L	5	AO	0.003	0.004	0.0113	0.009	0.0101	
Total Coliform	cfu/100ml	<1	MAC	<1	>200.5	>200.5[1]	>200.5	165.2	
Non-Coliform Background	cfu/100ml	<1	MAC	<1					
E.coli	cfu/100ml	<1	MAC	<1	<1.0	118.4[1]	<1.0	34.4	
Total Plate Count	cfu/100ml			<3					
Tannins & Lignins	mg/L	0.400	AO		0.4	1.2	0.5	2.5	
Trihalomethanes	mg/L	0.1	MAC	0.076					

[1]results are MPN/100mL (Most Probable Number)

Melrose Well Water Analysis Results

Well # 1: 3853 Melrose Road

Canadian Drinking Water Guidelines Package

CDWG=Canadian Drinking Water Guidelines MAC=Maximum Acceptable Concentration

AO= Asthetic Objective OG= Operational Guidance Value

Red font indicates non-compliance with Canadian Drinking Water Guidelines

Parameter	Water Quality Guidelines			19-Oct	24-Oct	22-Oct	14-Oct	14-Oct
	Units	CDWG		2005	2006	2007	2008	2009
Total Ammonia (N)	mg/L							
Color-Apparent	CU			200	<5	200	500	≥150
Conductivity	uS/cm			313	335	333	340	342
TDS	mg/L	≤500	AO	272	220	246	308	272
Hardness ($CaCO_3$)	mg/L	80-100	AO	**120**	**120**	**130**	**140**	**140**
pH	pH units	6.5-8.5	AO	7.3	7.1	6.85	7.1	7
Turbidity	NTU's	5	AO	**25.3**	**38**	1.7	**24.6**	**55**
Alkalinity	mg/L			81	76	82	69	66
Chloride	mg/L	≤250	AO	40.6	51.3	48.1	63	59
Fluoride	mg/L	1.5	MAC	<1.0	<1.0	<1.0	<1.0	<1.0
Sulfate	mg/L	500	AO	<2	<2.0	<2.0	2.6	<2.0
Nitrate (N)	mg/L	10	MAC	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite (N)	mg/L	1	MAC	<0.1	<0.1	<0.1	<0.1	<0.1
T-Aluminum	mg/L	0.100	OG	0.006	<0.01	0.006	<0.005	<0.005
T-Antimony	mg/L	0.006	MAC	<0.0002	<0.0004	<0.0002	<0.0002	<0.0002
T-Arsenic	mg/L	0.010	MAC	0.0004	<0.0004	0.0004	0.0003	0.0004
T- Barium	mg/L	1.0	MAC	0.022	0.022	0.026	0.02	0.023
T-Beryllium	mg/L							
T-Bismuth	mg/L							
T-Boron	mg/L	5.0	MAC	0.007	0.007	0.006	0.005	0.007
T-Cadmium	mg/L	0.005	MAC	<0.00001	<0.00002	<0.00001	<0.00001	<0.00001
T-Calcium	mg/L			32.3	30.5	34.1	33	33.9
T-Chromium	mg/L	0.05	MAC	0.0008	<0.001	0.0011	0.0005	0.0005
T-Cobalt	mg/L							
T-Copper	mg/L	≤1.0	AO	0.011	<0.002	<0.001	0.002	0.013
T-Iron	mg/L	≤0.3	AO	**8.8**	**8.6**	**9.4**	**8.63**	**9.36**
T-Lead	mg/L	0.010	MAC	0.0056	0.0006	<0.0001	0.0004	0.0023
T-Lithium	mg/L							<0.001
T-Magnesium	mg/L			10.4	11	11.4	12.9	13.1
T-Manganese	mg/L	≤0.05	AO	**0.224**	**0.232**	**0.26**	**0.211**	**0.219**
T-Mercury	mg/L	0.001	MAC	<0.0001	<0.0001	<0.0001	<0.01	<0.01
T-Molybdenum	mg/L							
T-Nickel	mg/L							<0.001
T-Phosphorus	mg/L							0.034
T-Potassium	mg/L			<0.4	<0.08	<0.4	0.2	0.4
T-Selenium	mg/L	0.01	MAC	<0.0002	<0.0004	0.0003	<0.0006	<0.0006
T-Silicon	mg/L							
T-Silver	mg/L							<0.00001
T-Sodium	mg/L	≤200	AO	7.6	8.3	9.2	8.69	11.5
T-Strontium	mg/L							
T-Thallium	mg/L							
T-Tin	mg/L							
T-Titanium	mg/L							
T-Uranium	mg/L	0.02	MAC	<0.0005	<0.001	<0.0005	<0.0004	<0.0004
T-Vanadium	mg/L							
T-Zinc	mg/L	≤5.0	AO	0.017	0.022	0.007	0.043	0.038
Total Coliform	cfu/100ml	<1	MAC	<1	<1	<1	<1	<1
Fecal Coliform	cfu/100ml	<1	MAC	<1	<1	<1	<1	
E.coli	cfu/100ml	<1	MAC		<1	<1	<1	<1

Westurne Community Water Well (WTN 67163)

North Island Laboratories
• 2755 B Moray Avenue, Courtenay, B.C. V9N 8M9 Tel: (250) 338-7786 Fax: (250) 338-7553

Certificate of Analysis

Report To:	Regional District of Nanaimo Attn: Heather Dorken 6300 Hammond Bay Rd Nanaimo, BC V9T 6N2	Lab Number: Date Reported: Date Completed: Date Received:	114106 19 Sep 14 19 Sep 14 8 Sep 14 14:06

114106-01 **Westurne Heights** **Well water**

Sampled By:

Sampling Date: 8 Sep 14 10:19

Test	Result	Units	Drinking Water Guideline
Alkalinity	46	mg/L (CaCO3)	
Total ammonia - N	<0.02	mg/L	
Chloride	1.4	mg/L	250 AO
Fluoride	<0.05	mg/L	1.5 MAC
Nitrate (N)	0.10	mg/L	10 MAC
Nitrite (N)	<0.05	mg/L	1 MAC
Sulphate	1.6	mg/L	500 AO
Colour - Apparent	<5	Colour Units	15
Conductivity	90.7	uS/cm	
T-Mercury	<0.00001	mg/L	0.001 MAC
pH at 25 C	7.2	pH Units	6.5-8.5
Total Coliforms (DES)	<1.0	MPN/100mL	<1
E. coli (DES)	<1.0	MPN/100mL	<1
Total Dissolved Solids	76	mg/L	500 AO
T-Aluminium	<0.025	mg/L	0.1 Operational Std
T-Antimony	<0.0005	mg/L	0.006 MAC
T-Arsenic	0.00041	mg/L	0.010 MAC
T-Barium	0.00315	mg/L	1.0 MAC
T-Beryllium	<0.00025	mg/L	
T-Boron	<0.010	mg/L	5 MAC
T-Bismuth	<0.0005	mg/L	
T-Cadmium	0.00015	mg/L	0.005 MAC
T-Calcium	11.7	mg/L	
T-Chromium	<0.0025	mg/L	0.05 MAC
T-Cobalt	<0.0005	mg/L	
T-Copper	0.0085	mg/L	1.0 AO

AO = Aesthetic Objective; MAC = Max. Allowable Concentration; IMAC = Interim MAC
> = Greater than; < = Less than
Results relate only to samples as submitted. This certificate must not be reproduced, except in its entirety, without written consent from the laboratory.
Canadian Drinking Water Guidelines as listed on Dec. 5th, 2005 and are subject to change. Method uncertainties for specified analyses are available upon request.

North Island Laboratories
• 2755 B Moray Avenue, Courtenay, B.C. V9N 8M9 Tel: (250) 338-7786 Fax: (250) 338-7553

114106-01 **Westurne Heights** **Well water**

Sampled By:

Sampling Date: 8 Sep 14 10:19

Test	Result	Units	Drinking Water Guideline
T-Iron	0.058	mg/L	0.3 AO
T-Lead	0.0035	mg/L	0.010 MAC
T-Lithium	<0.0025	mg/L	
T-Magnesium	3.16	mg/L	
T-Manganese	<0.0050	mg/L	0.05 AO
T-Molybdenum	0.00028	mg/L	
T-Nickel	0.0101	mg/L	
T-Potassium	<0.5	mg/L	
T-Selenium	<0.0005	mg/L	0.01 MAC
T-Silicon	7.5	mg/L	
T-Silver	<0.00025	mg/L	
T-Sodium	2.7	mg/L	200 AO
T-Strontium	0.028	mg/L	
T-Thallium	<0.00005	mg/L	
T-Tin	0.0006	mg/L	
T-Titanium	<0.0025	mg/L	
T-Uranium	<0.00005	mg/L	
T-Vanadium	0.0023	mg/L	
T-Zinc	0.121	mg/L	5.0 AO
Hardness (CaCO3)	42	mg/L	80-100
Turbidity	<0.5	NTU's	5 AO

AO = Aesthetic Objective; MAC = Max. Allowable Concentration; IMAC = Interim MAC
> = Greater than; < = Less than
Results relate only to samples as submitted. This certificate must not be reproduced, except in its entirety, without written consent from the laboratory.
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9/19/2014 14:29