Aquifer and Well Protection Plan for the Deep Bay Improvement District

13 October 2016

Prepared for

Deep Bay Improvement District

Prepared by

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PEG File: DBI-2-1

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1. Introduction

1.1 Purpose and Objectives

This Aquifer and Well Protection Plan (the Plan) identifies risks to the Quadra Sand Aquifer at Deep Bay, and then recommends measures to protect the aquifer and the Deep Bay drinking water wells. As requested by the DBID (Deep Bay Improvement District), the objectives of this plan are as follows:

1. Identify and evaluate risks to water quality in the aquifer.
2. Identify the resulting risks of contamination of the Deep Bay water supply wells.
3. Recommend measures to reduce these risks.

This Plan is based on the BC *Well Protection Toolkit,* a 239-page guideline published by the BC Ministry of Environment in 2004. This Plan is intended for the DBID to use to better manage water quality risks for the current water supply wells. In this context, **risk** is generally defined as: *A characteristic of a situation or action wherein two or more outcomes are possible, the particular outcome that will occur is unknown, and at least one of the possibilities is undesired* (Covello and Merkhofer, 1993). In this context of this *Well and Aquifer Protection Plan*, the **risk** is the risk of well water quality not meeting Canadian drinking water guidelines.

This Plan is the first stage of wellhead protection planning for the community of Deep Bay. The next stage involves consulting with users of the Deep Bay water system, and property owners inside of the Well Protection Area.

This report is subject to the attached Statement of General Conditions (Appendix 1).

1.2 Community Planning Team

For this aquifer protection plan, the Community Planning Team included the following:

1. Linda McKay, Trustee, DBID
2. Dave Simpson, Trustee, DBID
3. Claire Hilscher, Trustee, DBID
4. Leslie Carter, Administrator, DBID
5. Don Buchner, Certified Water System Operator, under contract to DBID
6. Michael Payne, PEng, PGeo, PEG (Payne Engineering Geology), North Saanich

1.3 Project Background

Table 1: Deep Bay Water System and Project Chronology – Abbreviated

Year	Significant events or reports
1969	Well # 3 drilled.
1972	Deep Bay Waterworks District, now the DBID, was established.
1973	Wells # 1 and # 2 drilled.
1977	Well # 4 drilled.
1978	Testing of Well # 2
1985	Well # 5 drilled.
1990	Well # 6 drilled.
1991	PHCL (Pacific Hydrology Consultants Ltd) report to DBID on *Groundwater Supply Potential in the Southwest Corner of DL 28 West of the Island Highway at Deep Bay*.
1992	VIHA (Vancouver Island Health Authority) issues the DBID a *Permit to Operate a Water Supply System*.
1995	PHCL report on *Evaluation of Maximum Groundwater Potential from Wells in the Southwest Corner of DL 28 West of the Island Highway at Deep Bay*.
1996	Well # 7 drilled, but not connected into the water supply system. PHCL report on *Results of Test Drilling and Performance Testing of Well 7-96 on DL 28 West of the Island Highway at Deep Bay*.
1997	Well # 8 drilled and connected to the water system. PHCL report on *Implications of October 1996 Aquifer Test of Deep Bay Wells Installed Within DL 28 West of the Island Highway to the Installation of Additional Production Wells.* PCHL report on *Installation and Testing of Well 8-97 and Re-evaluation of Groundwater Supply Potential of Quadra Sand Aquifer at Deep Bay*.
1999	PEG (Payne Engineering Geology) report to Deep Bay Joint Venture on *Preliminary Site Evaluation for Drainfields on Lots A, B, and C [District Lot 86, Newcastle District], Deep Bay, BC.*
2004	District installs water meters at each service connection.
2007	PHCL report on *Groundwater Study at Deep Bay Waterworks District.* Lanarc Consultants report to RDN (Regional District of Nanaimo) on *Drinking Water and Watershed Protection Action Plan.*
2008	McElhanney report on *Water System Evaluation.*
2010	Kala (Kala Geosciences Ltd) report to Baynes Sound Investments on *Deep Bay Proposed*

Year	Significant events or reports
	Residential Subdivision, Groundwater Feasibility Study.
2011	Kala report to Baynes Sound Investments on *Deep Bay Wastewater Treatment and Disposal Considerations, Feasibility Report*.
2012	VIHA adds conditions to the DBID *Permit to Operate*. Permit conditions include: *Develop and implement a wellhead protection plan*.
2013	GEC (Guiton Environmental Consulting) report on *Third Party Review of Groundwater Feasibility Study, Kala Geosciences Ltd., June 30th, 2010, Deep Bay, BC.* Waterline Resources Inc report to RDN on *Water Budget Project: RDN Phase One*.
2014	GW Solutions Inc report to Baynes Sound Investments on *Deep Bay Village Well Field Assessment*. GEC report on *Assessment of Deep Bay Well Field, GW Solutions – June 16th 2014, Third Party Review*. DBID retains PEG to prepare an Aquifer and Well Protection Plan
2015	PEG meets with the DBID water system operator, views the water supply wells and well capture zone, and analyses the hydrogeology of the Quadra Sand Aquifer in Deep Bay.
2016	PEG prepares this written Plan.

1.4 Related Reports

Table 1, above, and Appendix 2 include lists of reports and other references used to prepare this Plan, including reports on the Quadra Sand Aquifer and the Deep Bay water supply wells.

2. Background on the Aquifer and Wells

2.1 Summary of the Deep Bay Water System

The DBID owns eight water wells, and seven of these have a pump installed with a connection to the water system. The following table is a summary of the community and the water system.

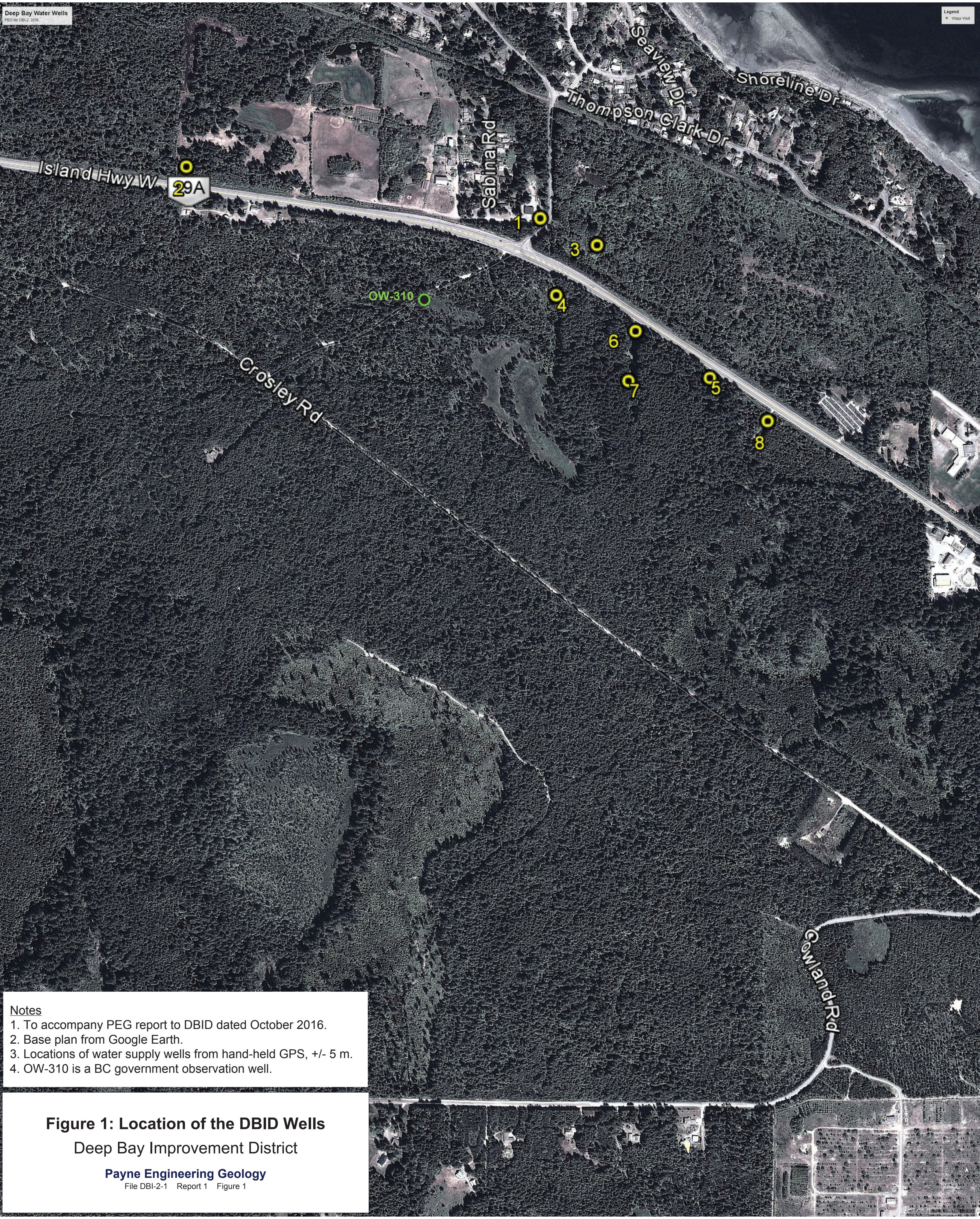
Table 2: Summary of the Existing Water System

WATER SOURCE		
Sources:	7 drilled water supply wells (1 unused well)	
Well locations:	Refer to the Figure 1 on the following page. Well construction: Refer to Table 3 below.	
SYSTEM	Current (2015-2016)	Forecast (at 2030)
Connections:	605	1081
Population estimate:	1,330	2,376. *Based on 3% per year*
Average water use (Lps)	4.2 Litres per second	7.6 Lps
- (cmpd)	*367 cubic metres per day*	*655 cmpd*
Peak day use (Lps)	12.7 Lps	22.7 Lps
- (cmpd)	*1,100 cu.m./day*	*1,960 cu.m./day*
Per capita average:	275 Litres per day	275 Lpd
Maximum month peaking factor:	1.8	
Treatment:	None	
Storage:	Reservoir capacity of 545 cubic metres	
Permit:	# 1310854 (Vancouver Island Health Authority, June 2012)	

Reference: Data above from McElhanney reports (Irish and Hoffstrom, 2008; Pogson, 2014) and DBID (2014).

Footnotes

(1) EOCP (Environmental Operators Certification program) certified water system operator, Water Distribution Level 1.



Notes
1. To accompany PEG report to DBID dated October 2016.
2. Base plan from Google Earth.
3. Locations of water supply wells from hand-held GPS, +/- 5 m.
4. OW-310 is a BC government observation well.

Figure 1: Location of the DBID Wells

Deep Bay Improvement District

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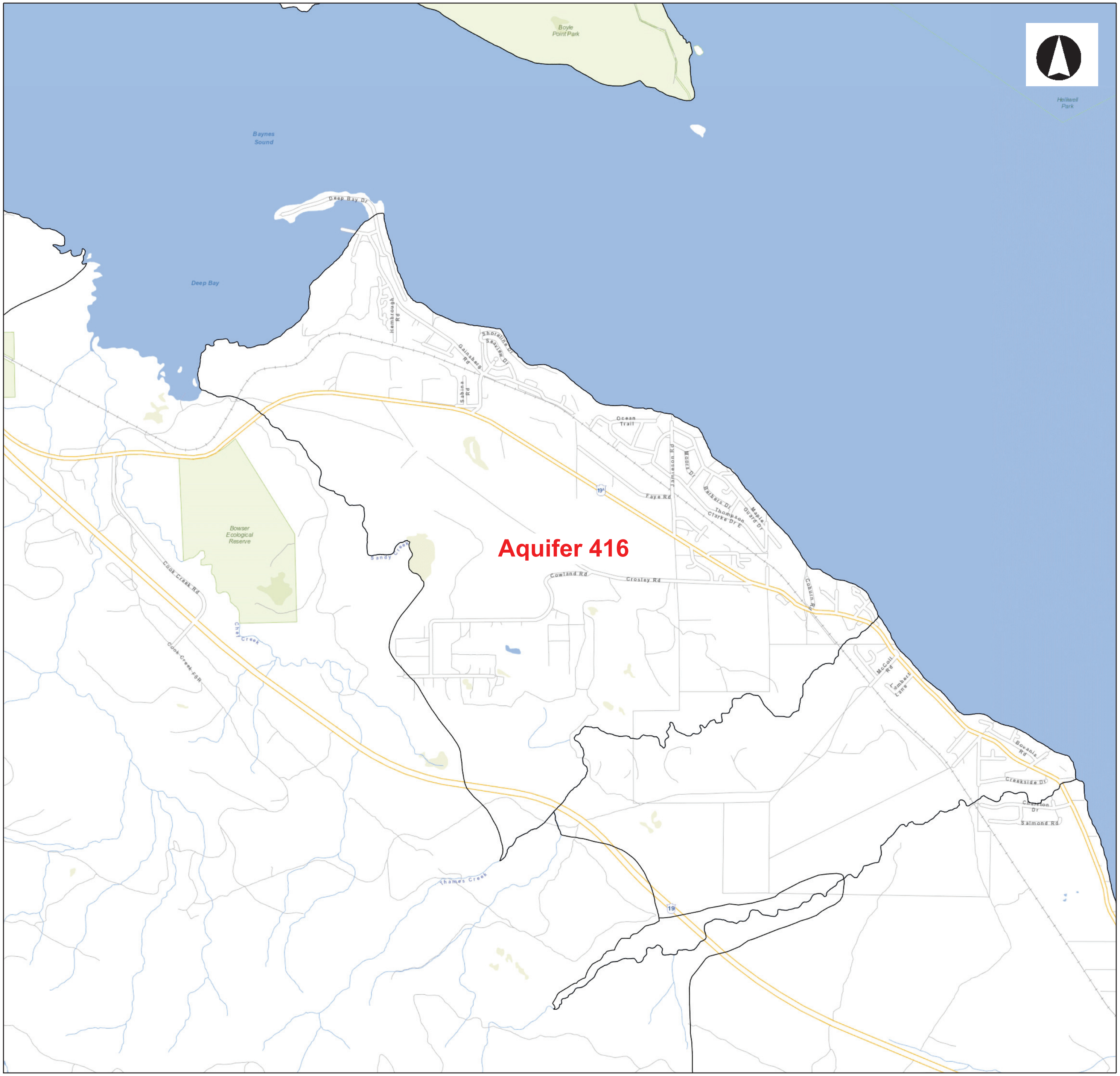
File DBI-2-1 Report 1 Figure 1

2.2 Quadra Sand Aquifer

The seven Deep Bay wells are screened in the Quadra Sand Aquifer, BC Aquifer # 416. Figure 2, on the following page, is a map of the aquifer. The following table is a summary of interpreted characteristics of the Quadra Sand Aquifer.

Table 3: Summary of the Quadra Sand Aquifer at Deep Bay

Characteristic	Comment	*References*
Area of aquifer:	13.7 square km	*BC Environment, 2016.*
Aquifer material:	Fine to coarse sand, stratified	
Confining layer:	Discontinuous blanket of Vashon Till	*Fyles, 1962.*
TYPICAL DEPTHS		*See Figure 4 and Table 3*
- Aquifer depth:	3 to 26 m	*Well logs*
- Elevation:	42 to 62 m	
- Thickness:	20 m	
Seasonal fluctuation in water level:	2 to 3 m	*Wendling, 2014*
Transmissivity:	See Section 3.1 of this report.	
Aquifer recharge area:	See Figure 3.	
Sustainable aquifer yield:	See Section 3.1 of this report.	
Observation well:	BC Government Well # 310.	



BRITISH COLUMBIA

Aquifer 416

Legend

☐ Aquifer Boundary - Outlined

0 1.02 2.03 km

1: 50,000

Notes

1. To accompany PEG report to DBID dated October 2016.

2. Base plan and aquifer outline from BC Water Resources Atlas.

Figure 2
Aquifer Map

Deep Bay Impr. District

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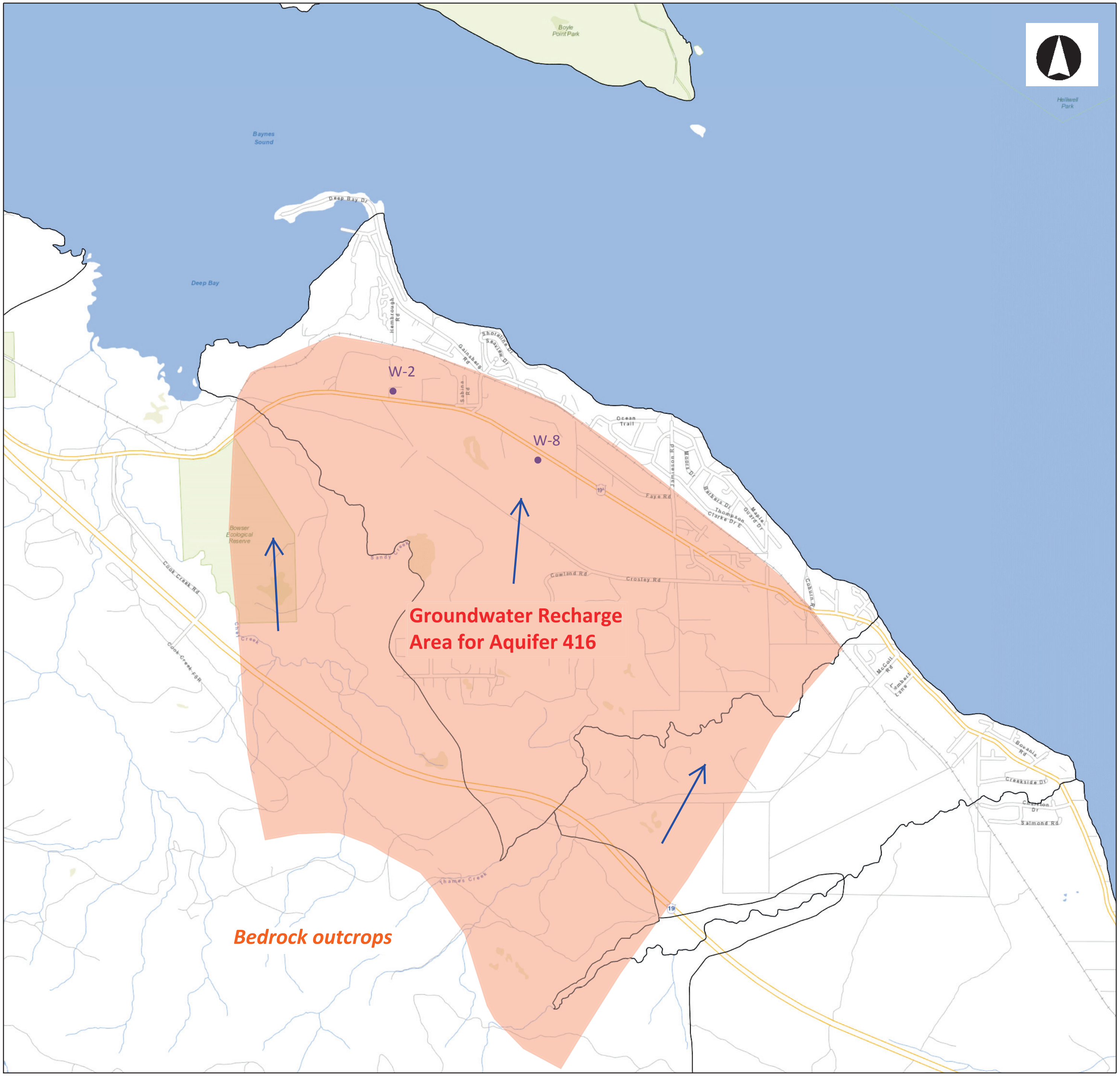
File DBI-2-1 Report 1 Figure 2



BRITISH COLUMBIA

Aquifer 416

Legend

☐ Aquifer Boundary - Outlined
TileCache

↗ Direction of groundwater flow

0 1.02 2.03 km

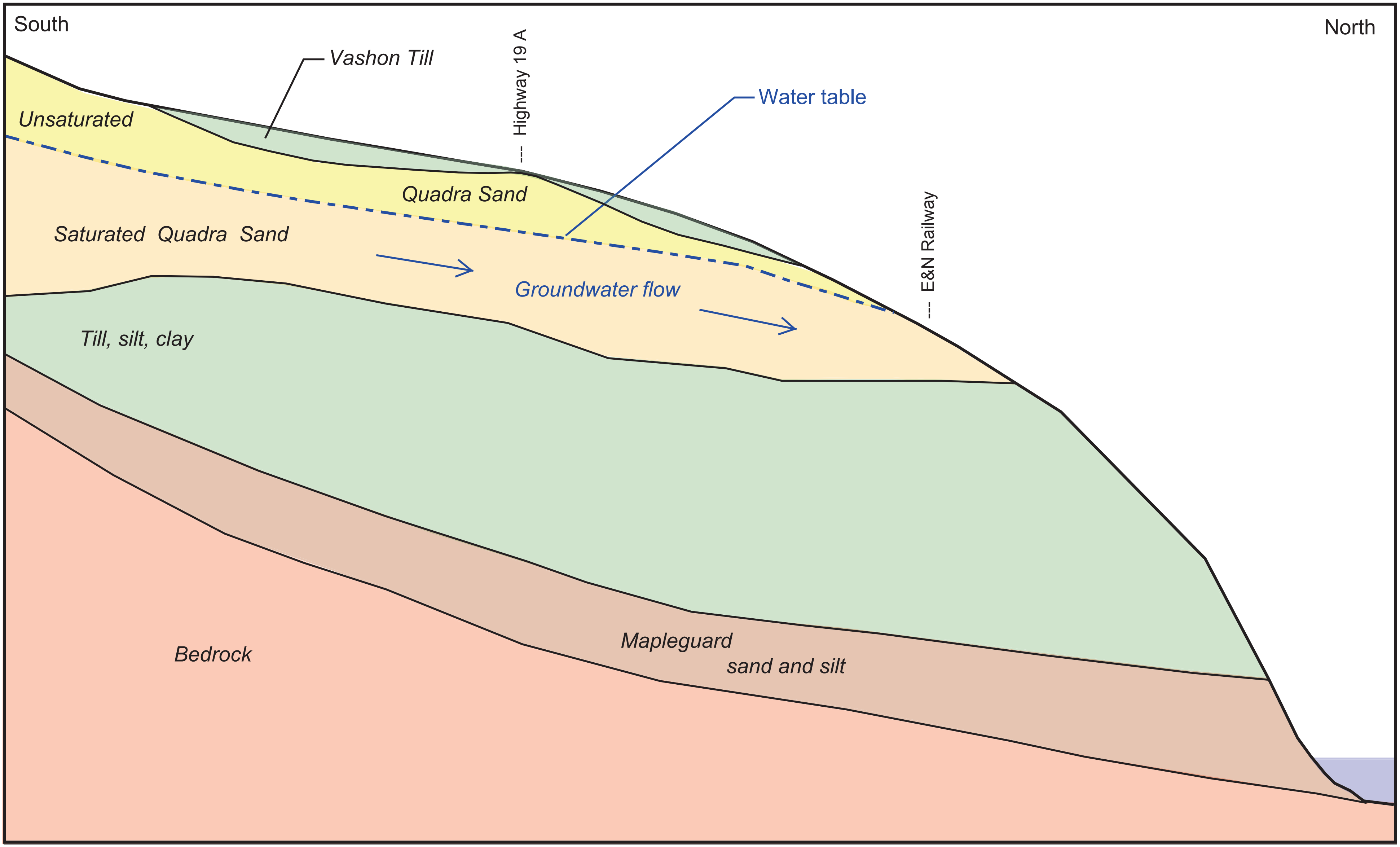
1: 50,000

Notes

1. To accompany PEG report to DBID dated October 2016.
2. Base plan from BC Water Resources Atlas.
3. Shows interpreted aquifer recharge area.

Figure 3
Aquifer Recharge Area
Deep Bay Impr. District

Payne Engineering Geology
File DBI-2-1 Report 1 Figure 3



Notes
1. To accompany PEG report to DBID dated October 2016.
2. Geological section based on PHCL (1995), Geological Survey of Canada Map 1111A (Fyles, 1962), and GSC Open File 7796 (Benoit et al, 2015).
3. This section is approximate and for illustrative purposes only.

Figure 4: Geological Cross Section

Deep Bay Improvement District

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File DBI-2-1 Report 1 Figure 4

2.3 Water Supply Wells

The Deep Bay Water System has seven water supply wells and one reserve well that is not connected to the water system. Of the seven wells, four wells (Wells #4, #5, #6, and #8) provided most or all of the water supply during 2015-2016. The other three have been inactive (#1, #2, and #3). Appendix 7 includes photos of the four wells. The following table is a summary of the wells.

Table 4: Summary of the Deep Bay Water Supply Wells

Well #	Plate #	Year drilled	Average pumping	Screen depth	SWL (date)	Reported well yield		Note
DBID	*(1)*		*Cu.m./d (2)*	*metres*	*metres*	*Litres/s*	*Cu.m./d*	
# 1	13731	*1973*	4.1	11.0 – 15.8	2.2 (Apr 2014)	4.9	430	(3)
# 2	13732	*1973*	1.1	8.2 – 11.6	1.6 (Sep 1973)	3.0	260	
# 3	13733	*1969*	1.0	12.2 – 16.4	0.8 (Sep 1973)	5.7	490	
# 4	13734	*1977*	1.5	14.4 – 19.4	3.4 (Jan 1978)	5.3	460	
# 5	13735	*1985*	163	16.6 – 21.5	1.3 (Jun 1985)	9.8	850	
# 6	13736	*1990*	12	16.2 – 23.2	1.6 (Dec 1980)	9.1	790	
# 7	255	*1996*	0	20.5 – 26.1	5.2 (Feb 2010)	9.5	820	(4)
# 8	13737	*1997*	185	17.8 – 23.0	1.2 (Oct 1997)	11.0	950	(5)

Notes to Table 4

(1) Plate # refers to the BC government issued steel identification plate attached to the top of the well casing.

(2) Reported average rate of pumping for January 2012 through December 2015.

(3) All seven wells have a nominal well casing diameter of 200 mm.

(4) Well # 7 does not have a pump installed and is not connected to the water supply system.

(5) Well # 8 has a backup electric generator installed in 2016.

Abbreviations

SWL - Static Water Level (and date measured)
NR - Not Recorded in the WELL Database

Data sources: BC government WELLS Database. PHCL reports. DBID 2014 report.

2.4 Relevant Bylaws and Regulations

This section of the report reviews provincial and federal laws and regulations that affect the use of water supply wells and the management of potentially hazardous materials and wastes within the aquifer recharge area.

2.4.1 Provincial Regulations

Appendix 3 is a summary of provincial regulations that affect the use and protection of aquifers in BC. This information was extracted from the Groundwater Bylaws Toolkit (Curran et al, 2009).

2.4.2 Regional District Bylaws

In 2004, the Regional District of Nanaimo established an Official Community Plan (OCP) for Electoral Area H, including Deep Bay, under Bylaw Number 1335. Relevant general comments in the OCP include the following:

> *SECTION 2.3 FRESHWATER RESOURCES*
>
> *All watercourses, streams, lakes, swamps, other wetlands, and known aquifers in the Plan Area shall be identified as Environmentally Sensitive Features on Map No. 2.*
>
> *Given the Area's reliance on groundwater as the source for all potable water in the area, the potential impact of the increased demand or contamination placed on aquifers as a result of new development shall be considered when making any land use decisions for the Plan Area.*
>
> *Aquifer areas are designated as Development Permit Areas in accordance with Appendix A of this Plan.*
>
> *Prior to approving any rezoning to increase the density and intensity of land use on any property which may include environmentally sensitive groundwater resources, the Regional District shall require a hydro geologic impact review and/or assessment on the water supplies of adjacent properties and on any nearby surface water resources. A qualified professional engineer or geoscientist, with proven knowledge and experience in groundwater management must certify, through a hydro geological impact assessment, assurance of the long term reliability of the water supply.*
>
> *SECTION 5.8 PARK LANDS*
>
> *This OCP designates all Provincial/Crown lands above known unconfined aquifers as Park Lands to protect finite groundwater resources into the future.*

The OCP bylaw establishes several *Development Permit Areas*, including aquifers and other *Environmentally Sensitive Areas*, as discussed in Section 3.5 of this report.

3. Analysis and Discussion

3.1 Aquifer Characteristics

3.1.1 Aquifer description

The Quadra Sand deposit is a critical resource on the east coast of Vancouver Island. As a whole, the Quadra Sand Aquifer covers a land area of approximately 150 square kilometres, and varies in thickness from a few metres to about 75 metres (Wilson et al, 2005; Clague, 1977). This sand was deposited during glaciation 15,000 to 30,000 years ago. Much of the aquifer is confined beneath Vashon Till or lower-permeability marine and swamp deposits. However, near Deep Bay, a good portion of the Aquifer is unconfined, being overlain by sandy marine deposits (Fyfe, 1962). For the purpose of aquifer mapping, the BC Ministry of Environment has divided the Quadra Sand Aquifer into sections that may be hydraulically independent of each other. This includes 15 sub-aquifers on the east coast of Vancouver Island (BC Environment, 2016).

The Deep Bay wells draw water from the portion of the Quadra Sand deposit known as Aquifer 416. As Figure 4 shows, this aquifer is mostly unconfined in the region of the Deep Bay wells. However, a confining layer of Vashon Till is present nearby, particularly beneath Gainsberg Swamp, which is approximately 140 metres south of Well # 4; this is the uppermost green layer in Figure 4. The Quadra Sand overlies an extensive and thick sequence of lower permeability deposits including glacial till, silt and clay.

3.1.2 Aquifer characteristics

The following three tables, Tables 5 to 7, estimate the characteristics of the Quadra Sand Aquifer at Deep Bay, including hydraulic conductivity, transmissivity, and storativity.

These three tables show a range of previously reported estimates of the hydraulic conductivity and yield of the Quadra Sand Aquifer at Deep Bay. For the purpose of this Aquifer Protection Plan only, we have selected the conservative values in the last row of each of these three tables. These estimates are consistent with our analysis of the relatively large aquifer recharge area (see Figure 3). The estimates in the last row of each table are conservative estimates for the purpose of this study; a larger aquifer yield implies faster groundwater movement and therefore a larger well capture zone and Well Protection Area. The estimate of sustainable aquifer yield, in Table 7, applies to the entire of Aquifer 416, not just to the DBID network of water supply wells. As a result, this analysis is different from the analysis used in other studies (Guiton, 2014).

Table 5: Character of the Quadra Sand Aquifer at Deep Bay

Author, date	Location	Transmissivity *sq.m./day*	Hydraulic Conductivity *m/day*	Storativity
Badry (PHCL), 1995	DBID Well # 6	1,240	70	
Badry (PHCL), 1996	DBID Well # 7	1,800	60	
Badry (PHCL), 1997	DBID Well # 7	2,200		
Badry (PHCL), 1997	DBID Well # 8	1,600	73	
Yin (Kala Geosciences), 2010	DBID Well # 7	165	7.5	
Wendling (GW Solutions), 2014 (1)	DBID # 5 & 6	1,800		0.006
Wendling (GW Solutions), 2014 (1)	DBID # 5 & 7	1,600		0.011
Wendling (GW Solutions), 2014 (1)	DBID # 5 & 8	2,400		0.0002
Payne, 2015	Bowser WWD	150	10	
Payne, 2016. Distance-drawdown.	DBID, Well # 8	740	34	
GSC (Benoit & Paradis, 2015)	Entire aquifer	36	1.8	
SELECTED VALUES (rounded):	**@ DBID wells**	**440**	**22**	**0.006**

(1) Median from drawdown and recovery analysis.

The table above shows that different hydrogeologists have calculated different properties for the Quadra Sand aquifer at Deep Bay, depending on the location and area of analysis, and depending on the methods of analysis. For the purpose of this Well Protection Plan only, we have selected the values in the last row for our analysis of the well capture zones. Our selected values are similar to the median values for the analyses completed by others.

Table 6: Hydraulic Gradient of the Quadra Sand Aquifer at Deep Bay

Author, date	Hydraulic gradient
Wendling, 2014.	0.025
Guiton, 2014.	0.013
Yin, 2010.	0.027
PHCL, 1997.	0.018
MEDIAN VALUE (rounded):	**0.022**

This table shows the hydraulic gradient, or slope of the water table, near the Deep Bay water supply wells, as reported by other hydrogeologists during 1997 through 2014. For the purpose of this Plan only, we have analysed well capture zones based on the median value in the last row of the table.

Table 7: Sustainable Aquifer Yield at Deep Bay

Author, date	Groundwater Recharge Rate *Lps*	Lateral Flow Rate *Lps*	Sustainable Aquifer Yield *Lps*	Note
Wendling, 2014.		420	420	
Yin (Kala Geo.), 2010.	21.4	63	56	
PHCL, 1997			> 47	
Payne, 2016	43	160	80	(1)
MEDIAN VALUES	21	110	68	
PEG Selected Value	**43**	**160**	**80**	

Footnotes

(1) Simplified calculation of lateral groundwater flow rate using areal averages of aquifer properties.

3.1.3 Aquifer vulnerability

Groundwater scientists and planners often refer to the intrinsic vulnerability of an aquifer. According to BC Ministry of Environment (Berardinucci and Ronneseth, 2002):

> *The level of vulnerability of an aquifer is a measure of its vulnerability to a contaminant that is introduced at the land surface. … Vulnerability in this system is considered to be intrinsic to the aquifer. This means that it is based on hydrogeology alone and does not consider the existing type of land use or nature of the potential contaminants.*
>
> *Assessment of vulnerability is not an assessment of the risk of contamination. For example, one aquifer in the city and the other in a pristine are in the country may be of equal vulnerability, but the one in the city is likely at higher risk of contamination.*
>
> *High vulnerability aquifers should be given first priority for the implementation of quality protection measures.*

In BC, groundwater scientists assess the vulnerability of an aquifer to contamination from surface sources. This is based on the type, thickness and extent of geologic materials overlying the aquifer, depth to water, and the type of aquifer materials (Kreye et al, 1994). Using this approach, provincial aquifer mapping indicates that Aquifer 416 has an overall moderate intrinsic vulnerability (BC Environment, 2016). However, looking closer at Aquifer 416, the intrinsic vulnerability varies depending on the presence or absence of a confining layer, in this case the Vashon Till (Berardinucci and Ronneseth, 2002; Humphrey, 2000; Newton and Gilchrist, 2010). Where this Till layer is present, the aquifer vulnerability is low. However, where the Till is absent, the aquifer vulnerability is high.

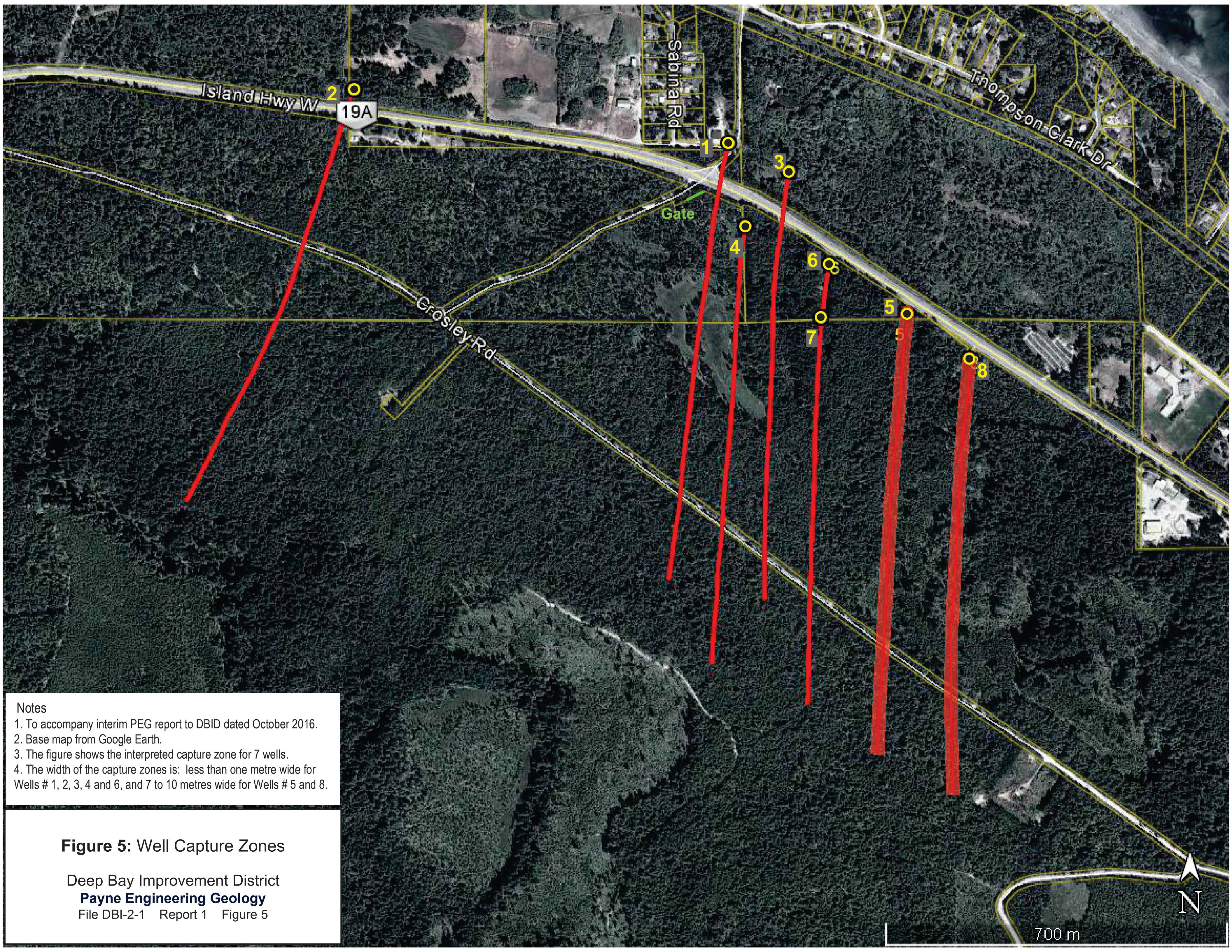
The mapped Well Protection Area covers a portion of the aquifer and, within this area, the aquifer is mostly unconfined. That is, there is no layer of Vashon Till overlying the Quadra Sand. As a result, the intrinsic aquifer vulnerability has been mapped as high for most of the Well Protection Area, except near Gainsberg Swamp and other wetlands, where the Vashon Till is present as a confining layer (Humphrey, 2000; Newton and Gilchrist, 2010).

3.2 Well Capture Zones

Figure 5 shows our analysis of the well capture zones for the seven Deep Bay wells. Each capture zone is the portion of the aquifer that supplies water to the well during typical well pumping conditions, and over a certain period of time. For this analysis, the mapped well capture zones outline the groundwater that is expected to reach each well in less than 530 days, or approximately 18 months. Referring to Figure 5, the following table show the calculated dimensions of the capture zone for each well.

Table 8: Dimensions of the Deep Bay Well Capture Zones

Well #	Length	Width
1	860 m	0.6 m
2	860 m	0.2 m
3	860 m	0.2 m
4	860 m	0.2 m
5	860 m	17 m
6	860 m	1.2 m
8	860 m	18 m



Notes
1. To accompany interim PEG report to DBID dated October 2016.
2. Base map from Google Earth.
3. The figure shows the interpreted capture zone for 7 wells.
4. The width of the capture zones is: less than one metre wide for Wells # 1, 2, 3, 4 and 6, and 7 to 10 metres wide for Wells # 5 and 8.

Figure 5: Well Capture Zones

Deep Bay Improvement District
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File DBI-2-1 Report 1 Figure 5

Figure 5 is based on the following:

- Method: uniform flow analytical model (US EPA, 1993).
- Subsurface travel time of 530 days, based on 8-log removal of viruses, 95% of the time
- Average pumping rates as provided by DBID, and ranging from 1.0 cubic metres per day (Well # 3) to 186 cubic metres per day (Well # 8)
- Average aquifer effective porosity of 0.30 or 30%
- length of well screen and aquifer thickness as indicated on well logs
- aquifer thickness ranging between 10 metres and 22 metres (from well logs)
- average aquifer hydraulic conductivity of 22 metres per day (from Table 5)
- hydraulic gradient of 0.022 or 2.2% (see Table 6)

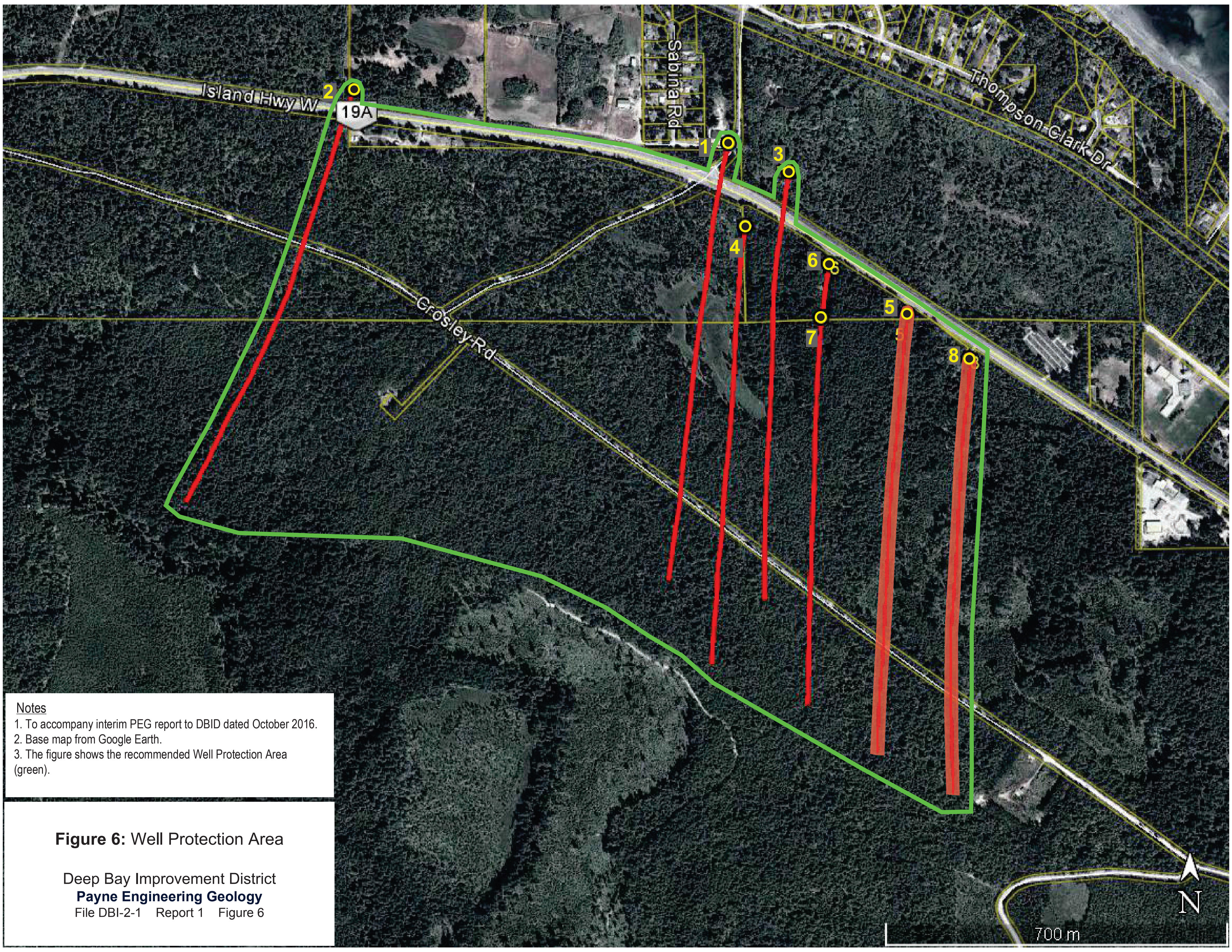
Figure 5 shows that the mapped well capture zones are long and thin, especially for the inactive wells. The capture zones are thin because the rate of pumping is very low relative to the capacity of each well and relative to the capacity of the aquifer.

The interpreted capture zones are relatively long, calculated at 860 metres long, because the groundwater moves relatively quickly through this permeable sand aquifer, at least in the vicinity of the Deep Bay wells. The rate of movement of the groundwater is estimated at 1 to 2 metres per day, which is considered fast for groundwater flow (Alley et al, 2013).

3.3 Well Protection Area

Figure 6, on the next page, outlines (in green) our recommended Well Protection Area (WPAs) for the Deep Bay wells. The Well Protection Area is the land area that warrants special measures to protect the aquifer from pollution. The WPA is based on the well capture zones in Figure 5, but also considers drainage of surface water into the well capture zones. For example, surface runoff from Highway 19A enters roadside drainage ditches within the capture zones of Wells # 1, # 2, and # 3.

The mapped Well Protection Area extends approximately 30 metres beyond the well capture zones to account for uncertainty in mapping the well capture zones, and also to account for the potential for liquid spills to spread across the land surface before seeping into the ground.



Notes
1. To accompany interim PEG report to DBID dated October 2016.
2. Base map from Google Earth.
3. The figure shows the recommended Well Protection Area (green).

Figure 6: Well Protection Area

Deep Bay Improvement District
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File DBI-2-1 Report 1 Figure 6

3.4 Potential Sources of Pollution

3.4.1 Potential pollution sources inside the Well Protection Area

Figure 7, on the following page, shows locations of potential sources of pollution within the Well Protection Area (WPA). This map shows the potential sources of pollution identified by the Community Planning Team. As a result, these potential sources of pollution, or hazards, do not necessarily present a significant risk to well water quality. Appendix 6 analyses the relative risk to well water quality resulting from each of these potential pollution sources or hazards.

There is a potential hazard arising from unrestricted vehicle access to the WPA, including the risk of dumping of wastes and the risk of someone starting a forest fire. There is currently only one gate and that gate does not prevent vehicle access to this area (see Appendix 4).

For this Plan, we also analysed the probability of pathogenic microorganisms, including viruses, reaching the intakes of the seven Deep Bay water wells. Appendix 5 is a summary of our analysis, or screening, of hazards related to pathogenic microorganisms. This analysis is based on BC Ministry of Health procedures for analysis of *GARP*, or *Groundwater At Risk of Pathogens*.

This is part of the analysis of risks from pathogenic microorganisms. The other critical part of the analysis is the ongoing bacteriological testing of the well water. This testing indicates a low risk of pathogens in the aquifer and water supply wells (Appendix 4).

LOW RISK WELLS

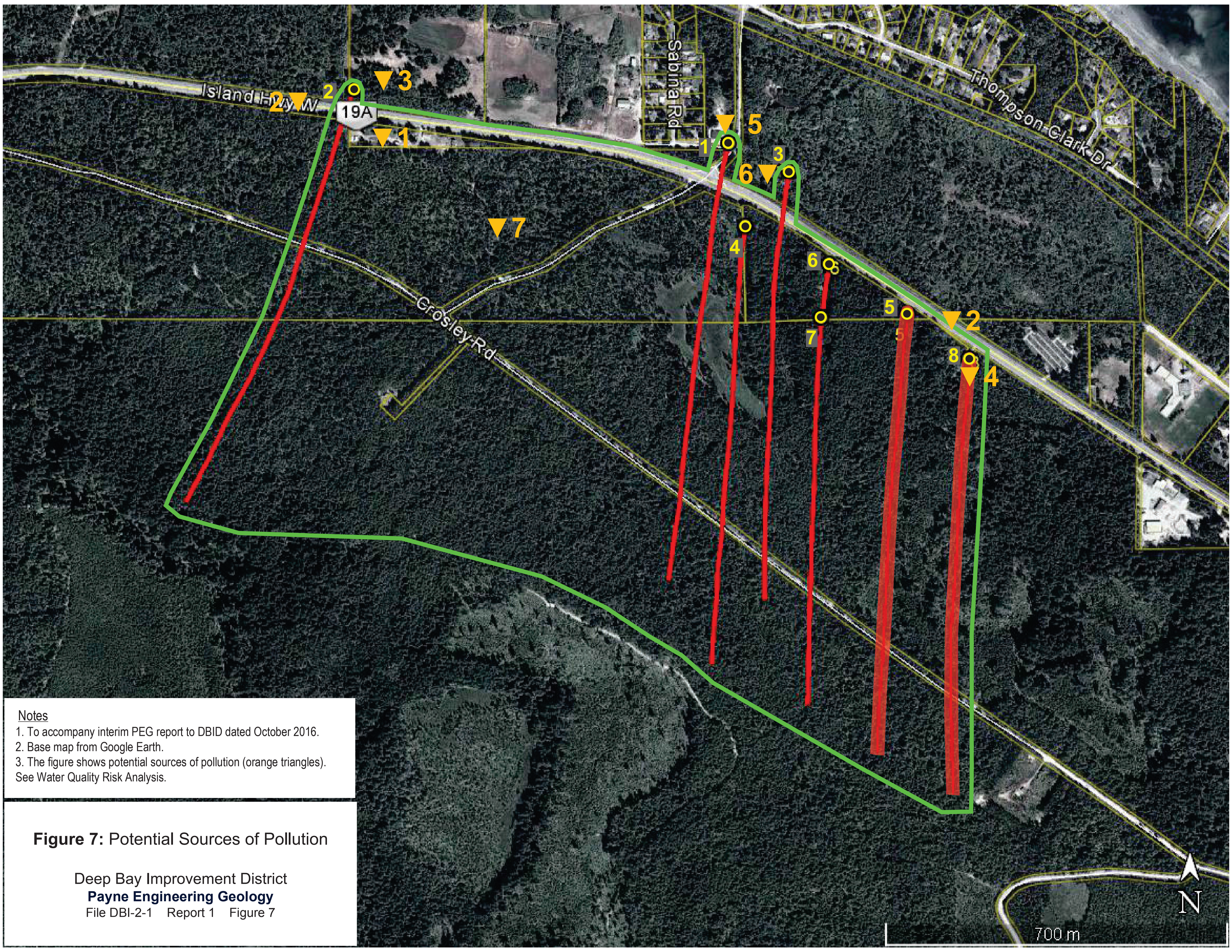
Overall, this screening analysis indicates a low to very low risk of pathogenic microorganisms reaching the following wells: #1, #4, #5, #6, and #8. Appendix 5 outlines the rationale or reasons supporting this assessment.

WELLS AT RISK

Analysis indicates a risk of pathogens reaching the following wells: #2 and #3. Appendix 5 discusses risk factors. In summary:

- Cattle have been grazing close to Well #2, and this is a relatively shallow well with inconsistent turbidity.
- Coliform bacteria have been detected in samples from Well #3, which is located relatively close to wetlands in an area with a shallow water table.

In the future, land uses may change within the WPA, and this could change our risk assessment. Section 4 of this Plan recommends risk management measures.



Notes
1. To accompany interim PEG report to DBID dated October 2016.
2. Base map from Google Earth.
3. The figure shows potential sources of pollution (orange triangles). See Water Quality Risk Analysis.

Figure 7: Potential Sources of Pollution

Deep Bay Improvement District
Payne Engineering Geology
File DBI-2-1 Report 1 Figure 7

3.4.2 Potential pollution sources outside of the Well Protection Area

This review focusses on potential pollution sources located within the Well Protection Area (Figure 6). However, we also identified some potential pollution sources that are outside of the Well Protection Area but still within the recharge area for Aquifer 416.

These potential sources are less of a concern relative to potential sources within the WPA, but are still of some concern. One such source is the former site of the Bowser Seed Orchard, located off Cowland Road. The Aquifer Protection Plan for the Bowser Waterworks District discusses this property in some detail and provides the following comments (Payne, 2015).

> *The [Ministry of Forests] monitoring results suggest an accidental spill of potassium sulphate, or other potassium fertilizer, at or near the [Bowser] seed orchard, during approximately September or October of 1994.*
>
> *The potassium contamination is not a direct concern since potassium in drinking water is not a health risk or an aesthetic concern. However, this causes concern indirectly because it suggests that a spill of fertilizer is a real risk and that water soluble fertilizer can move quickly through the sandy aquifer and contaminate several water supply wells over a short period of time. This monitoring result reiterates the importance of monitoring activities within the groundwater recharge area and also the importance of using solid slow-release fertilizers instead of liquid fertilizer. ….*
>
> *In summary, the Bowser Seed Orchard is not the only potential cause of the elevated potassium concentrations detected in October and November of 1994. However, regardless of the cause, the implication is the same: this aquifer recharge zone is intrinsically vulnerable to rapid contamination from water soluble contaminants including liquid fertilizers.*
>
> *This review did identify potential sources of groundwater contamination within the larger upslope groundwater recharge area, including activities at the Bowser Seed Orchard. However, as outlined in Appendix 5, overall water quality risks are insignificant or negligible based on current land use. …. In the future, land uses may change within the groundwater recharge zone, and this would change our risk assessment.*

Based on these comments, it will be important to monitor activities and land use changes at the Bowser Seed Orchard property.

3.5 Existing Land Use Restrictions

The figures on the following pages show various restrictions on land use, as proclaimed by provincial and regional districts, that directly affect the mapped Well Protection Area.

3.5.1 Provincial Old Growth Management Area

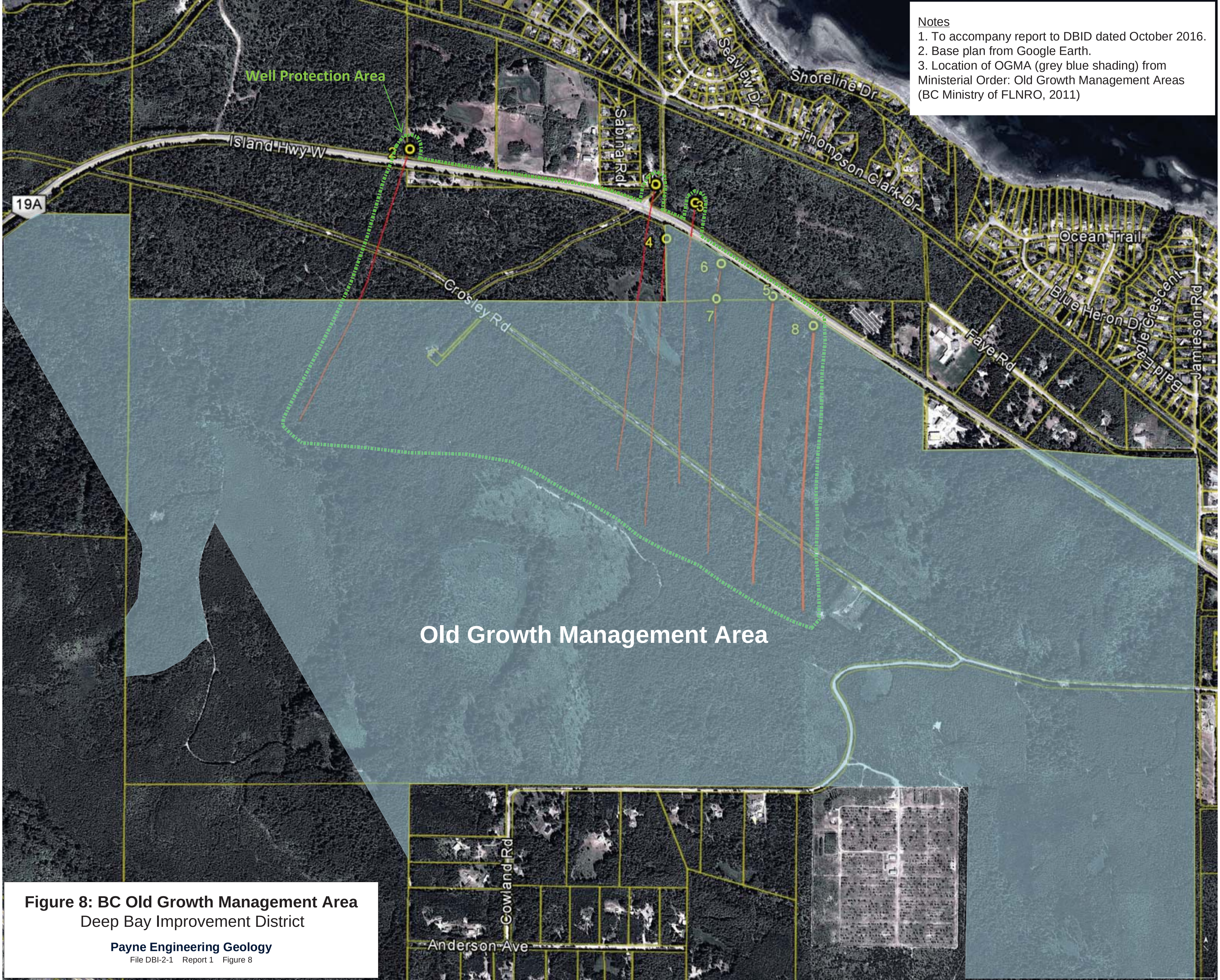
Figure 8, on the following page, shows portions of British Columbia's Old Growth Management Area (OGMA) that are located within the WPA. This OGMA covers approximately 80% of the Deep Bay Well Protection Area, and therefore is relevant to protecting the aquifer and wells.

According to the Ministerial order (BC Ministry of FLNRO, 2011), the objective of the OGMA is to "protect plant communities within the Old Growth Management Areas".

The BC MFLNRO has indicated that the Deep Bay Old Growth Management Area is a reserve, that is, a fixed geographical area established by a Ministerial order that means no harvesting of trees, and no activities are allowed that would damage the Coastal Douglas Fir plant communities (Jakobsen, 2016).

The Ministry also notes the following (Jakobsen, 2016):

> *There is a process for considering a change in land use; someone can apply to amend or change these areas. However, … no changes that would result in damage to the Coastal Douglas Fir plant communities would likely be considered. …. there is no logging or clearing allowed except for up to 5% may be disturbed should there be no alternative road access or infrastructure, or to address a safety concern.*



Notes
1. To accompany report to DBID dated October 2016.
2. Base plan from Google Earth.
3. Location of OGMA (grey blue shading) from Ministerial Order: Old Growth Management Areas (BC Ministry of FLNRO, 2011)

Figure 8: BC Old Growth Management Area
Deep Bay Improvement District

Payne Engineering Geology
File DBI-2-1 Report 1 Figure 8

3.5.2 Regional District Development Permit Area

Figure 9 shows the Regional District's development permit area (DPA), from the Official Community Plan. This DPA covers the entire of the mapped Well Protection Area for Deep Bay (Figure 6). The Regional District's Senior Planner has explained that:

> *... in the Environmentally Sensitive Features Development Permit Area, exemption #11 indicates that single family dwellings, duplexes, or accessory buildings and structures do not require a development permit if they are within the Village Centre, Rural Residential or Resort Commercial land use designations. That leaves multi-family residential and other non-residential developments to apply for a [development] permit.*
>
> *For the purpose of aquifer protection, Guideline 6 of the development permit applies: "The use or disposal of substances or contaminants that maybe harmful to area aquifers shall be discouraged and wherever practical, steps shall be taken to ensure the proper disposal of such contaminants". The property owner would have to demonstrate that this guideline is being met, and may be required to provide a report by a qualified professional to do so.*

According to the Regional District's permit application form, the Development Permit will include conditions of approval and will regulate the development of the property.

After meeting with RDN staff, our understanding is that the Regional District's DPA helps to protect the Quadra Sand Aquifer, within the mapped Well Protection Area, by requiring that the RDN evaluate the effects of a proposed land development before issuing a Development Permit. Our understanding is that the Regional District's permitting process may or may not include consultation with stakeholders or the general public.

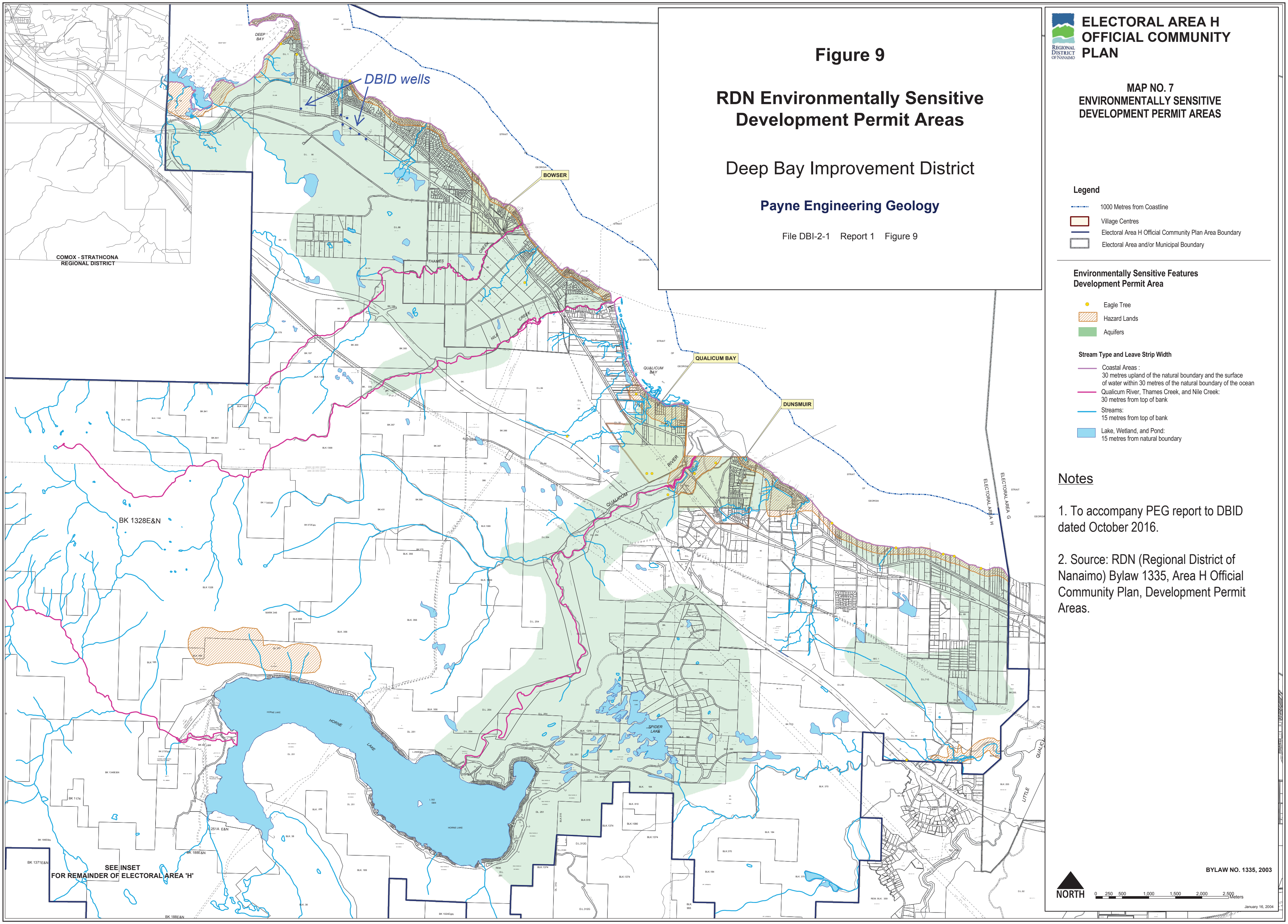


Figure 9
RDN Environmentally Sensitive Development Permit Areas
Deep Bay Improvement District
Payne Engineering Geology
File DBI-2-1 Report 1 Figure 9
DBID wells
ELECTORAL AREA H OFFICIAL COMMUNITY PLAN
REGIONAL DISTRICT OF NANAIMO
MAP NO. 7
ENVIRONMENTALLY SENSITIVE DEVELOPMENT PERMIT AREAS
Legend
1000 Metres from Coastline
Village Centres
Electoral Area H Official Community Plan Area Boundary
Electoral Area and/or Municipal Boundary
Environmentally Sensitive Features Development Permit Area
Eagle Tree
Hazard Lands
Aquifers
Stream Type and Leave Strip Width
Coastal Areas : 30 metres upland of the natural boundary and the surface of water within 30 metres of the natural boundary of the ocean
Qualicum River, Thames Creek, and Nile Creek: 30 metres from top of bank
Streams: 15 metres from top of bank
Lake, Wetland, and Pond: 15 metres from natural boundary
Notes
1. To accompany PEG report to DBID dated October 2016.
2. Source: RDN (Regional District of Nanaimo) Bylaw 1335, Area H Official Community Plan, Development Permit Areas.
BYLAW NO. 1335, 2003
NORTH
0 250 500 1,000 1,500 2,000 2,500 Meters
January 16, 2004
DEEP BAY
BOWSER
QUALICUM BAY
DUNSMUIR
THAMES CREEK
NILE CREEK
QUALICUM RIVER
HORNE LAKE
SPIDER LAKE
COMOX - STRATHCONA REGIONAL DISTRICT
ELECTORAL AREA H
ELECTORAL AREA G
BK 1328E&N
SEE INSET FOR REMAINDER OF ELECTORAL AREA 'H'
STRAIT OF GEORGIA

3.6 Well Water Quality

Appendix 4 is a summary of laboratory testing of water samples from the seven Deep Bay wells. This includes the following:

(1) Routine testing of bacterial water quality in the water distribution system.

(2) Annual water chemistry testing of samples from the wells.

3.6.1 Bacterial drinking water quality

For bacterial testing of the Deep Bay water system, the water system operator collects four samples per month, from four different locations within the water distribution system. As reported in Appendix 4, no coliform bacteria or E. coli were detected in the 100 samples collected over a 25 month period, from October 2013 to October 2015. In summary, bacterial water quality meets applicable guidelines. This shows that the natural slow-rate sand filter, also known as the Quadra Sand, is an effective and reliable system for water disinfection.

On one occasion in 2012, lab testing of a single sample from the reservoir did indicate an E. coli count of 1 MPN/100mL. However, E. coli bacteria were not found in repeat testing of the reservoir water or the water in the distribution system, so this was not considered a health risk.

3.6.2 Chemical drinking water quality

During 2011-2015, annual water quality sampling and laboratory analysis indicates that the well water meets drinking water quality guidelines for health protection, for the active water supply wells. In the active water supply wells, the reported concentrations were below Health Canada's *Maximum Acceptable Concentration* limits.

On a few occasions, water sampled from active wells did exceed the Health Canada *Aesthetic Objective* for turbidity, which is less than 1.0 NTU. In particular:

- In 2011 to 2013, the turbidity of Well #2 was 0.9 to 1.3 NTU.
- In 2013, the turbidity of Well #1 was 4.5 NTU.
- In 2014, the turbidity of Well #6 was 1.1 NTU.

3.6.3 Water quality for inactive wells

In some cases, inactive or stagnant water supply wells will tend to rust or will grow harmless coliform bacteria. The groundwater in the Deep Bay area is naturally corrosive. Water quality testing indicates a Langelier Saturation Index (LSI) in the range of minus 1.7 to minus 2.9. This is based on samples from Wells #1, #2, and #4 collected in 2011. Since the LSI is less than negative 0.5, this indicates moderately corrosive water (Swistock et al, 2016; Belitz et al, 2016). In our experience on many water supply projects, naturally corrosive groundwater is relatively common on Vancouver Island.

As a result of the corrosive groundwater inside inactive wells, some of the water samples collected from these wells indicated water quality that does not comply with all of the aesthetic water quality guidelines. However, despite impaired water quality, these water samples still comply with Maximum Acceptable Concentrations for health protection, with the rare exception of lead. In the inactive or stagnant wells, aesthetic water quality problems included the following:

- Turbidity ranged from 1.1 to 5.2 NTU in samples collected from Wells #1, #2, and #3. This exceeds the Operational Guideline of turbidity less than 1.0 NTU.
- Total coliform counts ranged from 0 to 12 in samples collected from Well #3 at times when that well was inactive.
- One sample from Well #4 indicated a total coliform count of 2, but the other annual samples indicated a total coliform count of zero (not detected).
- Samples from inactive Well #1 and Well # 2 indicated iron concentrations in the range of 0.36 to 0.77 mg/L. The Aesthetic Objective for iron is less than 0.30 mg/L. The iron is iron oxide, or rust, from rusting of the water well casing or other metal components in the well.
- Samples from inactive Well #1 and Well #2, in 2013-2014, indicated a notable colour of 16 to 21 colour units. The Aesthetic Objective is less than 15 colour units. The colour is the result of iron oxide in the water.

On occasion, stagnant corrosive well water can also leach and concentrate lead and copper from metal components in the well (CDCP, 2015). This can be a health hazard if the well is not thoroughly flushed prior to use as a drinking water supply. The Maximum Acceptable Concentration of lead in drinking water is 10 micrograms/litre (µg/L). One sample from Well #1, while inactive in 2015, had a lead concentration of 14 µg/L, and one sample from Well #4, in 2011, had a lead concentration of 11 µg/L.

As noted above, annual testing of samples collected from inactive wells has, on occasion, detected coliform bacteria in the stagnant well water. This is a common occurrence as bacteria can easily grow in stagnant wells or inactive wells. This situation is not expected to present a health hazard for the users of the water system, provided that inactive wells are thoroughly flushed and tested before the well water is pumped into the distribution system.

For the reasons discussed above, laboratory tests of samples collected from stagnant or inactive wells can be misleading, as the results do not represent the quality of water delivered to Deep Bay customers.

3.7 Compliance with the Groundwater Protection Regulation

During our onsite review, we found that the seven water supply wells comply with the BC Groundwater Protection Regulation (GWPR), including the following requirements (see also photos in Appendix 7):

- Steel well identification plates.
- Well caps.
- Flood proofing.
- Casing stickup at least 0.30 m (12 inches).
- Sump drainage away from the well.
- Surface water drainage away from the wellhead.

We did note the following minor departures from the GWPR:

- At Well #3, the casing stick-up is 0.28 m.
- At Well #4, the casing stick-up is 0.23 m.

These departures are so minor that, in our professional opinion, there is no value to extending the casing height by a mere 2 to 7 cm, just to comply precisely with the Regulation.

4. Recommended Aquifer and Well Protection

Follow these measures to protect water quality in the Quadra Sand aquifer and in the seven Deep Bay water supply wells.

4.1 Aquifer Protection

This study reviewed the risk to Deep Bay well water quality resulting from various hazards, including potential surface spills or releases of chemicals or pathogenic microorganisms (see Figure 7 and Appendix 6). Overall, the risk of aquifer or well pollution is considered low to negligible under current land uses and activities within the upslope groundwater recharge area. However, this situation could change with changes in land use. Therefore, the Deep Bay Improvement District should actively promote measures to reduce risks to groundwater quality.

Appendix 6 recommends measures to protect water quality. In summary, this includes the following approaches (based in part on RDN, 2007):

(1) measures to protect the Quadra Sand aquifer, especially within the Well Protection Area, including public awareness and cooperation with other organizations;

(2) changes to the use and operation of the seven DBID wells;

(3) improved routine testing of water quality in active water supply wells (see Section 4.2 below);

(4) measures to reduce risks arising from specific potential sources of pollution, including septic systems;

(5) measures to reduce risks from future changes to land use in the WPA; and

(6) an updated emergency response plan focused on responding promptly to a spill or leak of a hazardous substance.

4.2 Water Quality Monitoring

4.2.1 Routine bacterial testing

In consultation with Island Health, continue with routine sampling of tap water and bacterial water quality testing.

4.2.2 Chemical testing of well water quality

Continue with the current program of annual testing of the chemical water quality in the seven connected DBID wells, with sampling in October-November. When sampling inactive wells, flush the well thoroughly before sampling. The water system operator should develop a protocol for thorough flushing, and may seek advice from a professional hydrogeologist or engineer on this flushing protocol. Also, at the time of sampling, take field measurements of water quality including, at least, temperature, pH and turbidity.

This water sampling and testing schedule should be included in the water system operation and maintenance manual, along with a sampling plan and standard data quality checks. The results of all water quality monitoring must be reported to water users, as required by the Drinking Water Protection Regulation.

4.2.3 Chemical testing of reservoir water quality

Annually, in April-May of each year, collect a sample from the reservoir for additional chemistry testing. Submit the sample to a qualified laboratory for testing including, **at least**, the following parameters:

- iron,
- lead,
- zinc,
- ammonia-nitrogen,
- nitrate-nitrogen,
- chloride,
- potassium,
- sulphate,
- pH,
- turbidity,
- colour.

This is a shorter list than the long list of tests required by Island Health, in the Permit to Operate, for water quality testing once every three years (VIHA, 2012). This shorter list is appropriate because this is an additional set of samples, and is not part of the District's compliance with the Permit.

4.3 Water Quality Response Plan

Prepare an *Action Plan* outlining procedures to be followed if any laboratory testing detects water quality that does not meet drinking water objectives. Develop this plan in coordination with the water system operator and engineer, and consider the following provisions. This plan could be part of the District's existing *Emergency Response Plan,* or it could be a stand-alone plan.

The following is an example outline plan only; it is a starting point. It is based, in part, on small water system manuals and guidebooks (BC MoH, 1994; BC MoH, 2013; RCAP, 2006;

US EPA, 2004; US EPA, 2008).

This response plan should include the following general steps:

(1) Analyse the type and severity of the emergency.

(2) Take immediate action to save lives.

(3) Take action to reduce illness or injury, and system damage.

(4) Make repairs based on priority demand.

(5) Return the system to normal operation.

In a situation of bacterial or chemical contamination, this response may include the following steps:

4.3.1 Bacterial contamination

For monthly bacterial water quality testing, this should include at least the following:

(1) Notify the health authority (Island Health) and follow any and all instructions from the Drinking Water Officer.

(2) As soon as is feasible, resample the distribution system water at two or more locations, and submit the samples for laboratory testing for *E. coli* and total coliform bacteria. *Although there is potential for bacteria to contaminate the water distribution system, it is equally probable for bacteria to contaminate a water sample or sample bottle when bacteria are absent from the distribution system.*

(3) If the problem persists, then inform the health authority and advise water users to drinking only water that has been boiled for at least one minute (known as a Boil Water Notice).

(4) Maintain the Boil Water Notice until such time a consecutive water tests confirm that the problem has been remedied.

(5) After repeat laboratory testing confirms that the problem has been fixed, inform the health authority.

(6) With health authority approval, inform water users and return the system to normal operation.

Addition responses to bacterial contamination may include one or more of the following:

- Collect and test additional samples, from two or more locations, on two or more dates, to confirm the extent of contamination. This may include samples from the wells, reservoir, and the distribution system.
- Disinfect contaminated wells, or contaminated sections of the water system using a specified procedure. *Refer to the outline below.*
- Take one or more of the wells off-line until the problem has been cleared up.
- Retain one or more qualified professionals (may include water system operator, professional engineer, or groundwater specialist) to investigate the potential cause or causes, and potential

solutions to the problem, including temporary or permanent water disinfection methods.

- Repair or replace broken or faulty system components.

4.3.2 Chemical contamination

Responding to the unlikely event of a water sample failing the annual water chemistry test, the water quality response plan should include, at least, the following measures:

(1) Immediately inform the health authority (Island Health) of the problem and the measures being taken to deal with the problem.

(2) If the problem affects only one well, then take that well off-line until the scale of the problem has been confirmed.

(3) As soon as is feasible, flush the affected well or wells, resample, and re-test for the substance or parameter that exceeded the drinking water objective.

(4) If the problem persists, and affects all four water supply wells, then notify the health authority and residents and coordinate an alternative water supply.

(5) Take measures to remove the source of contamination (see below).

(6) Collect and test water samples to confirm the water is now safe for drinking.

(7) After repeat laboratory testing confirms that the problem has been fixed, inform the health authority.

(8) With health authority approval, inform water users and return the system to normal operation.

Addition responses to chemical contamination may include one or more of the following:

- Retain one or more qualified professionals (water system operator, professional engineer, groundwater specialist) to investigate the potential cause or causes, and potential solutions, including potential temporary or permanent water treatment methods.
- Repair or replace system components based on professional advice.

4.3.3 Shock chlorination equipment and procedures

In order to follow a Response Plan, as outlined above, the District should set up equipment, supplies and procedures for shock chlorinating portions of the water distribution system, and for shock chlorinating the water supply wells. In general, the chlorinating procedure would include the following (based on BC MoH, 2013; Pierson et al, 2001; Health Canada, 2008; RCAP, 2006; Eykelbosh, 2013):

- notify water users;
- if necessary, coordinate an alternate water supply during the chlorination procedure;
- physically isolate the contaminated well or portion of the water system;
- chlorinate at a specified free chlorine concentration and contact time;

- flush the chlorinated water;
- test the water to confirm a suitable residual chlorine concentration; and
- re-sample and re-test the water.

Chlorinated water must be re-used or disposed in a safe manner; this may involve dechlorinating the water prior to disposal.

4.4 Review of this Well Protection Plan

Once every 8 to 10 years, starting in 2025, update this Well and Aquifer Protection Plan, in consultation with a professional hydrogeologist. This review should include, at least, a review of water quality monitoring and well maintenance reports, and a site reconnaissance. This update may be viewed as similar to a medical check-up for the water supply system.

Original report signed by: DN: cn=Michael Payne, o=Payne Engineering Geology Ltd., ou, email=PayneEngineering@shaw.ca, c=CA Date: 2016.10.20 11:42:05 -07'00'

Michael Payne, P.Eng., P.Geo.

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Appendix 1: Statement of General Conditions

Scope of this Report

This review report satisfies only those objectives stated in the introduction. Payne Engineering Geology (PEG) has not conducted a *Site Investigation*, *Hydrogeology Study* or *Environmental Impact Assessment*.

Use of this Report

This Payne Engineering Geology (PEG) report pertains only to a specific project. If the project is modified, then our client will allow us to confirm that the report is still valid. We prepared this report only for the benefit of our Client and those agencies authorized by law to regulate our Client's activities. No others may use any part of this report without our written consent. To understand the content of this report, the reader must refer to the entire, signed report. We cannot be responsible for the consequences of anyone using only a part of the report, or referring only to a draft report. This report reflects our best judgement based on information available at the time. Any use of this report, or reliance on this report, by a third party is the responsibility of that third party. We accept no responsibility for damages, if any, suffered by a third party as a result of decisions made or actions taken based on this report.

Reliance on Provided Information

PEG has relied on the accuracy and completeness of information provided by its client and by other professionals. We are not responsible for any deficiency in this document that results from a deficiency in this information.

Logs of Test Holes or Wells and Subsurface Interpretations

Ground and ground water conditions always vary across a site and vary with time. Test hole and well logs show subsurface conditions only at the locations of the test hole or well. The precision with which geological and geotechnical reports show subsurface conditions depends on the method of excavation or drilling, the frequency and methods of sampling and testing, and the uniformity of subsurface conditions.

Descriptions of Geological Materials and Water Wells

This report includes descriptions of natural geological materials, including soil, rock, and ground water. PEG based these descriptions on observations at the time of the study. Unless otherwise noted, we based the report's conclusions and recommendations on these observed conditions.

Changed Conditions

Conditions encountered by others at this site may differ significantly from what we encountered, either due to natural variability of subsurface conditions, or as a result of construction activities. Our client will inform us about any such changes, and will give us an opportunity to review our recommendations. Recognizing changed soil and rock conditions, or changed well conditions, requires experience. Therefore, during construction or remediation, a qualified professional should be employed to visit the site with sufficient frequency to observe whether conditions have changed significantly.

Risks and Liability

We recommend that our client engage PEG to review all design drawings and constructed works that are based on our conclusions and recommendations. This is a requirement of the *Association of Professional Engineers and Geoscientists of BC.*

Standard of Care

We exercise a standard of care consistent with that level of skill and care ordinarily exercised by professionals currently practising under similar conditions.

Appendix 2: References and Information Retained on File

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Information Retained on File

In addition to the references listed above, Payne Engineering Geology has retained the following documents on file:

- field notes, GPS coordinates, and photographs from site reconnaissance on 2015-03-10 and 2016-03-17
- Excel spreadsheet summary of laboratory testing of water samples from wells and reservoir
- calculations of: (1) aquifer transmissivity at Well #8; (2) well capture zone; (3) aquifer yield
- maps and drawings

Appendix 3: Groundwater Regulations in BC

Most of this appendix has been copied from the ***Groundwater Bylaws Toolkit*** *(Curran et al, 2009), and updated for regulatory changes between 2009 and 2016. The Bylaws Toolkit report has been published on-line by the Okanagan Basin Water Board.*

The purpose of this section is to briefly outline the jurisdiction for groundwater: to define the roles different levels of government and aboriginal peoples play in groundwater management.

All levels of government have a role in groundwater management and sustainability. The federal and provincial governments share jurisdiction over water because the *Canadian Constitution* grants both levels of government various proprietary and legislative powers related to water, but does not allocate regulation or ownership of water to either level of government exclusively. That said, overall management responsibility rests with the Province. The provincial government, in turn, may allocate water management responsibility to local governments.

Although local governments have no regulatory authority over the quantity of groundwater used, how they exercise their land use jurisdiction affects both the quality and quantity of groundwater. They may also use groundwater as a source of community water supply. Local governments have considerable influence on groundwater extraction and infiltration through decisions about land use, in particular the location of development, the kinds of uses overlying aquifers that have the potential to contaminate groundwater, and the amount of impervious surface in a watershed that affects the rate of infiltration of water into aquifers. In short, good planning that creates compact complete communities and protects the rural working land base can also protect groundwater and community water supplies. Also, under the agricultural land reserve regime local governments have additional powers to regulate agricultural practices, such as the storage and application of compost and manure.

ABORIGINAL WATER RIGHTS

Aboriginal rights and title to water are unresolved in BC. There are few treaties in BC that settle water entitlements and most of the provincial land base is implicated in the ongoing BC treaty process. In addition, the rights and title of those aboriginal peoples that choose not to negotiate treaties continue to exist and may entitle indigenous communities to quantities of water of a certain quality at specified times of year, and base flows to sustain fish populations and waterways for navigation and trapping routes. These aboriginal water rights are unaccounted for in the existing provincial water licensing regime and could have a significant impact in watersheds as the treaty process and courts resolve First Nations' entitlements to water. The provincial and federal governments have certain duties to aboriginal people when their management of water resources may have an adverse impact on aboriginal water interests, such as fisheries and navigation.

FEDERAL JURISDICTION

The federal government may own water, for example in national parks, and may also enact regulations within federal subject areas, such as international aquifers and fisheries, that implicate groundwater. One of the most important federal laws related to groundwater is the *Fisheries Act*, under which protection of fish habitat can require protection of base flows. The *Canadian Environmental Protection Act (1999)* also addresses toxic substances and their release into the environment.

Despite the existence of numerous federal laws that the federal government could potentially use for groundwater protection, practically, it does not play a significant role in groundwater management or regulation except on federal land and where multiple jurisdictions (national and international) are involved. However, if provincial management had a significant impact on a federal area of jurisdiction, for example if groundwater withdrawals made a river unsuitable for fish or navigation, the federal government could challenge provincial action.

PROVINCIAL JURISDICTION

Under the *Canadian Constitution* the provincial government has the primary role in groundwater management. The province of BC's jurisdiction touches on groundwater in a variety of ways, including in the areas of environmental assessment, pollution control, drinking water (which is currently under the jurisdiction of regional Health Authorities), well construction, maintenance and closure, buildings, and geoexchange. Legislation that regulates activities on Crown land, such as forestry and mining, also addresses water quality.

The most relevant provincial laws related to groundwater from a local government perspective are listed below. Some of the provincial laws that enable greater groundwater protection are little used in practice. For example, the regulations that authorize the adoption of a water management plan or drinking water protection plan containing the power to restrict the drilling of wells, installation of well pumps and alteration of wells without a permit have not yet been used in BC.

Groundwater

In BC, the provincial Crown asserts ownership over all surface water and groundwater through the *Water Sustainability Act (2014),* and the regulations under that Act including the Water Sustainability Regulation (2016), and the Groundwater Protection Regulation (2016). Drinking water, including water from aquifers, is regulated under the *BC Drinking Water Protection Act* (2001) and Drinking Water Protection Regulation, as described below.

According to the Government of BC web site, the Water Sustainability Act (WSA) includes the following measures that relate to protecting water quality in aquifers and water wells.

> *Section 15, Environmental Flow Needs, brings in the requirement to consider environmental flow needs (EFN) in new water allocation decisions.*
>
> *Section 59 prohibits introducing foreign matter into a water supply well.*
>
> *Sections 5-6 vests water in government brings groundwater into the provisions to manage surface and ground water as a single resource.*
>
> *The Water Sustainability Regulation (2016) under the WSA describes provisions for licensing groundwater use and assigning water rights. The approach is similar to that for stream water.*
>
> *The Groundwater Protection Regulation (2016) under the WSA strengthens requirements related to the construction and maintenance of wells, and recognizes the types of professionals certified to perform these tasks.*
>
> *Section 82, Dedicated Agricultural Water, provides for the dedication of water for agricultural purposes on certain agricultural lands (e.g., land in the agricultural land reserve or zoned for an agricultural use).*
>
> *Section 131 expands on the provisions in the superseded Water Act and provides regulation-making authority for measuring, calculating and reporting on the quantity and quality of water diverted and used.*

Drinking Water

Public sources of drinking water, including water from community water supply wells, are regulated by the *Drinking Water Protection Act (2001)* and Drinking Water Protection Regulation (2003). This Act and Regulation set potable water standards and monitoring for drinking water suppliers, and prohibit contamination or tampering with a domestic water system, a drinking water source, a well recharge zone, or an area adjacent to a drinking water source. The Regulation prescribes water quality standards for potable water and requires that groundwater at risk of containing pathogens must be disinfected by a water supplier. A water supplier must obtain a permit for the construction, installation, alteration or extension of a water supply system, the application for which must include the results of water quality analyses in accordance with the Regulation. Drinking water officers have authority to make orders to prevent or address threats to drinking water.

A water supplier may be required to prepare a water system assessment to identify, inventory and assess the:

- Drinking water sources, including land use and other activities and conditions that may affect the source;
- Water supply system;
- Monitoring requirement; and

- Threats to the drinking water.

The Minister of Healthy Living and Sport, upon the recommendation of the Provincial health officer, may also designate an area to develop a drinking water protection plan (for groundwater sources, sometimes called a wellhead or aquifer protection plan) if satisfied that the plan will assist in addressing or preventing a threat to drinking water and no other practical measures are sufficient to address the health hazard.

Drinking Water Officers have required some large water suppliers to develop well protection plans as a condition of the system's operating permit. Other agencies require local governments to commit to a well protection plan under the environmental assessment review process or as a condition of receiving an infrastructure grant for drilling a municipal well.

Water Wells

In BC, the 2016 Ground Water Protection Regulation (GWPR) regulates activities related to water supply wells and groundwater. According to the BC government web site:

> *The GWPR: (1) regulates minimum standards for well construction, maintenance, deactivation and decommissioning, and (2) recognizes the types of qualified people certified to drill wells, install well pumps and perform related services*
>
> *All wells under the WSA are regulated, including those that provide water for domestic purposes.*
>
> *Constructing and decommissioning wells, installing well pumps, disinfecting wells and conducting flow tests are usually restricted activities that can only be performed by qualified well drillers or well pump installers, or professional engineers and geoscientists.*
>
> *The GWPR requires that any new water supply or dewatering well be set back at least 15 metres from an existing water supply well. To reduce the risk of contaminating water in water supply aquifers and nearby wells, the GWPR requires that stormwater recharge/injection wells be set back at least 60 metres from existing water supply wells.*
>
> *The GWPR regulates activities related to the construction, maintenance and decommissioning of a well to prevent contamination of the groundwater supply and drinking water.*
>
> *The well driller, professional or other person responsible for constructing a well is required to comply with the provisions of the GWPR related to how the well is constructed. This person must ensure that the well meets the minimum standards for the casing material, wellhead completion, surface seal, well caps and covers and well identification. A well pump installer or other professional is responsible for complying with the provisions of the GWPR when installing a pump in a well. Provisions include ensuring that the casing is not damaged, maintaining the surface seal, using appropriate materials and installing related equipment.*

The well owner, and in some cases the well driller, is required to ensure proper maintenance and care, whether or not the well is in service.

Sewage

The BC *Environmental Management Act (2003)* and the regulations under that *Act*, including the Agricultural Waste Control Regulation (1992) and Municipal Wastewater Regulation (2012), regulate the discharge of waste into watercourses and establish a system of permitting for waste discharges, including for municipal sewage.

The Municipal Wastewater Regulation prescribes design and permitting requirements for community wastewater collection, treatment and effluent dispersal systems, including systems that discharge treated effluent to the ground. These requirements include the completion of an environmental impact study, a major part of which is hydrogeological, and provision for long-term environmental monitoring, including groundwater monitoring.

The BC Sewerage System Regulation (2004) under the *Public Health Act (2008)* regulates the handling and treatment of sewage not serviced by a larger municipal or regional system (including septic tanks on rural properties). Only Registered Onsite Wastewater Practitioners and qualified professionals (generally Engineers) may construct and maintain on-site sewage systems.

The BC *Public Health Act* – Health Hazards Regulation (2011) prescribes setback requirements for drinking water supply wells. This includes, for example, 30 metres (100 feet) between a well and a probable source of contamination, 120 metres (400 feet) between a well and a cemetery.

Environmental Assessment

Projects with major groundwater impacts such as the development of new municipal water supplies or the construction or operation of pulp and paper mills, mining projects, fish hatcheries, or resorts, will be subject to the BC *Environmental Assessment Act (2002)*. Where groundwater extraction is being proposed from one or more wells at a combined rate of 75 litres or more per second, the project may be subject to an environmental assessment under the Reviewable Projects Regulation (2002). Thus, impacts of groundwater withdrawals must exceed the 75 litres per second limit before they will be considered.

Pollution Prevention and Waste Management

In BC, the *Environmental Management Act* regulates the storage, handling and disposal of wastes in B.C., and topic-specific regulations establish procedures and standards, such as for hazardous waste, petroleum storage and distribution, concrete, and anti-sapstain chemicals. Local governments have some limited roles under this regime, for example with contaminated sites and municipal or community sewage systems.

Agriculture

The application of pesticides is governed by the *Integrated Pest Management Act (2003)* and regulation that establishes a regime for the licensing, use, handling, release, transport, storage, disposal and sale of pesticides. The Hazardous Waste Regulation (1988) under the *Environmental Management Act* establishes standards for the handling and disposal of waste pest control product containers and waste containing pest control products.

Farmers do not require a permit for agricultural wastes handled according to the *Environmental Management Act's* Agricultural Waste Control Regulation (1992) and the Code of Agricultural Practice for Waste Management.

LOCAL GOVERNMENT JURISDICTION

Local government's role in groundwater sustainability is limited to using their land use and regulatory powers to:

- Ensure that rainwater is returned to aquifers and streams;
- Protect headwaters, riparian areas and other vulnerable aquifer recharge areas;
- Prevent groundwater contamination by limiting and regulating potentially polluting uses over aquifers and in groundwater recharge areas through zoning;
- Direct development to appropriate locations where the sufficiency of groundwater for domestic or commercial uses has been thoroughly assessed on a watershed scale before development occurs;
- Regulate the storage and application of fertilizers and compost;
- Obtain information about the location of existing and new wells (including geothermal wells) when new development occurs; and
- Develop well protection plans.

Local governments have broad authority to regulate the storage and application of fertilizer and compost. The Agricultural Land Reserve Use, Subdivision and Procedure Regulation (2002), under the *Agricultural Land Commission Act (2002),* enables local governments to regulate but not prohibit the following activities (except by a bylaw under s.917 of the *Local Government* Act):

- The storage and application of fertilizers, mulches and soil conditioners;
- The application of soil amendments collected, stored and handled in compliance with the Agricultural Waste Control Regulation;
- The production, storage and application of compost from agricultural wastes produced on the farm for farm purposes in compliance with the Agricultural Waste Control Regulation;
- The application of compost and biosolids produced and applied in compliance with the Organic Matter Recycling Regulation (2002); and

- The production, storage and application of Class A compost in compliance with the Organic Matter Recycling Regulation, if all the compost produced is used on the farm.

Under the Spheres of Concurrent Jurisdiction – Environment and Wildlife Regulation (2004) of the BC *Community Charter* (2003), municipalities have limited power to regulate, prohibit and impose requirements on the residential outdoor use of certain pesticides on trees, shrubs, flowers, and other ornamental plants and turf (grass). They may also control pesticide use on their own property.

Municipalities may not regulate those pesticides that are excluded under the provincial regulation for the use of pesticides:

- On land used for agriculture, forestry, transportation, public utilities, or pipelines unless the utility or pipeline is vested in the municipality;
- For the management of pests that transmit human diseases or have an impact on agriculture or forestry;
- On the residential areas of farms; and
- Used for buildings or inside buildings.

In aquifer protection zones or areas of watersheds where pesticide use may contaminate ground or surface water, pesticide control bylaws can assist local governments to minimize pollution. Characteristics of existing pesticide control bylaws include prohibitions on applying and using pesticides, and exemptions from the application of the bylaw. Several local governments have enacted pesticide control bylaws; however there is little experience with their enforcement to date.

Local governments address groundwater sustainability by establishing policies in Official Community Plans (OCPs) to protect the function of watersheds through protecting aquifers, headwaters and aquifer recharge areas. They also designate development permit areas for the protection of the natural environment to limit total impermeability in a watershed and minimize the impact of development on the local hydrologic cycle. Integrated rainwater (stormwater) management is becoming more prevalent where the focus is infiltrating more than 90 percent of rainwater events annually to maintain pre-development hydrologic patterns.

Local governments also prevent groundwater contamination by limiting and regulating polluting uses over aquifers and in groundwater recharge areas through zoning. They are beginning to map existing and new wells through the use of development information areas and development permit areas to understand the extent of the well network in each aquifer.

Appendix 4: Water Quality Testing

Monthly Bacterial Water Quality 2013-2015

DEEP BAY IMPROVEMENT DISTRICT

Facility Location:
5031 Mountain View Road
Bowser

Facility Information:

Facility Type: DWT

Facility Sampling History:

Location	Date	Total Coliform	E. Coli
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	26-Oct-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	26-Oct-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	13-Oct-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	13-Oct-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	28-Sep-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	28-Sep-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	14-Sep-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	14-Sep-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	31-Aug-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	31-Aug-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	17-Aug-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	17-Aug-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	5-Aug-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	5-Aug-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	20-Jul-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	20-Jul-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	6-Jul-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	6-Jul-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	16-Jun-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	16-Jun-2015	L1	L1

Location	Date	Total Coliform	E. Coli
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	3-Jun-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	3-Jun-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	19-May-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	19-May-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	4-May-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	4-May-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	14-Apr-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	14-Apr-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	31-Mar-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	31-Mar-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	16-Mar-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	16-Mar-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	2-Mar-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	2-Mar-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	16-Feb-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	16-Feb-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	2-Feb-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	2-Feb-2015	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	20-Jan-2015	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	20-Jan-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	5-Jan-2015	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	5-Jan-2015	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	15-Dec-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	15-Dec-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	2-Dec-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	2-Dec-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	24-Nov-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	24-Nov-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	12-Nov-2014	L1	L1

Location	Date	Total Coliform	E. Coli
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	12-Nov-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	20-Oct-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	20-Oct-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	6-Oct-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	6-Oct-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	22-Sep-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	22-Sep-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	8-Sep-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	8-Sep-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	25-Aug-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	25-Aug-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	11-Aug-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	11-Aug-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	21-Jul-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	21-Jul-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	7-Jul-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	7-Jul-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	16-Jun-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	16-Jun-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	2-Jun-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	2-Jun-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	12-May-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	12-May-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	5-May-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	5-May-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	14-Apr-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	14-Apr-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	7-Apr-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	7-Apr-2014	L1	L1

Location	Date	Total Coliform	E. Coli
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	24-Mar-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	24-Mar-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	17-Mar-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	17-Mar-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	24-Feb-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	24-Feb-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	4-Feb-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	4-Feb-2014	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	28-Jan-2014	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	28-Jan-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	8-Jan-2014	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	8-Jan-2014	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	18-Dec-2013	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	18-Dec-2013	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	11-Dec-2013	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	11-Dec-2013	L1	L1
4503 Maple Guard Drive, Deep Bay, SAMPLE STATION, Deep Bay BC	27-Nov-2013	L1	L1
4647 Thompson Clarke Drive, East, Deep Bay, Deep Bay WWD, Deep Bay	27-Nov-2013	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	13-Nov-2013	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	13-Nov-2013	L1	L1
Deep Bay Drive, Deep Bay, Deep Bay Drive, Deep Bay BC	28-Oct-2013	L1	L1
Deep Bay Fire Hall, Deep Bay, Deep Bay Fire Hall, Deep Bay BC	28-Oct-2013	L1	L1

Reference: *http://www.healthspace.ca/viha*

Water Chemistry: 1991 to 2015

As reported by Deep Bay Improvement District.

Underlined bold blue values exceed the Health Canada aesthetic objective (AO) or operational guideline (OG). **Bold red** values exceeded the maximum acceptable concentration (MAC) for health protection. *Some results have been rounded to two significant figures.*

Results from 1991 to 2015			Drinking Water		Range for Wells 1 to 8		
		Units	Guideline	Type	Min		Max
Routine Water							
Conductivity		uS			32	to	91
Corrosivity	Langelier	LSI	-0.5 to 0.5	OG(US)	-2.9	to	-1.7
Turbidity		NTU	< 1.0	OG	0.1	to	5.2
Alkalinity	Total	mg/L			17	to	52
Hardness	as CaCO3	mg/L	9 - 180	AO(D)	13	to	49
pH	25 C	pH	6.5 - 8.5	OG	6.5	to	7.9
Calcium	Dissolved	mg/L			3.9	to	13
Chloride	Dissolved	mg/L	< 250	AO	0.80	to	4.8
Fluoride	Dissolved	mg/L	< 1.5	MAC	0.019	to	0.080
Magnesium	Dissolved	mg/L			0.70	to	4.2
Nitrate - N	Dissolved	mg/L	< 10.0	MAC	0.034	to	0.22
Nitrite - N	Dissolved	mg/L	< 1.0	MAC	0.010	to	0.090
Phosphorus	Dissolved	mg/L			0.012	to	0.020
Potassium	Dissolved	mg/L			0.10	to	0.50
Silicon	Dissolved	mg/L			3.1	to	13
Sodium	Dissolved	mg/L	< 200	AO	2.1	to	6.7
Sulphate (SO4)	Dissolved	mg/L	< 500	AO	0.26	to	2.3
Sulphide		mg/L	< 0.05	AO	< 0.05	to	< 0.05
Total Ammonia (N)		mg/L			0.0080	to	0.080
Total Organic Carbon		mg/L	< 2.0	OG(US)	0.80	to	15
Total Organic Nitrogen		mg/L			NA		NA
Total Coliforms (MF)		CFU/100mL	< 1	MAC	0	to	0
Total Coliforms (DES)		MPN/100mL	< 1	MAC	0	to	12
E. coli (MF)		CFU/100mL	< 1	MAC	0	to	0
E. coli (DES)		MPN/100mL	< 1	MAC	0	to	0
Non-coliform bacteria		CFU/100mL			0	to	2,000
Fecal Coliforms (MF)		CFU/100mL	< 1	MAC	0	to	0

Results from 1991 to 2015		Units	Drinking Water Guideline	Type	Range for Wells 1 to 8 Min		Max
Metals - Total							
Aluminum	Total	mg/L	< 0.10	OG	<0.005	to	0.038
Antimony	Total	mg/L	< 0.006	MAC	<0.0002	to	<0.0002
Arsenic	Total	mg/L	< 0.010	MAC	<0.0002	to	0.0050
Barium	Total	mg/L	< 1.0	MAC	<0.001	to	0.022
Beryllium	Total	mg/L			<0.00004	to	0.0030
Bismuth	Total	mg/L			<0.0001	to	0.052
Boron	Total	mg/L	< 5.0	MAC	<0.005	to	0.020
Cadmium	Total	mg/L	< 0.005	MAC	<0.00001	to	0.00009
Calcium	Total	mg/L			3.8	to	13
Chromium	Total	mg/L	< 0.050	MAC	<0.0005	to	0.019
Cobalt	Total	mg/L			<0.00002	to	0.027
Copper	Total	mg/L	< 1.0	AO	<0.0005	to	0.11
Iron	Total	mg/L	< 0.30	AO	<0.01	to	0.77
Lead	Total	mg/L	< 0.010	MAC	<0.0001	to	0.014
Lithium	Total	mg/L			<0.0005	to	<0.0005
Magnesium	Total	mg/L			0.7	to	4.2
Manganese	Total	mg/L	< 0.05	AO	<0.001	to	0.022
Mercury	Total	ug/L	< 1.0	MAC	<0.00001	to	<0.00001
Molybdenum	Total	mg/L			<0.00005	to	0.033
Nickel	Total	mg/L			<0.001	to	0.11
Phosphorus	Total	mg/L			<0.01	to	0.020
Potassium	Total	mg/L			0.10	to	0.50
Selenium	Total	mg/L	< 0.05	MAC	<0.0001	to	<0.0001
Silicon	Total	mg/L			2.3	to	28
Silver	Total	mg/L			<0.00002	to	<0.00002
Sodium	Total	mg/L	< 200	AO	2.0	to	6.7
Strontium	Total	mg/L			0.021	to	0.031
Sulfur	Total	mg/L			NA		NA
Tellurium	Total	mg/L			<0.0001	to	<0.0001
Thallium	Total	mg/L			<0.00001	to	<0.00001
Thorium	Total	mg/L			<0.0001	to	<0.0001
Tin	Total	mg/L			<0.0001	to	0.0062
Titanium	Total	mg/L			<0.0001	to	0.013
Uranium	Total	mg/L	< 0.02	MAC	<0.00001	to	0.00002

Vanadium	Total	mg/L			0.0008	to	0.031
Zinc	Total	mg/L	< 5.0	AO	0.001	to	0.22
Zirconium	Total	mg/L			NA		NA
Physical and Aggregate Properties							
Colour	Apparent	Colour units	< 15	AO	2	to	21
Dissolved Solids	Total	mg/L	< 500	AO	20	to	93
Tannins & Lignins		mg/L	< 0.4	AO	< 0.1	to	0.10
UV Transmittance		%/cm			94.8	to	100.0

Appendix 5: Pathogen Hazard Screening

Based on *Guidance Document for Determining GARP, Version 2* (BC Ministry of Health, November 2015).

Water System Name: Deep Bay Improvement District

Well Names: #1, #2, #3, #4, #5, #6, and #8. *Each well is analyzed separately, on the following pages.*

BC Aquifer Number and Name (for all 7 wells): # 416. Quadra Sand, Thames River to Mapleguard Point.

Well # 1

BC Well Identification Plate Number: 13731. Well log: Reviewed.

Site sanitary survey conducted: 10 March 2015.

LATITUDE: N 49° 27′ 02.4″. LONGITUDE: W 124° 42′ 42.3″

Depths in metres below ground surface (mbgs)

Well depth: 52.0 mbgs

Water level in well: 2.2 mbgs (date: 2014-04-24)

Well casing diameter: 200 mm. Well location sketch: Figure 1.

Stage 2: GARP Determination

See the Hazard Screening and Assessment Checklist on the following page.

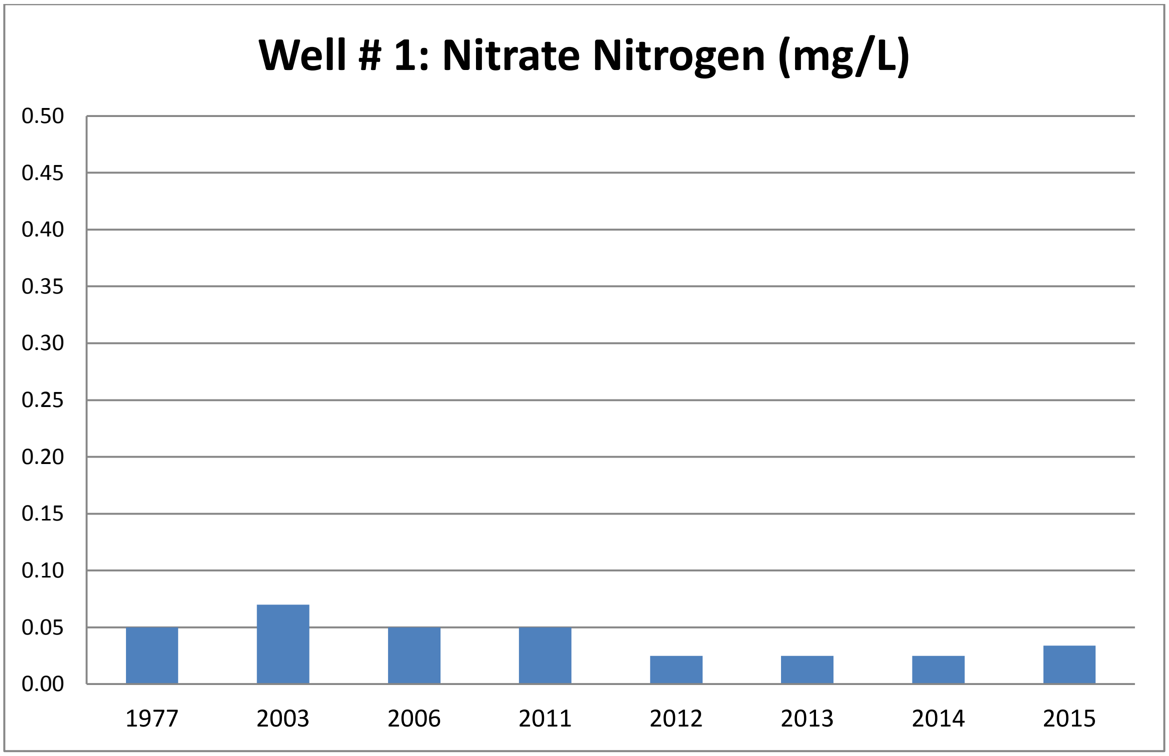
Assessment of Well #1: At Low Risk, based on the following assessment:

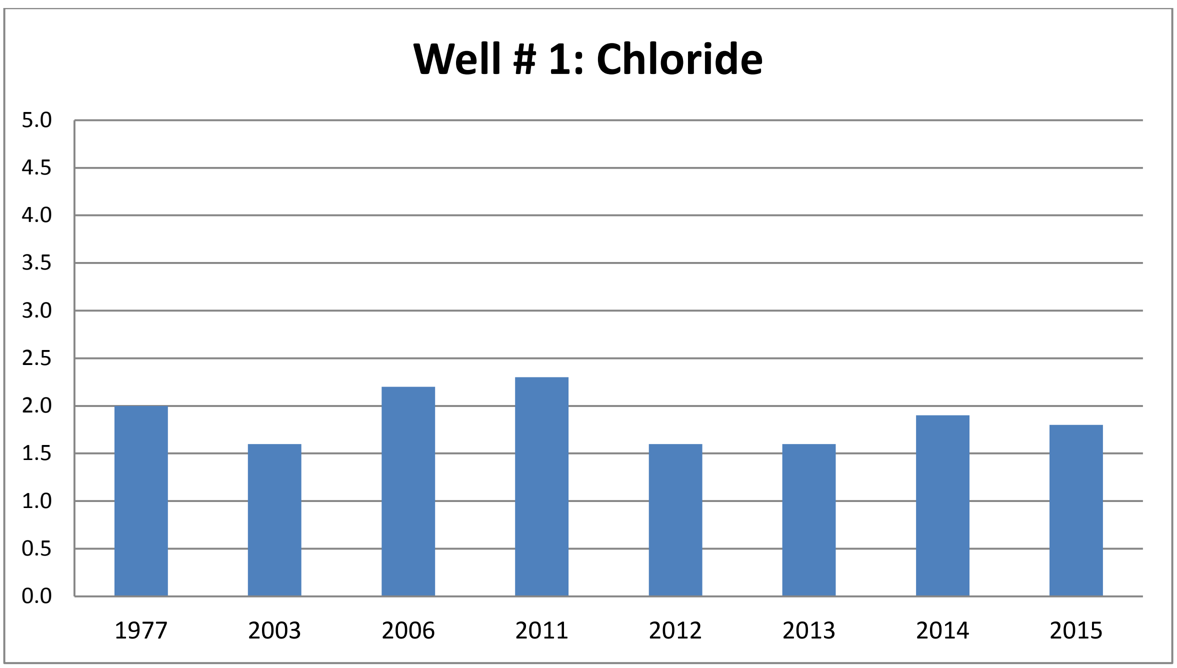
Both the wetland and the septic tank are located at a lower elevation than Well # 1, and outside of the well capture zone. Water quality monitoring, from 1977 to 2015, shows no evidence of sewage or wetland contamination of Well # 1.

While Well # 1 was in use as a water supply, turbidity was measured within the acceptable range of 0.3 to 0.7 NTU, indicating some integral ability of the aquifer to filter pathogens at this location.

The following two graphs show that Well # 1 chloride and nitrate concentrations have decreased over time. However, if the sewage was gradually contaminating Well # 1, we would expect these concentrations to increase. The nitrate and chloride concentrations remain much lower than the maxima allowed in drinking water.

Well #1 is currently off-line and the District does not plan to reconnect this well until after rebuilding the onsite sewage system that serves the Fire Hall. However, testing of the water quality from Well # 1, while in use as a drinking water supply, showed that the water quality complies with drinking water health protection guidelines.





In Well # 1, recent rusting of the well casing and pump column has increased the non-pumping turbidity, iron, manganese, lead, zinc, and colour in the well water.

Stage 3: Risk Mitigation for Well # 1

Provide alternate source of water:

If feasible, avoid Well # 1 as a water supply well, until the existing Fire Hall septic system can be replaced with a new system that conforms to applicable standards and guidelines.

Move to Stage 4 long-term monitoring:

When Well # 1 is in use as a drinking water supply well, sample and test the well water at least once every 12 months, for bacteria and chemical water quality. Also, continue to test the pumped water quality for indicator bacteria, as required by VIHA.

Other recommendations:

Well # 1 should be thoroughly flushed clean and resampled before being uses as a drinking water supply well. The pumped water should be tested for indicator bacteria.

Well # 1: Stage 1: Hazard Screening and Assessment

HAZARDS Water Supply System Well	SCREENING		ASSESSMENT		Footnotes
	Not Present	**Present**	**At Risk**	**At Low Risk**	
A. Water Quality Results					
A1: Exhibits recurring presence of total coliform bacteria, fecal coliform bacteria, or *Escherichia coli* (*E. coli*).	***X***				
A2: Has reported intermittent turbidity or has a history of consistent turbidity greater than 1 NTU.	***X***				(1)
B. Well Location					
B1: Situated inside setback distances from possible sources of contamination as per section 8 of the HHR.	***X***				
B2: Has an intake depth <15 m below ground surface that is located within a natural boundary of surface water or a flood prone area.	***X***				
B3: Has an intake depth between the high-water mark and surface water bottom (or < 15 m below the normal water level), and located within, or less than 150 m from the natural boundary of any surface water.		***X***		***X***	(2)
B4: Located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport.	***X***				(3)
C. Well Construction					
C1: Does not meet GWPR (section 7) for surface sealing.	***X***				
C2: Does not meet GWPR (section 10) for well caps and covers.	***X***				
C3: Does not meet GWPR (section 11) for flood-proofing.	***X***				
C4: Does not meet GWPR (section 12) for wellhead protection.	***X***				
D. Aquifer Type and Setting					
D1: Has an intake depth <15 m below ground surface.		***X***		***X***	(2)
D2: Is situated in a highly vulnerable, unconfined, unconsolidated or fractured bedrock aquifer.	***X***				
D3: Is completed in a karst bedrock aquifer, regardless of depth.	***X***				

(1) The Well # 1 water turbidity is usually > 1.0 NTU when the well is stagnant, but < 1.0 when the well is in use.

(2) Well # 1 screen is 11.0 m deep and well is 100 metres from a small seasonal wetland.

(3) There is a septic tank located 20 m down-gradient from Well # 1, outside of the inferred well capture zone. This is not a ***probable*** source of viruses in groundwater, but is a ***possible*** source.

Well # 2

BC Well Identification Plate Number: 13732. Well log: Reviewed.

Site sanitary survey conducted: 10 March 2015.

LATITUDE: N 49° 27′ 06.0″. LONGITUDE: W 124° 43′ 20.4″

Depths in metres below ground surface (mbgs)

Well depth: 38.0 mbgs

Water level in well: 1.6 mbgs (date: 1973-09-11)

Well casing diameter: 200 mm. Well location sketch: Figure 1.

Stage 2: GARP Determination

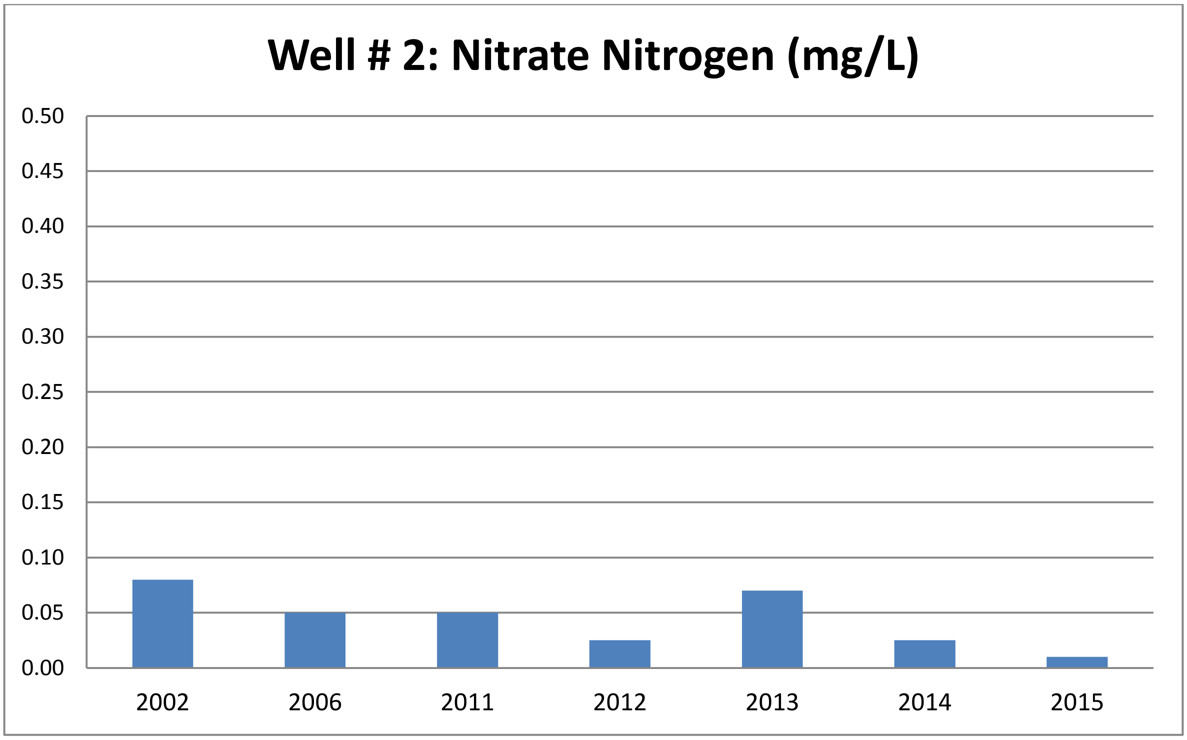
See Assessment Checklist on the following page.

Assessment of Well #2: At Risk (GARP-viruses only). This is based on the following reasoning:

- Cattle have been grazing to the edge of the fenced well compound, which is approximately 2 m from the wellhead, presenting a moderate risk to well water quality.
- The water table depth is moderate, about 2 m deep, and the well screen is about 8 metres deep.
- Well water turbidity, during use of Well #2, has varied between 0.3 and 1.3 NTU. This indicates a variable ability of the aquifer sands to filter fine materials including bacteria and viruses.

Over the next 20 years, without mitigation, the risk of well contamination by pathogenic microorganisms is considered low to moderate for the following reasons:

- Monitoring of Well # 2 water quality, from 2002 to 2015, did not detect bacteria in the well water. This included samples collected during 2013, 2014, and 2015, when Well #2 was inactive and therefore potentially susceptible to bacterial growth in the well.
- Monitoring of Well # 2 did not detect rises in other indicators of animal waste contamination, including nitrate and ammonia. The following page is a graph that shows the nitrate concentration in Well # 2.
- Surface water drains away from the well, not toward the well.
- The depth of unsaturated soil, about two metres, would generally be considered adequate to filter pathogenic microorganisms when loaded to the soil at a low loading rate, such as from grazing cattle.



Stage 3: Risk Mitigation for Well # 2

Provide alternate source of water:

Avoid using Well # 2 until such time as the protective fence can be rebuilt at a distance of at least 6 metres (20 feet) from the wellhead.

Move to Stage 4 long-term monitoring:

When Well # 2 is in use as a water supply well, test the pumped water quality for indicator organisms as required by VIHA. Also, sample and test the Well # 2 water quality at least once every 12 months, testing for bacteria and chemical water quality.

Other recommendations:

Prior to using Well # 2 as a drinking water supply well, thoroughly flush the well and collect a sample for testing for bacterial water quality.

Well # 2: Stage 1: Hazard Screening and Assessment

HAZARDS Water Supply System Well	SCREENING		ASSESSMENT		Footnotes
	Not Present	**Present**	**At Risk**	**At Low Risk**	
A. Water Quality Results					
A1: Exhibits recurring presence of total coliform bacteria, fecal coliform bacteria, or *Escherichia coli* (*E. coli*).	***X***				
A2: Has reported intermittent turbidity or has a history of consistent turbidity greater than 1 NTU.	***X***				(1)
B. Well Location					
B1: Situated inside setback distances from possible sources of contamination as per section 8 of the HHR.	***X***				
B2: Has an intake depth <15 m below ground surface that is located within a natural boundary of surface water or a flood prone area.	***X***				
B3: Has an intake depth between the high-water mark and surface water bottom (or < 15 m below the normal water level), and located within, or less than 150 m from the natural boundary of any surface water.	***X***				(2)
B4: Located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport.		***X***	***X***		(3)
C. Well Construction					
C1: Does not meet GWPR (section 7) for surface sealing.	***X***				
C2: Does not meet GWPR (section 10) for well caps and covers.	***X***				
C3: Does not meet GWPR (section 11) for flood-proofing.	***X***				
C4: Does not meet GWPR (section 12) for wellhead protection.	***X***				
D. Aquifer Type and Setting					
D1: Has an intake depth <15 m below ground surface.		***X***		***X***	(4)
D2: Is situated in a highly vulnerable, unconfined, unconsolidated or fractured bedrock aquifer.	***X***				
D3: Is completed in a karst bedrock aquifer, regardless of depth.	***X***				

(1) The well water turbidity is usually > 1.0 NTU when the well is stagnant, but < 1.0 when the well is in use.

(2) Well # 2 is more than 150 metres from the closest known surface water body.

(3) Cattle have been grazing within 3 m of the well and the water table is about 2 m deep.

(4) Well intake depth is 8.2 to 11.6 m depth.

Well # 3

BC Well Identification Plate Number: 13733. Well log: Reviewed.

Site sanitary survey conducted: 10 March 2015.

LATITUDE: N 49° 27′ 00.6″. LONGITUDE: W 124° 42′ 36.2″

Depths in metres below ground surface (mbgs)

Well depth: 53.7 mbgs

Water level in well: 0.8 mbgs (date: 1973-09-11)

Well casing diameter: 200 mm. Well location sketch: Figure 1.

Stage 2: GARP Determination

See Assessment Checklist on the following page.

Assessment of Well #3: At Risk (GARP). This is based on the following rationale:

- Coliform bacteria were detected in 3 out of 5 water samples collected from Well # 3. These indicator bacteria may or may not originate from the wetland, but nevertheless indicate compromised water quality.
- The water table is shallow, 0.5 to 1.0 metre deep. This indicates a limited ability of the thin unsaturated sand layer to filter bacteria, and other pathogenic microorganisms, from infiltrating surface water.
- The depth of the well intake is moderate, at 12 metres deep, but the nature of the annular seal is unknown.
- The travel path to Well #3 is through saturated sand, from 1 to 12 metres depth. This sand should have a moderate capacity to filter microorganisms.
- Well water turbidity is marginal, varying between 0.6 and 1.0 NTU while the well was in active use. This raises some questions regarding the ability of the aquifer sand to fully filter microorganisms.

Stage 3: Risk Mitigation for Well # 3

Provide alternate source of water:

Use Wells #4, #5, #6, and #8 as the primary water sources, and use the other wells as secondary or backup water sources. Prior to using one of the backup water supply wells, thoroughly flush the well and collect a sample or samples to test for bacteria contamination of the well.

Stage 4 long-term monitoring:

Whenever Well # 3 is used as a water supply well, collect well water samples at least once every 6 months to test for indicator bacteria and other indicator tests, as directed by a professional hydrogeologist. This would be in addition to the bacterial water quality monitoring required by VIHA.

Other recommendations:

If Well # 3 is returned to active use then, depending on water quality test results, the DBID may consider disinfecting the well water. Disinfection could involve ultraviolet radiation or chlorination or a combination of disinfection methods.

Comments:

The DBID could commission a Stage 2 or Stage 3 hydrogeology study and exposure assessment to evaluate risks of pathogenic microorganisms entering Well # 3. This decision will depend on the results of the monitoring described above, and will also depend upon advice from a professional hydrogeologist and VIHA.

Well # 3: Stage 1: Hazard Screening and Assessment

HAZARDS Water Supply System Well	SCREENING		ASSESSMENT		Footnotes
	Not Present	Present	At Risk	At Low Risk	
A. Water Quality Results					
A1: Exhibits recurring presence of total coliform bacteria, fecal coliform bacteria, or *Escherichia coli* (*E. coli*).		X	X		(1)
A2: Has reported intermittent turbidity or has a history of consistent turbidity greater than 1 NTU.	X				
B. Well Location					
B1: Situated inside setback distances from possible sources of contamination as per section 8 of the HHR.	X				
B2: Has an intake depth <15 m below ground surface that is located within a natural boundary of surface water or a flood prone area.	X				
B3: Has an intake depth between the high-water mark and surface water bottom (or < 15 m below the normal water level), and located within, or less than 150 m from the natural boundary of any surface water.		X		X	(2)
B4: Located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport.	X				
C. Well Construction					
C1: Does not meet GWPR (section 7) for surface sealing.	X				
C2: Does not meet GWPR (section 10) for well caps and covers.	X				
C3: Does not meet GWPR (section 11) for flood-proofing.	X				
C4: Does not meet GWPR (section 12) for wellhead protection.	X				
D. Aquifer Type and Setting					
D1: Has an intake depth <15 m below ground surface.		X		X	
D2: Is situated in a highly vulnerable, unconfined, unconsolidated or fractured bedrock aquifer.	X				
D3: Is completed in a karst bedrock aquifer, regardless of depth.	X				

(1) From sampling of Well # 3 between 2002 and 2015, 3 out of 5 samples indicated the presence of total coliforms, in the range of 3 to 12 MPN per 100 mL.

(2) For Well # 3, the well screen depth is 12.2 to 16.4 m, and the well is 35 m from a small seasonal wetland. However, the coliform bacteria in Well # 3 may or may not originate from the wetland.

Well # 4

BC Well Identification Plate Number: 13734. Well log: Reviewed.

Site sanitary survey conducted: 10 March 2015.

LATITUDE: N 49° 26′ 56.9″. LONGITUDE: W 124° 42′ 40.6″

Depths in metres below ground surface (mbgs)

Well depth: 63.5 mbgs

Water level in well: 3.4 mbgs (date: 1978-01-16)

Well casing diameter: 200 mm. Well location sketch: Figure 1.

Stage 2: GARP Determination

See Assessment Checklist on the following page.

Assessment of Well #4: At Low Risk, based on the following rationale:

- The water table is relatively deep, providing for a thick layer of unsaturated sand that can filter microorganisms.
- To date, well water quality has met guidelines, but with one notable exception. When sampled on 24 October 2012, the well water had a relatively high turbidity of 1.3 NTU and 2 total coliform per 100 mL. On other sampling dates, the well water turbidity was low at 0.2 to 0.3 NTU.
- Although Well # 4 is located 140 metres from a wetland, and down-gradient from the wetland, past water quality testing does not indicate any harmful effects. We checked for other potential indicators of wetland effects on the well, including nitrate and phosphorous, and we found that these concentrations remain low at Well # 4.
- Although the depth of the Well # 4 screen is less than 15 m, it is still moderated deep at 14.4 m.

Stage 3: Risk Mitigation for Well # 4

Since Well # 4 is considered at a low risk of containing pathogens, the BC guideline does not recommend risk mitigation beyond routine water quality monitoring, as follows:

Move to Stage 4 long-term monitoring:

When Well # 4 is in use as a drinking water supply well, continue with the routine monitoring required by VIHA. Also, when Well #4 is in use, collect well water samples at least once every 6 months to test for chemical water properties, under advice from a qualified hydrogeologist.

Well # 4: Stage 1: Hazard Screening and Assessment

HAZARDS Water Supply System Well	SCREENING		ASSESSMENT		Footnotes
	Not Present	**Present**	**At Risk**	**At Low Risk**	
A. Water Quality Results					
A1: Exhibits recurring presence of total coliform bacteria, fecal coliform bacteria, or *Escherichia coli* (*E. coli*).	***X***				
A2: Has reported intermittent turbidity or has a history of consistent turbidity greater than 1 NTU.	***X***				
B. Well Location					
B1: Situated inside setback distances from possible sources of contamination as per section 8 of the HHR.	***X***				
B2: Has an intake depth <15 m below ground surface that is located within a natural boundary of surface water or a flood prone area.	***X***				
B3: Has an intake depth between the high-water mark and surface water bottom (or < 15 m below the normal water level), and located within, or less than 150 m from the natural boundary of any surface water.		***X***		***X***	(1)
B4: Located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport.	***X***				
C. Well Construction					
C1: Does not meet GWPR (section 7) for surface sealing.	***X***				
C2: Does not meet GWPR (section 10) for well caps and covers.	***X***				
C3: Does not meet GWPR (section 11) for flood-proofing.	***X***				
C4: Does not meet GWPR (section 12) for wellhead protection.	***X***				
D. Aquifer Type and Setting					
D1: Has an intake depth <15 m below ground surface.		***X***		***X***	(1)
D2: Is situated in a highly vulnerable, unconfined, unconsolidated or fractured bedrock aquifer.	***X***				
D3: Is completed in a karst bedrock aquifer, regardless of depth.	***X***				

(1) Well # 4 has a well screen depth of 14.4 to 19.4 m and is located 140 m from a wetland.

Well # 5

BC Well Identification Plate Number: 13735. Well log: Reviewed.

Site sanitary survey conducted: 10 March 2015.

LATITUDE: N 49° 26’ 51.2”. LONGITUDE: W 124° 42’ 24.2”

Depths in metres below ground surface (mbgs)

Well depth: 70.5 mbgs

Water level in well: 1.4 mbgs (date: 1985-06-11)

Well casing diameter: 200 mm. Well location sketch: Figure 1.

Stage 1: Hazard Screening and Assessment

See Hazard Screening on the following page.

Assessment of Well #5: No hazards present; at low risk of containing pathogens.

During 2015, routine monitoring of drinking water pumped from Well #5, tested once every two weeks, did not indicate a presence of indicator bacteria (based on VIHA reporting).

Well # 5: Stage 1: Hazard Screening and Assessment

HAZARDS Water Supply System Well	SCREENING		ASSESSMENT		Footnotes
	Not Present	**Present**	**At Risk**	**At Low Risk**	
A. Water Quality Results					
A1: Exhibits recurring presence of total coliform bacteria, fecal coliform bacteria, or *Escherichia coli* (*E. coli*).	***X***				
A2: Has reported intermittent turbidity or has a history of consistent turbidity greater than 1 NTU.	***X***				
B. Well Location					
B1: Situated inside setback distances from possible sources of contamination as per section 8 of the HHR.	***X***				
B2: Has an intake depth <15 m below ground surface that is located within a natural boundary of surface water or a flood prone area.	***X***				
B3: Has an intake depth between the high-water mark and surface water bottom (or < 15 m below the normal water level), and located within, or less than 150 m from the natural boundary of any surface water.	***X***				
B4: Located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport.	***X***				
C. Well Construction					
C1: Does not meet GWPR (section 7) for surface sealing.	***X***				
C2: Does not meet GWPR (section 10) for well caps and covers.	***X***				
C3: Does not meet GWPR (section 11) for flood-proofing.	***X***				
C4: Does not meet GWPR (section 12) for wellhead protection.	***X***				
D. Aquifer Type and Setting					
D1: Has an intake depth <15 m below ground surface.	***X***				
D2: Is situated in a highly vulnerable, unconfined, unconsolidated or fractured bedrock aquifer.	***X***				
D3: Is completed in a karst bedrock aquifer, regardless of depth.	***X***				

Well # 6

BC Well Identification Plate Number: 13736. Well log: Reviewed.

Site sanitary survey conducted: 10 March 2015.

LATITUDE: N 49° 26’ 54.4”. LONGITUDE: W 124° 42’ 32.1”

Depths in metres below ground surface (mbgs)

Well depth: 76.0 mbgs

Water level in well: 1.6 mbgs (date: 1990-12-19)

Well casing diameter: 200 mm. Well location sketch: Figure 1.

Stage 1: Hazard Screening and Assessment

See Hazard Screening on the following page.

Assessment of Well #6: No hazards present; at low risk of containing pathogens.

Well # 6: Stage 1: Hazard Screening and Assessment

HAZARDS Water Supply System Well	SCREENING		ASSESSMENT		Footnotes
	Not Present	**Present**	**At Risk**	**At Low Risk**	
A. Water Quality Results					
A1: Exhibits recurring presence of total coliform bacteria, fecal coliform bacteria, or *Escherichia coli* (*E. coli*).	***X***				
A2: Has reported intermittent turbidity or has a history of consistent turbidity greater than 1 NTU.	***X***				
B. Well Location					
B1: Situated inside setback distances from possible sources of contamination as per section 8 of the HHR.	***X***				
B2: Has an intake depth <15 m below ground surface that is located within a natural boundary of surface water or a flood prone area.	***X***				
B3: Has an intake depth between the high-water mark and surface water bottom (or < 15 m below the normal water level), and located within, or less than 150 m from the natural boundary of any surface water.	***X***				
B4: Located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport.	***X***				
C. Well Construction					
C1: Does not meet GWPR (section 7) for surface sealing.	***X***				
C2: Does not meet GWPR (section 10) for well caps and covers.	***X***				
C3: Does not meet GWPR (section 11) for flood-proofing.	***X***				
C4: Does not meet GWPR (section 12) for wellhead protection.	***X***				
D. Aquifer Type and Setting					
D1: Has an intake depth <15 m below ground surface.	***X***				
D2: Is situated in a highly vulnerable, unconfined, unconsolidated or fractured bedrock aquifer.	***X***				
D3: Is completed in a karst bedrock aquifer, regardless of depth.	***X***				

Well # 8

BC Well Identification Plate Number: 13737. Well log: Reviewed.

Site sanitary survey conducted: 10 March 2015.

LATITUDE: N 49° 26’ 48.2”. LONGITUDE: W 124° 42’ 17.9”

Depths in metres below ground surface (mbgs)

Well depth: 75.4 mbgs

Water level in well: 1.2 mbgs (date: 1997-10-30)

Well casing diameter: 200 mm. Well location sketch: Figure 1.

Stage 1: Hazard Screening and Assessment

See Hazard Screening on the following page.

Assessment of Well #8: No hazards present; at low risk of containing pathogens.

During 2015, routine monitoring of drinking water pumped from Well #8, tested once every two weeks, did not indicate a presence of indicator bacteria (based on VIHA reporting).

Well # 8: Stage 1: Hazard Screening and Assessment

HAZARDS Water Supply System Well	SCREENING		ASSESSMENT		Footnotes
	Not Present	**Present**	**At Risk**	**At Low Risk**	
A. Water Quality Results					
A1: Exhibits recurring presence of total coliform bacteria, fecal coliform bacteria, or *Escherichia coli* (*E. coli*).	***X***				
A2: Has reported intermittent turbidity or has a history of consistent turbidity greater than 1 NTU.	***X***				
B. Well Location					
B1: Situated inside setback distances from possible sources of contamination as per section 8 of the HHR.	***X***				
B2: Has an intake depth <15 m below ground surface that is located within a natural boundary of surface water or a flood prone area.	***X***				
B3: Has an intake depth between the high-water mark and surface water bottom (or < 15 m below the normal water level), and located within, or less than 150 m from the natural boundary of any surface water.	***X***				
B4: Located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport.	***X***				
C. Well Construction					
C1: Does not meet GWPR (section 7) for surface sealing.	***X***				
C2: Does not meet GWPR (section 10) for well caps and covers.	***X***				
C3: Does not meet GWPR (section 11) for flood-proofing.	***X***				
C4: Does not meet GWPR (section 12) for wellhead protection.	***X***				
D. Aquifer Type and Setting					
D1: Has an intake depth <15 m below ground surface.	***X***				
D2: Is situated in a highly vulnerable, unconfined, unconsolidated or fractured bedrock aquifer.	***X***				
D3: Is completed in a karst bedrock aquifer, regardless of depth.	***X***				

Appendix 6: Risk Assessment and Management

BASIS OF THIS RISK ASSESSMENT:

Risk assessment must determine, characterize, and quantify the following factors: (1) the potential of the source to release a risk agent [the hazard]; (2) the intensity, frequency, and duration of the exposure, and the nature of the populations that might be exposed [exposure assessment]; and (3) the relationship between exposure and the resulting health or environmental consequences [risk assessment]. In this context, the risk is defined as follows: *A risk is a characteristic of a situation or action wherein two or more outcomes are possible, the particular outcome that will occur is unknown, and at least one of the possibilities is undesired* (Covello and Merkhofer, 1993). The following risk assessment is based on methods recommended by Canadian Centre for Occupational Health and Safety (CCOHS, 2016).

Water Quality Risk Analysis

HAZARD: The potential of the source to release a risk agent	EXPOSURE ASSESSMENT: Subsurface transport and attenuation	RISK ASSESSMENT: Resulting risk to well water quality
(1) Septic system at 7738 and 7744 Island Highway. Located upslope from Well #2. *See Footnote (3).* **Hazard:** There is an overall **<u>low probability</u>** of release of sewage pollutants to the water table. The risk is difficult to assess based on limited information about the septic system. These two septic systems are about 100 to 130 m upslope from Well 2. There is no direct surface water drainage toward Well 2. In general, the risk is low but, for any particular septic system, this depends on competent and proper: (1) site evaluation; (2) design; (3) installation; and (4) maintenance. If two or more of these steps was incomplete or completed in error, this creates a significant risk of pollution reaching the water table.	However, if contaminants do reach the water table, then the plume of contaminated groundwater is expected to move North toward Well #2 under the natural hydraulic gradient. The rate of movement is estimated at 1 to 2 metres per day, or approximately 50 to 100 days to travel 100 m. While improbable, it is possible that pathogenic viruses could occasionally travel from these septic systems to Well #2, based on the estimated travel time.	Based on this analysis, the overall risk to Well #2, resulting from the septic systems, is **<u>very low or negligible</u>**. Monitoring of Well #2 water quality indicates no evidence of contamination of well water by septic systems. Appendix 5 recommends extra precautions for Well #2.

HAZARD: The potential of the source to release a risk agent	EXPOSURE ASSESSMENT: Subsurface transport and attenuation	RISK ASSESSMENT: Resulting risk to well water quality
(2) Motor vehicle accident on Highway 19A. **Hazard:** Although there is a moderate probability of one or more accidents over the next 20 years, for example, the probability of a significant release of a hazardous material is considered **low to very low**. The hazard arises from a traffic accident that results in a spill of a hazardous or toxic substance, such as fuel or oil. The new Inland Island Highway, Highway 19, is now the main route for transport of hazardous goods on Central Vancouver Island, reducing the relative risk for Highway 19A.	In the unlikely event of a significant spill of a toxic substance, the risk to the DBID wells depends on the state of the substance. A solid material can usually be cleaned up by emergency response crews before leaching into roadside ditches. However, a spilled liquid could potentially flow into roadside ditches and seep into soils before crews are able to contain the spill. Fuels and oils move slowly through soil; they preferentially bind to the soil. As a result, the DBID would probably have ample time to respond by closing the wells likely to be affected by a spill. As a result, there is a negligible risk of a spill reaching one of the wells while that well is in use.	As a result of this analysis, the overall risk to the DBID water supply, resulting from a Highway accident, is considered **very low or negligible.**
(3) Cattle grazing near Well #2. **Hazard:** Based on Appendix 5, we have identified a **moderate** probability of grazing cattle resulting in a release of pollutant (bacteria or viruses) to the water table in the next 20 years, without mitigation.	Monitoring of Well #2 water quality indicates no evidence of past contamination of well water by cattle wastes. The nitrate nitrogen concentration, an indicator of urine contamination, has decreased from 2002-2006 to 2014-2015. Coliform bacteria and E. Coli have not been detected in well water samples. However, with the sandy soil and shallow water table, analysis shows that bovine pathogens could potentially move toward the well at a rate of 1 to 2 metres per day, thus reaching the well in a few days.	Overall, this analysis shows a **low** risk that grazing cattle would adversely affect well water quality under the current situation. The risk relates to viruses, rather than to larger microorganisms (bacteria and protozoa). Appendix 5 recommends measures to reduce the risk, including the relatively simple measure of enlarging the fenced area around Well #2.

HAZARD: The potential of the source to release a risk agent	EXPOSURE ASSESSMENT: Subsurface transport and attenuation	RISK ASSESSMENT: Resulting risk to well water quality
(4) Seasonal drainage ditch and small wetland near Well #8. **Hazard:** We find an overall **low to moderate** probability of seasonal release of surface water pathogens into the groundwater near to Well #8. The seasonal drainage ditch and wetland are located 8 metres from Well #8. These surface water features may leak and contribute pathogenic microorganisms to the shallow subsurface. The water table is relatively shallow, approximately 1.0 to 1.5 m deep.	The relatively high rate of pumping of Well #8 will draw shallow groundwater downward toward the well screen. The travel time is difficult to estimate from available information, but may be in the order of 20 to 40 days. The Well #8 screen is relatively deep, at 17.8 metres to the top of the screen. The current routing laboratory testing indicates that this travel time (20 to 40 days) is adequate to remove indicator bacteria, but the travel time may or may not be adequate for satisfactory removal of viruses, if present in surface water.	Overall, this analysis indicates a **very low or negligible** risk to Well # 8 water quality, as a result of the proximity to a seasonal ditch and wetland. Coliform bacteria and E. Coli have not been detected in well water samples to date, despite bi-weekly sampling. Turbidity has remained below 0.5 NTU. The DBID plans to culvert the ditch near Well #8.
(5) Septic system for Fire Hall, located near Well #1. **Hazard:** Overall, this septic system presents a **low to moderate probability** of release of a pollutant to the water table. This hazard is difficult to assess based on limited information about the septic system. This septic system treats wastewater from the Deep Bay Fire Hall. The septic tank is about 20 metres downslope from Well 1, and the septic field is about 30 metres downslope from the well. There is no particular reason to expect a release of pollutants to the water table, provided that the septic system was properly designed, constructed, and maintained. However, the short distance implies a risk that should be evaluated.	The Fire Hall septic system is located closer to Well #1 than the setback distances recommended in the BC Sewerage System Standard Practice Manual (SPM). However, the septic system is located downslope from the well and is outside of the calculated well capture zone. As a result, seepage from the septic field, and any potential leaks from the septic tank, is expected to move away from Well # 1.	Under current conditions, there is **no current risk** to drinking water because Well #1 is out-of-service. Overall, we find a **very low risk during pumping of Well # 1**, as a result of the proximity to the septic system. This is because of the location of the septic system relative to the well capture zone (Figure 5). Past monitoring of water quality in Well #1 supports this analysis. The water pumped from Well # 1 complied with drinking water quality guidelines; no coliform bacteria or E. Coli were detected. The nitrate concentration has remained below 0.10 mg/L, and has decreased between 1977-2003 and 2014-2015.

HAZARD: The potential of the source to release a risk agent	EXPOSURE ASSESSMENT: Subsurface transport and attenuation	RISK ASSESSMENT: Resulting risk to well water quality
(6) Small wetland located near to Well #3. **Hazard:** Overall, based on the depth of the water table near Well #3, we find a **low to moderate probability** of pathogenic microorganisms traveling from the wetland to the relatively shallow water table near Well #3. Refer to the GARP analysis, in Appendix 5, for further analysis and discussion.	This small wetland is approximately 35 m southwest of Well #3. Figure 5 shows that the wetland is outside of the Well #3 capture zone, but neither feature has been accurately mapped. A conservative analysis would assume that the wetland is inside of the well capture zone. At a rate of 1 to 2 m/day, the travel time from wetland to well could be 17 to 35 days. This is adequate time for some attenuation or inactivation of bacteria and viruses that may be present in the wetland. However, attenuation may be incomplete, depending on various site-specific factors, including the water quality in the wetland and the depth of the water table.	Overall, the small wetland near Well #3 presents a **low risk** to drinking water quality in Well # 3. This is based largely on results of monitoring of water quality (Footnote 1).
(7) Unknown future land uses within the Well Protection Area. **Hazard:** PRESENT: Currently, there is a low or insignificant probability of release of a chemical or pollutant within the Well Protection Area. There is a risk of dumping of wastes or forest fires within this area because of unrestricted vehicle access. FUTURE: Land use may change in the future. Overall, there is a **low probability** of a release from future land uses, because of existing restrictions on land use (Footnote 2). However, from our review, the greatest hazard is loosely regulated farming activity on Lot C and other properties located close to the wells.	Without enforce regulation governing farming activities and waste management, such activities could be located within one of the well capture zones, and groundwater could rapidly transport contaminants to one or more wells. Without information about the actual activities and locations, we cannot estimate subsurface transport and attenuation of contaminants of concern, including viruses.	We found **insufficient information** to estimate the overall risk to well water quality resulting from future land uses inside of the Well Protection Area.

FOOTNOTES:

(1) Monitoring of Well #3 water quality, between 2003 and 2015, shows coliform bacteria detected in Well # 3, in 3 out of 5 samples, indicating a significant risk. However, the absence of E. coli bacteria and fecal coliform implies that the risk is not high or severe. Well # 3 also shows generally low nitrate concentration of less than 0.10 mg/L,

decreasing from 2002 to 2015; this implies limited infiltration from the wetland to Well #3. As a result, it is difficult to conclude that the coliform bacteria in Well #3 have travelled from the wetland.

(2) These existing land use restrictions include: (1) the RDN Environmental Development Permit Area, covering the entire area; (2) the provincial Old Growth Management Area, covering much of the crown land; and (3) the Agricultural Land Reserve that includes Lot C of District Lot 86.

(3) These two houses do not have fuel or oil storage tanks, and we are not aware of any fuel or oil storage tanks located within the mapped Well Protection Area.

Recommendations for Managing Risks Affecting the Deep Bay Improvement District Wells

GENERAL RECOMMENDATIONS	Recommended Risk Reduction or Management Measures
AQUIFER PROTECTION: *applicable to the entire Well Protection Area*	• EDUCATE WATER USERS: Starting in 2016, actively promote public awareness, education, and stewardship of the aquifer and water supply wells. The Regional District's *Drinking Water Action Plan* (short title, RDN, 2007) includes specific recommendations that the DBID can follow, independently and in cooperation with the RDN. • COOPERATE WITH OTHER AGENCIES: Continue to cooperate with the RDN, Island Health and the BC government. At this time, important contacts include: (1) Julie Pisani, Drinking Water Coordinator, RDN; (2) Patricia Lapcevic, Head of Water Protection, BC Ministry of FLNRO; (3) Brian Epps, Source Water Protection Specialist, BC Ministry of FLNRO; and (4) Elizabeth Thomson, Environmental Health Officer, Island Health. • OFFICIAL COMMUNITY PLAN: Submit this Aquifer and Well Protection Plan to the RDN planning department and ask that this Plan be incorporated into the Official Community Plan, especially bylaws affecting Development Permit Areas. • ASSOCIATE WITH OTHER DISTRICTS: Continue to associate and cooperate with other improvement districts on Vancouver Island, especially those with the common interest of protecting the Quadra Aquifer. The RDN has recommended forming a Water Purveyor Working Group (RDN, 2007). • MONITOR PETROLEUM PRODUCTS: We did not identify any tanks storing petroleum products, including fuels and oils, within the Well Protection Area (WPA). Where feasible, within the WPA, take steps to avoid the use of tanks storing petroleum products in quantities larger than 500 litres (110 imperial gallons). This is the approximate size of a fuel tank for a large excavator. • LIMIT USE OF UNDERGROUND TANKS: Where feasible, limit the use of underground fuel or oil tanks of any size within the WPA. • PLAN EMERGENCY RESPONSES: At least once every 5 years, starting in 2017, update the DBID's *Emergency Response Plan (ERP)*. Follow the guidance of the *Emergency Response Planning for Small Waterworks Systems* (BC Ministry of Health, 1994). The updated ERP should include procedures to follow if routine testing indicates bacterial contamination of the water. This would include, at least: (1) notifying Island Health; (2) issuing a boil water advisory; (3) flushing the water supply wells and distribution lines; and (4) resampling and retesting. • INFORM RESIDENTS ABOUT HAZARDOUS WASTES: Regularly inform and update residents about the importance of safe disposal of hazardous materials, and about RDN programs for collection of hazardous wastes. • RESTRICT ACCESS TO THE WELL PROTECTION AREA: As much as is feasible,

GENERAL RECOMMENDATIONS	Recommended Risk Reduction or Management Measures
	restrict vehicle access to the Well Protection Area. This will reduce the risk of illegal dumping of wastes and the risks of a forest fire. • UPDATE DATABASES: Once every 5 years, starting in 2020, update the water system databases (spreadsheets) that were prepared as part of this Plan, including the Water Well Database, and the Water Quality Database. • UPDATE THIS PLAN: Once every 10 years, starting in 2025, update this Well and Aquifer Protection Plan.
WELL OPERATION: *applicable to all of the DBID water wells*	• PREFERRED WELLS TO USE: When feasible, use Wells #4, #5, #6, and #8 as the primary sources of drinking water. The other 3 wells, Wells #1, #2, and #3 are considered generally suitable as drinking water sources, but this review identified risks affecting those three wells. • BRINGING WELLS ON-LINE: Before connecting an unused well into the drinking water system, surge and flush the well until the flushed water has a turbidity of less than 1.0 NTU. Then, sample the well and test for a full set of chemical and bacterial tests as advised by a qualified groundwater professional. If the water quality meets drinking water guidelines, then the water may be considered suitable for pumping into the water system. If the water quality does not meet drinking water guidelines, then seek advice from a qualified professional.
WATER QUALITY MONITORING: *applicable to all of the DBID water wells*	• TESTING OF WELL WATER: For seven connected water wells, continue to sample and test the well water quality annually, in October-November of each year. • TESTING OF TAP WATER: Continue to sample and test bacterial water quality, four times per month, as currently required by Island Health. • TESTING OF RESERVOIR WATER: In addition to the current test programs, start an additional program to sample and test the reservoir water annually, in April-May of each year.

POTENTIAL SOURCES OF POLLUTION	Additional Risk Reduction or Management Measures
(1) Septic system at 7738 and 7744 Island Highway. Located upslope from Well #2.	• When this plan is complete, provide a copy of this plan to each of the homeowners at 7738-7744 Island Highway. The knowledge that their septic systems are specifically mentioned in this Aquifer Protection Plan should encourage them to be extra vigilant in properly operating and maintaining their septic systems. • Starting in 2016, coordinate with the RDN on encouraging the Vancouver Island Health Authority to actively enforce the *Health Act* – ***Sewerage System Regulation***, especially provisions that require homeowners to maintain their onsite sewage systems.
(2) Motor vehicle accident on Highway 19A.	• When this plan is completed, provide the local Fire Chief with the map of the Well Protection Area, and ask the Chief to alert the water system operator whenever there is a highway spill of a hazardous liquid within this area.
(3) Cattle grazing near Well #2.	• Avoid using Well # 2 until such time as the protective fence can be rebuilt at a distance of at least 6 m (20 ft) from the wellhead.
(4) Seasonal drainage ditch and small wetland near Well #8.	• Follow the *General Recommendations* listed above, including more frequent testing of well water quality in Well #8. • The District indicated that it plans to install a culvert to prevent or reduce leakage from the ditch near Well #8. • The District's water system operator should direct this work, and may seek advice from a groundwater professional.
(5) Septic system for Fire Hall, located near Well #1.	• The District has indicated that it plans to keep Well #1 off-line until the Fire Hall septic system has been replaced with a new system that complies with the BC ***Sewerage System Regulation***. The new system should either conform to the BC *Sewerage System Standard Practice Manual* or, alternatively, be approved by a qualified groundwater professional with respect to the setback distances.
(6) Small wetland located near to Well #3.	• Follow the *General Recommendations* listed above, including more frequent testing of well water quality when Well #3 is in use as a source of drinking water.

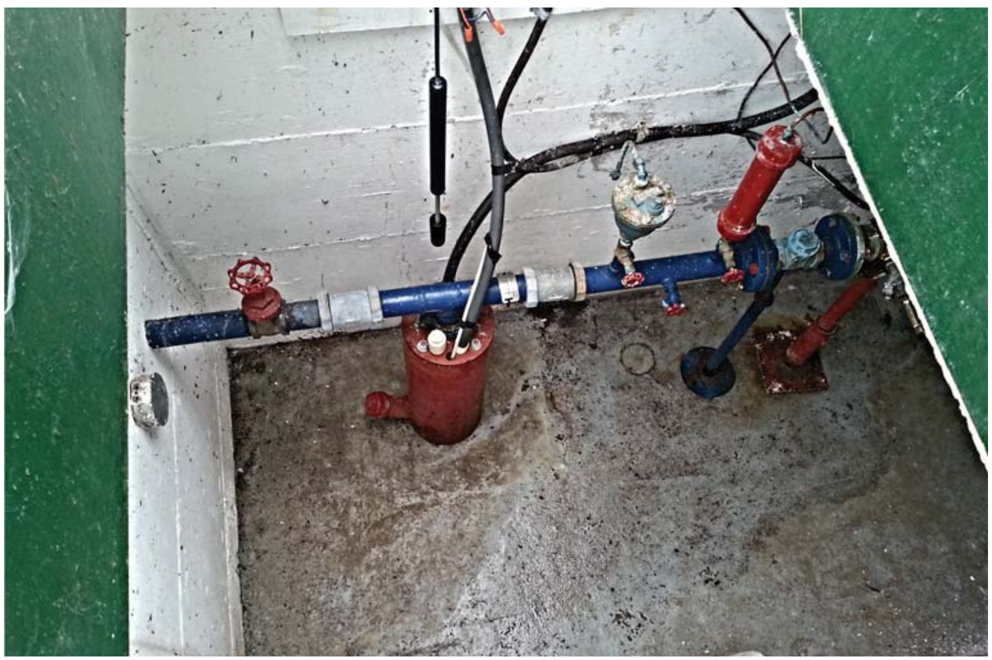
(7) Unknown future land uses within the Well Protection Area.	• Consider posting signs to identify the Aquifer Protection Area. • Continue to campaign for strict enforcement of land use restrictions, and waste management regulations, by the regional and provincial governments. • Regarding the RDN Development Permit Area, submit this report to the RDN and ask that the mapped Well Protection Area (WPA) be specifically considered for any development permit that affects land within the WPA. • Ask the RDN to consider the mapped WPA when rewriting the Official Community Plan for this area. • Regarding the provincial Old Growth Management Area (OGMA), submit this report to the BC Ministry of Forests and specifically ask that the WPA be considered for any proposed or planned change in land use within the OGMA.

Appendix 7: Photographs

See following five pages.

Well #1 - Overview

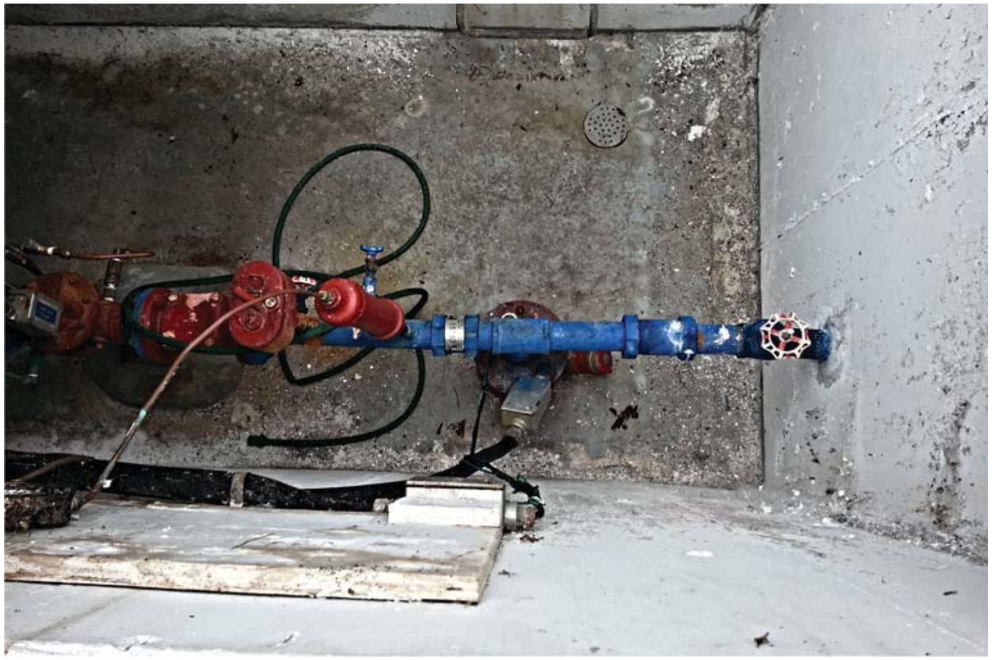
Well #2 - Wellhead completion



Well #1 - Wellhead completion

Well #2 - Overview

Well #3 - Wellhead completion



Well #4 - Wellhead completion

Well #3 - Overview

Well #4 - Overview


Well #5 - Wellhead Completion

Well #6 - Overview



Well #5 - Overview


Well #5 - Wellhead Completion

Well #6 - Wellhead Completion

Well #8 - Wellhead Completion

Well #6 - Wellhead completion

Well #8 - Overview

Well #8 - Wellhead Completion