Koksilah Water Supply Options and Feasibility Project: Appendices

Appendix A: Contacts from Consultation and Feasibility Research

Table 1: Individuals and Organizations Contacted in Koksilah Water Supply Options and Feasibility assessment

Name	Role, Organization	Contact Method
Tracy Fleming	Referrals Coordinator, Cowichan Tribes	Phone, email
Heather Adams	Lands Manager, Malahat Nation	Phone, email
Tristan Gale	Executive Director of Environment and Sustainable Development, Malahat Nation	Phone, email
Doug Pepper	Regional Agrologist, Ministry of Agriculture (MoA)	Phone, email
Andrew Peterson	Water Management Specialist, MoA	Phone, email
Megan Wainwright	Authorizations Specialist, MFLNRORD	
Jill Hatfield	(Retired) Regional Agrologist, MoA	Phone, email
Doug Pepper	Regional Agrologist, MOA	Phone
Pat Lapcevic	Director of Resource Management, MFLNRORD	Kick-off meeting
Russ Batyi	Vortech Plumbing	Phone
Keith Lawrence	Senior Environmental Analyst, Cowichan Valley Regional District (CVRD)	Phone
Ken Motherwell	Owner, Motherwell Excavating & Logging	Phone
Gordon Ross	Sales, CST Industries	Phone, text, email
Darren Brown	Director of Environmental Programs, BC ArdCorp	Phone, email
Brad Chapel	Producer, Heart of the Valley Farms	Phone
David Beleznay	Manager of Hydrology & Terrain, Mosaic Forest Management	Phone, email
Pam Jorgenson	Land Use Forester, Mosaic Forest Management	Email
Leah Godau	Management, Evan's Redi-Mix, Capital City Paving	Phone
Aggregates Manager	Aggregates Manager, Butler Concrete and Aggregate	Phone
Clay Reitsma	Senior Manager, Engineering, District of North Cowichan	Phone
Leroy Van Wieren	Project Manager (Weir), CVRD	Phone
John Pite	Manager of Engineering, City of Duncan	Phone
Wayne Haddow	(Retired) Regional Agrologist, organizer of the Koksilah Group EFP	Phone, Email
David Slade	(Retired) Drillwell Enterprises	Meeting
Brian Dennison	Manager, Water Management, CVRD	Phone
David Tattam	Water Use Manager, retired Dairy farmer, retired Environmental Farm Plan (EFP) representative	Phone
Jessica Doyle	Water Protection Section Head, MFLNRORD	Phone

Appendix B: Existing Lakes Feasibility Assessment

Table 2: Koksilah River at Cowichan Station (08HA003) Measured Mean Monthly and Annual Discharges

		Area (km2)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
Days in month	Years of record		31	28	31	30	31	30	31	31	30	31	30	31	**365**
Average flows (m^3/s)	1960-2018*	312	22.97	18.19	15.18	9.04	3.7	1.53	0.74	0.39	0.64	5.26	17.79	22.1	**9.79**
Min flows (m^3/s)	1960-2018*		4.75	5.41	4.08	2.71	0.89	0.3	0.19	0.15	0.18	0.21	2.39	3.2	**2.04**
Unit flows (m^3/s per km^2)			0.0736	0.0583	0.0487	0.0290	0.0119	0.0049	0.0024	0.001	0.0021	0.0169	0.0570	0.0708	**0.032**
Monthly volumes (ha-m)			6152	4,401	4,066	2,343	991	397	198	104	166	1,409	4,611	5,919	**30,887**
monthly volumes/km^2 (ha-m)			19.72	14.10	13.03	7.51	3.17	1.27	0.64	0.33	0.53	4.52	14.78	18.97	**99.00**
*Excludes data from January 1979, and July-Aug 2012, due to incomplete records Source: (Barosso & Wainwright, 2020)															

Table 3: Monthly, yearly, and wet season inflows to Koksilah lakes

	Catchment Area (km2)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Oct-Apr	Nov-Apr	Annual (m3/s)	Wet weather (Oct-Apr) inflows (m3/s)	Drought year inflows (m3/s)
Unit input for monthly inflow (ha-m/km2)		19.72	14.10	13.03	7.51	3.18	1.27	0.64	0.33	0.53	4.52	14.78	18.97	92.63	88.12	98.58		
Grant Lake	7.89	155.54	111.25	102.79	59.24	25.05	10.03	5.01	2.64	4.19	35.62	116.58	149.65	730.68	695.06	777.60	7,306,781	3,653,390
Dougan's Lake	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Wild Deer Lake	3.44	67.79	48.49	44.80	25.82	10.92	4.37	2.18	1.15	1.83	15.52	50.81	65.23	318.47	302.94	338.92	3,184,674	1,592,337
Kingzett Lake	0.95	18.73	13.40	12.38	7.13	3.02	1.21	0.60	0.32	0.51	4.29	14.04	18.02	88.00	83.71	93.65	880,000	440,000
Keating Lake	2.39	47.11	33.70	31.13	17.94	7.59	3.04	1.52	0.80	1.27	10.79	35.31	45.32	221.30	210.51	235.51	2,212,969	1,106,484
Unnamed Lake 1	3.04	59.98	42.91	39.64	22.85	9.66	3.87	1.93	1.02	1.62	13.74	44.96	57.71	281.79	268.05	299.88	2,817,853	1,408,927
Unnamed Lake 2	0.68	13.33	9.53	8.81	5.08	2.15	0.86	0.43	0.23	0.36	3.05	9.99	12.83	62.62	59.57	66.64	626,190	313,095
Unnamed Lake 3	0.70	13.80	9.87	9.12	5.26	2.22	0.89	0.44	0.23	0.37	3.16	10.35	13.28	64.84	61.68	69.01	648,421	324,211

Table 4: Koksilah Lakes Distance from Demands

Storage Option	Distance from Large Demands
Grant Lake	0 if water left in the river, 20-30km from larger irrigators. Due to the curved shape of the watershed, there is no direct route available to larger demands.
Dougan's Lake	0 to 9km (along road) to large irrigators.
Wild Deer Lake	Not explored further, as identified as a no-go zone by Cowichan Tribes
Kingzett Lake	0 to 17km from large irrigators. Located in a small drainage (Heather Bank Brook) with a small number of irrigators close by. Due to topography, it would be difficult to pipe water outside the subwatershed, unless along or in the Koksilah.
Keating Lake	3-15km from large irrigators
Unnamed Lake 1	35-40km
Unnamed Lake 2	35-40km
Unnamed Lake 3	35-40km

Appendix C: Dugout Storage Feasibility Assessment

To estimate potential storage volumes, the following tasks were done:

1. Identify areas where dugouts would be feasible.
2. Identified available land on farmed properties that is currently farmed, identified available land on farmed properties that is not currently farmed, and identified available land on farm properties that is treed.
3. Estimated potential volumes that could be stored on farmed/ irrigated properties.

1) Identify areas where dugouts may be feasible

To identify areas where dugouts may be feasible, the following factors were considered:

a) Depth to bedrock
b) Slope of land
c) Environmental sensitive areas
d) Lakes and wetlands
e) Required volumes of water
f) Sufficient minimum size.

This assessment did not consider soil quality in an area. This is a significant factor affecting dugout feasibility, but it is assumed that the soil mapping data is not of sufficient resolution and subsurface conditions would need to be investigated on-site.

The factors considered are explained:

a) Depth to bedrock: Selected areas where depth was >6m, as ponds require at least 16 feet of depth to not be worthwhile from an evaporation perspective.
Input: map of overburden depth – developed by GW Solutions Inc.

b) Slope of land: Selected areas where slope was <5% to reduce potential for building a dam.
Input: DEM developed from LiDAR data (from CVRD, MFLNRORD, GeoBC), developed by GW Solutions Inc.

c) Environmentally sensitive areas: Excluded areas that were identified as environmentally sensitive.
Input: Environmentally Sensitive Areas Mapping in the Cowichan Region (CVRD, 2018).

d) Excluded lakes and wetlands
Input: Freshwater Atlas mapping (MFLNRORD, 2021).

2) Identify area of available land on farmed properties that is currently farmed, not currently farmed, and treed

This was done using the following steps:

1) Identify farmed properties.
2) Identify land on farmed properties that is not currently farmed and is grass/shrub.
3) Identify land on farmed properties that is not currently farmed and is treed.
4) Identify land on farmed properties that is currently farmed.

These steps are described further below:

1) Identify farmed properties

To identify available land on farmed properties, lots were selected where the following land cover types were present: 'Cereals & oilseeds', 'Forage, pasture', Farm, Glass Greenhouse, PolyGreenhouse, Nursery and Tree Plantations, Specialty, Turf, Nut Trees, Tree Fruits, Vines & Berries. During this process it was observed that some properties were potentially incorrectly captured in the ALUI (e.g. Hydro ROWs identified as Tree Plantations). It is beyond the scope of this work to update the ALUI data, so these were left in. Leaving these in may result in an over-estimation of the total area of farmed land and the land available for dugouts.

2) Identify land on farmed properties that is not currently farmed and is grass/shrub

To identify land on farmed properties that is not currently farmed, the following land cover types were selected: 'Grass', 'Rough grass', 'Shrub'. An inspection of the results in relation to recent air photos showed that all areas identified as Rough Grass were not available due to other activities on the area. All areas identified as grass were either now residential or had been brought into production, and the areas identified as shrub were minimal. Given that total available land in this selection was 0.5km^2 and the majority of it appeared to be not available, it was decided that the area on farmed properties that is not currently farmed and is grass/shrub is not an area where storage would be feasible.

3) Identify land on farmed properties that is not currently farmed and is treed

To identify treed land on farm properties, the following land cover types were selected: 'Treed'. Within farmed areas, the results had a high degree of overlap with ESAs for mature forest. While a significant amount of land was available, the areas with trees was generally highly fragmented, with many discontinuous segments and long, narrow segments in riparian areas. The selection also included several hydro ROWs as tree plantations. The total area of land in this selection was 3.4 km^2. Given that much of it was not actually available for dugout creation, it was decided that dugouts on treed land in farmed areas do not a significant opportunity for storage.

4) Identify land on farmed properties that is currently farmed

To identify land on farm properties that is currently farmed, the following land cover types were selected: 'Cereals & oilseeds', 'Forage, pasture', and 'Vegetables'. 'Vines & berries' was not included as these crops take a long time to establish and have low water needs, so it is unlikely they would be replaced with a dugout.

3 Estimated potential volumes that could be stored

As the earlier assessment found that most storage would need to be created on currently cropped land, the following approach was used to identify the potential volumes of water that can be stored on farmed properties on land currently in production.

- For each lot, identified the total cropped area (considering all crops) and the maximum size of the feasible dugout area on the property.
- Estimated required dugout area by multiplying the total cropped area by 0.075 (percent of cropped area typically required to provide water for forage with a 12” depth of duty, where a 6 m dugout with 3:1 sides is possible (typical dugout sides in the Koksilah are 3:1, some can be 2:1; assuming 16" lost to evaporation and 15" lost to dead storage. The evaporation loss is based on estimates in the Tsolum River watershed, where it was assumed that 16” of water evaporates from water storage.)
- Checked to see if the dugout area required was greater than the available dugout area. If there was insufficient space, assumed a dugout would not be feasible for storing seasonal demand.
- If the maximum size of the feasible dugout area was <900m^2, then a dugout may not be able to be built to a sufficient depth to compensate for the evaporation losses (5 m, assuming 3:1 sides), so the feasible dugout area was set to 0.
- Calculated the volume of water that could be stored, using the equation for a prismoid:
  $V = (d/6) \times (A_t + A_b + 4 A_m)$

where,

$A_t = L \times W$

$A_b = (L - 2 \times ES \times d) (W - 2 \times SS \times d)$

$A_m = (L - ES \times d)(W - SS \times d)$

To estimate dugout sides (L, W), the square root of the estimated dugout area was taken. This assumes that the area where a dugout is feasible is square. While it is more likely that a dugout would be rectangular, and the area where a dugout is feasible may not be square, this provides a high-level approach to estimating storage potential (without considering soil types).

To estimate dugout depth (d): if the L, W < 35 and >30, the d= 5 m (this is the max depth with a 3:1 side slope). If L , W > 35, the depth was assumed to be 6 m. It was assumed that 31" of depth was lost due to evaporation and dead storage.

Additional consideration: If building a larger reservoir, need to consider egress and regress for trucks and tractors (Wayne Haddow, personal communication). This was not considered in this assessment.

Appendix D: Aquifer Storage and Recovery Feasibility Assessment

Aquifer Storage and Recovery Feasibility Study-Koksilah River Watershed

Prepared for:

Elucidate Consulting and BC Province

Prepared by:

GW Solutions Inc.

May 2021

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1 STUDY AREA

The Koksilah River watershed is located on southeastern Vancouver Island. The Koksilah River drains mountainous terrain up to 1,000 m in elevation to the southwest before flowing eastward to the Salish Sea (Figure 1). The main tributaries from upstream to downstream are: Fellows Creek, Wild Deer Creek, Kelvin Creek, Glenora Creek, and Patrolas Creek. Historical climate is characterized by cool, rainy winters and warm, dry summers. The annual precipitation is 1361 mm and the mean daily temperature is 16 °C from May to September and 6 °C from October to April.

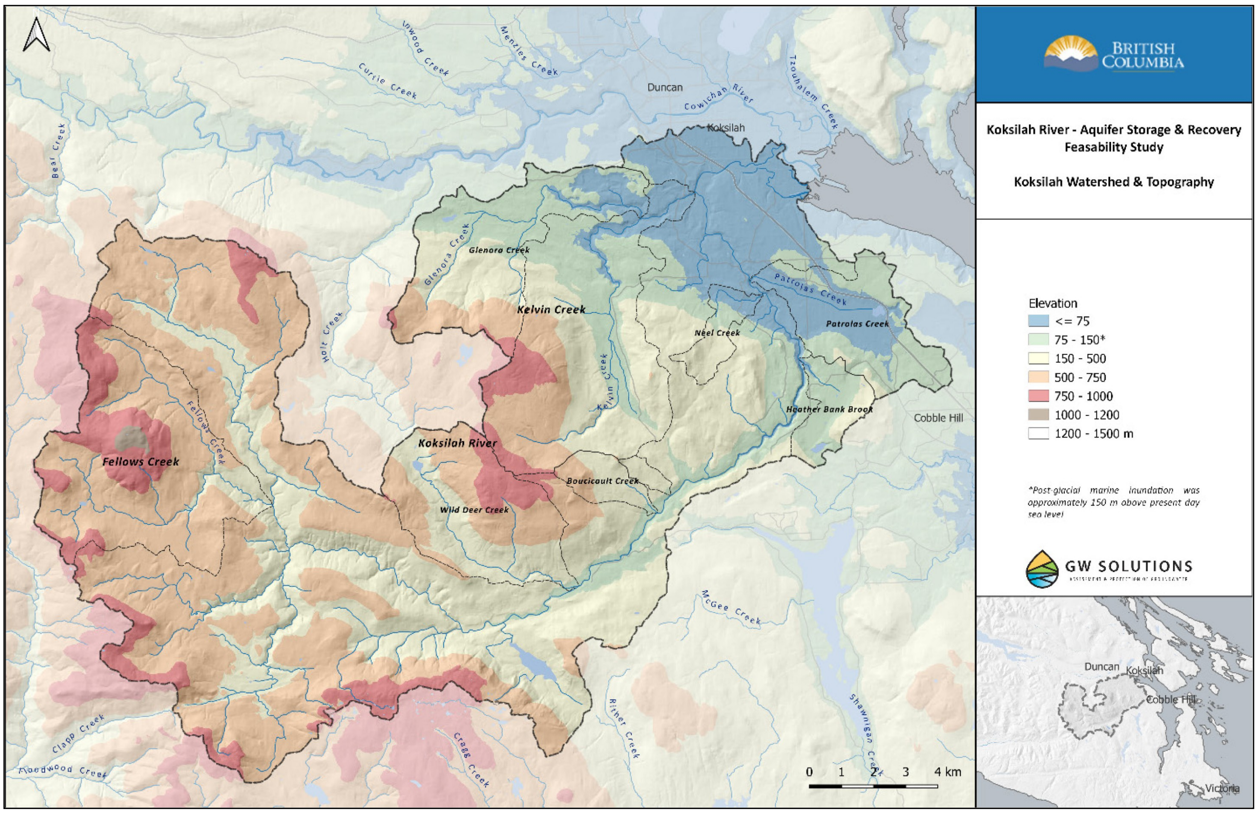

Figure 1. Koksilah watershed, sub-watersheds and topographic elevation.

1.1 Aquifers

Developed aquifers in the Koksilah watershed are concentrated in populated areas and at lower elevations (Figure 2). There are seven aquifers mapped by the Province within or intersecting the Koksilah watershed. These include overburden aquifers, numbered 186, 188, 197, 199, and 201, and bedrock aquifers, numbered 198 and 202. Attributes for each are summarized in Table 1. Bedrock aquifers #202 and #198 have the largest areal extents. Upland areas are dominantly volcanic bedrock (Aquifers #202); overburden aquifers here are relatively small and discontinuous (Aquifer #201). Lowland areas are characterized by thick accumulations of unconsolidated glacial, marine, and alluvial sediments that host Aquifers #197, #199, #186, and #188. Bedrock Aquifer #198 is comprised of Nanaimo Group sedimentary rocks and underlies the lowland, overburden aquifers.

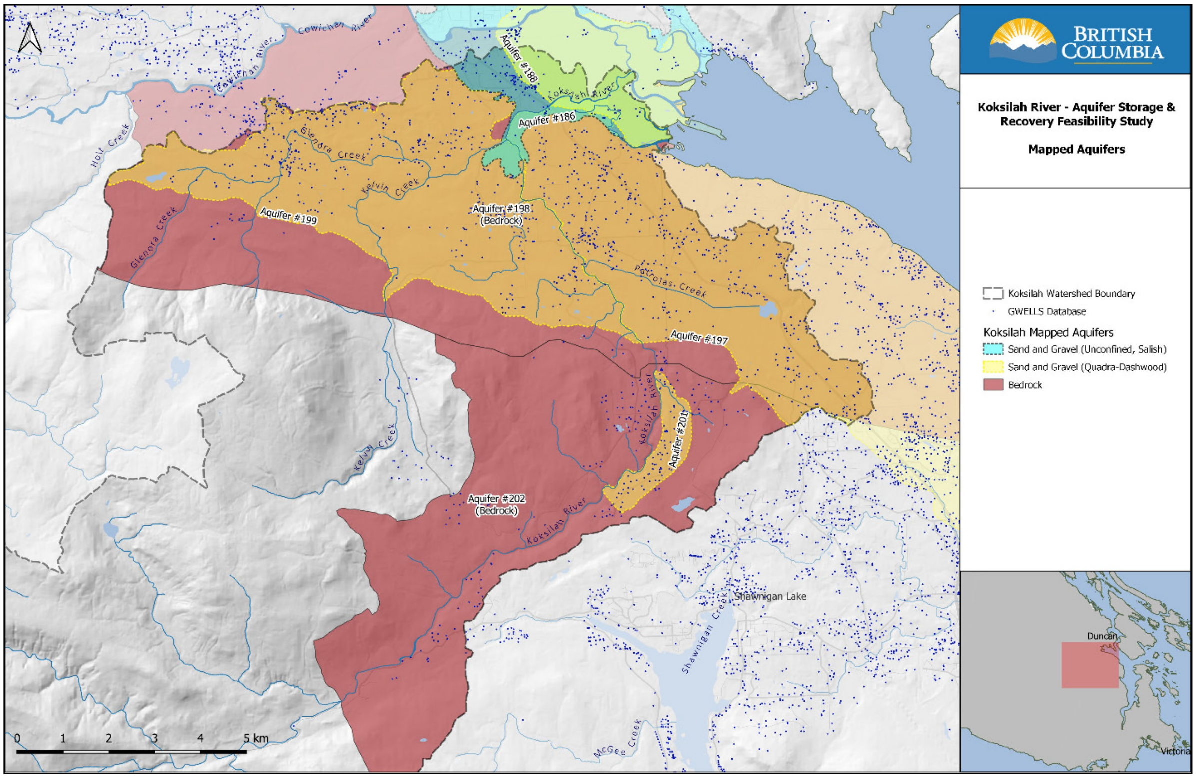

Figure 2 Provincial mapped aquifers within/intercepting Koksilah watershed.

Table 1 Relevant characteristics of the seven Provincially mapped aquifers for the study area

Aquifer ID	**#186**	**#188**	**#197**	**#198**	**#199**	**#201**	**#202**
Aquifer name	Lower Cowichan River A	Lower Cowichan River C	Cherry Point	Cowichan Bay	Fairbridge	Heather Bank	Koksilah River Valley
Descriptive location			Includes Cowichan Bay, Cowichan Station, Hillbank, Cherry point, and Dougan Lake	Includes Cowichan Bay, Cowichan Station, Hillbank, and Fairbridge	West of Koksilah River, include Fairbridge	West slope of Cobble Hill, along the east banks on the Koksilah River	Upgradient Koksilah River Valley
Material	Sand and Gravel	Sand and Gravel	Sand and Gravel	Bedrock	Sand and Gravel	Sand and Gravel	Bedrock
Confinement	Unconfined	Confined	Confined	Fractured sedimentary rock	Confined	Unconfined	Fractured crystalline bedrock
Strata unit	Salish Sediments	Vashon Drift	Quadra Sand/Dashwood Drift	Nanaimo Group, sedimentary rocks	Quadra Sand/Dashwood Drift	Quadra Sand/ Dashwood Drift	Bonanza Group and Sicker Volcanic rocks

GW Solutions assigned hydrogeological units to water well lithologies throughout the Koksilah watershed. This allowed for the interpolation of the thickness of individual hydrogeological units (aquifers and aquitards) as well as the total thickness of overburden material that blankets the bedrock. Bedrock is treated as one hydrogeological unit. The overall depth of bedrock aquifers #198 and #202 is significantly greater than that of the unconsolidated aquifers. The thickness of the overburden material relative to the mapped overburden aquifers is presented in Figure 3. Sediment thickness ranges from nil over upland areas to approximately 100 m at lower elevations. East of the Koksilah River, Aquifer #197 corresponds with the thickest accumulations of Quaternary sediments. In the Cowichan River plain, where Aquifers #186 and #188 are encountered, the total unconsolidated thickness is estimated to be less than 40 m. West of the Koksilah River, Aquifer #199 corresponds with sediment accumulations ranging up to 60 m deep.

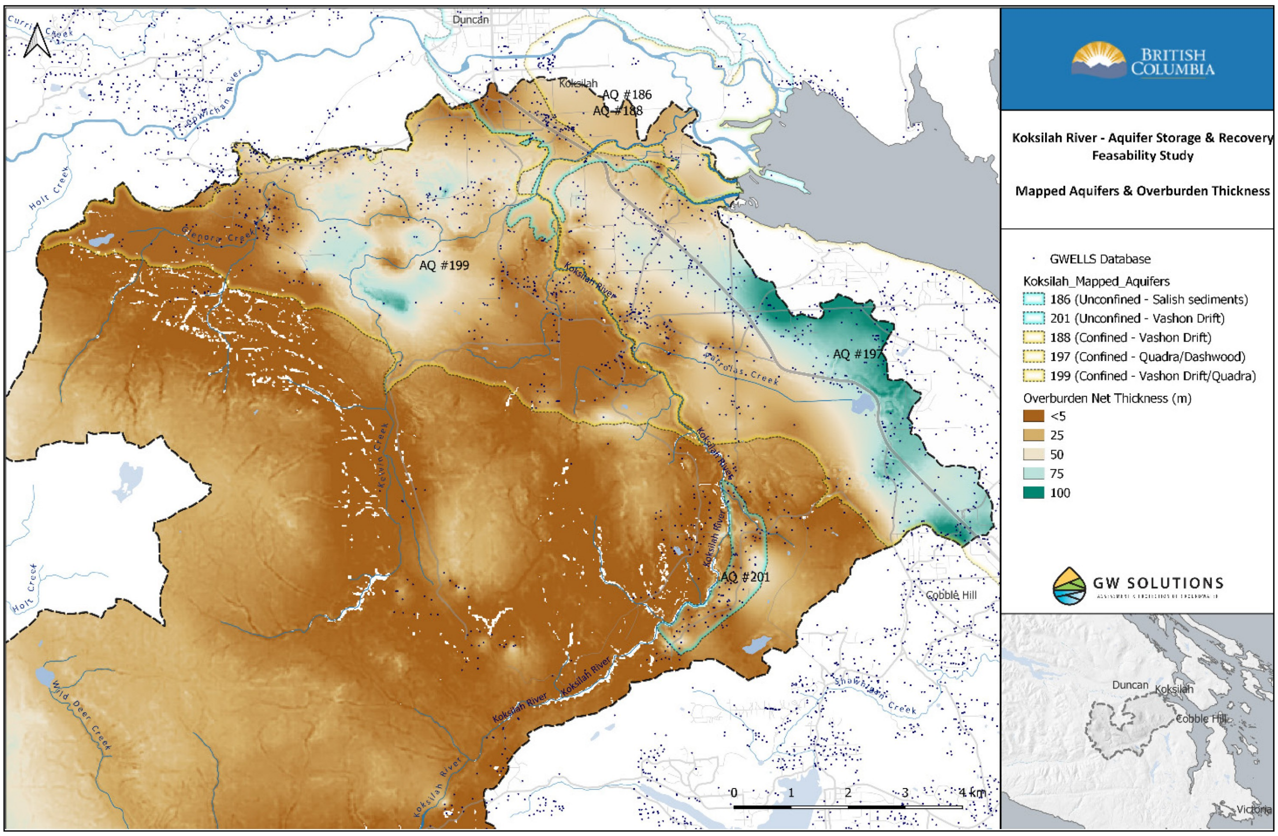

Figure 3 The overburden net thickness in northern parts of the Koksilah watershed.

1.2 Surface water

There are 7 surface water stations where the water quality, streamflow and water level are monitored (Figure 4). Only two surface water stations are currently active: Koksilah River at Trestle-08HA0022 and Koksilah River at Cowichan Station-08HA003. Station 08HA003 has the largest historical dataset starting in 1914.

Figure 5 shows the mean monthly flow (m^3/s) and the monthly trend in Koksilah River station (08HA003). Increasing flows in January are observed and relatively stable flows are noticed from October to December. However, flows from February to May show declining trends that could be attributed to reduced snow accumulation in the headwaters. June to September are characterized by low flows that decline steadily until the end of September.

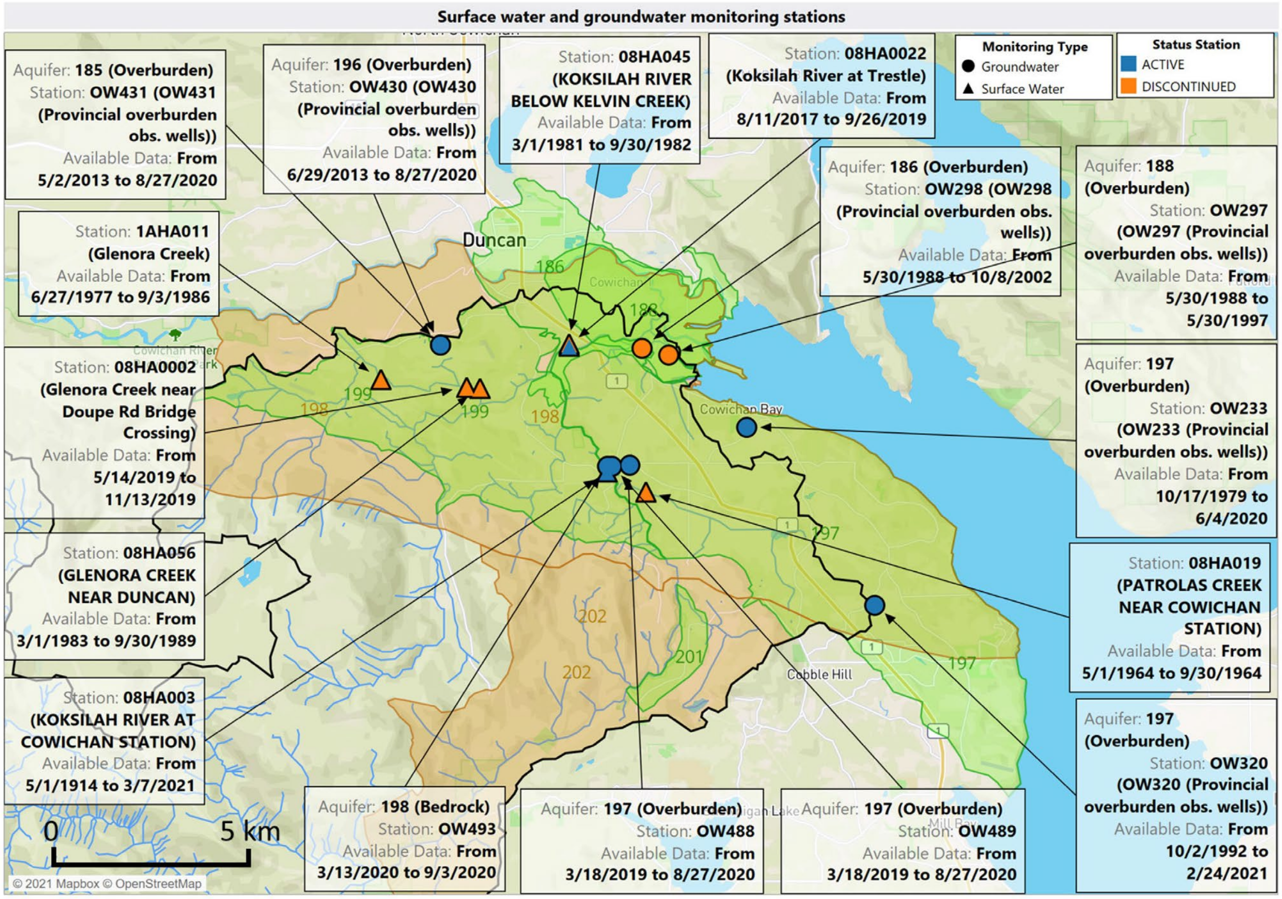

Figure 4 The surface water and groundwater stations monitoring stations in Koksilah watershed

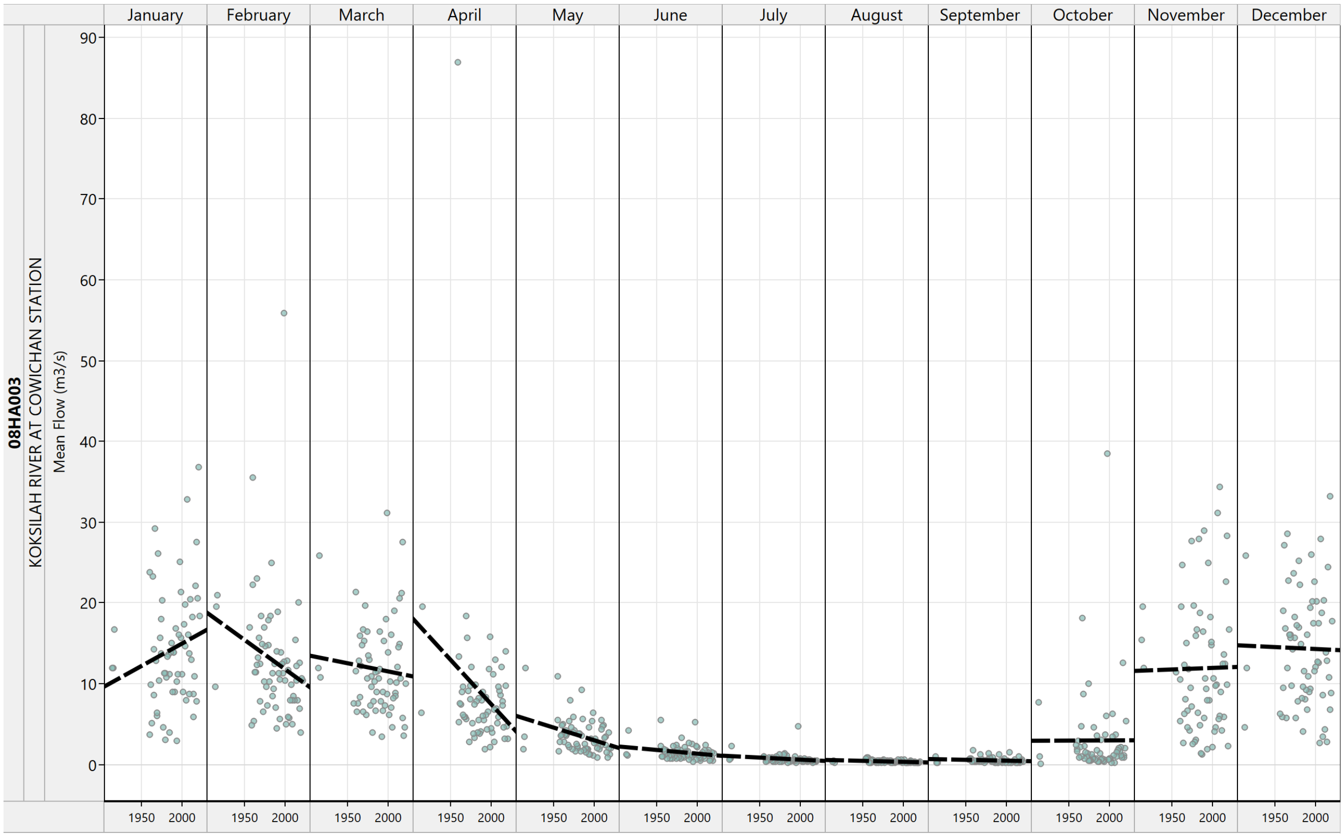

Figure 5. Mean monthly flow data and trend for the Koksilah River at Cowichan Station (08HA003)

2 AQUIFER STORAGE AND RECOVERY (ASR) FEASIBILITY ASSESSMENT

In assessing the suitability and feasibility of aquifers for a water storage and recovery, we investigated three broad criteria:

1- Water quantity,
2- Water quality, and
3- Operation.

For the water quantity component, we consider the available storage and holding capacity of suitable, geological units, and the level of local aquifer stress (groundwater demand). For the water quality component, we consider the chemistry of the recharge water and in situ groundwater. Finally, for the operations component, we consider the feasibility of implementation and operation of an ASR system with respect to location.

2.1 Water Quantity

The quantity of water that can potentially be stored in a candidate aquifer is related to its storage capacity, holding capacity, and the level of aquifer stress. These concepts are outlined in more detail below.

2.1.1 Storage capacity

The potential storage capacity of an aquifer is related to the available non-saturated volume in the materials comprising the aquifer. To assess candidate areas, we have used general characteristics such as aquifer area, aquifer thickness, total overburden thickness, unsaturated thickness above the aquifer, and total available volume (which is the aquifer volume times the storage coefficient).

Figure 6 illustrates the total thickness of unsaturated material overlying Aquifer #197: This is primarily comprised of Quadra sediments (sand and gravel) which underly a discontinuous layer of Vashon Drift (till and glaciomarine deposits). The unsaturated Quadra sand and gravel reaches a thickness of 60 m or more. Areas with thicker, unsaturated Quadra sediments (Figure 6) also broadly correspond with areas of thicker total overburden (Figure 3).

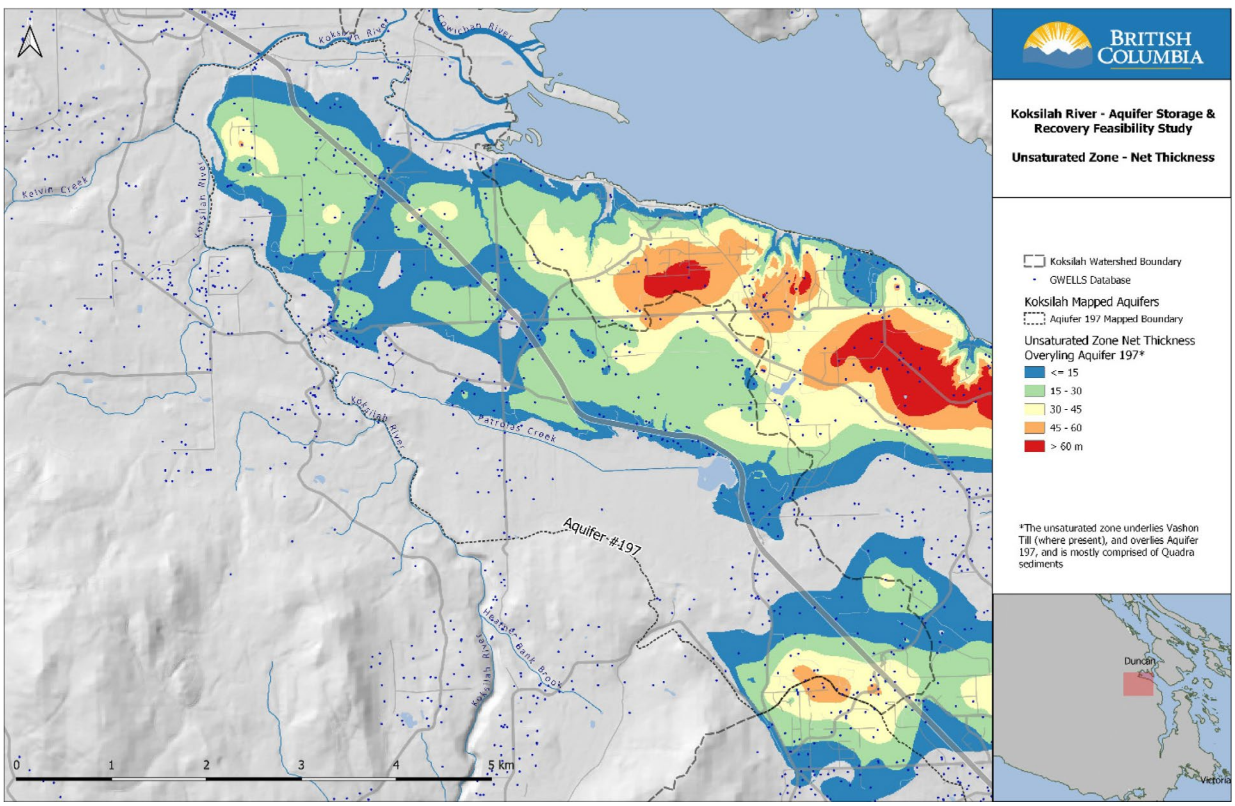

Figure 6 The unsaturated zone thickness above Aquifer #197. This is the distance from water elevation in Aquifer 197 to top of Quadra sediments or base of Vashon Drift.

2.1.2 Holding capacity

The holding capacity of an aquifer is the potential for the aquifer to retain the recharged water versus transmit water downgradient. The holding capacity of the aquifer is a function of the hydraulic gradient, transmissivity and the extent of the recharge zone. The hydraulic gradient and transmissivity together show the flow rate in the aquifer and the extent of the recharge zone or the areal extent of aquifer is a representative for its capacity in storing water. The contour map of groundwater surface elevation for Aquifer #197 is shown in Figure 7. The map shows the average hydraulic gradient is around 0.015 and ranges from 0.003 to 0.1.

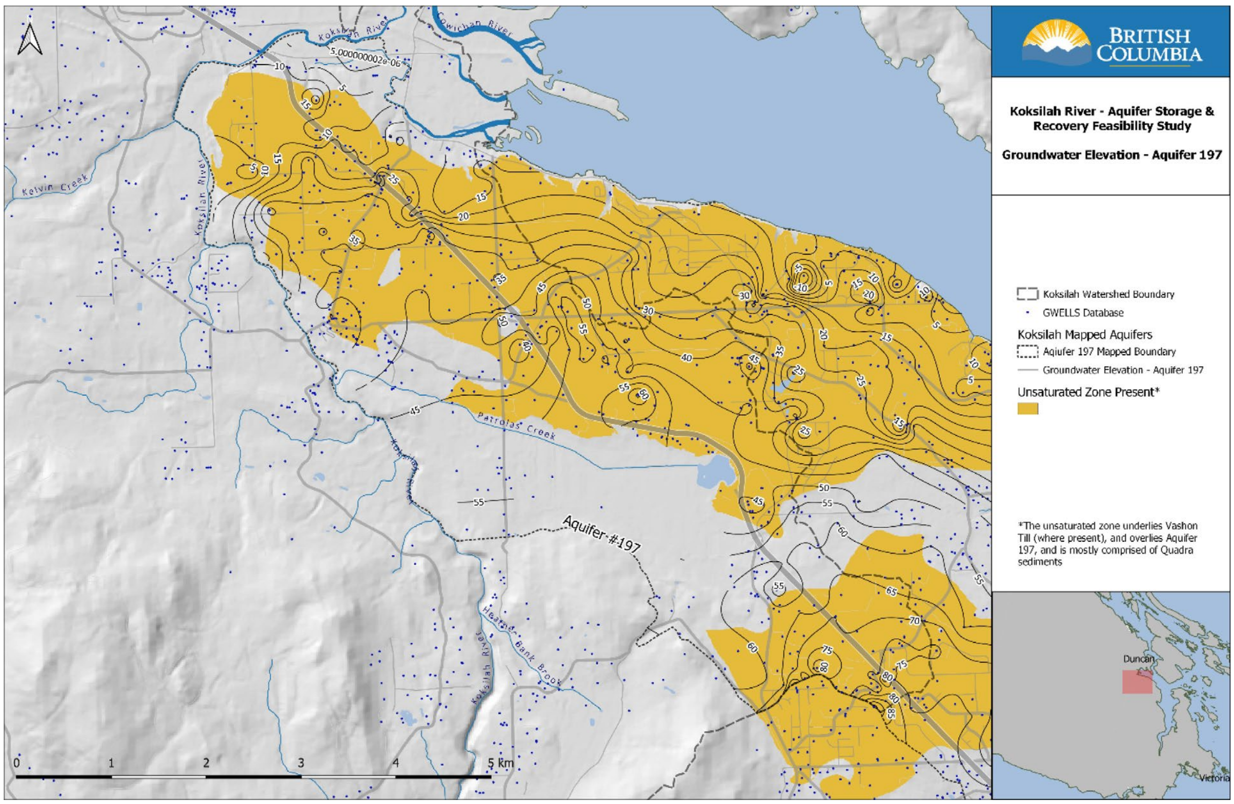

Figure 7 Contour map of the groundwater surface elevation for aquifer #197.

2.1.3 Aquifer stress

In this report, “aquifer stress” refers to the external stresses on the groundwater resource due to over pumping in heavily developed areas (Geller and Burt, 2020). Trends in groundwater levels, surface water flow and water quality provide indicators of overall aquifer stress. Since there is still widespread, unregulated, and unaccounted groundwater use throughout BC (Geller and Burt, 2020), the hydraulic head or water elevation trend in an aquifer is often a better indicator of the overall stress on the aquifer, than is the number of wells or extraction licenses.

Water demand estimates and stream depletion can also provide information on the level of stress on the aquifer (Geller and Burt, 2020).

2.1.4 Water quantity criteria and indices

The water quantity feasibility criteria summarized in Table 2 and discussed in detail below:

<u>Aquifer potential storage capacity</u>:

Multi-layer nature: Is the aquifer single or multi-layer?

Depth to water level or groundwater elevation: Average depth to groundwater

Storativity: Specific yield or porosity for the unconfined aquifer and specific storage for the confined aquifer

Total available volume: Total available volume for a confined aquifer is determined by multiplying the unsaturated volume of the aquifer (Figure 6) by the storativity of the aquifer (Table 2). The available volume per unit area is determined by dividing the total available volume by the aquifer area.

<u>Aquifer flow velocity/holding capacity</u>:

Average hydraulic gradient: The hydraulic gradient contours for Aquifer 197 is interpolated from water level elevations from GWELLS (Figure 7).

Transmissivity: Average aquifer transmissivity is estimated from available pumping test data. High transmissivity values indicate higher rates of recharge and groundwater flux; i.e. recharge water is likely to transit the system faster, reducing the holding capacity of the aquifer. Low transmissivities will reduce the rate of recharge. Moderate transmissivity values are therefore the most desirable for enhanced recharge.

Saturated thickness: For unconfined aquifers, the saturated thickness is equal to the elevation of the water table minus the elevation of the aquifer base. For confined aquifers, the saturated thickness is the thickness of the water bearing strata. For bedrock aquifers (#198 and #202) the saturated thickness was assumed to be 100 m.

Length of compliance zone : The length of compliance zone is calculated by estimating the distance travelled by groundwater flowing through the aquifer in one month (Pyne, 2003). The groundwater velocity was determined based on dividing the Darcy velocity by the storativity of the aquifer. Darcy velocities were determined by multiplying average hydraulic gradient (0.015) by the average, reported hydraulic conductivity for each aquifer. The hydraulic conductivities were calculated by dividing the average transmissivity by the saturated thickness (Table 2). The holding capacity o f the aquifer is higher when the length of compliance zone is shorter. Aquifer #197 has the shortest compliance zone length. The very short compliance zone length estimated for the bedrock aquifers results from extremely low hydraulic conductivities in these aquifers.

<u>Aquifer stress</u>:

Gaining water from stream: An aquifer is likely losing water to a stream where groundwater elevation contours are oriented sub-parallel to the stream axis, and the vector of the hydraulic gradient is towards the stream. In the Koksilah watershed, most of the aquifers likely lose water to streams (Table 2).

Stream depletion factor (Hatfield Consultants LLP, 2021; Sivak and Wei, 2019): The stream depletion factor measures the number of days for a pumping well to deplete stream flow, given a separation distance of 500 m or 1000 m. Shorter stream depletion factors correspond to higher potential stress levels. Aquifers #188, #197 and #199 are the most vulnerable to stress based on the calculated stream depletion factors.

Average groundwater level and river flow trends in dry and wet months: Trends in groundwater levels (m/year) and river flows (m^3/s/year) are indicative of the overall water stress of the system. The median and minimum monthly values of groundwater levels and stream flow rates are presented in Table B-1, Appendix D3. Aquifers #197, #188 and #199 show a negative (downward) trend in groundwater level are deemed to be are the most water stressed aquifers based in the study area.

Annual water demand and demand per unit area: The total demand for each aquifer was estimated based on the licensed and unlicensed wells or the total demand divided by the aquifer area. Aquifer #197 is the most water stressed aquifer based on it having the highest total demand (equivale to 57% considering the whole watershed) and the highest annual demand per unit area of 0.106 m.

Table 2 Water quantity criteria and rating indices (numbers in brackets) for the aquifers within the Koksilah watershed

Aquifer ID	#186	#188	#197	#198	#199	#201	#202
Aquifer potential storage capacity							
Multi-layer nature	Yes (10)	Yes (10)	No (5)	No (5)	No (5)	No (5)	No (5)
Depth to water level or piezometric level (m)	10 (4)	10 (4)	25 (10)	15 (6)	10 (4)	10 (4)	15 (6)
Storativity[$%]	0.2 (10)	0.05 (5)	0.05 (5)	0.005 (2)	0.05 (5)	0.2 (10)	0.005 (2)
Total available Volume (Target Storage Volume, TSVPA ^) for storage per unit area (per m^2)	2 (10)	0.5 (3)	1.25 (5)	0.075 (0)	0.5 (3)	2 (10)	0.075 (0)
Total available Volume (Target Storage Volume, TSV ^) for storage (m^3)	1.0957e7 (4)	1.4245e6 (1)	2.7440e7 (10)	5.2762e6 (2)	1.3813e7 (5)	3.8728e6 (1)	2.9676e6 (1)
Area (m^2)	5.4788e6 (2)	2.8490e6 (1)	2.1952e7 (5)	7.0350e7 (10)	2.7627e7 (3)	1.9364e6 (0)	3.9568e7 (4)
Aquifer flow velocity/Holding capacity							
Average hydraulic gradient	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Transmissivity (m^2/d)[$%]	300-1300 (5)	200 (10)	200 (10)	0.3-1.5 (5)	200 (10)	300-1300 (5)	1.5-3 (5)
Saturated thickness (m)	25 (3)	25 (3)	60 (6)	100 (10)	25 (3)	25 (3)	100 (10)
Hydraulic conductivity (m/d)	32	8	3.33	0.009	8	32	0.022
Length of compliance zone* in downstream direction in one month (m)	72 (2)	72 (2)	30 (6)	0.81 (10)	72 (2)	72 (2)	1.98 (9)
Aquifer Stress							
Gain water from streams (based on iso-potential lines)			Patrolas: No Koksilah: No Glenora: No (0)	Patrolas: No Koksilah:No Glenora: No (0)	Kelvin: No Glenora: No (0)	Bunt Bridge: yes/No (5)	Bunt Bridge: yes/No (5)
Stream depletion factor, for distance to nearest stream of 500 m (days)[%&]	200	80 (10)	80 (10)	950 (2)	80 (10)	200	950 (2)
Stream depletion factor, for distance to nearest stream of 1000 m (days)[%&]	300 (2)	2.5 (10)	2.5 (10)	170 (5)	2.5 (10)	300 (2)	170 (5)
Average groundwater level trend (m/yr) in dry months (May to Sept)		-0.009 (8)	0.062 (0)		-0.026 (10)		
Average groundwater level trend (m/yr) in wet months (Oct to April)		-0.008 (8)	0.046 (0)		-0.015 (10)		
Average river flow trend (m^3/s/yr) in dry months (May to Sept)	Cowichan: -0.075 (10)		Koksilah: -0.0076 (8)	Koksilah: -0.0076 (8)			

Aquifer ID	#186	#188	#197	#198	#199	#201	#202
Average river flow trend ($m^3/s/yr$) in wet months (October to April)	Cowichan: 0.046 (0)		Koksilah: -0.029 (10)	Koksilah: -0.029 (10)			
Aquifer Vulnerability to contamination	High/A	Low/C	Moderate/B	Low/ C	Moderate/B	High/A	Moderate/B
Annual water demand (licensed and unlicensed)/ Percentage of whole watershed demand [m^3/%]	327,000/8.0% (2)	37,000/0.9% (0)	2,316,000/56.5% (10)	186,000/4.5% (1)	475,000/11.6% (2)	56,000/1.4% (0)	122,000/3.0% (1)
Demand per unit area (m^3/m^2)	0.060 (6)	0.013 (1)	0.106 (10)	0.003 (0)	0.017 (2)	0.029 (3)	0.003 (1)
#Subtype			4b	5a	4b	4a/b	6b

#Aquifer subtype description is available on https://catalogue.data.bc.ca, *Pyne (2003), $ Barroso and Wainwright, (in press), %Hatfield Consultants LLP (2020, 2021), &Sivak and Wei (2019), ^ Zhu (2013)

2.2 Water Quality in ASR feasibility assessment

The interaction and compatibility of the injected water with the groundwater present in the host aquifer is a key aspect of ASR feasibility.

Geochemical interactions between the recharge water and in situ groundwater are critical in assessing the feasibility of ASR. The Parksville, Vancouver Island ASR Project was halted after injection resulted in arsenic mobilization within the aquifer (Geller and Burt, 2020). In this case, arsenic originating from the sediment resulted in the drinking water guidelines being exceeded during early cycle tests. Remediation of the resulting water to remove arsenic would have been cost prohibitive.

Change in geochemical conditions can cause changing in speciation of metals and affect their mobility and toxicity. Leaching of certain toxic metals such as arsenic, cobalt, iron, manganese, molybdenum, nickel, vanadium and uranium from the aquifer matrix to storage zone has been reported in several ASR systems (Arthur et al., 2005; Meng et al., 2002; Lin and Puls, 2003).

Another important consideration in coastal aquifers is their potential risk of saline water intrusion (Geller and Burt, 2020). Proximity to the coast increases this risk, however, the depth and type of strata are important criteria. Post-glacial marine intrusion on Vancouver Island was approximately 150 m above present-day sea level; Drillers have encountered saline or brackish water in deep, overburden and bedrock wells located far inland (GWELLS).

Water quality concerns can curtail the potential use of the stored water (e.g., as a drinking water source), present operational challenges, and increase the cost of treatment. Water quality monitoring data are essential in the assessment of the feasibility of ASR. Many aquifers in BC have background water quality issues due to local geochemistry (Geller and Burt, 2020). Arsenic in the Similkameen River watershed and manganese in the Surrey and Langley area are examples of such water quality issues. Agricultural activities can elevate nitrate levels in shallow groundwater, as is the case in the unconfined aquifers of Sumas, Hullcar, and Oliver.

Based on the existing report (Hatfield, 2021), the main concern about the water quality for both surface and groundwater in Koksilah, corresponds to the effect of increase in human water use and forestry, channel aggradation which cause sediment erosion along the streams and increase in water turbidity.

2.2.1 Recharge water source concerns

The source-water constituents of greatest concern include suspended solids, dissolved gases, nutrients, biochemical oxygen demand (BOD), microorganisms, and sodium adsorption ratio (National Research Council, 1994; Zhu, 2013). United States National Research Council (1994) study reviewed the potential of five surface water sources for groundwater recharge, assuming an end use of potable water (Table 3). The constituents of concern were determined based on a consensus on select contaminants from the US EPA regulatory list that could have negative impacts on the aquifer.

Table 3 Selected constituents in potential source waters (injection) and relative concern (National Research Council, 1994; Zhu, 2013)

Constituent	Wastewater Treated for Non-potable and Indirect Potable Use	Urban Stormwater Runoff	Surface Waters	Untreated Groundwater	Waters Treated to Drinking Water Standards
Salinity	High	Low to medium	Low or medium	Low	Low
Nutrient (NO3-, etc)	High	Medium	Medium	Medium	Low
Metalloids, including arsenic	Low	Medium to High	Low	Low to medium	Low
Mn, Mo, Fe, Ni, Co, V	Low	Medium	Low	Low to medium	Low
Trace organics	Medium	High	Medium	Low to medium	Low
Total organiccarbon (TOC)	Medium	Medium	Medium to high	Low to medium	Low
Disinfection by-products	High	Low	Medium	Low	High
Microorganisms	High	Medium	High	Medium to high	Low

2.2.2 Recharge water treatment methods

Depending on the contaminants present in the recharge water, different types of treatment may be required. The treatment methods can be generally divided to primary, secondary, and tertiary treatment.

Primary treatment usually refers to the removal of the suspended solids (SS) using coarse screening, grit removal, sedimentation, pre-secondary treatment such as pre-aeration, taste and odor control and chemical addition (Zhu, 2013). Primary treatment reduces approximately 50% of SS and 35% of organic matter. Primary treatment has little effect on dissolved or microbiological constituents (Tchobanoglous et al., 2002). High organic content stimulates microbial activity which enhances the rate of microbial degradation of nutrients and synthetic organic compounds (Lance et al., 1980).

The goal of *secondary treatment* is to remove remaining suspended solids, most of the BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand), and a significant portion of heavy metals (Water Pollution Control Federation, 1989). This stage usually involves an aerobic, biological process, coupled with a settling tank. Very few dissolved substances are removed by a conventional secondary process.

Tertiary treatment is used to remove excessive nutrients still present in the water after primary and secondary treatment. Advanced water treatment may include carbon adsorption, nano/microfiltration and reverse osmosis, activated sludge, granular-medium filtration, carbon adsorption, nitrification, denitrification, metal salt addition, biological phosphorous removal and biological nitrogen and phosphorous removal (Zhu (2013) Table 5) .

Disinfection is the last treatment step and probably the most important process in removing microbiology and pathogens to meet drinking water standards. The most common process for water disinfection includes chlorine, ozone, and/or ultraviolet (UV) radiation. Other methods include hydrogen peroxide, and ultrafine membrane processes.

When disinfection is used, attention must be paid to monitor the possibility of disinfection-by products (DBPs) formation within the aquifer. When chlorine and ozone react with organic compounds, they form DBPs such as trihalomethane (THM) and halo-acetic acids (HAAs) which are classified as carcinogenic by the US EPA.

Microorganisms and dissolved organics are typically the most important parameters of concern for groundwater and surface water sources (Zhu, 2013). Surface water sources (streams, reservoirs, or lakes) generally display larger seasonal changes in water quality. This is due to seasonal changes in contributions from precipitation, snowmelt and runoff sources. Uncontaminated groundwater typically has few organic pollutants, however, salinity and mineral content including heavy metals (e.g. arsenic) may be of concern.

2.2.3 Water quality exceedance analysis

To assess existing or in situ water quality (surface and groundwater), data from the Provincial Environmental Monitoring System (EMS) was compared to the Canadian Drinking Water Guidelines. A summary of water quality exceedances for aquifers and surface water bodies in the Koksilah watershed for the whole area is presented in Tables 4. The table is divided to 10 parts including bacteria and organisms, cyanide, ions, metals and others. In each part, different parameters are listed including the number of samples and the percent of samples that exceeds the guideline (I), or the ones that does not exceed the guideline (II) and those whose detection limit were greater than the guideline (III) are presented in front of each parameter. To be in conservative side we assumed the samples in column III included in column I in our calculations. Results for individual streams and aquifers are summarized in Table 5 and complete water quality analysis are presented in Appendix D2 (Burnt Bridge Creek (Table A-2), Cowichan River (Table A-3), Glenora Creek (A-4), Kelvin Creek (Table A-5), Koksilah River (Table A-6), Patrolas Creek (Table A-7), Quamichan Creek (Table A-8), Somenos Creek (Table A-9) and Aquifers numbers 186, 187, 188, 197, 198, and 199 (Tables A-10 to 15)).Table 5 the ranges of total number of samples and the percentages of the samples that exceed the guideline (includes both columns I and III) for each stream or aquifer and for each part (Bacteria and organisms, ions, metals, others) are presented. For example for Koksilah River and in metals part the total number of samples for different metals are in range of 34 to 375 samples and the range of exceedance percent for these metals are from 0 to 37.7%.

For both surface and groundwater, data include ions, metals, nutrients and physical properties. Bacteria and micro-organism exceedances are mostly available from surface water sources. Surface water bacteriological parameters exceedance ranges from 45 to 100% of samples. Exceedances for physical properties are reported both for groundwater and surface water. Over the entire study area, the highest number of exceedances are for bacteriological, certain metals (Manganese, Iron and Aluminum), and physical properties such as colour and pH.

Table 4 Exceedance analysis for groundwater and surface water – Compared to Canadian Drinking Water Quality Guidelines

		Number of samples			Percentage of samples		
Parameter code group	Parameter Standard	I	II	III	I	II	III
Bacteria and Organisms	Coliform - Fecal (CFU/100mL)	1404	105	208	81.1%	6.1%	12.1%
	Coliform - Fecal (MPN/100mL)	139		15	90.3%		9.7%
	Coliform – Total (CFU/100mL)	64		67	48.9%		51.1%
	Coliform – Total (MPN/100mL)	120		5	96.0%		4.0%
	Streptococcus – Fecal (CFU/100mL)	52		23	69.3%		30.7%
Cyanide	Cyanide SAD (mg/L)						
Ions	Sulfate (mg/L)		667			100.0%	
	Sodium Total (mg/L)		87			100.0%	
	Fluoride (mg/L)		286			100.0%	
	Chloride (mg/L)	3	810		0.4%	99.6%	
Metals	Arsenic Total (mg/L)	2	862	89	0.2%	90.5%	9.3%
	Copper Total (mg/L)		1140			100.0%	
	Lead Total (mg/L)	10	1055	72	0.9%	92.8%	6.3%
	Cadmium Total (mg/L)	2	871	197	0.2%	81.4%	18.4%
	Zinc Total (mg/L)		1125			100.0%	
	Manganese Total (mg/L)	277	813		25.4%	74.6%	
	Chromium Total (mg/L)		1060			100.0%	
	Iron Total (mg/L)	212	790		21.2%	78.8%	
	Aluminum Total (mg/L)	260	708		26.9%	73.1%	
	Selenium Total (mg/L)		792	7		99.1%	0.9%
	Barium Total (mg/L)		868			100.0%	
	Antimony Total (mg/L)	1	829	12	0.1%	98.5%	1.4%
	Uranium Total (mg/L)	1	845		0.1	99.9%	
	Boron Total (mg/L)		726			100.0%	
	Mercury Total (mg/L)		119			100.0%	
Nutrients	Nitrate as N (mg/L)	8	2209		0.4%	99.6%	
	Nitrite as N (mg/L)	13	833		1.5%	98.5%	
Organic Compounds	1:2 Dichlorobenzene (mg/L)		1			100%	
	Met.Tert.Butyl Ether (mg/L)		1			100%	
PAH (Poly. Arom. Hydr.)	Benzo(a)pyrene (mg/L)						
Pharmaceutical	Tetrachloroethylene (mg/L)						
Physical properties and	pH (pH)	113	1633		6.5%	93.5%	
misc	Total Dissolved Solids (mg/L)	7	283		2.4%	97.6%	
	Temperature – Field (C)	49	101		32.7%	67.3%	
	Color True (Col unit)	42	485		8.0%	92.0%	
	Color Apparent (Col unit)	1	36		2.7%	97.3%	
	Sulfide Total (md/L)		1			100.0%	
VOC (Volatile Organic	1:2-Dichloroethane (mg/L)		1			100.0%	
Compounds)	1:4-Dichlorobenzene (mg/L)		1			100.0%	

Table 4 -Continue

		Number of samples			Percentage of samples		
Parameter code group	Parameter Standard	I	II	III	I	II	III
VOC (Volatile Organic Compounds)	Benzene (mg/L)		1			100.0%	
	Bromodichloromethane (mg/L)		1			100.0%	
	Carbon Tetrachloride (mg/L)		1			100.0%	
	Chlorobenzene (mg/L)		1			100.0%	
	Ethylbenzene (mg/L)		1			100.0%	
	M; P-Xylene (mg/L)		1			100.0%	
	Toluene (mg/L)		1			100.0%	
	Trichloroethylene (mg/L)		1			100.0%	
	Vinyl Chloride (mg/L)		1			100.0%	

I: it exceeds guideline II: It does not exceed guideline III: Detection limit greater than guideline

Table 5 Average water quality exceedance based on the Canadian Drinking Water Quality Standard for different aquifers and surface water stations, along with the number samples for each water resources.

Name	Percent of exceedance (%), Number of samples (N)	Bacteria and organisms	Ions	Metal	Nutrients	PAH	Physical properties
Burnt Bridge Creek	%	100%	-	-	-	-	0%
	N	11-16	-	-	-	-	2
Cowichan River	%	93.4-100%	0%	0-32.2%	0%	-	0 – 33.3%
	N	1-815	14-418	27-567	421-1130	-	37-821
Glenora Creek	%	100%		0%	0%		0%
	N	14	-	2	8	-	12
Kelvin Creek	%	-	-	0%	0%	-	0-100%
	N	-	-	1	1-2	-	1
Koksilah River	%	92.3-100%	0%	0-37.7%	0%	0%	3.4-12.4%
	N	36-680	2-165	34-375	85-458	2	34-526
Patrolas Creek	%	100%	-	0-100%	0%	-	28.6%
	N	11	-	2	4	-	7
Quamichan Creek	%	100%	-	-	0%	-	0%
	N	9	-	-	2	-	2
Somenos Creek	%	100%	-	-	0%	-	44.4%
	N	3-6	-	-	8-9	-	9
Aquifer #186	%	100%	0%	0-62.5%	0%	-	0-30.8%
	N	1	4-33	3-9	20-40	-	26-31
Aquifer #187	%	-	0%	0-75%	0%	-	0%
	N	-	2-6	1-5	4-9	-	6
Aquifer #188	%	-	0%	0-100%	0%	-	0%

Name	Percent of exceedance (%), Number of samples (N)	Bacteria and organisms	Ions	Metal	Nutrients	PAH	Physical properties
	N	-	1-8	1-4	4-9	-	8-9
Aquifer #197	%	-	0%	-	0%	-	0%
	N	-	2	-	2-4	-	1-3
Aquifer #198	%	-	0-66.7%	-	0%	-	0-100%
	N	-	3	-	3-6	-	3
Aquifer #199	%	-	0%	-	0%	-	0%
	N	-	1-2	-	2-4	-	1
Total	%	93.8-100%	0-0.4%	0-26.9%	0.4 -1.5%	-	0-32.7%
	N	75-1717	87-813	119-1140	846-2217	-	1-1746

2.2.4 Water quality criteria and indices

Water quality indices provide us with a means of rating the suitability of a particular surface water source for ASR. The indices were based on the available water quality exceedances (WQE) of the Canadian Drinking Water Quality Standard. We assumed that recharge water would be sourced from the nearest stream. For example, Somenos Creek and Quamichan Creek are near Aquifers #187, and #186 Kelvin Creek is nearest to Aquifer #199. The stream and their associated aquifers are listed in Table 6.

Table 6 Aquifers in Koksilah watershed and their related streams

Stream	Relevant aquifer (Aquifer number)
Somenos Creek	#186, #187
Patrolas Creek	#197, #198
Koksilah River	#197, #198
Kelvin Creek	#199
Glenora Creek	#197, #198, #199
Cowichan River	#186, #187
Burnt Bridge Creek	#201, #202

To assign a water quality score to each aquifer-stream pair, we applied a score based on the average exceedance percentages presented in Table 5. To derive a score, the weighted average of the exceedance percentages for each criterion was divided by -10 and presented as a value between 0 to -10. The weighted average of exceedance for each part or each criterion (i.e. ions, metals and others) was calculated based on the total number of samples for each parameter within each criterion (i.e. Arsenic total within metals) and the total number of samples in different parameters with the given criterion (i.e. the total number of Arsenic total compared to total number of samples for other metals). For instance, the weighted average exceedance percentage of metals in Aquifer #186 is average 8.4% which is corresponded with score of -0.84 (Table 5). That is because there is only 98 metal samples in Aquifer #186 compared with the total number of metals samples of 13745 in the whole area. So, based on this weighting the percent of exceedance for metals in Aquifer #186 (8.4%) is negligibly larger than the average value for the entire Koksilah area of 8.3%.

An index was calculated considering the worst case scenario both for the aquifer and the connected streams. For example, Aquifer #186 has five water quality criteria (Table 7) with scores of -0.01, -0.07, -0.62, -0.84 and -9.43. The retained score is -9.43. For the Koksilah River the score is -9.47, chosen between 0, -0.01, -0.06, -0.84 and -9.47. After finding the representative scores for each aquifer and its associated surface water, the final score for each aquifer is the sum of the representative scores for the aquifer and its associated stream. Should there be more than one associated stream, the average score for all the associated stream is used. For example, for Aquifer #186 the score is -19.06 which is the sum of its score as an aquifer (-9.43) and rounded average of -9.51, -9.39, -10 which is -9.63 for the three streams it is connected to.

Table 7 Aquifer and streams water quality criteria and indexes

Aquifer ID	**#186**	**#188**	**#197**	**#198**	**#199**	**#201**	**#202**
Aquifer WQE## for:							
Bacteria and organisms	**-9.43**						
Ions	-0.01	-0.02	-0.02	-0.03	-0.02		
Metals	-0.84	-0.90					
Nutrients	-0.07	-0.07	-0.07	-0.07	-0.07		
Physical properties	-0.62	-0.59	-0.77	**-0.60**	-0.59		
Relevant surface water resources WDE##:							
Burnt Bridge Creek							
Bacteria and organisms						-9.45	-9.45
Physical properties						-0.68	-0.68
Cowichan River							
Bacteria and organisms	-9.51						
Ions	-0.01						
Metals	-0.75						
Nutrients	-0.03						
Physical properties	-0.72						
Glenora Creek							
Bacteria and organisms			**-9.39**	**-9.39**	-9.39		
Metals			-0.84	-0.84	-0.84		
Nutrients			-0.04	-0.04	-0.04		
Physical properties			-0.64	-0.64	-0.64		
Kelvin Creek							
Metals					-0.73		
Nutrients					-0.07		
Physical properties					-0.63		

Aquifer ID	#186	#188	#197	#198	#199	#201	#202
Koksilah River							
Bacteria and organism			**-9.47**	**-9.47**			
Ions			-0.01	-0.01			
Metals			-0.84	-0.84			
Nutrients			-0.06	-0.06			
PAH			-0	-0			
Physical properties			-0.59	-0.59			
Patrolas Creek							
Bacteria and organisms			**-9.39**	**-9.39**			
Metals			-0.84	-0.84			
Nutrients			-0.04	-0.04			
Physical properties			-0.65	-0.65			
Quamichan Creek							
Bacteria and organisms	**-9.39**						
Nutrients	-0.04						
Physical properties	-0.64						
Somenos Creek							
Bacteria and organisms	**-10**						
Nutrients	-0.07						
Physical properties	-0.67						
Resulting Indices	**-19.06**	**-0.9**	**-10.19**	**-10.02**	**-5.65**	**-9.45**	**-9.45**
Aquifer Vulnerability	High/A	Low/C	Moderate/B	Low/ C	Moderate/B	High/A	Moderate/B

#Zhu, (2013), **NRC (2008), ##WQE (Water Quality exceedance based on the Canadian Drinking Water Quality Standard)

2.3 ASR feasibility of operation

The feasibility of ASR from an operational standpoint includes the accessibility and rates of recharge and recovery, the availability of supply, and the need for, and complexity of treatment. We used a couple of metrics to evaluate the feasibility of ASR operation and one of the most important one is “revised metric” developed by Woody (2007) and Brown et al.(2005) to assess the injection rates relative to potential groundwater storage rates. For ASR to be economically viable, the operation would need to store a minimum amount of water over a given time. The aquifer has an intrinsic maximum storage rate, related to transmissivity (T) and head space (h) in the aquifer (Figure 8). If the aquifer storage volume is greater than the volume of water to be stored, this increases the feasibility of ASR.

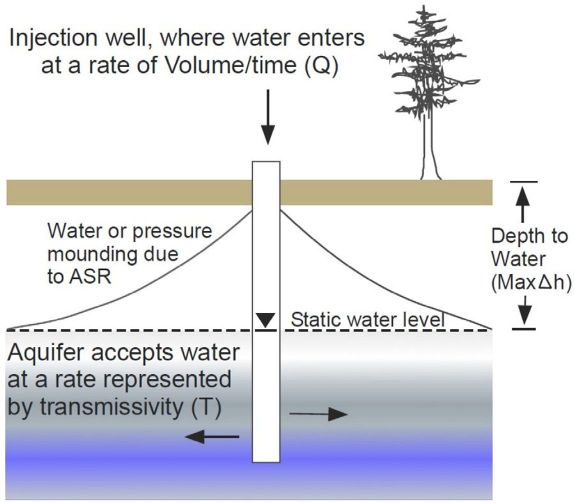

Figure 8. The aquifer has an intrinsic maximum storage rate, related to transmissivity (T) and head space (h) in the aquifer. The feasibility metric compares the rate at which water is available relative to the rate at which water can be accepted by the aquifer (After Woody, 2007).

In an unconfined aquifer, depth to water (h) cannot approach zero (i.e., above the land surface). In a confined or semi-confined aquifer, it is possible to inject water until the potentiometric surface is above the land surface, however, this can cause negative down gradient effects (i.e., artesian flow in neighboring wells, springs, or seeps) (Woody, 2007).

2.3.1 Revised Metric

The revised metric is a type of volumetric assessment of the aquifer feasibility for ASR. A "Revised Metric" proposed by Woody (2007 is calculated as:

$$RRRRRRRRRRRRRR\ MMRRMMMRRMM = \frac{TT \times mmmmm(\Delta h)}{2.3\ QQ(lllll(TT) + 2.35)}$$

Where TT is transmissivity (L2/T), QQ is the flow rate (L3/T) and Δh is available head build up (distance from ground surface to well static level). QQ and TT are available from the GWELLS database, observation well network, and studies from the EcoCat database (Wei et al., 2010). Q and T can also be calculated from the specific capacity results reported from on driller's logs. Woody (2007) estimated T based on the relationship between specific capacity and transmissivity for both unconsolidated and bedrock aquifers. These parameters can also be estimated from pumping test results. In this report, we assessed an average Revised Metric for each aquifer. We have assigned an average value for Q based on the total annual demand and the average transmissivity for each aquifer using available reports (Barroso and Wainwright, [in press]; Hatfield Consultants LLP, 2021). The average depth to water was estimated based on the available water level data from GWELLS (Figure 6).

2.3.2 ASR operation criteria and indices

Distance to river/squared root of aquifer area (m): The average distance between the aquifer mid-point and the river. It is calculated from the square root of the aquifer area. The smaller distances have the maximum scores.

Depth to confining bed or water level (m): The depth to the aquifer confining bed or depth to water level shows how accessible the aquifer is for both recharge and recovery. A shorter depth scores higher.

Treatment technology requirement for the recharge (surface) water: The treatment technology can also be representative of the ease of operation since the easiest condition is when no treatment is needed for the recharge water. The highest score is for “no treatment” and the lowest score is for cases that need all forms of treatments (primary, secondary, tertiary and disinfection).

Annual average recharge water volume (m^3): This criterion represents the total volume of the recharge water in the river that is nearest to the aquifer. If the total available water is adequate to meet demand, there is no need for transfer recharge water from sources located further away. Therefore, the annual average recharge water volume is a useful criterion to quantify ease of operation. The annual recharge water is calculated using the average monthly river flows. We have assumed that 15% of the average annual flow is required for environmental flow needs, and that excess flows are available for recharge (Table 8).

Annual average recharge water volume per unit area of the aquifer (m^3/m^2): the available recharge water per unit area of the aquifer was calculated by dividing the annual average recharge water by the surface area of the aquifer.

Revised Metric: The last criterion is the Revised Metric (Woody, 2007; Brown et al., 2005), discussed in detail in section 2.3.1. The Revised Metric can be calculated for each water well using the well discharge rate, the aquifer transmissivity, and the depth to water. To calculate an average value for each aquifer we have calculated an average for each of these parameters in each aquifer. For example, the average discharge rate for each aquifer was determined by dividing the total annual demand over 5 months (associated with the period of irrigation between May and September). The average depths to the water level and aquifer transmissivities are summarized in Table 2. For bedrock Aquifers #198 and #202, the depth to groundwater was evaluated based on Sivak and Wei (2019). For other aquifers, the depth to groundwater was based on the Leapfrog model (Figure 3 and Figure 6). The aquifers with a Revised Metric value of 1 or greater are suitable for ASR. Except for bedrock Aquifers #198 and #202, all the studied aquifers reported Revised Metric larger than 1.

Table 8 The parameter values and their scores (in parenthesis) for assessment of ease of operation for Koksilah aquifers

Aquifer ID	#186	#188	#197	#198	#199	#201	#202
Distance to river/square root of aquifer area (m)	2340 (8)	1690 (9)	4690 (5)	8390 (0)	5260 (4)	1390 (9)	6290 (3)

Depth to confining bed or water level (m)	10 (4)	10 (4)	25 (10)	15 (6)	10 (4)	10 (4)	15 (6)
Treatment technology requirements for the recharge (surface) water**	TD^{+}, TM^{++}, TPP^{+++} (2)	TPP^{+++} (8)	TD^{+}, TM^{++}, TPP^{+++} (2)	TD^{+}, TM^{++}, TPP^{+++} (2)	TD^{+}, TPP^{+++} (5)	TD^{+} (8)	TD^{+} (8)
Annual average rechange water volume (m^3)							
Koksilah River			2.681e+8 (1)	2.681e+8 (1)			
Cowichan River	1.422e+9 (10)						
Annual average rechange water volume per unit area of the aquifer (m^3/m^2)							
Koksilah River			12.2 (2)	3.81 (1)			
Cowichan River	263.3 (8)						
Revised Metric $$	1.8 (9)	3.8 (9)	6.93 (10)	0.16 (0)	3.95 (9)	34.1 (10)	0.91 (0)

#Aquifer subtype description is available on https://catalogue.data.bc.ca, **NRC (2008), $$Woody (2007) and Brown et al. (2005), +Treatment for Disinfection (TD), ++Treatment for metals (TM), +++Treatment for physical properties (TPP)

Note: Aquifer 201 extent needs to be redefined; therefore, the estimation of Revised Metric might not be representative of this aquifer

3 COST ESTIMATE

To implement the ASR project, three phases have been considered:

- Phase 1: ASR Pilot Design and baseline
- Phase 2: ASR Pilot Implementation
- Phase 3: ASR Full Expansion

The cost estimate is presented in Table 9. We assumed 12 injection/recovery wells (two during pilot and 10 during full expansion). The cost per well is approximately $1 million. Aquifer #197 can potentially store approximately 27 million m^3, suggesting that approximately 2 million m^3 can be stored and recovered for one million dollars (2 m^3 per dollar).

Table 9 Cost estimate for ASR implementation

PHASE	SCOPE	TASK	DESCRIPTION	SUB-TOTAL	TOTAL PHASE COST
Phase 1: ASR Pilot Design and baseline	Develop understanding of the defined area for Recharge, Storage and Recovery	Desktop studies to highlight the data gaps and where more data needed to be collected	Conduct desktop studies for the location of Monitoring points	$7,500	**$421,000**
		Implementation of monitoring program and baseline data	Surface water gauge installation (three gauges)	$59,900	
			Develop observation well network at multiple levels by drilling and testing boreholes (minimum 6 test wells)	$218,000	
			Surface water sampling (water quality) for one year (monthly sampling)	$41,400	
			Groundwater sampling (water quality assessment) (twice a year in 6 test wells and 4 private neighbouring wells)	$35,800	
	Baseline development	Update desktop studies based on the new findings	Analyze and interpret the data collected	$9,000	
			Structure a database and develop the baseline for water quality and water pressure for the project	$12,000	
	Coordination	Definition of the framework	Determination of monitoring locations/ time stages/ facilities and equipment for pilot	$7,500	
		Coordination	Planning/ordering/ permit(s) applications/safety	$30,000	
Phase 2: ASR Pilot Implementation	ASR Pilot design study/ Pilot Implementation	Construction	Drilling 4 boreholes (100m) and pump testing	$141,547	**$1,885,000**
			Drilling and completion of 2 production wells (70m)	$100,640	
			Pumping test in production wells (minimum 72 hour for 2 of wells)	$52,000	
			Lefranc and Lugeon permeability tests	$30,000	
			Data interpretation to select the location of Pilot ASR	$15,000	
			Fencing to protect water source areas	$20,000	
			Pipeline design and installation	$765,000	
			Electrical pump and controller or solar pump	$80,000	
			Pressure system (if it is needed)	$0	
			Treatment system (Design, material and installation)	$156,000	
			Pump and utility house construction	$150,000	
			Water storage tank (material and installation)	$0	
		Operation	Start up the ASR Cycle	$36,000	
	ASR Pilot Evaluation and Risk Assessment	Evaluation	Monthly water quality monitoring (10 tests wells, 2 production wells and 4 neighbouring private wells)	$220,800	

PHASE	SCOPE	TASK	DESCRIPTION	SUB-TOTAL	TOTAL PHASE COST
			Monitoring groundwater pressure	$18,000	
			Monitoring surface water level/flow	$18,000	
			Aquifer modelling	$45,000	
			Data Interpretation to estimate Aquifer storage and recovery rate	$12,000	
			Determination the technical issues and other concerns / uncertainties	$12,000	
		Risk Assessment	Data interpretation to conduct risk assessment for the Pilot study and risk prediction for ASR full implementation	$7,500	
			Contingency Plan to reduce the risk and modification	$6,000	
Phase 3: ASR Full Expansion	Optimization analysis	Feasibility analysis to optimize/ enhance the initial ASR Plan		$30,000	**$9,762,000**
	Expansion	Expand the ASR Implementation with additional 10 injection wells		$9,731,600	
Subtotal					$12,068,000
Communication with the multidisciplinary teams and contractors (12% of engineering cost)					$121,860
TOTAL					$12,190,000

The cost estimate includes the following main assumptions:

- Test boreholes would be drilled to depths of 100 m and production wells would be drilled to depths of 80 m
- ASR system includes surface water intake, pipes (inflow and outflow), treatment system (stage 2), pumping wells, pump house
- Water quality will be monitored at surface water intake/before treatment, after treatment, at the location of pumping wells. Lab cost at $650 per sample for full potability analysis.
- Consulting field work supervision rate ($1500/day)
- Monitoring equipment includes Level logger at $1500 per logger (Pressure, temperature and conductivity) and baro logger at $350 per logger.
- Pipelines lengths in Aquifer #197 from 0.5 km to 3 km. Design and construction of 8" pipe $250,000/Km
- Treatment plant for pilot $150,000 (stage 2)
- Pump for 1000US GPM exploration estimated at $20000 per pump
- No storage tank was included.

4 SUMMARY AND SELECTION OF SUITABLE AQUIFER

Aquifer #197 was selected as the most suitable aquifer for ASR based on the water quantity, water quality and ease of operation criteria. Aquifer #197 would be able to store approximately 27 million m^3 should its saturated thickness increase from 25 m to 60 m. The has the second largest area (22 million m^2) and the shortest length of compliance zone in one month (30 m) when compared to the other unconsolidated aquifers. It has one of the smallest stream depletion factor, given a separation of 500 m and 1000 m to a pumping well.

Aquifer#197 is the most stressed aquifer based on the negative trend of flow in the nearest river. The Koksilah River flow is trending -0.029 m^3/s/yr. Aquifer #197 has the greatest water demand (equivalent to 56.5% of the whole watershed demand), and the highest demand per square meter per year (0.106 m/yr). This aquifer is also the most vulnerable aquifer due to its minimum negative score for water quality and its relevant recharge water source quality.

The negative scores for water quality in Aquifer #197 suggest ASR would need three types of water treatment (disinfection, treatment for metals, and treatment for physical properties).

The average depth to water in Aquifer #197 is the greatest of all the unconsolidated aquifers, thus offering the largest volume for potential storage. In addition, the proximity of the Koksilah River would support its artificial recharge.

Additionally, the Revised Metric value for Aquifer #197 is 6.93, the largest compared to the other unconsolidated aquifers (discounting Aquifer #201, which is smaller in extent with uncertain delineation).

The cost to recover and store two cubic meters of water is equivalent to a cost of 1 dollar for the ASR design, implementation and operation.

5 STUDY LIMITATIONS

This document was prepared for the exclusive use of the BC Province and Elucidate Consulting (the client). The inferences concerning the data, site and receiving environment conditions contained in this document are based on information obtained during investigations conducted at the site by GW Solutions and others and are based solely on the condition of the site at the time of the site studies. Soil, surface water and groundwater conditions may vary with location, depth, time, sampling methodology, analytical techniques and other factors.

In evaluating the subject study area and water data, GW Solutions has relied in good faith on information provided. The factual data, interpretations and recommendations pertain to a specific project as described in this document, based on the information obtained during the assessment by GW Solutions on the dates cited in the document, and are not applicable to any other project or site location. GW Solutions accepts no responsibility for any deficiency or inaccuracy contained in this document as a result of reliance on the aforementioned information. The findings and conclusions documented in this document have been prepared for the specific application to this project and have been developed in a manner consistent with that level of care normally exercised by hydrogeologists currently practicing under similar conditions in the jurisdiction.

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If new information is discovered during future work, including excavations, sampling, soil boring, water sampling and monitoring, predictive geochemistry or other investigations, GW Solutions should be requested to re-evaluate the conclusions of this document and to provide amendments, as required, prior to any reliance upon the information presented herein. The validity of this document is affected by any change of site conditions, purpose, development plans or significant delay from the date of this document in initiating or completing the project.

The produced graphs, images, and maps have been generated to visualize results and assist in presenting information in a spatial and temporal context. The conclusions and recommendations presented in this document are based on the review of information available at the time the work was completed, and within the time and budget limitations of the scope of work.

The BC Province and Elucidate may rely on the information contained in this report subject to the above limitations.

6 CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this report.

This report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix 1. GW Solutions was pleased to produce this document. If you have any questions, please contact us.

Yours truly,

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7 REFERENCES

-Arthur J.D., Dabous A.A., Cowart J.B (2005) “Water-rock geochemical considerations for aquifer storage and recovery: Florida case studies” In C.F. Tsang & J.A. Apps (Eds.), Underground injection science and technology, developments in water science, Amsterdam (pp. 327-339) Elsevier.

-Barroso S., Wainwright M. (in press) “Water Use and Management in the Koksilah River Watershed” Water Science Series, 2020-02. Victoria, B.C.

-Brown C.J., Weiss R., Sutterfield S., Verrastro R., Kwaitkowski P., Schubert S. et al. (2005) "Development of an aquifer storage and recovery (ASR) site selection suitability index in support of the comprehensive everglades restoration project" J. Environ. Hydrol. 13. www.hydroweb.com/journal-hydrology-2005-paper-20.

-Geller D., Burt W. (2020) "Assessment of Managed Aquifer Recharge (MAR) and Aquifer Storage and Recovery (ASR) Potential in British Columbia: Regional Opportunities and Regulatory Approaches" Water Science Series WSS2020-01. Province of British Columbia, Victoria B.C.

-Hatfield Consultants LLP (2020), "Provincial Groundwater Observation Well Network Review". Prepared for Ministry of Environment & Climate Change Strategy, May 2020

-Hatfield Consulatants LLP (2021) "Koksilah Watershed Hydrological Analysis" #200-850 Harbourside Drive, North Vancouver, BC, Canada. https://www.hatfieldgroup.com

-Lance J.C., Rice R.C., Gilbert R.G. (1980) "Renovation of sewage water by soil columns flooded with primary effluent" J. Water Pollut. Contr. Fed., 52(2), 381-388.

-Lin Z., Puls R.W. (2003) "Potential indicators for the assessment of arsenic natural attenuation in the subsurface" Advances in Environmental Research 7, 825-834.

-Meng X., Korfiatis G.P., Bang S., Bang K.W. (2002) "Combined effects of anions and arsenic removal by iron hydroxides" Toxicology Letters 133(1), 103-111.

-National Research Council (1994) "Groundwater Recharge using waters of impaired quality" USA. Washington, DC, USA: National Academy Press.

-NRC (2008) "Committee on Sustainable Underground Storage of Recoverable Water, National Research Council. Water Quality considerations. Prospects for managed underground storage of recoverable water (). Washington, DC: The National Academics Press.

-Pyne R.D.G. (2003) "Water quality in aquifer storage recovery (ASR) wells" American Water Works Associations Annual Meeting, Orlando, Florida.

-Sivak T., Wei M. (2019) "Koksilah River Watershed: Preliminary Assessment of Hydraulic Connection" Water Science Series, WSS2019-05. Prov. B.C., Victoria B.C.

-Tchobanoglous G., Burton F.L., Stensel H.D. (2002) "Wastewater Engineering" (4th edition ed.) Metcalf & Eddy.

-Water Pollution Control Federation (1989) "Water reuse—manual of practice (2nd Ed. Ed.)" Alexandria, VA: Water Pollution Control Federation.

-Wei M., Allen D.M., Carmichael V., Ronneseth K. (2010) "State of understanding of the hydrogeology of the Grand Forks aquifer" Victoria: B.C. Ministry of Environment.

-Woody J. (2007) "A preliminary assessment of hydrogeologic suitability for aquifer storage and recovery (ASR) in Oregon" Master of Science Thesis, Oregon State University. 325 p.

-Zhu N. (2013) “Geochemical Modeling of an Aquifer Storage and Recovery Project in Union County, Arkansas” Master Thesis, Massachusetts University of Technology, US.

APPENDIX D1

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these "General Conditions and Limitations".

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

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During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

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The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

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(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

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The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW

SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

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The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

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Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

APPENDIX D2

Water Quality Exceedance based on the guideline for Canadian Drinking Water Quality

Appendix D2: Water Quality Exceedance based on the guideline for Canadian Drinking Water Quality

Table A-1 Water quality exceedance for groundwater and surface water resources including aquifers

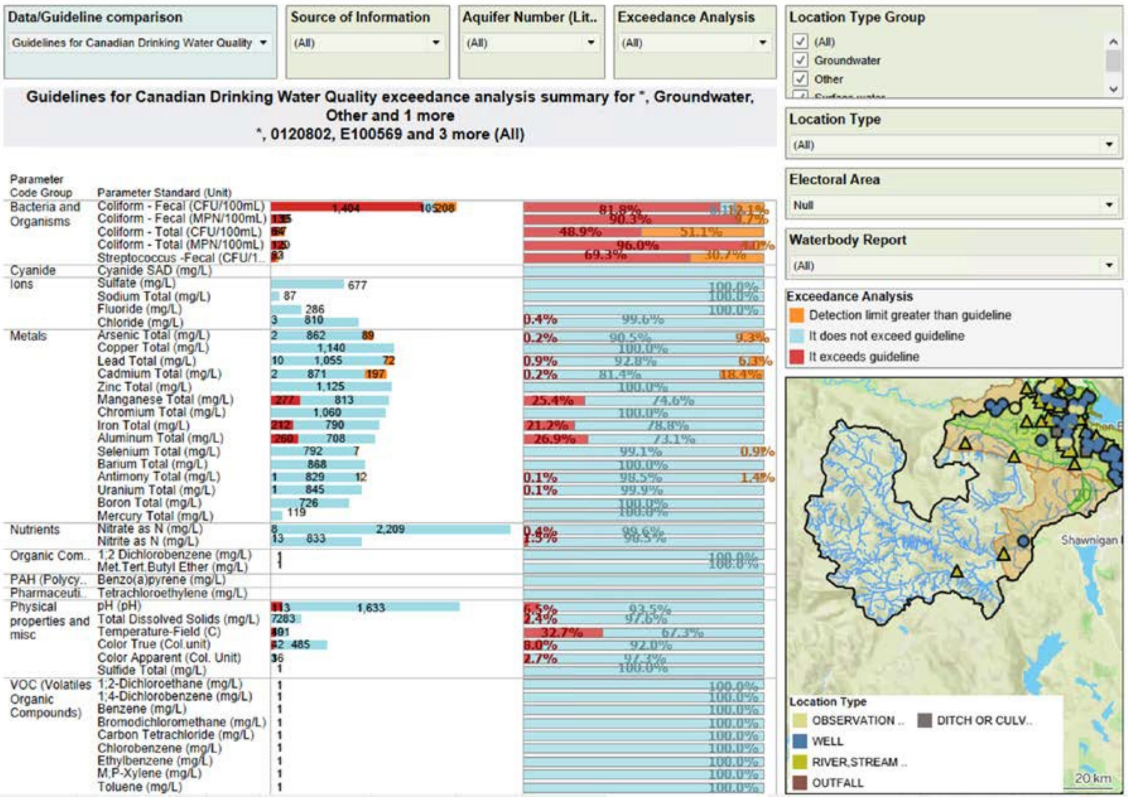


Table A-2 Water quality exceedance for Burnt Bridge Creek

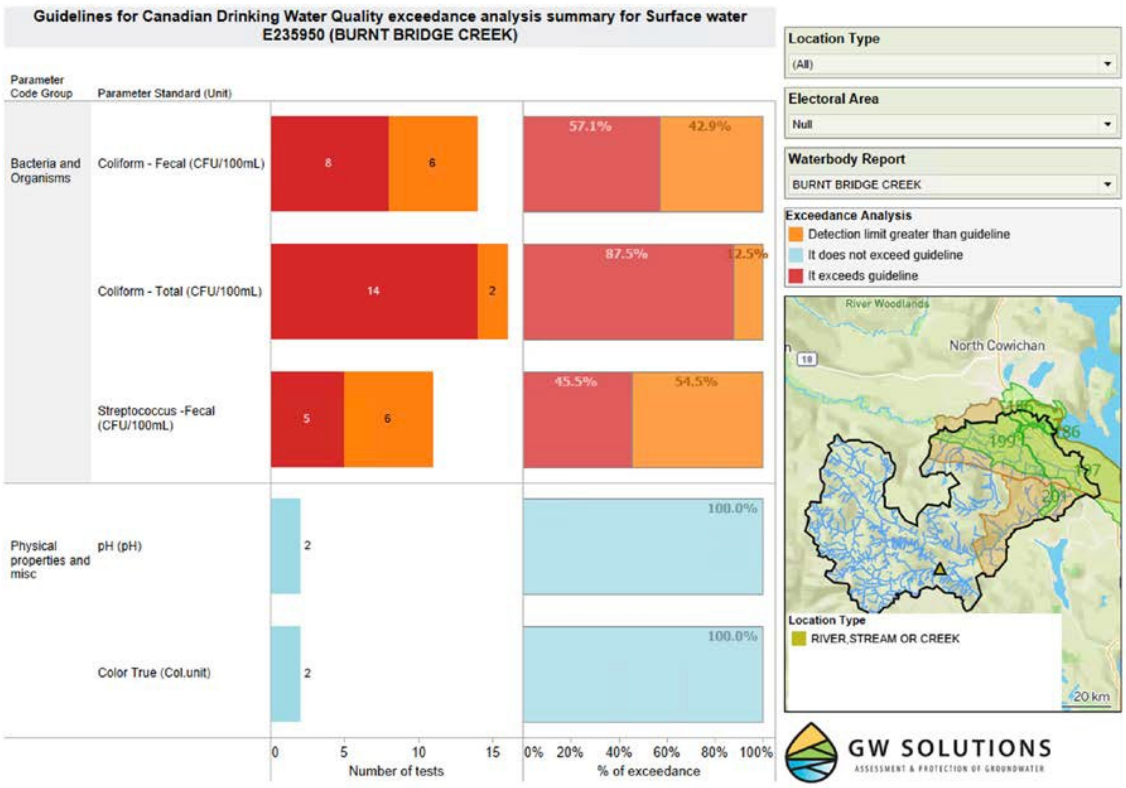


Table A-3 Water quality exceedance for Cowichan River

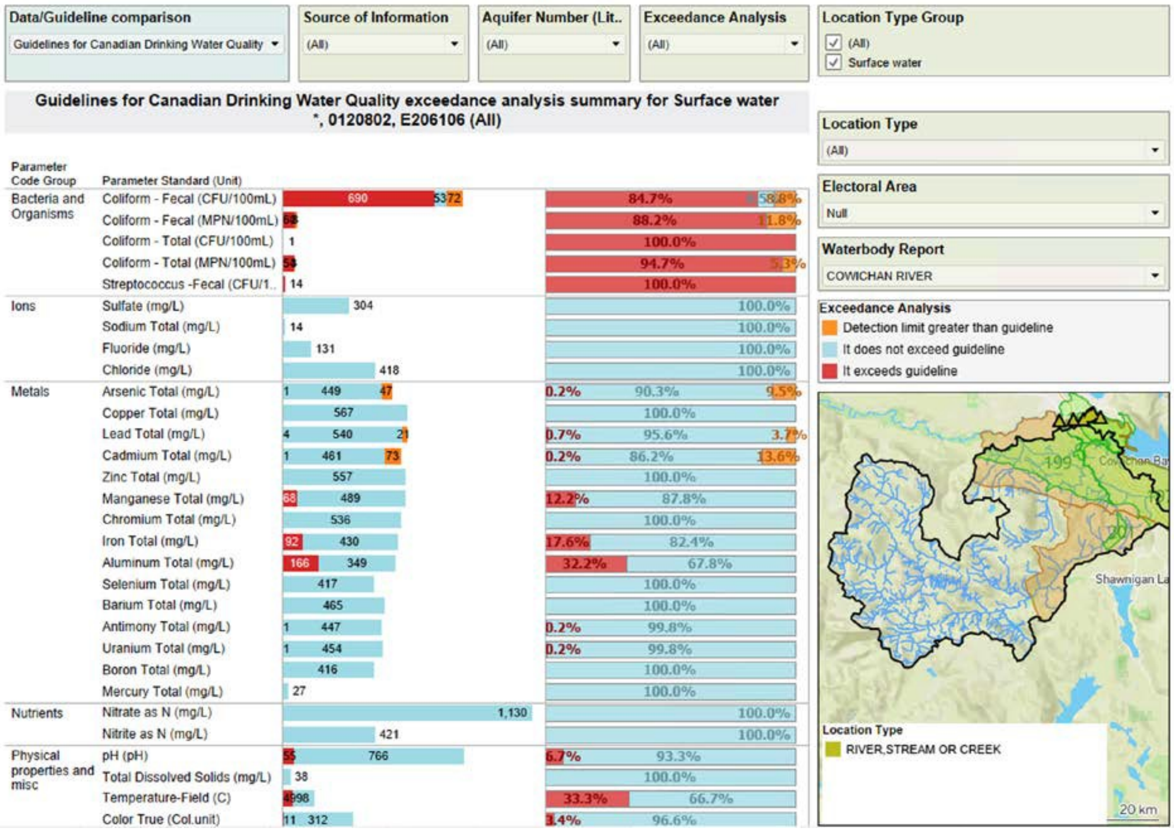


Table A-4 Water quality exceedance for Glenora Creek

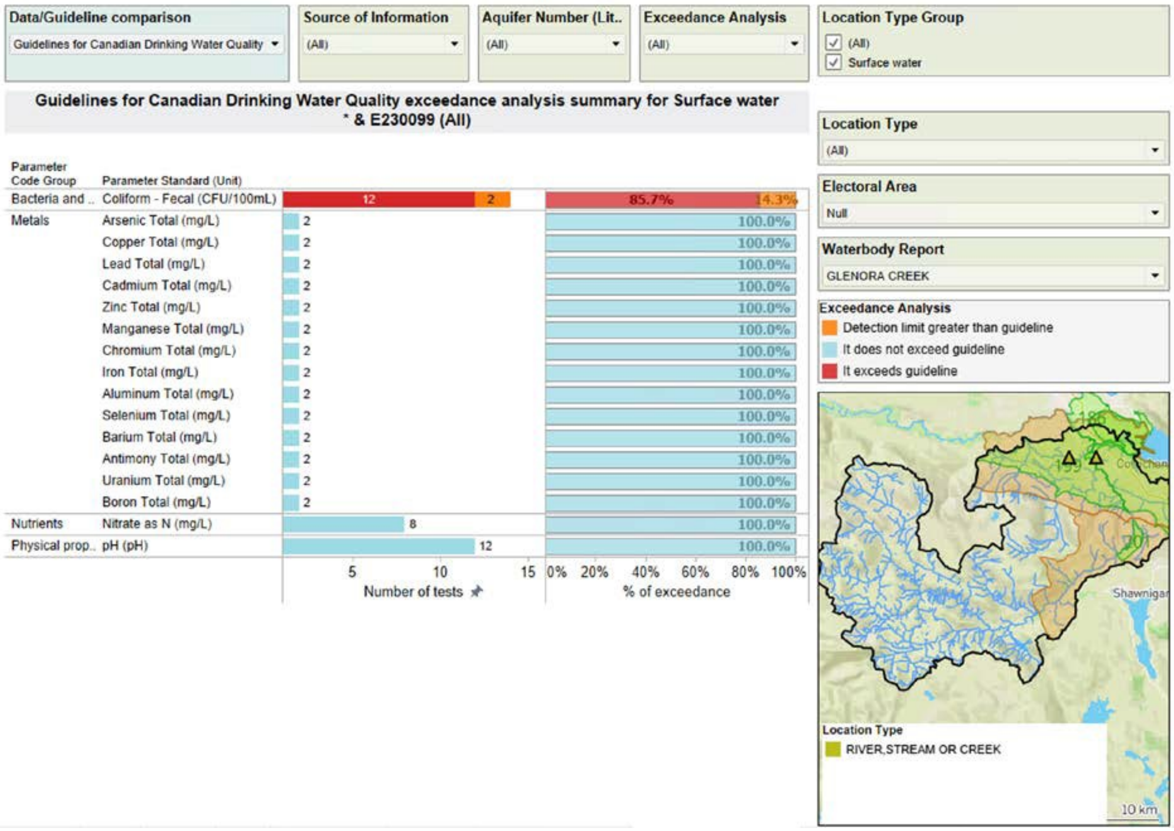


Table A-5 Water quality exceedance for Kelvin Creek

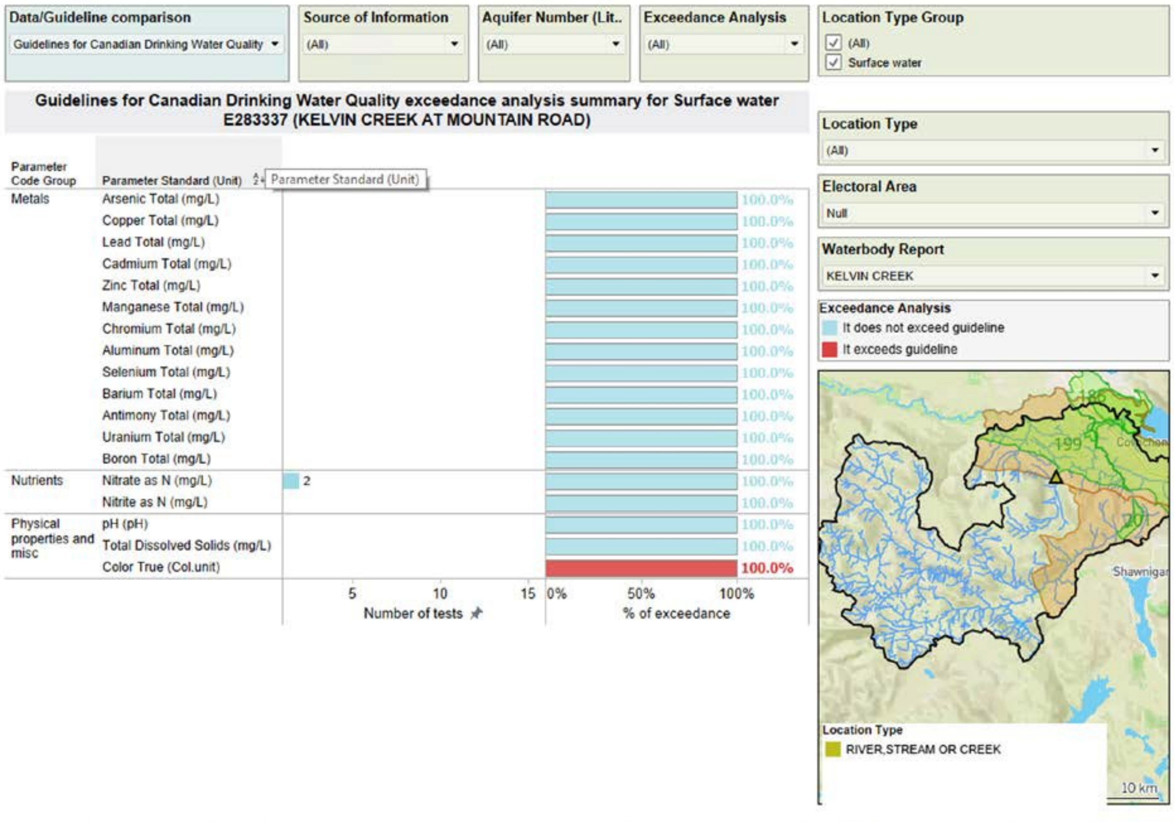


Table A-6 Water quality exceedance for Koksilah River

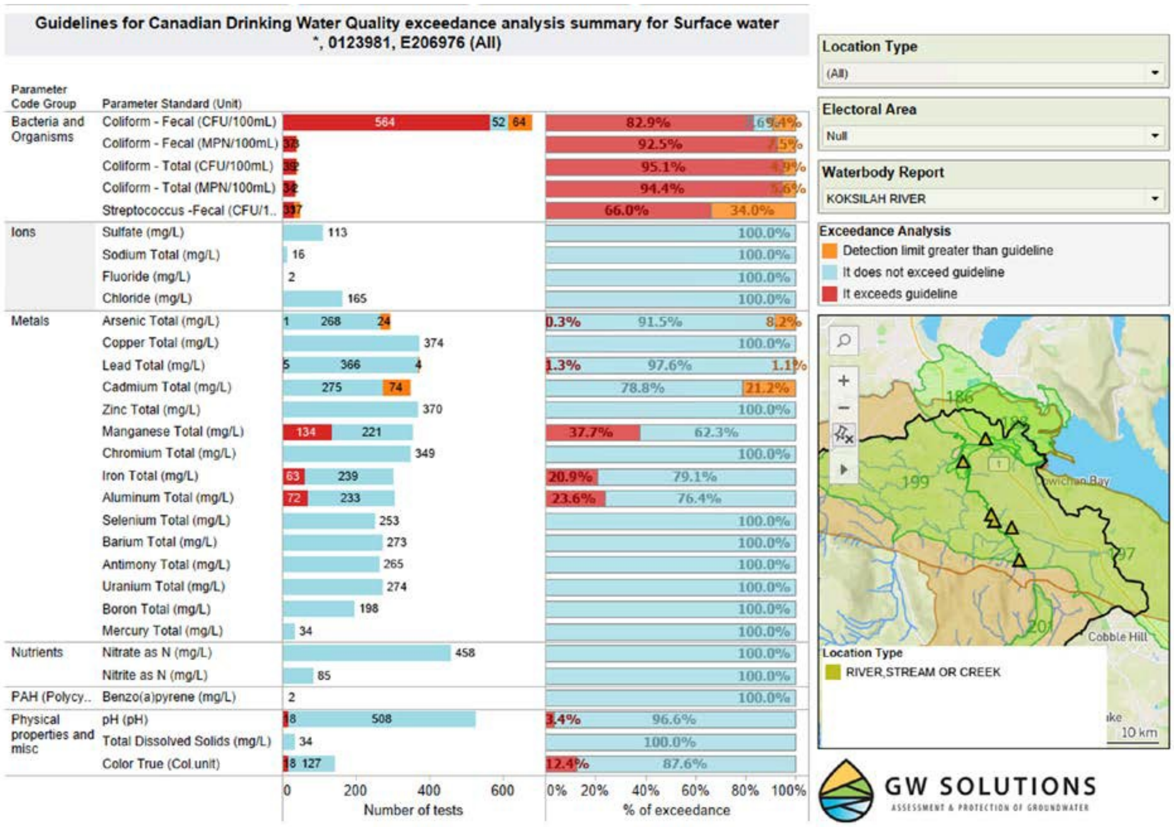


Table A-7 Water quality exceedance for Patrolas Creek

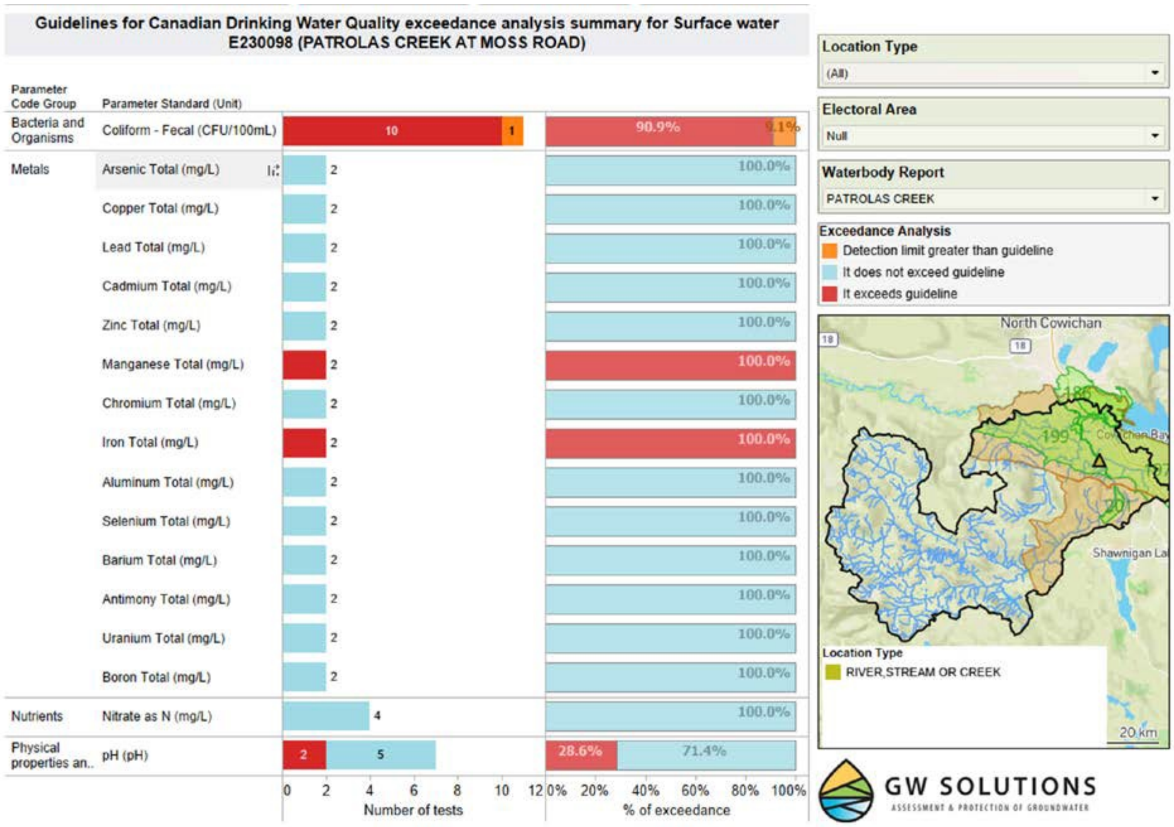


Table A-8 Water quality exceedance for Quamichan Creek

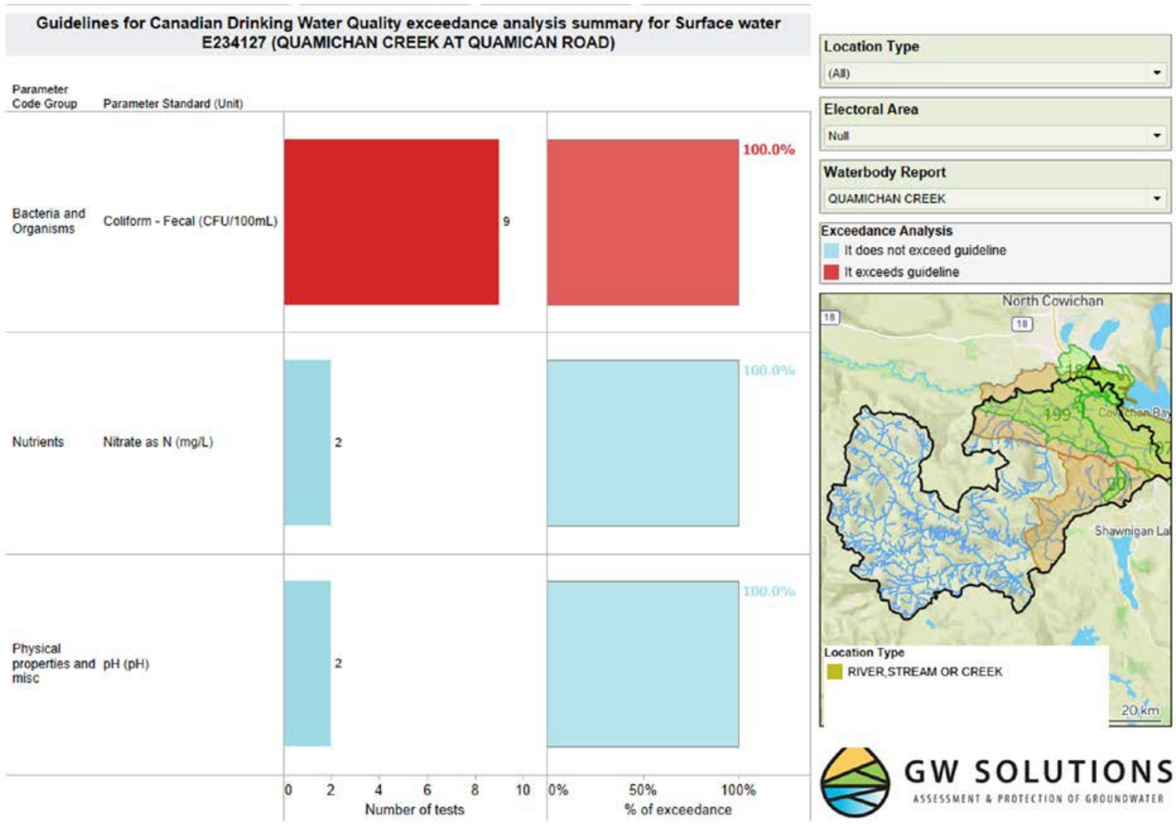


Table A-9 Water quality exceedance for Somenos Creek

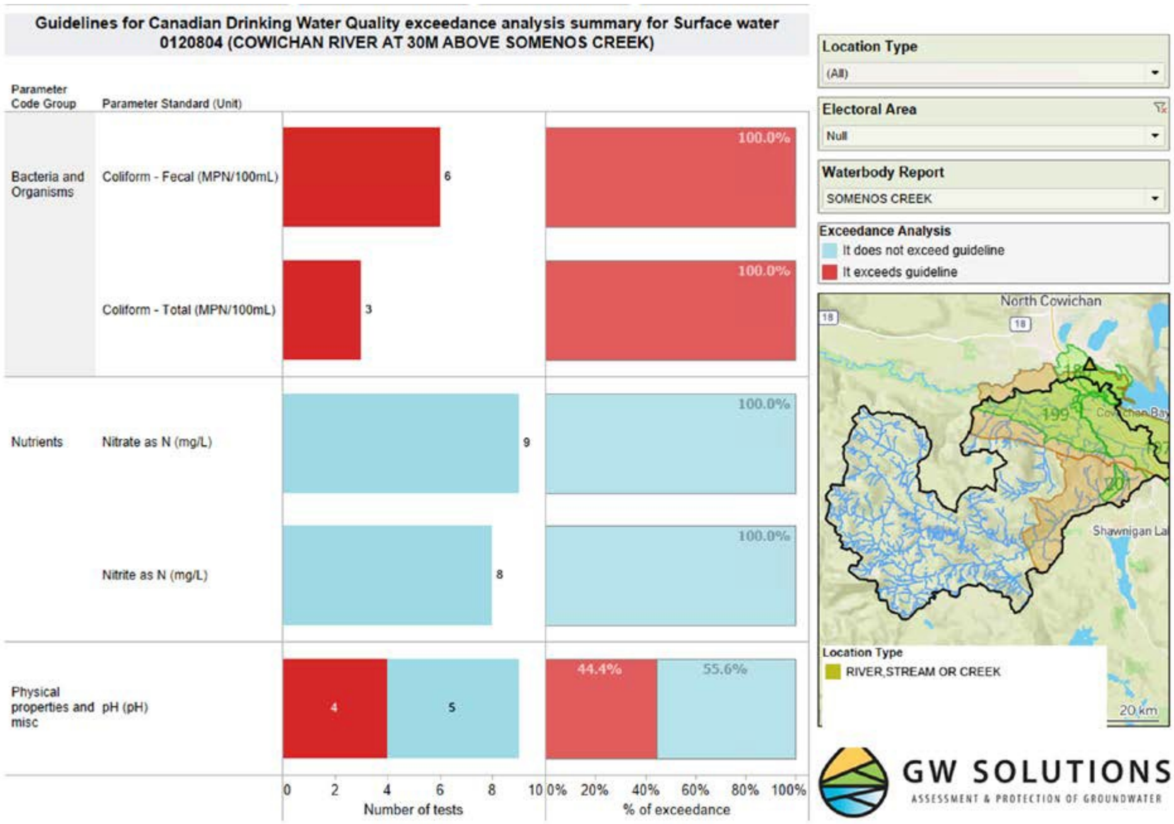


Table A-10 Water quality exceedance for aquifer# 186

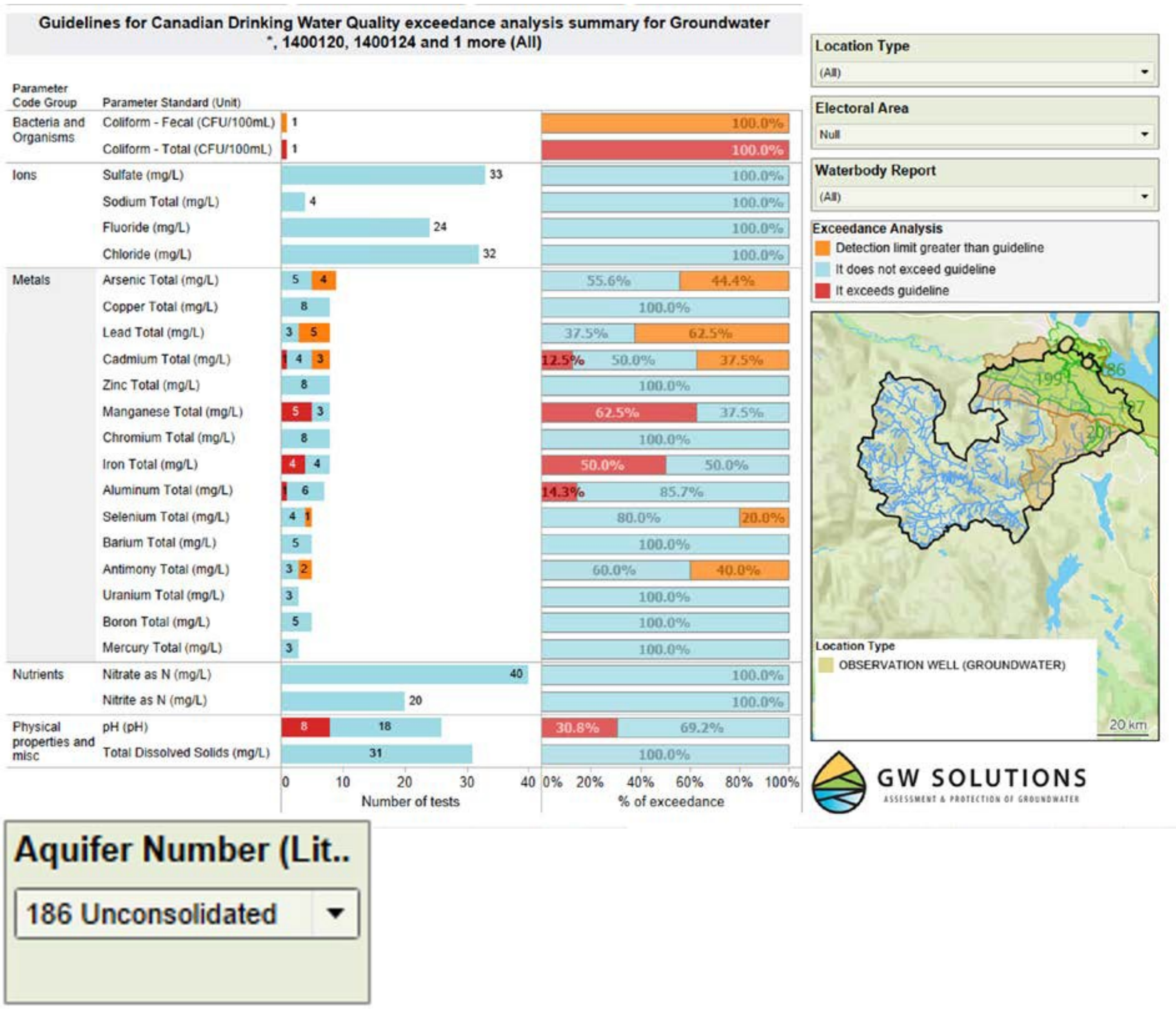
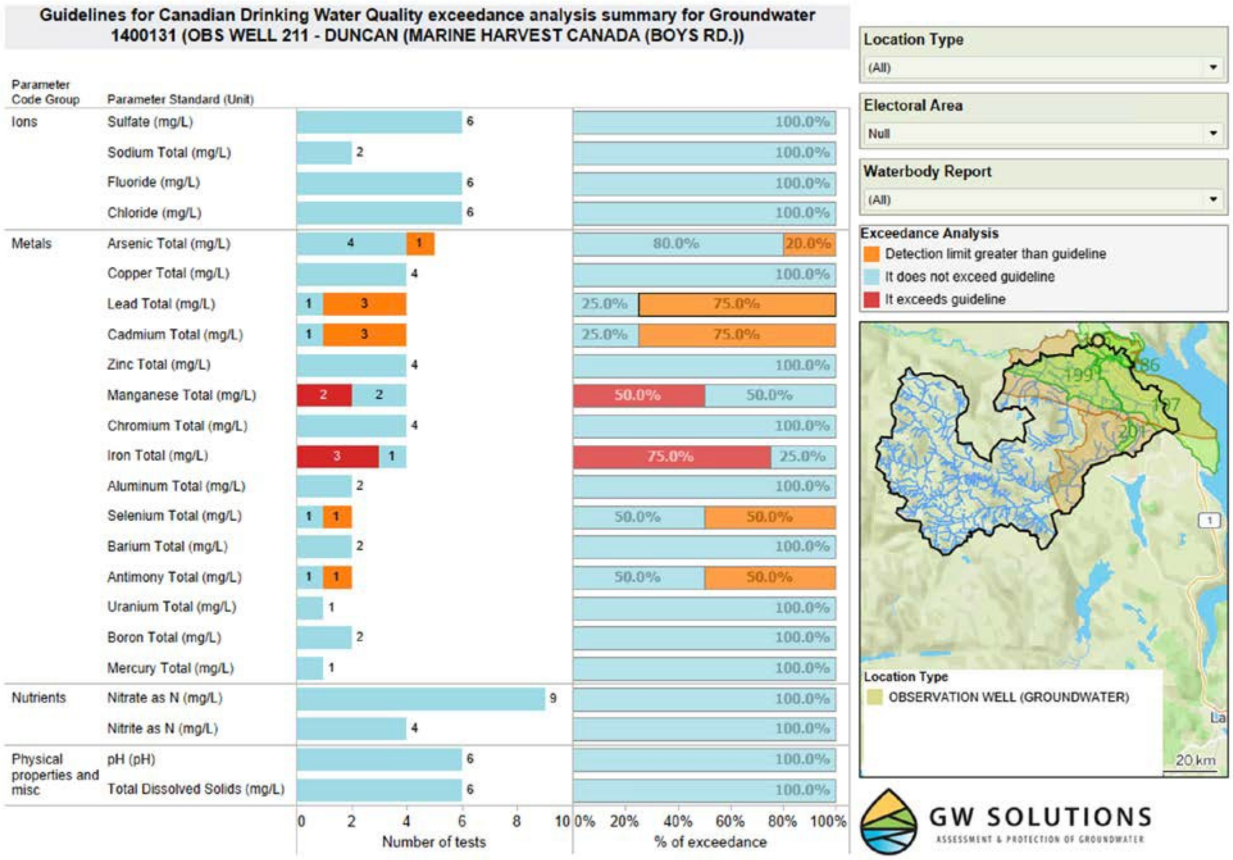


Table A-11 Water quality exceedance for aquifer# 187



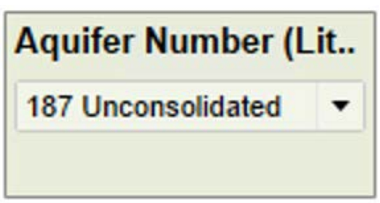
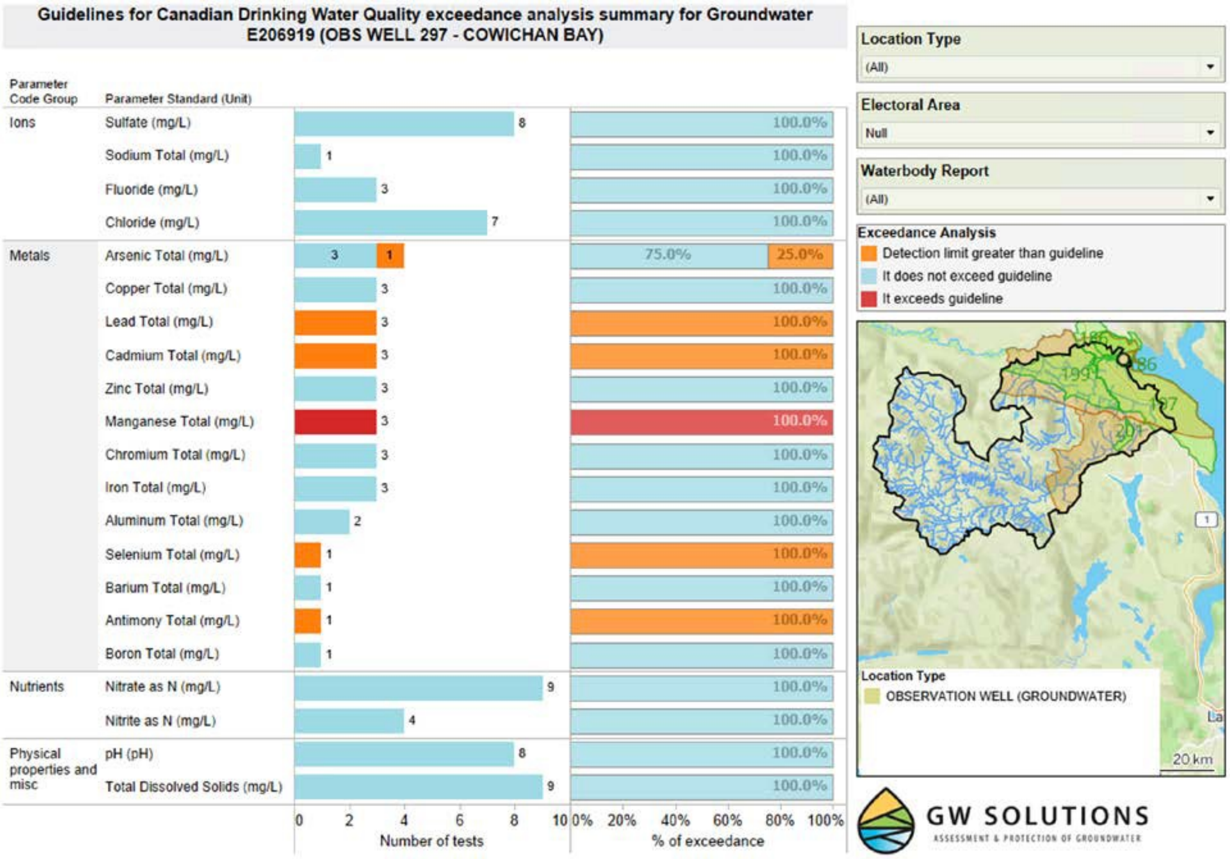


Table A-12 Water quality exceedance for aquifer# 188



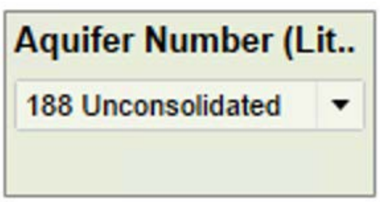
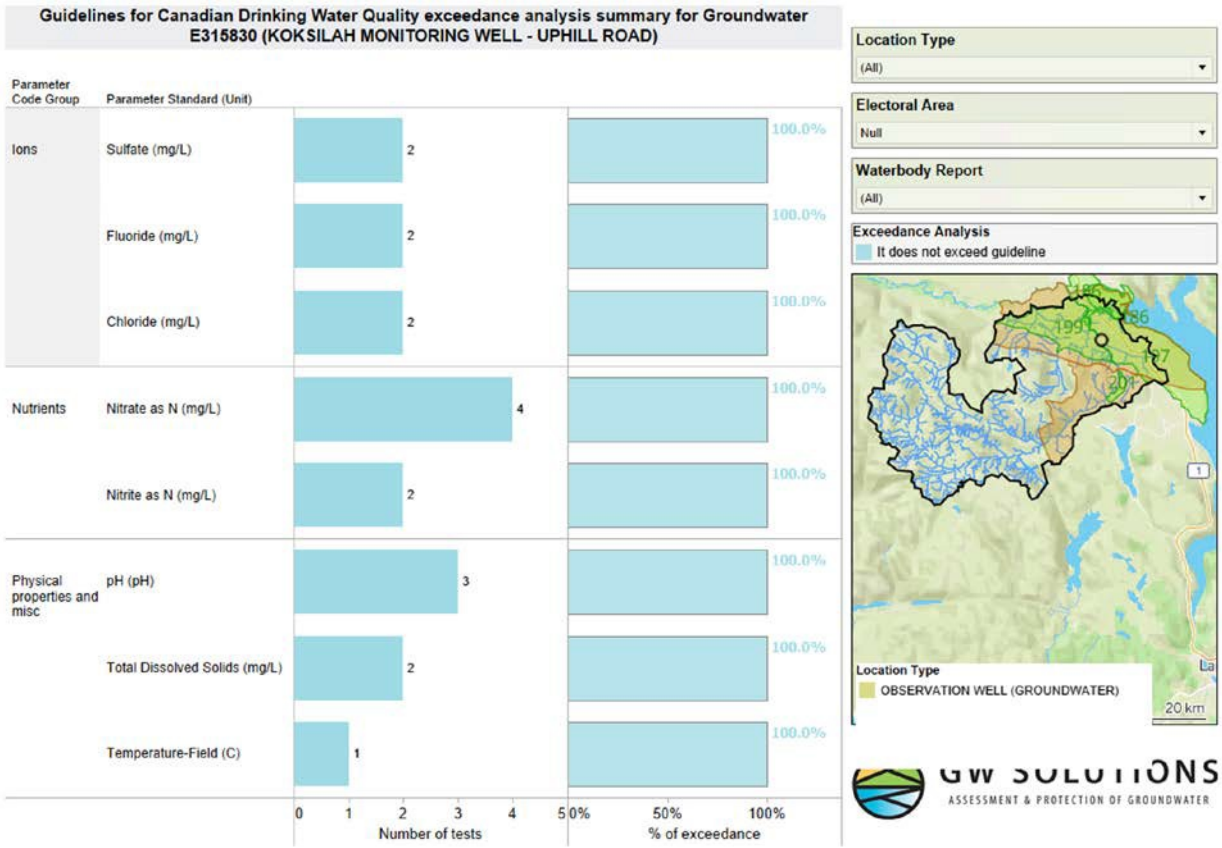


Table A-13 Water quality exceedance for aquifer# 197



Aquifer Number (Lit..

197 Unconsolidated ▾

Table A-14 Water quality exceedance for aquifer# 198

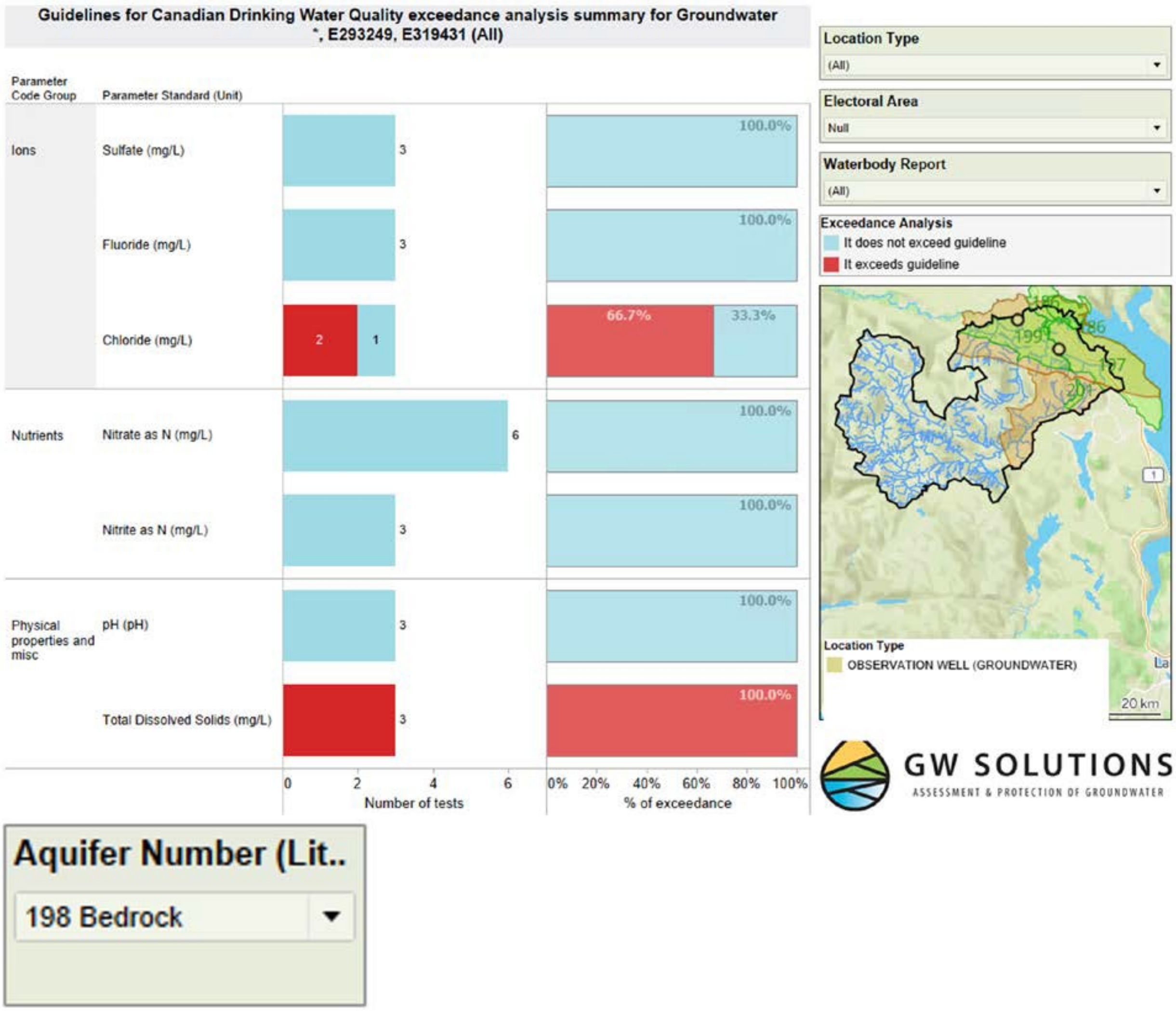
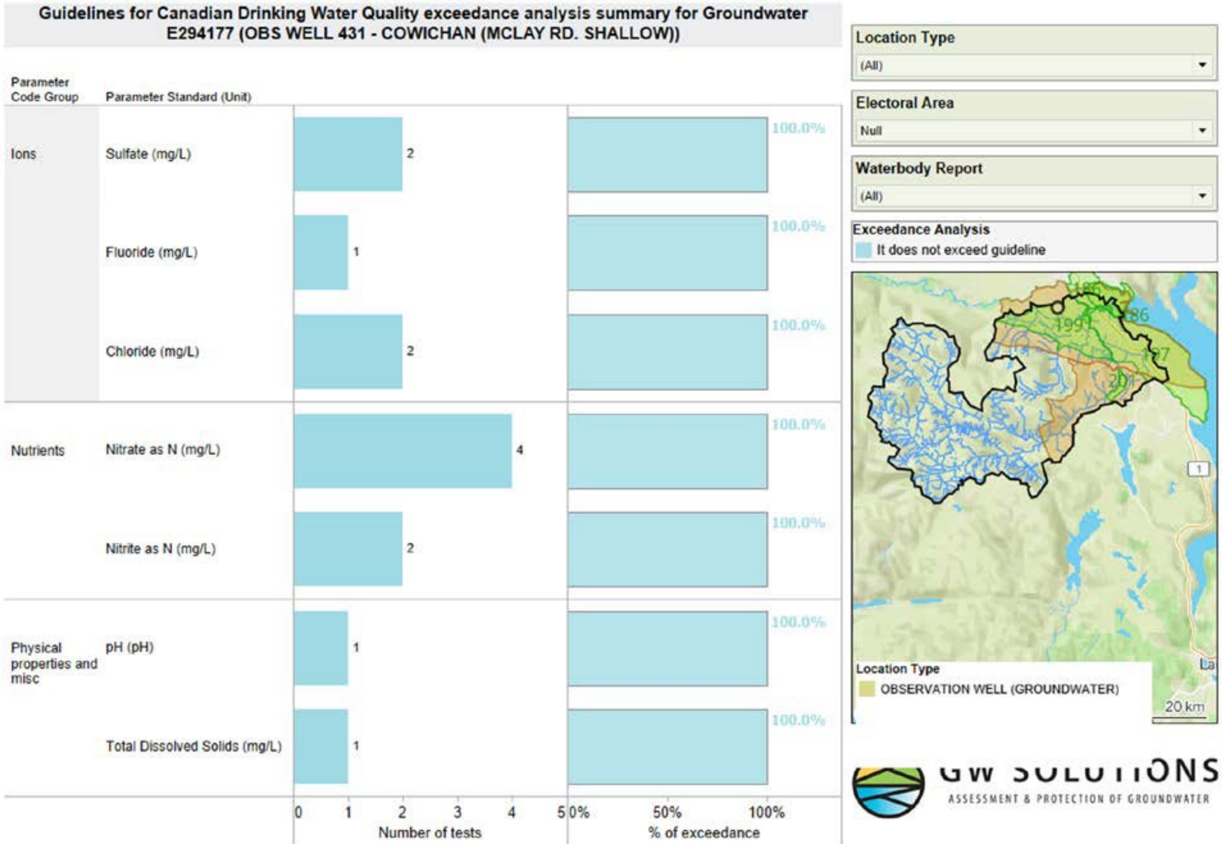
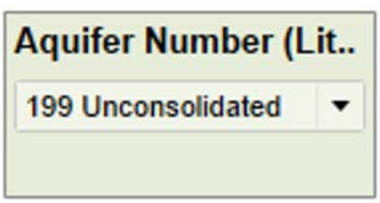


Table A-15 Water quality exceedance for aquifer# 199





APPENDIX D3

Monthly trends in dry and wet months for the median and minimum monthly water levels in different aquifers and rivers

Appendix D3

Monthly trends in dry and wet months for the median and minimum monthly water levels in different aquifers and rivers.,

Table B-1 Annual and monthly trends in well water levels (m/yr) and river flow rates ($m^3/s/yr$)

Well	Aquifer	Annual		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
OW430	#199	3.13E-05	Median	0.057	0.091	-0.008	-0.023	-0.014	0.032	-0.005	-0.033	-0.059	-0.031	-0.049	-0.026
			Min	0.022	0.099	-0.005	-0.016	0.005	0.027	-0.013	-0.029	-0.003	-0.032	-0.037	-0.0002
OW208	#199	-1.50E-04	Median	-0.084	-0.112	-0.05	-0.011	-0.047	-0.005	-0.049	-0.063	-0.057	-0.061	0.076	-0.011
			Min	-0.11	-0.08	-0.027	-0.035	-0.039	-0.016	-0.052	-0.065	-0.046	-0.062	0.076	0.016
			Average	-0.02875	-0.0005	-0.0225	-0.02125	-0.02375	0.0095	-0.02975	-0.0475	-0.04125	-0.0465	0.0165	-0.0053
				Wet months average		-0.01547		Dry months average		-0.02655					
OW320	#197	3.22E-06	Median	-0.004	-0.002	-0.009	-0.01	-0.004	-0.013	-0.02	-0.027	-0.029	-0.012	-0.005	-0.012
			Min	-0.008	-0.006	-0.013	-0.012	-0.021	-0.02	-0.039	-0.033	-0.047	-0.019	-0.008	-0.016
OW233	#197	2.78E-04	Median	0.112	0.144	0.112	0.105	0.185	0.194	0.195	0.198	0.141	0.158	0.143	0.122
			Min	0.054	0.084	0.063	0.042	0.124	0.144	0.108	0.135	0.075	0.101	0.116	0.068
			Average	0.0385	0.055	0.03825	0.03125	0.071	0.07625	0.061	0.06825	0.035	0.057	0.0615	0.0405
				Wet months average		0.046		Dry months average		0.0623					
OW297	#188	-1.80E-05	Median	-0.023	-0.06	-0.041	0.027	0.0047	-0.0102	-0.0087	-0.0077	-0.036	-0.016	-0.0088	0.0086
			Min	-0.029	-0.061	-0.049	0.023	0.00012	-0.0102	-0.0087	-0.0053	-0.036	-0.016	-0.0088	0.0021
OW298	#188	-6.22E-05	Median	0.017	0.033	0.016	0.026	0.021	0.025	0.025	0.098	0.016	0.029	0.034	0.0095
			Min	0.014	0.033	0.024	0.03	0.021	0.023	0.025	0.099	0.015	0.031	0.034	0.0074
OW211	#188	-2.76E-05	Median	-0.018	-0.026	-0.0223	-0.029	-0.035	-0.042	-0.048	-0.044	-0.043	-0.03	-0.02	-0.022
			Min	-0.032	-0.036	-0.035	-0.041	-0.052	-0.059	-0.068	-0.059	-0.057	-0.044	-0.035	-0.035
			Average	-0.01183	-0.0195	-0.01788	0.006	-0.0067	-0.01223	-0.0139	0.0135	-0.0235	-0.00767	-0.00077	-0.0049
				Wet months average		-0.00808		Dry months average		-0.00857					
08HA003	#197 #198	3.07E-05	Median	0.056	-0.074	-0.0205	-0.111	-0.032	-0.009	-0.005	-0.002	-0.002	0.0004	0.0039	-0.0048
Koksilah River			Min	0.00095	-0.045	-0.036	-0.115	-0.013	-0.007	-0.003	-0.002	-0.001	0.0005	-0.043	-0.022
			Average	0.02848	-0.0595	-0.02825	-0.113	-0.0225	-0.008	-0.004	-0.002	-0.0015	0.00045	-0.01955	-0.0134
				Wet months average		-0.02925		Dry months average		-0.0076					
08HA011	#186 #187	1.32E-04	Median	0.411	-0.291	0.018	-0.005	-0.211	-0.067	-0.089	-0.049	-0.076	0.161	0.375	-0.076
Cowichan River			Min	0.255	-0.107	-0.064	-0.053	-0.149	-0.022	-0.035	-0.016	-0.036	0.021	0.0197	-0.012
			Average	0.333	-0.199	-0.023	-0.029	-0.18	-0.0445	-0.062	-0.0325	-0.056	0.091	0.19735	-0.044
				Wet months average		0.04662		Dry months average		-0.075					