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# Hydrogeology, Ground-Water Quality, and Sources of Nitrate in Lowland Glacial Aquifers of Whatcom County, Washington, and British Columbia, Canada

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*(Selected pages)*

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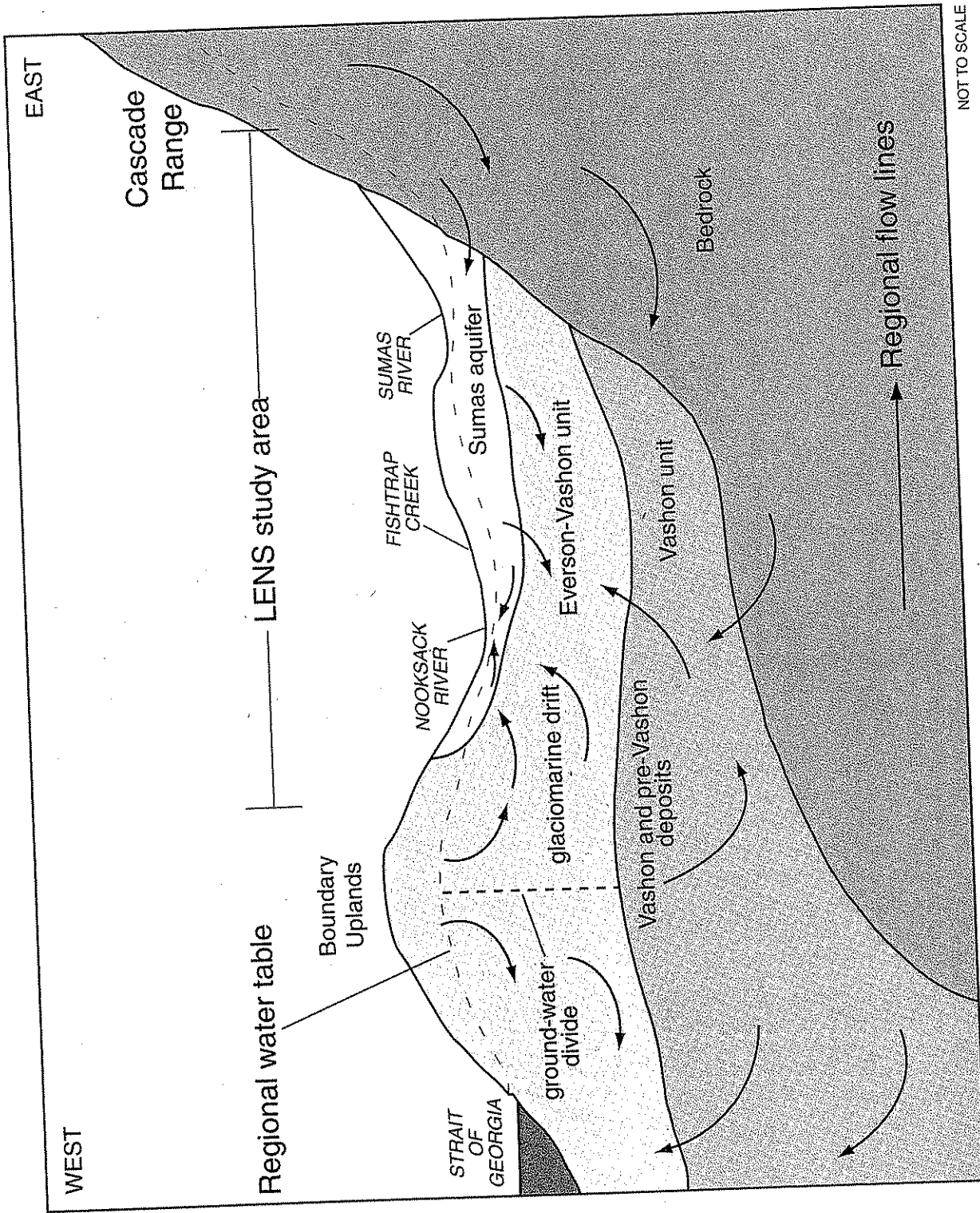
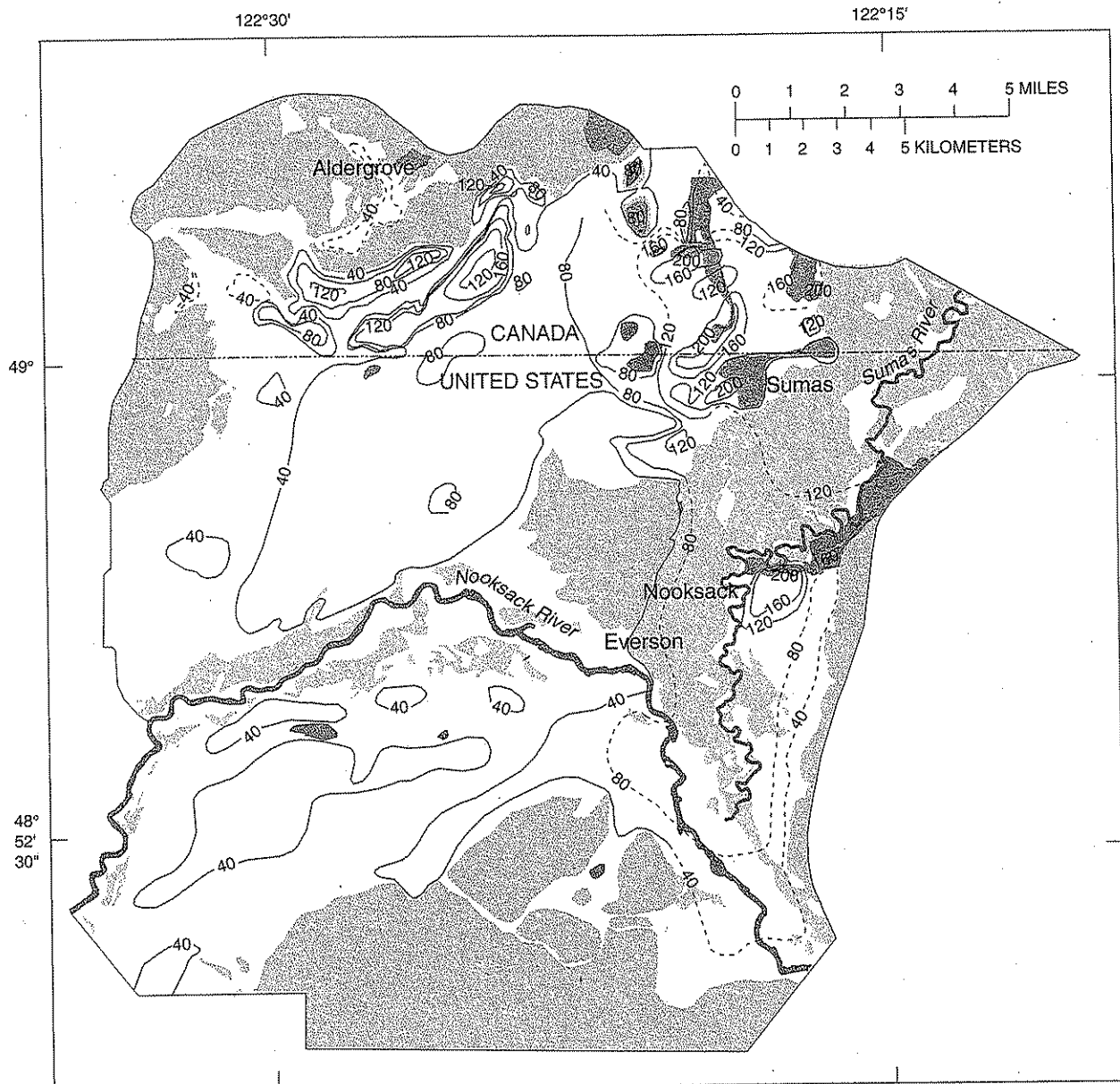








Figure 12. Conceptual model of the ground-water flow system of the Lynden-Everson-Nooksack-Sumas (LENS) study area.

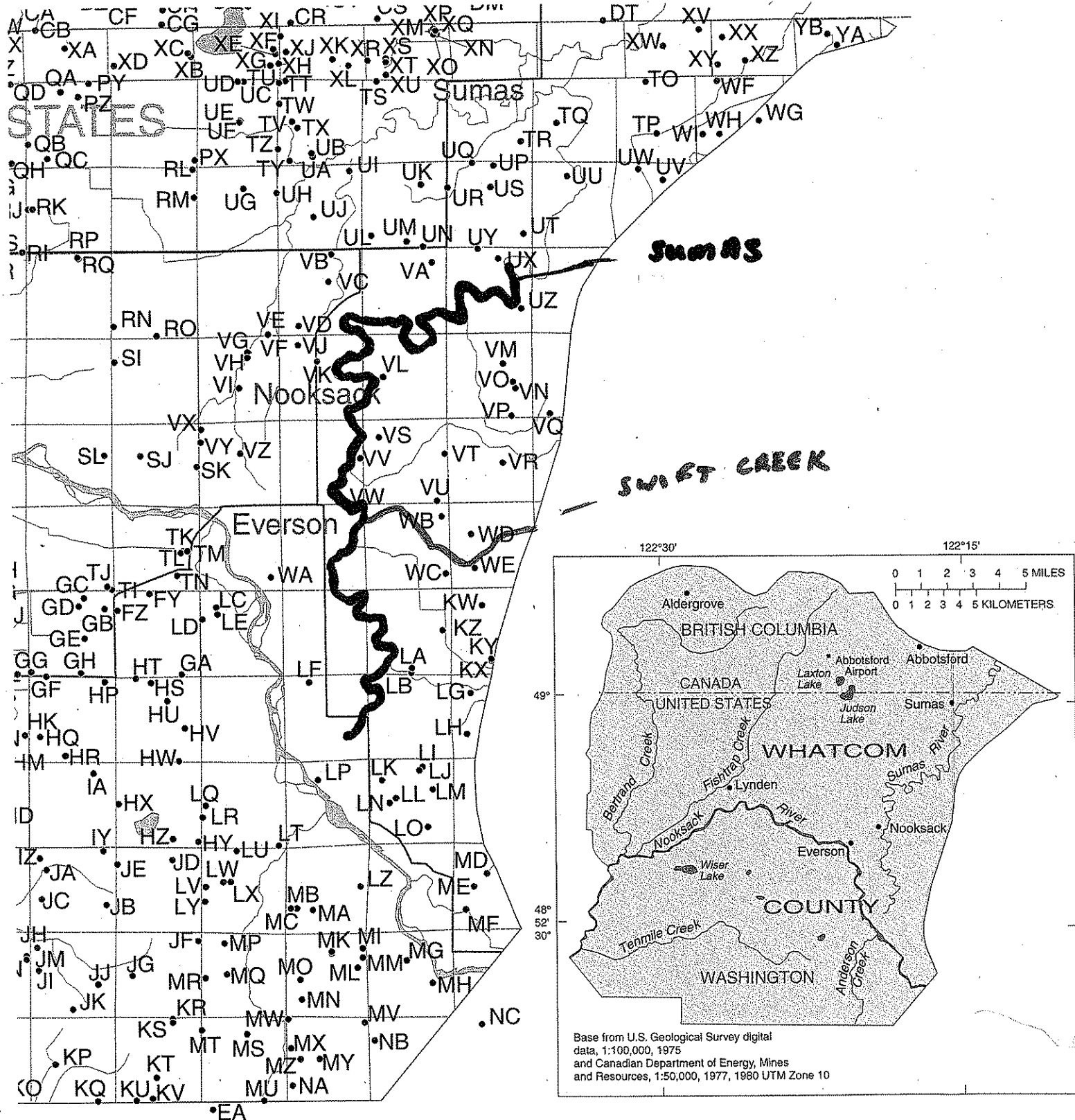


Base and hydrology from U.S. Geological Survey digital data, 1:100,000, 1975 and Canadian Department of Energy, Mines and Resources, 1:50,000, 1977, 1980.

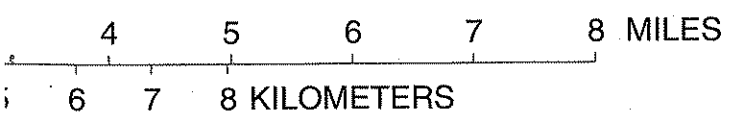
Hydrology by S.E. Cox and S.C. Kahle, 1994

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|--|--|
| <ul style="list-style-type: none"> <li> Sumas aquifer: predominantly outwash sands and gravels; generally unconfined</li> <li> Sumas aquifer: predominantly outwash sands and gravels; overlain by lacustrine silts or the fine-grained alluvial deposits, generally confined</li> <li> Sumas aquifer: intermixed sand and gravels with fine-grained ice contact deposits; shallow wells generally unconfined, deeper wells confined</li> </ul> | <ul style="list-style-type: none"> <li> Sumas aquifer not present: contact with Sumas aquifer represents zero thickness of Sumas aquifer</li> <li> Water</li> <li> —80— Line of equal thickness of Sumas aquifer; dashed where inferred; contour interval is 40 feet</li> </ul> |
|--|--|

**Figure 8.** Extent, approximate thickness, and hydrologic condition of the Sumas aquifer.



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Base from U.S. Geological Survey digital data, 1:100,000, 1975 and Canadian Department of Energy, Mines and Resources, 1:50,000, 1977, 1980 UTM Zone 10

**Table 6.** Median values and concentrations of water-quality constituents in ground waters from four hydrogeologic units

[The number of samples from each hydrogeologic unit is variable; deg C, degrees Celsius;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25°Celsius; mg/L, milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter

Water-quality constituent	Hydrogeologic units <sup>1</sup>			
	Sumas aquifer	Everson-Vashon semiconfining unit	Vashon semiconfining unit	Bedrock semiconfining unit
Temperature (deg C)	10	10.8	9.6	11.5
Specific conductance, field ( $\mu\text{S}/\text{cm}$ )	233	309	844	710
Specific conductance, lab ( $\mu\text{S}/\text{cm}$ )	231	480	1,190	1,380
pH, field (standard units)	6.5	8.0	8.3	8.4
pH, lab (standard units)	6.7	8.1	7.8	8.3
Dissolved oxygen (mg/L)	4.0	0.2	0.4	0.1
Hardness, total (mg/L as $\text{CaCO}_3$ )	86	68	130	26
Calcium, dissolved (mg/L)	22	16	35	9.9
Magnesium, dissolved (mg/L)	6.4	7.0	12	0.7
Sodium, dissolved (mg/L)	6.0	98	190	220
Sodium (percent)	13	77	48	95
Sodium adsorption ratio	0.3	5	6	24
Potassium, dissolved (mg/L)	1.4	3.8	2.2	1.2
Alkalinity (mg/L as $\text{CaCO}_3$ )	45	190	75	230
Sulfate, dissolved (mg/L)	15	2.7	5.0	1.3
Chloride, dissolved (mg/L)	8.8	7.7	182	37
Fluoride, dissolved (mg/L)	<0.1	0.3	0.2	0.4
Silica, dissolved (mg/L)	19	19	17	9.9
Total dissolved solids (mg/L)	147	252	132	567
Iron, dissolved ( $\mu\text{g}/\text{L}$ )	26	80	54	48
Manganese, dissolved ( $\mu\text{g}/\text{L}$ )	8	17	20	13
Ammonia as nitrogen, dissolved (mg/L)	0.02	0.15	0.03	0.30
Ammonia as nitrogen, total (mg/L)	0.01	0.31	0.16	0.14
Nitrite as nitrogen, dissolved	<0.01	<0.01	<0.01	<0.01
Nitrite as nitrogen, total	<0.01	<0.01	<0.01	<0.01
Ammonia plus organic nitrogen, dissolved (mg/L)	0.30	0.40	0.40	0.70
Ammonia plus organic nitrogen, total (mg/L)	0.20	0.40	0.42	0.50
Nitrate plus nitrite as nitrogen, total (mg/L)	3.8	0.10	<0.10	<0.10
Nitrate plus nitrite as nitrogen, dissolved (mg/L)	3.7	<0.05	<0.10	<0.05
Phosphate, ortho as phosphorus, dissolved (mg/L)	<0.01	0.26	0.02	<0.01
Phosphate, ortho as phosphorus, total (mg/L)	<0.01	0.73	0.09	0.03
Dissolved organic carbon (mg/L)	0.7	0.6	1.7	1.2
Boron, dissolved ( $\mu\text{g}/\text{L}$ )	20	120	30	60
Bromide, dissolved (mg/L)	0.03	0.03	<0.01	1.1

<sup>1</sup> The number of samples for each constituent from each hydrogeologic unit are shown in tables 7 to 10.

**Table 7.** Statistical summary of values and concentrations of water-quality constituents in the Sumas aquifer

[deg C, degrees Celsius;  $\mu\text{S/cm}$ , microsiemens per centimeter at 25°Celsius; mg/L, milligrams per liter;  $\mu\text{g/L}$ , micrograms per liter; <, less than]

Constituent name	Number of samples	Mean	Median	Minimum	Maximum	25th percentile	75th percentile
Temperature (deg C)	79	10	10	8.0	14	10	11
Specific conductance, field ( $\mu\text{S/cm}$ )	224	246	233	50	1,770	161	289
Specific conductance, lab ( $\mu\text{S/cm}$ )	101	264	231	72	1,220	168	294
pH, field (standard units)	78	6.7	6.5	5.6	12	6.2	6.9
pH, lab (standard units)	97	6.8	6.7	5.8	8.7	6.4	7.1
Dissolved oxygen (mg/L)	74	6.8	4.2	0	12.6	1.6	7.1
Hardness, total, (mg/L as $\text{CaCO}_3$ )	97	98	86	27	400	59	120
Calcium, dissolved (mg/L)	97	24	22	6.5	94	14	31
→ Magnesium, dissolved (mg/L)	97	9.1	6.4	1.8	51	4.7	9.4
Sodium, dissolved (mg/L)	97	8.9	6.0	3.1	61	4.7	8.7
Sodium (percent)	97	16	13	6	42	11	19
Sodium adsorption ratio	97	0.4	0.3	0.1	3	0.2	0.4
Potassium, dissolved (mg/L)	97	4.2	1.4	0.5	110	0.9	2.6
Alkalinity (mg/L as $\text{CaCO}_3$ )	97	64	45	10	560	26	70
Sulfate, dissolved (mg/L)	100	18	15	0.1	120	7.3	24
Chloride, dissolved (mg/L)	331	13	8.8	0.3	210	5.6	13
Fluoride, dissolved (mg/L)	100	<0.1	<0.1	<0.1	0.4	<0.1	0.1
Silica, dissolved (mg/L)	97	22	19	8.7	53	16	24
Total dissolved solids (mg/L)	93	169	147	53	760	109	190
Iron, dissolved ( $\mu\text{g/L}$ )	117	2,100	26	<3	36,000	6	140
Manganese, dissolved ( $\mu\text{g/L}$ )	97	160	8	<1	3,500	2	110
(per milliliter)							
Ammonia as nitrogen, dissolved (mg/L)	22	6.7	7.05	1.5	12	4.0	9.0
Ammonia as nitrogen, total (mg/L)	97	1.1	0.02	<0.01	63	<0.01	0.06
Nitrite as nitrogen, dissolved (mg/L)	65	1.3	0.01	<0.01	46	<0.01	0.03
Nitrite as nitrogen, total (mg/L)	97	0.02	<0.01	<0.01	0.37	<0.01	0.01
Ammonia plus organic as nitrogen, dissolved (mg/L)	65	0.02	<0.01	<0.01	0.34	<0.01	0.01
Ammonia plus organic as nitrogen, total (mg/L)	96	1.5	0.30	<0.2	63	0.20	0.60
Nitrate plus nitrite as nitrogen, total (mg/L)	39	2.6	0.20	<0.20	50	0.20	0.51
Nitrate plus nitrite as nitrogen, dissolved (mg/L)	230	5.6	3.8	<0.05	43	0.60	8.8
Phosphate, ortho as phosphorus, dissolved (mg/L)	108	6.0	3.7	<0.05	43	0.44	9.8
Phosphate, ortho as phosphorus, total (mg/L)	81	<0.10	<0.01	<0.01	3.3	<0.01	0.01
Dissolved organic carbon (mg/L)	65	<0.01	<0.01	<0.01	0.14	<0.01	0.01
Methylene blue active substances, MBAS (mg/L)	71	2.0	0.7	0.2	39	0.5	1.2
Boron, dissolved ( $\mu\text{g/L}$ )	56	<0.02	<0.02	<0.02	0.09	<0.02	<0.02
Bromide, dissolved (mg/L)	59	20	20	10	120	10	30
	33	0.15	0.03	0.01	3.1	0.01	0.04

**Table 13.** Summary of concentrations of trace elements in ground water from four hydrogeologic units  
 [--, no U.S. Environmental Protection Agency (USEPA) drinking water guideline; HC = Health Canada; < = less than]

Element	Number of wells with analysis reported	Number of wells with elements detected	Number of wells with elements not detected in analysis	Detected concentrations, dissolved, in micrograms per liter			USEPA and (HC) drinking water reference* (µg/L)	Number of wells exceeding standard
				Minimum	Median	Maximum		
Arsenic	48	6	42	1	1.5	**6	50 (50)	0
Barium	43	40	3	3	12	1,100	2,000 (1,000)	0 (1)
Beryllium	18	0	18	--	--	--	4	0
Cadmium	46	2	44	1	2	3	5 (5)	0
Chromium	46	1	45	2	2	2	100 (50)	0
Cobalt*	28	1	27	3	3	3	--	0
Copper	46	35	11	1	6	190	1,300b (1,000)	0
Lead	44	2	34	1	1	1	15b (10)	0
Lithium	6	2	4	4	11	18	--	0
Mercury	18	0	18	--	--	--	2 (1)	0
Molybdenum*	28	3	25	10	20	40	--	0
Nickel	28	0	19	--	--	--	100 (10)	0
Selenium	30	1	29	1	1	1	50	0
Silver	36	9	27	1	1	2	100a	0
Strontium	18	18	0	49	102	1,700	--	0
Vanadium	28	3	25	3	5	6	--	0
Zinc*	46	43	3	6	30	240	5,000a (5,000)	0

\* Primary drinking water standard, unless noted, a = secondary standard, b = action level.

\*\* Two wells reported non-detects at 250 µg/L, not included in concentration range.