

Aquifer Classification Worksheet for Wark-Colquitz Aquifer (680)

Aquifer number: 680

Proposed name of aquifer: Wark-Colquitz Aquifer (680).

Aquifer Classification: IB (14)

Aquifer Priority Ranking for Observation Wells: 68.33

Descriptive location of aquifer:

The aquifer is found on south-eastern Vancouver Island, covering a land area that includes much of the municipalities of Colwood, Langford, and all of Esquimalt, Victoria, Oak Bay, Saanich, View Royal and District of Highlands.

Date: June 2004. (New well information from 092B053 was included and overall statistics were updated on March 13, 2012 by Margaret Scott)

NTS mapsheet: 092B/05, 092B/06, 092B/11, 092B/12.

TRIM mapsheets: 092B.043, 092B.044, 092B.053, 092B.054.

What geological formation does the aquifer belong to?

Four bedrock types are included within this single aquifer: Colquitz gneiss, Wark gneiss, Karmutsen volcanics, and Leech River metavolcanic and metasedimentary bedrock. The majority of the aquifer is made up of Paleozoic crystalline igneous and meta-igneous rocks of the West Coast Crystalline Complex, which includes the Wark-Colquitz Complex. This metamorphic complex has been described by Massey (1994), and includes quartz diorite, tonalite, hornblende-plagioclase gneiss, quartz-feldspar gneiss, amphibolite, diorite, agmatite, gabbro, marble and metasediments. On the eastern area of the aquifer, the rock is mainly the Colquitz gneiss, a quartz-rich, layered, dark to light coloured unit that is thought to have formed from sedimentary protolith¹. On the mid- to west area of the aquifer is found the Wark gneiss, a darker, more massive, hornblende-rich meta-igneous to meta-volcanic rock formed from an igneous diorite and volcanic protolith, which is interbedded with the lighter Colquitz gneiss. The Wark-Colquitz complex is separated from the meta-volcanic rocks of the Leech River Complex to the west by the San Juan-Survey Mountain Fault, in the area of Florence Lake and Mt. Finlayson (Yorath and Nasmith, 1995).

¹ The primary rock from which the metamorphic rock was formed.

Lesser bedrock units, mainly concentrated along the western area of the aquifer, include Jurassic to Cretaceous meta-volcanic and meta-sedimentary rocks of the Leech River Complex, which includes meta-basalt, meta-rhyolite, chlorite schist, ribbon chert and cherty argillite, or slate, phyllite, schist, meta-greywacke, meta-arkose and interbedded meta-volcanic sequences (Massey, 1994). The meta-volcanic Leech River Complex also occurs in the municipality of Oak Bay between Oak Bay and McNeill Bay. At Gordon Head, at the south end of Cordova Bay, there is an isolated occurrence of Middle to Upper Triassic Karmutsen Formation (Vancouver Group) a volcanic basalt and tuff unit that makes up the adjacent aquifer (614) to the north (Yorath and Nasmith, 1995; Massey, 1994).

The majority of well records describe the bedrock of this aquifer as green, white, and black “granite.” Other records describe the occurrence of diorite and gabbro with feldspar and quartz veination; dark volcanics including red and black basalt; sedimentary rock such brown, black and green siltstone, brown and grey sandstone; with lesser occurrences of chert, mainly in the uplands of the Gowland-Tod mountain range in the Highlands area. Limestone (thought to be associated with the “marble” of the Wark-Colquitz complex) is described within approximately 50 wells, in the Mill Stream area, south of Teanook and Matsan Lakes, along Millstream Lake Road, and as far east as Prospect, Elk and Beaver Lakes on the Saanich Peninsula. Numerous well records also indicate subsurface layers of trace water-bearing “soft” rock, which may be weathered granitic bedrock or grus, described by Clapp (1913), possibly concentrated within zones of high fracture density.

What type of aquifer is it (unconsolidated/bedrock? Confined/unconfined)?

The aquifer is a partially confined bedrock aquifer. Confinement is provided clay and till sediments. Pleistocene till (poorly sorted silt, sand and gravel) are found in isolated occurrences, generally less than a few meters thick, though thicker drumlinoid ridges of these sediments, overlain by Victoria clay, are found in the area of the University of Victoria and Cadboro Bay. Monahan and Levson (2000) indicate that Victoria clay is found over much of the study area, generally below an elevation of 60 m. This clay was formed at the end of the Fraser Glaciation (13,000 years B.P.) (Blyth and Rutter, 1993a) and is classified as brown or grey clay according to the degree of permanent saturation (Monahan and Levson, 2000). The clay unit can reach thicknesses of up to 20 m or greater locally, but is generally < 10 m thick, with varying thicknesses of grey and brown facies. Colluvial weathered bedrock forms the surficial layer over much of aquifer, in particular at elevations higher than 60 m (Monahan and Levson, 2000; Blythe and Rutter, 1993b, 1993c).

How was the aquifer boundary delineated?

The aquifer boundaries were determined based on the location of major bedrock contacts shown on the geology map by Massey (1994). The marine coastline along the Juan de Fuca and Georgia Strait forms the southern and eastern aquifer boundaries, and the western boundary is formed by the coastline at Finlayson Arm, in the Saanich Inlet. The northern boundary lies on the southern

Saanich Peninsula in the area of Elk and Durrance Lakes; while the south-western margin extends from Finlayson Arm, along Goldstream River and Langford Creek to Langford Lake, and southeast along the Survey Mountain Fault boundary to Esquimalt Lagoon (Yorath and Nasmith, 1995; Massey, 1994).

The information provided from the well logs was insufficient to distinguish between the major bedrock units of the aquifer; Clapp (1913) noted that the Colquitz gneiss intruded as a batholith upon the Wark gneiss, and the two rock types are mixed and largely indistinguishable as separate rock bodies over the aquifer area. All of the bedrock has undergone varying degrees of metamorphosis, therefore the occurrence and properties of fractures, which are the primary conduits for water flow in the rock, are expected to be similar between the metamorphic bedrock types.

What is the size of the aquifer? 209.0 km²

What is the aquifer's productivity?

The productivity of the aquifer is considered moderate. The aquifer is comprised of fractured meta-igneous, meta-volcanic and meta-sedimentary bedrock, which may be expected to produce higher yields than igneous or volcanic bedrock, due to pervasive fracturing that can occur during metamorphism and orogeny². However, the average yields are generally lower than for unconsolidated sand or gravel aquifers.

The median estimated well yield (based on 1222 wells or 96% of well records) is 0.32 L/s (5.0 gpm), ranging from 0.0032 to 16 L/s (0.050 to 250 gpm). The arithmetic mean estimated well yield is 0.76 L/s (12 gpm). Approximately 5.2% of the wells produce yields greater than 3.0 L/s (50 gpm), 51% of the wells have estimated yields between 0.3 and 3.0 L/s (5 – 50 gpm), and 43.8% have estimated yields < 0.3 L/s (5 gpm). Transmissivity, based on pump tests of four high capacity wells in the District of Highlands, ranges from 3.15×10^{-4} m²/s to 7.25×10^{-4} m²/s (2190 to 5040 USgpd/ft); while the storativity ranges from 7.28×10^{-4} to 1.38×10^{-3} (Thurber Engineering Ltd., 2003). The aquifer is expected to yield low water quantities, via joints and fractures in the bedrock, rather than through primary porosity. Karst topography, associated with the occurrences of limestone and marble, may also provide conduits for water flow; for example, small caves and sinkholes are found in the area of Munn Rd. and Millstream Lake Rd.

What is the groundwater pumped from the aquifer used for?

The groundwater is used predominantly for drinking water in areas such as District of Highlands, and parts of Saanich and View Royal where connection to a municipal surface water supply is not available (Capital Regional District, 2002). A total of 722 wells (56.5%) are classified for

² Process of mountain building, including deformation, folding, faulting and uplift of bedrock bodies, due to tectonic plate movement.

domestic use, 12 wells (0.9%) are used for irrigation, and 6 wells (0.47%) are classified for other purposes (including commercial use). Well usage is classified as unknown for 531 wells (41.6%) which are thought to be largely for domestic use, and 1 well has been slated for observation of water levels and well interference in the Millstream Road area (Thurber Engineering Ltd., 20023). Domestic and irrigation water is also obtained from Mill Stream, Langford Creek, Goldstream River, Hazlitt Creek, Craigflower Creek, Colquitz River, Blenkinsop Creek and Elk, Beaver, Prospect, Blenkinsop, Durrance, Pease, Eagles, Teanook, Fork, Maltby, Pike, McKenzie, Thetis, Second, Third, Mitchell, Florence, Colwood, and Langford Lakes. There are seventy-three issued water licences for these water bodies, for the purposes of domestic use, conservation, storage, power, irrigation, waterworks and land improvement (Land and Water B.C. Inc., 2004). Within the City of Victoria and immediately surrounding areas, many of the historically constructed wells are likely not used, or are abandoned, and wells are thought to be used mainly for irrigation supply.

What is the level of groundwater demand?

The level of groundwater demand is interpreted to be high. There are records of 1276 wells completed into this aquifer, corresponding to a well density of 6.1 wells/km². Well use is thought to be low within the majority of the aquifer area in the municipalities of Victoria, Oak Bay, Esquimalt, View Royal, Colwood and Langford, where the main water supply is from the Greater Victoria Water Supply Area (CRD Water District). However, water demand is interpreted as high due to the high density and usage of wells in the District of Highlands, on the western part of the aquifer, where municipal water supplies are not available.

Describe the reliance on the aquifer for supply.

Reliance on the aquifer water supply is considered moderate. The rationale is similar as for demand, above, where there is a low demand over much of the aquifer area, but a high demand in specific areas such as the District of Highlands, where there is no opportunity to connect to a municipal domestic water supply. Irrigation and domestic drinking water may be obtained from the surface water bodies listed above.

Are there any known water use conflicts?

There are no water use conflicts reported for the aquifer. However, due to the linear, rather than radial, flow characteristics of water in fractured bedrock aquifers, potential exists for well interference along major fracture networks.

Describe the groundwater flow direction(s).

Groundwater is expected to flow from high elevation recharge areas to discharge areas at lower elevations. The information available at present is insufficient to describe the groundwater flow direction.

Describe the source(s) of recharge to the aquifer.

The source of aquifer recharge is thought to be from infiltration and runoff of precipitation throughout the surface watershed area overlying the aquifer, or locally from surface stream and river infiltration. Local tributaries and wetlands are also expected to be a source of aquifer discharge.

How deep is the water table or the aquifer?

The arithmetic mean depth to the water table is 17 m (56 ft), and the median depth to water is 6.1 m (20 ft) ranging from 0.30 to 110 m (1.0 to 360 ft). These values may not be representative as they were calculated using information available from 171 of 1276 well records (13 % of the wells). The arithmetic mean well depth is 73 m, the median well depth is 61 m, the minimum well depth is 4.3 m, and the maximum well depth is 250 m (239.5, 200, 14 and 820 ft respectively). The bedrock layer is relatively shallow; the arithmetic mean depth to bedrock is 2.8 m (9.2 ft), median bedrock depth is 1.5 m (4.9 ft) ranging from 0 to 65 m (0 to 213 ft). The majority (74%) of water bearing fractures are observed at depths from 0 to 61 m (0 to 200 ft); while the highest yielding fractures are observed between depths of 30 to 61 m (100-200 ft). A qualitative assessment of well lithology suggests that fracture yield increases with depth of occurrence. This was also observed by Yusuf AlMooji (1982) when he studied the hydrologic properties of the highland of Saanich granodiorite aquifer. However, a preliminary examination of the data does not confirm any correlation between fracture depth and yield.

Is the aquifer vulnerable to human activities at the land surface? If so, why?

The aquifer as a whole is considered moderately vulnerable to contamination from surface pollutants. Parts of the aquifer are overlain by Capilano sediments and Vashon till, in the form of unconsolidated sand, gravel, silt, till and clay (Monahan and Levson, 2000; Blythe and Rutter, 1993a, 1993b and 1993c). Marine clay ranging from <1 m up to 20 m thick is observed at elevations below 60 m over much of Victoria and Esquimalt and glacial diamict, including compacted silty sand and gravel, has been mapped in parts of Saanich, including along the eastern margin of aquifer 680 at Cadboro Bay (Monahan and Levson, 2000). Upland areas (above approximately 60 m elevation) in particular on the western side of the aquifer are considered to have a much higher degree of intrinsic vulnerability, as they are generally overlain by shallow weathered bedrock or colluvium, with little or no confining properties (Monahan and Levson, 2000; Blythe and Rutter, 1993a, 1993b and 1993c). In 26% (329 of 1276 wells) there is a confining layer of clay, till or combined clay and till. Approximately 64% (815 wells) indicate no confining layer is present. In an additional 10% of the wells there was insufficient information to confirm the presence or absence of a confining layer. The arithmetic mean and median depth of confinement are 4.5 m and 3.0 m respectively (15 and 10 ft). The range of confining layer thickness is from 0.15 to 36 m (0.5 to 118 ft). The boundaries of this aquifer do coincide with the coastline indicating that the aquifer may be vulnerable to salt water intrusion. Vulnerability indices such as the Aquifer Vulnerability Index (Van Stempvoort, et al., 1993) or DRASTIC (Aller, et al., 1987) were not used to evaluate individual well or aquifer vulnerability at this time.

Are there any documented water quantity concerns?

There are no concerns regarding water quantity documented in Water Protection Section files.

Are there any documented water quality concerns that are health-related?

High iron concentrations have been reported in some areas (Bruce Woodbury, Administrator, District of Highlands, pers. comm., April 29, 2004). Laboratory analytical data from the Millstream Road area indicate the water is moderately hard (Thurber Engineering Ltd., 2003), likely due to the presence of limestone and calcite veination. Locally, the aquifer has been impacted from leachate from the Capital Regional District (CRD) Hartland Landfill, where leachate collection and observation well networks have been established to monitor and prevent contaminant transport off-site (Mary Anne Fillipone, Supervisor, Hartland Environmental Contaminated Sites Environmental Programs, pers. comm., June 23, 2004). Numerous contaminated sites exist overlying the aquifer; however, no WLAP files indicate associated impact to water wells. Within Water Protection Section files there are no health-related water quality concerns affecting wells in the aquifer.

Observation Wells

There are no WLAP Observation Wells constructed within the aquifer.

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Aquifer Classification Summary for Wark-Colquitz Aquifer (680)

Classification

Level of development (use):	I – High
Degree of vulnerability:	B - Moderate
Classification	IB

Ranking Value

Productivity:	2 – Moderate
Vulnerability:	2 – Moderate
Size:	3 – >25 km ²
Demand:	3 – High
Type of Groundwater Use:	3 – Multiple use
Documented Quantity Concerns:	0 – None reported
Documented Quality Concerns Related to Human Health:	1 – Isolated
Rank	14

Aquifer classification by: S. Kenny
 Reviewed by: M.Wei, P.Eng.

	Well Depth (m)	Water Depth (m)	Bedrock Depth (m)	Yield (L/s)	Confining Thickness (m)
COUNT	1274	170	1038	1222	329
ARITHMETIC MEAN	73	17	2.8	0.76	4.5
GEOMEAN	NC	NC	NC	0.35	NC
MEDIAN	61	6.1	1.5	0.32	3.0
MIN	4.3	0.30	0.0	0.0032	0.15
MAX	250	110	65	16	36