COWICHAN VALLEY REGIONAL DISTRICT

South Cowichan Water Plan Study

A Preliminary Assessment of Water Supply & Needs within the South Cowichan Region

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SYNOPSIS

WorleyParsons and Westland Resource Group were jointly retained by the Cowichan Valley Regional District (CVRD) to undertake a preliminary water plan study of the South Cowichan region. This water plan study was designed to provide CVRD with the tools necessary to develop a water management framework for the region that will maintain its unique hydrological and ecological values while supporting appropriate kinds and scales of human activities.

The region that forms the subject of this report (the Study Area) consists of CVRD's Electoral Areas A and C in their entirety, and those parts of Electoral Areas B, D, and E that lie within the Shawnigan, Cowichan and Saanich Inlet watersheds. The Study Area covers 20,853 hectares of land, and is centred on latitude 48^{o}38'N and longitude 123^{o}36'W (UTM coordinates 5388132N 455163E, Zone 10).

The main objectives of this project were as follows:

- To compile a comprehensive summary of existing technical information relating to the region's current water resources and needs, including calculation of the area's existing water balance using available data and evaluation of interactions between its key components;
- To estimate future population growth, land use patterns, and water supply / demand for the next 30 years using projections based on past trends, with emphasis on the identification of key issues that could potentially result in water shortages within the region;
- To evaluate the effects of existing government policies and regulations on water use within the region; and
- To develop a Terms of Reference for CVRD that will facilitate the development of a comprehensive Water Management Plan for the region that will ensure the South Cowichan region's water supply is capable of meeting projected demand in a sustainable and ecologically sensitive fashion.

At the request of CVRD, water resource data collection and evaluation focused on defining the occurrence, distribution, development, and usage of groundwater within the Study Area.

The key findings of this study are presented below.

Water Uses and Needs

- The three watersheds in the South Cowichan area each support a diverse range of land uses and ecological habitats;
- More than 17,000 people currently live in the South Cowichan communities of Cobble Hill, Mill Bay, Malahat, Shawnigan Lake Village, and Cowichan Bay, and are contained within 7,477 housing units. The Shawnigan watershed contains the greatest number of housing units (3,992), followed by the Cowichan watershed (2,680 units), and the Saanich Inlet watershed (805 units). Provincial government estimates suggest that the number of housing units in South Cowichan could grow by 28% to 9,500 by 2036. If residential developments now being planned are built, the number of units

could potentially reach 13,700 by 2036. Depending on the extent of future development, the 2036 population could range from 22,000 to 32,000. It is important to recognize that global phenomena, such as climate change and economic fluctuations, increase the uncertainty associated with projections of future growth in the South Cowichan area;

- A variety of plans, regulations, and guidelines currently affects water and land use in the South Cowichan area. Ten provincial acts and four federal acts are relevant to water and watershed management in the Study Area, and community land use plans have been developed for all of its electoral areas. CVRD authority in water management is presently unclear since local governments' abilities to implement and enforce water use policies within their jurisdictions are limited by the present water governance structure in British Columbia;

- Uncontrolled water use for farming, cattle rearing, wineries, and new land development projects in the South Cowichan area will place increasing pressure on its existing water resources. The present estimated water demand for all land uses use within the South Cowichan area is estimated at 26 million m^3/yr. By 2036, these demands may grow to 34 million m^3/yr. With active water conservation measures and urban densification, total water demand in 2036 could remain the same as today's estimated consumption, as would the distribution of demand among future agricultural, residential, and other urban uses. Without conservation, the residential component could grow from 7 to 10 million m^3/yr, which highlights the importance of future land use decisions as part of a sound water management strategy;

- Agricultural activities account for a substantial proportion of current water use in the South Cowichan area (15 million m^3 for agricultural use, compared to 7 million m^3 for residential and 3 million m^3 for "other" urban uses). Detailed information is not presently available concerning the amounts of water used by different agricultural activities. Based on the disproportionate use of water by agricultural activities within the Study Area, prudent water management planning should carefully consider the value of conservation measures to ensure that an adequate supply of water is available for the region's other users, and should identify potential obstacles to attaining water use efficiencies;

- The South Cowichan area's five First Nations reserves and major non-governmental water users (primarily educational institutions) constitute a relatively small component of its overall water use, although their demand volumes in the Shawnigan and Cowichan watersheds exceed commercial and industrial consumption. Water use on First Nations reserves is currently fairly limited, but may grow significantly as their respective residential community plans and commercial developments are implemented;

- The relative proportion of current groundwater to surface water use within the Study Area is not currently known with precision, since regional groundwater extraction rates are not monitored with the same accuracy as surface water diversion rates;

- The hydrology and patterns of water use in the South Cowichan area could change substantially by the conversion of existing forest land to urban uses. More information on the likelihood of these conversions will be needed as the water planning process proceeds. Specific estimates water supply demand to service new forest-urban land conversion developments should be undertaken, as well as projections regarding the extent of potential modifications to the surface water and groundwater hydrological regimes on the subject developments and their cumulative effects on downstream land parcels; and

- Many opportunities exist in the South Cowichan area for water conservation and demand reduction, although very little area-specific information on these topics is currently available. Future regional water planning should include the identification and implementation of such measures, which could be used to forecast future water use more accurately and determine the potential effects of urban growth on the area's groundwater and surface water resources.

Groundwater

- Government mapping has delineated 13 groundwater aquifers within the South Cowichan area. Surficial aquifers are mainly hosted by unconsolidated glaciofluvial and morainal sand and gravel deposits of the Vashon Drift and Capilano Sediments. Bedrock aquifers are hosted in discrete fracture zones within a wide range of consolidated bedrock lithologies and ages;
- There are very few regional-scale geologic cross-sections currently available for the South Cowichan area that demonstrate its aquifers' hydrostratigraphic settings or connectivity. Groundwater flow directions have been inferred from the presence of prospective recharge zone (upland locations) and discharge zones (rivers, streams, lakes and marine environment). Groundwater flow directions in surficial aquifers are expected to be largely topography driven, while flow in bedrock aquifers may also be subject to site-specific geologic controls (location and inter-connectivity of fracture zones);
- Surficial aquifers within the Study Area appear to be generally more productive than bedrock aquifers, but are highly variable from one aquifer to the next due to significant localized differences in media conductivity and stratigraphy;
- Government mapping suggests that bedrock aquifer productivities generally increase eastward within the Study Area, although this assertion appears to have been based on airlifted yields recorded at the time of well completion as opposed to evaluations of the region's hydrostratigraphic settings and structural geologic regimes. Given the comparatively large surface extent of the area's mapped bedrock aquifers and the currently inadequate level of understanding of their geological settings, significant opportunities may exist for increasing bedrock groundwater use. However, identifying productive bedrock groundwater zones (fractures) may prove to be technically challenging and costly;
- Total annual groundwater inflows from natural recharge within the South Cowichan area may range between 25 million m^3 and 110 million m^3, with a best estimate of about 45 million m^3. Based on this best estimate recharge value and assuming that roughly 50% of total water usage within the Study Area originates from groundwater sources, it is estimated that about 30% of annual groundwater inflows may be currently allocated for water use, with the remainder (70%) being available for discharge to streams, lakes, wetlands and the marine environment. A portion of irrigation and domestic water use is also expected to end up as groundwater return flow (artificial recharge). Taking uncertainty of recharge into account, the confidence in these estimated percentages is relatively low;

- Areas where surficial aquifers are unconfined and may permit relatively high groundwater recharge rates, or areas where bedrock aquifers outcrop at the land surface or are overlain by a thin soil veneer, are expected to be characterized by relatively high groundwater vulnerability to surface contamination. A collaborative vulnerability mapping project for the area is currently being completed by others (the "Vancouver Island Water Resources Vulnerability Mapping Project"), the findings from which should form an integral part of the future South Cowichan area water plan;
- Groundwater recharge may potentially increase due to climate change, leading to a possible positive impact on water supplies. The degree to which this will occur is dependent on local geological constraints (for example, low permeability tills or massive bedrock might locally limit groundwater infiltration). Climate change may negatively affect groundwater resources through increased evaporation in areas where shallow water table conditions exist;
- Long-term trends in water levels measured for MOE observation wells in the Cherry Point aquifer were correlated against precipitation records. Water levels in this aquifer have declined in recent years, which have been attributed to increased groundwater use. This study suggests that water level declines may be due to a combination of groundwater withdrawals and natural fluctuations, given that the 2000 to 2005 period was characterized by below-average annual precipitation. Shallow domestic wells in particular appear to be very sensitive to either natural or anthropogenically-induced declines in water table elevation, as evidenced by the need for deepening of some domestic wells in the Cherry Point aquifer. The analysis of well hydrographs for the Cherry Point aquifer seem to confirm that surficial groundwater systems within the South Cowichan area may be highly sensitive to climate variability; and
- This study revealed the hydrostratigraphic complexity of the region's groundwater aquifers, the current lack of quantitative information regarding these aquifers' development and usage, and the general sparseness of reliable data. Consequently, the understanding of the Study Area's groundwater resources at this time remains conceptual and largely qualitative in nature, which indicates the need for the development of an area-specific groundwater assessment to address current knowledge gaps. The development of a groundwater model for the region is recommended. This model could be used to distinguish between natural and anthropogenic pressures on groundwater flows, determine groundwater budgets on an aquifer-by-aquifer basis, support aquifer recharge zone and well-specific vulnerability assessments and protection strategies, and facilitate long-term water supply planning. Steps required to complete this new groundwater model development are outlined within this report.

Surface Water

- The British Columbia Ministry of Environment's (MOE's) climate models predict that the availability of water within South Cowichan by the year 2050 may be influenced by increases to the average air temperature by 2 to 3°C and annual precipitation by 20%, that summers will be hotter and drier while the winters will be wetter, and that the frequency of 24-hr precipitation events greater than 80mm will increase;

- Monthly water balance models were developed as part of this project to estimate the current and future volume of surface water within the South Cowichan region. These models were based on unit-area runoff estimates, precipitation, lake evaporation, surface water abstractions, and climate change scenarios.
- The results of this modelling for all scenarios (current and future) suggest that an overall net annual surplus of surface water can be expected, with a significant excess of surface water during the winter months (December through March) and a slight deficit during the late summer months and early fall (note that monthly surface water balance deficits do not necessarily indicate that creeks and rivers are dry during the summer months, but that dry weather flows are maintained by release of water stored in lakes and groundwater base flows).
- The present calculated water balance for the South Cowichan area shows an annual net surplus of approximately 135 million m^3, increasing to 160 million m^3 by 2036 as the result of drier summers, warmer temperatures, and increase demand. The 33% water efficiency goals set by British Columbia's 'Living Water Smart' water plan only have a slight impact on the overall water balance, increasing the 2036 annual net surplus by 4%, with the summer/early fall months still in deficit; and
- Summer low flows in Lower Shawnigan Creek are detrimental to aquatic system health and are due in part to having insufficient lake storage to support both domestic use and downstream needs in summer. Low flow issues are also apparent in many creeks and streams within the South Cowichan area, including Garnett Creek, Johns Creek, and Spectacle Creek. These issues may be linked to excessive surface water diversion, decreased groundwater base flow, and/or climate variability.

Knowledge Gaps and Issues Requiring Further Study

It is recommended that a phased approach be adopted to develop a Water Management Plan for the South Cowichan area, with major existing knowledge gaps being addressed as stand-alone studies prior to development of the Plan. Recommended studies to be conducted prior to development of the Water Management Plan include the following:

- The acquisition of more detailed current surface water and groundwater withdrawal data is necessary to allow a better understanding of potential demand versus supply issues. This will require co-operation from major water users (improvement districts, etc.) and involvement from CVRD;
- A comprehensive, area-specific groundwater resource evaluation should be completed, which will culminate in the development of a numerical model that will establish detailed water budgets on an aquifer-by-aquifer basis. The groundwater resource evaluation and model development should take into account findings from MOE's aquifer vulnerability mapping project currently being completed, and use the model to refine understanding of local aquifer vulnerabilities;
- A comprehensive, baseline surface water quality monitoring program should be undertaken. This program should include, at a minimum, the collection of surface water samples on a quarterly basis from the area's key streams, lakes and reservoirs over a 1 to 2 year period. Prospective sampling locations should be identified through consultation with regional directors to identify potential areas

of concern. Those locations for which the baseline program indicates possible water quality concerns could be incorporated in a longer-term monitoring program; and

- The potential effects of regional, national, and global pressures on population trend projections for the CVRD should be considered. Climate change could alter migration of people from areas experiencing water supply shortages or sea level increases. Economic upheavals and demographic shifts in Canadian society might also change housing choice and settlement patterns. The effects of such phenomena are difficult to anticipate and may increase the uncertainty in population trend projections for the CVRD.

Water Management Plan

Once the supplemental investigations and monitoring programs outlined above have been undertaken, a comprehensive Water Management Plan for the South Cowichan area can be developed to address issues raised by this preliminary study. Terms of Reference for the creation of this Water Management Plan are presented in this report.

Completion of this Water Management Plan should result in the following tangible benefits:

- Enhanced understanding of local water issues;
- A workable management structure for each of Study Area's three watersheds over a 30-year planning horizon that represents the interests of all stakeholders; and
- A sense of balance between the future water needs of agriculture, a growing population, and the ecosystems of the South Cowichan area.

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1. INTRODUCTION

1.1 Terms of Reference

WorleyParsons and Westland Resource Group were jointly retained by the Cowichan Valley Regional District (CVRD) to undertake a preliminary water plan study of the South Cowichan region. This water plan study is designed to provide CVRD with the tools necessary to develop a water management framework for the region that will maintain its unique hydrological and ecological values while supporting appropriate kinds and scales of human activities.

The main objectives of this project are as follows:

- To compile a comprehensive summary of existing technical information relating to the region's current water resources and needs, including calculation of the area's existing water balance using available data and evaluation of interactions between its key components;
- To estimate future population growth, land use patterns, and water supply / demand for the next 30 years using projects based on past trends, with emphasis on the identification of key issues that could potentially result in significant water shortages within the region;
- To evaluate the effects of existing government policies and regulations on water use within the region; and
- To develop a Terms of Reference for CVRD that will facilitate their eventual development of a comprehensive Water Management Plan for the region that will ensure the South Cowichan region's water supply is capable of meeting projected demand in a sustainable, ecologically sensitive fashion.

At the request of CVRD, water resource data collection and evaluation focused on defining the occurrence, distribution, development, and usage of groundwater within the Study Area.

Conclusions and recommendations presented herein are based on desktop reviews of publicly-available technical literature, private and public Internet websites, aerial photographs, and local regulatory / planning documents, as well as personal interviews with individuals familiar with the water resources and demands of the region. No intrusive investigations were conducted as part of this study.

1.2 Study Area Location

The South Cowichan region is situated near the south end of Vancouver Island along its east shore. The region that forms the subject of this report (the Study Area) consists of CVRD's Electoral Areas A and C in their entirety, and those parts of Electoral Areas B, D, and E that lie within the Shawnigan, Cowichan and Saanich Inlet watersheds (see Figure 1).

The Study Area covers 20,853 hectares of land, and is centred on latitude 48^{o}38'N and longitude 123^{o}36'W (UTM coordinates 5388132N 455163E, Zone 10).

1.3 Community Settings & Challenges

More than 17,000 people live in the rural communities of Mill Bay, Malahat, Shawnigan Lake, Cobble Hill, Cowichan Bay, and Cowichan Station. The region's temperate climate, high recreational and landscape value, and proximity to larger urban areas (Duncan and Victoria) make the South Cowichan region a highly desirable place for people to live, work, and enjoy recreational pursuits. Water use for farming, cattle rearing, wineries and growing development has already put pressure on the water resources of South Cowichan.

Population within the South Cowichan area is projected to grow by more than 4,400 people over the next three decades[1]. This significant growth will be accompanied by an increased demand for water, placing even greater strain on this crucial resource. Consequently, CVRD has determined that a Water Management Plan should be developed to balance the needs of agriculture, a growing population, and the ecosystems that lend the South Cowichan area its valued place on Vancouver Island.

1.4 Report Structure

The report is organized as follows:

- Section 2 describes the biophysical setting of the Study Area including its physiography, climate and hydrology, and surface water and groundwater resources, based on available data collected by the study team;
- Section 3 describes the human setting (water use), including policies and plans that may affect water use;
- Section 4 analyzes current and future water use and demand;
- Section 5 puts these water use and demand estimates in the context of estimated surface water and groundwater balances (water supply); and
- Section 6 provides the Terms of Reference for the development of the Water Management Plan.

To assist non-technical readers in understanding some of the more obscure hydrogeological terminology used in this report, consultation of the following glossaries may be useful:

- Groundwater glossary: http://www.groundwater.org/gi/gwglossary.html
- Environment Canada freshwater (groundwater and surface water) glossary: http://www.ec.gc.ca/water/en/info/gloss/e_gloss.htm

[1] The projections in this study are based on Statistics Canada projections for regional populations and households, adjusted to account for development trends (as discussed with CVRD planners). Global and continental changes to climate, the economy, fossil fuel prices, and demography could affect population distribution in the South Cowichan area. The effects of these phenomena on population are uncertain, and were not assessed as part of this study.

- United States Environmental Protection Agency, safe water glossary: http://www.epa.gov/safewater/glossary.htm

Non-technical readers may also wish to refer to the following Streamline Watershed Management Bulletin article providing an overview of basic groundwater concepts:

- “Groundwater, more than water below the ground!” (Smerdon and Redding, 2007): http://www.forrex.org/publications/Streamline/ISS35/Streamline_Vol10_No2_art1.pdf

2. ENVIRONMENTAL SETTING

2.1 Climate

The climate of the South Cowichan area is described as “Transitional Cool Mediterranean”, and is characterized by warm, humid summers and mild, wet winters (Tuller, 1979). The South Cowichan area is positioned within the rain shadow of the Vancouver Island Insular Ranges to the west, but is also influenced to a limited extent by the Olympic Mountains to the south. These mountains significantly modify easterly-moving, moisture-laden air masses, causing the area to be dominated by low-pressure systems in winter and high-pressure systems in summer.

The climatic uniqueness of this region enhances the importance of groundwater as a source of freshwater supply. Based on the Thornthwaite classification, there can be a moisture surplus of 40 - 160 cm in winter but a moisture deficit of 5 - 20 cm in summer. This lack of precipitation in the summer season may be a major factor for many water deficiency related problems encountered throughout the Nanaimo Lowland physiographic province.

2.1.1 Precipitation

The following six Environment Canada climate stations gather precipitation data within and around the South Cowichan area, as shown on Figure 1:

- Mill Bay 1 Southwest (ID No.1015136);
- Shawnigan Lake (ID No. 1017230);
- Sooke Lake North (ID No. 1017563);
- Duncan Glenora (ID No. 1022571);
- Duncan Kelvin Creek (ID No. 1012573); and Malahat (ID No. 1014820).

Table 1 below shows precipitation data from each of these stations for the years from 1997 to 2006 (2007 data had not been published at the time of writing of this report). The precipitation values include rain and snow water equivalent. This table also has the Canadian Climate Normals from 1971 – 2000 of the Shawnigan Lake and Sooke Lake North stations. As the Malahat station did not have a complete data set, it was excluded from the table.

Table 1 Total Precipitation (Rain and Snow Water Equivalent)

Year	Station Name				
	Shawnigan Lake (mm)	**Sooke Lake North (mm)**	**Duncan Glenora (mm)**	**Duncan Kelvin Creek (mm)**	**Mill Bay (mm)**
2006	1594.6	1904.5	1726.6	1821.7	Incomplete
2005	1089.6	1274.4	Incomplete	Incomplete	1226.5
2004	1104.2	1297.8	1285.1	1216.3	1037.1
2003	1382.0	1576.6	1579.7	Incomplete	1319.2
2002	1104.8	1333.0	1311.6	1236.2	965.8
2001	1115.2	1323.0	Incomplete	1164.0	1115.2
2000	943.8	1064.1	1106.4	959.8	812.3
1999	1710.2	2063.4	1975.6	1782.0	1528
1998	1487.8	1801.4	Incomplete	1533.8	1314.8
1997	1565.5	1984.0	1729.6	1695.0	1438.2
Average Precipitation	**1309.8**	**1562.2**	**1530.7**	**1426.1**	**1195.2**
Climate Normals 1971-2000	**1247.6**	**1492.4**			

Data presented in Table 1 above indicates that precipitation has increased in the last ten years (1997-2006) as compared to the 1971-2000 Climate Normals. Most significantly, the data shows that average yearly precipitation varies greatly between the stations, indicating that there are several microclimates within the Study Area. For example, based on the Canadian Climate Normals, Sooke Lake North receives approximately 20% more precipitation than Shawnigan Lake, although they are separated by only 9 km in distance and 93 m in elevation.

2.1.2 Temperature

The Shawnigan Lake climate station is the only station within the South Cowichan area that meets the World Meteorological Organization's (WMO) standards for temperature data. Figure 2 shows average monthly temperatures at Shawnigan Lake between 1971 through 2000 and 1997 through 2006. This data indicates that average daily temperatures over the last ten years have increased for all months by an average of 0.6ºC, as compared to the Canadian Climate Normals.

2.1.3 Evapotranspiration

Average monthly actual evapotranspiration data for the Study Area were taken from water balance tabulations for Victoria International Airport station calculated by Environment Canada, which was the closest climate station to the Study Area. Monthly average Potential Evapotranspiration (PE) data were calculated using the Thornthwaite and Mather Method (1955). In the Environment Canada water balance tabulations, when the total available free water equals or exceeds the PE for the period, actual evapotranspiration (AE) is set equal to PE. When the total available free water is less than the PE for the period, water is drawn from soil storage to satisfy the evaporative demand. Monthly average calculated AE values for Victoria International Airport are presented in Table 2 below.

Table 2 Average Monthly Actual Evapotranspiration (Calculated) – 1951 to 1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Actual Evapotranspiration (mm)	12	18	28	46	72	62	27	28	39	40	22	15	409

2.1.4 Snowfall and Snowpack Accumulation

Although precipitation varies greatly within the South Cowichan area, snowfall does not vary as much. According to the 1971 – 2000 Canadian Climate Normals, the Shawnigan Lake station had a yearly average snowfall of 75.5 mm and Sooke Lake North station had a yearly average snowfall of 79.2 mm. This constitutes only a 5% difference as opposed to the 20% difference in total precipitation between the two stations.

Much of the snow that falls in higher elevations of the southwest portion of the Study Area (near Sooke Lake North) accumulates through the winter, melts in the spring and summer, and subsequently infiltrates into the ground and/or runs into surface water bodies. The snow that falls in the lower elevations does not accumulate throughout the winter, and instead melts and runs off shortly after falling onto the ground (typically in less than two weeks).

The Jump Creek station (ID No. 3B23P) shown on Figure 1, located approximately 1,160 m above sea level and 7.5 km north of Cowichan Lake, is the only BC Ministry of Environment (MOE) station that keeps track of snow in terms of snow water equivalent near the Study Area. Figure 3 shows snow pillow data in terms of snow water equivalent for this station.

It is difficult to quantify how much snow is locked up in the winter months for the entire Study Area. What can be inferred from the data is that a majority of the snow from higher elevations melts in the spring and summer and turns into runoff and groundwater infiltration.

2.2 Physiography

The South Cowichan region is positioned within the Nanaimo Lowland zone of the Insular Mountain Range physiographic province (Holland 1976).

The Nanaimo Lowland forms a strip of low lying country below 600 metres elevation that extends for 280 km along the east coast of Vancouver Island from Sayward on Johnstone Strait to Jordan River west of Victoria. Georgia Strait and the Gulf Islands archipelago flank the Lowland to the east, while rugged, mountainous country of the Vancouver Island Ranges forms its western border. The Nanaimo Lowland reaches a maximum width of 32 km between Galiano Island and Shawnigan Lake.

The major geomorphic features of the Nanaimo Lowland are the product of structural, erosional, and depositional processes. Folding and faulting of the bedrock, erosion and repeated glaciation, as well as isostatic and eustatic changes of sea level, have all contributed to the physiographic features of this region.

Differential erosion of bedrock throughout this physiographic zone has produced a distinctive pattern of cuesta-like landforms where areas underlain by competent sandstone, conglomerate, and volcanic or intrusive igneous rocks form ridges, and soft shale, mudstone, or areas with intense bedrock fracturing form bowls or valleys. In areas predominantly underlain by metamorphosed granitoid rocks such as to the east, west, and south of Shawnigan Lake, the terrain tends to be more rugged with the development of steep, conical hills and bedrock fracture-controlled valley lineaments. The bedrock surface between the north end of Shawnigan Lake and Cowichan Bay has been extensively modified by glaciation, which deposited a thick mantle of heterolithic debris over most of the area during the glaciers' advancing and retreating phases.

2.3 Bedrock Geology

Rocks from two discrete geological provinces, known as the Wrangellia and Overlap Terranes, underlie most of the South Cowichan area (BCGS, 2008). The boundary between the Wrangellia and Overlaps Terranes is represented by a northwest-trending erosional unconformity that runs south of the Cowichan Bay area and meets the marine shoreline at Cherry Point. Rocks from a third discrete geological province, known as the Crescent Terrane, underlie the southernmost tip of the Study Area at the Goldstream River estuary. This terrane is separated from the Wrangellia Terrane by the regional-scale Survey Mountain Fault.

The Overlap Terrane consists of sedimentary rocks of the Upper Cretaceous Nanaimo Group (see Figure 4). The Nanaimo Group in the South Cowichan area is represented by the Comox and Haslam Formations, a conformable sequence of marine and non-marine sedimentary rocks that grades upwards from carbonate-rich deltaic sandstone and conglomerate, through rhythmic marine beds of siltstone, sandstone, and coal-bearing shale, into pure shale and mudstone. Nanaimo Group rocks are only rarely exposed within the South Cowichan region due to their deep burial by glacial sediments, but are often encountered at depth by drilled wells throughout the Cowichan Bay and Cherry point areas.

The Wrangellia Terrane is represented by a range of igneous, volcanic, and sedimentary rocks of various ages within the Horne Lake – Cowichan uplift (see Figure 4), one of a number of northwest-trending geanticlines within the Wrangellia Terrane that make up the structural backbone of southern Vancouver Island. Stratigraphic components within this terrane are as follows:

- The central core of the Horne Lake – Cowichan uplift in the South Cowichan area is formed by Palaeozoic-aged, granitoid rocks of the Westcoast Crystalline Complex, and includes the Wark and Colquitz Gneiss Formations (see Figure 4). Westcoast Crystalline Complex rocks are commonly exposed as conical hills throughout the southern half of the South Cowichan area, and along the shoreline of Saanich Inlet from Bamberton to Goldstream;

- The northern flank of the Horne Lake – Cowichan uplift in the South Cowichan area adjacent to the Westcoast Crystalline Complex consists of a structurally complex assemblage of sedimentary and volcanic rocks of the Sicker, Buttle Lake, Vancouver, and Bonanza Groups:
  - Sicker Group rocks are represented by a large, northeast-trending block of basaltic volcanic rocks of the middle to upper Devonian-aged Duck Lake Formation. These rocks tend to be erosionally recessive and are locally exposed north of Cobble Hill near Hutchison and Cobble Hill Roads;
  - Buttle Lake Group rocks consist of several small, northeast-trending slivers of marble of the Mississippian to Lower Permian-aged Mount Mark Formation. Buttle Lake rocks were historically mined at the Cobble Hill quarry, are host to a number of small karst formations west of Cobble Hill village, and is erosionally recessive;
  - Vancouver Group rocks are represented by one small, northwest-trending sliver of marble of the Middle to Upper Triassic-aged Quatsino Formation. This isolated rock package outcrops on the east shore of Shawnigan Lake to the immediate south of Old Baldy Mountain, and is erosionally recessive; and
  - Bonanza Group rocks consist of a large, northwest-trending package of calc-alkaline basaltic rocks of Lower Jurassic age. These rocks form a series of conical hills around the north and east sides of Shawnigan Lake, and are exposed along the shoreline of Saanich Inlet from the Mill Bay ferry terminal to Bamberton;
- An ovoid area around Mill Bay village that fronts Saanich Inlet from Cherry Point to the Mill Bay ferry terminal consists of a complex of granodiorite stocks of early to middle Jurassic-aged Island Plutonic suite. These are coeval with the Bonanza Group volcanics and intrude older rocks of the Sicker Group to the north.

The structural geology of the South Cowichan area is complex. Rocks within the Wrangellia Terrane exhibit a coarse, northwest-trending fabric. Most regional-scale faults in this terrane assume north to northwest orientations with the exception of a single, east-northeast trending major structure that cuts across the north end of Shawnigan Lake and offsets the older northwest-trending faults. Rocks of the Wrangellia and Overlap Terranes also underwent extensive folding and faulting along a northwest axis during the Late Tertiary era when the Cascade and Olympic Mountains were being formed in Washington State. This late-stage deformation manifests as a series of low-angle thrust faults and fold axes that are locally offset by minor, northeast-trending normal faults.

With the exception of the highly regionally metamorphosed gneisses of the Wark and Colquitz Formation rocks south of Shawnigan Lake, metamorphic grade in the South Cowichan area is generally quite low but generally increases with the age of the rock packages. Bonanza Group rocks are heavily veined and show minor replacement by laumontite, stilbite, calcite and minor quartz, assemblages typical of the zeolite metamorphic facies. Carbonate rocks of the Vancouver and Buttle Lake Groups commonly consist of recrystallized marble. Basalts of the Sicker Group commonly show amygdule infillings and veins of chlorite, calcite, epidote and quartz, typical of lower greenschist facies metamorphism.

2.4 Surficial Geology

Four laterally extensive, mappable stratigraphic units are present within the South Cowichan area (Huntley, 2001). Dominant landforms and sediments in this region are late glacial in age and record the advance, maximum, and retreat phases of the late Pleistocene-aged Fraser Glaciation. Minor landforms and sediments are of post-glacial age and represent the fluvial and marine reworking of all earlier deposits. The thickness of the surficial cover within the South Cowichan region generally increases from southwest to northeast.

The stratigraphy of these units is described below and shown on Figure 5:

- Advance-phase glacial outwash materials, known as the "Quadra Sands", represent the oldest surficial deposits in the area. These include ice-distal sand and gravel-rich glaciofluvial sediments and glaciolacustrine deposits, ice-proximal gravel-rich outwash, and ice-contact debris-flow diamicton. Quadra Sand deposits do not outcrop within the South Cowichan, but have been recognized at depths of over 50 m below surface and up to elevations of 80 m above mean sea level beneath the Cowichan Bay / Cherry Point area, and likely occur in elongated lenses or beds with thicknesses in the range 15 – 20 m;
- Glacial maximum deposits, known as the "Vashon Drift", include massive lodgement till and glacigenic debris flows, with minor interbedded, subglacial and/or ice-contact glaciofluvial sand and gravel interbeds. These moraine deposits overlie the Quadra Sands materials described above, and can locally exceed 60 m in thickness. Deposition of the Vashon Drift was widespread throughout the South Cowichan Area, with deposition occurring at all elevations and in most areas. Glaciofluvial deposits of the Vashon Drift are known to underlie, onlap, and/or incise the morainal deposits, often vary widely in thickness, and can occur in usual topographic settings such as on hilltops or as hanging valley terraces;
- Retreat-phase glacial deposits, known as the "Capilano Sediments", include glaciomarine and minor glaciofluvial sediments. These deposits, which are the product of wasting tidewater glaciers and sediment deposition along retreating ice-margins, are present within the Koksilah and Cowichan valleys, Cowichan Bay and Satellite Channel areas, and within Saanich Inlet. Capilano Sediments overlie winnowed deposits of the Vashon Drift described above, and are present on hillsides up to elevations of roughly 80 m above mean sea level. Glaciomarine and glaciolacustrine deposits of the Capilano Sediments occur as draping veneers and blankets up to 15 m thick, while glaciofluvial deposits are confined to impersistent, linear deposits and kame deltas that occupy glacial melt water channels; and
- Post-glacial materials, known as the "Salish Sediments", represent the youngest surficial deposits in the area, and include fluvial, alluvial, deltaic, and marine deposits that represent recent reworking of all earlier deposits. Salish Sediments overlie all other deposits, and are present along most watercourses, in estuaries, and along shorelines throughout the South Cowichan area.

2.5 Groundwater

2.5.1 Data Collection / Analysis

Data collection and analysis for the groundwater component of this project was achieved using the following methods and sources:

- Collation and review of geology and groundwater data, including:
  - Maps of surficial geology (Guthrie and Penner,2005) and bedrock geology (Massey et al., 2003a,b; Guthrie, 2005);
  - MOE aquifer classification polygons (BC Water Resources Atlas[2]) and associated aquifer classification worksheets;
  - MOE groundwater observation well network data (Province of BC, 2007);
  - BCGS aquifer information (MOE Aquifer Classification Database, 2007); and
  - Water well information for the Mill Bay, Cobble Hill, and Cowichan areas as selected through the WELLS database. This includes well tag numbers, depth of well, yield, bedrock depth, and aquifer lithology;
- Search of digital libraries, including EcoCat and GSC/MOE archives, for pertinent reports, and review of these reports. Identified reports from Ecocat are listed in Table 3 below;
- Collection of information on major water users (e.g., improvement districts) within the Study Area;
- Liaison with MOE's regional hydrogeologist, Nanaimo region (Pat Lapcevic), and MOE's senior groundwater specialist in Victoria (Mike Wei), including:
  - Discussion of review of observation well data for the Cobble Hill aquifer for evidence of declining water levels;
  - Obtaining aquifer classification worksheets (see above); and
  - Obtaining information on geologic cross sections for the Study Area as produced by MOE; and
- Collation of other expertise on groundwater resources in the Study Area:
  - A one-day tour of the Study Area with Mr. David Slade (Drillwell Enterprises Ltd.); and
  - A telephone interview with Ms. Gypsy Fisher, graduate student working at SFU on hydrostratigraphic modeling and analysis of the Comox-Merville aquifer and underlying fractured sedimentary bedrock, Vancouver Island.

[2] http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html

Based on the above information, the groundwater component of this study sought to synthesize current understandings of groundwater systems within the South Cowichan area. Specific objectives were to:

- Develop a conceptual understanding of aquifers in the Study Area based on existing information, including identification of aquifer boundaries and inter-connectedness, recharge mechanisms, groundwater flow directions and well yields; and
- Develop a preliminary general water budget for the Study Area.

A preliminary conceptual hydrogeological model is developed below, while water budget calculations are presented in Section 5.1.

Table 3 Reports from Ecocat Search

Author	Title	Year
H.W.Nasmith	Groundwater for Irrigation in the Cowichan Valley of Southern Vancouver Island	1953
H. Nasmith	Groundwater for Farm Use in Lower Cowichan Valley, Vancouver Island	1955
J.C.Foweraker	Notes on Groundwater Supplies in Cowichan Indian Reserve No.1, Duncan BC	1970
J.C.Foweraker	Groundwater Potential available to the Corporation of the District of North Cowichan at the South end of the District	1975
A.P. Kohut	Groundwater Potential, Chemanius Area, North Cowichan Municipality	1975
J.C.Foweraker	Groundwater Research project Cowichan River Aquifers near Duncun BC Final Report	1976
J.C.Foweraker	Cowichan River Aquifers near Duncan	1976
A.P. Kohut	Cowichan Estuary Task Force - Preliminary Groundwater Study	1978
M.Zubel	Somenos Road Area of the North Cowichan Groundwater Potential	1978
A.P. Kohut	CVRD - North Oyster Diamond Settlement Plan - Cassidy Aquifer	1979
G.Buble	Bootsman Well and Related Water Problems in Cobble Hill Area	1979
K.D. Ronneseth	Agricultural Capability Assessment A Groundwater potential Study: Cowichan Valley to Mill Bay	1981
A.P. Kohut	Salt Water Intrusion Problem Cowichan Bay	1981
MOE	Cobble Hill Waterworks	1983
M. Wei	Cowichan Bay Waterworks District Review of data from the new Well	1985
A.P. Kohut	Groundwater Quality Monitoring and Assessment program 1985/1986 Cowichan-Koksilah Estuary	1985
A.P. Kohut	Groundwater Quality Monitoring and Assessment program 1985/1986 Cowichan-Koksilah Estuary Fall Field Survey	1985
M.Zubel	Cowichan-Koksilah Water Management Plan - Groundwater Input	1985
R.P. Richards	Cowichan River Surface/Groundwater Study	1986
A.P. Kohut	Groundwater Quality Monitoring - Cowichan Bay Area – Duncan	1986
MOE	Ministry of Environment and Parks Cowichan-Koksilah Water Management Plan Executive Summary	1986
J. Kwong	Saltwater Intrusion Mill Bay Area, Shawnigan Lake District	1987
A.P. Kohut	Groundwater Quality Monitoring and Assessment Program Cowichan-Koksilah Estuary , Summary of Sampling	1989
A.P. Kohut	Water Chemistry differences of the upper and lower aquifers near the Cowichan-Koksilah Estuary	1989
W.S. Hodge	Well Information Telegraph Road Cowichan Bay	1989
B.I. Ingimundson	Groundwater Supply Mill Bay B.C. Thurber Engineering	1992
W.R.Turner	Community Water Supply Well Test Shawnigan Hills Production Well No. 9 (Turner Groundwater Consultants)	1994
M. Wei	Wheelbarrow Springs, Mill Bay Waterworks District, Mill Bay, BC	1996
F.Chwojka	Groundwater Quality Monitoring and Assessment Program Cowichan-Koksilah Estuary , concerns and problem areas	1997

2.5.2 Groundwater Occurrence / Distribution

The occurrence and distribution of groundwater resources within the South Cowichan area is typical of Vancouver Island's heavily glaciated coastal regions (MOE 1991). In these areas, low-porosity bedrock is often covered by a heterogeneous assemblage of unconsolidated glacial and post-glacial deposits, whose relative porosities may be spatially variable and related to their depositional origins.

Groundwater in bedrock will tend to collect mainly within open joint and fracture systems, along bedding plane partings, to a lesser extent within intergranular pore spaces of the rock itself. In the case of limestone, groundwater can also collect in channels and voids formed by the dissolution of the rock by water. Wells completed within massive rocks of the Sicker, Buttle Lake, Vancouver, Bonanza, and Nanaimo Groups, as well as within the intrusive rocks of the Westcoast Crystalline Complex and Island Plutonic Suite, that do not intersect fracture systems contain very little groundwater due to these rocks' low primary porosity. Bedrock fracture aquifers can be either confined or unconfined depending on their structural geometry and degree of fracture connectivity.

Wells completed in closely-spaced joint systems and/or intense zones of bedrock fracturing (i.e. where swarms of multiple, subparallel faults are present, or where fault zones with differing orientations intersect) can often initially produce high groundwater flow rates. However, the long-term flow rates and sustainability of these wells can often be highly variable and expensive to evaluate due to variations in bedrock fracture geometry and intensity. Specific fracture systems within major fault zones may also be more hydraulically significant than others due to differences in their bulk hydraulic conductivities, often related to the type of tectonic stress regime hosting the fracture systems, fracture connectivity, and/or blockage by impermeable materials.

Groundwater may be present within near-surface, unconsolidated sediments with high primary porosity as unconfined or semi-confined aquifers. In particular, laterally extensive glaciofluvial deposits of the Vashon Drift, Capilano Sediments, and Salish Sediments can be highly significant in terms of their groundwater potential. The amount of water that can be extracted by individual wells completed in these aquifers may be highly variable depending on the permeability of the aquifer materials, the thickness and extent of the aquifer, the rate of aquifer recharge, and on well construction. Recharge of these aquifers is likely to be primarily from the infiltration of precipitation or surface water sources. Unconfined aquifers of this type may be highly vulnerable to surface contamination.

At intermediate depths, groundwater may occur within thin, permeable interbeds within thick, loosely consolidated morainal (till) deposits of the Vashon Drift. In particular, deep subglacial and/or ice-contact glaciofluvial sand and gravel beds and lenses may be highly significant in terms of their groundwater potential. Wells completed in these materials often initially report high yields, but such aquifers may not be sustainable over the long term due to unpredictable facies variations, deposit extents, and recharge potentials. Semi-confined aquifers of this type may be moderately vulnerable to surface contamination depending on their stratigraphic setting. Many private properties and rural developments within the Mill Bay, Cobble Hill, Cowichan Station, Cowichan Bay, and Cherry Point areas are serviced by wells developed within these near-surface and intermediate depth unconsolidated sediments.

Groundwater may also be present in deep, confined aquifers within permeable, loosely consolidated sediments that are overlain by deposits of low permeability glaciomarine clay and till. In particular, glaciofluvial outwash deposits of Quadra Sands are highly significant in terms of their groundwater potential. The amount of water that has been historically extracted along the east side of Vancouver Island by wells completed in the Quadra Sands aquifers is considerable, and several municipalities maintain well fields that draw their water supply from these deposits. However, individual well yields may be locally variable depending on the permeability of the aquifer materials, the thickness and extent of the aquifer, and on well construction. The recharge of Quadra Sands aquifers is not clearly understood due to their characteristically deep stratigraphic position. Infiltration of water through overlying, low-permeability tills may contribute some recharge, as may underlying, water-bearing geological structures where the Quadra Sands deposits are in direct contact with bedrock. In some areas, wells developed within the Quadra Sands show declining water levels over time, which may suggest that extraction rates locally exceed recharge. Aquifers of this type are not as vulnerable to surface contamination as near-surface, unconfined aquifers. A small number of agricultural and private properties south of Cowichan Bay between Duncan and Cherry Point are developed within these deep unconsolidated materials.

Recent fluvial deposits of the Salish Sediments often host important aquifers (such as the Cowichan River's river gravels from which the City of Duncan draws its municipal water supply). However, extensive deposits of this type are not present within the Study Area's boundaries. Glaciolacustrine and glaciomarine deposits of the Capilano Sediment, as well as dense morainal diamicton deposits of the Vashon Drift, are not considered hydrogeologically significant due to their inherent low permeabilities.

Free-draining ice-contact deposits of the Capilano Sediments and recent colluvial debris flows, which are both common surficial deposit types within the Study Area, are not considered prospective to host groundwater since they are often positioned above the level of the local water table.

2.5.3 Groundwater Flow

To date, groundwater flow directions have mostly been inferred based on the presence of prospective discharge locations. Regional groundwater flow patterns in surficial aquifers largely mirror topography, with groundwater recharge taking place at higher elevations and discharge occurring at lower elevations. Groundwater discharge is usually detectable as base flow in creeks, as linear seepage zones or spring lines on hillsides, and as sag ponds or wetlands in low-lying surface depressions.

Groundwater divides in unconsolidated glacial and post-glacial deposits typically tend to be roughly coincident with surface catchment divides, although the total volume of water entering bedrock aquifers may originate from more than one surface water catchment (i.e. determined by whether the geological structure crosses surface watershed divides). Local flow regimes and hydraulic gradients within different bedrock fracture aquifers may be complex and distinct from regional patterns due to their unique geometric arrangements. While surface fracture mapping may provide an understanding of the fundamental structural characteristics of specific bedrock aquifers, this information does not always directly equate to subsurface groundwater occurrence or flow patterns. For example, fractures observable at surface may not represent the system's most significant groundwater flow conduits or storage media.

Groundwater flow rates within bedrock fracture zones are expected to be rapid compared to flow within surficial deposits. The majority of groundwater flow in bedrock aquifers usually occurs within 100 m of surface. If large scale fault systems are present, significant groundwater flow may also occur at depths of hundreds of metres and across adjacent surface watersheds, with deep flow systems eventually discharging into major river systems, lakes, and/or the marine environment.

2.5.4 Groundwater Quality

Groundwater quality within the South Cowichan area's aquifers is linked to the parent chemistry of the aquifer media and the residency time of the aquifer's contained water resources. Groundwater in the Study Area's surficial and bedrock aquifers is generally of acceptable quality for most uses. Groundwater drawn from surficial aquifers tends to be of higher quality than that extracted from bedrock aquifers, with bedrock wells often producing comparatively harder and more mineralized groundwater with elevated pH levels. Groundwater drawn from bedrock formations with high concentrations of disseminated iron pyrite and/or hydrothermal mineralization systems may over the long-term produce water with elevated concentrations of iron, manganese, or other deleterious compounds, particularly if mineralized zones become dewatered and subsequently oxidized by sustained well pumping. Long-duration pump testing of any new wells developed within the Study Area is recommended to determine whether groundwater being extracted may be subject to seasonal and/or long-term water quality variations.

Wells developed adjacent to marine shorelines in either surficial or bedrock aquifers may be subject to varying degrees of contamination by seawater. The degree of saline intrusion is often unpredictable, and may be the product of a number of site-specific issues, including groundwater extraction rates, well construction, and the degree of hydraulic connectivity between the aquifer and the marine environment.

2.5.5 Groundwater Vulnerability

The relative sensitivities of groundwater aquifers to contamination, as well as the degree of influence on their contained groundwater by surface water bodies, is dictated largely by whether the aquifers are confined or unconfined (i.e. on the presence or absence of overlying aquitards or aquicludes), and on their geomorphic setting.

Areas where surficial aquifers are unconfined and permit relatively high groundwater recharge rates, or where bedrock aquifers outcrop at the land surface or are overlain only by a thin soil veneer, will be highly susceptible to surface contamination. Unconfined aquifer locations often coincide with large deposits of fluvial and glaciofluvial sediments and include the Mill Bay Aquifer #206. Examples of highly vulnerable bedrock groundwater systems include the Shawnigan Lake Aquifer #203 and the Malahat Aquifer #208.

Bedrock fracture aquifers are particularly vulnerable to surface contamination, since groundwater flow rates through open fracture systems and bedrock voids (such as karst systems) are typically rapid compared to movement through intergranular pore spaces of unconsolidated aquifers. Consequently, management of bedrock groundwater resources should include the preservation of soil cover and vegetation, and the establishment of areally extensive wellhead and catchment protection areas.

At the initiation of this project, MOE's regional hydrogeologist, Pat Lapcevic, indicated that a collaborative vulnerability mapping project for the area was underway ("Vancouver Island Water Resources Vulnerability Mapping Project", based primarily from Vancouver Island University[3], which the CVRD is supporting). It was agreed upon with the regional hydrogeologist that this project would not undertake any vulnerability assessments for the Study Area so as not to duplicate this valuable work that will address threats to the aquifers in the Study Area. On 28 January 2009, MOE's regional hydrogeologist indicated that the vulnerability mapping was nearing completion and that results from this project would be released to the public in a few months time. The CVRD should have access to these results by February 2009 for comment and feedback. The results from the vulnerability project will consist of:

- Maps indicating areas of low, medium or high vulnerability. Alternatively, maps of low, low-medium, medium, medium-high and high vulnerability may be created. The level of detail of the vulnerability classification that is warranted (based on available data) is in the review stage.
- A report outlining the basis for the vulnerability maps (a DRASTIC modelling approach, Wei, 1998), and providing guidance regarding the interpretation of these maps.

The findings from this aquifer vulnerability mapping project should be included in developing the South Cowichan water plan. The recommended development of a groundwater model may be able to provide additional information on aquifer vulnerabilities, wellhead protection areas and sensitive recharge areas.

2.5.6 Groundwater Surface Water Interactions

Traditionally, management of water resources has focused on surface water or groundwater as if they were separate entities. As development of land and water resources increases, it is apparent that development of either of these resources affects the quantity and quality of the other.

Nearly all surface-water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with groundwater. These interactions take many forms. In many situations, surface-water bodies gain water and solutes from groundwater systems (i.e. base flow) and in others the surface water body may be a source of groundwater recharge (i.e. a losing stream) and causes changes in groundwater quality. As a result, withdrawal of water from streams can deplete groundwater or conversely, utilization of groundwater can deplete water in streams, lakes, or wetlands. Pollution of surface water can cause degradation of groundwater quality and conversely pollution of groundwater can degrade surface water.

Consequently, effective land and water management requires a clear understanding of the linkages between groundwater and surface water as it applies to any given hydrologic setting.

[3] http://web.mala.bc.ca/groundwater/

2.5.7 Regional Groundwater Development

The BC provincial government has delineated 13 discrete aquifers within the Study Area based primarily on aquifer media similarities encountered in drilled, water-bearing wells throughout the region. Synoptic descriptions of these aquifers are presented in Table 4 below, with their locations shown on Figure 6. Detailed aquifer descriptions are provided in Appendix 1.

Table 4 Summary of mapped aquifers

Tag	Name	Descriptive Location	Type	Size (km^2)
197	Cherry Point	Cowichan Bay / Cobble Hill	Sand and Gravel	39
199		Cowichan Station	Sand and Gravel	3.5
201	Kingburne	Cobble Hill	Sand and Gravel	1.7
205	Carlton	Cobble Hill / Shawnigan Lake	Sand and Gravel	2.6
206	Mill Bay	Mill Bay	Sand and Gravel	2.7
196	South Cowichan	Deerholm / Duncan	Bedrock	45.8
198	Cowichan Station	Cowichan Station / Duncan	Bedrock	6.1
200	Kelvin Creek	Cobble Hill / Duncan	Bedrock	27.7
202	North Shawnigan	Shawnigan Lake / Cobble Hill	Bedrock	20
203	Shawnigan Lake	Shawnigan Lake / Cobble Hill	Bedrock	30.5
204	Cobble Hill	Cobble Hill / Mill Bay	Bedrock	21.4
207	Bamberton	Mill Bay / Shawnigan Lake	Bedrock	27
208	Malahat	Malahat	Bedrock	20.5

Note: Information derived from aquifer classification worksheets. No worksheet was received for aquifer 199; this aquifer is not described below

Eight bedrock aquifers have been delineated within the Study Area that collectively cover an area of almost 200 km^2. Most private properties and rural developments surrounding and south of Shawnigan Lake, as well as those located west of Saanich Inlet from Bamberton to Goldstream, are serviced by wells developed within bedrock aquifers. Although areally extensive bedrock aquifers have also been mapped beneath the Cobble Hill, Cowichan Station, Mill Bay, and Deerholm areas, only a small proportion of water users in these areas rely on wells developed within these aquifers as their primary water sources.

Five surficial aquifers have been delineated within the Study Area that collectively cover an area of about 50 km^2 and locally overlie the bedrock aquifers described above (see Figure 6). Many private properties and rural developments within the Mill Bay, Cobble Hill, Cowichan Station, Cowichan Bay, and Cherry Point areas are serviced by wells developed within near-surface and intermediate depth unconsolidated sediments of the Vashon Drift and Capilano Sediments.

The lack of mapped bedrock aquifers in the Cowichan Bay area (below the Cherry Point Aquifer 197) and southeast of Shawnigan Lake (between bedrock aquifers 203 and 208; Figure 6) is conspicuous and needs to be investigated. Bedrock groundwater systems likely exist in these areas but may not yet have been mapped by MOE.

Searches of publicly available information sources revealed that there is a general lack of lack of regional-scale geologic cross-sections for the Study Area that depict aquifer boundaries and their degree of inter-connection. Existing cross-sections are only local-scale and can be found in historical documents provided on EcoCat, including studies for the Cobble Hill waterworks (MOE, 1983), the Mill Bay waterworks district (Wei,1996), the Cowichan-Koksilah estuary (Wei, 1985), and a salt water intrusion study for Cowichan Bay (Kohut, 1981). The Cobble Hill waterworks cross-sections are reproduced as Figures 7A and 7B. These cross-sections identify the Cherry Point aquifer in the area of greatest groundwater use and reveal the following hydrostratigraphic sequence:

- A surficial till layer;
- A shallow water bearing zone (apparently present as discontinuous sand lenses);
- An intermediate till layer (local present between the shallow water bearing zone and the aquifer);
- A deeper water bearing zone (Cherry Point aquifer);
- A deeper till layer (locally present between the aquifer and bedrock); and
- Bedrock (stratification within bedrock is not distinguished).

This study attempted to develop a number of regional-scale geologic cross-sections for the area, but was hampered by the limited data search-and-retrieve capabilities of MOE's existing WELLS database. A clear understanding of the hydrostratigraphy of the South Cowichan area should be obtained prior to the development of a water management strategy for the region. Development of a conceptual hydrostratigraphic model would be the first step towards development of a numerical model for groundwater balance calculations.

2.5.8 Estimated Groundwater Recharge Rates

To date, limited information is available on groundwater recharge mechanisms and rates within the South Cowichan area (see Table 5 below). For the Mill Bay aquifer, Lowen (1994a) estimated the percentage to be approximately 45% of the annual rainfall, while Kreye et al. (1996) provided an estimate of 62%. These estimates likely apply to the unconfined southern portion of the Mill Bay aquifer, which is the local groundwater recharge area. Within the Study Area as a whole, areas where surficial aquifers are unconfined and may permit relatively high groundwater recharge rates appear to be relatively rare. Such locations are potentially indicated by fluvial and glaciofluvial sediment cover (Figure 5). It is expected that recharge to groundwater-bearing surficial zones and bedrock aquifers covered by moraine or glaciomarine / glaciolacustrine deposits (i.e. confined aquifers) is lower than the percentages indicated above. The groundwater model developed by EBA Engineering Consultants for the Cobble Hill Protection Plan (EBA, 2006) utilized a recharge rate of 295 mm/yr or about 23% of annual precipitation at the Shawnigan Lake station. This latter recharge rate may be applicable to the confined Cherry Point aquifer.

Based on analysis of well hydrograph data, the period of time to recharge is expected to the on the order of several years for the Cherry Point aquifer. Significantly longer time periods may be expected in areas where the regional water table is considerably below land surface. For example, if the water table is 10 m below ground surface, it may take up to 34 years for infiltration to reach the groundwater system based on a rate of 295 mm/yr. As such, regional-scale groundwater systems may respond relatively slowly to climate change and other regional influences (e.g., water abstraction) and it may take years or decades for corresponding effects to fully establish.

Additional work is required to better estimate groundwater recharge rates on a regional basis (i.e. for the Study Area as a whole). This work could be based on a combination of approaches:

- Well hydrograph analyses (e.g., from MOE's observation well network) to assess aquifer hydraulic properties and aquifer responses to seasonal and inter-annual variations in recharge conditions. Well hydrograph analysis is complicated by the influence of both recharge conditions and water withdrawals on measured groundwater levels and as a stand-alone option is therefore not expected to yield reliable results regarding groundwater recharge rates;
- Hydrograph separation / base flow regression analyses to estimate groundwater discharge fluxes from seasonal low flows. Apart from the fact that limited gauging data exists for the Study Area, base flow regression analyses are complicated by the fact that streams are regulated and (or) influenced by water diversions. As such, this approach is not expected to yield reliable results; and
- Groundwater recharge calculations as the residual of precipitation, evaporation, surface runoff and soil water storage using either the HELP (Hydrologic Evaluation of Landfill Performance) model (Schroeder et al., 1994) or the MIKE-SHE model (Abbott et al., 1986; Refsgaard and Storm, 1995). Both models have been used for this purpose in a variety of settings in British Columbia (e.g., Scibec and Allen, 2006; Denny et al., 2007). This is considered the most promising approach.

Once estimates of recharge rates are obtained, this information would ideally be combined in a groundwater model for the Study Area that also incorporates information on well yields (aquifer transmissivity) and groundwater levels. These data would be used to calibrate the groundwater model to ensure that it accurately represents groundwater flow directions, rates and volumes. The purpose of the groundwater model would be to better evaluate groundwater budgets for aquifers within the Study Area and to assess groundwater availability within the context of climate change and water demand projections. The groundwater model could also be used to generate planning densities (i.e. by preferentially locating population in designated areas linked to high-yielding (portions of) aquifers), although planning at this level of detail would likely require much more comprehensive, quantitative, and site-specific hydrogeologic information than is presently available.

Development of maps of groundwater flow directions, while planned for this project, was hampered by limitations of the WELLS database. Once groundwater surface elevations have been determined from the WELLS database, this information could be used to map groundwater flow directions directly. However, the preferred option would be to use this information to calibrate a groundwater flow model, which could be used to quantitatively assess flow directions, velocities, and recharge/discharge relationships, including:

- Hydraulic connectivity of aquifers with surface waters and highland recharge areas; and
- Hydraulic connectivity between overburden and bedrock aquifers.

Table 5 Aquifer vulnerability, recharge and groundwater flow information

Tag	Aquifer Vulnerability	Confining Unit Thickness (m)	Depth to Water (mbgs)	Inferred Recharge Mechanisms	Groundwater Flow Direction
197	Low	20.0 (0 - 87.8)	27.4 (0 - 93.0)	Precipitation	North to Cowichan Bay
199	Low	No aquifer classification worksheet available			
201	Low	10.7 (0 - 48.2)	6.1 (2.4 - 25.9)	Precipitation, runoff	West to Koksilah River
205	Low	23.5 (0 - 65.5)	12.8 (0 - 37.8)	Precipitation (probably)	Not determined
206	High	7.5 (0 - ??)	6.7 (0 - 38.1)	Precipitation and/or upslope zones	North and northeast
196	Low	7.5 (0 - 69.5)	8.5 (1.2 - 89.6)	Precipitation, runoff surficial aquifers	To Cowichan River
198	Low	13.6 (0 - 41.1)	9.7 (0.5 - 49.7)	Precipitation, surficial aquifers	Not determined
200	Moderate	3.0 (0 - 28.7)	11.9 (0 - 44.2)	Not determined (precipitation)	Not determined
202	Moderate	2.1 (0 - 53.3)	8.4 (0 - 81.7)	Not determined (precipitation)	Not determined
203	High	0.3 (0 - 59.7)	5.9 (0 - 59.7)	Precipitation, runoff	To Shawnigan Lake
204	Moderate	3.0 (0 - 62.5)	5.2 (0 - 50.3)	Not determined (precipitation)	Toward Saanich Inlet
207	Moderate	4.6 (0 - 64.3)	7.6 (0 - 61.0)	Not determined (precipitation)	East and/or north
208	High	1.2 (0 - 16.2)	15.8 (1.5 - 76.2)	Precipitation, runoff	Toward Saanich Inlet

2.5.9 Aquifer Productivity / Well Yields

Surficial aquifers within the South Cowichan region are generally more productive than the bedrock aquifers, as indicated by the summary of well yields in Table 6 below. Reported bedrock aquifer productivity (MOE, 1994) generally increases eastward from low to moderate. However, these conclusions may be of limited relevance since estimates of aquifer productivity have been based primarily on airlifted well yields at the time of well development and not on aquifer yield and sustainability data from extended pump testing (not presently recorded by MOE). Long-duration pump testing of any new wells developed within the Study Area is prudent to determine whether local groundwater extraction rates are sustainable during dry summer conditions, and to confirm that such extraction does not result in deleterious effects on ambient environmental receptors or neighbouring human interests.

Given the comparatively large size and structural complexity of the region’s bedrock aquifers, opportunities may exist for increasing bedrock groundwater use in the South Cowichan area. However, identifying productive bedrock groundwater zones may prove to be technically challenging and costly since the majority of bedrock groundwater is hosted by fracture systems of unknown morphologies and orientations. Comprehensive assessment of the area’s fractured bedrock groundwater potential will require more site-specific hydrogeologic information than is presently available. Lithological and/or structural evaluations of the region’s bedrock and surficial deposit groups could provide a more reliable depiction of their primary and secondary porosity potentials

Table 6 Productivity, well yield and water use information for mapped aquifers

Tag	Productivity	Demand	Type of Water Use	Reliance on Source	Well Yield (L/s)
197	Moderate	Moderate	Multiple	Conjunctive (surface water, bedrock)	0.63 (0.01 - 17.35)
199	Moderate	Moderate	Multiple	No aquifer classification worksheet available	
201	Moderate	Moderate	Domestic	Conjunctive (surface water)	0.76 (0.38 - 4.73)
205	Moderate	Moderate	Multiple	Conjunctive (surface water)	0.85 (0.19 - 3.16)
206	Moderate	Moderate	Multiple	Conjunctive (surface water, bedrock)	0.75 (0.09 - 22.1)
196	Low	Low	Domestic	Conjunctive (surface water)	0.13 (0.02 - 0.63)
198	Low	Low	Domestic	Conjunctive (surface water, surficial aquifer)	0.13 (0.06 - 1.26)
200	Low	Low	Domestic	Conjunctive (surface water)	0.19 (0.02 - 1.58)
202	Low	Moderate	Multiple	Conjunctive (surface water)	0.19 (0.02 - 5.68)
203	Low	Moderate	Multiple	Conjunctive (surface water)	0.19 (0.01 to 4.42)
204	Moderate	Moderate	Multiple	Conjunctive (surface water, surficial aquifer)	0.25 (0.03 – 8.52)
207	Moderate	Moderate	Multiple	Conjunctive (surface water, surficial aquifer)	0.25 (0.02 - 12.62)
208	Moderate	Low	Domestic	Conjunctive (surface water)	0.38 (0.03 to 3.79)

Notes

Aquifer tags and productivity/demand rankings from MOE (BC Water Resources Atlas; MOE, 1994). Type of water use, reliance on source and well yield estimates derived from aquifer classification worksheets. Well yields in brackets indicate ranges; values before brackets indicate median values

The relative proportion of current groundwater and surface water use is not currently known with precision, since groundwater usage within the South Cowichan area is not metered or regulated. More detailed information on well yields and aquifer transmissivity is being compiled in a joint venture between the Geological Survey of Canada (GSC) and the MOE, conducted at Simon Fraser University (SFU) under the lead of Dr. Dianna Allen. The purpose of this study is to provide quantitative estimates of aquifer hydrogeologic properties based on compilation of well installation and testing reports (Jessica Liggett, SFU, personal communication). The SFU project has been ongoing concurrently with this Phase 1 water study. As such, findings from the SFU project could not yet be incorporated in this report.

2.5.10 Observation Well Network

Table 7 below summarizes the five MOE observation wells within the Study Area, the locations of which are shown on Figure 6. Three active observation wells have been completed in the Cherry Point Aquifer (197): #233 (Cowichan Bay), #320 (Braithwaite Estates), and #345 (Arbutus Ridge). Two additional wells (#255 and #256) appear to have been completed in the Cobble Hill bedrock aquifer while the remaining well (#350) is located in a gravel pit in the Mill Bay Aquifer #206.

Observation well hydrographs for the Cherry Point observation wells are provided in Figure 8 together with precipitation data for the period of record.

Table 7 Observation Well Summary

Observation Well	Aquifer and Type	Well Depth (m)	Period of Record
Cowichan Bay (233)	Cherry Point 197 (surficial)	58	1978 - present
Braithwaite Estates (320)	Cherry Point 197 (surficial)	36	1992 - present
Arbutus Ridge (345)	Cherry Point 197 (surficial)	87	1999 - present
Cobble Hill (256)	Cobble Hill 204 (bedrock)	261	1980 - 2003
Mill Bay (350)	Mill Bay 206 (surficial)	39	2001 - 2006

2.5.11 Water Level Trends

Study team personnel met with Mr. David Slade from Drillwell Enterprises Ltd., who facilitated a tour of the South Cowichan area. Mr Slade is very knowledgeable on the geology and groundwater resources in the Study Area, and has been concerned with apparent declining groundwater levels and the need for deepening of domestic wells in the Hutchinson Road area. These concerns would appear to align with declining water levels noted for MOE observation well #320 in the same area. The area for which declining water levels and/or deepening of wells is tentatively indicated in Figure 6 ("Area of Concern"). A complete discourse of findings from the tour with Mr. Slade in provided in Appendix 2.

MOE has reviewed evidence for declining water levels based on data provided by Mr. Slade, and historical data from MOE observation wells in the area. This review was summarized in a January 23, 2007 letter from MOE's regional hydrogeologist to Gerry Giles of the CVRD. A copy of the analysis by MOE's regional hydrogeologist and accompanying letter is provided in Appendix 3.

The water level measurements for the three deepened domestic wells, the Cobble Hill Improvement District main well, and the monitoring well at the Cobble Hill Elementary School (data provided by Mr. Slade to MOE) suggest water level declines of between 0.07 to 0.17 m/yr are occurring, with total recorded water level changes of between 0.85 m (School well; 5 year period of record) and 3.96 m (domestic well #1; 24 year period of record). Between 2001 and 2006, the Braithwaite Estates observation well #320 showed a drop in peak water levels of 0.9 m, which was similar to that observed in the school well). The Arbutus Ridge observation well #345 showed a drop in peak annual water levels of 1.3 m over the last 4 years.

Based on this information, MOE concluded that "…while at first glance all of the data mentioned above suggests a drop in groundwater levels, it is important to note that Well #320 at Braithwaite Estates (the longest continuous record in the aquifer) also indicates a longer cycle likely related to precipitation where peak annual levels increased between 1995 and 2000, decreased between 2000 and 2003 and have been fairly steady since 2003. Clearly, this discrepancy should be analysed further to better understand the natural fluctuations in the aquifer. Our current observations are based on very limited data and levels in the two observation wells are impacted by pumping in neighbouring wells…"

This study's research team took an additional step and correlated measured water levels from the MOE observation wells against precipitation data for the Shawnigan Lake climate station (Figure 8). Striking trends are apparent between the precipitation and water level data. Between 1985 and 1993, average annual precipitation was about 1100 mm/yr, while between 1994 and 1999 precipitation was considerably higher, averaging almost 1500 mm/yr. Between 2000 and 2005, annual precipitation declined again to an average of about 1100 mm/yr, while recent data for 2006 suggests a possible return to above-average precipitation. The trends noted in recorded water levels at the Braithwaite Estates observation well #320 would appear to reasonably match up with these temporal trends in precipitation, with a possible 1 to 3 year delay in the groundwater response. Such a delay would be expected based on the time it might take for infiltration from precipitation at land surface to reach the water table. Hence, it is not inconceivable that recent water level declines between 2000 and 2003 at the Braithwaite Estates observation well are at least in part due to natural fluctuations. Shallow wells in particular are expected to be very sensitive to either natural or anthropogenically-induced declines in water table elevation.

Groundwater levels recorded at the Arbutus Ridge observation well #345 in the Cherry Point aquifer also appear to be declining, but the record for this location is too short to comment on any correlation with precipitation or anthropogenic pressures (Figure 8). At the Cowichan Bay observation well #233, groundwater levels appear to be relatively stable or may have been increasing somewhat between 1994 and 2000. The trend in groundwater levels at observation well #233 is distinctly different from the other two stations in the Cherry Point aquifer, possibly reflecting the location of this well in a groundwater discharge zone (Cowichan Bay) and/or location away from groundwater extraction points.

While the above well hydrograph analysis has shed additional light on the possible cause(s) of declining water levels in the Cherry Point aquifer, it is recommended that a groundwater model analysis be conducted to more unambiguously distinguish between natural water level fluctuations and possible water level declines due to anthropogenic pressures in the Cherry Point aquifer.

2.5.12 Limitations and Future Work

At the outset of this project, the WELLS database was expected to provide information with sufficient spatial coverage to assess hydraulic gradients, groundwater flow directions, and aquifer inter-connectivity within the South Cowichan area, as well as provide data on well yields and for developing geologic cross-sections that would aid the development of a conceptual hydrogeological model for the area. However, the present configuration of this database renders screening and interpretation of the thousands of well records within the Study Area extremely time-consuming:

- Individual wells need to be selected using Internet-based forms, which makes information retrieval difficult and time-consuming.
- Information cannot easily be linked to a GIS system to display spatial information;
- The resolution of the BGCS coordinates provided (kilometre scale accuracy) is inadequate for the purposes of this study and does not fully make use of the actual location information for each well;
- Well records cannot be viewed and selected spatially; and
- Numerous inconsistencies and errors in the database are apparent.

As of mid-January 2009, the study team was granted access to an improved database created at SFU (Toews and Allen, 2007) that addresses the above concerns. The WELLS database has been corrected and standardized at SFU under contract of the MOE, and repackaged into a Microsoft Access database to provide rapid and convenient viewing of all the well records, as well as the ability to modify information (and track changes made such that the original information is not compromised) and view / select well records from a GIS (optional).

Several steps are still required to make the SFU database more useful for this project. The required processing steps are:

- Selecting the well records in the Study Area from the database using the GIS option. The total number of well records is expected to range in the thousands;
- Screening of the selected well records for completeness and quality of information, notably lithological records (for the purpose of the geologic cross-sections), static water levels (groundwater flow directions), and well yields (aquifer productivity). This quality assurance and control step is required because water well drillers do not always provide the necessary data (i.e. many records will be incomplete), and when provided the quality of the information is typically highly variable. Also, the bulk of the domestic wells contained in the database is expected to be relatively shallow (e.g., dug wells) and is therefore of limited use for this study. Emphasis should be put on relatively deep wells that maximize information on the regional hydrostratigraphy; and
- Using GIS to link the SFU database to digital topographic information to estimate the ground surface elevation for each well. This step is necessary to convert water table depths listed in the database to groundwater surface elevations for use in flow direction mapping.

Once the above steps have been completed, the resulting information can be analyzed and interpreted to further enhance the conceptual hydrogeologic model of the Study Area.

2.6 Surface Water

Three watersheds are present within the South Cowichan area, namely the Saanich Inlet, Shawnigan, and Cowichan Watersheds (see Figure 1).

The portion of the Saanich Inlet Watershed within the Study Area covers approximately 6,187 hectares, and is located in its rugged southeast portion. Water drains into many of the large creeks located in this watershed. This area is characterized by a parallel drainage pattern in which a majority of the waterways start off at high elevations in the western part of the watershed, and flow down eastwards into the Saanich Inlet parallel to one another.

The Shawnigan Watershed, which lies entirely within the rugged western portion of the Study Area, covers approximately 11,305 hectares. The majority of this area is characterized by a centripetal drainage pattern in which all waterways flow toward a central topographic that hosts Shawnigan Lake. The northeastern portion of this watershed has a more dendritic drainage pattern, with Shawnigan Creek being the main artery.

A small portion of the Cowichan Watershed lies within the north part of the Study Area adjacent to the south shore of Cowichan Bay, and covers approximately 3,361 hectares. Terrain within this portion of the watershed is relatively flat and highlighted by an unusual ravine system along Cowichan Bay and Saanich Inlet. Most of the water drains into many of the ravines and small creeks that empty into the Bay and Inlet. This area can be classified as a radial drainage pattern.

Each watershed has the following surface water bodies as identified on the BC Water Resources Atlas (see Table 8 below).

Table 8 Surface Water Bodies

Saanich Inlet Watershed	Shawnigan Watershed	Cowichan Watershed
Arbutus Creek	Shawnigan Creek	Garnett Creek
Handysen Creek	Van Horne Creek	Manley Creek
Malahat Creek	Hollings Creek	Hutchinson Lake
Johns Creek	Elkington Lake	
Bamberton Creek	Devereaux Lake	
Spectacle Creek	Stebbings Lake	
Colpman Creek	Shawnigan Lake	
Irving Creek		
Camsusa Creek		
Wrigglesworth Lake		
Oliphant Lake		
Spectacle Lake		

Figure 9 shows the relationship between mean monthly precipitation from the Shawnigan Lake climate station and mean monthly discharge from Shawnigan Creek near the Mill Bay hydrometric station from the years 1978 through 2006. This figure indicates that the best time to extract and store water from surface water bodies would be in the fall and winter between November and March. This would help ensure that the critical low flow season vital to aquatic habitat is not affected.

2.7 Ecological Features

2.7.1 Biogeoclimatic Zones

There are two biogeoclimatic zones in South Cowichan: the Coastal Douglas Fir zone (CDF) and the Coastal Western Hemlock zone (CWH).

The CDF zone is limited to small pockets of southeast Vancouver Island, several islands in the Gulf of Georgia, and a narrow strip of the Lower Mainland, on elevations mostly below 150 m. The CDF zone is characterized by warm, dry summers and mild, wet winters. Mean annual precipitation varies from 647 to 1263 mm, with very little falling as snow from November to April. Snow generally melts within a week of falling (D. Meidinger and J. Pojar, 1991).

Most forests found in the CDF zone today are second growth stands, regenerated after logging that occurred in the early 1900s. The coastal variety of Douglas-fir is the most common tree species in upland forests. Mature and old growth coniferous forests are important for birds that eat conifer seeds or wood boring and bark insects, including Pileated Woodpecker, Yellow-bellied Sapsucker, Steller's Jay, Raven, Chestnut-backed Chickadee, and others. Deciduous thickets and shrubs offer a variety of flying insects and seeds for breeding populations of House Wren, Hutton's Vireo, Black-headed Grosbeak, and White-crowned Sparrow (D. Meidinger and J. Pojar, 1991). Figure 10 shows the location of the CWH and CDF biogeoclimatic zones in relation to the South Cowichan area. Eastern parts of the Study Area occur in the dryer CDF zone, while higher elevations and more western parts of the Study Area that receive greater annual rainfall are in the CWH zone.

The CWH zone occurs at low to middle elevations west of the coastal mountains, along the entire British Columbia coast and into Alaska and Washington. The CWH zone covers much of Vancouver Island, occupying elevations from sea level to 900 m on windward slopes in the south and mid-coast, and up to 1050 m on leeward slopes (D. Meidinger and J. Pojar, 1991). The CWH zone is generally the rainiest biogeoclimatic zone in British Columbia and is characterized by cool summers and mild winters. Mean annual precipitation ranges from 1,000 to 4,400 mm. Less than 15 percent of total precipitation occurs as snowfall in the south (D. Meidinger and J. Pojar, 1991).

Tree, shrub, and herb species commonly found in CDF and CWH zones are listed in Table 9 below.

Table 9 Vegetation Characteristic of CDF and CWH Zones

Vegetation Layer	CDF Zone Species	CWH Zone Species
Tree	Douglas-fir, Bigleaf maple, Western redcedar, Grand fir, Western flowering dogwood, Shore/lodgepole pine	Douglas-fir, Western hemlock, Western redcedar, Shore/lodgepole pine, red alder, bigleaf maple
Shrub	Salal, Dull Oregon-grape, Labrador tea, Indian-plum, Salmonberry, Red elderberry	Salal, Dull Oregon-grape, Red huckleberry, Salmonberry, Devil's club, Labrador tea
Herb	Sword fern, Vanilla leaf, Three-leaved foamflower, Lady fern, Skunk cabbage, False lily-of-the-valley.	Vanilla-leaf, Sword fern, Wall-lettuce, Bracken, Sweet-scented bedstraw, Three-leafed foamflower, Deer fern, Lady fern, Oak fern, Skunk cabbage.

2.7.2 Riparian Areas

Riparian zones provide an important link between aquatic and terrestrial habitats in a landscape. Riparian areas allow wildlife to travel between habitat 'islands' and help to circulate nutrients among different ecosystems. Riparian vegetation connects the water's edge with dry land and plays an important role in maintaining aquatic system health in the following ways:

- Trees and shrubs that border and overhang waterbodies keep water cool through the process of evapotranspiration, which moderates the temperature of lake, river, and stream water, benefiting fish and aquatic invertebrates, and preventing excess algae growth;

- Plants growing along stream, lake, and estuary banks collect sediment, preventing banks and shorelines from eroding. This provides structure and strength through root growth;
- Leaf, twig, and needle drop provides nutrients to aquatic invertebrates, which in turn nourish fish; and
- Vegetation protects stream banks, and trees that fall into waterbodies create pools and hiding places for fish.

Riparian zones provide habitat for a large array of mammals, birds, fish, and invertebrates that depend on riparian vegetation for nourishment, travel, and protection (CRD website). Riparian areas are characterized by shallow water table conditions.

2.7.3 Invasive Vegetation Species

When invasive species alter an ecosystem, many of the benefits that people and animals derive from those areas are lost. Invasive species can significantly affect an ecosystem or landscape by altering the chemical composition and pH of soil, altering the structure of the foreshore, displacing species that rely on native plants or animals, altering fire regimes, and fragmenting the landscape where patches of invasive plants flourish (Capital Regional District website). There are a number of invasive plant species of concern on Southern Vancouver Island, including:

- European Beachgrass and Japanese Weed in marine shoreline areas
- Eurasian watermilfoil, Reed Canary Grass, and Purple Loosestrife in freshwater and wetland areas, and
- Scotch Broom, Himalayan Blackberry, Orchard Grass, Common Holly, English Ivy, Laurel-leafed Daphne, Gorse, Canada Thistle, Sweet Vernalgrass, and Hedgehod Dogtail in upland areas.

2.7.4 Fisheries

Maintaining fisheries requires intact and healthy fish habitat. Reliable water flows throughout the year are crucial, and are affected by weather conditions, reservoir storage and release practices, and relationships of groundwater and surface water. Base flows of many streams are maintained by inflows from groundwater. Hence, infiltration of rainfall into groundwater helps to protect stream flows, as does ensuring that groundwater removal via wells does not excessively lower water tables. During summer, groundwater temperatures are typically lower than those of surface water, so groundwater entering streams and lakes helps to protect fisheries against excessively warm water. Maintaining a healthy riparian area is important to moderating water temperature, protecting stream bank integrity, and providing food and organic matter inputs to streams.

The lakes, rivers, and streams in South Cowichan area support fish stocks of Coho, Kokanee, and Steelhead salmon, Rainbow, Eastern brook, and Cutthroat trout, Brown bullhead, Smallmouth bass, Yellow perch, and Pumpkinseed sunfish. Water-bodies providing important fish habitat include Shawnigan Lake, Shawnigan Creek, Spectacle Lake, Manley Creek, Camsusa Creek, and Garnett Creek

(Caskey, pers. comm., 2008). Riparian areas provide important habitat for fish while groundwater contributions to rivers and streams are vital for maintaining low-flows and regulating stream temperatures, issues that are essential for the survival and reproduction of aquatic life.

Shawnigan Creek has never supported Coho in its natural state due to the presence of impassable waterfalls at its outlet into Mill Bay. However, a run was established in the late 1970s by stocking the creek with Coho fry from Goldstream hatchery. Volunteers capture adult Coho each year when they return to the falls and truck them to release points upstream to spawn (Best, 2001).

Shawnigan Lake supports an isolated population of native Kokanee salmon. The salmon are landlocked descendants of sockeye that were stranded in the lake when ocean levels dropped after the most recent ice sheets melted. Following deglaciation, isostatic rebound caused Vancouver Island to rise, creating falls at the lower reaches of Shawnigan Creek (Best, 2001). Rainbow and Cutthroat trout, Smallmouth bass, Yellow perch, and Pumpkinseed sunfish are also found in Shawnigan Lake. Stocks of Rainbow trout are replenished in the lake on an ongoing basis, with almost 7,000 having been released into the Lake since March 2008 (Go Fish BC website).

Lower Shawnigan Creek flows from the northern end of Shawnigan Lake and winds approximately 11 km through suburban, forestry, and agricultural land to the falls at Mill Bay. In 1964, a weir was constructed approximately 450 metres downstream of the Lake on Lower Shawnigan Creek to store 1.2 million cubic meters (1,000 acre-feet) of spring runoff in the lake. The original 60 cm (two-foot) high weir consisted of a cement base poured directly onto the bedrock, with a 3m (9 foot) wide stoplog opening (Best, 2001). Two years ago, the CVRD replaced the original weir with a new, larger weir that better provides for fish passage between the lake and the creek (Law, pers. comm., 2008).

MOE oversaw operation of the original weir, but responsibility for operation of the new weir was transferred to the CVRD. MOE endorses maintaining a 20% Mean Annual Discharge (MAD) in waterways modified by flow control structures to protect a healthy fish habitat. In reality, agreements reached with waterworks authorities often provide for a much lower MAD. In Shawnigan Creek, the flow equates to 1% of MAD, or 0.014 m^3/s, at the outlet (March to October), resulting in insufficient flow to sustain the ecological function of the system (Law, pers. comm., 2008). Maintaining healthy fish habitat is challenged by domestic use, as water withdrawn in summer months to supply increasing numbers of homes around Shawnigan Lake, compromises critical summer flow volumes in the creek (Best, 2001).

Low flow issues are apparent in many other creeks and streams in South Cowichan, including Garnett Creek, Johns Creek, and Spectacle Creek (Law, pers. comm., 2008).

2.7.5 Wildlife

The South Cowichan region provides habitat for many bird and wildlife species. Species often found in riparian areas, wetlands, meadows, floodplains, lakes, and streams in the CDF and CWH zones are listed in Table 10 below.

Many of the wildlife species depend on surface water for food (prey), water and in some instances nesting (waterfowl, otters etc.) There are only indirect linkages with groundwater (e.g., base flow supporting fish habitat with the fish acting as prey). Riparian habitats tend to have the greatest amount of biomass and are often identified as key habitats in the life history of much terrestrial and aquatic wildlife. Though species relying on surface water for part or all of their life history, such as amphibians, shrews, and water birds are closely linked to riparian habitats, many terrestrial wildlife species also use riparian habitats. Riparian forests are suitable for a diverse suite of breeding birds, including waterfowl, woodpeckers, owls, and passerines. Because of the rich biomass in riparian areas, many mammal species higher in the food chain use these corridors for movement and feeding. Riparian areas support a large number of rare and endangered wildlife species.

The South Cowichan region is situated on the Pacific Flyway, a major bird migration route used by more than 220 bird species, including Savannah sparrows, Urasian widgeon, and species of waterfowl listed in Table 10 below. Memory Island Provincial Park in the Shawnigan watershed provides sanctuary and habitat for a variety of small mammals, amphibians, and reptiles and because of its isolation from lakeshore development, protects nesting waterfowl during the spring (BC Parks website). Resident breeding birds in Memory Island Provincial Park include Common mergansers, Belted kingfishers, and Common snipe.

Table 10 Wildlife Species in CDF and CWH Zones

CDF Zone Wildlife Species	CWH Zone Wildlife Species
Black-tailed Deer, Black Bear, Grey Wolf, Raccoon, River Otter, Mink, Deer Mouse, Wandering and Vagrant Shrew	Black-tailed Deer, Black Bear, Grey Wolf, River Otter, Mink, Deer Mouse, Wandering Shrew, Roosevelt Elk, Pacific Jumping Mouse, Pacific Water Shrew
Osprey, Short-eared Owl, Blue and Ruffed Grouse, Trumpeter Swan, Canada Goose, Ring-necked Duck, Redhead, Harlequin Duck, Wood Duck, Red-throated Loon, Common Merganser, Wilson's Phalarope, Black Tern, Mew Gull, American Dipper, Bald Eagle, Great Blue Heron, Green-backed Heron, Yellow-headed Blackbird, Purple Martin	Osprey, Short-eared Owl, Snowy Owl, Ruffed Grouse, Trumpeter Swan, Sandhill Crane, Ring-necked Duck, Redhead, Harlequin Duck, Wood Duck, Red-throated Loon, Common Merganser, Wilson's Phalarope, Black Tern, Mew Gull, American Dipper, Bald Eagle, Great Blue Heron, Green-backed Heron, Yellow-headed Blackbird, Purple Martin
Western Garter Snake, Northwestern Garter Snake, Painted Turtle, Western Toad, Bullfrog, Red-legged Frog, Northwestern Salamander, Long-toed Salamander, Rough-skinned Newt, Sharp-tailed Snake.	Common Garter Snake, Western Garter Snake, Northwestern Garter Snake, Painted Turtle, Western Toad, Bullfrog, Red-legged Frog, Northwestern Salamander, Long-toed Salamander, Rough-skinned Newt, Tailed Frog, pacific Giant Salamander.

2.7.6 Conservation Initiatives

The forests, meadows, wetlands, lakes, rivers, and streams of the South Cowichan area provide habitat for a diverse range of flora and fauna. Growth and expansion of urban centres can place pressure on sensitive areas that support important wildlife habitats. Conservation initiatives undertaken in South Cowichan protect some of the important aquatic and terrestrial habitats in the area. Initiatives relating to water management are described below.

Sensitive Ecosystem Inventories Project

The Sensitive Ecosystem Inventories (SEI) Project is a joint federal and provincial initiative of Environment Canada (Canadian Wildlife Service), the BC Ministry of Environment, and the Habitat Conservation Trust Fund. The purpose of the SEI Project is to “identify remnants of rare and fragile terrestrial ecosystems [in British Columbia] and to encourage land use decisions that will ensure the continued integrity of these ecosystems” (MOE website). A Conservation Manual has been produced for the SEI for East Vancouver Island and Gulf Islands, providing guidance on the protection of sensitive ecosystems. The project identifies 166 ha of ‘Older Second Growth Forest’ (defined as a large stand of conifer dominated forest, between 60 and 100 years old) at McCurdy Point in the Saanich Inlet watershed, and 62 ha of ‘Old Forest’ (defined as a conifer dominated forest with an average tree age of 100 years or greater) near Oliphant Lake, also in the Saanich Inlet watershed, as rare and fragile ecosystems that require protection (MOE website).

Vancouver Island Wetlands Management Program

The Vancouver Island Wetlands Management Program (VIWMP) is a partnership between The Nature Trust, BC Ministry of Environment (MOE), Ducks Unlimited Canada, Habitat Conservation Trust Fund, and Canadian Wildlife Service. The program involves the management of more than 50 conservation areas, of which most are coastal wetlands and estuaries owned by The Nature Trust and managed by MOE. Projects are implemented by the program’s Vancouver Island Conservation Land Manager through planning and funding support from program partners (The Nature Trust website).

Ducks Unlimited Canada (DUC)

DUC is working to protect more than 52,600 hectares of waterfowl habitat in the Georgia Basin, including the East Coast of Vancouver Island.

DUC is working with government to:

- Effect policy changes that protect priority areas;
- Purchase land;
- Eestablish conservation easements; and
- Undertake on-farm planning with landowners to protect diminishing areas (Ducks Unlimited Canada website).

South Cowichan Stewardship Project

The South Cowichan Stewardship Project was a two-year environmental program, operating throughout 2002-2004. The initiative was designed to conserve and protect ecologically sensitive areas along critical streams and rivers in the region, including Shawnigan Creek. Privately owned land bordering sensitive streams were the primary focus of the project.

The purpose of the project was to assist individual landowners in identifying critical habitat along streams and rivers on their properties and to build awareness of the need for management to protect the resources (South Cowichan Stewardship Project website).