7.0 WATER REGION # 5 - SOUTH WELLINGTON TO NANOOSE

7.1 Regional Overview

The South Wellington to Nanoose water region (WR5-SW-N) is defined as the area extending from the Nanoose Peninsula in the northwest part of the water region to South Nanaimo in the southeast, and from the coast around Departure Bay to the top of Mount Benson (Figure 62). It is 3rd largest water region within the RDN covering an area of approximately 322 km^2 (Table 41).

The region is densely populated as it encompasses the City of Nanaimo, District of Lantzville, and the Nanoose Peninsula. There are approximately 23 watersheds and subwatersheds in WR5 (SW-N), the largest of which is associated with Bonell and Nanoose Creeks which drain into Nanoose Bay (Figure 62). Nine hydrometric stations, seven climate stations, and approximately 248 surface water diversion licenses exist within the region (Figure 62, and Table 41).

Table 41: WR5 (SW-N) - Watersheds, Wells and Surface Water Licenses

Total Water Region Area	***315 km^2**
Major Watersheds	**Drainage Area[1] (km^2)**
Craig Creek	11.7
Nanoose Creek	34.0
Bonell Creek	51.2
Millstone River	100
Chase River	28.7
Beck Creek	13.9
Wells and Surface Water Diversion Points	**No.**
# Water Wells listed in MOE DB	1685
Surface water diversion licenses	248

Note: Drainage Areas are based on 1:50,000 BC Watershed Atlas. *The total water region area includes areas which drain directly to the ocean and are not within a major watershed area.

According to the MOE Wells Database (BCGOV ENV Water Protection and Sustainability Branch, 2012) WR5 (SW-N) has the second highest number of water wells (1685 wells) of the six water regions in the RDN. The MOE database likely only represents a fraction of the actual wells currently in use. Many well records may not have been entered into the database and some wells may simply not be in use or have been abandoned. As there is no mandatory requirement for submitting well logs or well abandonment records, it is not possible to determine the groundwater demand from private wells with any degree of certainty, nor is it possible to assess the vulnerability that may exist with improperly abandoned or standing water wells.

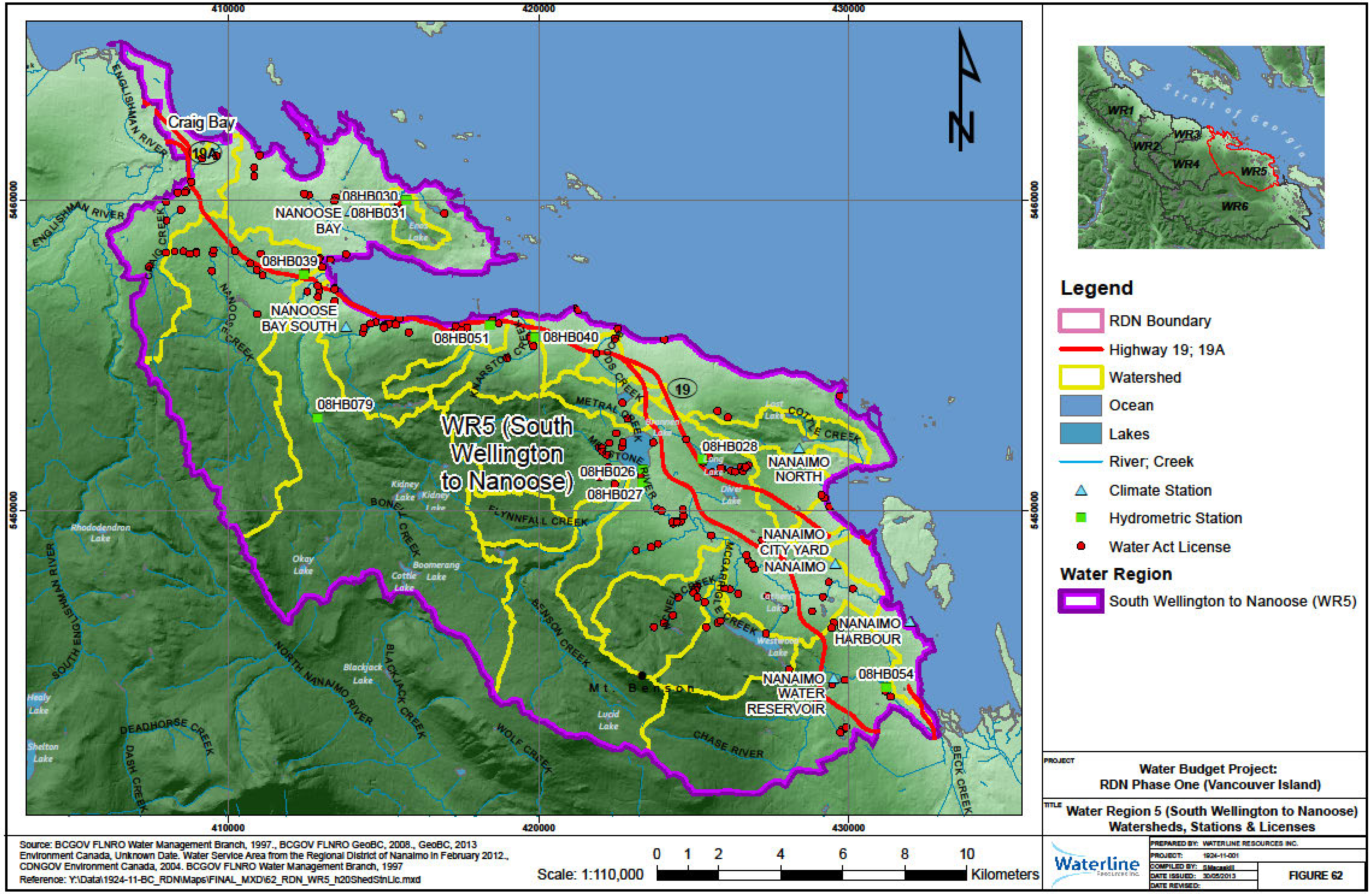


Figure 62: WR5 (SW-N) – Watersheds, Stations & Licenses

7.2 Surface Water Assessment

7.2.1 Terrain and Topography

The South Wellington to Nanoose Water Region (#6) includes all of the watersheds and lands between the Englishman River watershed and the Nanaimo River Watershed. Four major watersheds lie within the region including Nanoose Creek, Bonell Creek, Millstone River and Chase River. In addition, the water region includes all the smaller watersheds which flow into the Strait of Georgia from Craig Bay near Parksville to the Nanaimo River estuary south of Nanaimo. The major watersheds in the WR5 (SW-N) are shown in Figure 62.

The majority of the lands in the water region lie within privately managed forest lands. The lower portions of the water region consist of a range of land uses from rural development with agriculture land to high density residential, commercial and light industrial development within the City of Nanaimo.

The highest point in the water region is Mount Benson at 1,023 m. The north-east slopes of Mount Benson lie within the Mount Benson Regional Park. In general, the major watersheds all flow from the slopes of Mount Benson with streams on the west side of the mountain generally flowing north towards Nanoose Harbour and streams on the east side of the mountain flowing east and south towards Nanaimo Harbour. There are several lakes in the region with the largest being Brannen Lake in the Millstone Watershed followed by Long Lake, Westwood Lake, and Diver Lake. There are also many other smaller lakes.

7.2.2 Climate

The climate for the South Wellington to Nanoose Water Region is similar to the rest of the RDN with cool wet winters and mild dry summers. Two Environment Canada weather stations lie within the region at the Nanaimo City Yard on Labieux Road and in Departure Bay. Climate station locations are shown on Figure 62.

The average total annual precipitation recorded at the Nanaimo City Yard and Departure Bay for the 1971 to 2000 period was 937.8 mm and 1,140.9 mm, respectively. Figure 63 shows the monthly distribution of temperature and precipitation recorded at the Departure Bay climate station. No temperature data is available for the Nanaimo City Yard station.

Compared to other Water Regions, the South Wellington and Nanaimo Water Region lies predominantly at lower elevation and therefore does not likely accumulate as much snowpack as other areas. There are no snow observation stations within the region.

Both of the Environment Canada stations lie at lower elevation within the water region and are therefore not representative of precipitation at higher elevations. Maps showing the distribution of annual total precipitation and average annual temperature over the water region are shown in Figure 64 and Figure 65, respectively. These maps show that precipitation increases with elevation with a maximum total annual precipitation amounts of approximately 2,000 mm to 2,500 on Mount Benson.

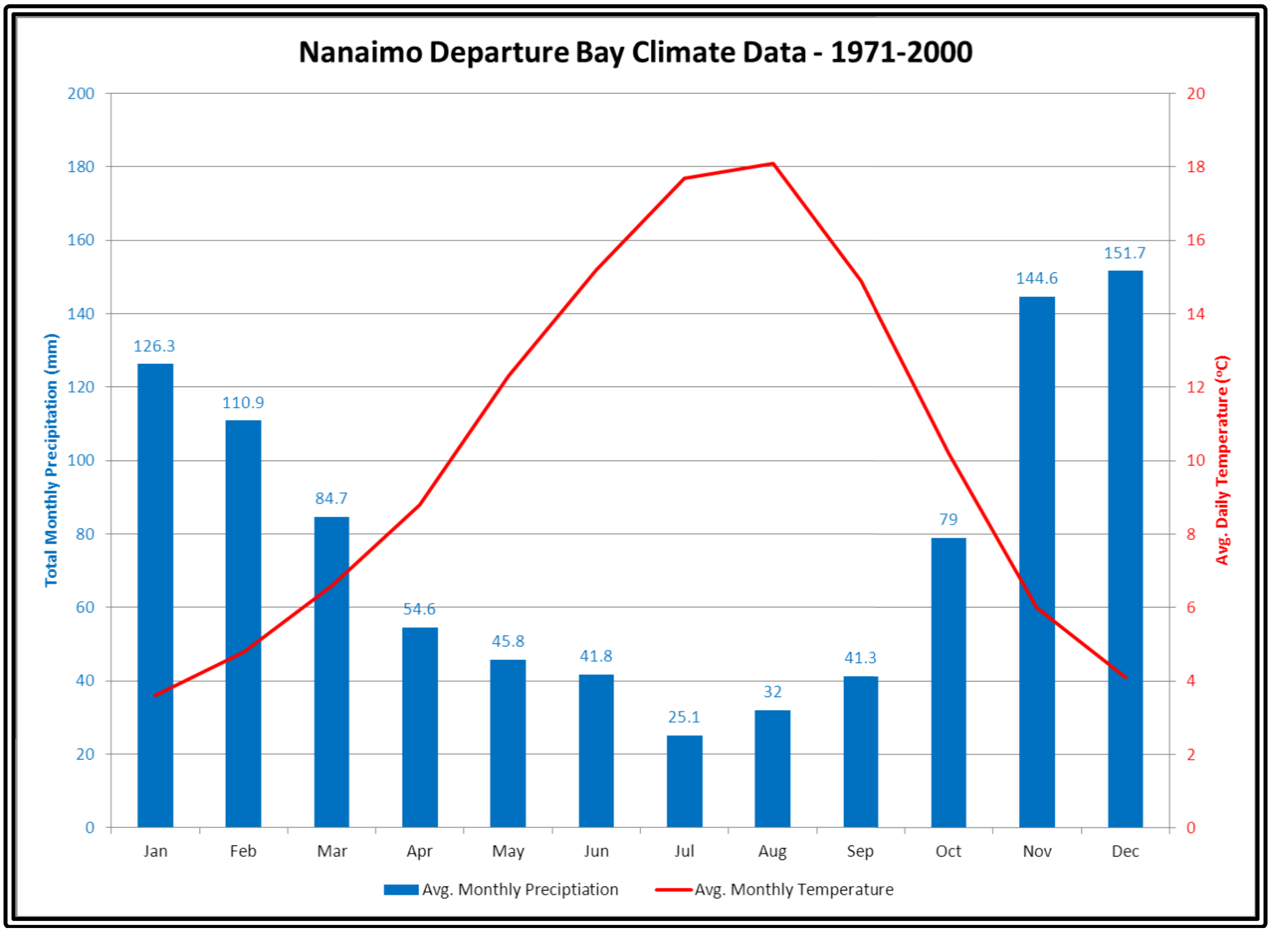


Figure 63: WR5 (SW-N) – Departure Bay Monthly Climate (1971 to 2000 Normal)

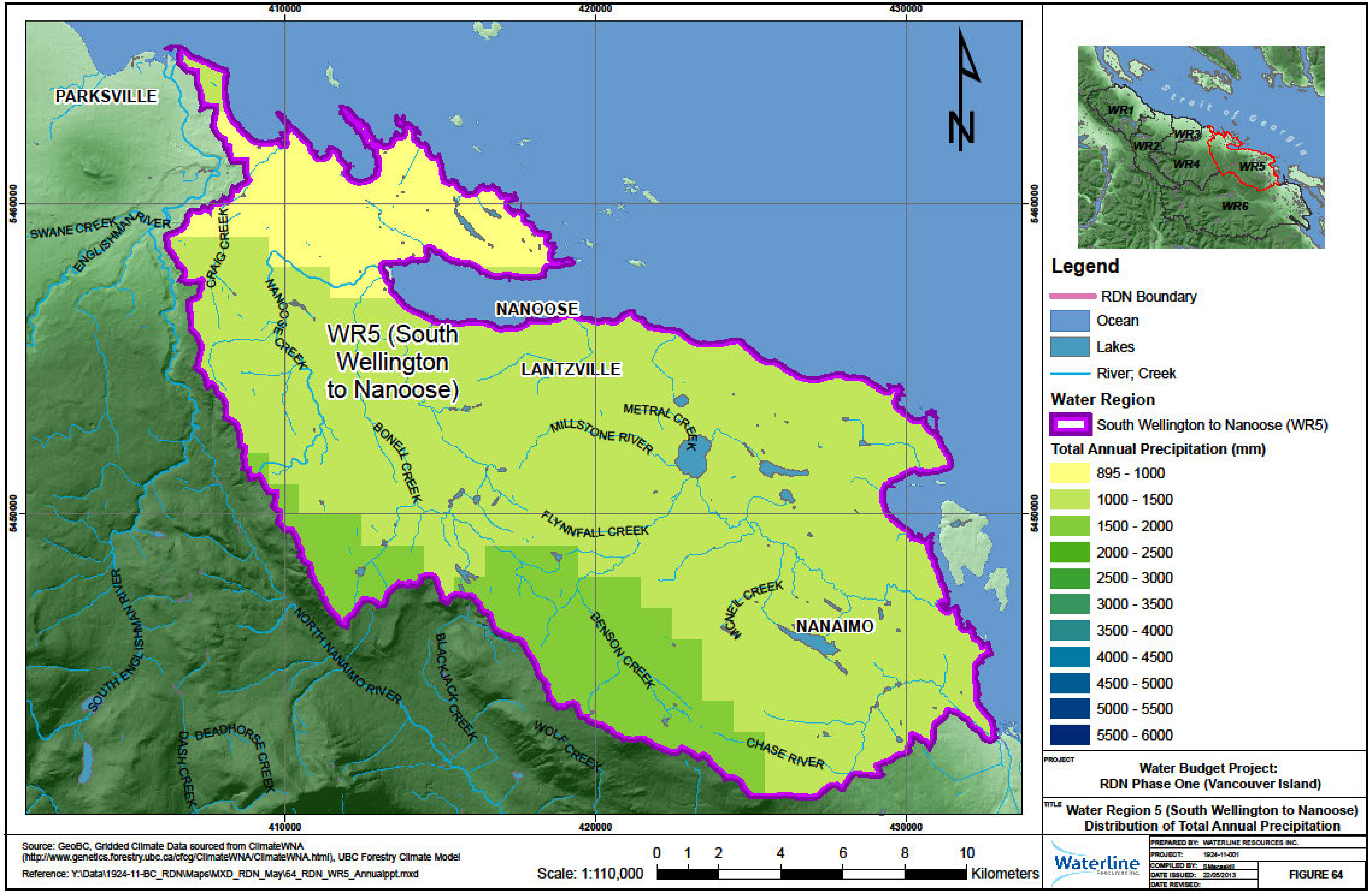


Figure 64: WR5 (SW-N) - Distribution of Total Annual Precipitation

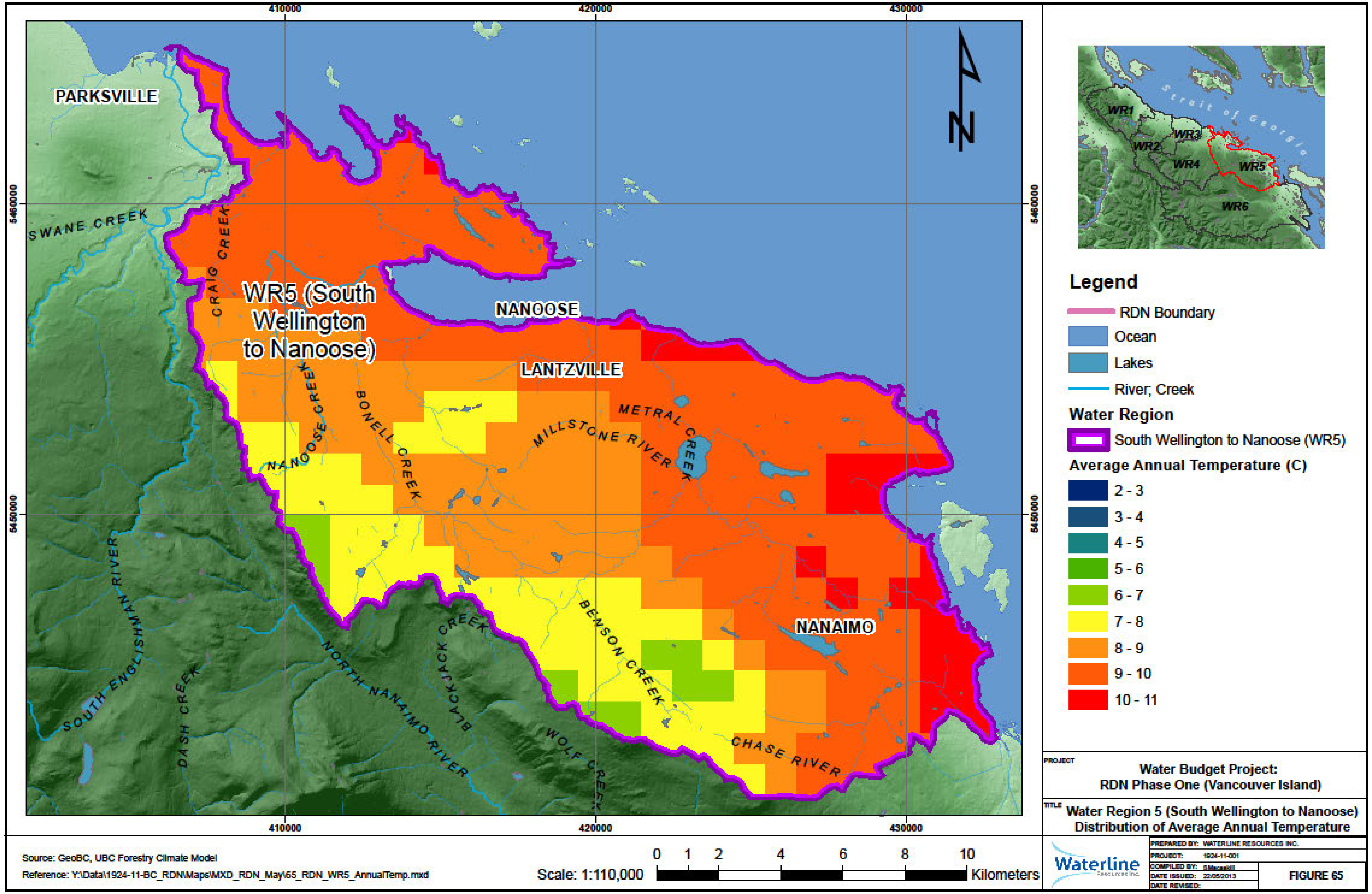


Figure 65: WR5 (SW-N) - Distribution of Average Annual Temperature

7.2.3 Stream Gauging and Monitoring

One active and four discontinued water survey of Canada hydrometric stations are located within the South Wellington to Nanoose Water Region. There are also three discontinued lake levels gauges at Brannen Lake, Long Lake and Enos Lake. The details for each of the stations are included in Table 42.

Table 42: WR5 (SW-N) – Water Survey of Canada Records

Station	Period	Natural or Regulated	Drainage Area to Gauge (km^2)	Mean Annual Discharge (m^3/s) and Volume (million m^3)	Mean Summer Discharge (m^3/s) and Volume (million m^3)
Millstone River at Nanaimo (08HB032)	1961 to Present	Natural (with Summer Releases from Westwood Lake since 2008)	86.2	2.55 m^3/s 80.4 million m^3	0.073 m^3/s 0.580 million m^3
Millstone River near Wellington (08HB027)	1961 to 1974	Natural	46.1	1.56 m^3/s 49.2 million m^3	0.056 m^3/s 0.455 million m^3
Enos Creek near Nanoose (08HB030)	1962 to 1978	Regulated	1.68	0.04 m^3/s 49.2 million m^3	0.0 m^3/s
Chase River near Nanaimo (08HB054)	1976 to 1978	Regulated		Summer Only	0.064 m^3/s 0.506 million m^3
Nanoose Creek at the Mouth (08HB039)	1970 to 1972	Natural		Summer Only	0.016 m^3/s 0.127 million m^3
Bonell Creek near Nanoose (08HB079)	1991	Natural		Summer Only	-

Monthly average hydrographs for Millstone River at Nanaimo are shown in Figure 66. The figure provides an indication of the impact that regulation in the system has had on river flows.

7.2.4 Hydrology and Surface Water Resources

The Regional Hydrological Model has been used to estimate mean annual discharge and volume as well as summer average discharge and volume for the major ungauged watersheds in the South Wellington to Nanoose Area. The recorded flows for Millstone River have been adjusted using watershed area ratio to estimate the available surface water resources for Millstone River. The results are shown in Table 43.

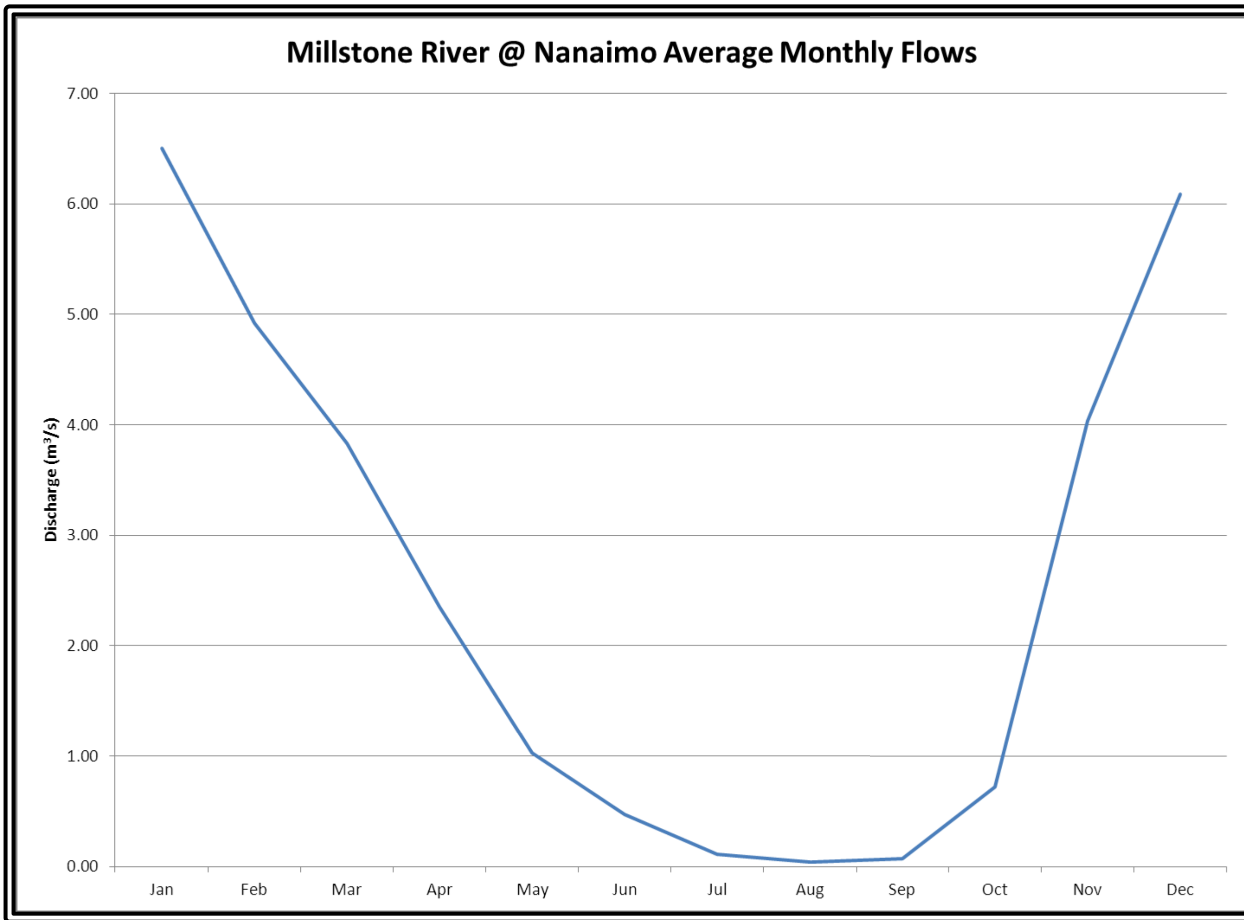


Figure 66: WR5 (SW-N) – Millstone River at Nanaimo Monthly Hydrograph

Table 43: WR5 (SW-N) – Natural (Unregulated) Surface Water Resources (1971 to 2000)

Watershed	Drainage Area (km^2)	Mean Annual Discharge (m^3/s) and Volume (million m^3)	Mean Summer Discharge (m^3/s) and Volume (million m^3)	Previous Estimate of MAD (m^3/s)
Craig Creek	11.7	0.21 m^3/s 6.62 million m^3	Less than 0.01 m^3/s	0.25
Nanoose Creek	34.0	0.87 m^3/s 27.4 million m^3	Less than 0.01 m^3/s	0.97
Bonell Creek	51.2	1.59 m^3/s 50.1 million m^3	0.01 m^3/s 0.08 million m^3	1.79
Chase River	28.7	0.73 m^3/s	Less than 0.01 m^3/s	0.96
Millstone River	100	2.95 m^3/s 93.1 million m^3	0.084 m^3/s 0.67 million m^3	2.32
Beck Creek	13.9	0.28 m^3/s 8.72 million m^3	Less than 0.01 m^3/s	0.13

Notes: Previous estimates of MAD from the BC Ministry of Environment Water Allocation Plans (Cook and Baldwin, 1994) have been included for reference. Drainage Areas are based on 1:50,000 BC Watershed Atlas

7.2.5 Surface Water Demand

Table 44 summarizes the surface water licences in WR5 taken from the BC Surface Water Licence Database. Table 45 outlines the licenced surface water storage. The locations of the surface water licences for WR5 are shown in Figure 62.

Table 44: WR5 (SW-N) - Surface Water Demand

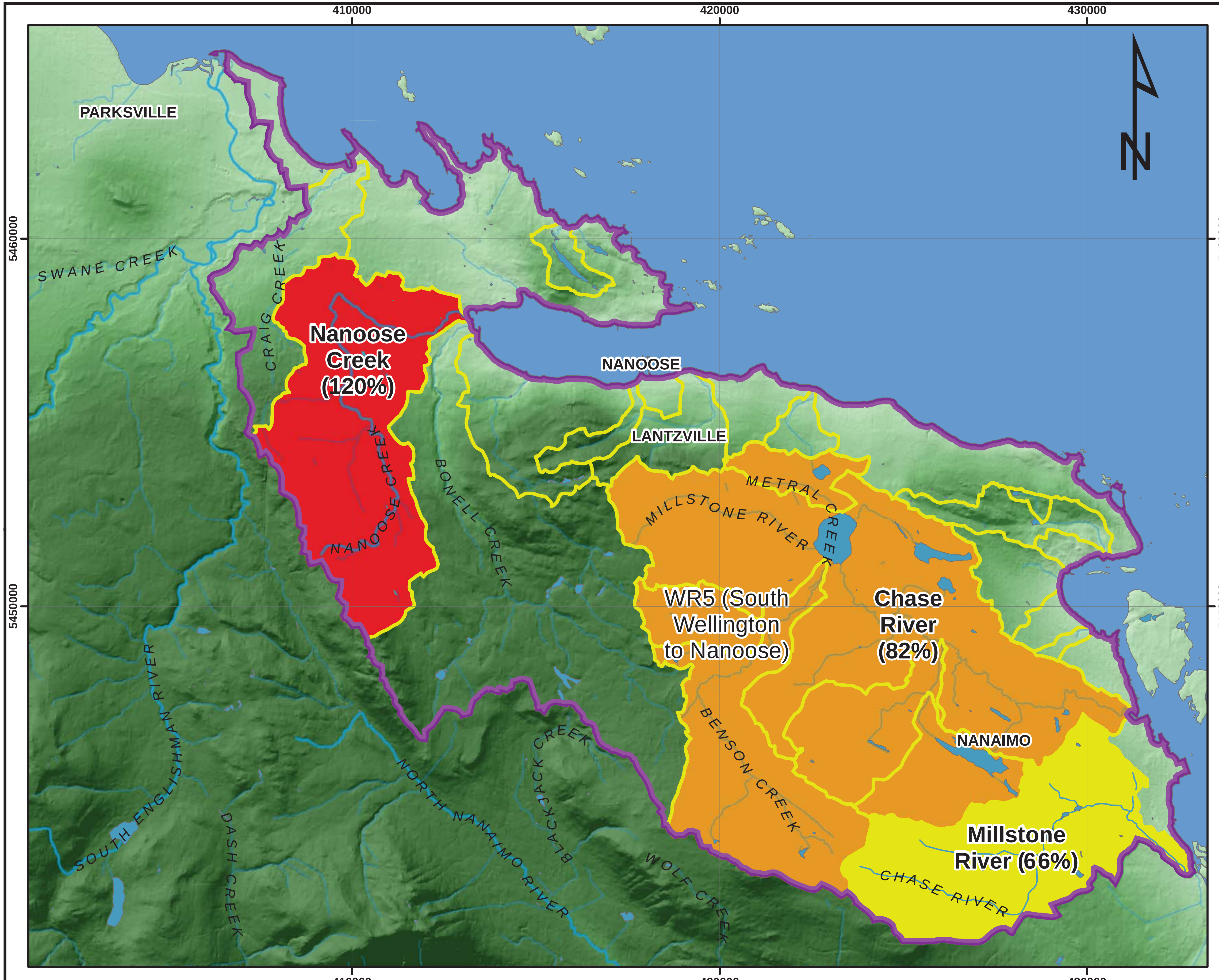
Type of Demand	Monthly (m^3/month)	Annual (million m^3)	Summer (Jul-Sept) (million m^3)
Consumptive Demand			
Agriculture	34,800	0.418	0.313
Domestic	23,100	0.277	0.093
Industrial	1,980	0.023	0.006
Institutional	-	-	-
WaterWorks	125,000	1.51	0.496
Total Consumptive	185,400	2.23	0.908
Non- Consumptive Demand			
Power	699,840	8,398,080	
Conservation	-	-	
Total Non-Consumptive	699,840	8,398,080	

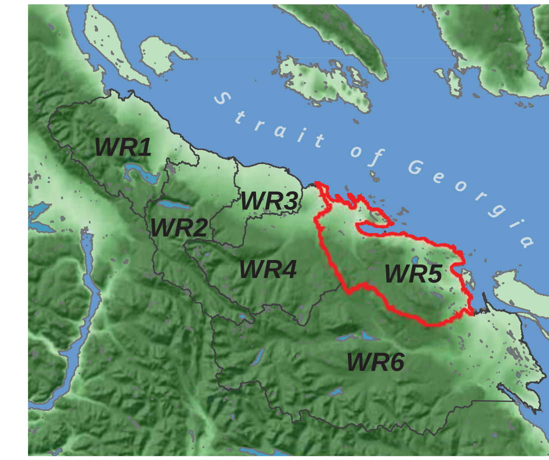
Table 45: WR5 (SW-N) - Licensed Surface Water Storage

Type of Demand	Total Storage (Million m^3)
Storage	0.38
Conservation Storage	0.39
Other Storage	3.29
Total Storage	4.07

7.2.6 Surface Water Stress Analysis

As outlined in Section 2.5.2, a surface water stress analysis for the major watersheds has been completed. Water budget analysis for other smaller ungauged subwatersheds within WR5 (SW-N) should be completed when data is available and as part of a more detailed Tier 1 or Tier 2 water budget assessment (OMNR 2011). The results of the allocation and actual demand stress analysis for the watersheds in WR5 (SW-N) are shown in Table 46. A map showing the relative stress for each watershed evaluated is shown in Figure 67.





Legend

- RDN Boundary
- Watershed
- Ocean
- Lakes
- River; Creek

Water Region

- South Wellington to Nanoose (WR5)

Allocated Surface Water Stress Level (%)

- Low (0 - 25)
- Low - Moderate (25 - 50)
- Moderate (50 - 75)
- Moderate - High (75 - 100)
- High - Very High (> 100)

PROJECT
Water Budget Project: RDN Phase One (Vancouver Island)

TITLE
Water Region 5 (South Wellington to Nanoose) Relative Surface Water Stress

Source: UBC Forestry Climate Model, BC FLNRO Water Management Branch, RDN Soil and Land Cover, GeoBC

Reference: Y:\Data\1924-11-BC_RDN\Maps\MXD_RDN_May\67_RDN_WR5_WaterStress.mxd

Scale: 1:110,000 — 0 1 2 4 6 8 10 Kilometers

Waterline Resources Inc.

PREPARED BY: WATERLINE RESOURCES INC.
PROJECT: 1924-11-001
COMPILED BY: SMacaskill
DATE ISSUED: 23/05/2013
DATE REVISED:

FIGURE 67

Table 46: WR5 (SW-N) – Relative Surface Water Stress Assessment Results

Watershed	Average Natural River Flow Supply (million m^3)	Storage (million m^3)	Conservation Flow (10% of MAD) (million m^3)	Licensed Demand (million m^3)	Allocation Stress	Stress Level
Nanoose Creek	0.6	0.0	0.7	0.02	**120%**	**High**
Millstone River	0.67	4.07	2.21	0.9	**66%**	**Moderate**
Chase River	0.6	0.5	0.6	0.3	**82%**	**Moderate to High**

Note: Volumes indicated in the table are average volumes for summer period (Jul to Sep). Average natural river flow is the estimated or recorded unregulated flow in the watershed. Total storage is based on licenced storage volume and assumes all storage is available to support conservation flow and licenced demand for the July to September period. The 10% of Mean Annual Discharge (MAD) conservation flow is based on current Ministry of Forest, Lands and Natural Resource Operations (MELP, 1996) minimum conservation flow policies for the east coast of Vancouver Island. Licenced demand is the total licenced volume for summer based on consumptive water licences. Allocation stress = (Average Natural supply + storage) / (Conservation Flow + Licenced Demand) Surface water stress color codes: blue=low, green =low to moderate, yellow =moderate, brown =moderate to high, red=high to very high. Values reflect average flow conditions and do not consider drought years.

7.3 Groundwater Assessment

7.3.1 Existing Groundwater Studies and Data – WR5 (SW-N)

Given the regional scale of the Phase One Water Budget Assessment, the most important data compiled and geo-referenced by Waterline was the water well information, elevation data, soil and geology maps, land cover, aggregate resource map, mapped aquifers, and water service areas. Other maps were generated using the input data as part of Waterline's work and some samples are provided in Appendix C for illustration purposes (Eg: overburden thickness (Map C7), piezometric contour maps (Maps C8 and C9), air temperature (Map C14), precipitation (Map C15), runoff (Map C16 and C17), evapotranspiration (Map C18), infiltration (Map C19), Water Service Areas (Map C20), and Water Demand Assessment in Non-service areas (Map C21). All of these maps are provided in Appendix C for the entire RDN study area with an explanation of how the map was geo-reference or created by Waterline. These data and layers are now available in the ARC GIS Geodatabase at the RDN Scale, water region scale, watershed scale, on other local scale needed for site specific assessments. These data will be provided to the RDN in electronic format as part of the ARC GIS Geodatabase system which was constructed by Waterline for use by the RDN. These regional datasets form the framework for construction of the conceptual hydrogeologyical model.

Although only some of the data in certain reports may have been incorporated into Waterline's Geodatabase, the primary studies in the region were used in Waterline's water budget assessment to provide local hydrogeological context are provided in Table 47.

Table 47: WR5 (SW-N) – Hydrogeology Reference Reports

Author	Year	Study Title
EBA Engineering Consultants Ltd.	2005	Madrona Heights Water Supply Assessment
EBA Engineering Consultants Ltd.	2006	New Production Well Madrona Well #8
Hodge Hydrogeology Consulting	2008	Testing of TW1-07 Claudet Road / Nanoose, BC
Hodge Hydrogeology Consulting	2009	Nanoose Well No.7 (Claudet Rd) Report Addendum
Hodge Hydrogeology Consulting	2009	2009 Pumping Test Results- ADDENDUM to report, Claudet Road
Hodge Hydrogeology Consulting	2009	Report on Groundwater Quantity and Quality for PW1-2008, Lot 1, Plan 26234, DL 62, Claudet Road, Nanoose Land District, BC
Levelton	2009	Well Yield Confirmation Madrona Heights Subdivision
Lowen Hydrology Consulting	2006	Well Water Source Development
Pacific Hydrology Consultants	1991	Completion Report – Evaluation of Confirmatory Pump Testing of Ring Contracting (Madrona No. 7) Well
Pacific Hydrology Consultants Ltd.	1984	Progress Report – Test Drilling Program – Madrona Point Water System
Pacific Hydrology Consultants Ltd.	1984	Capacity of Madrona Point Well No. 2
Pacific Hydrology Consultants Ltd.	1986	Madrona Water Specified Area – Test Production Drilling & Construction & Testing of Madrona Point Well No. 4
Pacific Hydrology Consultants Ltd.	1987	Madrona Water Specified Area – Construction & Testing of Wells No. 5 & No. 6
Pacific Hydrology Consultants Ltd.	1988	Completion Report – Construction & Testing of Fairwinds Test Well No. 1
Pacific Hydrology Consultants Ltd.	1990	Completion Report – Construction & Testing of Fairwinds Wells 2 and 3
Pacific Hydrology Consultants Ltd.	1990	Evaluation of the Capacity of Craig Bay Estates Campground Well No. 2-1984 and potential for developing Additional Groundwater Supplies for Golf Course Irrigation at Craig Bay Estates
Pacific Hydrology Consultants Ltd.	1990	Completion Report - Test Production Drilling, Construction and Testing of Production Well – Lot A DL 22 Plan 445R Nanoose District
Pacific Hydrology Consultants Ltd.	2007	Nanoose Bay Water Supply Fairwind Well#3 Pilot Study Report
Pacific Hydrology Consultants Ltd.	2008	Completion Report Evaluation and Capacity Testing of Fairwinds Community & Resort Wells 3-08 4-08 5-08
Pacific Hydrology Consultants Ltd.	2008	Water Source Assessment Study for Electoral Area E
Terracon Geotechnique Ltd.	1994	Regional Groundwater Study - Nanoose Peninsula
Lowen Hydrogeology Consultants	2010	Arrowsmith Water Service Englishman River Water Intake Study Groundwater Management. Discussion Paper 5-1. Existing Groundwater Supply Evaluation and Aquifer Yield Assessment, Prepared by Dennis Lowen, Alan Kohut and Bill Hodge, January 25, 2010.

7.3.2 Description of Aquifers and Water Wells

A total of three unconsolidated aquifers and six bedrock aquifers have been mapped within WR5 (SW-N) (Table 48). Quadra and Capilano aquifers (219, 215, and 167) exhibit moderate yield, and are generally confined low vulnerability and moderate use. With the exception of Aquifer 213, bedrock aquifers within WR5 (SW-N) are exhibit low productivity, moderate to light use, and moderate to low vulnerability.

The majority of supply wells are completed in unconsolidated Quadra and Capilano sand and gravel aquifers (Figure 68). However, underlying bedrock aquifers are also being developed for water supply (Figure 69). There are a total of 1685 overburden and bedrock wells listed in the MOE data base in WR5 (SW-N) (Table 41). As there are no regulatory requirements in BC to submit wells logs to MOE for capture in the BC Wells Database, the water wells shown on Figure 68 and Figure 69 likely represents only a fraction of wells actually drilled.

Table 48: WR5 (SW-N) – Summary of Mapped Aquifers

Aquifer Tag No.	Aquifer Lithology	Location Within Water Region	Potential Groundwater-Surface Water or Aquifer to Aquifer Interaction	Developed Aquifer Surface Area	Confined, Semi, or unconfined, Aquifer Vulnerability Code	Yield
				(m^2)		(L/M/H)
219	Quadra	Nanoose Penninsula	Nanoose Creek, Ocean	2.13E+07	Confined, IIC	M
214	NG	Nanoose NW Bay Rd. Area	Ocean	5.62E+06	Semi-Confined, IIIC	L
210	Buttle Lake Group - Fourth Lake Formation & Mount Hall Gabbro	Mid. Nanoose Cr.	Nanoose Creek, downgrad Fault Contact & NG	4.11E+06	Confined, IIB	L
218	Benson Fm, IP, VG	Nanoose Penninsula, Fairwinds area	Ocean	1.36E+07	Confined, IIB	L
213	VG	Lower and Upper Lantzville	Coal Works and Ocean	4.19E+07	Confined, IIC	M
215	Quadra	Entire Aquifer Nanoose Reserve to North Nanaimo – Bayshore Dr.	Ocean	1.46E+07	Confined, IIC	M
166	VG & NG	Long Lake to Stephen Point, Nanaimo.	Radial Flow to Long Lk., Dep. Bay, Neck Pt. etc… Ocean	1.20E+07	Confined, IIIB	L
211	VG & NG	Mt Benson to Parkway	Underground Coal Works	2.16E+07	Confined, IIB	L
167	Vashon or Quadra	Below Westwood Lk	Aq 211	2.36E+06	Confined, IIIC	M

Notes: A/B/C is high/moderate/low vulnerability, I/II/III is heavy/moderate/light use, H/M/L means high/medium/low productivity/yield. All aquifer classification parameters, codes and yield are defined at the following MOE web address http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/Aq_Classification/Aq_Class.html#class. NG means Nanaimo Group, IP means Island Plutonic Suite, VG means Vancouver Group (Karmutsen Formation).

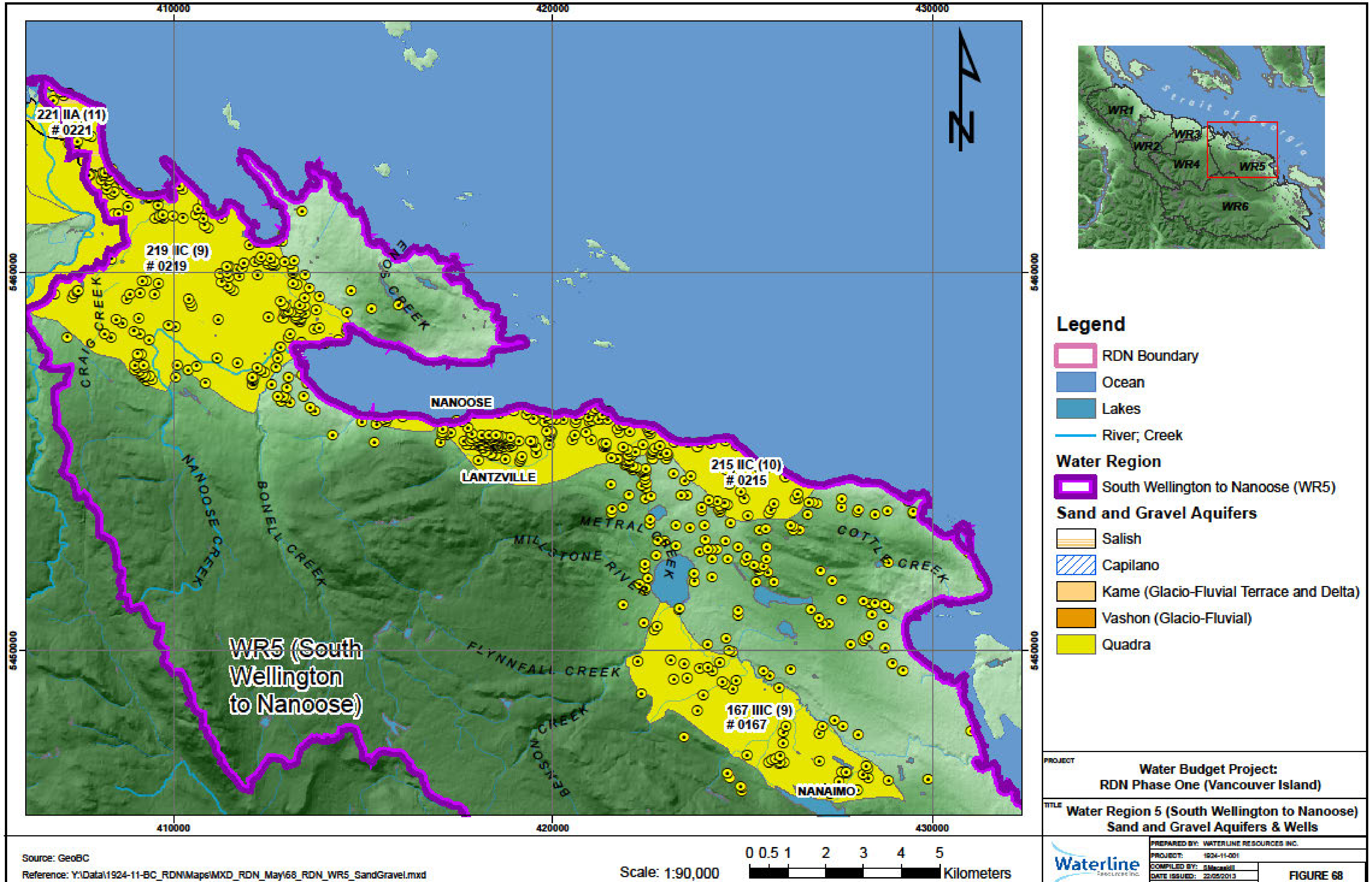


Figure 68: WR5 (SW-N) – Mapped Sand and Gravel Aquifers & Wells

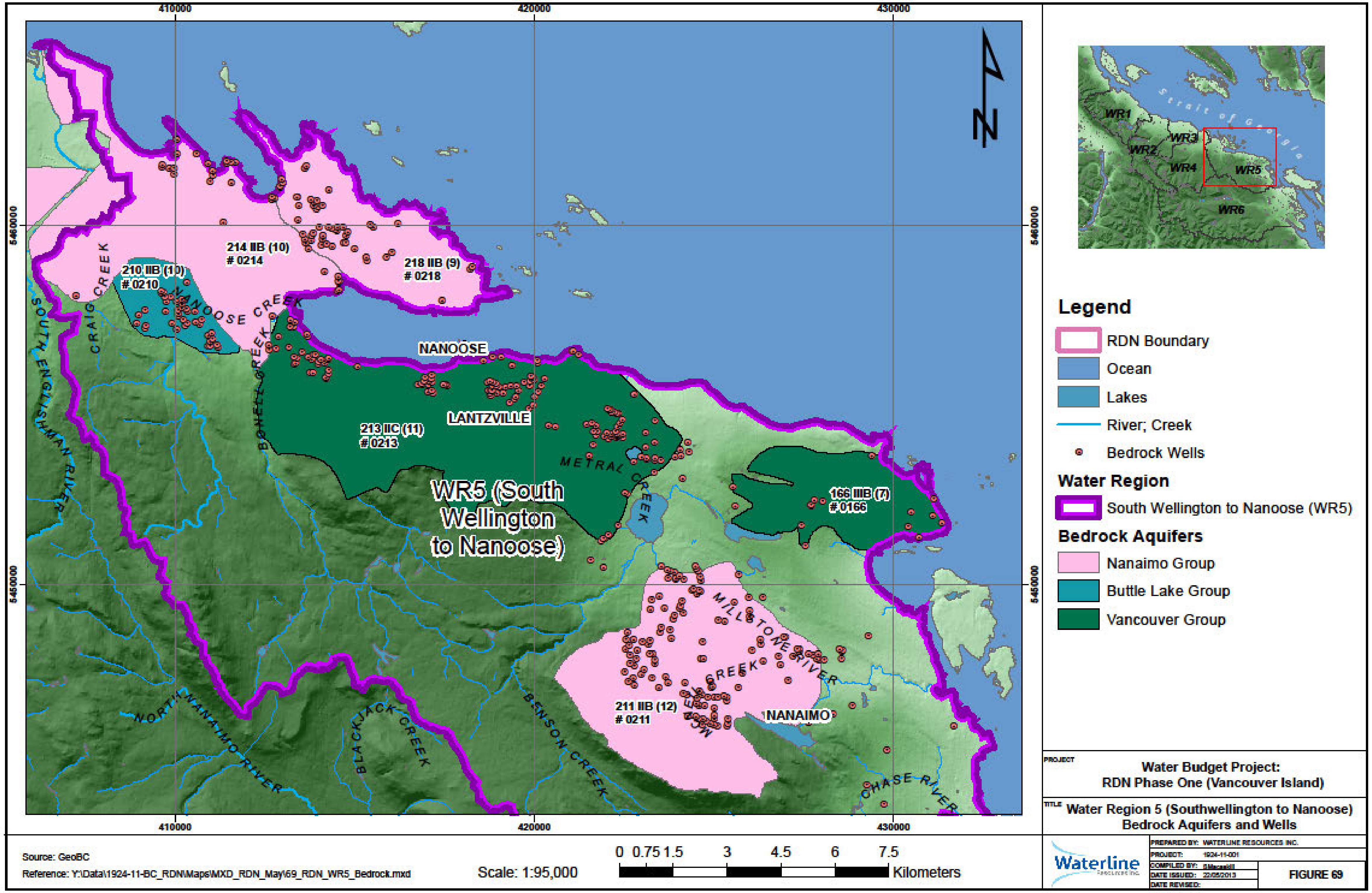


Figure 69: WR5 (SW-N) – Mapped Bedrock Aquifers & Wells

7.3.3 Groundwater-Surface Water Interaction - Conceptual Hydrogeological Model

A conceptual hydrogeological model of each aquifer with WR5 (SW-N) was developed in order to understand the key elements and linkages between surface water and groundwater systems required to complete the water budget assessment. Although conceptual hydrogeological model developed by Waterline includes numerous cross-sectional views developed within the Waterline Geodatabase, only one 3D view into the subsurface will be presented here.

Figure 70 shows a 3D block diagram illustrating the relationship between surface and subsurface geology in the Lantzville area of WR5 (SW-N) where major water supply aquifers have been mapped. View 1 show how the Quadra sand aquifer (0215) is highly developed with closely spaced supply wells beneath the District of Lantzville. Quadra aquifer 215 appears to thin to the east and overlies bedrock aquifer 213 which is less well developed in the Lantzville area.

Figure 71 shows a 3D block diagram illustrating the relationship between surface and subsurface geology in the Nanoose Creek area of WR5 (SW-N). View 1 shows the Quadra aquifer pinching out to the north as it abuts onto bedrock aquifer 218 near Northwest Bay. View 2 shows how the Quadra sand aquifer (0219) may be interacting with Nanoose Creek.

Water levels in wells measured at the time of drilling provide an indication of groundwater flow and indicated that groundwater is flowing downward from the Quadra aquifer to the deeper bedrock aquifer, and both flow systems are directing water towards the ocean.

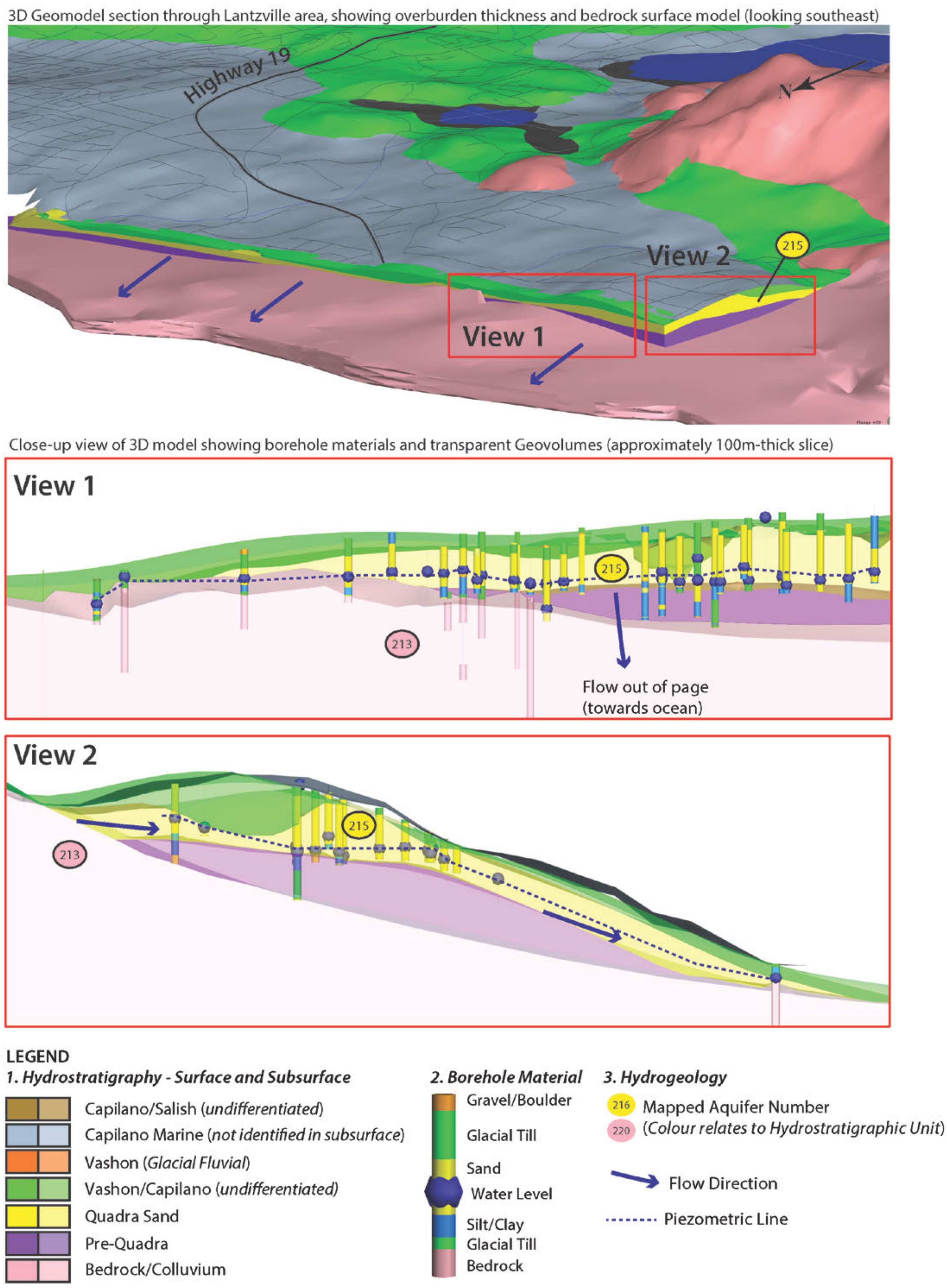


Figure 70: WR5 (SW-N) – Hydrogeological Conceptual Model – Lantzville Area

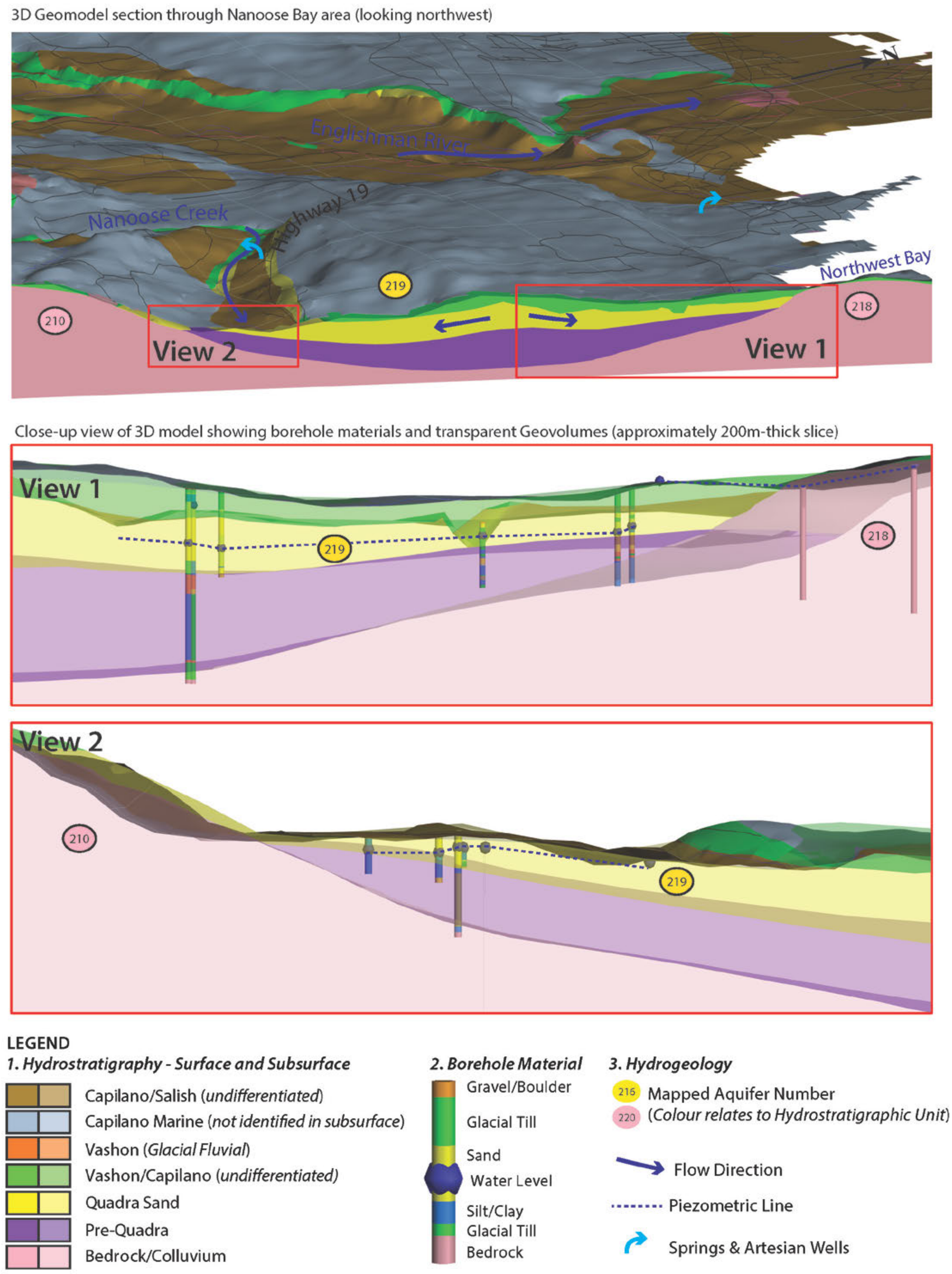


Figure 71: WR5 (SW-N) – Hydrogeological Conceptual Model – Nanoose Area

7.3.4 Significant Recharge Areas

Significant recharge areas within WR5 (SW-N) were determined as part of the assessment of infiltration across the region base on topography, mapped textural soil characteristics, land cover (bare land, vegetation, impermeable surfaces), and leaf area index. These areas are important for maintaining recharge to aquifers and base flow to creeks and rivers. The preliminary assessment presented herein is based on the integration of numerous datasets which may be incomplete and therefore will require further field verification. Figure 72 shows significant recharge areas mapped in WR5 (SW-N) as part of the water budget project.

Significant recharge areas are shown in red/orange and extend to the upper reaches of WR5 (SW-N) and into the up part of Nanoose Creek, Bonell Creek, Benson Creek, Millstone River, and Chase River. Some of the areas indicated are moderately developed (Benson Meadows, Millstone River). Future development planning needs to consider these areas to ensure that aquifer recharge continues to be maintained. There is a need to develop protection zones around critical areas contributing recharge to underlying aquifers to ensure the future sustainability of groundwater resources in this region. Better definition of these areas should be completed as the current modelling completed by Waterline and KWL was done on a 1 km square grid.

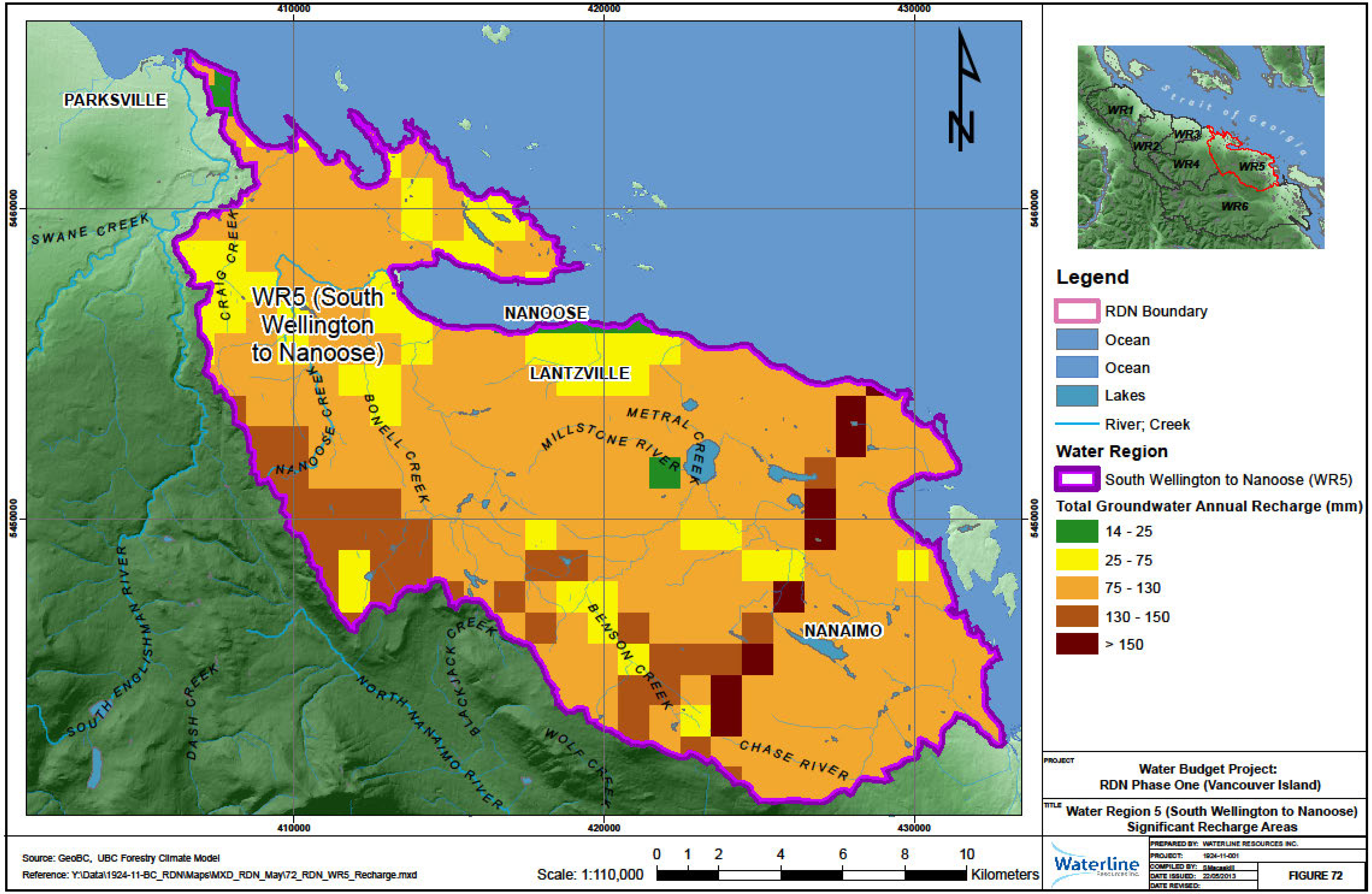


Figure 72: WR5 (SW-N) – Significant Recharge Areas

7.3.5 Groundwater Level Monitoring - BCMOE Observation Well Network

Long-term water level monitoring data provides an indication of an aquifer's response to global, regional, and local environmental changes in climate, groundwater pumping, and the impacts (if any) of other activities related land development. Long-term records also allow for establishing hydraulic linkages between the groundwater and surface water systems.

Figure 73 shows the locations of MOE observation wells and long-term water level monitoring records in relation to community water supply wells identified from the MOE Wells Database (E.g.: Large municipal users, the RDN, private utilities wells). Although numerous community wells are listed in the database, Waterline understands that not all of these wells shown on Figure 73 are currently active.

One of the problems encountered by Waterline during the water budget project was that community well owners generally do not cross-reference active production wells to respective well logs in the MOE database. Often wells are referred to by local names (E.g.: RDN well # 1, #2, etc…). As water budget calculations require that production wells be assigned to specific aquifers, it is important that cross-referencing with the MOE well logs be done. Well owners are encouraged to report the MOE well plate number so that accurate water level and groundwater extraction volumes can be allocated to the corresponding MOE well log and mapped aquifer.

Water level monitoring records are available for five MOE observation wells in WR5 (SW-N) (Figure 74 to Figure 78, inclusive). MOE well 393 is completed in Quadra sand aquifer 219 (Figure 74), MOE well 394 in Benson Formation aquifer 218 (Figure 75), MOE wells 340 and 232 in Quadra sand aquifer 215 near Lantzville, and MOE well 388 in Karmutsen Formation (volcanic bedrock) aquifer 211 near Benson Meadows. Water levels in MOE observation wells were plotted along with the Nanaimo City Yard precipitation record and the PDO trend, where appropriate.

MOE well 393 completed in Quadra Aquifer 219 shows seasonal variation in water level, but the record is too short to establish a long-term trend. MOE well 394 completed in Aquifer 218 along the coast in Nanoose Bay clearly shows tidal influence, but the water level has been stable over the several months it has been operating. MOE observation wells (340 and 232, Figure 76, and Figure 77) completed in the Quadra sand aquifer 215 beneath Lantzville exhibit declining water levels over the period of record which dates back to 1982 (well 232). The long-term hydrographs for MOE wells 232, 340, and perhaps even 388 appear to follow the PDO trend suggesting that long-term climate variability is affecting aquifer recharge. MOE well 388 completed in bedrock aquifer 211 near Benson Meadows exhibits over 8 m of fluctuation seasonally with essentially full water level recovery during the rainy winter season.

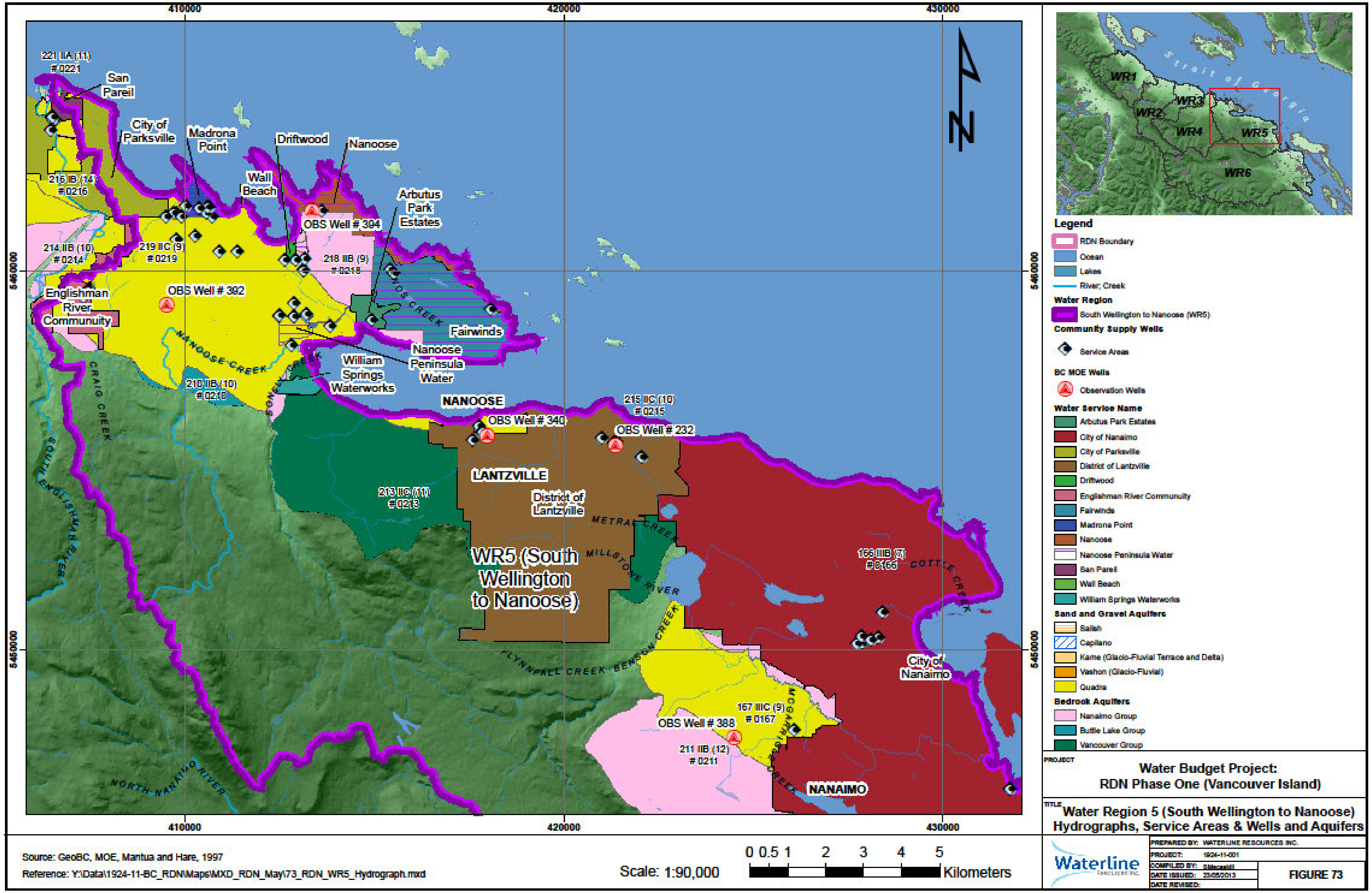


Figure 73: WR5 (SW-N) – MOE Well Hydrographs, Service Areas & Wells, and Aquifers.

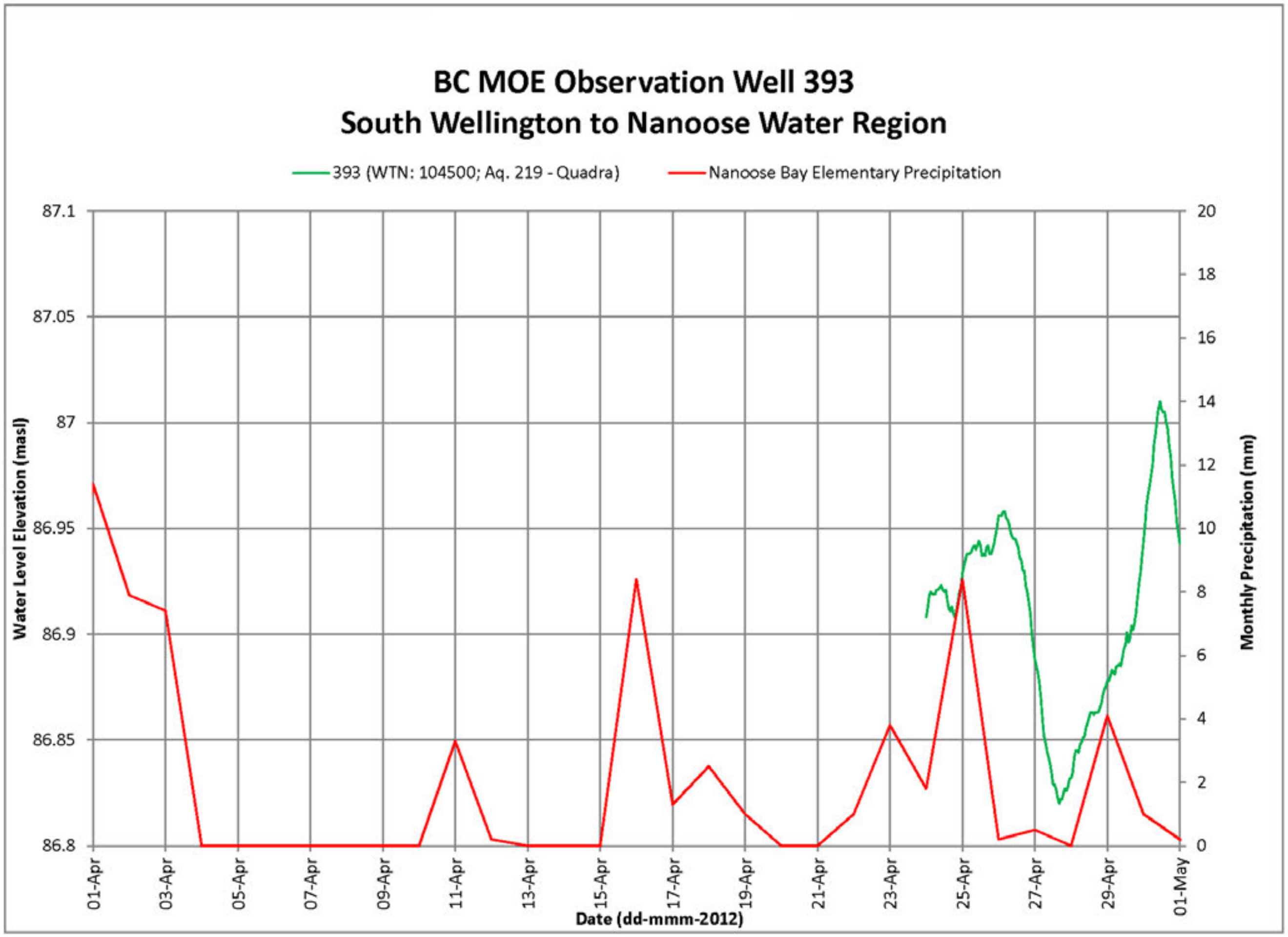


Figure 74: WR5 (SW-N) – Water Level Hydrograph BCMOE 393.

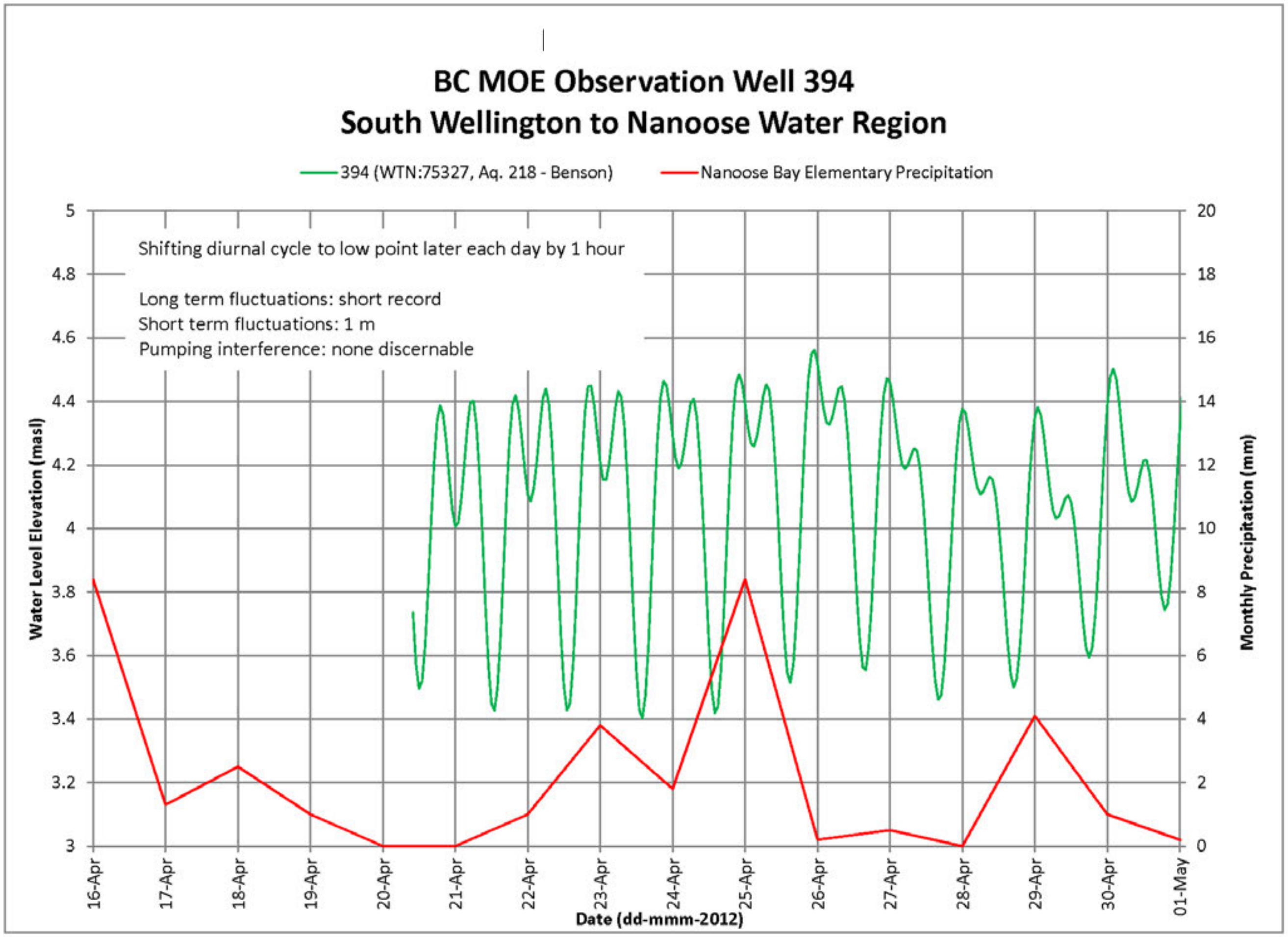


Figure 75: WR5 (SW-N) – Water Level Hydrograph BCMOE 394.

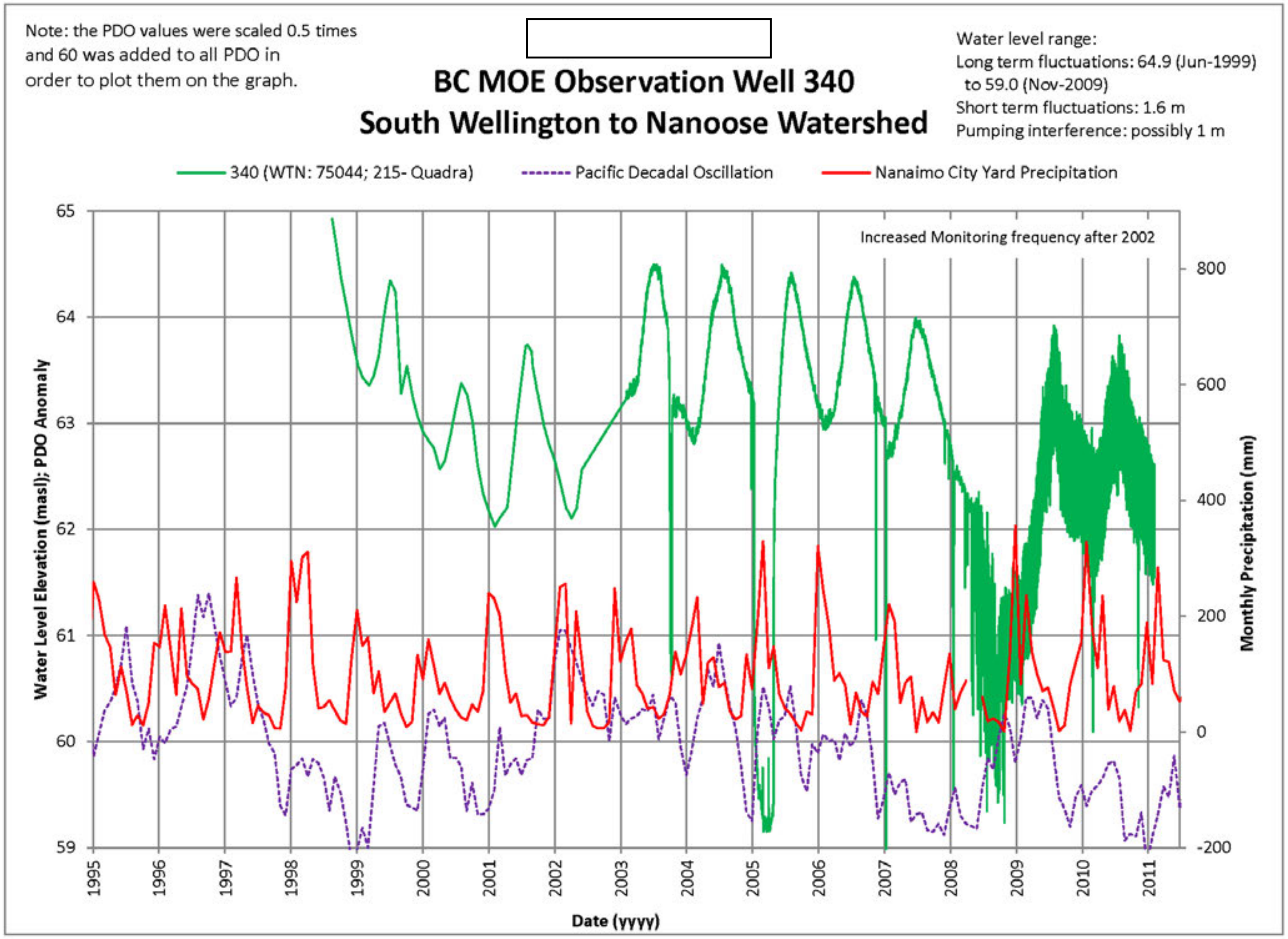


Figure 76: WR5 (SW-N) – Water Level Hydrograph BCMOE 340.

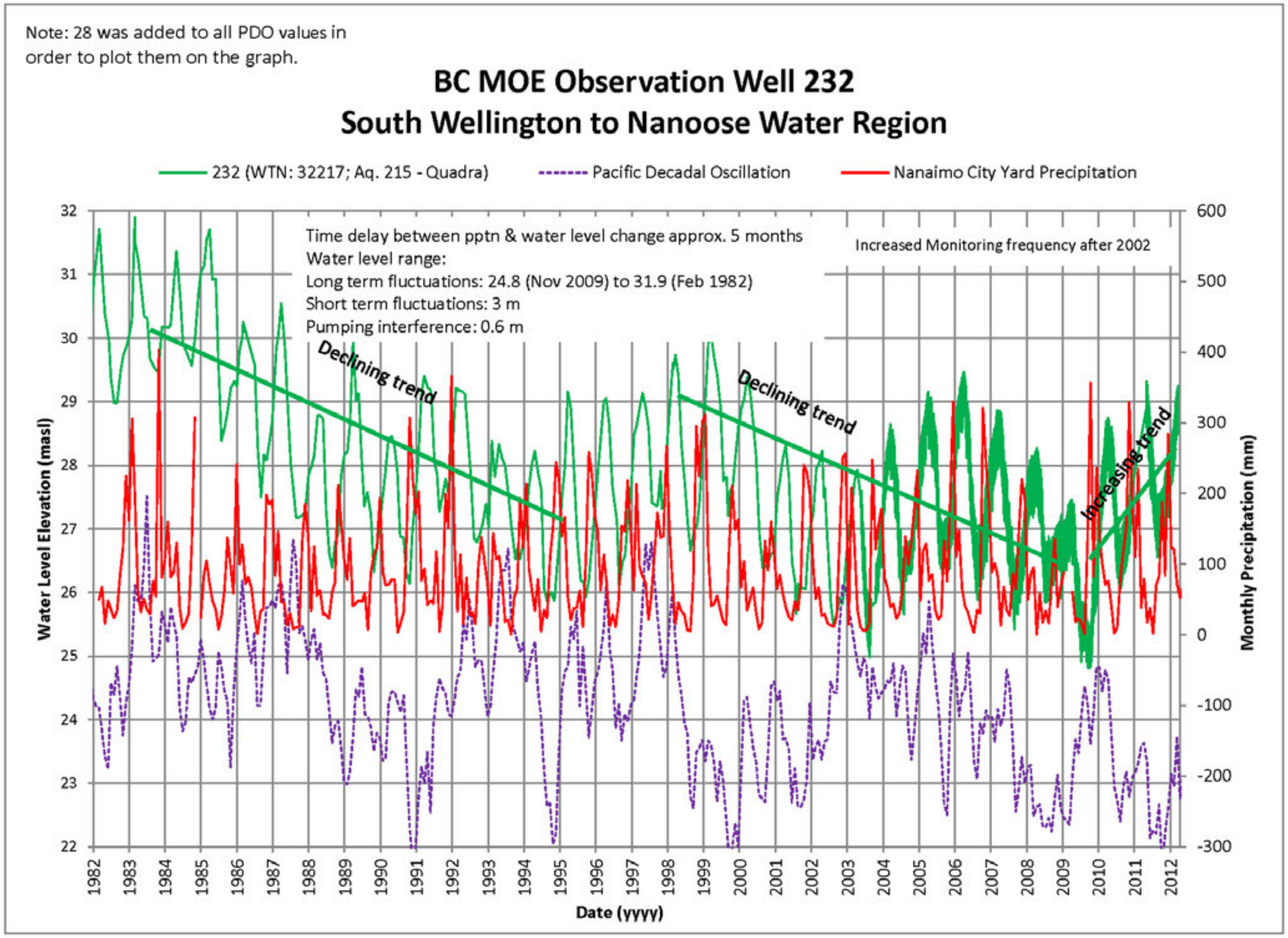


Figure 77: WR5 (SW-N) – Water Level Hydrograph BCMOE 232.

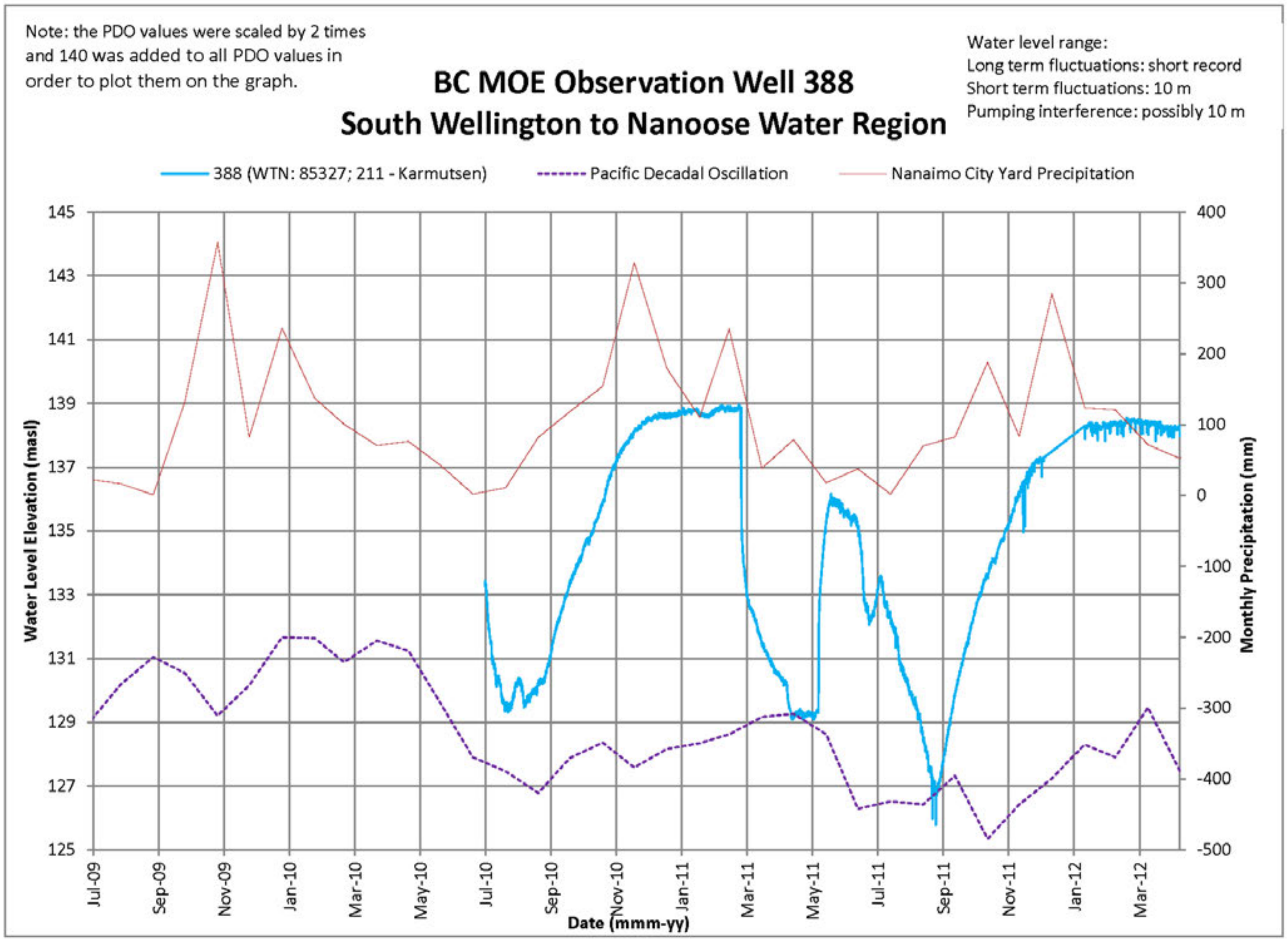


Figure 78: WR5 (SW-N) – Water Level Hydrograph BCMOE 388

7.3.6 Anthropogenic Groundwater Demand

Table 49 summarizes the available groundwater demand data available for WR5 (SW-N). The annual water use for serviced areas within the RDN (large municipal users, RDN wells, and private utilities) is typically measured and was provided by the RDN or taken from annual reports for 2010. The groundwater demand estimate for non-service areas was calculated from water use data provided by the RDN for serviced areas, and then applied to non-serviced areas based on civic addresses and zoning classification. The method of assessment is further described in Appendix C (Map C21) and Appendix D.

There may also be groundwater discharging from aquifers that is required for conservation of flow in creeks and rivers based on the physical model developed by Waterline. The total groundwater demand for each aquifer, including conservation flow requirements, was compared against the estimated aquifer recharge to assess the stress on each aquifer.

7.3.7 Aquifer Water Budgets and Stress Analysis

Table 50 provides a summary of the final water budget calculations for each aquifer mapped within WR5 (SW-N). Detailed water budget calculations are provided in Appendix D (Tables D7 and D8). Water budgets for aquifers that extend from one water region to an adjacent water region (E.g.: Aquifer 219, Figure 68) were completed on the portion of the aquifer which lies within each region. The water budget calculations were also designed to be additive so that a complete water budget of an entire mapped aquifer that extends across a water region boundary could be easily developed.

As indicated above, there are a total of 1685 overburden and bedrock wells listed in the MOE data base in WR5 (SW-N) which represents the second largest number of wells in all of the 6 water regions across the RDN on Vancouver Island. It is also recognized that this number may only represent as little as 50% of water wells actually in operation in this region. This clearly demonstrates that the demand for groundwater in WR5 (SW-N) is very high and that there is an urgent need to better manage groundwater extraction in this region.

Based on the water budget estimates for mapped aquifers within WR5 (SW-N) Aquifers 219 (Nanoose Creek area), 214 (Nanoose coastal area), 213 (bedrock aquifer in Lantzville), and 166 (Neck Point to Stephenson Point) indicate low stress. Aquifer 213 was reported to be locally stressed in the Superior Road area (HB Lanarc, 2010), but this is not reflected in the aquifer-wide water budget assessment.

The water budget assessment for Aquifer 210 (Nanoose Creek above Hwy 19) indicates a moderate to high stress. Aquifer 218 (Nanoose Peninsula) indicates high degree of stress on the aquifer. Water levels in bedrock aquifer (218) should be monitored closely as its hydrograph demonstrates a tidal influence and the potential for salt water intrusion likely exists.

Although there are a number of wells completed in Aquifer 167, it appears that there is little groundwater use based on the higher number of wells completed in the deeper bedrock aquifer (Aquifer 221). However, as Aquifer 167 overlies Aquifer 211 which indicates stress, "conservation" recharge flux has been allocated to Aquifer 167 in order to ensure that the underlying aquifer continues to receive recharge.

Table 49: WR5 (SW-N) – Summary of Anthropogenic Groundwater Demand Analysis

Aquifer Tag No.	RDN Rivers Edge	RDN Nanoose Bay Water Service Wall Brook wells).	RDN Nanoose Bay Madrona Wells	RDN Nanoose Bay Water Service Nanoose, Fairwinds, & Westbay wells	RDN Fairwinds Arbutus	District of Lantzville	Nanoose First Nation	Other Private Wells (From RDN Water Use Est. based on Zoning from GIS)	Total Ground Water Use Est. (ANTH out)
	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)
219	5.5E+04	?	1.0E+05	5.8E+04	1.5E+05	NA	NA	2.4E+06	2.8E+06
214	NA	NA	NA	NA	NA	NA	NA	4.4E+02	4.4E+02
210	NA	NA	NA	NA	NA	NA	NA	3.2E+05	3.2E+05
218	NA	NA	NA	NA	1.5E+05	NA	NA	1.2E+05	2.7E+05
213	NA	NA	NA	NA	NA	?	?	7.2E+05	7.2E+05
215	NA	NA	NA	NA	NA	NA	NA	4.4E+05	4.4E+05
166	NA	NA	NA	NA	NA	NA	NA	0.0E+00	0.0E+00
211	NA	NA	NA	NA	NA	NA	NA	2.3E+06	2.3E+06
167	NA	NA	NA	NA	NA	NA	NA	0.0E+00	0.0E+00

Notes: NA means not applicable, ? Means not known or unavailable, ANTHout means anthropogenic water extraction from aquifer.

Table 50: Summary of Water Budget and Stress Analysis – WR5 (SW-N)

Aquifer Tag No.	Aquifer Lithology	Potential Groundwater-Surface water or Aquifer to Aquifer Interaction	MOE Obs Well	Seas. Fluc.	Long Term Fluc.	WL Trend (up or down)	Total Est. AQ. Rec. (TRin) (Rp/l + Rmb)	Est. Ann. Disch to Cr. & Down Grad Aquifer (Tc out)	Ground Water Use Estimate (ANTHout)	Total Out [TcOut + $ANTH_{out}$]	Stress Anal. % GW Use of the avail. AQ. Rec.	Relative Stress Assess.
			ID	(m)	(m)	U/D	(m^3/yr)		(m^3/yr)	(m^3/yr)	(%)	Lo, Mod, Hi
219	Quadra	Nanoose Creek, Ocean	392, 393	?	?	L	1.6E+08	1.56E+07	2.8E+06	1.83E+07	11	Lo
214	NG	Ocean	NA	NA	NA	NA	6.2E+05	0.00E+00	4.4E+02	4.40E+02	0	Lo
210	Buttle Lake Group - Fourth Lake Formation & Mount Hall Gabbro	Nanoose Creek, downgrad Fault Contact & NG	NA	NA	NA	NA	3.1E+06	2.45E+06	3.2E+05	2.77E+06	89	Mod-Hi
218	Benson Fm, IP, VG	Ocean	394	?	?	?	2.0E+06	4.06E+06	2.7E+05	4.33E+06	212	V. High
213	VG	Coal Works and Ocean	NA	NA	NA	NA	1.4E+07	4.12E+05	7.2E+05	1.13E+06	8	Lo
215	Quadra	Ocean	340, 232	1.6, 3.0	5, 7	D/L	6.3E+07	6.05E+07	4.4E+05	6.09E+07	97	Mod-Hi
166	VG & NG	Radial Flow to Long Lk., Dep. Bay, Neck Pt. etc… Ocean	NA	NA	NA	NA	2.2E+06	0.00E+00	0.0E+00	0.00E+00	0	Lo
211	VG & NG	Underground Coal Works	388	10.0	?	precip	3.8E+06	9.18E+06	2.3E+06	1.15E+07	306	V. High
167	Capilano	Benson Fm	NA	NA	NA	NA	3.6E+07	1.77E+07	0.0E+00	1.77E+07	49	Lo-Mod

Notes: SW-N means South Wellington to Nanoose, NA means not applicable, AQ means aquifer, Seas. Fluc. means seasonal fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, Est means estimated, Disch. means discharge, Rec. means recharge ,Cr. Means creek, TRin means total recharge into aquifer, Rp/l means total recharge from precipitation and/or leakage from overlying aquifer, Rmb means total lateral recharge from up gradient aquifer or mountain block, Tc out means total aquifer groundwater discharge to creek, assess. means assessment , Total out means total discharge from aquifer (not including discharge to ocean), ANTH out mean total groundwater Anthropogenic groundwater extraction from aquifer, aquifer stress color codes: blue=low, green =low to moderate, yellow =moderate , brown =moderate to high, red=high to very high.

Aquifer 211 (Benson Meadows) also was classified as having a high degree of stress based on the water budget estimates. This aquifer is located high in the watershed and has limited catchment for recharge. Many surface water licences divert potential aquifer recharge from streams crossing the area. There is also relatively high well density so well to well interference may be affecting water levels in this low productivity aquifer. The aquifer is immediately up gradient of coal workings that may represent a groundwater sink. Long-term monitoring and cumulative impact assessment is highly encouraged in this area.

The water budget estimate for the Quadra aquifer (215) in Lantzville indicates a moderate to high level of stress. Aquifer 215 has a relatively small catchment area (i.e. limited recharge potential) and little to no mountain block recharge. The well to well density is high in this area.

More accurate water budget and aquifer stress estimates could only be accomplished using a computer modelling approach, but again the lack of aquifer data would likely render this exercise inconclusive as well. Rigorous testing requirements and complete aquifer test analysis by groundwater practitioners to determine aquifer transmissivity and storativity properties, in addition to long-term groundwater monitoring data in each aquifer would be required to fully assess the actual stress on each aquifer in this region.

7.4 Water Management Planning Within WR5 (SW-N)

General guidance on water management planning for all water regions is provide in later sections of this document. Specific to WR5 (SW-N), the following recommendations are presented for consideration by RDN to improve the state of knowledge in the water region:

- At least one observation well should be installed in each mapped aquifer. Mapped aquifers that currently do not have MOE observation wells include aquifers 214, 210, 213, 166, and 167;
- Well owners should identify the MOE well plate and tag numbers for each of their active water wells. In this manner, water use and monitoring data can be easily cross-referenced with the BC MOE well records. These include River’s Edge wells, Nanoose Bay Water Service Wall Brook wells, Nanoose Bay Water Service Madrona wells, Nanoose Bay Water Service Nanoose, Fairwinds, and Westbay wells, Fairwinds and Arbutus wells, District of Lantzville (Harby Road) wells, and Nanoose First Nation wells;
- The significant recharge area map needs to be further updated by further processing of the NRCAN remote sensing data and by field verification;
- Reactivation of WSC surface water gauge for Nanoose Creek (08HB030) and Enos Creek (08HB039) is recommended;
- Reactivation of WSC lake level gauges on Brannen Lake and Enos Lake is recommended;
- Summer lake level and discharge data from Westwood Lake should be obtained from the City of Nanaimo or the BC Conservation Foundation and included in the Regional Water Database; and
- Collect weekly summer base flow measurements (June to Sept) for Bonell Creek, Chase River and Beck Creek as part of the Community Watershed Monitoring Network program to better understand summer base flow discharges in smaller watersheds in the region.