3.0 WATER REGION # 1 - BIG QUALICUM

3.1 Regional Overview

The Big Qualicum water region (WR1-BQ) is defined as the area extending from Mud Bay in the north, to the Qualicum River in the south, and from the coast to the Beaufort Mountain Range in the west (Figure 9). It should be noted that the actual water region boundary in the northernmost part of WR1 (BQ) was extended beyond the RDN boundary to coincide with the drainage basin. Although the RDN has no jurisdiction over this area, the water budget assessment needed to be completed at the basin scale and water resource management of this area will need to be a joint effort with the Comox Valley Regional District.

WR1 (BQ) is the fourth largest water region within the RDN covering an area of approximately 292 km^2. The region includes several major watersheds as listed in the Table 1. The largest watershed is associated with the Big Qualicum River itself. Horne Lake is a major surface water feature within WR1 (BQ). Four hydrometric stations, three climate stations, and approximately 37 surface water diversion licenses exist within the region (Figure 9, and Table 1). Not all 37 surface water diversions licenses locations can be seen on Figure 9 as the scale of the drawing is such that numerous points plot on top of each other due to their close proximity.

Table 1: WR1 (BQ) - Watersheds, Wells and Surface Water Licenses

Total Water Region Area	***292 km^2**
Major Watersheds	**Drainage Area[1] (km^2)**
Rosewall Creek (including Roaring Creek)	44.1
McNaughton Creek	9.0
Cook Creek (including Chef Creek)	27.0
Sandy Creek	2.7
Thames Creek	8.5
Nile Creek	18.3
Big Qualicum River (including Hunts Creek and Horne Lake)	146.0
Annie Creek	8.2
Wells and Surface Water Diversion Points	**No.**
# Water Wells listed in MOE DB	221
Surface water diversion licenses	37

Note: Drainage Areas are based on 1:50,000 BC Watershed Atlas. * Total water region area includes areas that drain directly to the ocean and are not part of a major watershed.

According to the MOE Wells Database (BCGOV ENV Water Protection and Sustainability Branch, 2008), WR1 (BQ) has the lowest number of water wells (221 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.

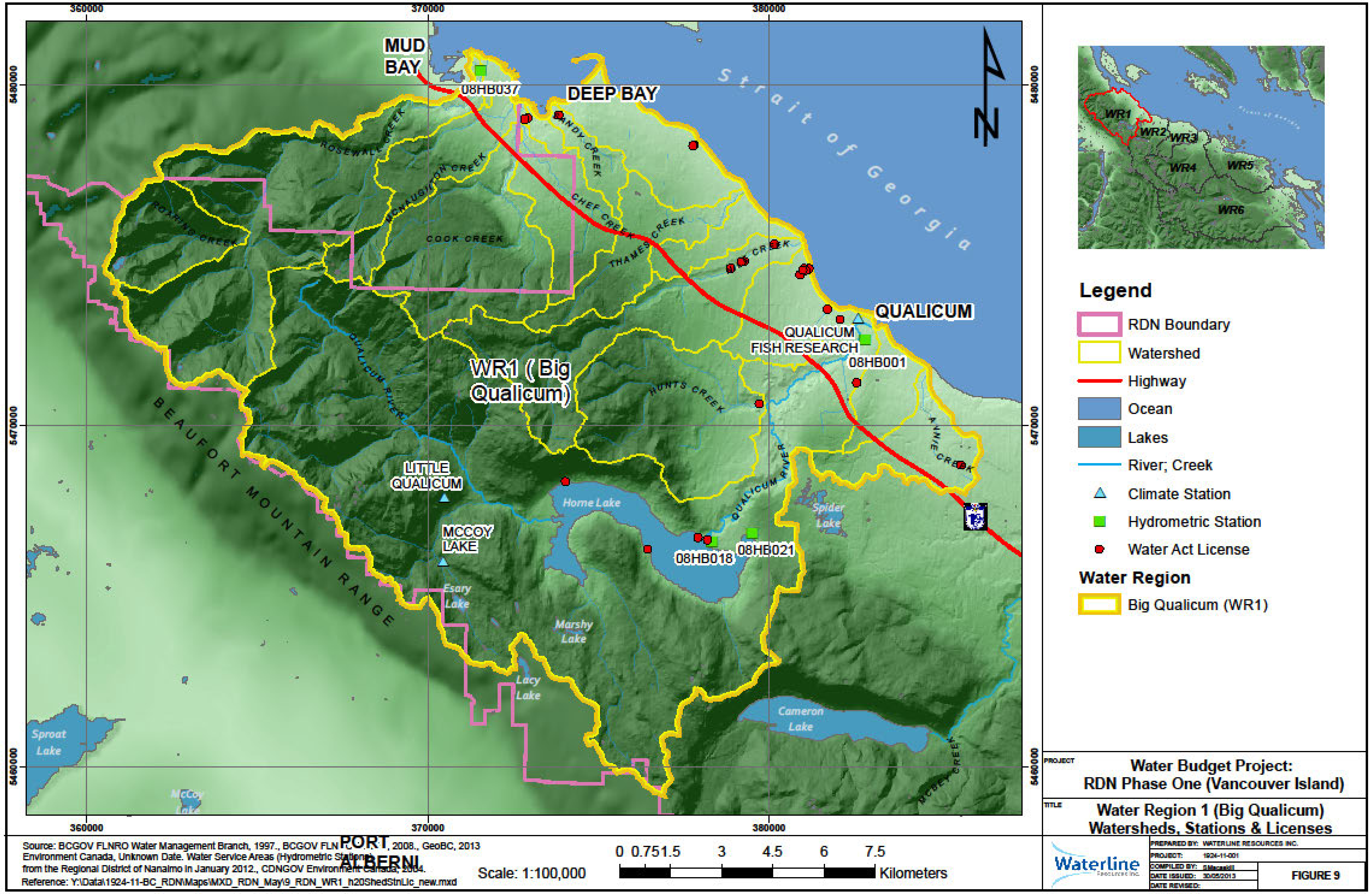

Figure 9: WR1 (BQ) – Watersheds, Hydrometric/Climate Stations & Licenses

3.2 Surface Water Assessment

3.2.1 Terrain, Topography and Land Use

WR1 (BQ) water region covers the northern section of the RDN. The region lies mostly within the Nanaimo Lowlands with the Beaufort Mountains defining the western boundary of the area. Elevations in the region range from sea level up to 1,306 m at Mount Irwin near the headwaters of the Big Qualicum River.

The majority of the lands within the water region are privately owned forest lands with some small areas of crown forest land in the northern portion of the region within the Rosewall Creek, McNaughton Creek, Cook Creek, and Thames Creek watersheds. The lower reaches of the region are rural development with agricultural lands, and low density residential. Some light industrial and commercial development is located in Bowser and Qualicum Bay.

Most of the watersheds in the region drain the east to north east facing slopes of the Beaufort Mountains towards Baynes Sound and the Strait of Georgia. The most significant water feature in the region is the Big Qualicum River and Horne Lake. The major watersheds in the region from North to South are listed in Table 1.

3.2.2 Climate

The climate for the Big Qualicum Water Region is similar to the rest of the RDN with cool wet winters and mild dry summers. In general, climate records indicate that this region tends to be wetter than the other water regions with average total annual precipitation for the 1971 to 2000 Climate Normal Period of 1704.9 mm and 1314.2 mm for the Mud Bay and Qualicum Fish Research Climate Stations, respectively (see Figure 10 and Figure 11 for average monthly climate conditions). This compares with recorded average total annual precipitation of 1,162.7 mm at the Nanaimo Airport. Figure 12 shows the distribution of total annual precipitation across WR1 (BQ) as modelled by KWL. Figure 13 shows the distribution of average annual air temperature across WR1 (BQ) as modelled by KWL. Climate station locations are shown on Figure 9.

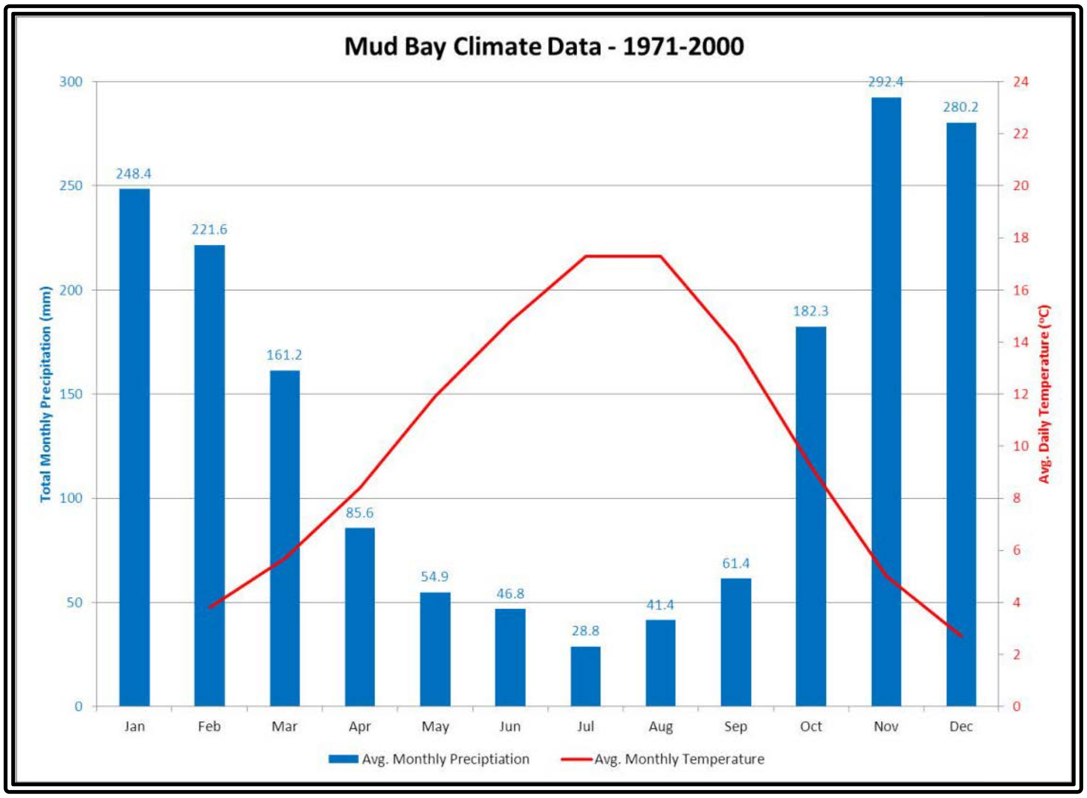

Figure 10: WR1 (BQ) - Mud Bay Monthly Climate (1971 to 2000 Normal Period)

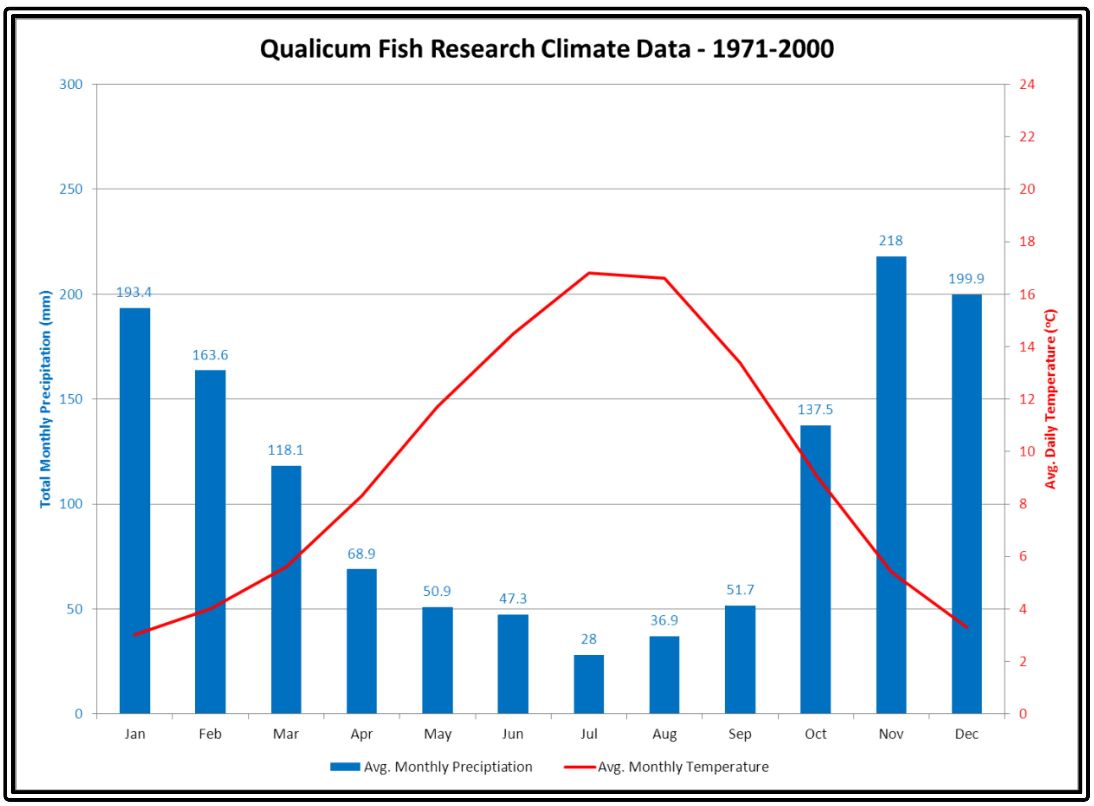

Figure 11: WR1 (BQ) - Qualicum Fish Research Monthly Climate (1971 to 2000 Normal)

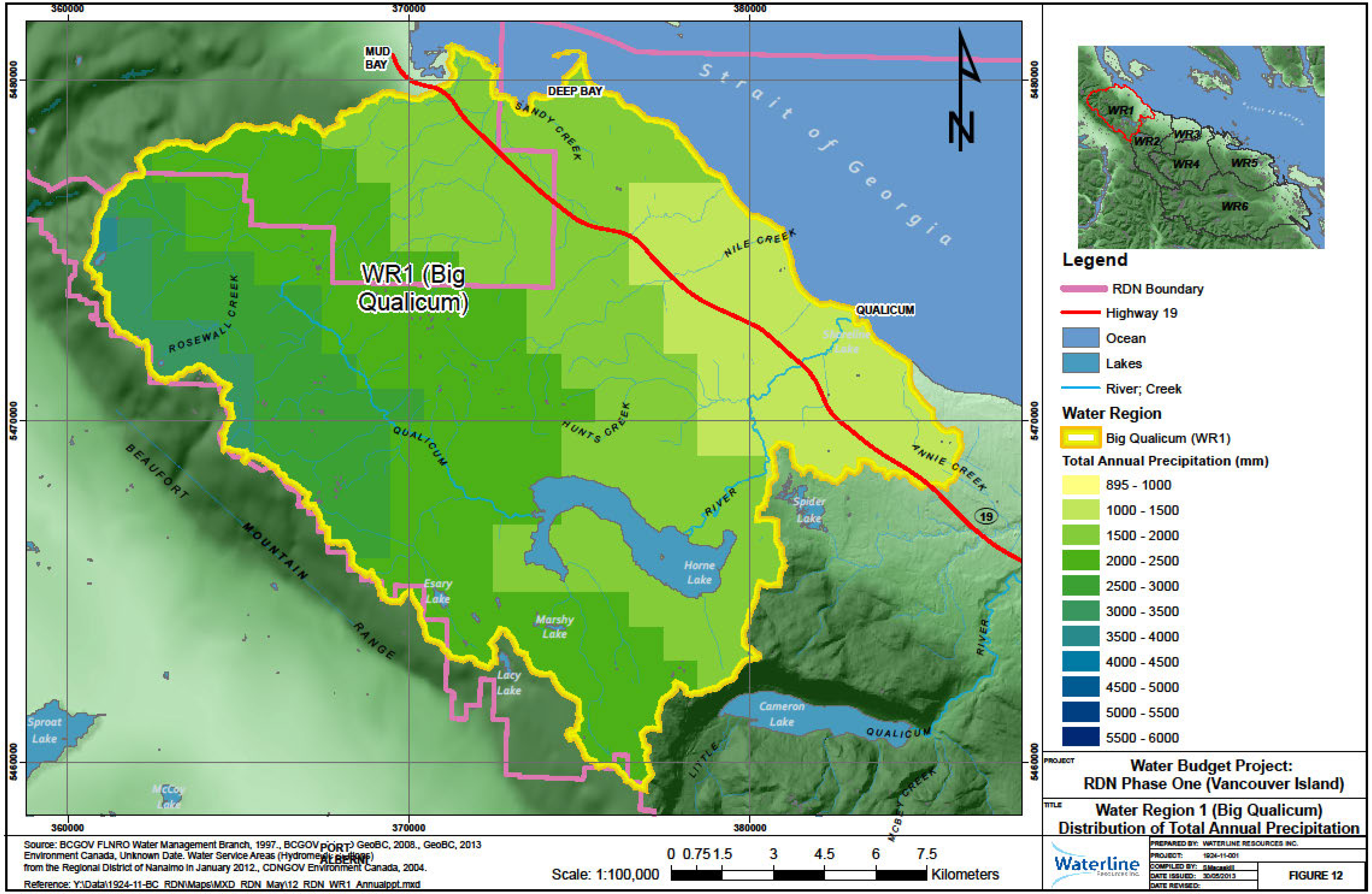

Figure 12: WR1 (BQ) - Distribution of Total Annual Precipitation

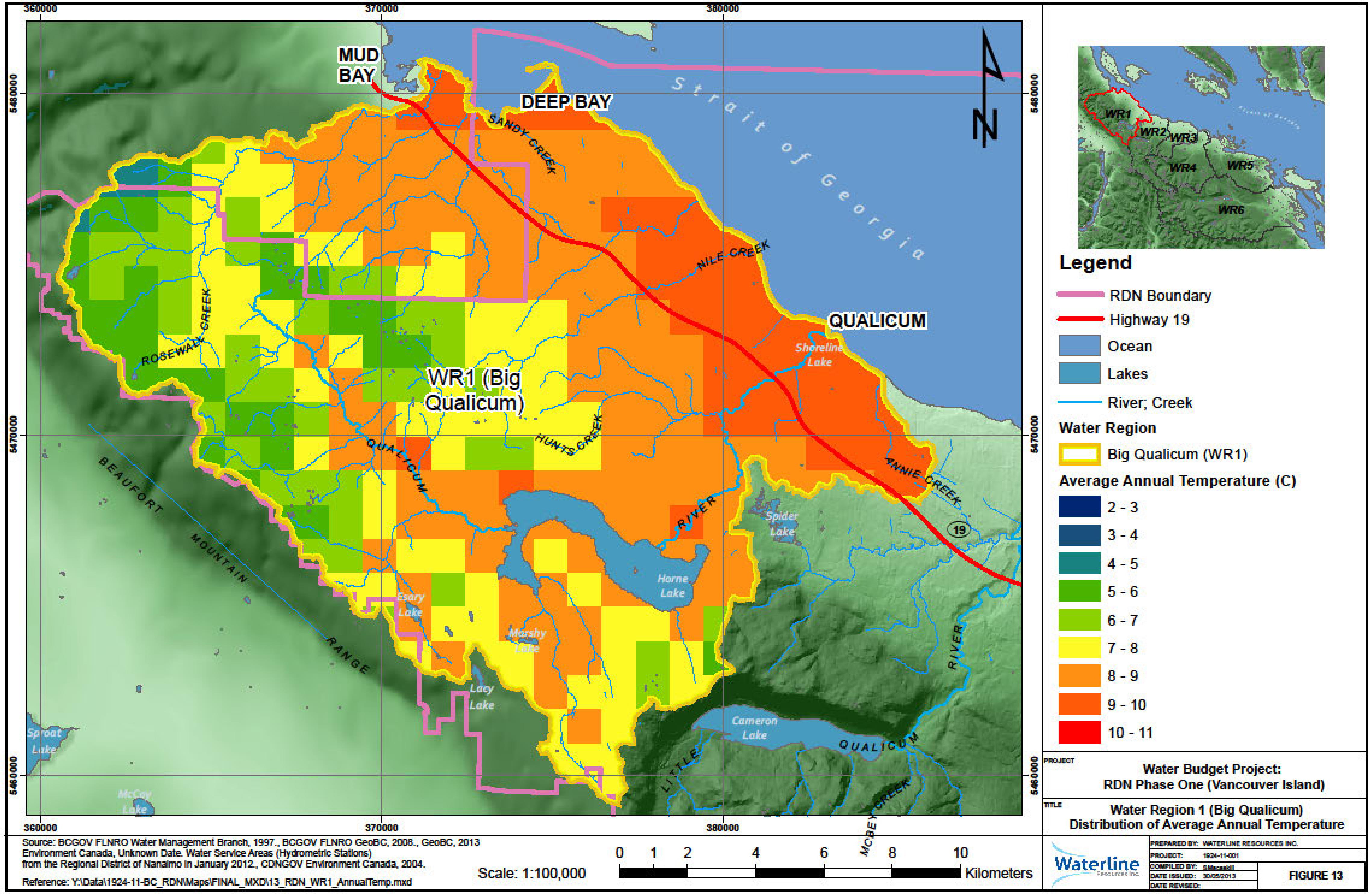

Figure 13: WR1 (BQ) - Distribution of Average Annual Temperature

3.2.3 Stream Gauging and Monitoring

Table 2 lists the names of the hydrometric stations are located in the WR1 (BQ) and they are shown in Figure 9.

Table 2: WR1 (BQ) – Water Survey of Canada Records

Station Name (WSC Number)	Period of Record	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)
Big Qualicum at Bowser (08HB001)	1956 to 1974	Regulated	146	7.5 m^3/s 236 million m^3	3.07 m^3/s 24.4 million m^3
Nile Creek at Bowser (08HB002)	1960 to Present	Natural	15	1.0 m^3/s 31.5 million m^3	0.24 m^3/s 1.9 million m^3
Rosewall Creek at the Mouth (08HB037)	1968 to 1978	Natural	43.3	2.62 m^3/s 82.6 million m^3	0.85 m^3/s 6.76 million m^3

Note: 1 – Summer Period July to September (three lowest average months)

The monthly average discharge for Nile Creek is shown in hydrograph in Figure 14.

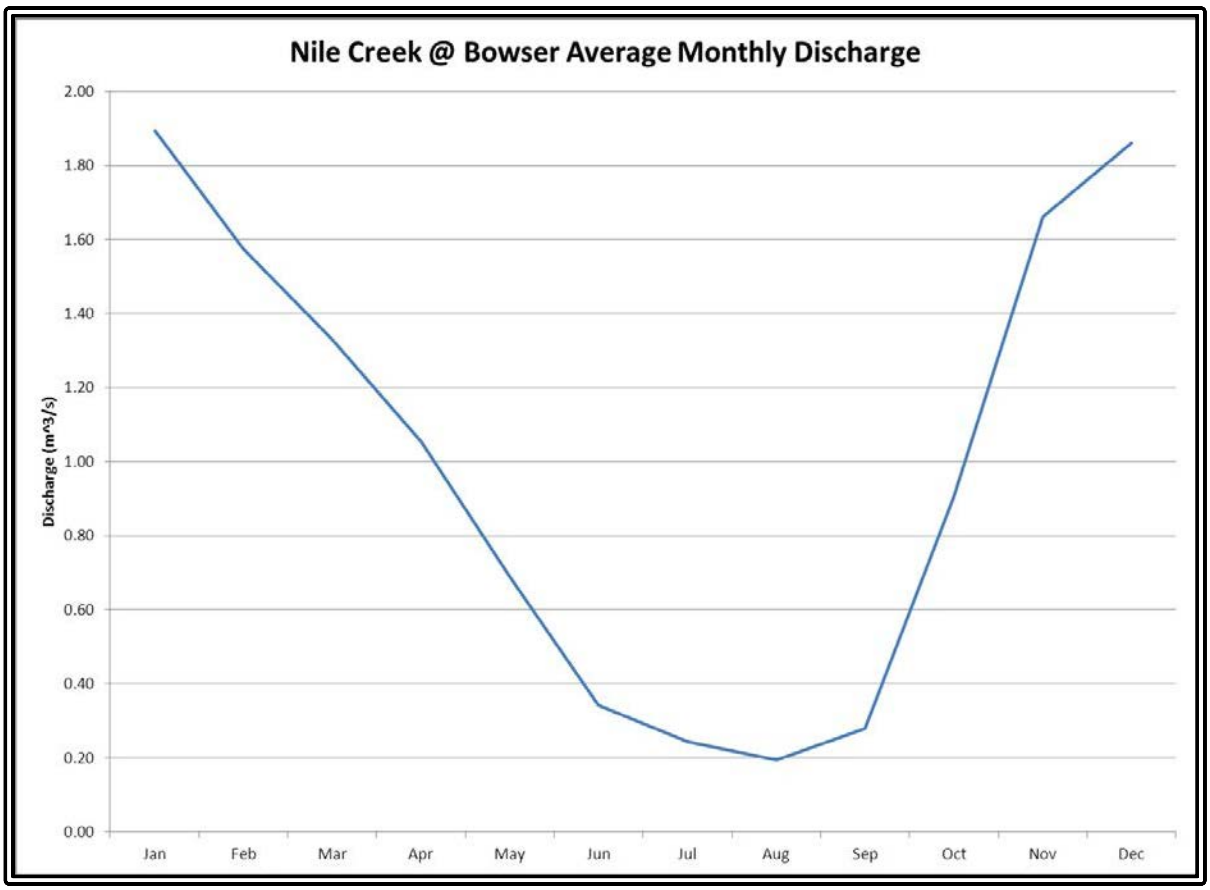

Figure 14: WR1 (BQ) - Nile Creek Monthly Discharges

3.2.4 Hydrology and Surface Water Resources

The hydrological model has provided estimates of average available surface water resources for the major watersheds in the region for the year and the summer (Table 3).

Table 3: WR1 (BQ) – Available Surface Water Resources (Avg. for 1971 to 2000 period)

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)
Rosewall Creek (including Roaring Creek)	43.3	2.93 m^3/s 432.9 million m^3	0.26 m^3/s 2.1 million m^3	
McNaughton Creek	9.0	0.42 m^3/s 13 million m^3	Less than 0.01 m^3/s	0.6
Cook Creek (including Chef Creek)	27.0	1.3 m^3/s 40 million m^3	0.034 m^3/s 0.27 million m^3	1.3
Sandy Creek	2.7	0.08 m^3/s 2.7 million m^3	Less than 0.01 m^3/s	0.24
Thames Creek	8.5	0.28 m^3/s 8.8 million m^3	Less than 0.01 m^3/s	0.56
Nile Creek	18.3	1.0 m^3/s 31.5 million m^3	0.24 m^3/s 1.9 million m^3	1.0
Qualicum River (including Hunts Creek and Horne Lake)	146 km^2	7.5 m^3/s 236 million m^3	3.07 m^3/s 24.4 million m^3	7.3
Annie Creek	8.2	0.22 m^3/s 7.0 million m^3	Less than 0.01 m^3/s	0.14

Notes: Drainage Areas are based on 1:50,000 BC Watershed Atlas. Previous estimates from the BC Ministry of Environment Water Allocation Plans (Braybrook et. al., 1995; Pirani and Bryden, 1996) have been included for reference.

3.2.5 Surface Water Demand

Table 4 summarizes the surface water licences in WR1 from the BC Surface Water Licence Database. A summary of the licensed storage in the water region is included in Table 5. The locations of some of the surface water licences for WR1 (BQ) are shown on Figure 9. The actual geo-reference locations will be provided in the ARC GIS Geodatabase and will not be presented here.

Table 4: WR1 (BQ) - Surface Water Demand

Type of Demand	Monthly (m^3/month)	Annual (m^3)	Summer (Jul-Sept) (m^3)
Consumptive Demand			
Agriculture	154	1,850	1,390
Domestic	28,800	345,700	114,100
Industrial	136	1,640	410
Institutional	-	-	-
WaterWorks	17,300	207,300	68,400
Total Consumptive	46,400	556,500	184,300
Non- Consumptive Demand			
Power	-	-	
Conservation	18,400,000	221,300,000	55,300,000
Total Non-Consumptive	18,400,000	221,300,000	55,300,000

Table 5: WR1 (BQ) - Licenced Surface Water Storage

Type of Storage	Total Storage (Million m^3)
Storage	175.2
Conservation Storage	0
Other Storage	0.04
Total Storage	175.2

The largest licensed water user in WR1 (BQ) is the Department of Fisheries and Oceans to maintain conservation flows in the Big Qualicum River and to supply the Qualicum Fish Hatchery. These flows are supported by storage at Horne Lake which is controlled by a dam and outlet tunnels. The total licensed storage on Horne Lake is 175,154,160 m^3. It is interesting to note that private domestic surface water license amounts in the area exceed the total annual licensed municipal water withdrawals. The largest domestic surface water license in the region is held by the owners of Strata Plan VIS5160 (Horne Lake Recreation Strata) located on Horne Lake and totals 331,900 m^3 per year for privately owned and managed water systems for recreational properties around Horne Lake.

3.2.6 Surface Water Stress Analysis

As outlined in Section 2.5.2, a surface water stress analysis for some of the major watersheds within each water region has been completed. The results of the stress analysis which could be reasonably assessed for watersheds in WR1 (BQ) are shown in Table 6. Water budget analysis for other smaller ungauged subwatersheds within WR1 (BQ) should be completed when data is available and as part of a more detailed Tier 1 or Tier 2 water budget assessment (OMNR 2011). A map showing the relative stress for each watershed is shown in Figure 15.

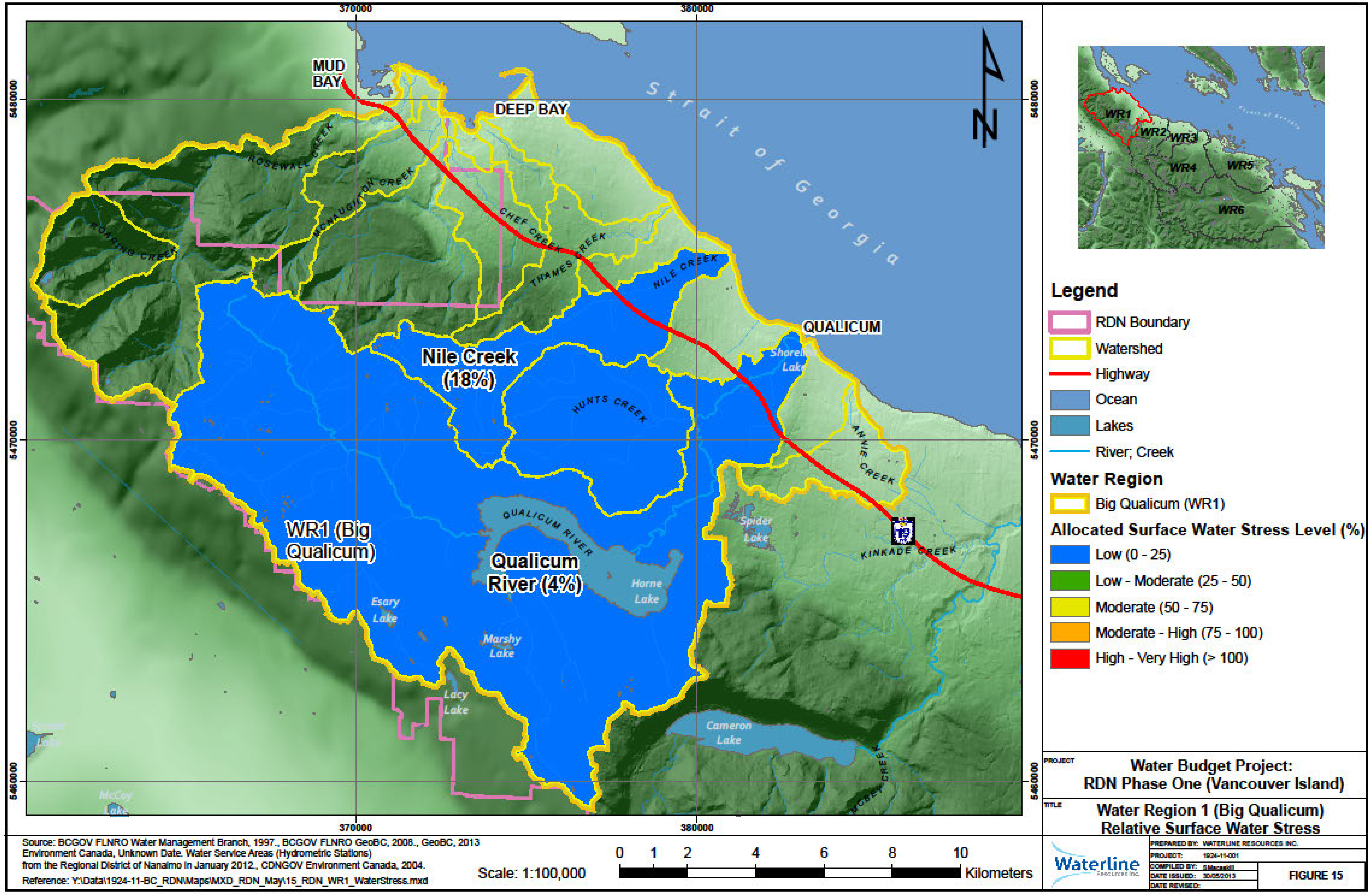

Figure 15: WR1 (BQ) - Relative Surface Water Stress

Table 6: WR1 (BQ) - Surface Water Stress Analysis

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
Nile Creek	1.90	0.00	0.26	0.07	18%	Low
Big Qualicum River	3.7	175.2	6.2	0.1	4%	Low

Notes: 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 Jul to Sep period. The 10% of Mean Annual Discharge (MAD) conservation flow is based on current Ministry of Forest, Lands and Natural Resource Operations (BC 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.

3.3 Groundwater Assessment

3.3.1 Existing Groundwater Studies and Data – WR1 (BQ)

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 the local hydrogeological are provided in Table 7.

Table 7: WR1 (BQ) – Hydrogeology Reference Reports

Author	Year	Study Title
Pacific Hydrology Consultants Ltd.	1997	Completion Report: Installation and Testing of Well 8-97 and Re-evaluation of Groundwater Supply Potential of Quadra Sand Aquifer at Deep Bay
Pacific Hydrology Consultants Ltd.	2007	Groundwater Study at Deep Bay Waterworks District
Pacific Hydrology Consultants Ltd.	2007	Completion Report: Groundwater Study at Deep Bay Waterworks District

3.3.2 Description of Aquifers and Water Wells

A total of four unconsolidated aquifers have been mapped within WR1 (BQ) (Figure 16). Table 8 provides a summary the aquifer ID, lithology, location, potential interactions with the surface water and other aquifers, aquifer area, vulnerability, and aquifer yield/productivity according to BC MOE aquifer classification. Quadra sand aquifers (416 & 421) in the north are variable in terms of productivity and are generally confined[22] to semi-confined[23] with low vulnerability and light to moderate use indicated. Based on Waterline's conceptual model, Quadra Aquifer 421 and Capilano Aquifer 665 appear to be connected to Nile Creek and likely provide needed base flow during the summer and fall seasons to the creek.

Table 8: WR1 (BQ) – 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 Classification Code	Yield
				(km^2)		(L/M/H)
416	Quadra	North of Thames Creek	Ocean	14.2	Confined, IIB	H
421	Quadra	Between Nile and Thames	Ocean, Nile	61.6	Semi-confined, IIIB	L
665	Capilano	Overlies Quadra between BQ to Thames	Ocean, Nile Creek, BQ	22.8	U, IIIB	M
662	Quadra	South of BQ and into LQ	Ocean (Quadra Exposed)	28.4	C, IIC	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.

[22] Aquifer is capped by a low permeability or impermeable layer.
[23] Aquifer is partially capped by a low permeability or impermeable layer.

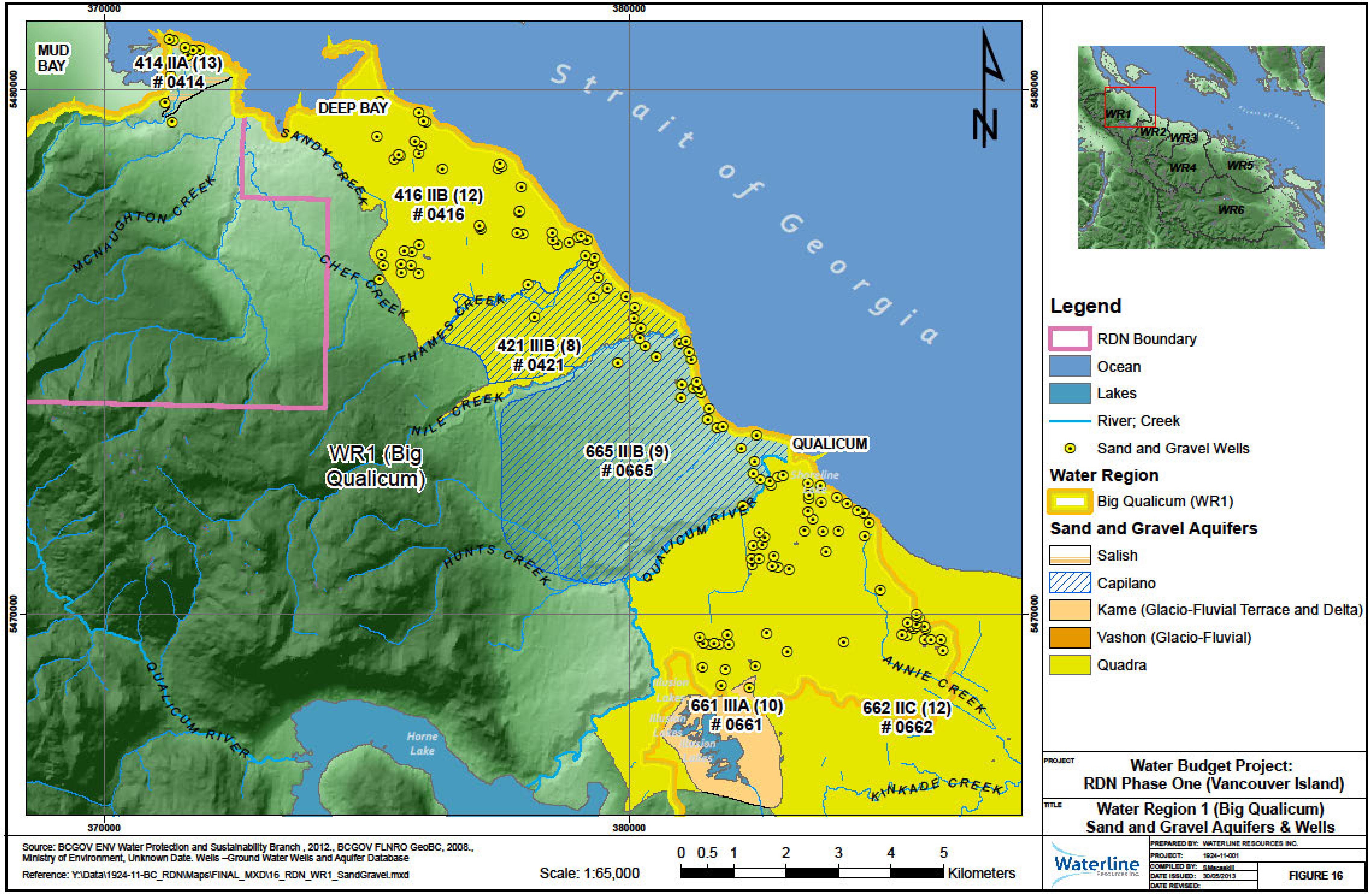

Figure 16: WR1 (BQ) – Sand and Gravel Aquifers & Wells

The majority of supply wells are completed along the coast in unconsolidated Quadra and Capilano sand and gravel aquifers (Figure 16). There are a total of 221 overburden and bedrock wells listed in the MOE data base (Table 1). As there are no regulatory requirements in BC to submit wells logs to MOE for capture in the BC Wells Database (reference), the water wells shown on Figure 16 likely represent only a fraction of wells actually drilled and represents a source of uncertainty in the water budget calculations.

3.3.3 Groundwater-Surface Water Interaction - Conceptual Hydrogeological Model

A conceptual hydrogeological model of each aquifer with WR1 (BQ) 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 the conceptual hydrogeological model developed by Waterline includes numerous cross-sectional views developed within the Waterline Geodatabase, only one 3D view into the subsurface is presented for WR1 (BQ).

Figure 17 shows a 3D block diagram illustrating the relationship between surface and subsurface geology in the area of WR1 (BQ) where major water supply aquifers have been mapped. The schematic shows how the Quadra sand aquifer (662) is exposed in the Big Qualicum River valley and likely contributes important base flow to the creek during the summer and fall season. The model also shows the considerable thickness of overburden in the region and possible interactions between the unconfined Capliano aquifer (665) and the underlying Quadra Aquifer (662).

View 1 shows the unconfined and perched Vashon aquifer (661) in the Spider Lake area situated in the adjacent water region (WR2 (LQ)) and how the deposit extends towards the Big Qualicum River in WR1 (BQ). Water levels in wells completed in the deeper confined Quadra sand aquifer (662) are considerably lower (deeper) than water levels in the overlying Vashon aquifer (661) suggesting disconnected flow systems and a strong downward gradient between the two aquifers.

View 2 shows that the unconfined Vashon aquifer (661) does not extend far into WR1 (BQ) and therefore is not expected to contribute baseflow to the Big Qualicum River in WR1 (BQ). The underlying Quadra Sand Aquifer (662) is considerably deeper and appears to cross into the adjacent water region (WR2 (LQ)) and likely also discharges groundwater to the base of the Big Qualicum River Valley. Water levels in wells completed in the deeper confined Quadra sand aquifer (662) are considerably lower (deeper) than water levels in the overlying Vashon aquifer (665) suggesting poor connection between the two flow systems. It appears that aquifer 661 likely only flows toward the Little Qualicum River, whereas the underlying Quadra sand aquifer may be interacting with both the Big Qualicum and the Little Qualicum Rivers.

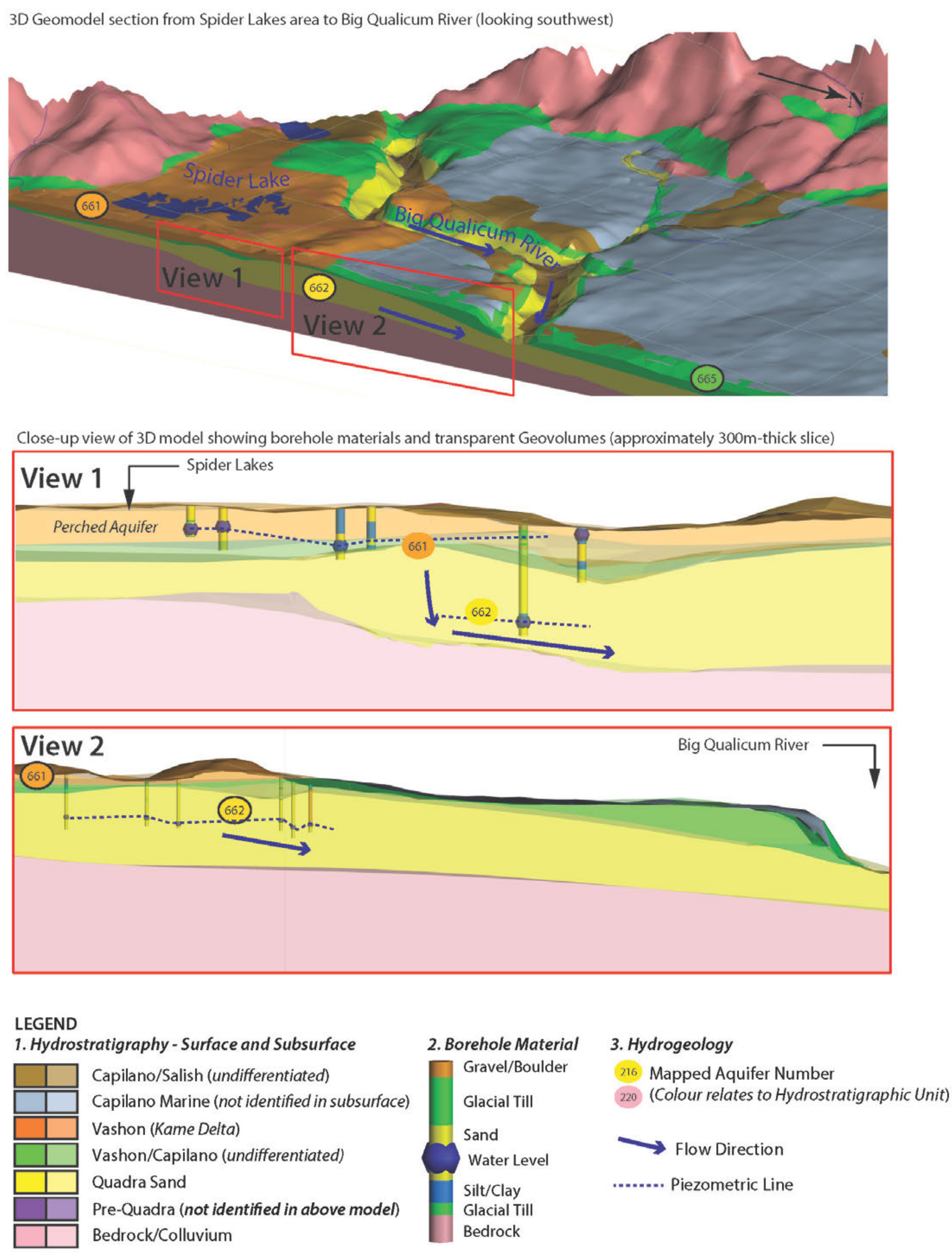

Figure 17: WR1 (BQ) – Hydrogeological Conceptual Model – Big Qualicum River

3.3.4 Significant Recharge Areas

Significant recharge areas within WR1 (BQ) were determined as part of the assessment of infiltration across the region by Waterline and KWL. The analysis was based on existing topography, mapped textural soil characteristics, land cover (bare land, vegetation, impermeable surfaces), and leaf area index obtained from NRCAN Remote Sensing data (Appendix C, Map C11). 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 18 shows areas where high infiltration capacity is indicated within WR1 (BQ) based on data integration into the USGS distributed watershed model run by KWL.

Significant recharge areas in extend to the upper reaches of WR1 (BQ) (Roaring Creek, Rosewell Creek, Qualicum River) and into the upper reaches of and Thames Creek. Many of the areas indicated are not well developed. 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. Future development planning needs to consider these areas to ensure aquifer recharge continues to be maintained. There is a need to develop protection zones around areas contributing recharge to underlying aquifers to ensure the future sustainability of groundwater resources in this region.

3.3.1 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 19 shows the locations of MOE observation wells and long-term water level monitoring records (MOE 2012b) 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 19 are currently active and need to be reconciled through field verification. In addition, many of the community service wells have been given local names by the owners and could not be cross-referenced with those listed in the MOE Database used to create the conceptual model. It is strongly recommended that reconciliation with the database be completed so that a more accurate water budget accounting can be complete when the RDN moves to a full Tier 1 or Tier 2 water budget assessment (OMNR 2011).

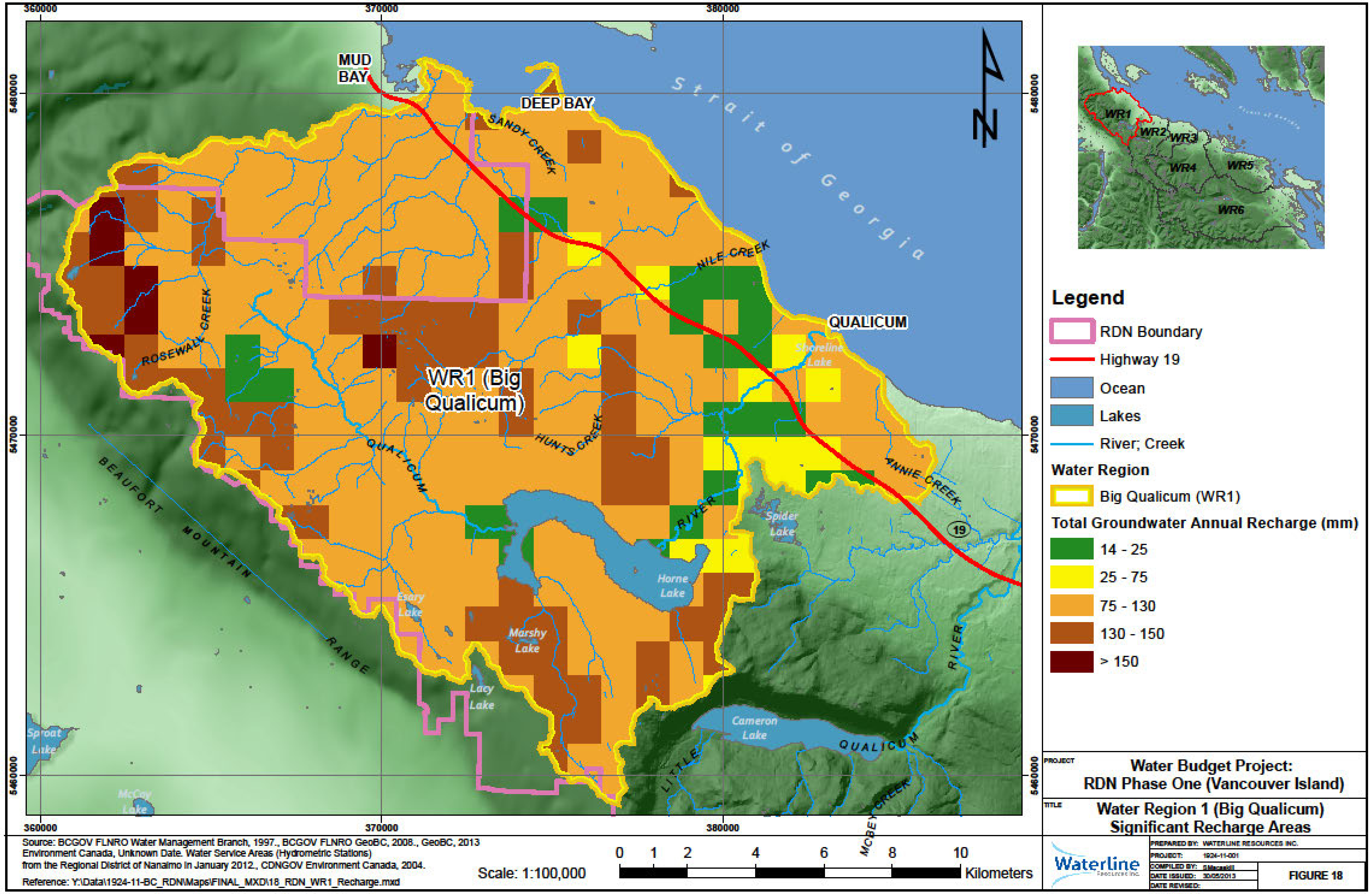

Figure 18: WR1 (BQ) – Significant Recharge Areas

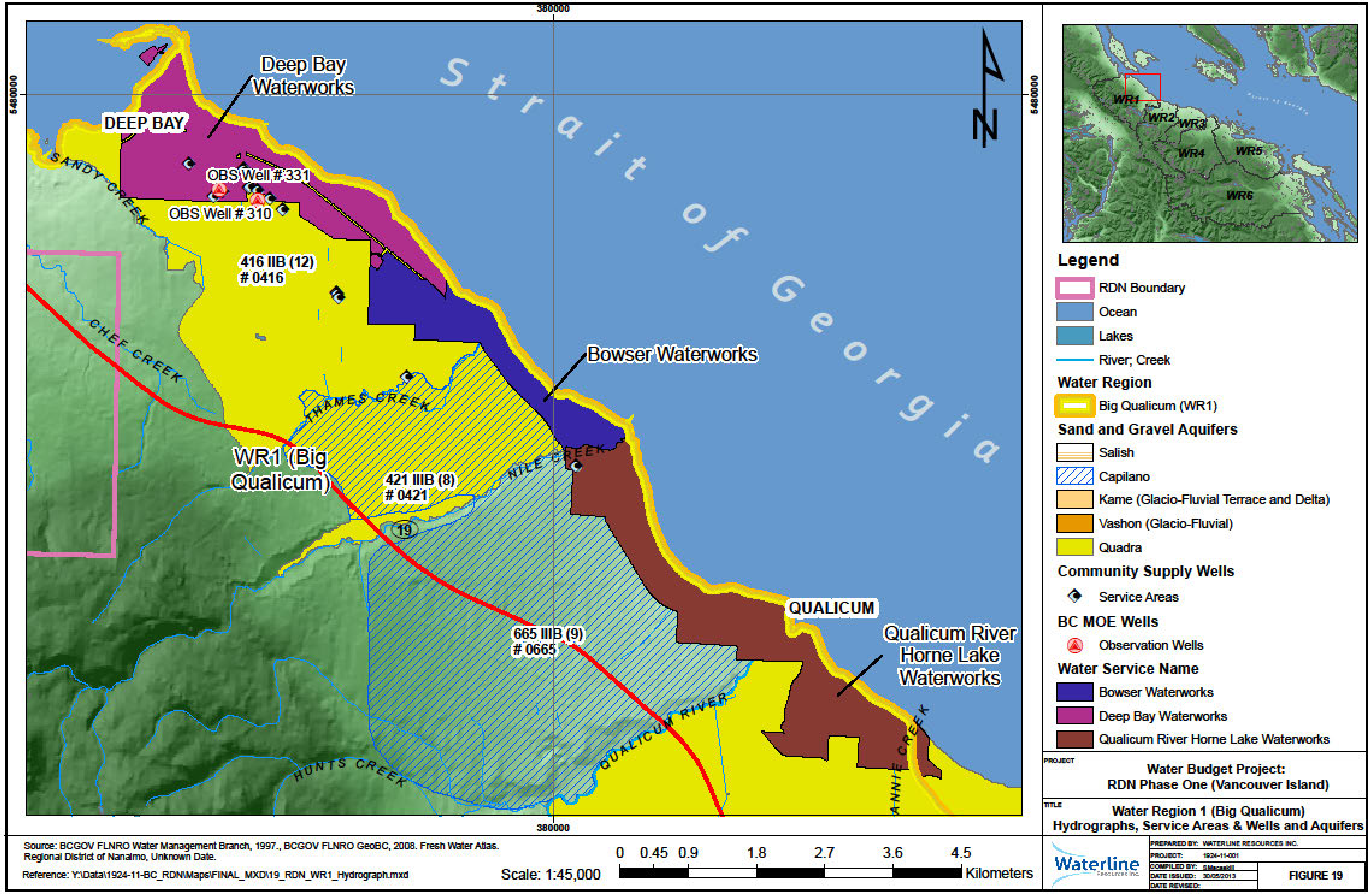

Figure 19: WR1 (BQ) – MOE Well Hydrographs, Service Areas & Wells, and Aquifers.

Figure 20 and Figure 21 show water level hydrographs for MOE Observation Wells 310 and 331. Water level data was along with the Qualicum River Research Station precipitation record and the PDO trend (Mantua and Hare, 1997)

Both MOE wells are completed in Quadra sand aquifer 416 near Bowser Waterworks District production wells. The wells both show a slight declining trend starting in 1999-2000 with some recovery indicated by 2003. The decline may be related to water extraction practices in the Bowser area combined with lower total cumulative precipitation. When Deep Bay Improvement District introduced metering, usage decreased by about 50% which is thought to be related to the observed increasing water levels in MOE Well 331 after 2003 (Lapsevic 2013).

The record for MOE well 310 (Figure 20) is about 22 years and the water level trend follows the precipitation record. The record for MOE Well 331 (Figure 21) is a bit longer and shows that the water level in the aquifer follows precipitation with a 2-5 day delay.

There is some indication that long-term climate variability (PDO graph) related to changes in sea surface temperature in the North Pacific (explained in Section 2.6.3) may result in a decline in precipitation and corresponding decline in aquifer recharge. This is indicated in both water level hydrograph for MOE wells 310 and 331 where the water level trend appears to generally follow the PDO trend.

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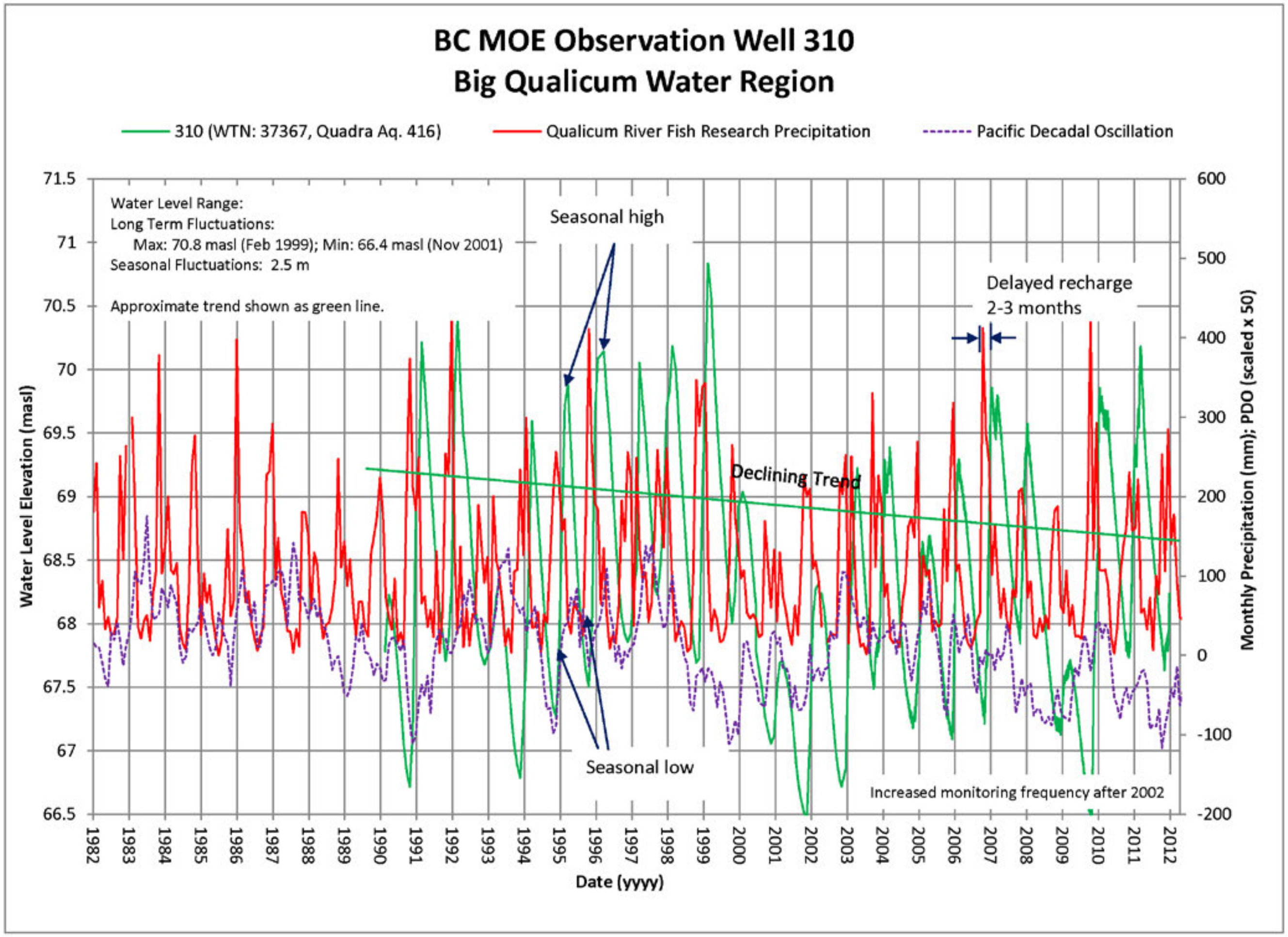

Figure 20: WR1 (BQ) – Water Level Hydrograph BCMOE 310.

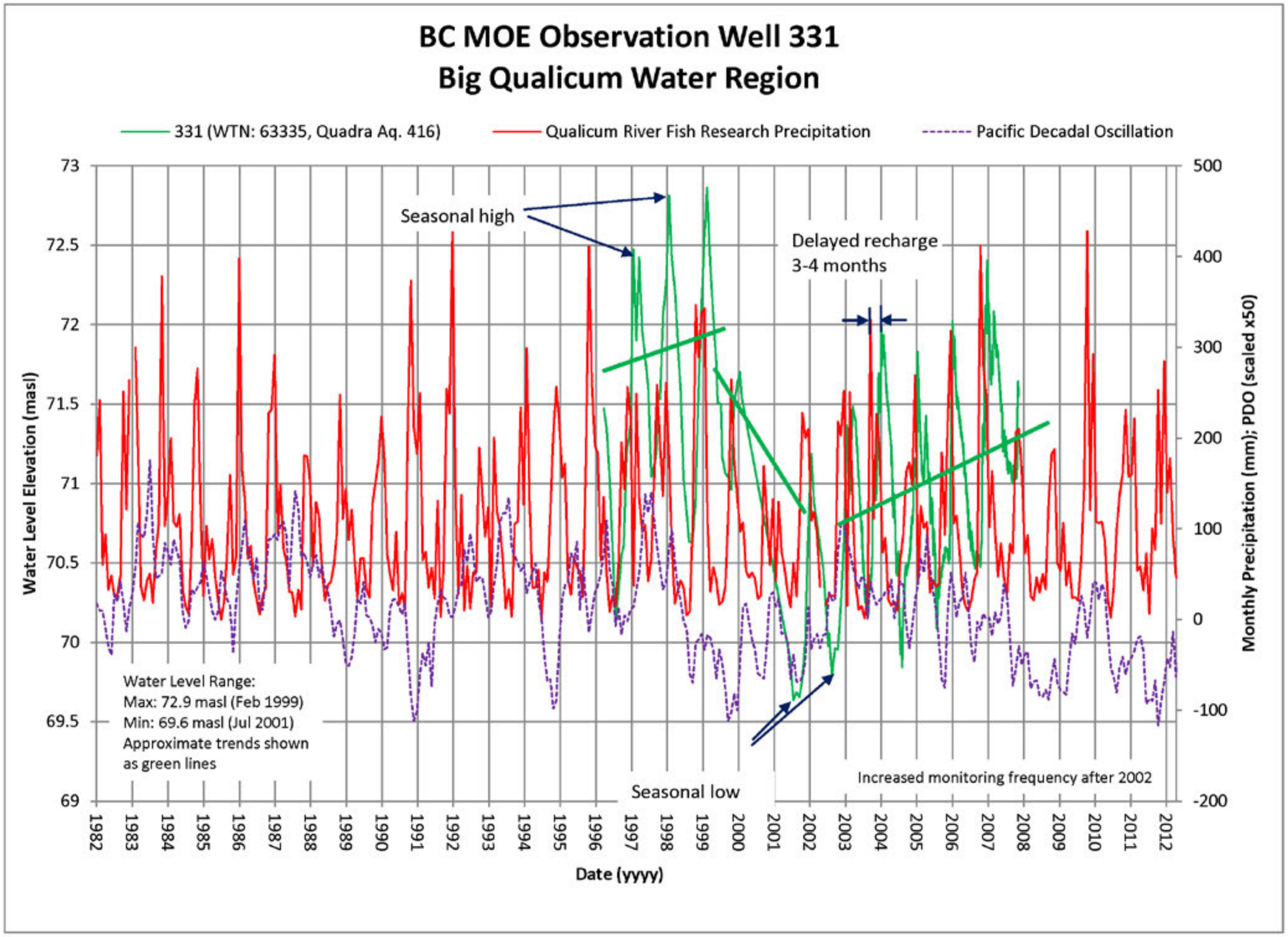

Figure 21: WR1 (BQ) – Water Level Hydrograph BCMOE 331.

3.3.2 Anthropogenic[24] Groundwater Demand

Table 9 summarizes the available groundwater demand data available for WR1 (BQ).

Table 9: WR1 (BQ) – Summary of Anthropogenic Groundwater Demand Analysis

Aquifer Tag No.	Qualicum Bay & Horne Lake WWD @ Nile Creek	Qualicum Bay & Horne Lake WWD @ Thames Creek	Bowser WWD	Deep Bay ID	Other Private Wells (From RDN Water Use Est. based on Zoning compiled on GIS)	Total Ground Water Use Estimate (ANTHout)
	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)
416	NA	?	9.2E+04	1.7E+05	5.4E+04	3.1E+05
421	?	NA	NA	NA	0.0E+00	0.0E+00
665	NA	NA	NA	NA	7.0E+00	7.0E+00
662	NA	NA	NA	NA	6.7E+05	6.7E+05

Notes: NA means not applicable,? Means not known or unavailable, ANTHout means anthropogenic water extraction from aquifer, WWD means Waterworks District, ID means Improvement District.

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 and 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. In addition, Waterline understands that Qualicum Bay and Horne Lake WWD may also be discharging water to Nile Creek for river level conservation measures (Donnelly, Pers. Comm., 2012). 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. The results are presented in the following section.

3.3.3 Aquifer Water Budgets and Stress Analysis

Table 10 provides a summary of the final water budget calculations for each aquifer mapped within WR1 (BQ). 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 662, Figure 16) 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.

[24] Human induced

Table 10: Summary of Water Budget and Stress Analysis - WR1 (BQ)

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)	(m^3/yr)	(%)	Lo, Mod, Hi
416	Quadra	Ocean	310, 331	2.5	4.4	U	5.1E+06	0.0E+00	3.1E+05	3.1E+05	6	Lo
421	Quadra	Ocean, Nile	NA	NA	NA	NA	1.7E+06	1.3E+06	0.0E+00	1.3E+06	78	Mod-Hi
665	Capilano	Ocean, Nile Creek, BQ	NA	NA	NA	NA	9.8E+08	3.3E+08	7.0E+00	3.4E+08	33	Lo-Mod
662	Quadra	Ocean (Quadra Exposed)	NA	NA	NA	NA	1.2E+07	4.1E+06	6.7E+05	4.8E+06	41	Lo-Mod

Notes: BQ means Big Qualicum, 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 upgradient 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.

Based on the water budget estimates for mapped aquifers within WR1 (BQ), overall conditions appear to be stable with low to moderate stress indicated. Some concerns existed in the Bowser area where a 4.4 m water level drop in the MOE observation well completed in Aquifer 416 was noted from 1999 to 2003 but the declining trend appears to have reversed after 2003.

The water budget assessment for Aquifer 421 indicates a moderate to high stress, which is due to the assessed groundwater discharge to Nile Creek. This is supported by conceptual model where the Quadra sand appears exposed in the creek bed, and also supported by the surface water budget developed for Nile Creek.

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.

3.4 Water Management Planning Within WR1 (BQ)

General guidance on water management planning for all water regions is provided in later sections of this document. Specific to WR1 (BQ), the following recommendation 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. Aquifers that currently do not have observation wells include 421, 665 and 662;
- 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 the Qualicum Bay & Horne Lake Waterworks District (WWD) well at Nile Creek and Thames Creek, and the Bowser WWD wells, and Deep Bay Improvement District (ID) wells;
- Major water users should be requested to provide RDN with annual operations records (i.e.: water levels, water use, chemistry);
- The significant recharge area map needs to be updated by further processing of the NRCAN remote sensing data and by field verification;
- Further mapping of the groundwater surface water interactions is also required in Nile Creek to confirm the preliminary assessment; Waterline recommends specialized analysis (E.g.: isotopes[25], noble gases) of groundwater samples in this region to assist in determining groundwater age and origin. Thermal imaging of the river during high and low flow many help to quickly pinpoint areas where more detailed studies may be required;
- Big Qualicum River Flow and Horne Lake Level data collected by DFO should be obtained at regular intervals and included in the Regional Water Database; and
- Weekly or bi-weekly summer low flow measurements should be collected for Nash Creek, Sandy Creek, Cook Creek, Thames Creek, McNaughton Creek and Annie Creek as part of the Regional Community Watershed Monitoring Network project to better understand summer low flows in these smaller watersheds.

[25] Elements of the same family but with different atomic weights. Technique is used to assess recharge elevation and age of water.