6.0 WATER REGION # 4 - ENGLISHMAN RIVER

6.1 Regional Overview

The Englishman River water region (WR4 (ER)) is defined as the area extending from Parksville along the coast to the top of the Englishman River and South Englishman River catchment in the southwest (Figure 51). It is second largest water region within the RDN covering an area of approximately 322 km^2. The region includes several major watersheds as listed in Table 31. The largest watersheds are associated with Englishman and the South Englishman Rivers. One hydrometric station, two climate stations, and approximately 52 surface water diversion licenses exist within the region (Figure 51, and Table 31).

Englishman River Water Service (ERWS) will obtain water in the future from the Englishman River for distribution outside of the water region (Nanoose area). The City of Parksville will also be an ERWS water recipient. Numerous studies have been completed in this water region in relation to the ERWS activities, the City of Parksville well fields and regional aquifer mapping and characterization as indicated below.

Table 31: WR4 (ER) - Watersheds, Wells and Surface Water Licenses

Total Water Region Area	***322 km^2**
Major Watersheds	**Drainage Area[1] (km^2)**
Englishman River (to the mouth including tributaries)	316
Morison Creek (tributary to Englishman River)	38.1
South Englishman River (tributary to Englishman River)	100
Wells and Surface Water Diversion Points	**No.**
# Water Wells listed in MOE DB	245
Surface water diversion licenses	52

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. The Englishman River drainage area includes drainage area of tributaries (Morrison Creek and South Englishman River)

According to the MOE Wells Database (BCGOV ENV Water Protection and Sustainability Branch, 2012) WR4 (ER) has the 2nd lowest number of water wells (245 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.

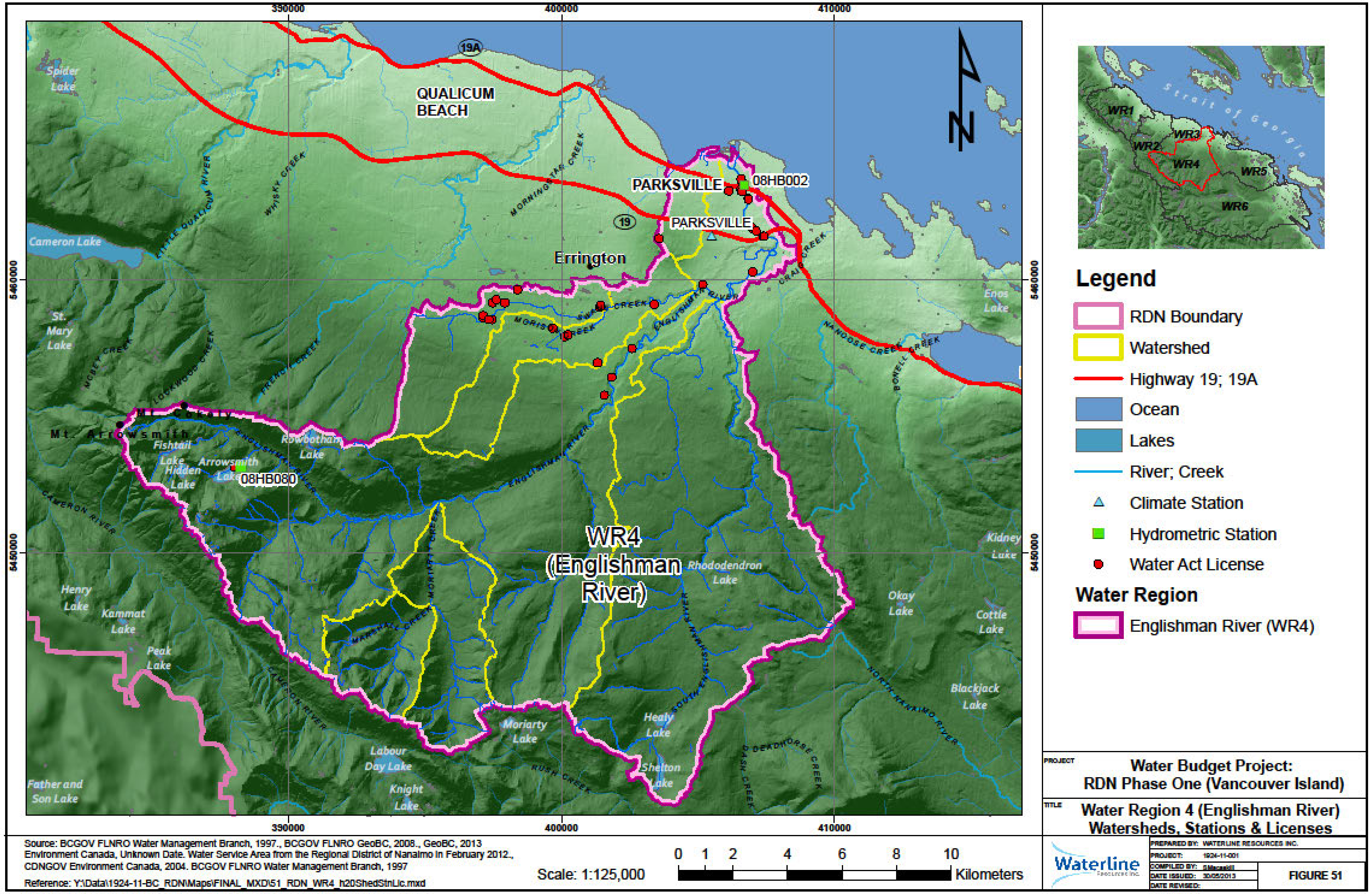

Figure 51: WR4 (ER) – Watersheds, Stations, & Licenses.

6.2 Surface Water Assessment

6.2.1 Terrain and Topography

The Englishman River Water Region (WR4) lies near the City of Parksville and includes the Englishman River Watershed and its major tributaries as well as smaller watersheds lying immediately to the north and south of the Englishman River. The region lies along the course of the Englishman River which rises up to Mount Arrowsmith (1,819) near the headwaters. Mount Arrowsmith lies within a UNESCO Biosphere Reserve and Mt. Arrowsmith Regional Park. The majority of the remainder of the watershed is private forest lands managed by Timberwest and Island Timberlands. The river generally flows north east to the estuary on the shores of the Strait of Georgia.

Some of the major tributaries to the Englishman River include the South Englishman River which flows from Shelton and Healley Lakes near the watershed boundary with the Nanaimo River to the south and Morison Creek which drains the area near Errington. The major watersheds in the WR4 are shown in Table 31.

6.2.2 Climate

The climate for the Englishman River Water Region is similar to the rest of the RDN with cool wet winters and mild dry summers. Significant snowpack accumulations are generally found in the higher elevation sections of the watershed through the winter and spring. The Mount Cokley Snow Course (03B02A) operated by the BC River Forecast Centre, which has been operated since 1980 indicates a normal April 1st snowpack Snow Water Equivalent (SWE) of 864 mm and has a maximum recorded SWE of 2,100 mm on April 1st 1999. A single Environment Canada weather station is located near the region at Coombs which has an average total precipitation of 1,126.4 mm (see Figure 52). This compares with recorded average total annual precipitation of 1,162.7 mm at the Nanaimo Airport. The City of Parksville has also collected daily precipitation data at their works yard since 2004. The total annual precipitation recorded in 2011 at the Parksville Works yard was 846.8 mm. The climate station is located at low elevation in relation to the remainder of the watershed which receives greater rainfall amounts (Figure 51).

Maps showing the distribution of annual total precipitation and average annual temperature over the water region are shown in Figure 53 and Figure 54, respectively. These maps show the influence of elevation on precipitation and temperature with annual precipitation estimated to be greater than 4,000 mm at high elevations.

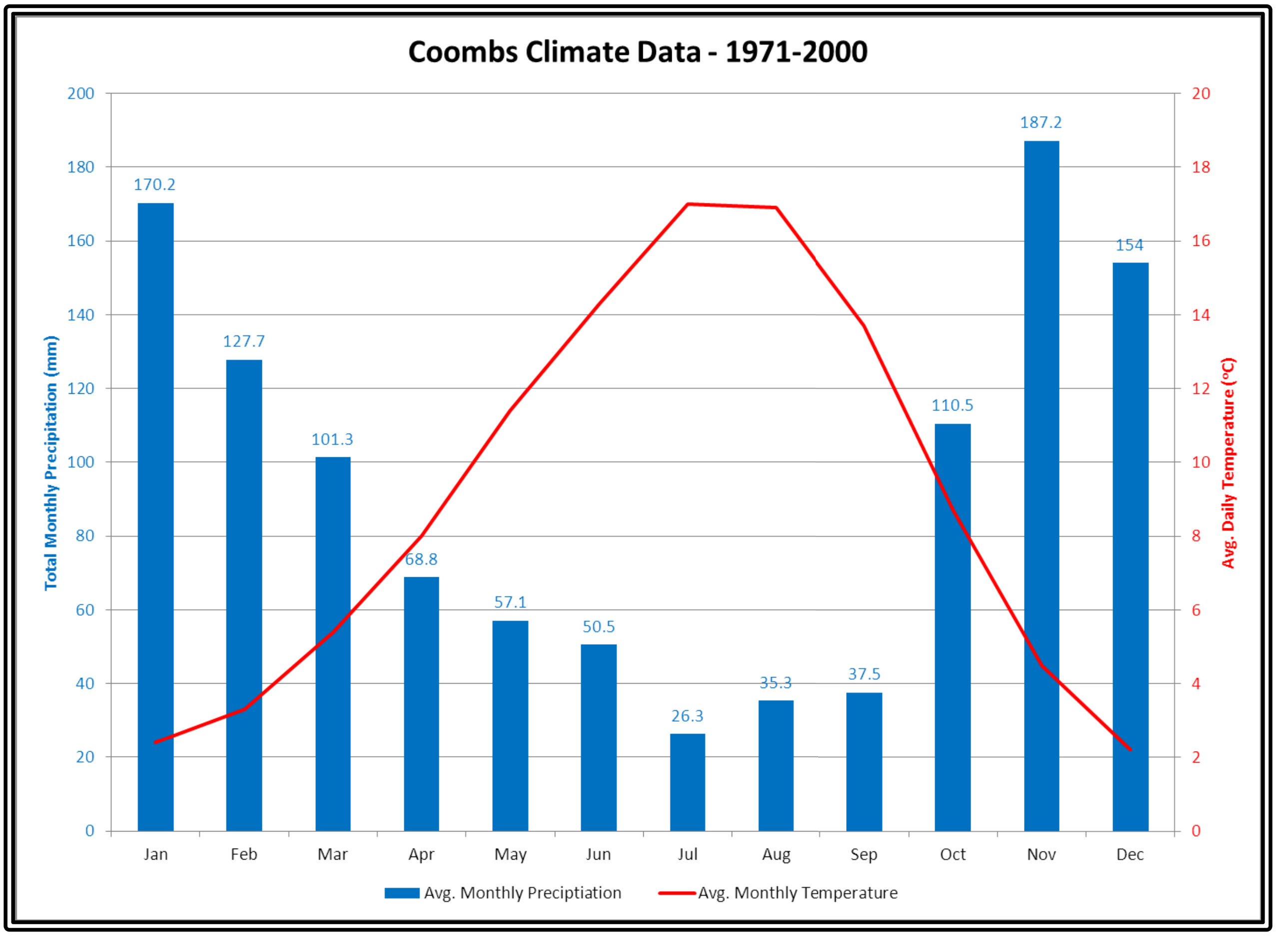

Figure 52: WR4(ER) - Coombs Monthly Climate (1971 to 2000 Normal Period)

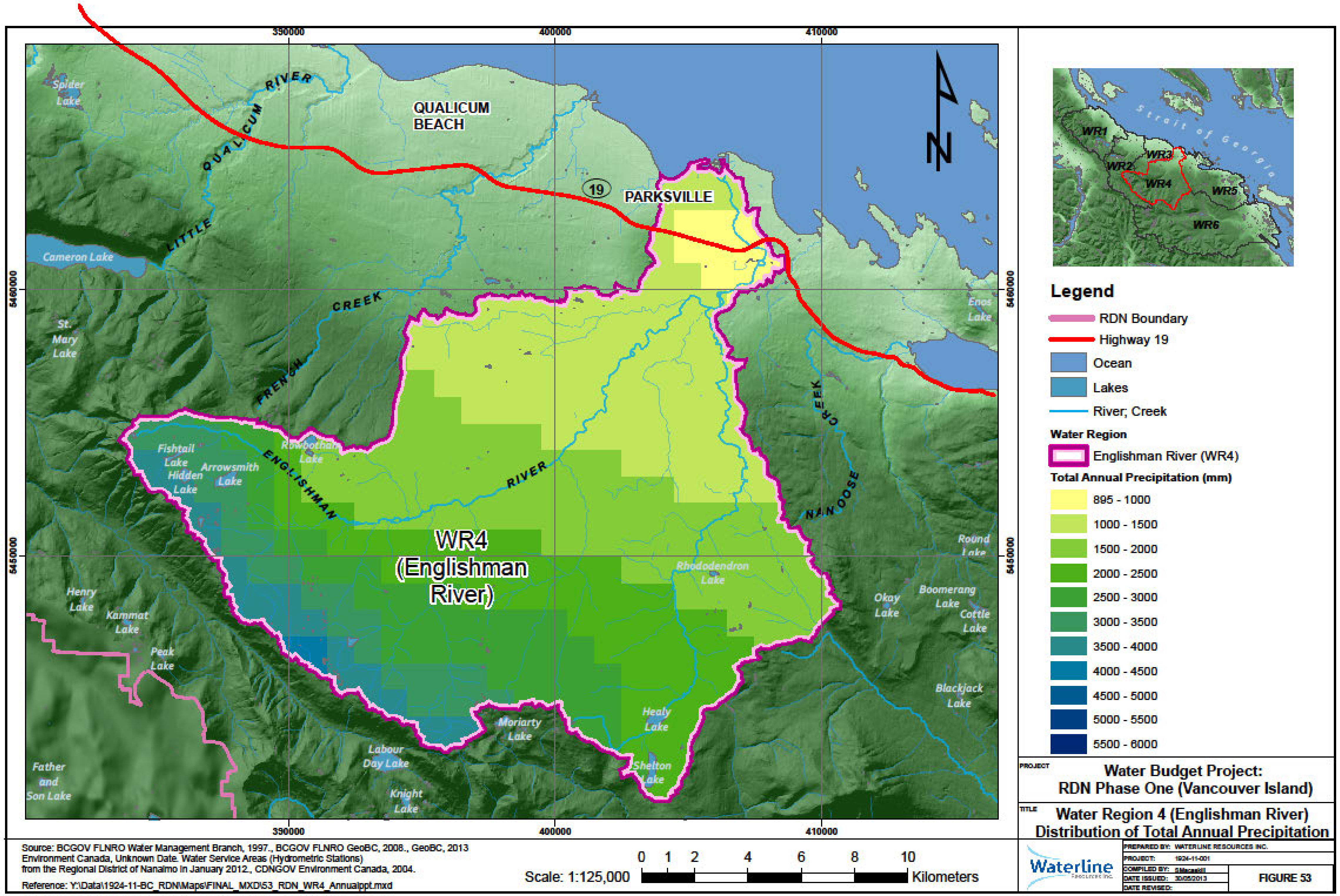

Figure 53: WR4 (ER) - Distribution of Total Annual Precipitation

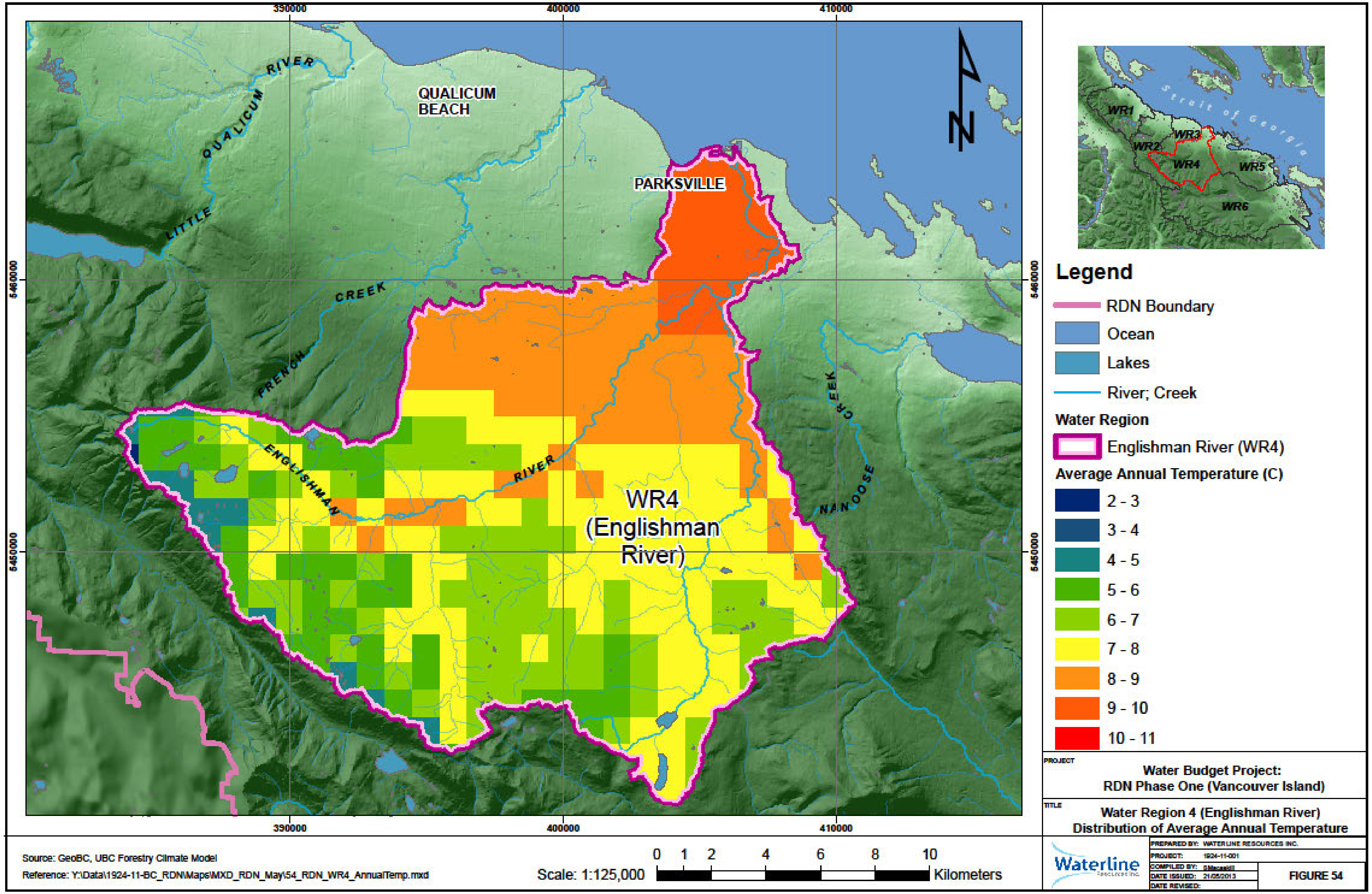

Figure 54: WR4 (ER) - Distribution of Average Annual Temperature

6.2.3 Stream Gauging and Monitoring

A single long term hydrometric gauge is operated by Water Survey of Canada on the Englishman River located at the Highway 19A bridge, upstream of the City of Parksville water supply intake (see Figure 51). The station has continuous flow records for the period from 1913 to 1917 and from 1979 to present. Table 32 lists the mean annual and average summer discharges recorded at the site. It should be noted that this gauge is influenced by summer flow releases from the Arrowsmith Lake dam. Therefore, two periods are shown in the records pre- and post-construction of the dam.

Table 32: WR4 (ER) – 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)
Englishman River at Parksville (08HB002)	1913 to 1917 & 1979 to 1998	Natural	316	13.73 m^3/s 432.9 million m^3	1.77 m^3/s 14.0 million m^3
Englishman River at Parksville (08HB002)	1999 to 2011	Regulated	316	13.21 m^3/s 416.4 million m^3	2.28 m^3/s 18.1 million m^3

Hydrographs showing monthly recorded flows for the two periods of record are shown in Figure 55. This clearly shows the increase in summer base flows as a result of construction of the dam for storage and release of summer flows. It should be noted that flows are recorded upstream of the City of Parksville intake and therefore do not indicate the remaining conservation flow in the river and estuary downstream of the intake.

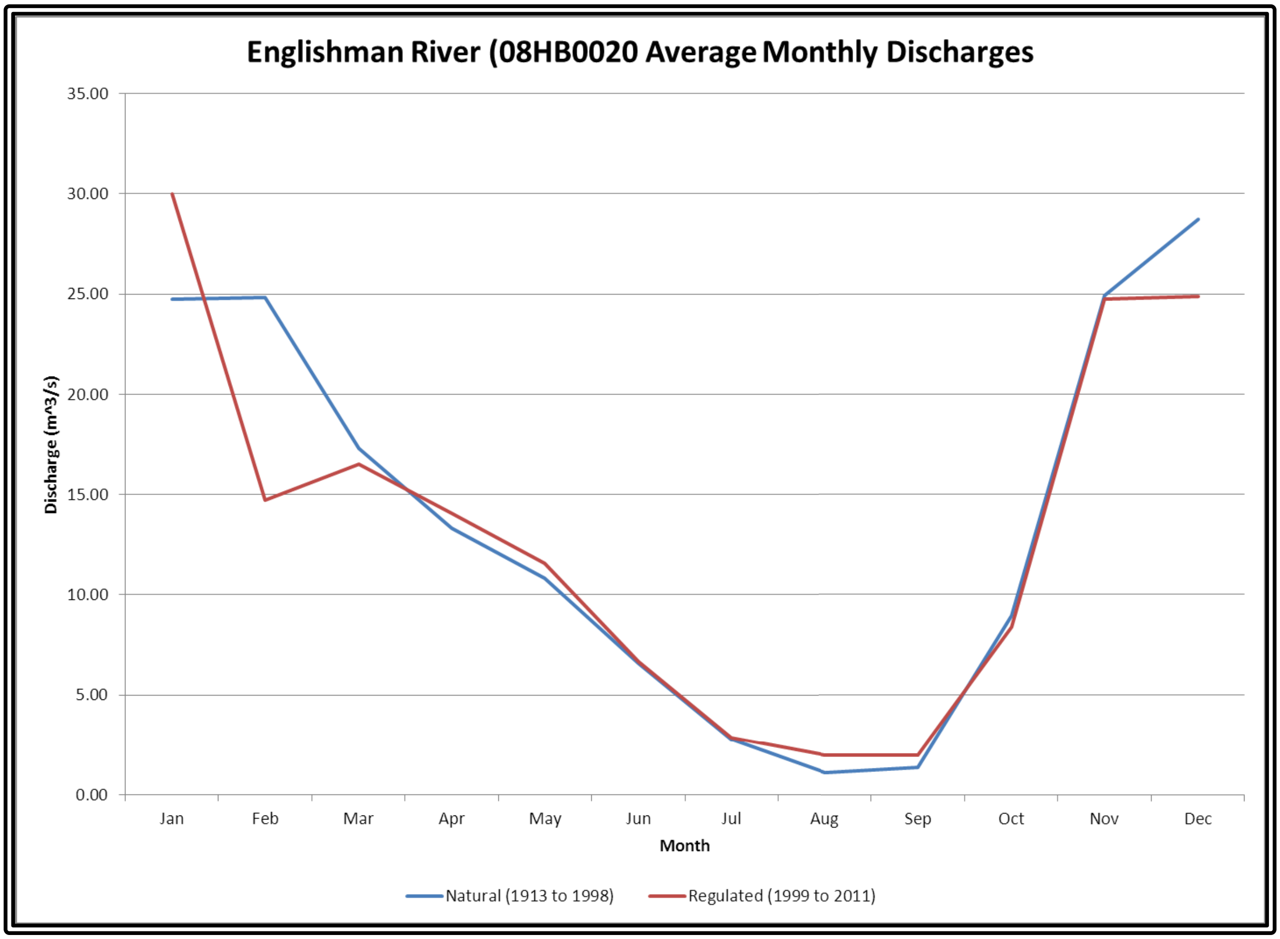

Figure 55: Englishman River Recorded Discharges

6.2.4 Hydrology and Surface Water Resources

The records from the Water Survey of Canada gauge near the mouth of the Englishman River have been used to quantify available water resources for the watershed as a whole. However, both Morison Creek and South Englishman River are not gauged systems. Results from the Regional Hydrologic Model for these systems are shown in Table 33

Table 33: WR4 (ER) – 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)
Morrison Creek	38.1	1.1 m^3/s 34 million m^3	0.040 m^3/s 0.3 million m^3
South Englishman River	100	3.8 m^3/s 119 million m^3	0.23 m^3/s 1.86 million m^3

The Englishman River Water Allocation Plan (Boom and Bryden, 1994) estimated the Morrison Creek and South Englishman River Mean Annual Discharges to be approximately 2.1 m^3/s and

3.3 m^3/s. However, these were based solely on factoring the recorded Englishman River by the watershed area ratios.

6.2.5 Surface Water Demand

Table 34 summarizes the surface water licences in WR4 from the BC Surface Water Licence Database. Table 35 outlines the licenced surface water storage. The location of the surface water licences for WR4 is shown on Figure 51.

Table 34: WR4 (ER) - Surface Water Demand (in m^3)

Type of Demand	Monthly	Annual	Summer (Jul-Sept)
Consumptive Demand			
Agriculture	9,710	117,600	87,420
Domestic	8,730	104,700	34,560
Industrial	1,640	19,600	4,910
Institutional	-	-	-
WaterWorks	697,183	8,366,000	2,761,000
Total Consumptive	717,260	8,607,000	2,888,000
Non- Consumptive Demand			
Power	-	-	
Conservation	18,440,000	221,300,000	55,320,000
Total Non-Consumptive	18,440,000	221,300,000	55,320,000

Table 35: WR4 (ER) - Licenced Surface Water Storage

Type of Demand	Total Storage (Million m^3)
Storage	9.126
Conservation Storage	0
Other Storage	0.079
Total Storage	9.205

The largest licensed water user in WR4 (ER) is the Arrowsmith Water Service for municipal water supply to the City of Parksville and Regional District of Nanaimo under the Englishman River Water Service (ERWS) agreement. The municipal water demand during the summer is supported by storage at Arrowsmith Lake which is controlled by a dam and outlet works. The total licensed storage at Arrowsmith Lake is 9.00 million m^3. The dam was designed to support municipal demand as well as to support minimum conservation flows of 1.13 m^3/s in the Englishman River downstream of the intake.

The ERWS is currently in the process of final design and construction of a relocated intake and treatment plant located upstream of the current intake location. As part of the planning for this process, detailed hydrology studies were carried out by KWL (KWL, 2010). The result of this study indicates that the operating rules for the dam will be altered to meet increased municipal demands while supporting in stream conservation flows. As the proposed new rules have not yet been approved, the stress analysis is based on water license amounts as of 2012.

In addition to allocated water amounts, the AWS records daily withdrawals from the Englishman River. During the summer of 2010, the total volume withdrawn from the Englishman River for municipal water supply was 600,000 m^3. This has been used to assess actual stress in comparison with allocated stress.

6.2.6 Surface Water Stress Analysis

As outlined in Section 2.5.2, a surface water stress analysis for the Englishman River watersheds has been completed. Water budget analysis for other smaller ungauged subwatersheds within WR4(ER) 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 Englishman River watershed in WR4 (ER) are shown in Table 36. A map showing the relative stress is shown on Figure 56.

Table 36: WR4(ER) – 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	Actual Demand (million m^3)	Actual Stress
Englishman River	14.4	9.2	13.2	2.7	68%	Moderate	0.6	8%

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 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 (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.

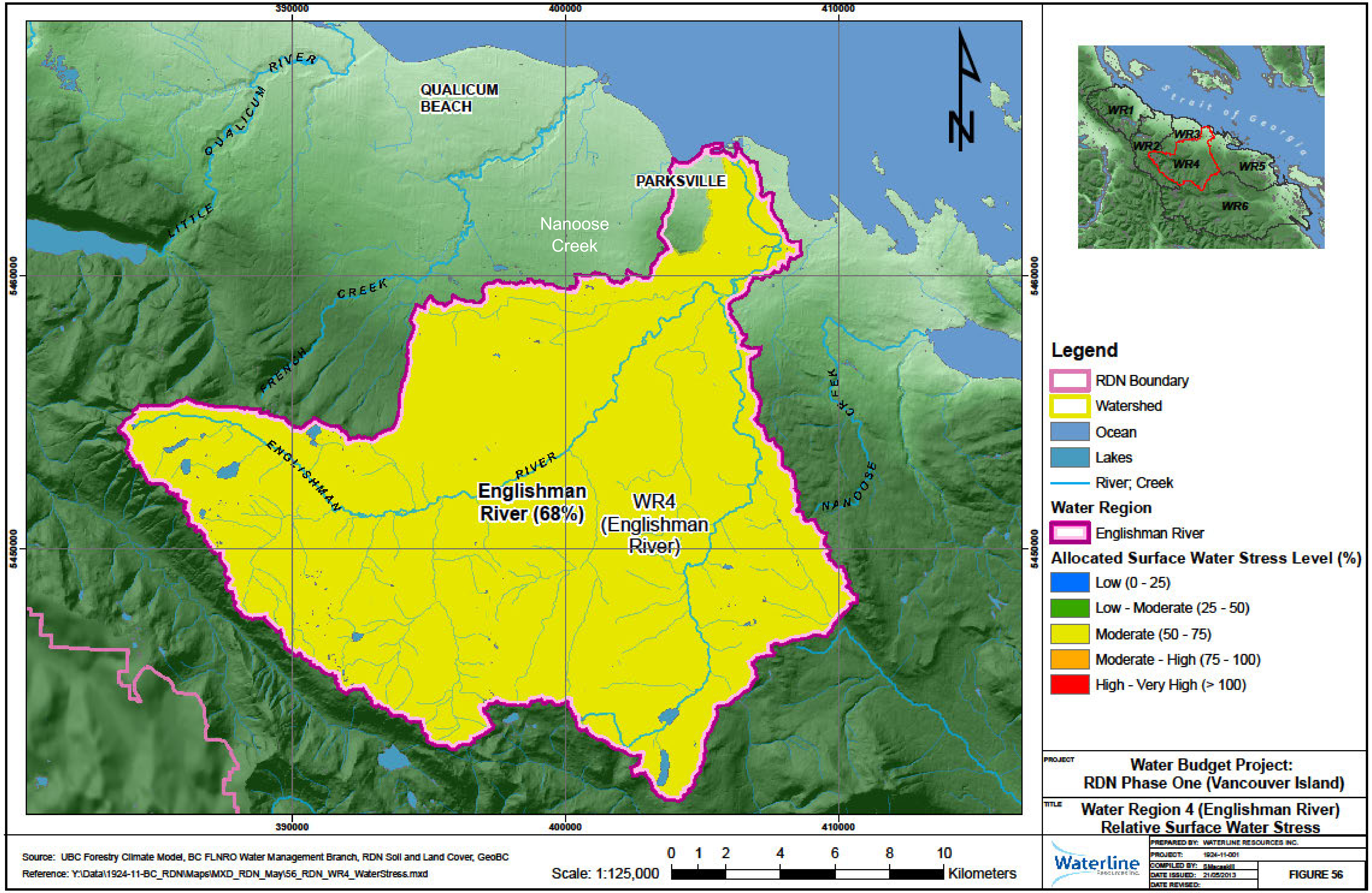

Figure 56: WR4 (ER) - Relative Surface Water Stress

6.3 Groundwater Assessment

6.3.1 Existing Groundwater Studies and Data

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 37.

Table 37: WR4 (ER) – Hydrogeology Reference Reports

Author	Year	Study Title
EBA Engineering Consultants Ltd.	2002	Hydrogeological Assessment for Proposed Subdivision
EBA Engineering Consultants Ltd.	2003	Preliminary Hydrogeological Assessment of Water Supply for Proposed Rural Residential Subdivision
EBA Engineering Consultants Ltd.	2004	Report on Testing of Water Source Well PW2
EBA Engineering Consultants Ltd.	2004	Water Supply for Subdivision of Block 564
EBA Engineering Consultants Ltd.	2005	Well Protection Plan and Groundwater Monitoring Plan for River's Edge Subdivision (Block 564)
Levelton	2009	Well Yield San Pareil Well #4 Water Supply Well
Pacific Hydrology Consultants	2006	Groundwater Report and Well Test Analysis of Proposed Rascal Lane Well
Pacific Hydrology Consultants Ltd.	2003	Groundwater Source Evaluation RE Capacity Testing of Water Well at Rascal Trucking Gravel Pit
Wendling, G.	2012	Lower Englishman River Groundwater and Surface Water Interaction. Submitted to Mid Vancouver Island Habitat Enhancement Society
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.

6.3.2 Description of Aquifers and Water Wells

A total of four unconsolidated aquifers and two bedrock aquifers have been mapped within WR4 (ER). Table 38 provides a summary of information on mapped aquifers within WR4(ER). Quadra sand aquifers (209, 216, and 219) are reported to have moderate yield/productivity and are generally confined to semi-confined with low to moderate vulnerability and moderate to heavy use. The unconfined Salish aquifer 221 located at the mouth of the Englishman River has been mapped as high productivity with moderate use, but high vulnerability (Table 38).

Table 38: WR4 (ER) – 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)
209	Quadra	Upper ER close to Thrust Fault	Haslam	8.52E+06	Confined, IIC	M
220	Haslam	Upper WR4 (ER)	ER, FC	4.19E+06	Confined, IB	L
216	Quadra	Lower WR4 (ER) into FC	ER	6.13E+06	Semi-Confined, IB	M
219	Quadra	Along ER	Ocean, ER	9.13E+06	Confined, IIC	M
214	NG	Along Coast		5.62E+06	Semi-Confined, IIIC	L
221	Salish	Mouth of ER	Ocean, ER	4.03E+06	Unconfined, IIA	H

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.

Wells completed in unconsolidated aquifers are shown on Figure 57 and wells completed in bedrock aquifers are shown on Figure 58. The majority of supply wells are completed in unconsolidated, Quadra sand and gravel aquifers (Aquifer 209 and 216, Figure 57). There are a total of 245 overburden and bedrock wells listed in the MOE data base in WR4 (ER) (Table 31). 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 57 and Figure 58 likely represents only a fraction of wells actually drilled.

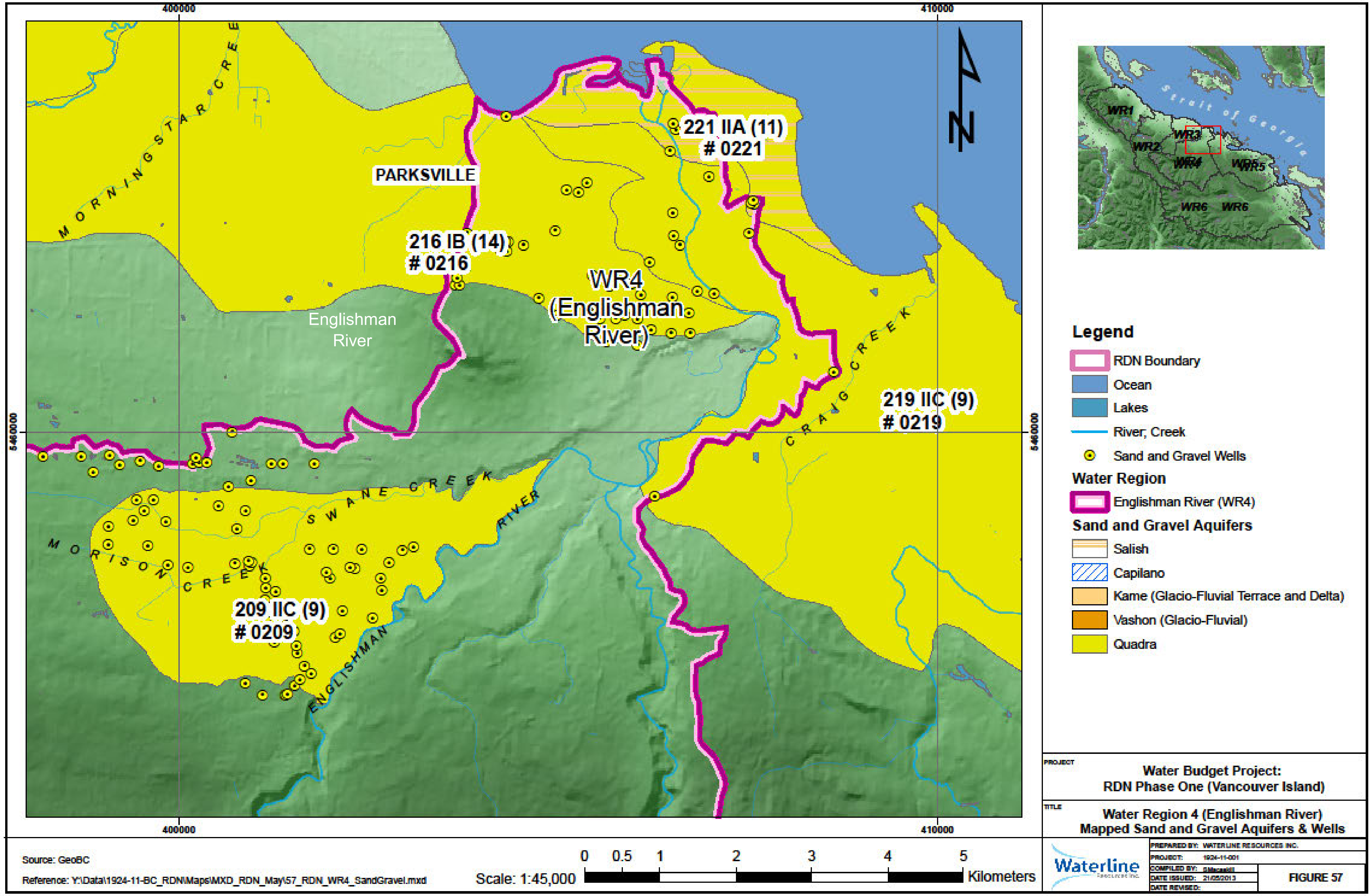

Figure 57: WR4 (ER) – Mapped Sand and Gravel Aquifers & Wells

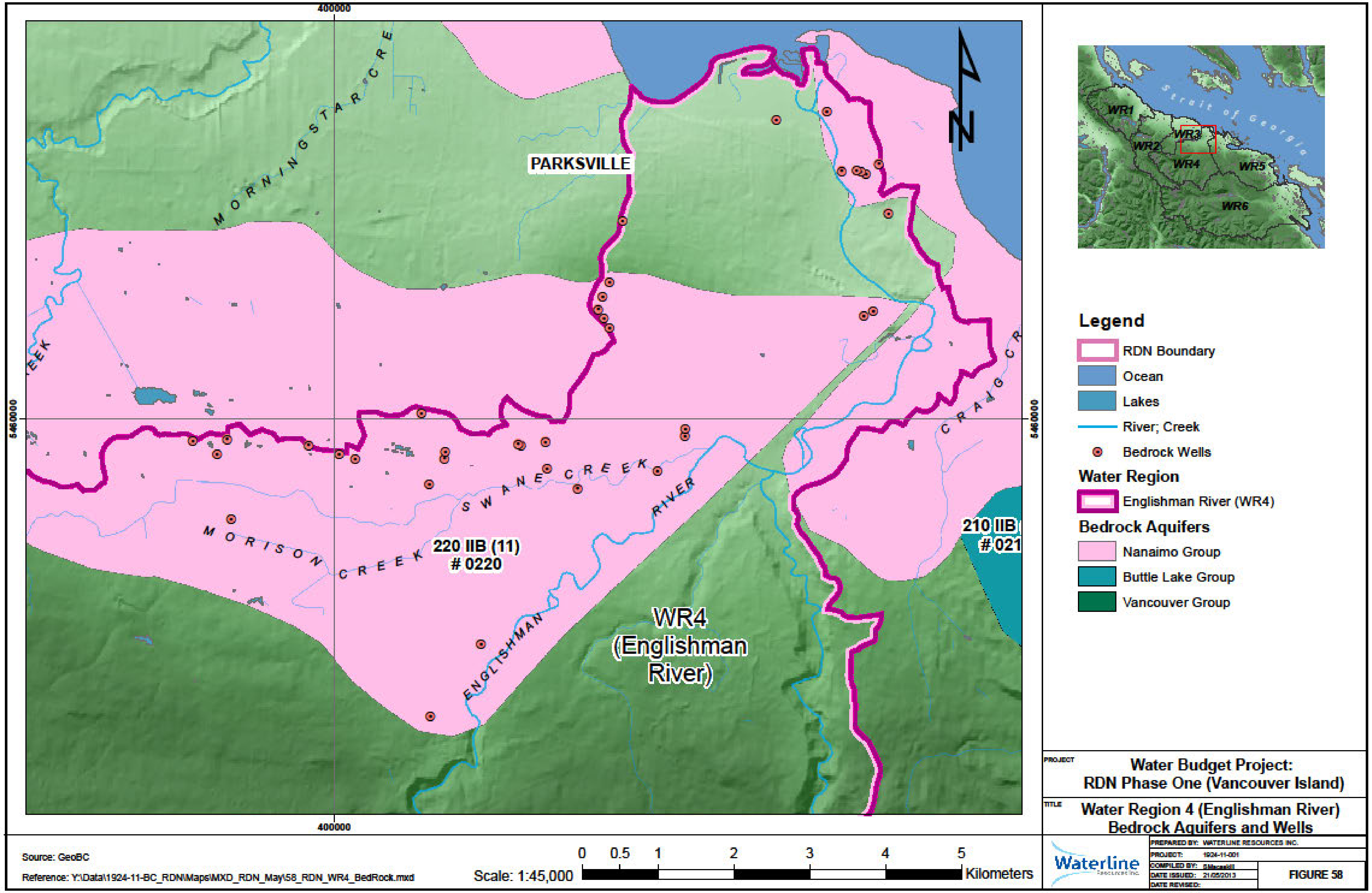

Figure 58: WR4 (ER) – Mapped Bedrock Aquifers & Wells

6.3.3 Groundwater-Surface Water Interaction - Conceptual Hydrogeological Model

A conceptual hydrogeological model of each aquifer with WR4 (ER) 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 will be presented here.

Figure 59 shows a 3D block diagram illustrating the relationship between surface and subsurface geology in WR4 (ER) where major water supply aquifers have been mapped. The schematic shows how the Quadra sand aquifer (219) on the east side of the Englishman River (View 1), and Quadra aquifer 216 on the west side of the river (View 2) may direct groundwater toward the Englishman River Valley and ultimately towards Georgia Strait.

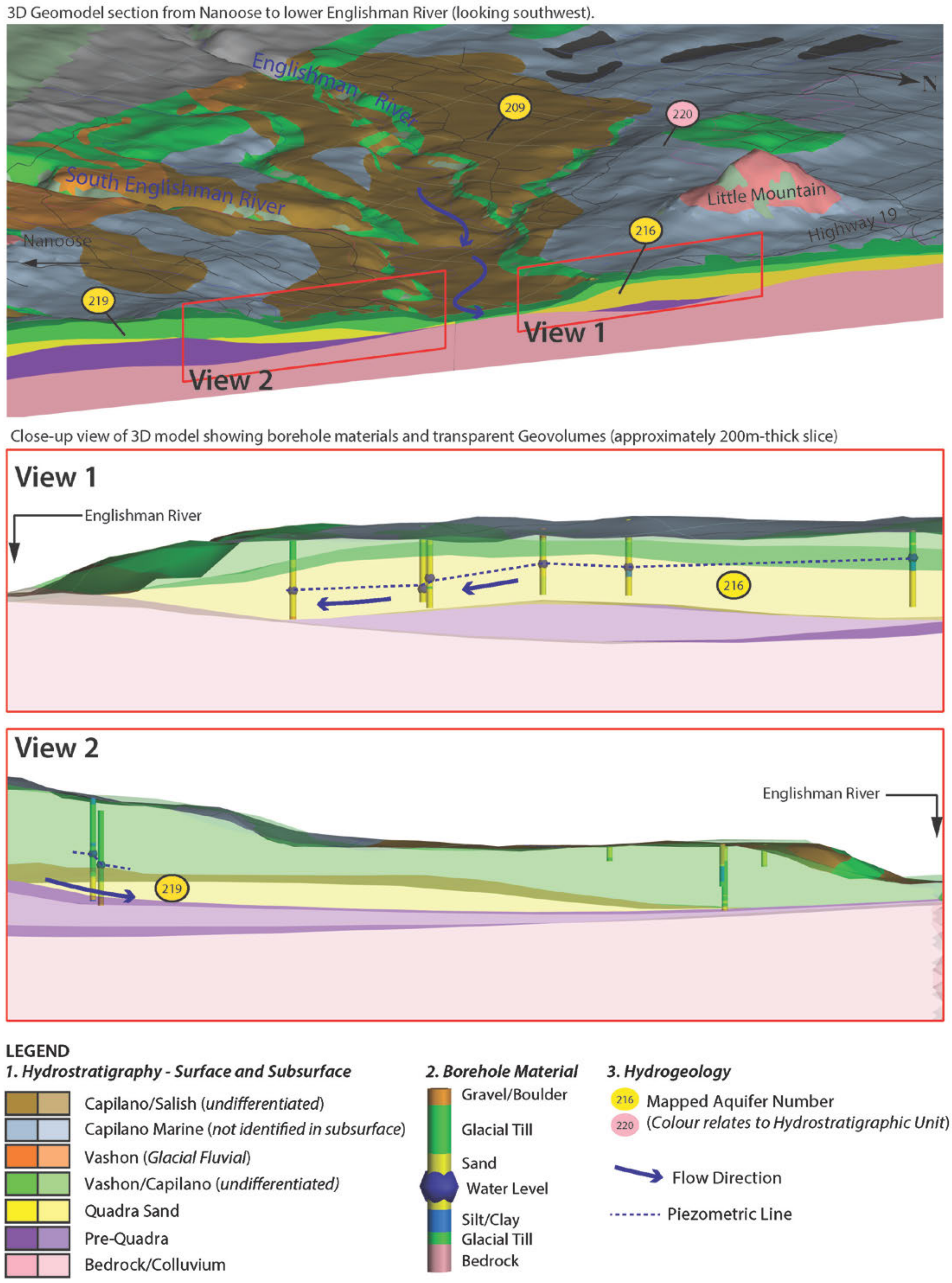

Figure 59: WR4 (ER) – Hydrogeological Conceptual Model – Englishman River

Quadra aquifer 219 to the east of the Englishman River is the location of the ERWS, Aquifer Storage and Recovery project. More recent information regarding groundwater flow in aquifer 219 may be available but was not available for the present study.

6.3.4 Significant Recharge Areas

Significant recharge areas within WR4 (ER) 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. 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.

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 60 shows significant recharge areas mapped as part of the water budget project.

The unique character of the WR4 (ER) is the large catchment area that exists in the upper part of the water region. In addition, the upper part of the water region is underlain by intensely fractured and folded bedrock. In fact, the Englishman River itself is controlled by a large fault system (see Appendix C (Map C4) showing the bedrock geology map in Appendix D) that occurs in the underlying bedrock which is believed to be a conduit for channeling flow from up gradient areas in the water region where significant recharge areas have been mapped.

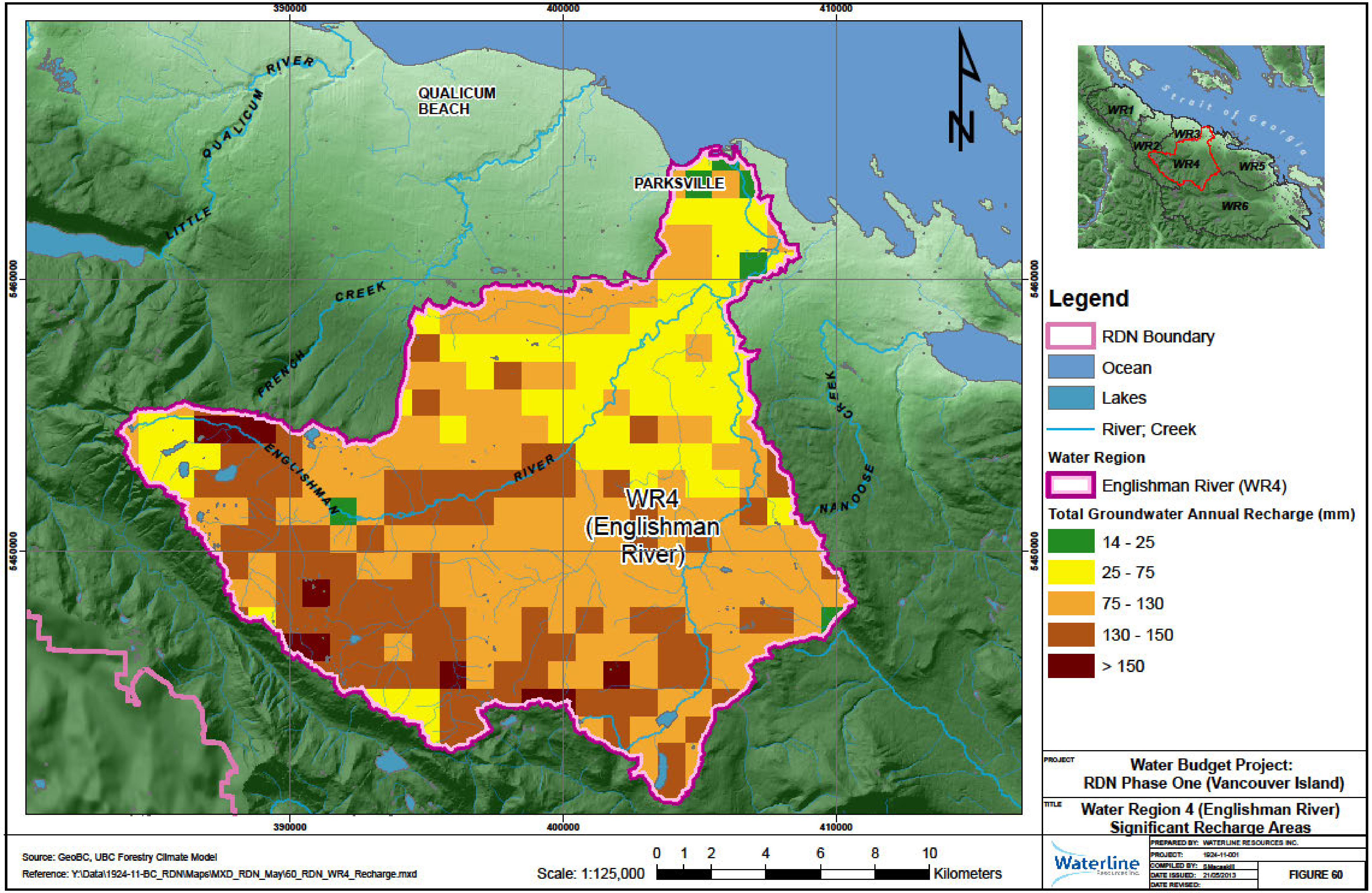

Figure 60: WR4 (ER) – Significant Recharge Areas

6.3.5 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 61 shows that there are no MOE observation wells and long-term water level monitoring records in WR4 (ER). Water supply wells in the region were 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 61 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 completed. Well owners are encouraged to report the MOE well plate ID so that accurate water level and groundwater extraction volumes can be allocated to the corresponding well and mapped aquifer.

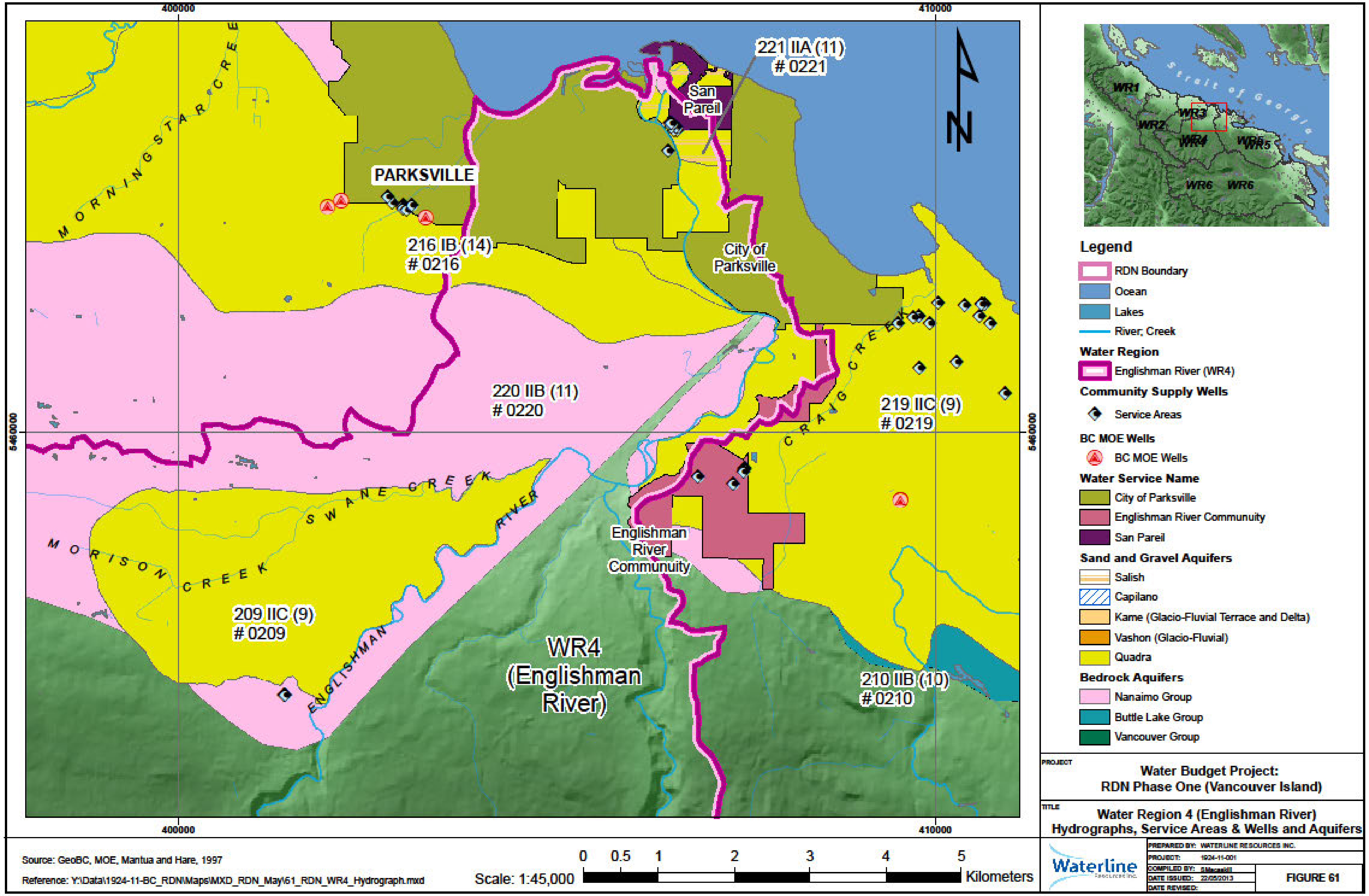

Figure 61: WR4 (ER) – MOE Well Hydrographs, Service Areas & Wells, and Aquifers.

6.3.6 Anthropogenic Groundwater Demand

Table 39 summarizes the available groundwater demand data available for WR4 (ER).

Table 39: WR4 (ER) – Summary of Anthropogenic Groundwater Demand Analysis

Aquifer No.	Parksville Railway (includes Trill well)	RDN San Pareil Well	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)
209	NA	NA	1.1E+06	9.77E+06
220	NA	NA	1.2E+06	1.22E+06
216	?	NA	7.6E+05	4.76E+06
219	NA	NA	8.3E+03	6.05E+06
214	NA	NA	1.4E+05	1.40E+05
221	NA	8.0E+04	9.5E+04	1.75E+05

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

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. The results are presented in the following section.

6.3.7 Aquifer Water Budgets and Stress Analysis

Table 40 provides a summary of the final water budget calculations for each aquifer mapped within WR4 (ER). 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 209, 216, 219, Figure 57) 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 245 overburden and bedrock wells listed in the MOE data base in WR4 (ER) which represents the one of the lowest 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 generally agrees with the lower indicated demand for groundwater in WR4 (ER) in comparison to other regions. Nevertheless, there is a need to better manage groundwater extraction as the population increases in this region.

Table 40: Summary of Aquifer Stress Analysis – WR4 (ER)

Aquifer Tag No.	Aquifer Lithology	Potential Ground Water-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
209	Quadra	Haslam	NA	NA	NA	NA	2.15E+07	8.67E+06	9.77E+06	9.77E+06	45	Lo-Mod
220	Haslam	ER	287	2.5	9.1	D	9.73E+05	1.72E+04	1.22E+06	1.22E+06	125	Hi
216	Quadra	ER	314	1.60	3.60	D/L	6.04E+06	4.00E+06	4.76E+06	4.76E+06	79	Mod. Hi
219	Quadra	Ocean, ER	NA	NA	NA	NA	1.83E+07	6.04E+06	6.05E+06	6.05E+06	33	Lo-Mod
214	NG	Ocean	NA	NA	NA	NA	6.18E+05	0.00E+00	1.40E+05	1.40E+05	23	Lo
221	Salish	Ocean, ER	NA	NA	NA	NA	2.87E+05	0.00E+00	1.75E+05	1.75E+05	61	Mod

Notes: ER means Englishman River, 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.

Based on the water budget estimates for mapped aquifers within WR4 (ER), overall conditions appear to be variable with low to high stress indicated. Water budget estimates for Quadra aquifer 216 and Haslam bedrock aquifer 220 indicate a moderate to high and high level of stress in the water region, respectively. Dense development and substantial demand for water (E.g. RDN, City of Parksville, Epcor, and private wells) likely contribute to the stress assessed for Quadra aquifer (216). This may be exacerbated in localized areas where the water wells are in close enough proximity to be competing for the groundwater resource (well-to-well interference).

Salish aquifer 221 exhibits moderate stress. Quadra aquifers 209 and 219 exhibit low to moderate stress, while the Nanaimo Group bedrock aquifer 214 exhibits low stress.

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.

6.4 Water Management Planning Within WR4 (ER)

General guidance on water management planning for all water regions is provide in later sections of this document. Specific to WR4 (ER), 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. Mapped aquifers that currently do not have MOE monitoring wells include Aquifers 209, 219, 214, and 221;
- 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 Parksville Railway wells, and the RDN San Pareil wells;
- The significant recharge area map needs to be further 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 Englishman River to confirm that significant recharge is being directed through the extensive bedrock fault network. Waterline recommends specialized analysis (E.g.: isotopes[28], 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 flows may help to quickly pinpoint areas where more detailed studies may be required;
- Arrowsmith Lake Reservoir Level and Discharge Data collected by the Arrowsmith Water Service be obtained at regular intervals and be included in the Regional Water Database;
- Shelton Lake and South Englishman River Flow data collected by the BC Conservation Foundation be obtained at regular intervals and be included in the Regional Water Database; and
- Weekly flow measurements during the summer period (June to Sept) should be collected as part of the Community Watershed Monitoring Network program for Morrison Creek and Swane Creek to better understand summer low flows in these smaller watersheds.

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