APPENDIX A

GLOSSARY OF TERMS

Alluvial Applying to the environments, actions, and products of rivers or streams.

Aquifer Any water-saturated body of geological material from which enough water can be drawn at a reasonable cost for the purpose required. An aquifer is only a relative term determined largely by economics and is best illustrated by extreme examples. An aquifer in an arid prairie area required to supply water to a single farm may be adequate if it can supply 1 m^3/day. This would not be considered an aquifer by any industry looking for cooling water on the order of 10,000 m^3/day. A common usage of the term aquifer is to indicate the water-bearing material in any area from which water is most easily extracted.

Aquifer management unit A hydraulically-connected groundwater system that is defined to facilitate management of the groundwater resources (quality and quantity) at an appropriate scale.

Aquitard A water-saturated sediment or rock whose permeability is so low it cannot transmit any useful amount of water. An aquitard allows some measure of leakage between the aquifer intervals it separates.

Bedrock The solid rock that underlies unconsolidated surficial sediments.

Block-Faulted High-angle faulting in which blocks of the crust move vertically up or down relative to each other. Often occurs in areas undergoing horizontal extension.

Bedrock aquifer A bedrock unit that has the ability to transmit significant volumes of water to a well completed within it. Typical examples include sandstone and siltstone or significantly fractured intervals.

Channel An eroded depression in the soil or bedrock surface within which alluvial deposits accumulate (i.e. gravel, sands, silt, clay).

Contaminant A substance that is present in an environmental medium in excess of natural baseline concentration.

Contemporaneous Formed or existing at the same time

Cumulative Effects The changes to the environment caused by all past, present, and reasonably foreseeable future human activities.

Evapotranspiration The process by which water is discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and transpiration by plants. Transpiration is the process by which water passes through living organisms, primarily plants, into the atmosphere.

Fault A break in material in which material on one side of the break has moved relative to that on the other side. In the Foothills and Rocky Mountain Front Ranges Thrust faulting is the most common – Thrust faults are low angle faults in which older material may be ‘thrust over’ younger material.

Fluvial Produced by the action of a stream or river

Geometric mean A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing transmissivity estimates, which may vary

	over 10 orders of magnitude. A geometric mean is a log (base 10) transformation of data to enable meaningful statistical evaluations.
Groundwater	All water beneath the surface of the ground whether in liquid or solid state.
Hydraulic Conductivity	The rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time.
Hydraulic Gradient	In an aquifer, the rate of change of total head per unit distance of flow at a given location and direction. It has both horizontal and vertical components.
Hydrogeology	The science that relates geology, fluid movement (i.e. water) and geochemistry to understand water residing under the earth's surface. Groundwater as used here includes all water in the zone of saturation beneath the earth's surface, except water chemically combined in minerals.
Infiltration	The flow or movement of precipitation or surface water through the ground surface into the subsurface. Infiltration is the main factor in recharge of groundwater reserves.
Instream Flow Needs	The amount of water required in a river to sustain a healthy aquatic ecosystem, and/or meet human needs such as recreation, navigation, waste assimilation or aesthetics.
km	kilometre
Lacustrine	Fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits
m	metres
mm	millimetres
m^2/day	metres squared per day
m^3	cubic metres
m^3/day	cubic metres per day
Monitoring Well	A constructed controlled point of access to an aquifer which allows groundwater observations. Small diameter observation wells are often called piezometers.
Overburden	Any loose material which overlies bedrock (often used as a synonym for Quaternary sediments and/or surficial deposits) or any barren material, consolidated or loose, that overlies an ore body.
Permeability	A physical property of the porous medium providing an indication of how easily water will flow through the material. Has dimensions $Length^2$. When measured in cm^2, the value of permeability is very small, therefore more practical units are commonly used - Darcy (D) or millidarcy (mD). One darcy is equivalent to 9.86923×10^{-9} cm^2.
Receptor	Components within an ecosystem that react to, or are influenced by, stressors.
Recharge	The infiltration of water into the soil zone, unsaturated zone and ultimately the saturated zone. This term is commonly combined with other terms to indicate some specific mode of recharge such as recharge well, recharge area, or artificial recharge.

Significant Aquifer — A permeable water-bearing horizon of sufficient thickness and lateral extent that can yield useable quantities of water. An aquifer in excess of 5 m thick, 100 m or more in width and extending a lateral distance of 500 m or more may be considered a significant aquifer.

Stratigraphy — The geological science concerned with the study of sedimentary rocks in terms of time and space.

Stress — Physical, chemical and biological factors that are either unnatural events or activities, or natural to the system but applied at an excessive or deficient level, which adversely affect the receiving ecosystem. Stressors cause significance changes in the ecological components, patterns and processes in natural systems.

Strike — The strike line of a bed, fault, or other planar feature is a line representing the intersection of that feature with a horizontal plane.

Subcrop — An occurrence of the strata directly beneath an unconformity (e.g., base of unconsolidated materials constituting a weathering surface).

Surficial Deposits — See Overburden.

Sustainable — A characteristic of an ecosystem that allows it to maintain its structure, functions and integrity over time and/or recover from disasters without human intervention.

Thalweg — The line defining the lowest points along the length of a river bed or valley. Also the line defining the central (long) axis of a buried channel or valley.

Thrust Faulting — A shallow dipping fault in which the hanging wall moves up relative to the footwall. It is caused by horizontal compression. This results in placing older rock over younger rock.

Till — A sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders.

Total Dissolved Solids — Concentration of all substances dissolved in water (solids remaining after evaporation of a water sample).

Transmissivity — The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient; a measure of the ease with which groundwater can move through the aquifer: **Apparent Transmissivity**: the value determined from a summary of aquifer test data, usually involving only two water-level readings; **Effective Transmissivity**: the value determined from late pumping and/or late recovery water-level data from an aquifer test; and **Aquifer Transmissivity**: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer.

Trend — The relationship between a series of data points (e.g. Mann Kendall test for trend).

Water Management — A framework to enable water planning, allocation and Framework management of water resources.

Water Management Plan — A plan that provides guidance for water management and sets out clear and strategic directions for how water should be managed.

Watershed	The geographic area of land that drains water to a shared destination. The boundary is determined topographically by ridges, or high elevation points. Water flows downhill, so mountains and ridge tops define watershed boundaries.
Water Well	A hole in the ground for the purpose of obtaining groundwater; "work type" as defined by AEW includes test hole, chemistry, deepened, well inventory, federal well survey, reconditioned, reconstructed, new, old well-test.
Yield	A regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer: **Apparent Yield**: based mainly on apparent transmissivity, and **Long-Term Yield**: based on effective transmissivity.
AMSL	above mean sea level
BGP	Base of Groundwater Protection
DEM	Digital Elevation Model
NPWL	non-pumping water level also often referred to as static water level
TDS	Total Dissolved Solids

APPENDIX B
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APPENDIX C

WATERLINE GEODATABASE DEVELOPEMENT
MAJOR COMPILED/INTERPRETED HYDROGEOLOGY AND HYDROLOGY GIS MAPS AND DATASETS

Waterline
Resources Inc.

LIST OF MAPS - APPENDIX C

WATERLINE GEODATABASE DEVELOPMENT AND WATER BUDGET ASSESSMENT

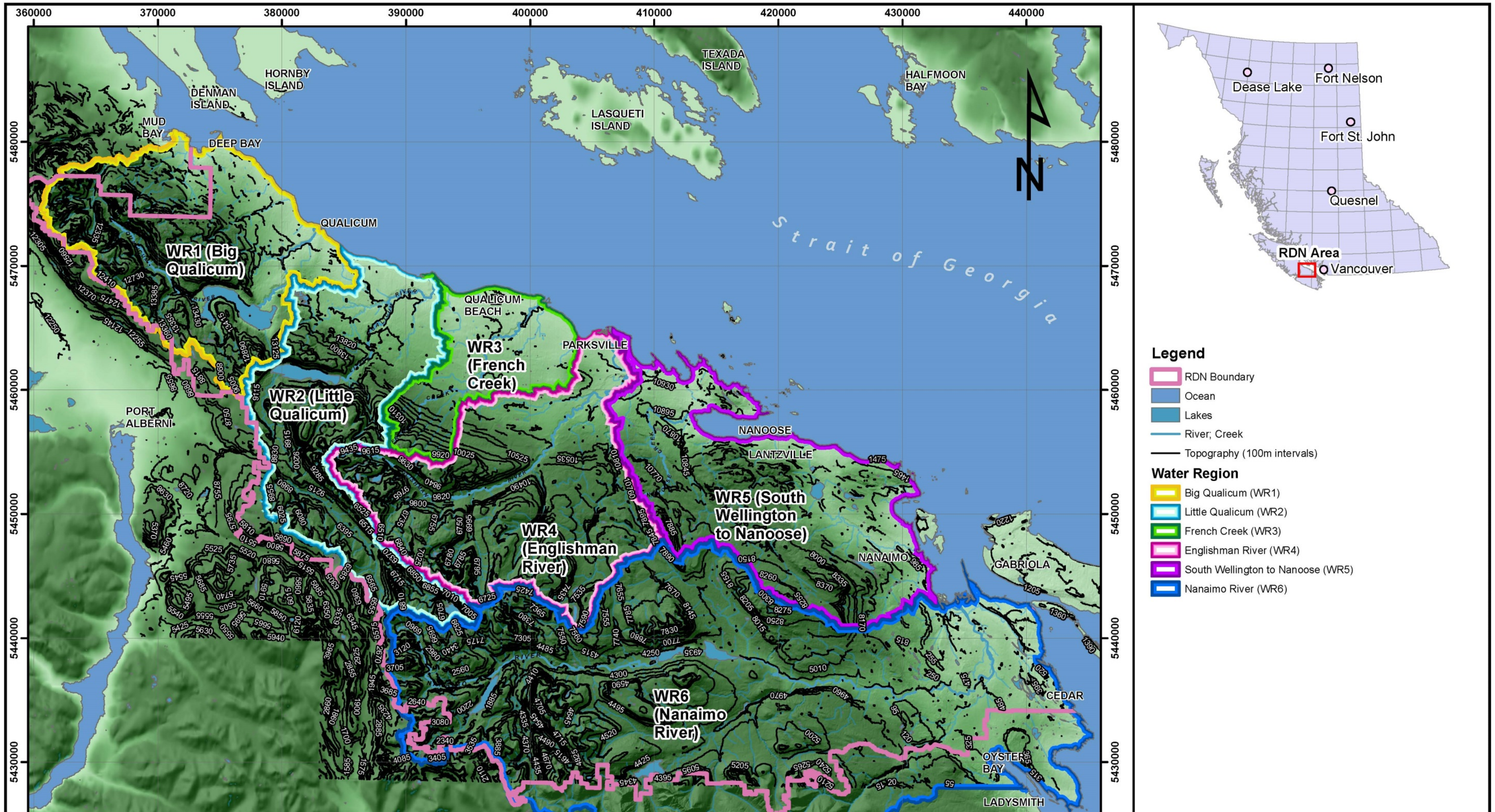
The first task for the RDN Phase One Water Budget project was to assemble all available groundwater, surface water, geological and time series data into a GIS. Many of the publicly available datasets can be brought directly into ArcGIS for mapping and analysis. Others require extensive processing, including the thirty thousand raw driller's descriptions that were refined in an iterative capture process using a data refining application, down to 10 material classes (e.g. sand/gravel, silt/clay, till, etc.). The boreholes and geology were brought into a 3D geological modelling application in order to establish a coherent picture of subsurface hydrogeology (aquifers & aquitards) which forms the conceptual model for each water region and aquifer within each region. The output from the 3D model include a bedrock subsurface topography, water table and piezometric surfaces, geometry and thickness of bedrock of overburden aquifers (confined and unconfined), and potential interconnections with surface water bodies. The results of this processing, refinement and analysis of all the source data form the conceptual model and allows for establishing the inputs for the water budget calculations.

In order to bring a consistent structure to the large amount of data involved in the RDN Water Budget project, Waterline developed a custom ArcHydro Groundwater data model and geodatabase. Once constructed, the data model helped to organize, structure, visualize, and analyze multidimensional groundwater and environmental data. This includes aquifers and wells/boreholes, 3D geological and hydrogeological models, time series information, and various other multi-disciplinary datasets.

A set of scripts and tools are available for ArcGIS that are designed specifically to work with the ArcHydro Groundwater data model. The groundwater model developed for the Water Budget is a companion to an ArcGIS Surface Water data model (ArcHydro). Although some surface water information is included in the ARC Hydro Geodatabase, the main focus was on groundwater related information in order to facilitate the aquifer water budget and stress analysis. Additional surface water components can be added to the geodatabase as needed in the future. The ArcHydro geodatabase developed for the RDN Water Budget can be used directly by GIS staff at the RDN, or the database schema can be imported to a relational database management system (e.g. SQL Server, ArcSDE) for further development.

In conjunction with other geological software (i.e.: Leapfrog Hydro) Waterline was able to manipulate these data to produce visualizations, maps, graphs and cross-sections as well as develop 3D conceptual hydrogeological models of key aquifers within the RDN. These dataset and models could at some point in the future be used as input to numerical groundwater flow modeling programs such as MODFLOW or FEFLOW, which will be required if the RDN wish to move to a full Tier 1 or Tier 2 watershed analysis (OMNR 2012). The GSC is currently modelling the Nanaimo Lowlands aquifers in the area and is using Leapfrog Hydro for the conceptual Model input.

As there are 100's of combinations of maps and cross-sections that could now be produced from the geodatabase and the 3D Model, it is not reasonable, nor is it within the present scope of work to present more than several key visualizations as was provided in the body of this report. The Phase One Water Budget report provides only key maps used to explain the approach to the aquifer and surface water budgets. The sample maps provided in this appendix are presented for illustration purposes to show some of the various layers and other datasets that were considered in Waterline's water budget assessment. More data exist in the ArcGIS Geodatabase which will be provided to the RDN. The intent of Waterline's work in developing the geodatbase system was that the RDN would be able to use the database to develop a secure user website (similar to the RDN Water Map) which could serve the data publicly. The maps herein are samples provided for illustration purposes only of some (not all) of the data available in the ArcGIS database developed by Waterline, for use by the RDN.



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

TITLE: **Topography**

Unknown Source, Date. 1:20,000 TRIM Raster data obtained by the RDN in 2011., Geo BC, 2013.
Hill Shade. Downloaded from http://www.basemaps.gov.bc.ca/ in 2013.,
BCGOV FLNRO GeoBC, 2008. Fresh Water Atlas. Details at http://geobc.gov.bc.ca/freshwater_atlas.html, in January 2012.

Reference: Y:\Data\1924-11-BC_RDN\Maps\MXD_RDN_May\AppendixC\C1_RDN_Topo1.mxd

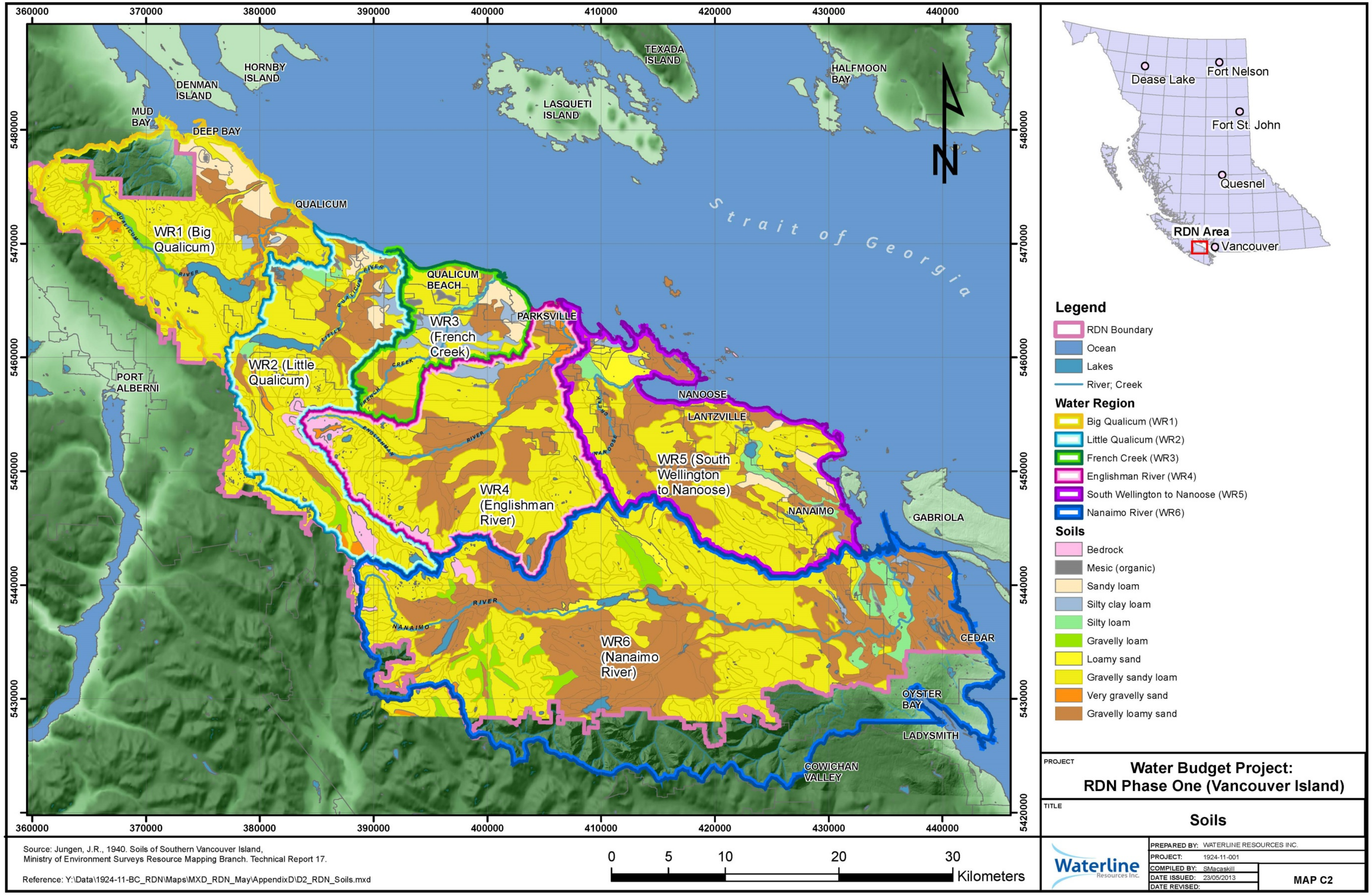
Waterline Resources Inc.

PREPARED BY:	WATERLINE RESOURCES INC.
PROJECT:	1924-11-001
COMPILED BY:	SMacaskill
DATE ISSUED:	29/05/2013
DATE REVISED:	

MAP C1

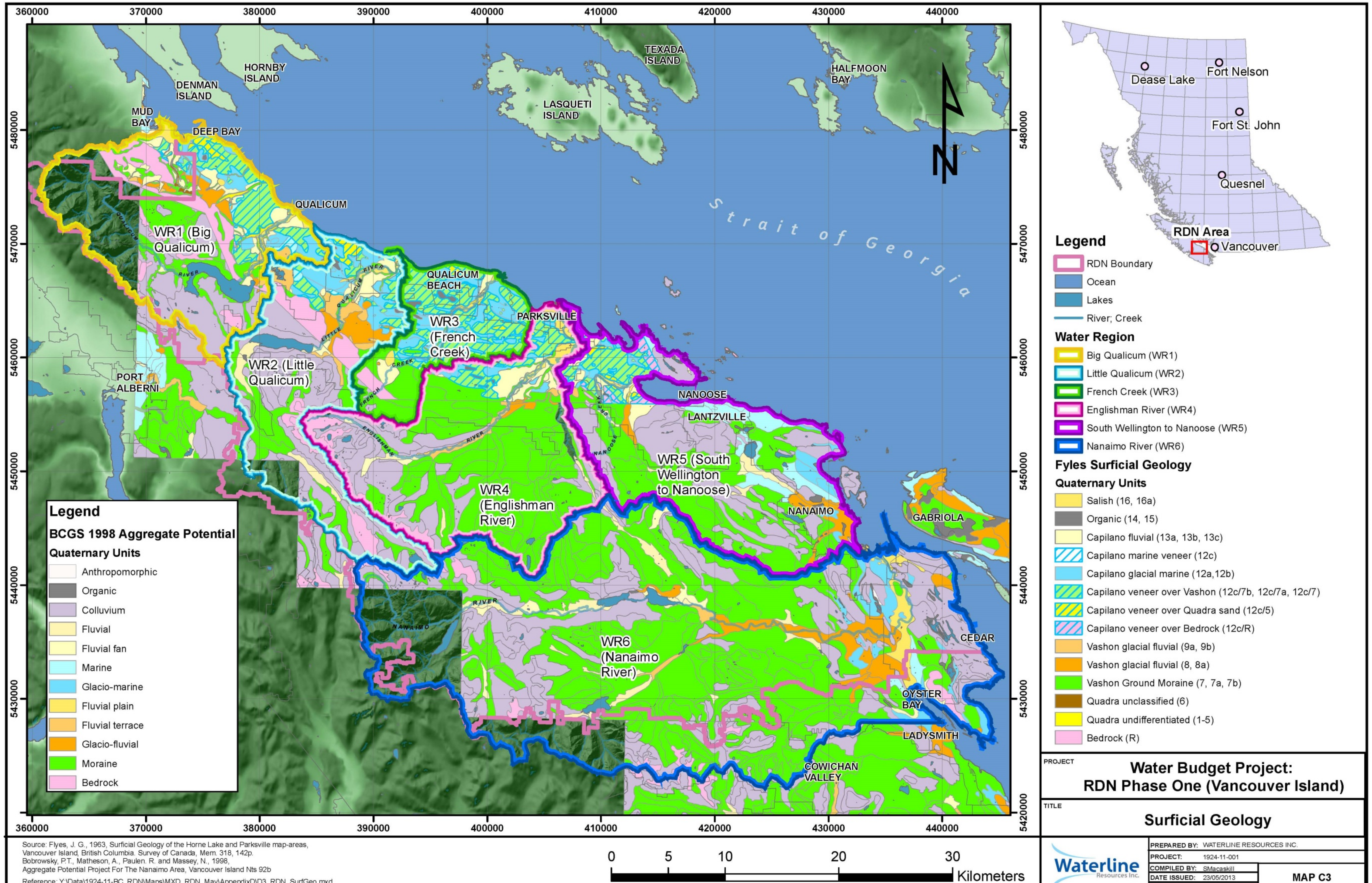
Map C1: Topography

The topography layer was developed from 1:20,000 TRIM data provided by the RDN. The elevation data was a critical dataset in the development of the3D geomodel for the RDN as it was the surface layer onto which all surface and subsurface data was geo-referenced. Waterline evaluated some discontinuous LIDAR data that was available from various communities across the RDN but selected the 1:20,00 Trim data since it provided full coverage across the study area. The sample provided here is for illustration purposes only as it is not possible to show labeled contours over such a large area.



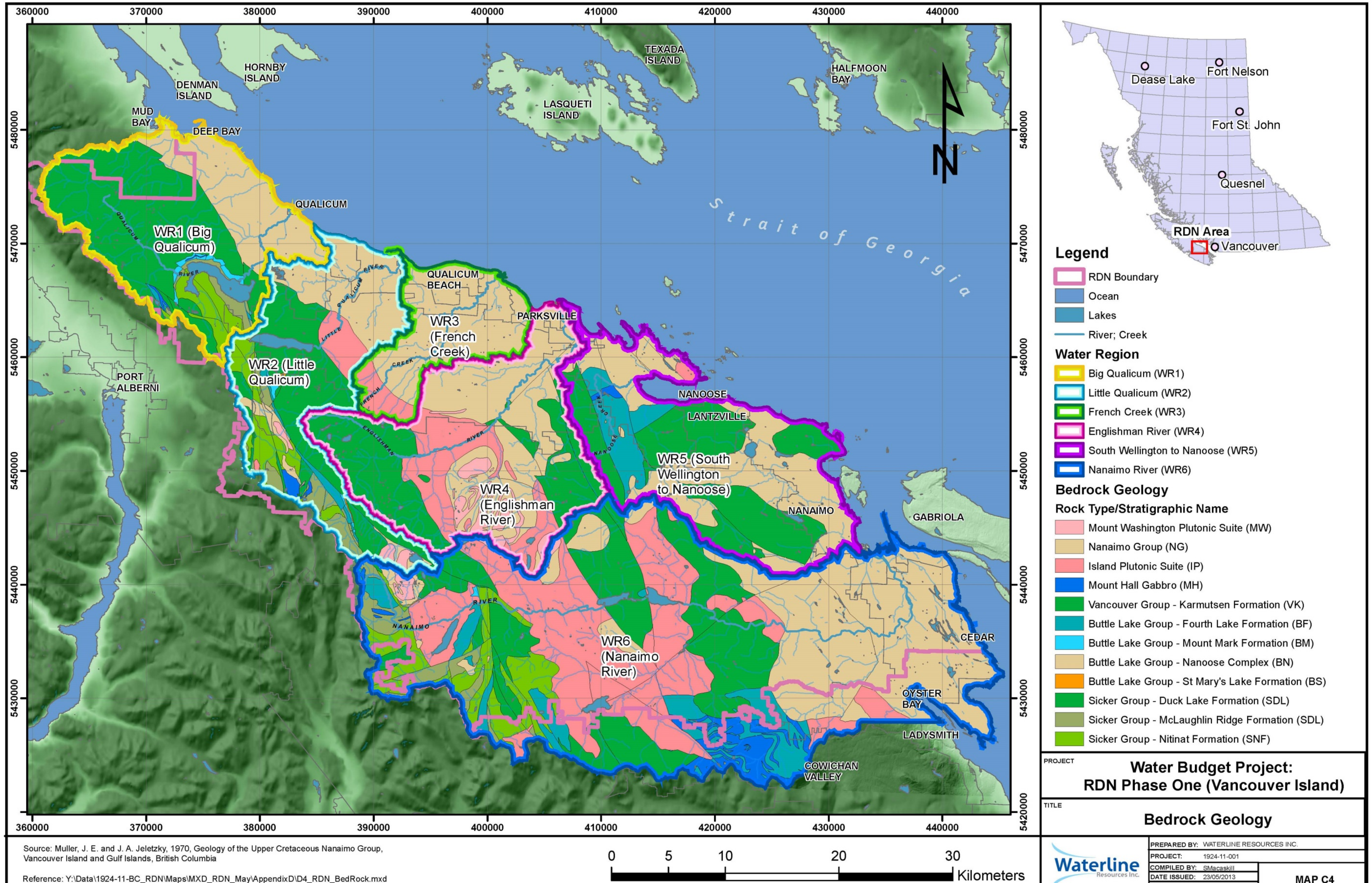
Map C2: Soils

The soils layer was source from the Ministry of Environment (see reference on Map) and was important in mapping potentially significant recharge areas when combined with NRCAN Remote Sensing Data (see Maps C11, C12, and C3) The soils data was integrated with borehole lithology, 1:20,000 Trim elevation mapping, surficial geology mapping, and remote sensing data to assess infiltration and recharge characteristics within each water region across the RDN.



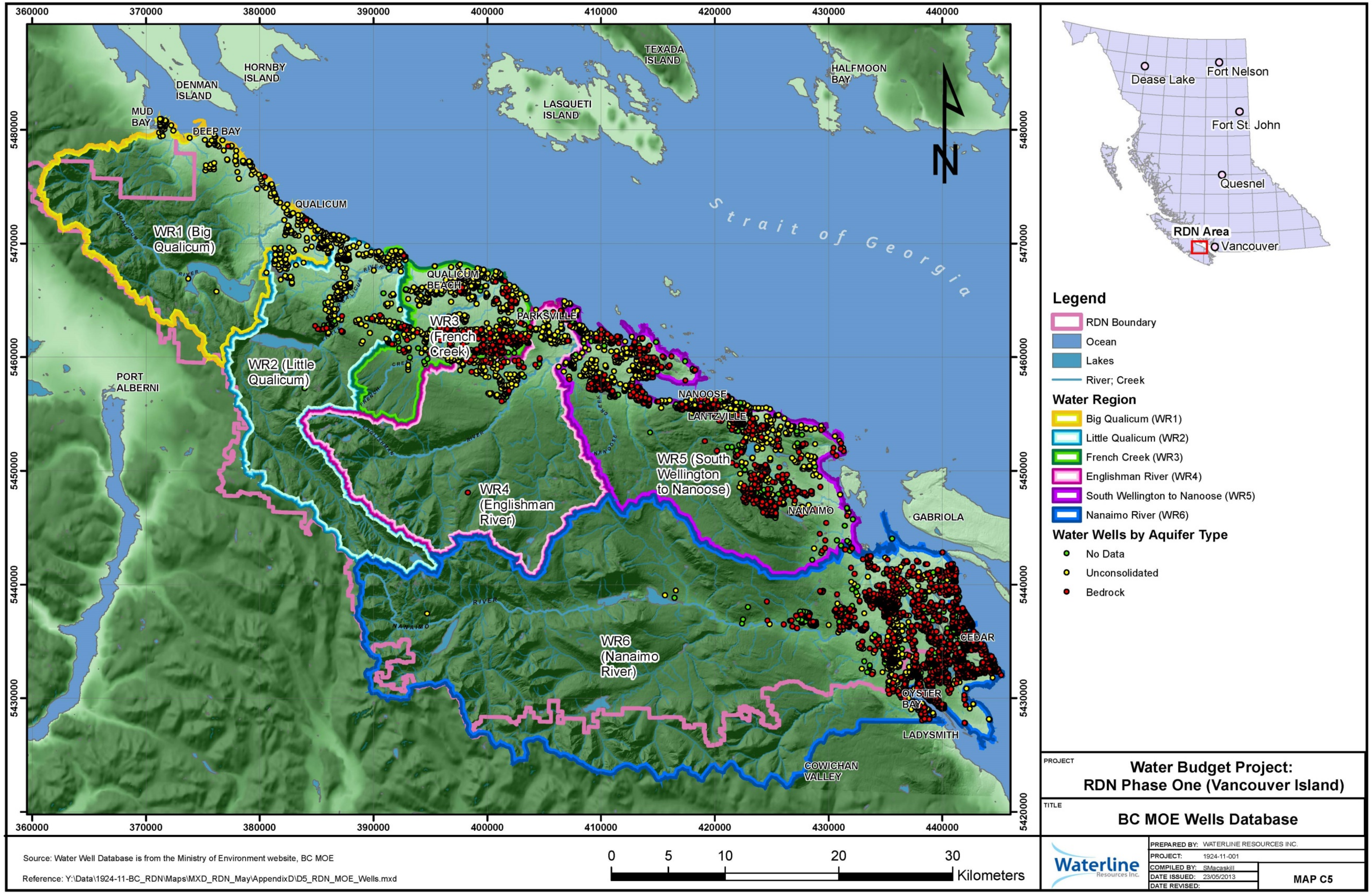
Map C3: Surficial Geology

The surficial geology layer was taken from Fyles (1963) and, where absent, was filled in with the Aggregate Resource Mapping series. This data was integrated with borehole lithology, 1:20,000 Trim elevation mapping, and soils mapping to correlate glacial deposits and develop conceptual geology and hydrogeology of the various unconsolidated aquifers across the RDN. The data was a key part of the assessment of groundwater-surface water interactions for the various creeks and rivers across the RDN. NRCAN in Victoria is currently re-mapping this map sheet and expect to have an updated version within the next year or so.



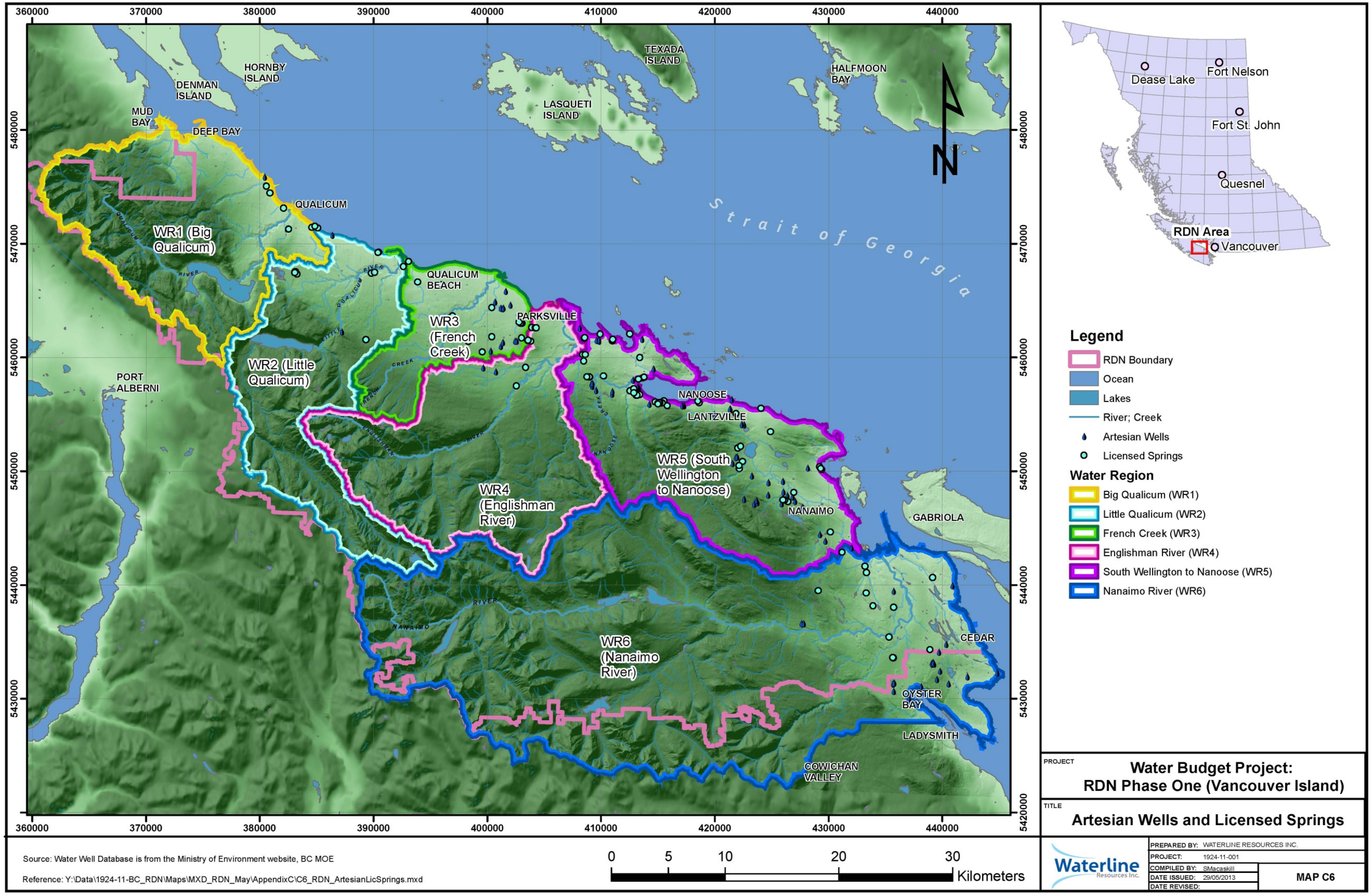
Map C4: Bedrock Geology

Bedrock geology layers were downloaded from the Geo BC website and compiled into Waterline's ARC GIS Geodatabase. This information was integrated with borehole lithology, along with GSC seismic data (unpublished) to develop a bedrock surface topography map, and overburden thickness isopach map (see Map C7). The data was also integrated with mapped aquifer information to develop conceptual models of the hydrogeology of each bedrock aquifer previously mapped within the RDN.



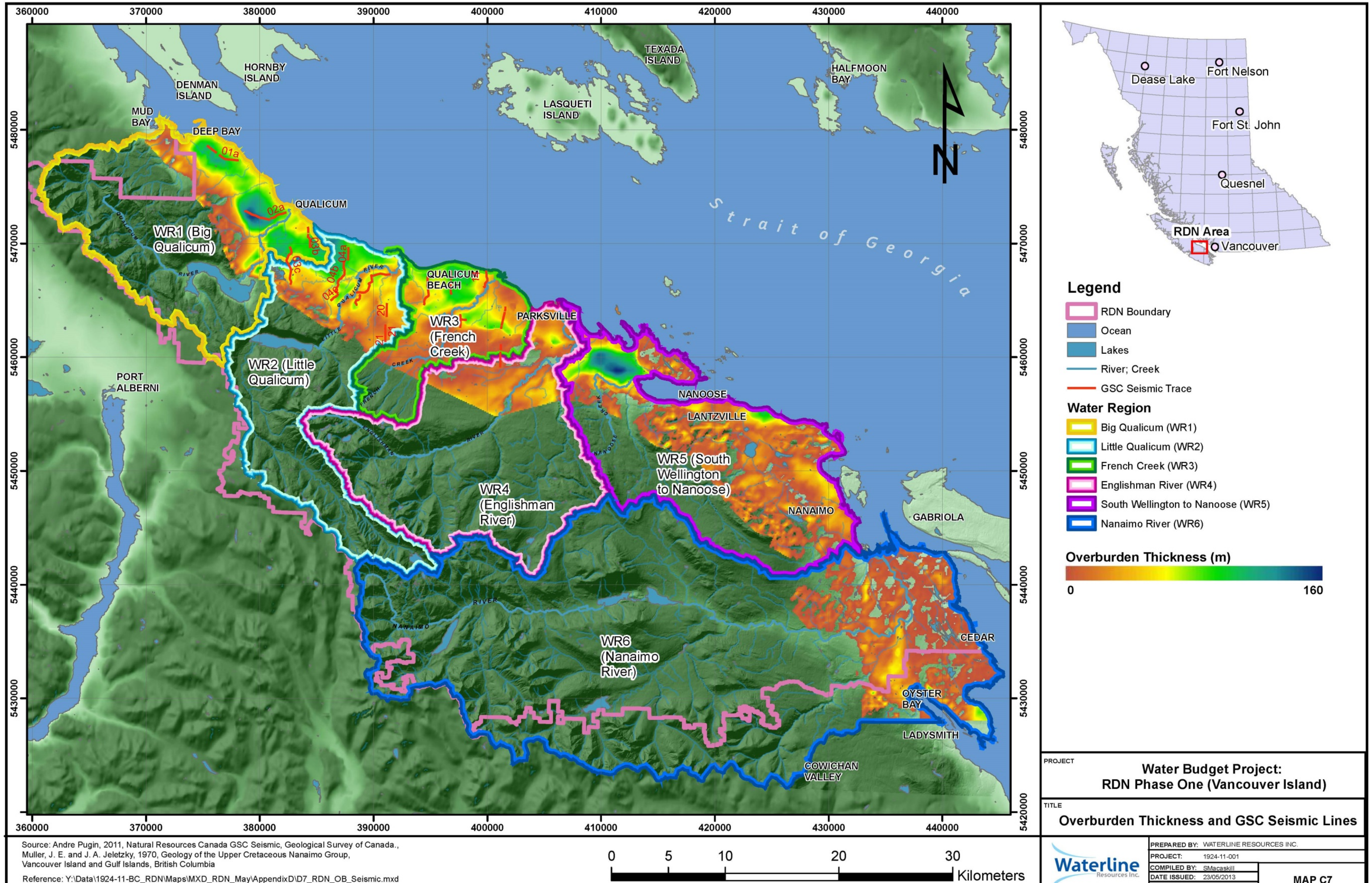
Map C5: BCMOE Wells Database

Over 6000 Wells exist within the RDN on Vancouver Island. The data were processed within Waterline's Geodatabase and sorted according to well completion into overburden (yellow points), bedrock (pink points), and indeterminate (green points). Data conditioning, filtering and refinement were further completed by Waterline geologists and hydrogeologists using specialize tools and algorithms. The intent was to process the information and make the lithology descriptions consistent with GSC mapping study and geology nomenclature developed by researchers at Simon Fraser University. The lithology refinement process conducted by Waterline reduced the information from 1000's to 100's to approximately 10 lithology descriptors which enabled the development of final hydrostratigraphy to link to mapped surface geology (Maps C2, C3, C4) to subsurface borehole geology. This information was the foundation for the development of conceptual geological, hydrogeological, hydrological models for each Water Region.



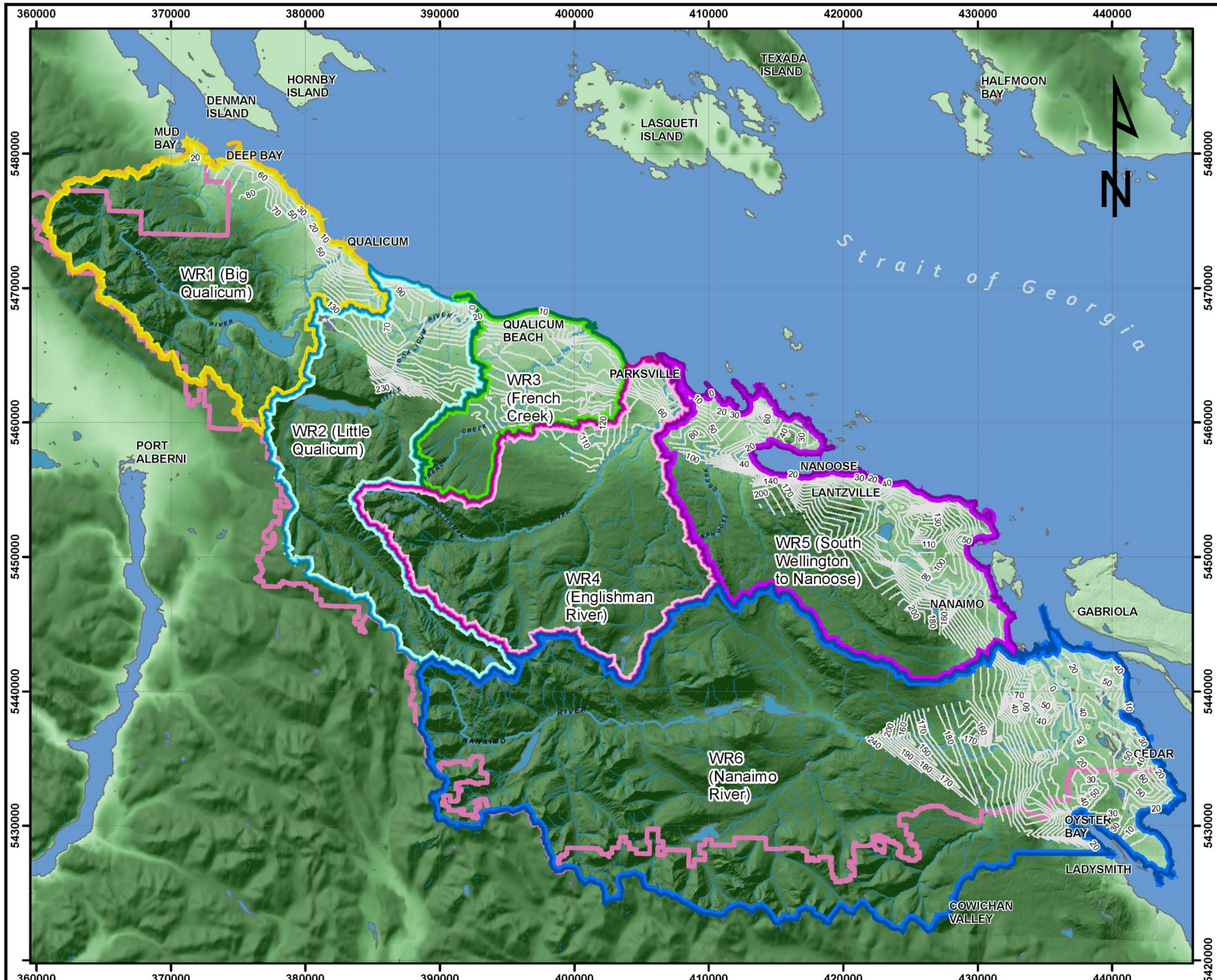
Map C6: Artesian Wells & Licensed Springs

BC MOE WELLS database was searched for flowing artesian wells, geo-referenced and plotted. The location of licensed springs was obtained from the Water Resource Atlas database. These data are useful in assessing aquifers which hare under artesian pressure and discharge zones within each water region.



Map C7: Overburden Thickness Contours

Overburden thickness mapping was completed by integrating surface topography data (Map C1), borehole data (C5), GSC seismic data, and bedrock outcrop data (C4). The data was compiled and refined within Waterline's Geodatabase system and contoured in ARC GIS. The GSC Seismic lines define the area of the GSC's Nanaimo Lowland study.



Legend

- RDN Boundary
- Ocean
- Lakes
- River; Creek
- Piezometric Surface Contours (Wells from 0-25m deep) 10m Intervals

Water Region

- Big Qualicum (WR1)
- Little Qualicum (WR2)
- French Creek (WR3)
- Englishman River (WR4)
- South Wellington to Nanoose (WR5)
- Nanaimo River (WR6)

Source: Andre Pugin, 2011, Natural Resources Canada GSC Seismic, Geological Survey of Canada., Muller, J. E. and J. A. Jeletzky, 1970, Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia

Reference: Y:\Data\1924-11-BC_RDN\Maps\MXD_RDN_May\AppendixC\C8_RDN_PiezSurf25.mxd

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

TITLE
Piezometric Surface Contours (Wells from 0-25m deep)

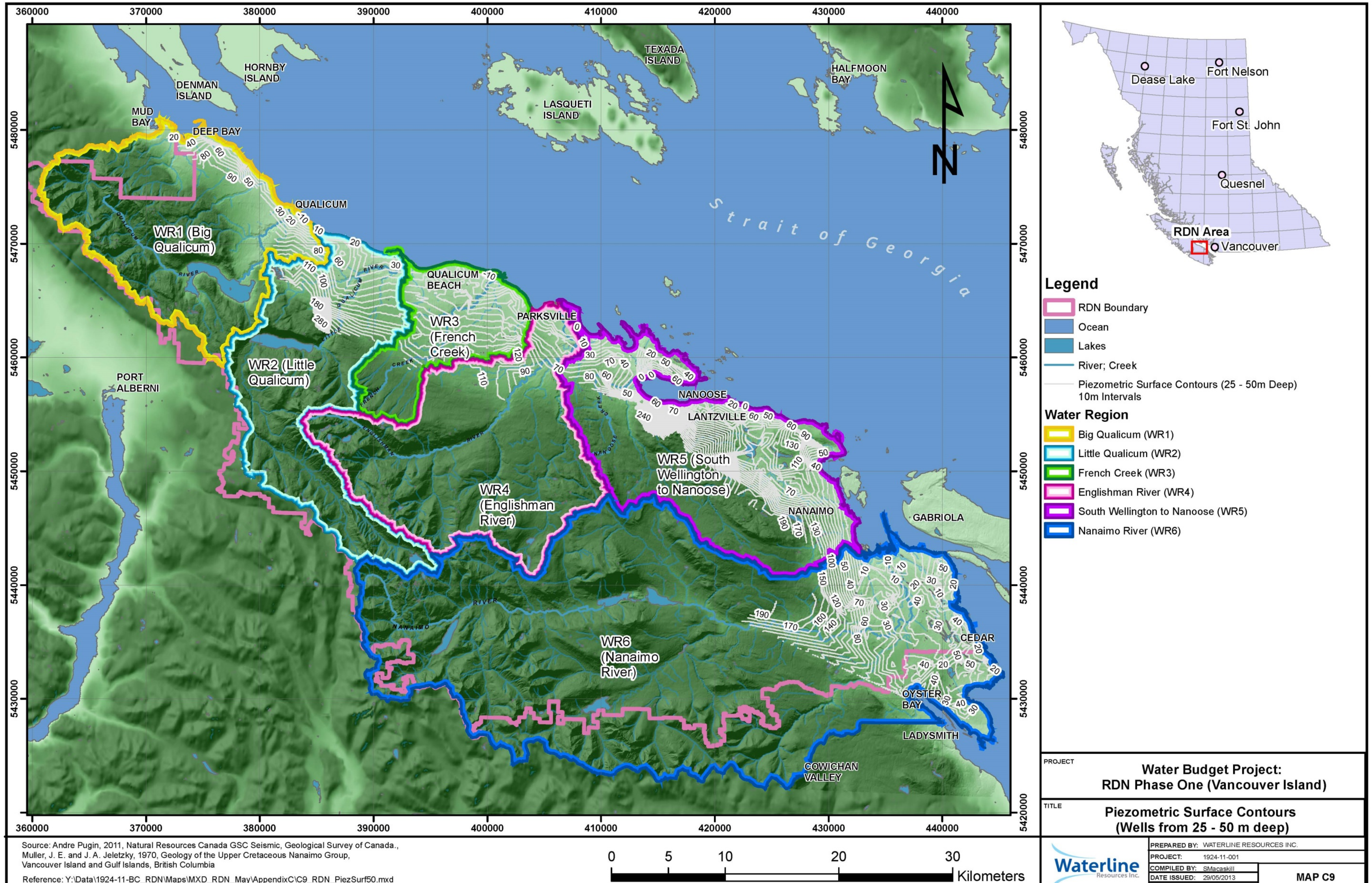
Waterline Resources Inc.

PREPARED BY:	WATERLINE RESOURCES INC.
PROJECT:	1924-11-001
COMPILED BY:	SMacaskill
DATE ISSUED:	29/05/2013
DATE REVISED:	

MAP C8

Map C8: Piezometric Surface Contours (Wells from 0-25 M Deep)

A piezometric surface contour map was developed using a sorting routine in the Waterline Geodatabase to identify all the wells completed between 0-25 m below ground. The measured water level at the time of drilling was then used to produce the contour map shown as Map C8 in order to get a general sense of the shallow groundwater flow direction. Ideally, current water level data from similar hydrostratigraphic zones should be used for this analysis. However, no current water level data is available in one database and would have been difficult to reconcile existing data to MOE well ID for inclusion in this analysis. It should be noted that at the regional scale of the Phase 1 water budget assessment this analysis provides a rough indication of the direction of shallow groundwater and hydraulic gradient which are required for aquifer water budget estimates. The data indicates that all shallow groundwater essentially mimic topography and flows to the ocean which is expected. Hydraulic gradient estimates taken from the 0-25 m deep contours were applied to water budget estimates for shallow aquifers (Capilano, Kame Deltas, Salish, and where appropriate Quadra and bedrock aquifers). A typical calculation is shown below in Appendix D.



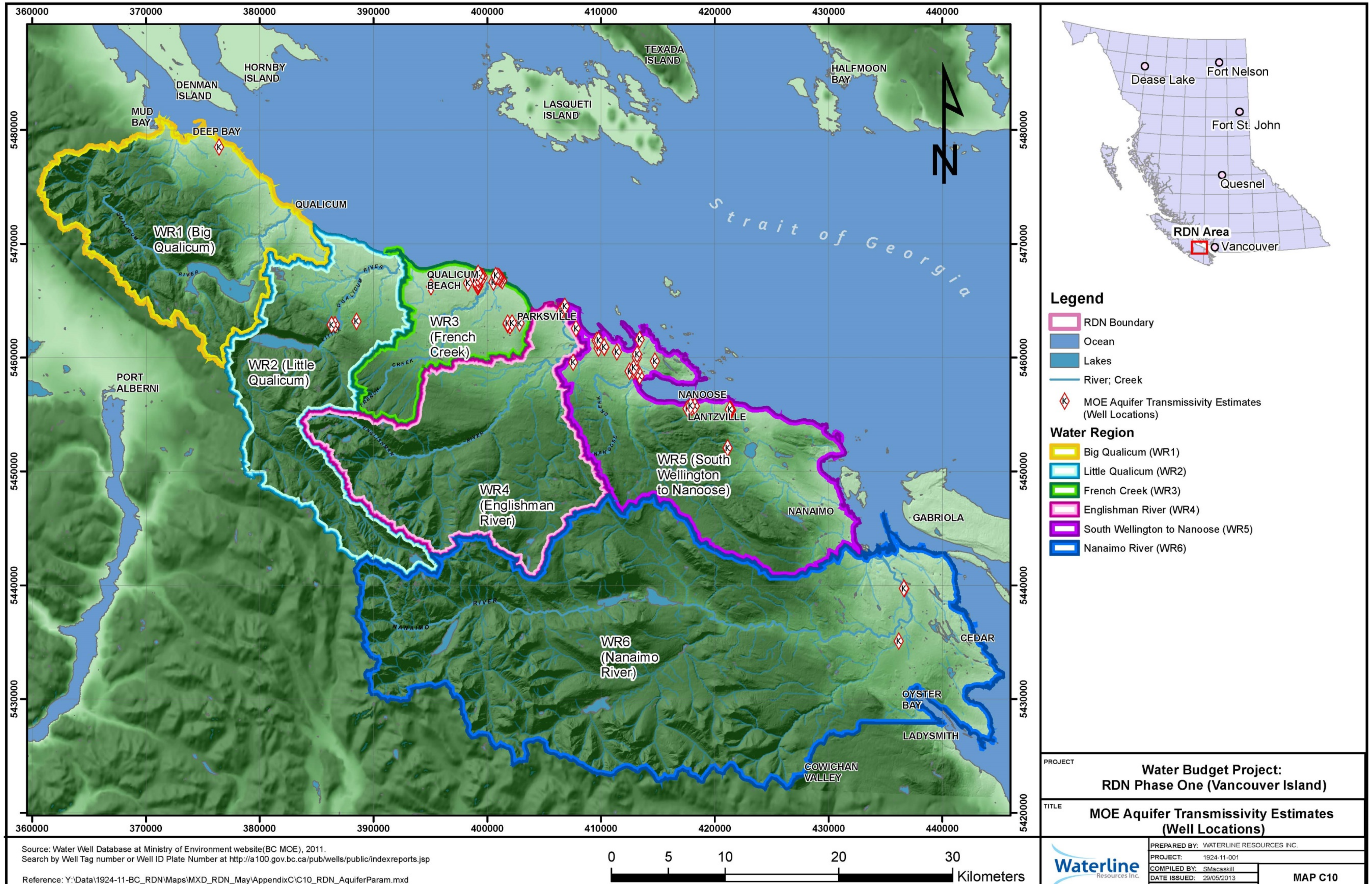
Map C9: Piezometric Surface Contours (Wells from 25-50 M Deep)

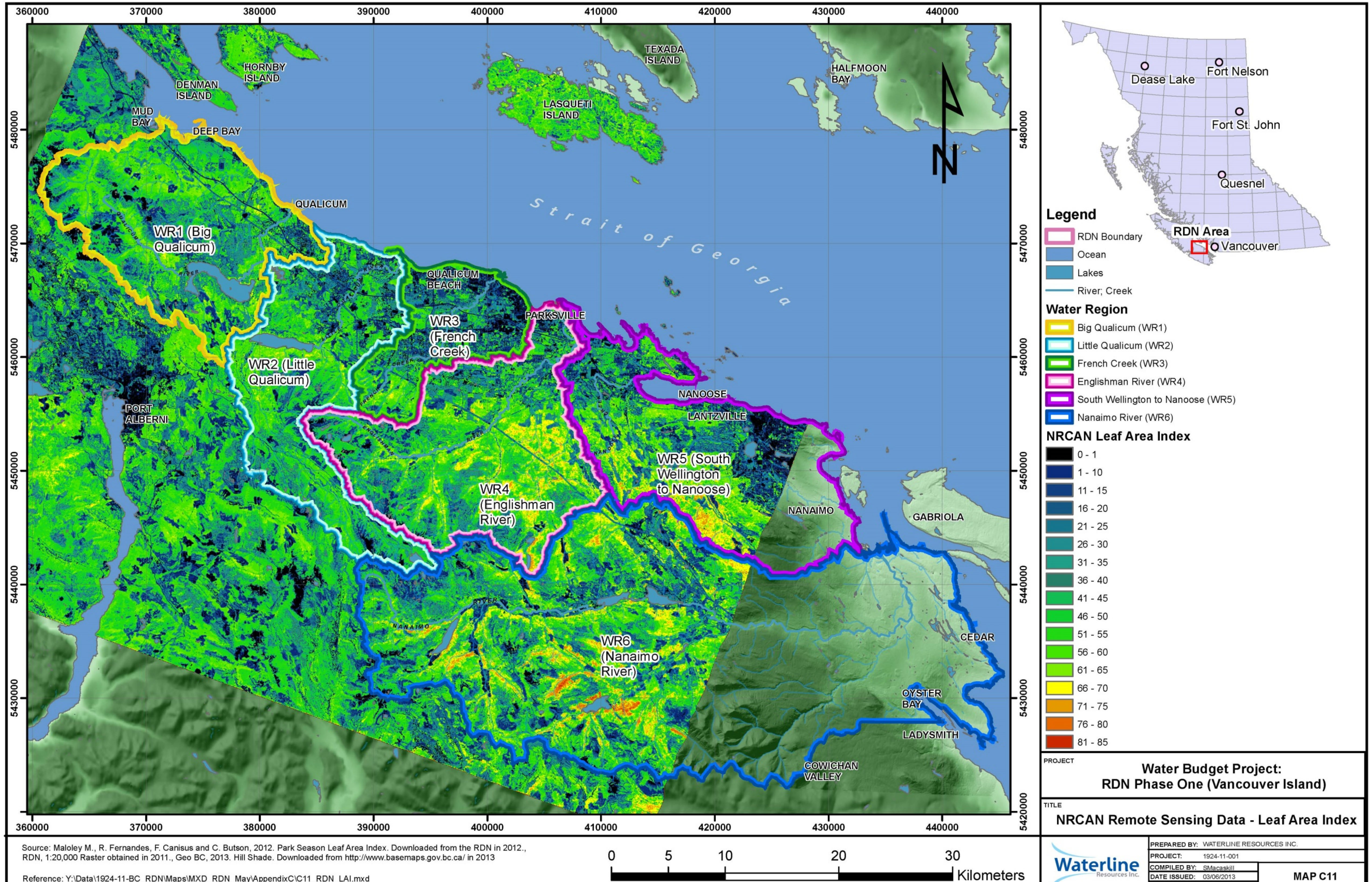
A piezometric surface contour map was developed using a sorting routine in the Waterline Geodatabase to identify all the wells completed between 25-50 m below ground. The measured water level at the time of drilling was then used to produce the contour map shown as Map C8 in order to get a general sense of the shallow groundwater flow direction. Ideally, current water level data from similar hydrostratigraphic zones should be used for this analysis. Hydraulic gradient estimates taken from the 25-50 m deep contours were applied to water budget estimates for deep aquifers across the RDN (Quadra, Vashon, and bedrock aquifers). A typical calculation is shown below in Appendix D.

Map C10: MOE Aquifer Transmissivity Estimates (Well Locations)

Fundamental parameters that allow and assessment of groundwater permeability of an aquifer (transmissivity, hydraulic conductivity) or storage properties (storativity, specific yield) are needed to complete aquifer water budgets.

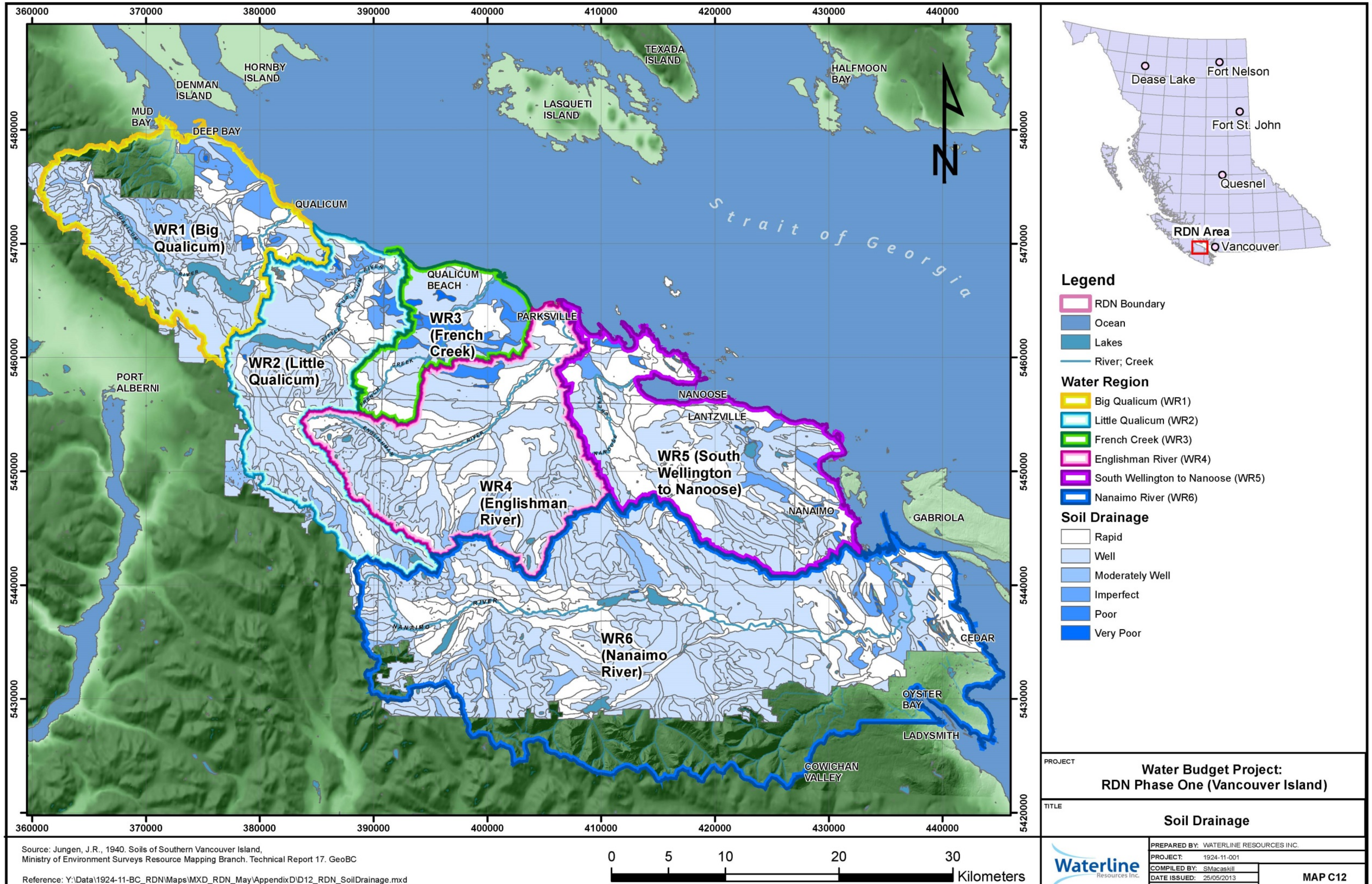
BC MOE undertook to evaluate over 100 historical pumping tests across the RDN which are shown plotted on the image below. This data were critical to the completion of the Phase 1 Water Budget project. Appendix D explains how this quantitative data was compiled with well yield data from preliminary tests completed at the time of drilling to assign aquifer transmissivity values to all 28 mapped aquifers in the RDN.





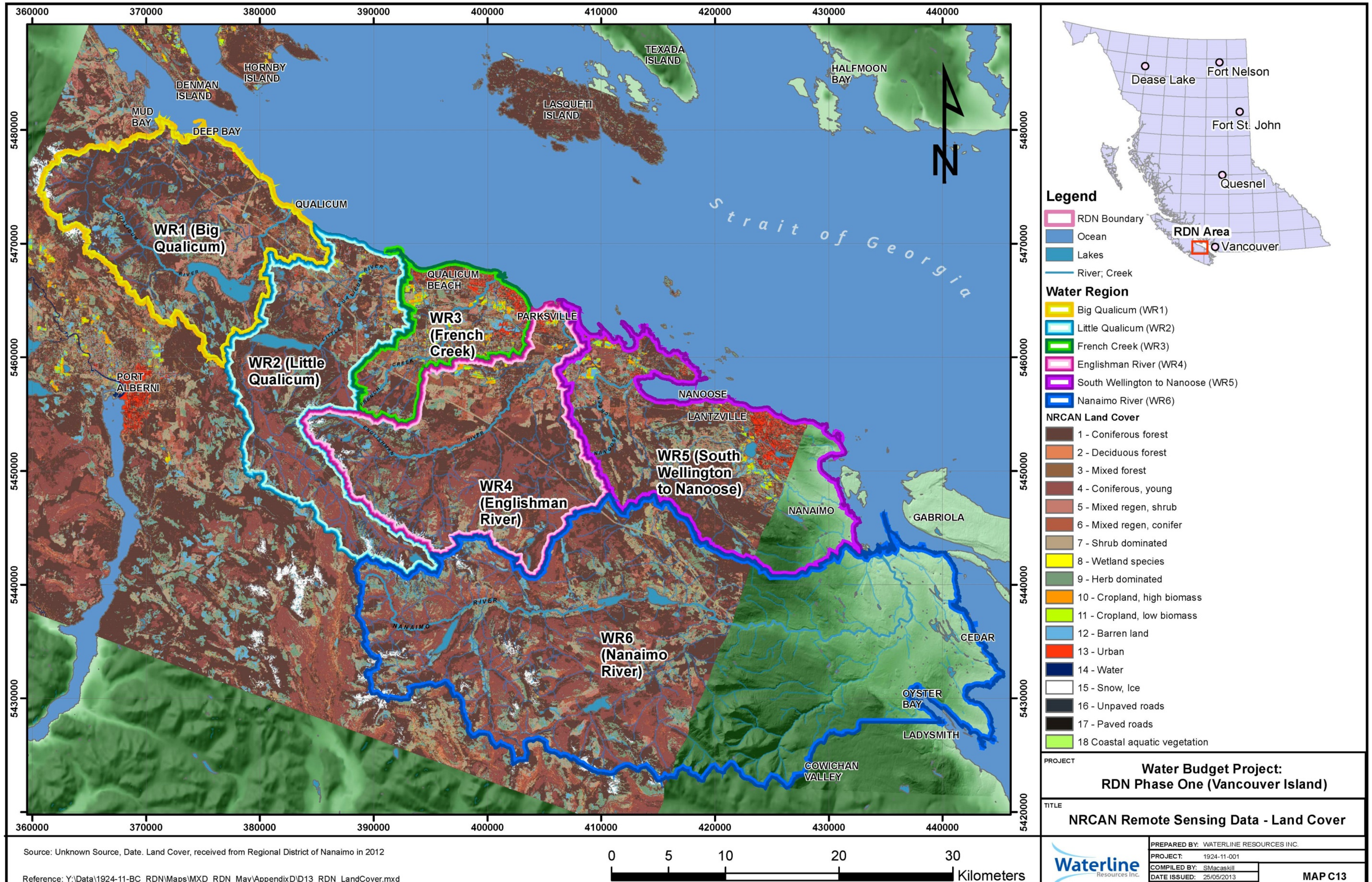
Map C11: NRCAN Remote Sensing Data – Leaf Area Index

Leaf Area Index (LAI) data collected by NRCAN as part of a regional remote sensing program was reprocessed by Waterline and KWL so that it could be used to adjust estimates of snow accumulation and melt over the RDN. Grid cells with area weighted average LAI of greater than 50% LAI where considered to be forested while grid cells having area weighted average LAI of less than 50% were considered to be open. Forested areas where were assumed to have melt rates approximately half of forested areas. This ratio is based on information provided in the Compendium of Forest Hydrology (Winkler, 2010) and discussions with W. Floyd (Floyd, 2012). For additional details on how snowmelt accumulation and melt has been calculated please refer to Appendix D.



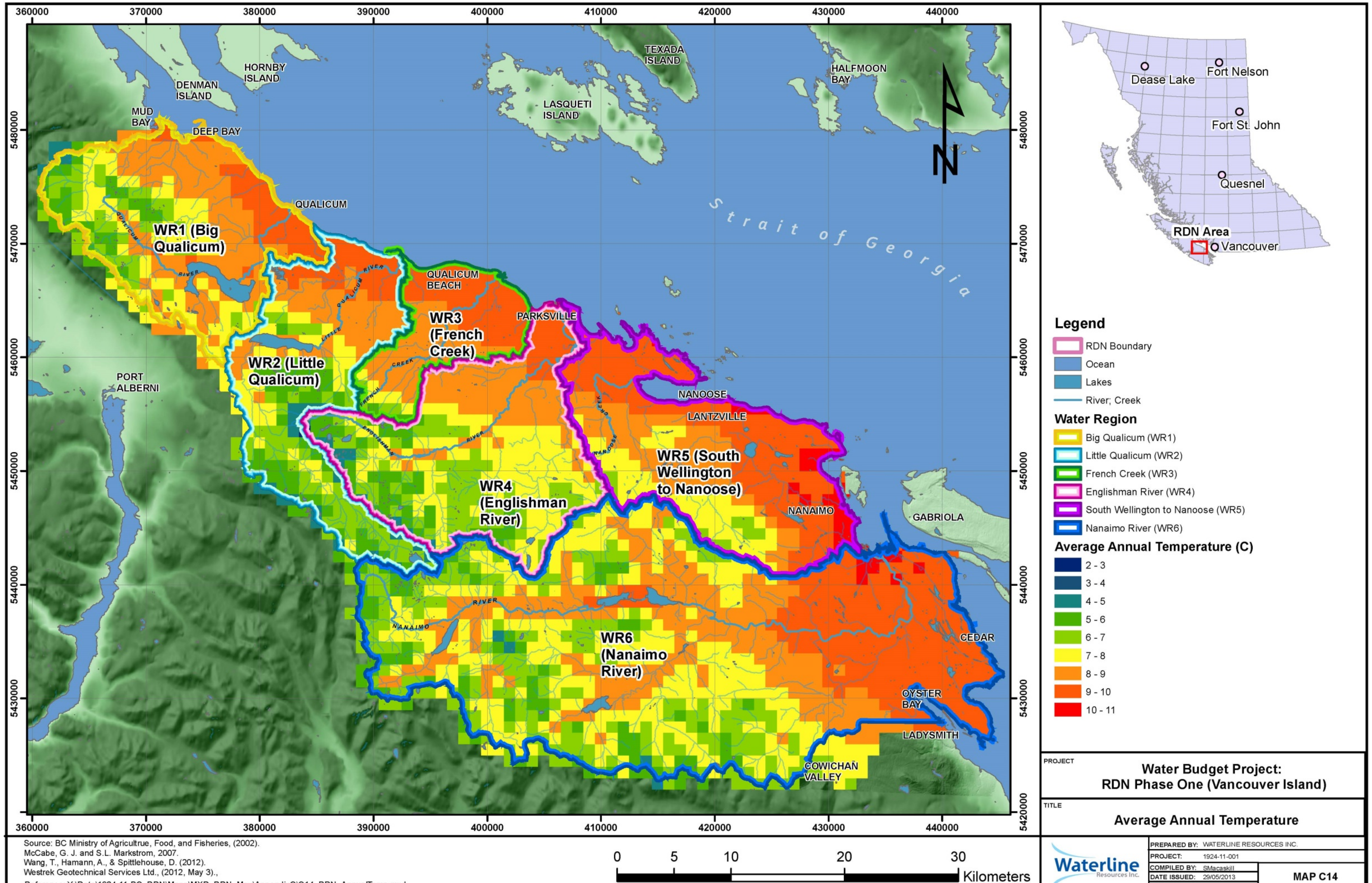
Map C12: Soil Drainage

Waterline reprocessed the government soils map data (Map C2) and assigned drainage values to defined soil polygons. This information was then input into the surface water model by Kerr Wood Leidal and gridded infiltration values assigned across the RDN (Maps C19, and C20). This data, along with LAI (Map C11), and land cover data (Map C13) allowed for the surface water model to calculate infiltration rates over a 1x1 Km grid pattern (Maps C19, and C20).



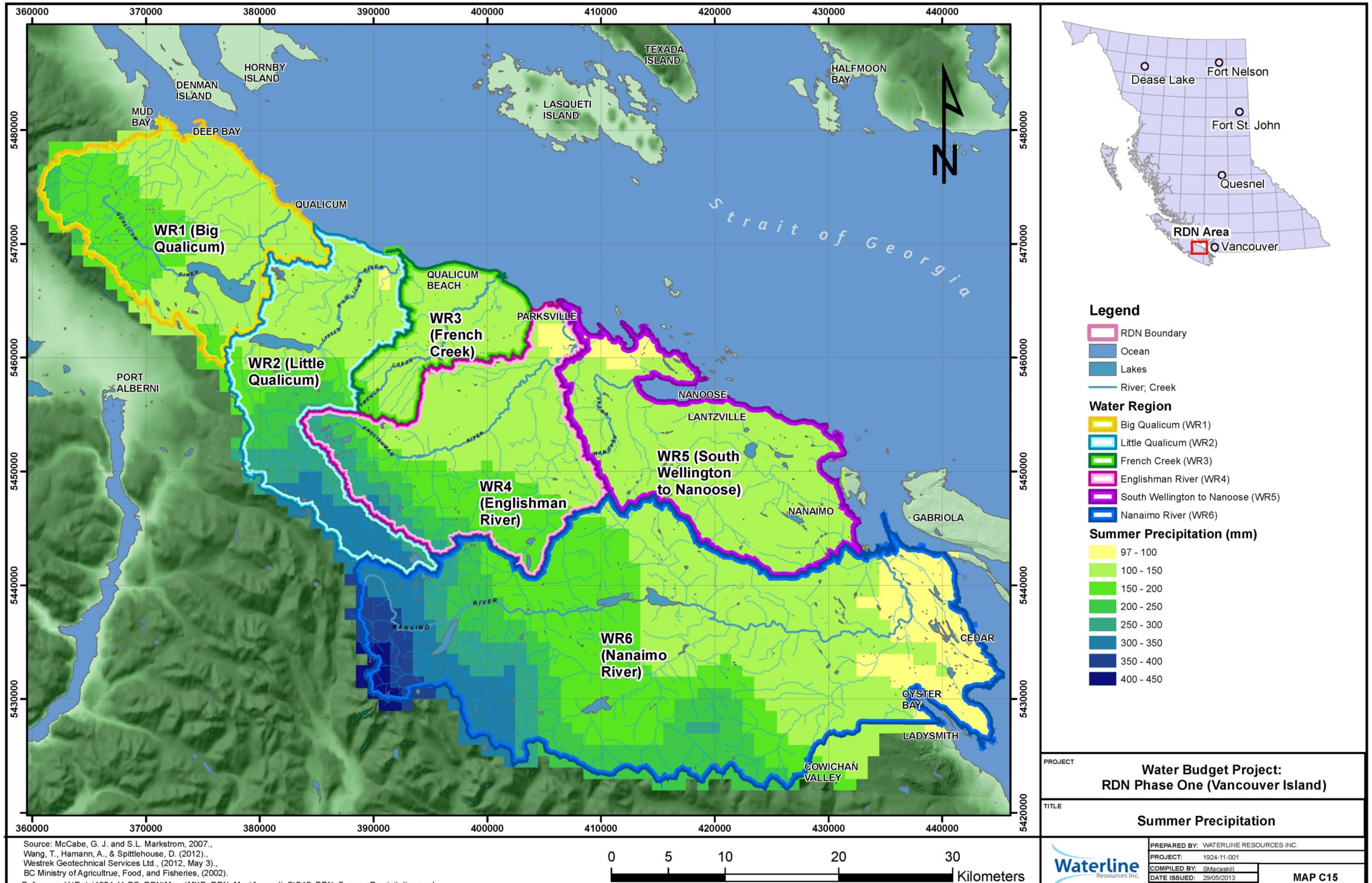
Map C13: NRCAN Remote Sensing Data – Land Cover

Land cover data collected by NRCAN as part of a regional remote sensing program was reprocessed by Waterline so that it could be used to adjust base potential evapotranspiration estimates calculated using the Hamon Equation to account for variation in land cover. The PET adjustment parameters for each 1 km^2 grid cell are based on the area weighted average of each land cover type within the grid cell. These have then been used to calculate PET and actual evapotranspiration within the regional surface water balance model. Further details of the model are described in Appendix D.



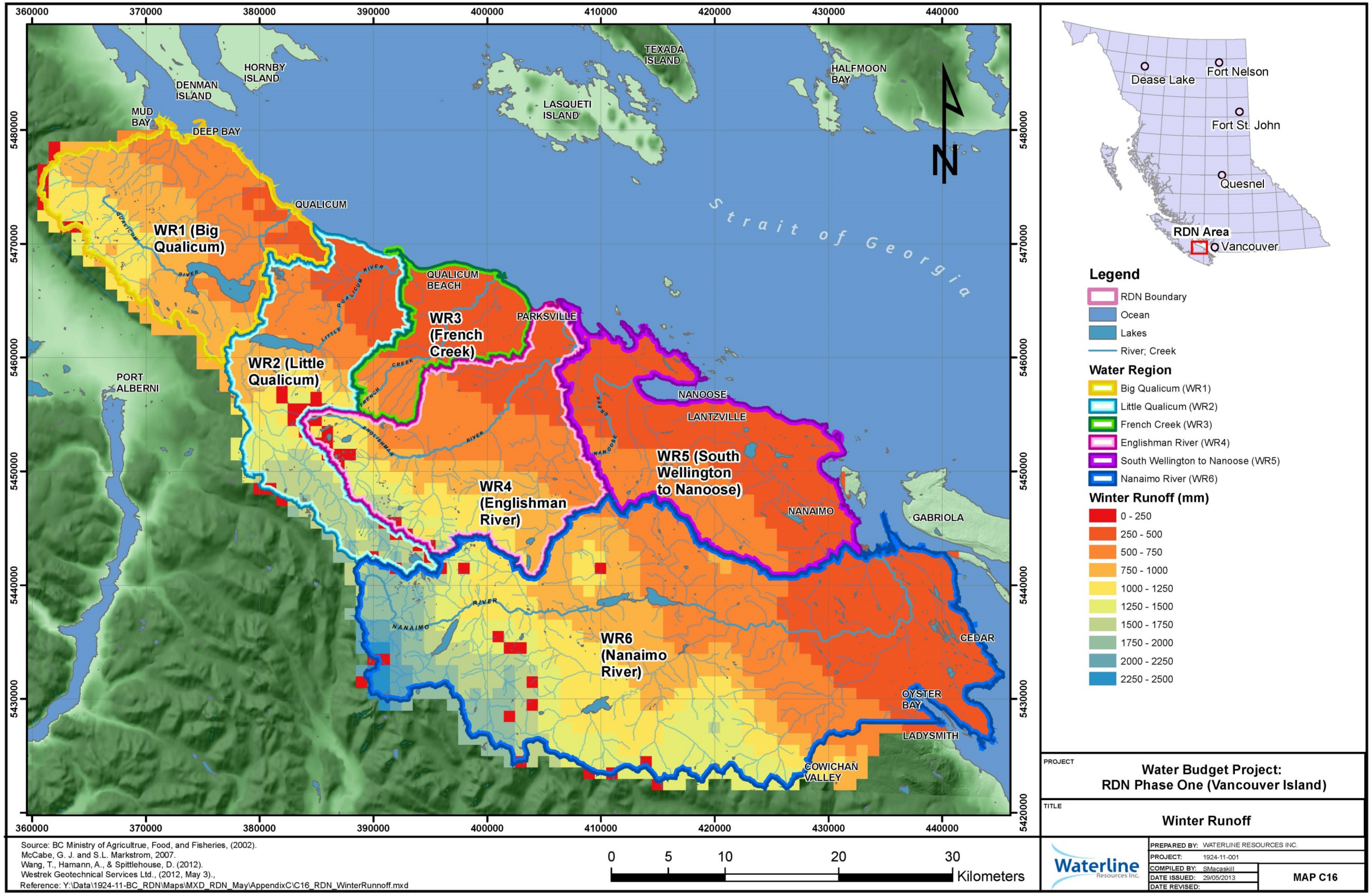
Map C14: Ave. Annual Temperature

Monthly average temperature data for the 1971 to 2000 climate normal period have been extracted from the Climate Western North America model (Climate WNA) (Wang et. al., 2012) at 1 sq. km. grid spacing. The Climate NWA model uses temperature and precipitation lapse rates to downscale the Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate data set (Daly et. al. 2002). PRISM is a unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. The model incorporates point data, a digital elevation model, and expert knowledge of complex climatic extremes, including rain shadows, coastal effects, and temperature inversions. Monthly data has been used in the analysis but average annual temperature data is shown in Map C-14 for clarity.



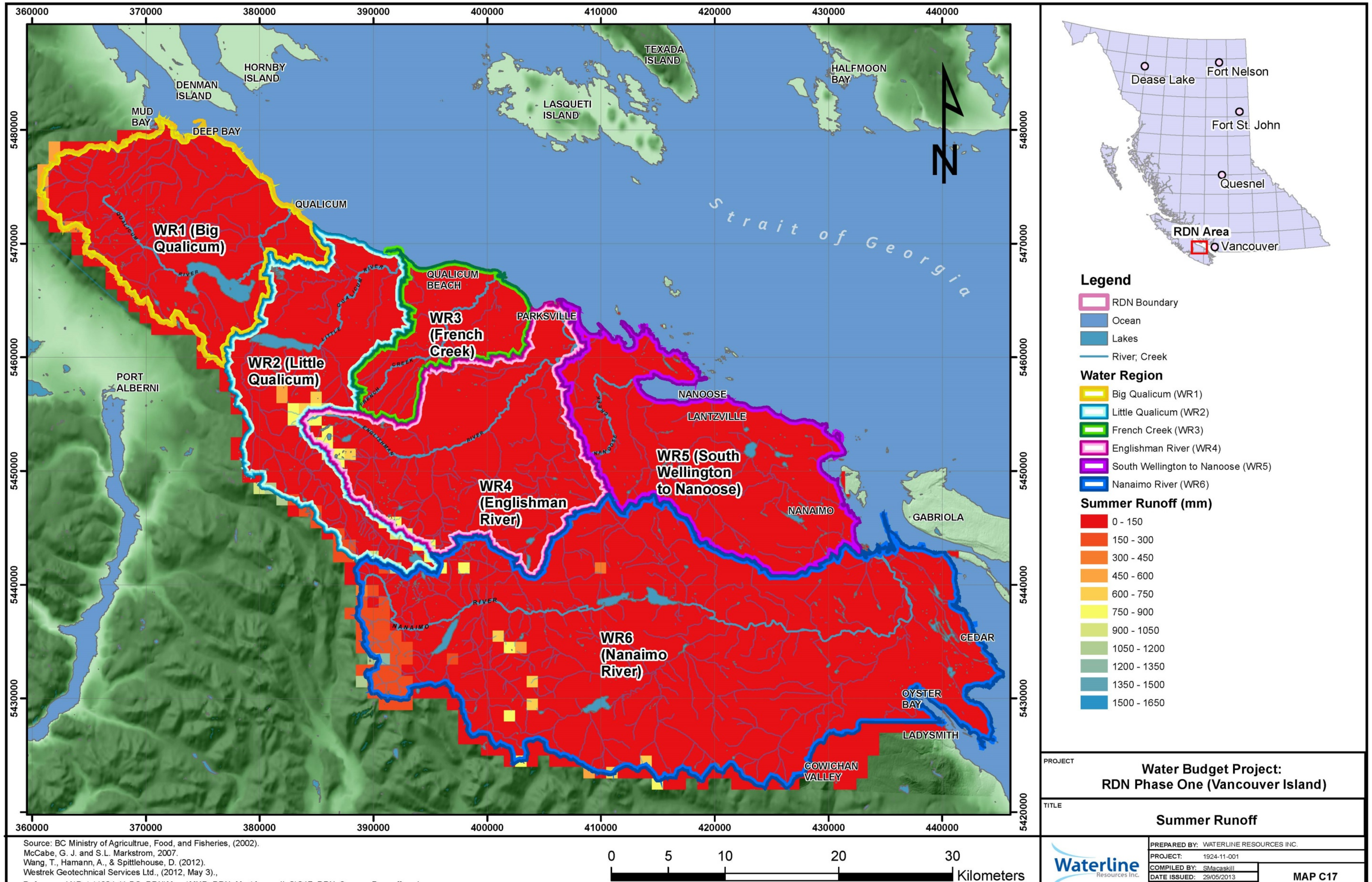
Map C15: Summer Precipitation

Monthly average precipitation data for the 1971 to 2000 climate normal period have been extracted from the Climate Western North America model (Climate WNA) (Wang et. al., 2012) at 1 sq. km. grid spacing. The Climate NWA model uses temperature and precipitation lapse rates to downscale the Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate data set (Daly et. al. 2002). PRISM is a unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. The model incorporates point data, a digital elevation model, and expert knowledge of complex climatic extremes, including rain shadows, coastal effects, and temperature inversions. Monthly data has been used in the analysis but summer and winter average precipitation plots are included in Map C-15 and Map C-16 for clarity.



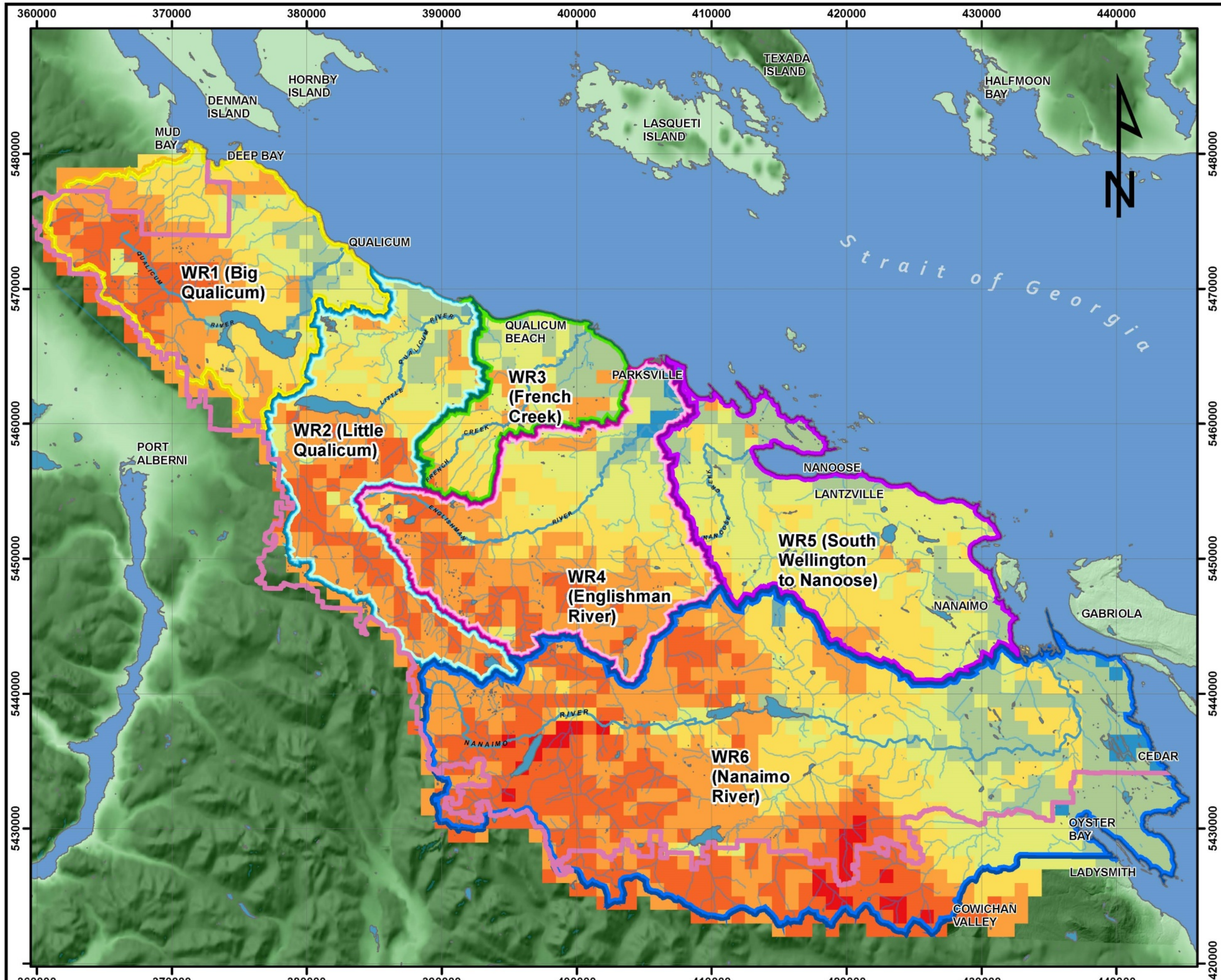
Map C16: Winter Runoff

Gridded Runoff (discharge per unit watershed area) has been calculated using the gridded Climate WNA temperature and precipitation (Maps C14 to C17) and the adapted USGS Monthly Water Balance model (McCabe and Markstrom, 2007). The USGS water balance model converts precipitation into surface water runoff and ground water recharge by accounting for how water is collected in storage including snow storage, soil moisture storage, surface storage (lakes and reservoirs) and ground water storage as well as the flux into and out of these storage areas including evapotranspiration, snow melt, infiltration, ground water recharge and surface water runoff. A more detailed outline of the model is included in Appendix D. Monthly estimates of runoff have been calculated but winter and summer runoff is included in Maps C16 and C 17 for clarity.



Map C17: Summer Runoff

See map C16 for description.



Legend

- RDN Boundary
- Ocean
- Lakes
- River; Creek

Water Region

- Big Qualicum (WR1)
- Little Qualicum (WR2)
- French Creek (WR3)
- Englishman River (WR4)
- South Wellington to Nanoose (WR5)
- Nanaimo River (WR6)

Summer Evapotranspiration (mm)

- 90 - 100
- 100 - 125
- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275

0 5 10 20 30 Kilometers

Source: BC Ministry of Agricultrue, Food, and Fisheries, (2002).
McCabe, G. J. and S.L. Markstrom, 2007.
Wang, T., Hamann, A., & Spittlehouse, D. (2012).
Westrek Geotechnical Services Ltd., (2012, May 3).,
Reference: Y:\Data\1924-11-BC_RDN\Maps\MXD_RDN_May\AppendixC\C18_RDN_SummerEvap.mxd

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

TITLE
Summer Evapotranspiration

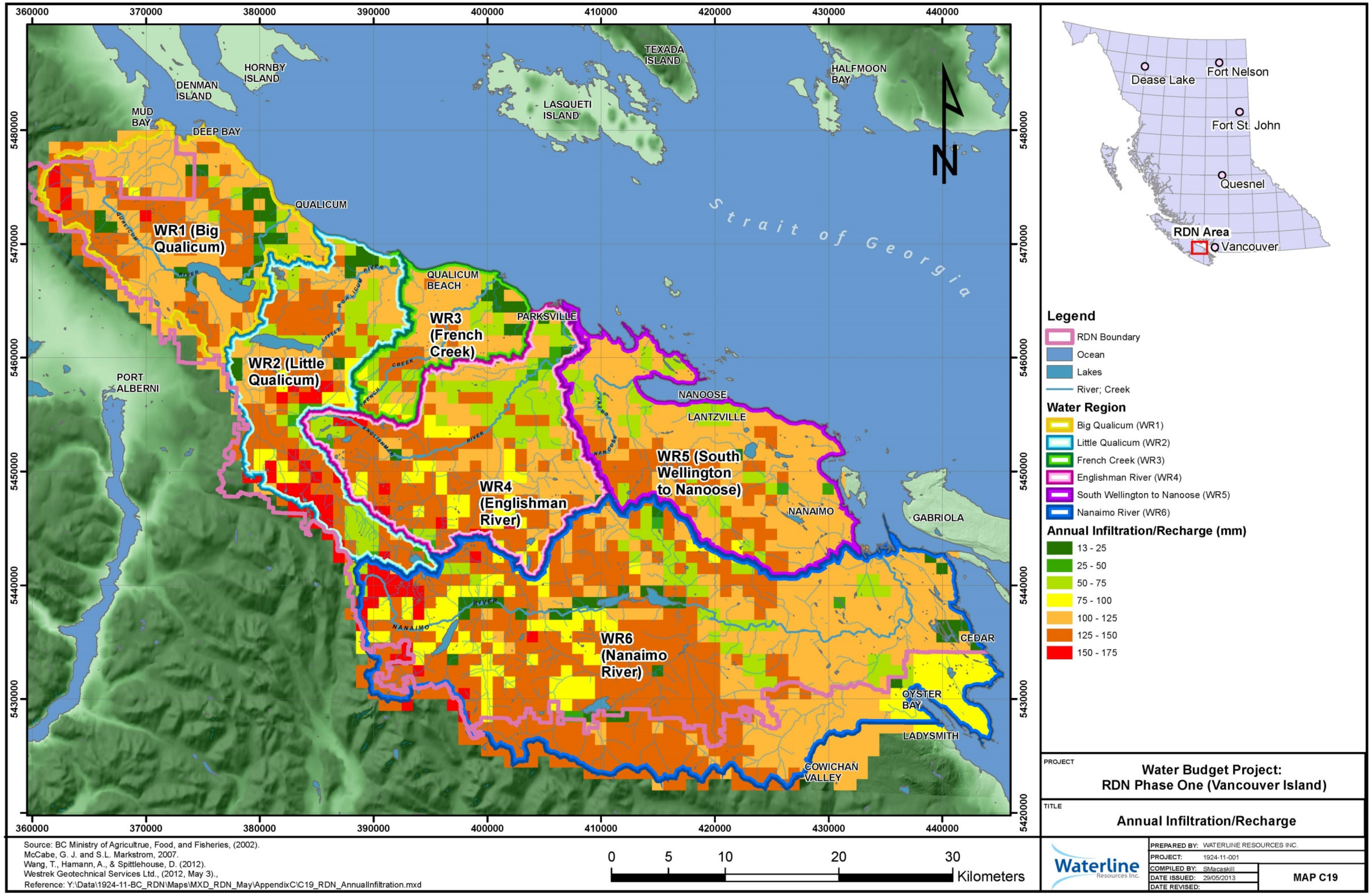
Waterline Resources Inc.

PREPARED BY: WATERLINE RESOURCES INC.
PROJECT: 1924-11-001
COMPILED BY: SMacaskill
DATE ISSUED: 29/05/2013
DATE REVISED:

MAP C18

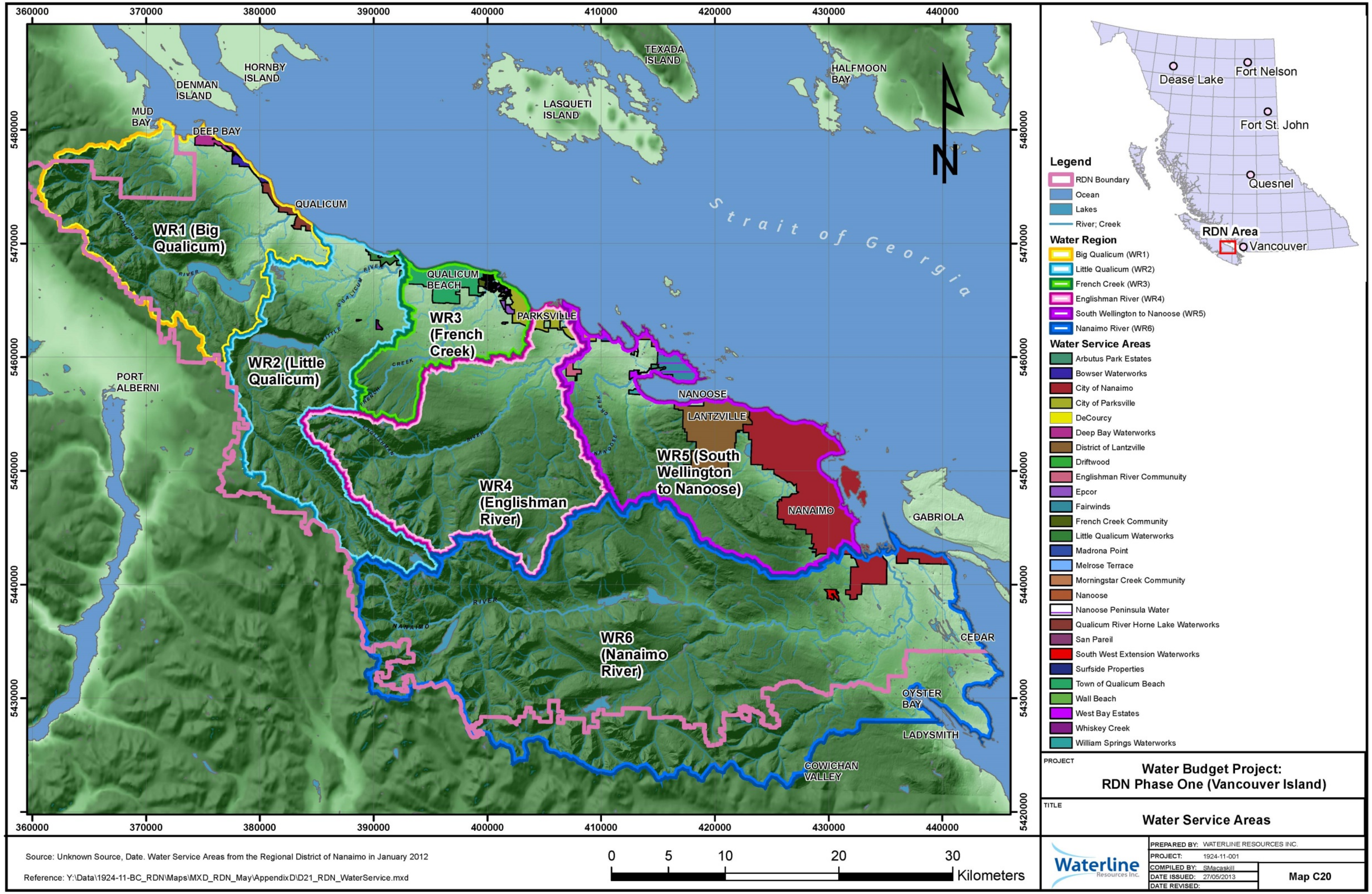
Map C18: Summer Avapro-transpiration

See map C13 for description.



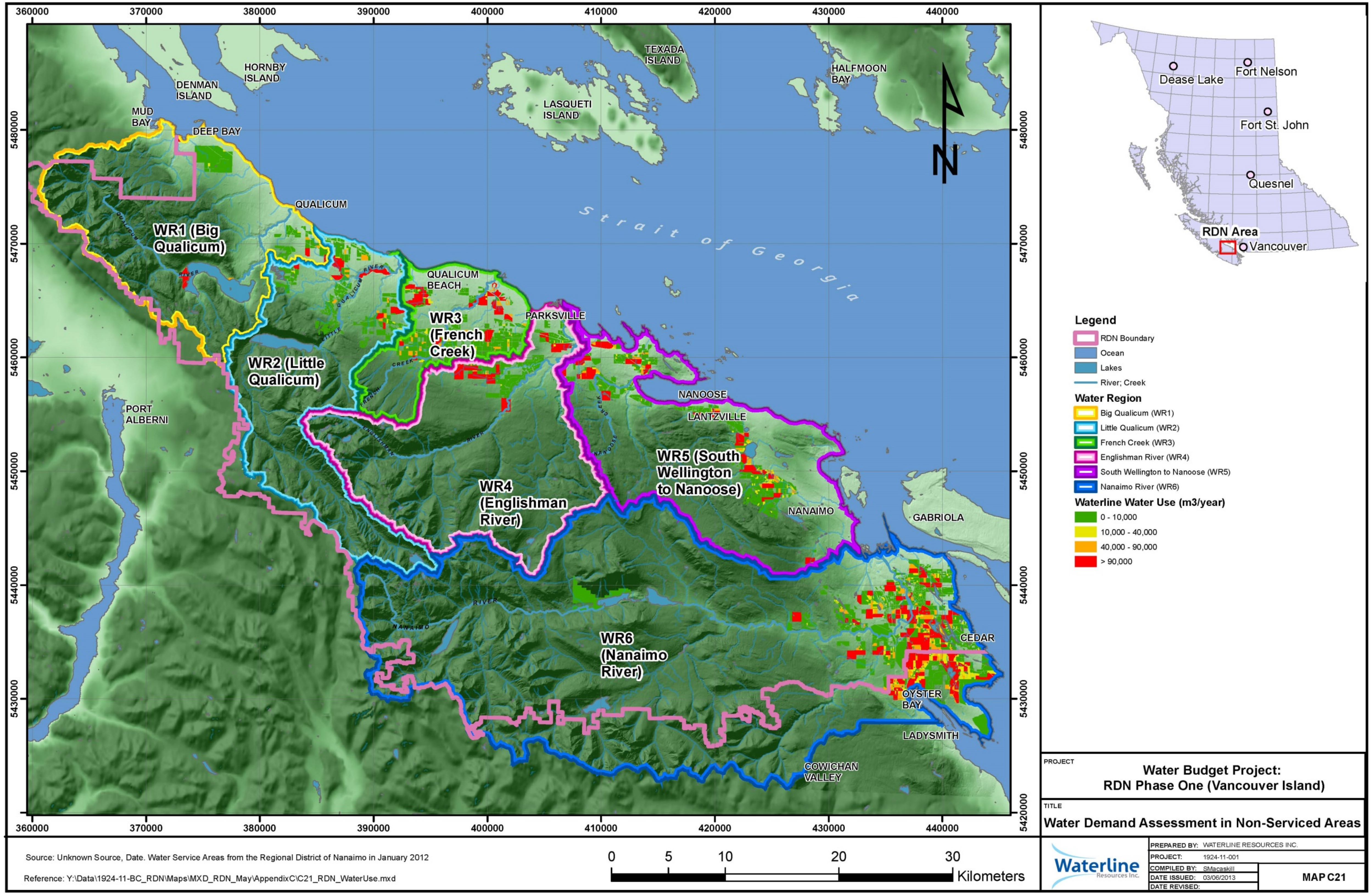
Map C19: Annual Infiltration/Recharge

Gridded Recharge (ground water recharge per unit watershed area) has been calculated using the gridded Climate WNA temperature and precipitation (Maps C14 to C17) and the adapted USGS Monthly Water Balance model (McCabe and Markstrom, 2007). The USGS water balance model converts precipitation into surface water runoff and ground water recharge by accounting for how water is collected in storage including snow storage, soil moisture storage, surface storage (lakes and reservoirs) and ground water storage as well as the flux into and out of these storage areas including evapotranspiration, snow melt, infiltration, ground water recharge and surface water runoff. A more detailed outline of the model is included in Appendix D. Monthly estimates of recharge runoff have been calculated but total annual recharge is shown on Map C20 for clarity.



Map C20: Water Service Areas

Data provided by RDN.



Map C21: Water Demand Assessment in Non-Service Areas

The RDN provided parcel water use data from metered RDN and municipal water service areas. Waterline removed all forest and vacant land parcels from the data set as there is no water use in these area. We retained agricultural parcels & lots already approved for development which were, primarily residential, and the assigned agricultural water use values based on Ministry of agriculture recommended method. Waterline then cross-referenced against the 2011 air photos and civic addresses outside municipal service areas to confirm surface or groundwater use. In the analysis, Waterline assumed all water use in non-service areas get supply from wells which was verified on the Waterline Geodatabase using civic address, air photo, water wells, and license surface water points layers. A final calibration check was completed by aggregating parcel water use estimates within service areas against measured water use values.

APPENDIX D
METHODOLOGY FOR SURFACE WATER AND WATER BUDGET CALCULATIONS

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1.0 SURFACE WATER BUDGET CALCULATIONS

1.1 Water Budget Assessment and Assumptions

Water balance techniques have been extensively used to make quantitative estimates of water resources and the impact of various human activities on the hydrologic cycle within a defined water region or watershed. It is possible to evaluate quantitatively individual contribution of sources of water in the system, over different time periods, and to establish the degree of variation in the water regime due to changes in components of the system. The basic concept of water budget is that input to the system, minus outflow from the system is equal to change in storage of the system over a specified period of time.

The water budget assumes that a watershed is a closed system with only precipitation as input with evapotranspiration, surface water runoff and groundwater exfiltration as output. This assumes that groundwater table generally follows the surface topography such that groundwater flow into and out of the watershed is negligible. For those areas where aquifers are known to cross surface watershed boundaries, more detailed analysis has been carried out under the ground water balance section described in Section 2 below.

The monthly water balance assessment carried out also assumes that travel time for surface water flow is less than one month, except for surface water storage. In other words, all surface water runoff that is generated flows to the outlet of the watershed within one month. The only exception is surface water storage such as lakes or reservoirs which are accounted for separately in the water budget.

Finally, the surface water budget assumes that ground water and surface water storage can be assumed to act similar to a linear reservoir in which the outflow from the storage at time T+1 is a function of the amount of water in storage at time T. The linear reservoir parameters for surface water and ground water are developed through calibration of the model to recorded values. Once general ground water balance (i.e.: ground water recharge and outflow) is established in the surface water model. The values have been used to refine the estimates in the ground water budget described in Section 2.

1.2 USGS Monthly Water Balance Model

The surface water supply for the Regional District of Nanaimo was assessed using the US Geological Survey (USGS) monthly water balance model (McCabe and Markstrom, 2007). The model is a GIS-based distributed conceptual model which calculates surface runoff (surface flow per unit watershed area), unit groundwater recharge for each one square kilometer grid cell in the watershed. Runoff and ground recharge are calculated by using climate variables (precipitation and temperature), soil characteristics and land cover. The model calculates runoff and ground water recharge for each square kilometer grid in the watershed, which is then used to estimate total runoff from watersheds using flow accumulation routine in GIS.

1.3 Model Overview

The USGS Model is a water balance accounting model which calculates how water moves between various storage components, such as snowpack storage, soil moisture and groundwater, and how much water is lost to atmosphere through evapotranspiration, surface water runoff or groundwater recharge. The model runs on a monthly time scale using monthly average climate data.

The model accounts for snow accumulation and melt using precipitation and temperature climate data, evaporation and soil moisture using a Thorntwaite based approach to estimate potential evapotranspiration (PET) and actual evapotranspiration (ET), and ground water recharge through soil moisture estimates and soil infiltration estimates based on soil types (Thorntwaite, 1948).

A schematic of the model algorithm is shown in Figure 1. More detailed description of these various components is outlined below.

1.3.1 Climate

The monthly climate data (temperature and precipitation) used in the model is based on output from the Climate BC model developed by the UBC Faculty of Forestry (Wang, et. al., 2006). The model down scales climate variables (temperature, precipitation, etc.) from larger scale data sources such as; historical climate data from the PRISM data set as well as forecast future climate from Global Circulation Models (GCMs) or Regional Climate Models (RCMs). Climate BC model uses temperature and precipitation lapse rates (rate of change of climate with elevation) to adjust the larger scale data to take account of topography not captured in the larger grid sizes of the larger scale datasets. For the RDN study, the watersheds have been divided into one square kilometer grid cells. For each grid cell, the average elevation has been estimated using the 1:50,000 National Topographic Survey (NTS) digital elevation model. The latitude and longitude of the centroid of each grid cell and the average elevation have been used as input to the ClimateBC model to estimate average monthly temperature and precipitation data for each grid cell across the region. For the RDN study, only average monthly data for the 1971 to 2000 normal climate period have been used.

1.3.2 Snow Accumulation and Melt

Snow accumulation and melt is derived from monthly average precipitation and temperatures. The phase of precipitation as rain or snow is estimated by assuming when average temperature is less than -2oC then all precipitation falls as snow and when monthly average temperatures are greater than 2oC then all the monthly precipitation falls as rain. When monthly average temperatures fall between -2oC and 2oC then ratio of snow to rainfall during the month is assumed to be the percentage that the observed temperature of the range between -2oC and 2oC, such that:

$$P_{rain} = P\ (Tmonth – (-2oC) / 4oC)$$
$$P_{snow} = 1 – P\ (Tmonth – (-2oC) / 4oC)$$

Where P is the total monthly precipitation (rain and/or snow), P_{rain} is the total monthly rainfall and P_{snow} is the total monthly snowfall.

The temperature range was based on a review of temperature records to determine at what average temperature do daily temperature tend stay below zero for the entire month as well as model calibration with available snow pack data.
A melt rate function for snow was based on a standard rate . The melt rate was adjusted to account for open areas versus forested areas. Forested areas were assumed to have a melt rate approximately half of the forested areas (Floyd, 2012 and Winkler, 2010)

1.3.3 Vegetation/Land Cover Component and Potential Evapotranspiration

Land cover data was determined by using the Land cover data provided by the RDN. Land cover was classified into 18 unique categories as shown below. The land cover classifications are based on photo interpretation of SPOT Satellite imagery collected in 2011.

The land cover data was analyzed at each grid cell to determine a Potential Evapotranspiration (PET) factor which is used to adjust PET calculated using the Hamon Equation (Hamon, 1961) to account for variations in PET with land cover. PET factors were applied based on the knowledge that a heavily vegetated area will have a higher PET than open areas. A listing of the PET factors used for each of the land classes is shown in Table 2.

Water Balance Model Schematic:

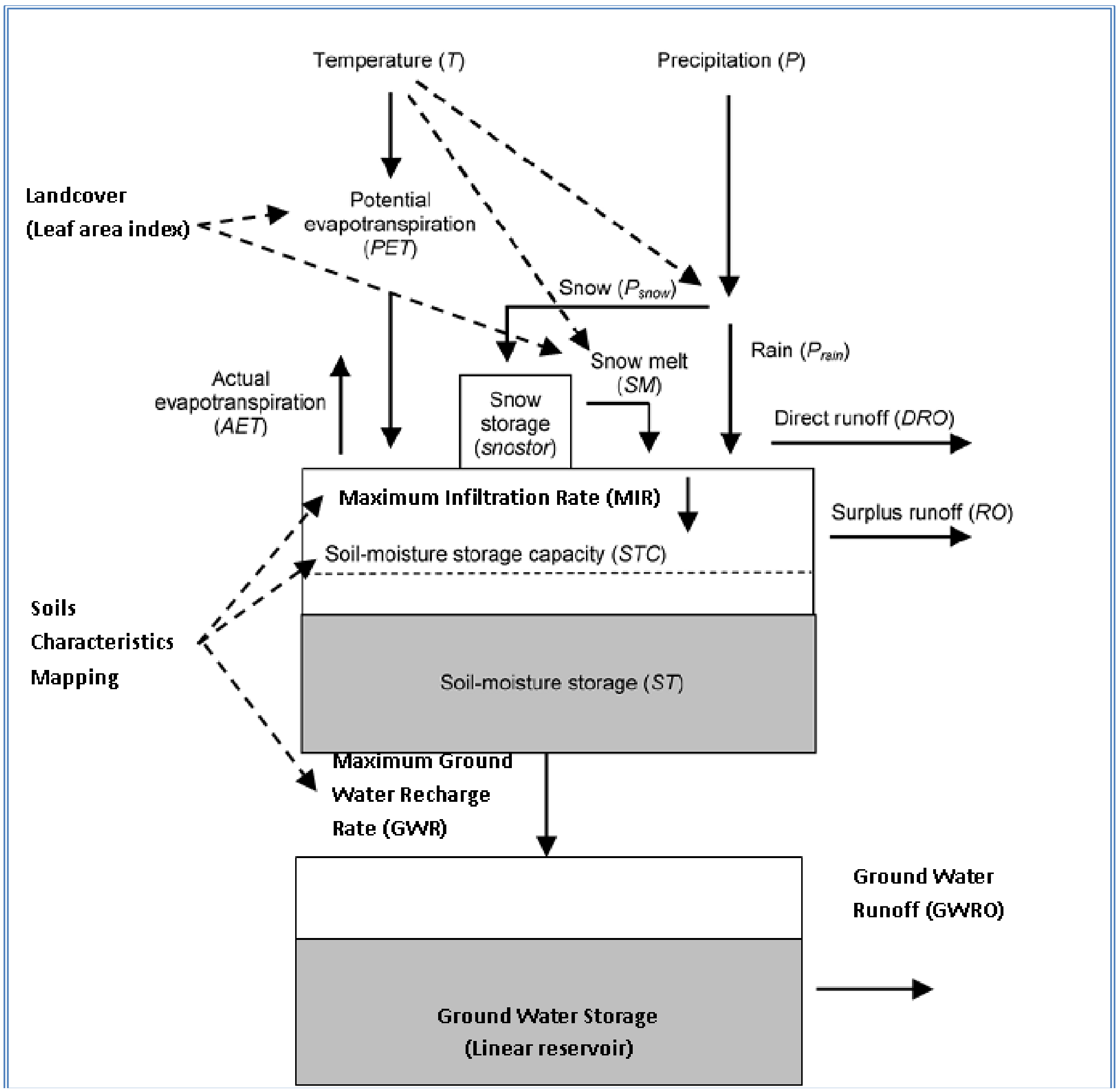
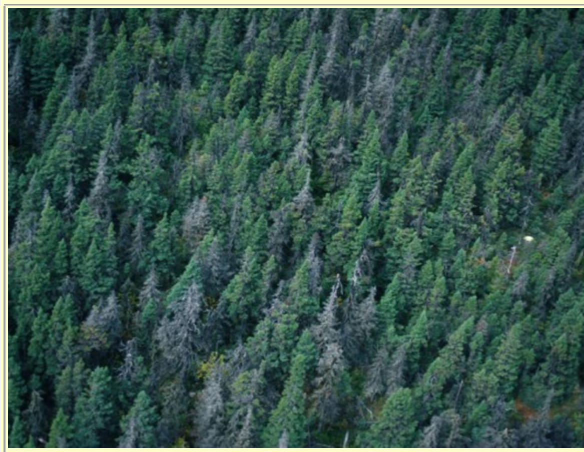
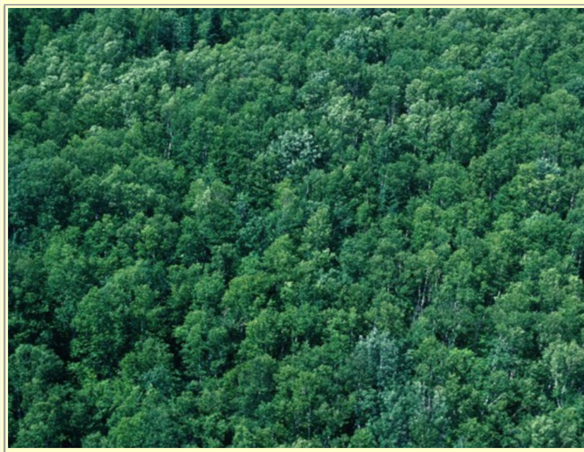
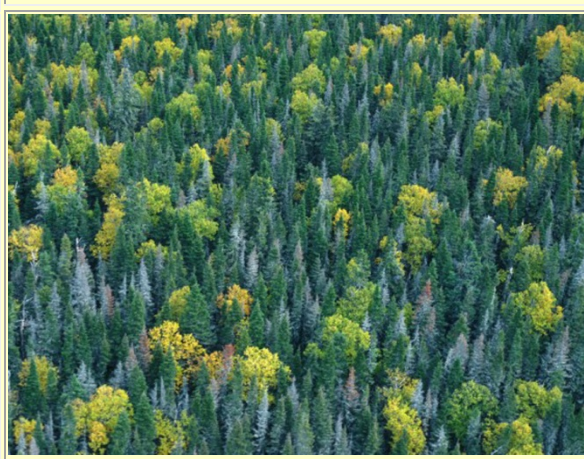


Table D1:Land Cover Map of Nanaimo Region, BC Descriptions of Land Cover Classes

TREE DOMINATED Land dominated by vegetation with a tree (woody plants with a height exceeding approximately 5 metres in most cases) crown density (percentage of the surface covered by projected tree crown perimeters) greater than 25%.	
	**(1) Coniferous (210 conifer forest)** Predominantly coniferous forests or treed areas. Dense forest with structural variability and gap dynamics.
	**(2) Deciduous (220 deciduous forest)** Predominantly broadleaf/deciduous forests or treed areas. Moderate to dense predominately deciduous forest.
	**(3) Mixed (230 mixed forest)** Mixed coniferous and broadleaf/deciduous forests or treed areas. Moderate to dense mixed forest.

	**(4) Coniferous recent disturbance origin ~last 50 years (210 conifer forest)** More dense canopies with reduced vertical structural variability compared to Coniferous (1) of disturbance origin within the last 50 years.
	**(5) Mixed Regeneration Shrub Dominated (50 shrubland)** Regeneration from disturbance typically after tree planting creating a mixed forest condition, generally dominated by shrub.
	**(6) Mixed Regeneration Conifer Dominated (230 mixed forest)** Older regeneration from disturbance, where conifer trees have become greater than 2 m tall and more dominate coverage.
SHRUBLAND Land dominated by vegetation with a shrub (perennial woody plants that branches at ground level from several stems) cover generally greater than 0.5 m in height with individuals or clumps not touching together.	

(7) Shrub (50 shrubland)

Predominantly woody vegetation of relatively low height (generally ±2 meters). Comments: May include grass or grassland wetlands with woody vegetation, regenerating forest.

HERB DOMINATED

Land dominated by plants without woody stems, including grasses, forbs and ferns.

(8) Wetland (80 wetland)

Land with a water table near/at/above soil surface for enough time to promote wetland or aquatic processes (semi-permanent or permanent wetland vegetation, including fens, bogs, swamps, sloughs, marshes, etc.). Comments: This class is mapped based on cover properties corresponding with image date(s) conditions.

(9) Low Vegetation (100 herb)

Grass and other low lying herbaceous covers.

	**(10) Cropland high biomass (120 cultivated cropland)** Agricultural land with cultivated crops.
	**(11) Cropland low biomass (120 cultivated cropland)** Agriculture land where crops have not be cultivated, typical pasture and fallow post harvesting.
NONVASCULAR DOMINATED Barren land.	
	**(12) Barren (33 exposed land)** Predominately non-vegetated and non-developed. Includes: exposed lands, snow, glacier, rock, sediments, burned areas, rubble, mines, other naturally occurring non-vegetated surfaces. Comments: Mines or similar human activity may be mapped by this class, or may be mapped by the developed class.
VEGETATION NOT DOMINANT Vegetation is scattered or nearly absent; total vegetation cover is generally less than 10%.	

	**(13) Urban (34 developed)** Land that predominantly built-up or developed. This includes road surfaces, railway surfaces, buildings and paved surfaces, urban areas, industrial sites, mine structures.
	**(14) Water (20 water)** Area covered with liquid water including open ocean, lakes, and rivers.
	**(15) Snow/Ice (31 snow/ice)** Land covered with permanent ice or snow.

	**(16) Unpaved Road (33 exposed land)** Gravel or dirt roads.
	**(17) Paved Road (33 exposed land)** Asphalt or concrete roads.
No image available.	**(18) Coastal Aquatic Vegetation** Sea grasses, algae, and other marine plane life along the sea coast.

Table D2:Potential Evapotranspiration Factors for various land cover types.

Land Cover ID	Description	PET Factor
LND_CVR_1	Coniferous Forest	1
LND_CVR_2	Deciduous Forest	0.95
LND_CVR_3	Mixed Forest	0.95
LND_CVR_4	Coniferous - recent disturbance	0.9
LND_CVR_5	Mixed Regeneration Shrub	0.9
LND_CVR_6	Mixed Regeneration Confider Dominated	0.9
LND_CVR_7	Shrub	0.85
LND_CVR_8	Wetland	0.9
LND_CVR_9	Low vegetation	0.9
LND_CVR_10	Cropland High biomass	0.85
LND_CVR_11	Cropland low biomass	0.8
LND_CVR_12	Barren	0.5
LND_CVR_13	Urban	0.7
LND_CVR_14	Water	1
LND_CVR_15	Snow/Ice	1
LND_CVR_16	Unpaved Road	0.5
LND_CVR_17	Paved Road	0.7
LND_CVR_18	Coastal Aquatic Vegetation	0.65

Notes: PET Factor is used to adjust standard PET calculated using Thortnwaite Equation to account for various land cover type. These are based on textbook values and calibrated for regional conditions.

1.1.1 Soil Component

Soil data was provided by the RDN (Westrek, 2012) and integrated with GIS to determine the soil properties of each grid cell in the study area. Soil varies greatly through the region from impermeable bedrock to porous gravel. Each unique soil type in the RDN was assigned a value for the following properties:

- Soil Moisture Storage Capacity (STC) [mm]
- Maximum Infiltration Rate (MIR) [mm]
- Maximum Groundwater Recharge Rate (GWR) [mm]

The STC for each soil type was estimated using values from the (BC Ministry of Agriculture, Food, and Fisheries, 2002) as shown in Table D3 for reference.

Table D3:Soil Moisture Storage Capacity

Textural Class	Soil Moisture Storage Capacity (mm water / m soil)
Clay	200
Clay Loam	200
Silt loam	208
Clay loam	200
Loam	175
Fine sandy loam	142
Sandy loam	125
Loamy sand	100
Sand	83

Source: BC Ministry of Agriculture, Food, and Fisheries)2002)

STC values for soil types in the RDN that are not in Table D3 were estimated by using the known values as a reference. For example, it is expected that gravelly sand will have a lesser STC than sand.

The Maximum infiltration rate (MIR) was determined through model calibration and limited permeability data (Westrek, 2012). MIR was used to determine the soil moisture recharge rate, the drier the soil the quicker the soil can recharge compared to when it is near saturation

.

Groundwater recharge (GWR) was included in the USGS model through a slight modification. The model assumed that a portion of the soil moisture provided groundwater recharge during periods of saturated soils (i.e. wet winter months). The model assumed that a portion of the groundwater supply was released as surface water, and provided discharge during dry summer periods.

GWR was estimated to be 10% of the MIR through model calibration and discussions with technical groundwater experts. A groundwater-surface water interaction monitoring program would provide essential data to confirm and improve the hydrologic model.

1.1.2 SURFACE WATER BUDGET

Surface water budgets for each of the major watersheds have been developed using estimates of monthly natural flow from output from the regional hydrology model, the licenced water withdrawal volumes, licenced storage volumes, recorded water withdrawal volumes (where available), and estimates of required minimum conservation flows (see Figure 2 in main report). As limited surface water withdrawal data is available, the total annual volumes quoted in water licences have been used as an estimate of the actual water withdrawal amount.

The total monthly withdrawal volumes have been estimated using the annual withdrawal volume and typical demand distributions. For waterworks demand, the distribution is based on water withdrawal records from the City of Nanaimo, and Town of Parksville, for domestic demand it has been assumed that July, Aug and September demand is twice the demand during the remainder of the year, industrial demand has been assumed to be constant throughout the year and agricultural demand is assumed to take place during the spring and summer months only from May to September at a constant rate. Where recorded withdrawal data is available, actual water demand values have been used in the assessment.

The required minimum conservation flow is based on typical value of 10% of average discharge. This is based on the modified Tennant (Montana) method (Tennant, 1976) and is considered to be standard planning value used by the Ministry of Environment for river habitat protection.

2.0 AQUIFER WATER BUDGET CALCULATIONS

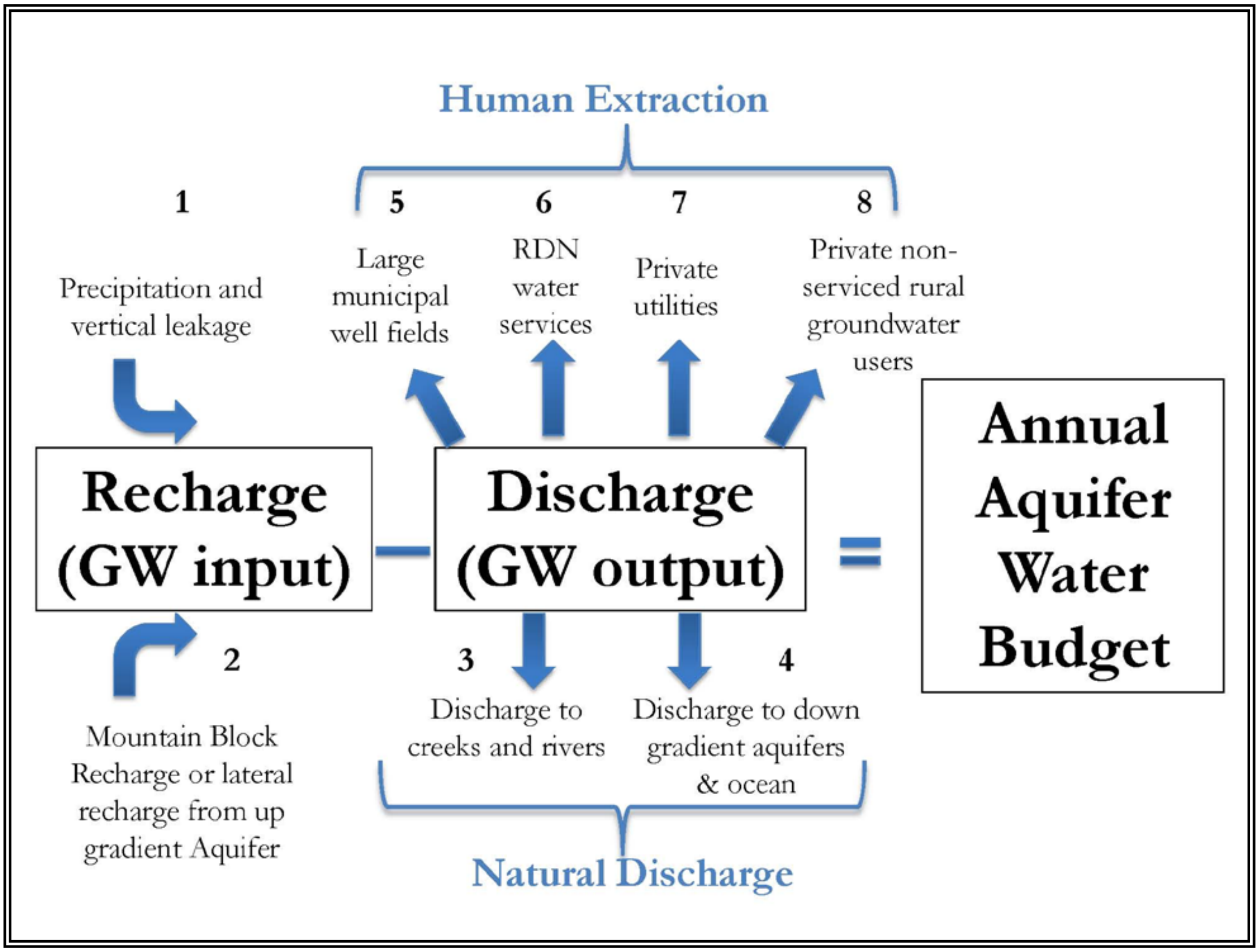
2.1 Approach Used For Water Budget Calculations

The RDN is bounded to the west by mountains and to the east by Georgia Strait. Surface water and groundwater drain from high to low elevations, thus the steep coastal profile creates a natural gravity-driven system with relatively high hydraulic gradients to the ocean. Fresh water resources that do not evaporate or transpire will eventually flow to the ocean, unless intercepted by wells or surface intakes for water supply use. The groundwater flow paths in aquifers across the RDN tend to follow the topography of the land and flow towards the ocean. Maps C8 and C9 (Appendix C) show piezometric surface contour maps developed for wells from 0-25 m and 25-50 m depth below ground.

Surface water and groundwater systems are dynamic systems and constantly in a state of flux in accordance to the changing seasons and longer term climate variability on the Pacific Coast of North America. Both surface and groundwater systems in the RDN are expected to have short residence times resulting in relatively young groundwater (10's to 100's of years old) from the point of recharge at higher elevations to discharge points in local creeks, or near the coast. Rivers and creeks exchange water with shallow aquifers through the watershed. Over time, rivers and creeks erode away surficial materials and cut down into underlying aquifers causing direct exchange between the surface water and groundwater systems.

Aquifer recharge occurs when precipitation percolates (infiltrates) through the soil and replenishes the underlying groundwater systems. In addition, as groundwater flows from areas of high topographic elevation to areas of lower elevation, aquifers can also receive lateral recharge from adjacent up gradient aquifers. This is referred to as 'mountain block recharge'.

The following generalized equation was used to assess aquifer water budgets. The stress on each aquifer was estimated as a percentage of the groundwater demand versus aquifer recharge from precipitation (vertical) and the upgraident mountain block or lateral recharge.



Aquifer Water Budget Components.

Each parameter is described as follows:

1. Precipitation and vertical leakage is rainwater or snowmelt that recharges the subsurface or water that moves from an overlying aquifer to an underlying aquifer through vertical leakage,
2. Lateral through-flow and mountain block recharge is an important source of aquifer recharge. Aquifers that have been mapped at the higher elevations tend to receive recharge directly from the upgradient mountain block and will also then feed aquifers at lower elevation located near the coast and is referred as lateral recharge from upgradient;
3. Some of the creeks are in direct hydraulic communication with the various creeks and rivers within each water region. There is a certain amount of groundwater that discharges to these creeks and it is important that this is maintained in an effort to preserve a healthy ecosystem. This volume of groundwater was estimated for aquifers that were considered to be connected to a local creek or river and factored into the aquifer water budget analysis;
4. All aquifers mapped in each water region will discharge to an adjacent down gradient aquifer which maintains the health and water balance in the system. The volume of groundwater moving out of one aquifer (discharge) and into a down gradient aquifer (recharge) was also considered in the aquifer water budget assessment;

5. Human extraction of groundwater by pumping was also considered wherever data was available. Annual extraction from large municipal wells that service communities were consider in the Aquifer Water budget assessment;
6. Similarly, RDN has a number of water service wells located in various aquifers and locales across the RDN. Annual water abstraction data for each system was used to assess aquifer water budgets in each respective area;
7. In areas not serviced by a community system, the water use was estimated by assigning water use parcels based on zoning and land use. For instance, agricultural parcels were assign a groundwater use based on the BC Ministry of Agriculture and Lands water demand model previously developed for the RDN. Other land use parcels such as residential, commercial, and industrial were assigned water use values in accordance to estimates provided by the RDN for water service areas where the water use was metered. The estimates were applied to non-service areas where groundwater was thought to be in use based on the existence of water wells in those respective areas.
8. The final aquifer water budget (surplus or deficit) was determined by the summing the recharge components (inputs) and subtracting the sum of all discharge components (outputs). A negative number would indicate that there is less water recharging the aquifer than is discharging from the aquifer. In which case one would expect declining water levels in the aquifer. Where available, the long-term water levels trends were considered in the final aquifer water budget assessment as a calibration check.

2.2 Fundamental Assumptions – Aquifer Water Budgets

Several fundamental assumptions are implicit in the aquifer water budget assessment as follows:

- As very little aquifer parameter data was available (see Map C10, Appendix C) each aquifer was assumed to be ideal in terms of uniformity and homogeneity and was represented by average aquifer parameters (transmissivity and storativity terms). In reality, however; unconsolidated layered sedimentary deposits or fractured bedrock aquifers tend to be more complex and rarely uniform or homogeneous. In order to elevate the level of accuracy of the groundwater flow estimates, regulatory change must be implemented whereby pumping tests are interpreted to provide aquifer transmissivity values. The values obtained for aquifers mapped within the RDN were taken from Carmichael (2012).
- Although the exchange of water between aquifers and rivers/creeks varies seasonally, insufficient long-term monitoring data are available at the aquifer scale to allow for meaningful assessment of aquifer water budgets on a monthly basis. Therefore, it was assumed that annual aquifer water budgets would provide some indication of stress on major aquifers within the RDN. A more detailed assessment can only be completed once more time series data is available and a computer model is developed during full Tier 1 or Tier 2 assessment as per OMNR (2012).
- Given the steep natural water table gradients directing water downslope towards the ocean, Waterline assumed that groundwater was constantly discharging to the major rivers/creeks (no seasonal change causing creek/rivers to reverse from influent to effluent). This provides a conservative approach to the water budget calculation.
- Where aquifers were assessed to discharge directly to the ocean, the volume of groundwater leaving the system was not considered in the water budget and stress calculation. The rationale for this is that any groundwater that can be captured before discharging to should not have a significant impact to the environment. This assumption makes the water budget estimate for coastal aquifers more favorable in comparison to

upgradient aquifers that provide needed recharge to down gradient aquifers or to rivers and creeks that may rely of groundwater discharge to maintain base flow.

- In terms of anthropogenic groundwater use, Waterline used measured water use data for the 2010 period as it appeared to provide the most complete data set for all municipal, RDN, and private water utilities across the RDN. Where no groundwater extraction data was available for large users or for rural areas not serviced by a water supply system, it was assumed that groundwater demand could be estimated based on measured demand in serviced areas and applied based on designated land use parcels. However, it is recognized that this is a very crude estimate of groundwater use which need to be confirm by actual measurements.

These simplifying assumptions allow for completion of the aquifer groundwater budget assessment in the absence of detailed data. However, it should be cautioned that non-ideal aquifer conditions and a sparse data set can lead to erroneous conclusions and aquifer protection and management decisions. The aquifer water budget calculations completed by Waterline allow for a relative, aquifer to aquifer comparison, rather than providing absolute measure of groundwater availability. All aquifer water budgets calculations should therefore be considered as qualitative for use in assessing and conceptualizing interconnections between aquifers and surface water features inferred by the geological model or observations made but not measured. As the RDN moves to an equivalent Tier 1 or Tier 2 level of assessment (OMNR 2012) in each water region, more data will lead to more certainty.

2.3 Vertical Recharge from Precipitation

Aquifer recharge from above was estimated by applying the gridded infiltration/recharge values developed by KWL over the surface area of the aquifer taken from the ARC GIS Model. The infiltration values were generated by KWL using the modified USGS model as described in the section above and shown on Map C19 (Appendix C).

Table D4 presents estimated average infiltration values for each aquifer mapped within the 6 water regions across the RDN. These values were used to estimate vertical recharge to aquifers in the aquifer water budget calculations

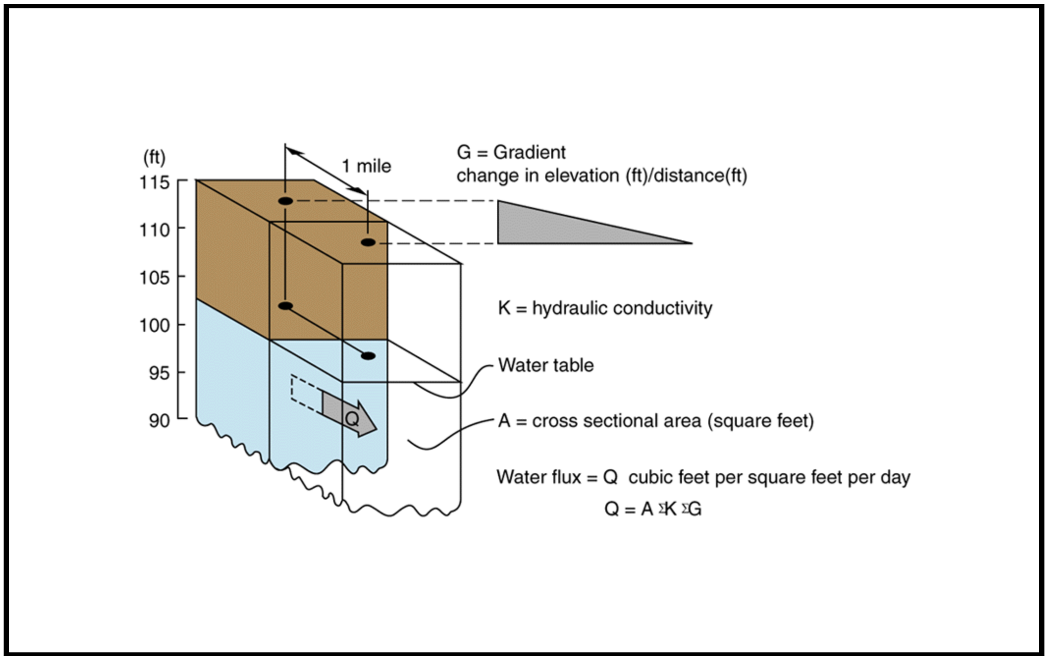
Table D4: Estimated Average Infiltration Values Per Aquifer (From KWL Model)

Aquifer	# of values	Min. Infiltration. (mm)	Max. Infiltration. (mm)	Ave. Infiltration. (mm)	Material at Surface
0160	5	120	195	150.0	Sand and Gravel
0161	31	30	195	162.4	Sand and Gravel
0162	78	30	195	163.9	Bedrock
0163	1	175	175	175.0	Sand and Gravel
0164	6	100	195	175.8	Bedrock
0165	15	120	195	169.3	Bedrock
0166	13	175	195	179.6	Bedrock
0167	2	175	175	175.0	Sand and Gravel
0209	8	120	195	150.0	Sand and Gravel
0210	5	120	175	164.0	Bedrock
0211	20	100	195	174.0	Bedrock
0212	7	50	195	119.3	Bedrock
0213	41	30	195	151.0	Bedrock
0214	5	30	195	110.0	Bedrock
0215	15	30	195	145.0	Sand and Gravel
0216	22	50	195	116.1	Sand and Gravel
0217	40	120	195	174.9	Sand and Gravel
0218	13	120	195	150.0	Bedrock
0219	30	30	195	151.8	Sand and Gravel
0220	43	120	195	174.5	Bedrock
0221	4	30	195	71.3	Sand and Gravel
0416	14	100	195	176.8	Sand and Gravel
0421	7	100	195	167.1	Sand and Gravel
0661	8	120	195	129.4	Sand and Gravel
0662	56	30	195	141.3	Sand and Gravel
0663	10	120	195	135.0	Sand and Gravel
0664	5	30	175	146.0	Sand and Gravel
0665	23	30	195	133.5	Sand and Gravel

Notes: Min means minimum, Max means Maximum, Ave. means Average. (See Map C19, Appendix C)

2.4 Mountain Block (Lateral) Recharge and Creek Discharge

Groundwater flow through an aquifer was calculated using the simplified Darcy flow equation as illustrated in below and provide as equation 1.



$$Q = KiA \qquad (1)$$

Where:

- Q = Volumetric Flow of water through an aquifer;
- K = hydraulic conductivity (permeability) from pumping tests (see Table D4 below);
- i = Hydraulic gradient or slope of the water table or piezometric surface measured from wells developed piezometric surface maps; and
- A = cross-sectional area of flow through and aquifer (from ARC GIS Database).

Hydraulic conductivity (K) values were assigned to each aquifer based on data compiled by Carmichael 2012 and provided to Waterline. Where no data was available, hydraulic conductivity values were estimated by comparing well yield values on driller's reports to calculated aquifer transmissivity in equivalent aquifer materials. Table D4 below summarizes the approach and hydraulic conductivity values used for each mapped aquifer within the RDN.

As described in the caption of Maps C7 and C8, Appendix C, the hydraulic gradient was estimated from piezometric surface maps developed in the area of each mapped aquifer.

Table D5: Aquifer Hydraulic Conductivity Values (From Carmichael 2012)

Aq #	Lithology	Water Region	Yield in BR		Yield S&G		Hydraulic Conductivity K (m/s)				
			# Records	Ave. Yield m^3/day	# Records	Ave. Yield m^3/day	# Records	Min.	Max.	Ave.	Estimated*
0416	Quadra	BQ	1	2.7	25	210.0	1	3.21E-05	3.21E-05	3.21E-05	3.21E-05
0421	Quadra	BQ	1	1.6	1	136.3	NA	NA	NA	NA	7.00E-04
0665	Capilano	BQ	NA	NA	3	1086.7	NA	NA	NA	NA	1.00E-02
0661	Kame	BQ/LQ	NA	NA	16	73.0	NA	NA	NA	NA	5.00E-04
0662	Quadra	BQ/LQ	1	130.9	141	80.1	NA	NA	NA	NA	5.75E-04
0663	Kame delta	FC/LQ			14	84.3	1	7.98E-04	7.98E-04	7.98E-04	7.98E-04
0664	Salish	FC/LQ	1	163.5	19	442.7	NA	NA	NA	NA	4.00E-03
0217	Quadra	ER/FC/LQ	7	29.9	121	147.4	41	3.06E-05	4.35E-03	6.68E-04	6.68E-04
0221	Salish		NA	NA	NA	NA	4	3.34E-04	3.24E-03	2.12E-03	2.12E-03
0214	NG		NA	NA	NA	NA	NA	NA	NA	NA	1.00E-06
0220	Haslam Fm	FC/ER	118	32.3	54	67.2	NA	NA	NA	NA	2.00E-06
0209	Quadra	ER	3	5.1	22	90.1	NA	NA	NA	NA	5.50E-04
0216	Quadra	FC/ER	11	30.7	105	118.7	6	4.98E-05	2.75E-04	1.69E-04	1.69E-04
0212	NG	ER	10	25.8	2	408.8	NA	NA	NA	NA	1.00E-06
0167	Capilano	SW-N	3	5.3	7	140.3	NA	NA	NA	NA	7.00E-04
0215	Quadra	SW-N			17	88.6	11	4.10E-05	1.60E-03	5.86E-04	5.86E-04
0219	Quadra	ER/SW-N	36	63.5	116	281.9	23	1.50E-05	2.41E-03	5.53E-04	5.53E-04
0166	VG	SW-N	13	35.5	0	NA	NA	NA	NA	NA	2.00E-06
0210		SW-N	36	52.0	4	21.5	NA	NA	NA	NA	3.00E-06
0211		SW-N	51	118.2	6	52.0	NA	NA	NA	NA	2.00E-04
0213	VG	SW-N	150	43.5	170	74.3	2	2.27E-06	1.08E-02	2.82E-06	2.82E-06
0218	Benson Fm	SW-N	44	43.2	7	525.5	2	1.33E-05	3.57E-05	2.45E-05	2.45E-05
0160	GF Vashon	NR/Cedar	5	79.9	92	162.4	NA	NA	NA	NA	8.00E-04
0161	Capilano	NR/Cedar	20	21.5	65	1824.2	3	3.7E-03	1.1E-02	7.9E-03	5.00E-02
0163	Quadra	Cedar	NA	NA	NA	NA	NA	NA	NA	NA	6.00E-04
0164	Extension Fm	NR	56	37.0	4	77.1	NA	NA	NA	NA	2.00E-06
0165	NG	NR	249	53.0	7	200.0	NA	NA	NA	NA	3.00E-06

Notes: FM means Formation, BQ=Big Qualicum, LQ=Little Qualicum, ER=Englishman River, FC-French Creek, SW-N=South Wellington to Nanoose, NR=Nanaimo River, BR means Bedrock aquifer, S&G means sand and gravel aquifer, NA means not available, Ave means average, min means minimum, max means maximum. * used in water budget calculation (Table D7 and D8)

The Darcy flow equation was used to estimate the volumetric flux of groundwater moving laterally into (and out of) an aquifer and also used to estimate groundwater discharging to creeks and rivers where the physical model constructed by Waterline, or a previous study, indicated that groundwater contribution to river baseflow was indicated (E.g.: Wendling 2012). The following approach was taken to complete the water budget calculation:

Recharge from Upgradient Lateral Flow from Mountain Block or adjacent aquifer

- Assess cross -sectional area of aquifer at up gradient boundary from 3D GIS mapping;
- Used average K value assigned to aquifer (Table D4);
- Use appropriate horizontal hydraulic gradient estimate from 0-25 or 0-50 m piezometric contour maps (Map C7 or C8, Appendix C) depending on the aquifer depth;
- Complete Darcy flux calculation (solve for Q in equation 1);
- Provides a conceptual value only.

Discharge to Creeks/Rivers or to adjacent down gradient aquifer

- Assess cross -sectional area of aquifer at up gradient boundary from 3D GIS mapping;
- Used average K value assigned to aquifer (Table D4);
- Use appropriate horizontal hydraulic gradient estimate from 0-25 or 0-50 m piezometric contour maps (Map C7 or C8, Appendix C) depending on the aquifer depth;
- Complete Darcy flux calculation (solve for Q in equation 1);
- Provides a conceptual value only.

2.5 Groundwater Use (Anthropogenic)

Wherever possible, actual measured values of anthropogenic groundwater use was considered in the water budget analysis for 2010 as it was found to be the most complete record across the RDN. These include the following:

- Large/small Municipal Wells (E.g.: Improvement Districts, Parksville, Qualicum Beach, etc...),
- RDN Water Systems (Annual data for 2010 on RDN website);
- Private Water Systems (E.g.: Epcor).

It should be noted that some of the water use records for large municipal wells and private water systems were incomplete, or requests for data by the RDN was not provided by the system purveyor, the water demand was estimated using the same approach for other non-serves areas described in the following sub-section.

2.6 Water Demand Assessment - Non-Service Areas

The RDN provided Waterline with water use data at the parcel level estimated based on water consumption data for the RDN and the City of Nanaimo. The shape files provided by the RDN included water consumption values for both the high-use and low use periods for each parcel, based on actual land use codes assigned based on the BC Land Assessment designation. Consumption data was not available for parcels with agricultural land use activities as the RDN retained the Ministry of Agriculture to complete the agricultural water demand model for the RDN which was released in February 2013. Although some attempt was made to incorporate MAL

Waterline performed a systematic clean-up of the parcels, removing those parcels falling within Water Service Areas (e.g. Municipalities, RDN water service areas, and Private Water purveyors). Forest, vacant, or undeveloped lands were also removed through queries on the Actual Use codes and by comparison against 2011 digital orthimagery provided by the RDN.

The Agricultural Water Demand Model being worked on by MAL was not complete at the time of submission of Waterline's Draft report. Therefore a simplified method to calculate the water demand for agricultural parcels was applied by Waterline at the recommendation of MAL (Ted W. Van der Gulik, Pers. Comm, November 2012). The method involved an assessment of the moisture deficit from the closest climate station data available provided by Farmwest (2012) which was identified as the Qualicum Airport station. The moisture deficit value effectively indicates the amount of water required for irrigation. The values used for the RDN water budget calculations were reported for June 1st to Oct 10th, 2012 450 mm per unit area (Farmwest Model, 2012). Waterline then applied this value uniformly to agricultural lands across the entire RDN by multiplying the moisture deficit by the area of each agricultural parcel.

To complete the analysis, Waterline removed all forest and vacant land parcels from the data set as there is no water use in these area. Waterline then cross-referenced against the 2011 air photos and civic addresses outside municipal service areas to confirm surface or groundwater use. A final calibration check: was completed by aggregating parcel water use estimates within service areas against measured water use values. The calibration showed good agreement with the measured water demand numbers provided by the RDN for service areas across the RDN.

Once all water use parcels were updated in the Waterline geodatabase, the mapped aquifer layers were cross-referenced with the aquifer boundaries and then an aquifer number was assigned to each water use parcel. Once completed, the agricultural water use per aquifer was then assessed and annual water use numbers applied in the final aquifer water budget calculation for each aquifer.

2.7 Aquifer Water Budget and Stress Assessment

Tables D7and D8 presents of the aquifer water budget calculations. Table D8 is a continuation of Table D7 but the spreadsheet is too large to place in a single table. Each parameter is described in each column and equations are provided where applicable. The final aquifer stress assessment in Table D8 is the same that was provided in Table 40 in the main report. The general approach to assessing aquifer stress was provided in section 2.6 of the main report.

The analytical method used provides a crude approximation of stress to a particular aquifer. It should be noted that by using this method of assessment it is possible for an aquifer to be classified as being under some level of stress even though there is no significant anthropogenic use (i.e.: groundwater pumping). In this case the aquifer stress is natural and it may mean that the aquifer is vulnerable to pumping and development resulting from generally reduced recharge due to assessed ground/soil conditions or perhaps due to natural climate variability causing declining precipitation and recharge.

More detailed aquifer data and complex computer simulations (numerical modelling) are required to fully couple surface and groundwater systems, which would allow for a more accurate and quantitative assessment. Such calculations should be considered as the RDN moves to full Tier 1 or Tier 2 water budget assessments on a per watershed or subwatershed basis (OMNR 2012). As indicated previously, the stress assessment provided herein should only be used for comparison purposes only and should not be considered as a quantitative assessment for design or detailed watershed management purposes.

Table D6: Aquifer Water Budget Calculations

Water Region	Significant Aquifer			Potential Groundwater -Surface Water Interaction (From Geomodel)		Ave Annual Aquifer Recharge From Precipitation and/or vertical leakage from overlying aquifer (R_i)			Annual Recharge Laterally from Upgradient Mountain Block						Total Est. Aquifer Recharge (TR_{in})
	Aquifer Tag No.	Aquifer Name/ Lithology	Location Within Water Region	Potential Groundwater-Surface water or Aquifer to Aquifer Interaction	Confined, Semi, or unconfined, Aquifer Vulnerability Code	Developed Aquifer surface Area	Estimated Infiltration rate (IR) from KWL SW model (see Map C19, Appendix C)	Estimated Ave Annual Recharge from Precipiptation and snow melt (R1)	Ave Horizizontal. Gradient (i) Estinmated. from Piezometric Maps (Appendix C, Map C8 or C9)	Estimated Hydraulic Conductivity Value of Aquifer (K) from MOE and Well Yield Estimate provided in Table D 2)	Saturated Thickness (T2) @ Upgradient part of aquiferbased on nearest wells in GIS Database	Upgradient Aquifer Width (W2) (From GIS database)	Approx. Upgradient Cross-sectional area (A2) of developed Aquifer	Upgradient Mountain Block Recharge (MBR)	
	Parameter/Equation					A1	IR	R1=A1*IR	i	K	T2	W2	A2=T2* W2	MBR= i*K*A2*60*1440*365	Trin=Rmbr+R1
		Units				(m^2)	(m/yr)	(m^3/yr)	(m/m)	(m/s)	(m)	(m)	(m^2)	(m^3/yr)	(m^3/yr)
Big Qualicum River - WR1 (BQ)	416	Quadra	North of Thames Creek	Ocean	Confined, IIB	1.42E+07	0.1768	2.50E+06	2.70E-02	3.21E-05	20	4700	94000	2.57E+06	5.07E+06
	421	Quadra	Between Nile and Thames	Ocean, Nile	Semi-confined, IIIB	6.16E+06	0.1671	1.03E+06	4.86E-02	3.21E-05	8	1700	13600	6.70E+05	1.70E+06
	665	Capilano	Overlies Quadra between BQ to Thames	Ocean, Nile Creek, BQ	U, IIIB	2.28E+07	0.1335	3.04E+06	6.49E-02	1.00E-02	8	6000	48000	9.82E+08	9.85E+08
	662	Quadra	South of BQ and into LQ	Ocean (Quadra Exposed)	C, IIC	2.84E+07	0.1413	4.01E+06	3.29E-02	5.75E-04	8	1600	12800	7.63E+06	1.16E+07
Little Qualicum River - WR2 (LQ)	662	Quadra	Extends from BQ, connected to Kame 661	Ocean, LQ, Aq. 661	Confined , IIC	2.84E+07	0.1413	4.01E+06	1.88E-02	5.75E-04	15	5500	82500	2.82E+07	3.22E+07
	661	Kame	Along LQ, Springs towards Kinkade Creek	Spider LK, Horne?	Unconfined, IIIA	9.63E+06	0.1294	1.25E+06	3.05E-02	5.00E-04	25	1500	37500	1.80E+07	1.93E+07
	664	Salish	Lower LQ	Ocean, LQ	Unconfined, IA	4.96E+06	0.146	7.24E+05	3.16E-02	4.00E-03	10	905	9050	3.61E+07	3.68E+07
	663	Kame (Vashon Gf) top of Whiskey Creek	Upper Whisky Creek at border with WR3 (FC)	Whiskey Creek, LQ	Unconfined, IIIA	9.63E+06	0.135	1.30E+06	4.29E-02	7.98E-04	7	4800	33600	3.62E+07	3.75E+07
	217	Quadra	Below Kame and Above Haslam 220	LQ and Ocean	Confined , IB	6.02E+06	0.1749	1.05E+06	2.14E-02	6.68E-04	8	1700	13600	6.14E+06	7.19E+06
French Creek - WR3 (FC)	220	Haslam	FC and Albernie Hwy.	FC	Confined, IB	3.35E+07	0.1745	5.85E+06	1.29E-02	1.80E-06	70	11000	770000	5.64E+05	6.42E+06
	216	Quadra	Daylights in FC below Albernie Hwy	FC	Semi-Confined, 1B	1.84E+07	0.1161	2.13E+06	2.26E-02	5.75E-04	15	7000	105000	4.30E+07	4.51E+07
	217	Quadra	Lower FC	FC and Ocean	Confined, IB	3.79E+07	0.1749	6.64E+06	1.43E-02	7.00E-04	8	650	5200	1.64E+06	8.27E+06
	212	NG	FC Mouth	Ocean	Confined, IIIC	5.90E+06	0.1193	7.04E+05	3.13E-02	1.00E-06	50	3500	175000	1.72E+05	8.77E+05
Englishman River - WR4 (ER)	209	Quadra	Upper ER close to Thrust Fault	Haslam	Confined, IIC	8.52E+06	0.1500	1.28E+06	1.11E-02	5.50E-04	30	3500	105000	2.02E+07	2.15E+07
	220	Haslam	Upper WR4 (ER)	ER, FC	Confined, IB	4.19E+06	0.1745	7.32E+05	2.73E-02	2.00E-06	20	7000	140000	2.41E+05	9.73E+05
	216	Quadra	Lower WR4 (ER) into FC	ER	Semi-Confined, IB	6.13E+06	0.1161	7.11E+05	2.50E-02	1.69E-04	10	4000	40000	5.33E+06	6.04E+06
	219	Quadra	Along ER	Ocean, ER	Confined, IIC	9.13E+06	0.1518	1.39E+06	2.31E-02	5.53E-04	35	1200	42000	1.69E+07	1.83E+07
	214	NG	Along Coast		Semi-Confined, IIIC	5.62E+06	0.1100	6.18E+05	2.00E-02	1.00E-06	0	0	0	0.00E+00	6.18E+05
	221	Salish	Mouth of ER	Ocean, ER	Unconfined IIA	4.03E+06	0.0713	2.87E+05	2.00E-02	2.12E-03	0	0	0	0.00E+00	2.87E+05

Water Region	Significant Aquifer			Potential Groundwater -Surface Water Interaction (From Geomodel)		Ave Annual Aquifer Recharge From Precipitation and/or vertical leakage from overlying aquifer (R_i)			Annual Recharge Laterally from Upgradient Mountain Block						Total Est. Aquifer Recharge (TR_{in})
	Aquifer Tag No.	Aquifer Name/ Lithology	Location Within Water Region	Potential Groundwater-Surface water or Aquifer to Aquifer Interaction	Confined, Semi, or unconfined, Aquifer Vulnerability Code	Developed Aquifer surface Area	Estimated Infiltration rate (IR) from KWL SW model (see Map C19, Appendix C)	Estimated Ave Annual Recharge from Precipiptation and snow melt (R1)	Ave Horizizontal. Gradient (i) Estinmated. from Piezometric Maps (Appendix C, Map C8 or C9)	Estimated Hydraulic Conductivity Value of Aquifer (K) from MOE and Well Yield Estimate provided in Table D 2)	Saturated Thickness (T2) @ Upgradient part of aquiferbased on nearest wells in GIS Database	Upgradient Aquifer Width (W2) (From GIS database)	Approx. Upgradient Cross-sectional area (A2) of developed Aquifer	Upgradient Mountain Block Recharge (MBR)	
	Parameter/Equation					A1	IR	R1=A1*IR	i	K	T2	W2	A2=T2* W2	MBR= i*K*A2*60*1440*365	Trin=Rmbr+R1
		Units				(m^2)	(m/yr)	(m^3/yr)	(m/m)	(m/s)	(m)	(m)	(m^2)	(m^3/yr)	(m^3/yr)
South Wellington to Nanoose - WR5 (SW-N)	219	Quadra	Nanoose Penninsula	Nanoose Creek, Ocean	Confined, IIC	2.13E+07	0.1518	3.23E+06	0.02	5.53E-04	50	7700	385000	1.60E+08	1.63E+08
	214	NG	Nanoose NW Bay Rd. Area	Ocean	Semi-Confined, IIIC	5.62E+06	0.1100	6.18E+05	0.02	1.00E-06			0	0.00E+00	6.18E+05
	210	Buttle Lake Group - Fourth Lake Formation & Mount Hall Gabbro	Mid. Nanoose Cr.	Nanoose Creek, downgrad Fault Contact & NG	Confined, IIB	4.11E+06	0.1640	6.75E+05	0.12	3.00E-06	60	3500	210000	2.45E+06	3.12E+06
	218	Benson Fm, IP, VG	Nanoose Penninsula, Fairwinds area	Ocean	Confined, IIB	1.36E+07	0.1500	2.04E+06	0.07	2.45E-05	0	0	0	0.00E+00	2.04E+06
	213	VG	Lower and Upper Lantzville	Coal Works and Ocean	Confined, IIC	4.19E+07	0.1510	6.33E+06	0.06	2.82E-06	140	10500	1470000	7.21E+06	1.35E+07
	215	Quadra	Entire Aquifer Nanoose Reserve to North Nanaimo - Bayshore	Ocean	Confined, IIC	1.46E+07	0.1450	2.11E+06	0.05	5.86E-04	5	12000	60000	6.05E+07	6.26E+07
	166	VG & NG	Long Lake to Stephen Point, Nanaimo.	Radial Flow to Long Lk., Dep. Bay, Neck Pt. etc… Ocean	Confined, IIIB	1.20E+07	0.1796	2.16E+06	0.06	2.00E-06	0	0	0	0.00E+00	2.16E+06
	211	VG & NG	Mt Benson to Parkway	Underground Coal Works	Confined, IIB	2.16E+07	0.1740	3.75E+06	0.06	2.00E-04	0	0	0	0.00E+00	3.75E+06
	167	Capilano	Below Westwood Lk	Aq 211	Confined, IIIC	2.36E+06	0.1750	4.13E+05	0.05	7.00E-04	10	3000	30000	3.53E+07	3.57E+07
Nanaimo River - NR6 (NR)	160	Vashon	Lr. Cassidy	NR	Semi-Confined, IIC	5.95E+06	0.1500	8.93E+05	2.73E-02	8.00E-04	10	1700	17000	1.17E+07	1.26E+07
	161	Capilano	Cassidy	NR	Unconfined, IIA	2.99E+07	0.1624	4.86E+06	3.00E-02	7.90E-03	6	2700	16200	1.21E+08	1.26E+08
	162	NG	Cedar, Yellowpoint	NR, Ocean	Unconfined, IA	7.92E+07	0.1639	1.30E+07	5.00E-02	3.00E-06	0	0	0	0.00E+00	1.30E+07
	163	Quadra	North Holden Lk., Cedar	Ocean	Unconfined, IIB	1.64E+06	0.1750	2.87E+05	4.29E-02	6.00E-04	0	0	0	0.00E+00	2.87E+05
	164	NG	Extension	NR	Confined, IIB	6.25E+06	0.1758	1.10E+06	2.86E-02	2.00E-06	3	2300	6900	1.24E+04	1.11E+06
	165	NG	South Wellington	NR	Confined, IIB	1.71E+07	0.1693	2.89E+06	5.45E-02	3.00E-06	5	12000	60000	3.10E+05	3.20E+06

Table D7: Aquifer Water Budget Calculations – Continued from Table D7

Water Region	Aquifer Tag No.	Annual Groundwater Discharge from Major Aquifers to Major Rivers/Creeks – Discharge to local creeks/rivers or adjoining aquifers for assume worst case where groundwater discharge occurs year around (GWC/R_{out})				Groundwater Output to down gradient aquifer – Discharge to adjoining down gradient aquifers except where aquifer discharges to ocean which is not needed for to maintain downgradient resource (GW_{out})				Total GW Use ($ANTH_{out}$)	Total GW out	Aquifer Stress Analysis	
		Estimated Length (L3) of Exposure Along Creek boundary (From GeoDB)	Estimated Seepage Face Width/Height (W3) on both valley walls (from GeoDB)	Approximate Seepage Face Area along Creek (A3)	Estimated Annual Discharge to Creek/River (GWC/Rout)	Saturated. Thickness (T4) @ Downgradient side of aquifer based on nearest wells from GIS Database	Aquifer Width (W4) @ down gradient from GIS Database	Cross Sectional Area (A4) of Aquifer from GIS database	Estimated Discharge Flux to down gradient Aquifer (GW_{out})		[GWC/R_{out} + GW_{out} + $ANTH_{out}$]	GW Output Versus Available Recharge (Total GW out/TRin) x 100)	Relative Aquifer Stress
		L3	W3	A3=L3*W3	GWC/Rout = i*K*A3*60*1440*365	T4	W4	A4	GWout = i*K*A4*60*1440*365	= P1+P2+P3			
		(m)	(m)	(m)	(m^3/yr)	(m)	(m)	(m)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(%)	Lo, Mod, Hi
Big Qualicum River - WR1 (BQ)	416	0	0	0.00E+00	0.00E+00	12	5500	6.60E+04	0.00E+00	3.11E+05	3.11E+05	6	Lo
	421	2700	10	2.70E+04	1.33E+06	2	2200	4.40E+03	0.00E+00	0.00E+00	1.33E+06	78	Mod-Hi
	665	2300	4	9.20E+03	4.53E+05	3	5300	1.59E+04	3.25E+08	7.00E+00	3.26E+08	33	Lo-Mod
	662	4200	20	8.40E+04	4.14E+06	2	2000	4.00E+03	0.00E+00	6.71E+05	4.81E+06	41	Lo-Mod
Little Qualicum River - WR2 (LQ)	662	0	0	0.00E+00	0.00E+00	5	5200	2.60E+04	0.00E+00	1.22E+06	1.22E+06	4	Lo
	661	2200	11	2.42E+04	1.16E+07	0	0	0.00E+00	0.00E+00	4.13E+04	1.17E+07	65	Mod
	664	0	0	0.00E+00	0.00E+00	8	1200	9.60E+03	0.00E+00	1.39E+06	1.39E+06	4	Lo
	663	3000	9	2.70E+04	2.91E+07	0	0	0.00E+00	0.00E+00	1.08E+05	2.92E+07	81	Mod-Hi
	217	3600	3	1.08E+04	4.88E+06	5	1700	8.50E+03	0.00E+00	4.42E+05	5.32E+06	87	Mod-Hi
French Creek - WR3 (FC)	220	0	0	0.00E+00	0.00E+00	70	10000	7.00E+05	5.13E+05	2.2E+06	2.7E+06	42	Lo-Mod
	216	4000	12	4.80E+04	1.97E+07	15	3500	5.25E+04	2.15E+07	4.1E+06	4.5E+07	100	Hi
	217	4000	5	2.00E+04	6.31E+06	7	7000	4.90E+04	0.00E+00	4.7E+06	1.1E+07	133	Hi
	212	0	0	0.00E+00	0.00E+00	50	3500	1.75E+05	0.00E+00	5.0E+05	5.0E+05	58	Mod
Englishman River - WR4 (ER)	209	4500	10	4.50E+04	8.67E+06	0	0	0.00E+00	0.00E+00	1.1E+06	9.8E+06	45	Lo-Mod
	220	0	0	0.00E+00	0.00E+00	10	1000	1.00E+04	1.72E+04	1.2E+06	1.2E+06	125	Hi
	216	3000	10	3.00E+04	4.00E+06	10	2400	0.00E+00	0.00E+00	7.6E+05	4.8E+06	79	Mod. Hi
	219	0	0	0.00E+00	0.00E+00	10	1500	1.50E+04	6.04E+06	8.3E+03	6.0E+06	33	Lo-Mod
	214	0	0	0.00E+00	0.00E+00	0	0	0.00E+00	0.00E+00	1.4E+05	1.4E+05	23	Lo
	221	0	0	0.00E+00	0.00E+00	0	0	0.00E+00	0.00E+00	1.8E+05	1.8E+05	61	Mod
South Wellington to Nanoose - WR5 (SW-N)	219	0	0	0.00E+00	0.00E+00	15	2500	3.75E+04	1.56E+07	2.8E+06	1.83E+07	11	Lo
	214	0	0	0.00E+00	0.00E+00	0	7700	0.00E+00	0.00E+00	4.4E+02	4.40E+02	0	Lo
	210	0	0	0.00E+00	0.00E+00	60	3500	2.10E+05	2.45E+06	3.2E+05	2.77E+06	89	Mod-Hi
	218	0	0	0.00E+00	0.00E+00	5	15000	7.50E+04	4.06E+06	2.7E+05	4.33E+06	212	V. High
	213	0	0	0.00E+00	0.00E+00	8	10500	8.40E+04	4.12E+05	7.2E+05	1.13E+06	8	Lo
	215			0.00E+00	0.00E+00	5	12000	6.00E+04	6.05E+07	4.4E+05	6.09E+07	97	Mod-Hi
	166	0	0	0.00E+00	0.00E+00	5	14000	7.00E+04	0.00E+00	0.0E+00	0.00E+00	0	Lo
	211	0	0	0.00E+00	0.00E+00	5	4500	2.25E+04	9.18E+06	2.3E+06	1.15E+07	306	V. High
	167	0	0	0.00E+00	0.00E+00	5	3000	1.50E+04	1.77E+07	0.0E+00	1.77E+07	49	Lo-Mod
Nanaimo River - NR6 (NR)	160	0	0	0.00E+00	0.00E+00	6	1900	1.14E+04	7.84E+06	2.7E+03	7.8E+06	62	Mod-Hi
	161	6400	2	1.28E+04	9.57E+07	3	400	1.20E+03	8.97E+06	2.0E+07	1.2E+08	99	Mod-Hi
	162	35000	20	7.00E+05	3.31E+06	0	0	0.00E+00	0.00E+00	1.1E+07	1.4E+07	110	Hi
	163	1400	1	1.40E+03	1.14E+06	0	0	0.00E+00	0.00E+00	3.1E+05	1.4E+06	502	V.Hi
	164	2800	1	2.80E+03	5.05E+03	0	0	0.00E+00	0.00E+00	8.5E+05	8.6E+05	77	Mod-Hi
	165	8000	10	8.00E+04	4.13E+05	8	12000	9.60E+04	0.00E+00	1.8E+06	2.2E+06	68	Mod