Regional District of Nanaimo Phase 1 Water Budget Project

Vancouver Island

Drinking Water and Watershed Protection

Technical Advisory Committee Meeting

December 13, 2012

Waterline Resources Inc.

Nanaimo BC

REGIONAL DISTRICT OF NANAIMO

KERR WOOD LEIDAL consulting engineers

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Introductions: Waterline Project Team

- Hydrogeology – Waterline Resources
  - ✓ Darren David, M.Sc., P.Geo.
  - ✓ Matt Skinner, M.Sc., GIS
- Surface Water Engineering - KWL
  - ✓ Craig Sutherland, M.Sc., P.Eng.

Presentation Outline

- Introduction to RDN Water Budget Project:
  - ✓ Study objectives, Ont. MNR approach.
- Overview of method and conceptual models
- Methods - SW Budgets (Craig):
  - ✓ Results of SW Budgets for each WR.
- Methods - GW Budgets (Darren):
  - ✓ Results of GW Budgets for Major aquifers in each WR.
- Wrap up (Data Gaps, Priorities, Move Forward).

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Study Objectives

- "Sustainable" planning and development….
  - ✓ Need to understand water availability per water region;
  - ✓ Develop water Budgets (surface and groundwater);
  - ✓ Complete stress analysis on major watersheds and mapped aquifers.

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"Big Picture" RDN Project

- RDN Water Budget Project… Proactive Approach:
  - ✓ Develop a centralized system to allow RDN to compile and track water-related information;
  - ✓ Eventually make available to SW & GW practitioners to allow consistent assessment and improve the knowledge base with every study.
- Cumulative Impacts (natural or anthropogenic)
  - ✓ Continual updating of data allows for informed decision making and Watershed planning to advance knowledge;
  - ✓ Balanced aquatic, terrestrial and community needs for water;
  - ✓ Development planning on a watershed basis;
  - ✓ Concept of "water sustainability" becomes truly possible.

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Water Budget – Scale of Assessment

- Ontario MNR Model was used for RDN Project:
  - ✓ OMNR takes a tiered approach;
  - ✓ Increasing complexity and certainty;
  - ✓ Must be accompanied by increasing level of detail in understanding the water demand/water supply systems (all Tiers).
- Conceptual Water Budget (RDN Project):
  - ✓ Characterization and visualization;
  - ✓ Watershed or Water Region Scale.
- Tier 1 Water Budget:
  - ✓ GIS-based Water Budget
  - ✓ Supply, Demand, Stress Assessment (RDN Project makes an attempt but very preliminary)
  - ✓ Subwatershed Scale

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Water Budget – Scale of Assessment

- Tier 2 Water Budget (OMNR):
  - ✓ 3D GW Flow or continuous SW Flow Model;
  - ✓ Subwatershed scale
- Tier 3 Water Budget (OMNR):
  - ✓ 3D GW Flow or continuous SW Flow Model;
  - ✓ Water Quantity Risk Assessment;
  - ✓ Local scale (well capture, GW protection zones).

RDN Phase 1 Water Budget Study

- Data Compilation:
  - ✓ Get data in electronic format in Waterline DB Framework.
- Develop Conceptual Models:
  - ✓ Focused on data conditioning & interpretation.
- Water Budgets:
  - ✓ Used a USGS Watershed model for SW;
  - ✓ Analytical Approach for GW and results.
- Stress Assessment:
  - ✓ Water availability versus water use.
- Data Gaps & Priorities.
- Watershed planning (Next Step for RDN):
  - ✓ Data requirements and monitoring recommendations needed to improve Phase 1 Water Budget calculations.

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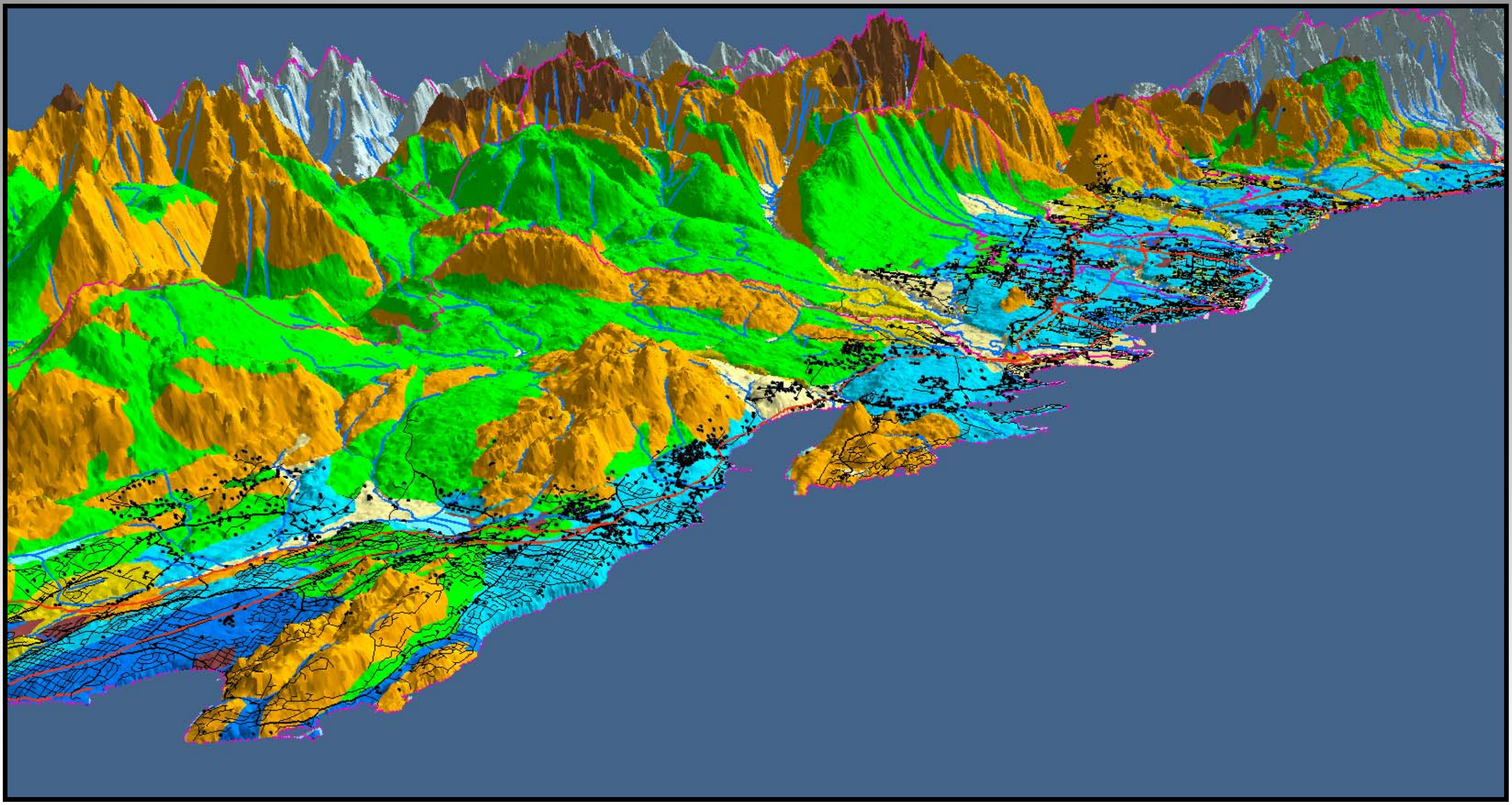
VIDEO FLY OVER RDN



- 4 x vertical exaggeration

KWL Watershed Distributed Hydrology Model

- Model Predicts stream flow at un-gauged locations:
  - ✓ Watershed Scale (from 10s km^2 to 100s km^2)
  - ✓ Average monthly time scale (both current climate and future climate predictions)
  - ✓ Used in rainfall, and snowmelt dominated watershed

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KWL Watershed Distributed Hydrology Model

- Model Input:
  - ✓ Gridded Temperature and Precipitation (1 sq. km grid)
  - ✓ Topography (1:50,000 Topographic Mapping)
  - ✓ Landcover and Leaf Area Index (Satellite Imagery)
- Model Output:
  - ✓ Gridded Infiltration (1 sq. km grid)
  - ✓ Gridded Evapo-Transpiration(1 sq. km grid)
  - ✓ Monthly Average River Flow (at mouth and key locations in watershed)

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KWL Watershed Distributed Hydrology Model

- What the Model Can do:
  - ✓ Efficiently estimates average monthly flows over large areas and multiple watersheds for water supply/water balance purposes;
  - ✓ Indicates change inflow along watercourse (ie: contributions from tributary streams);
  - ✓ Preliminary climate change impact assessment.
- What the Model can NOT do:
  - ✓ Detailed single event modeling (ie: flood hydrology);
  - ✓ Detailed (ie: daily or hourly) flow forecasting.
  - ✓ Detailed routing and reservoir assessments

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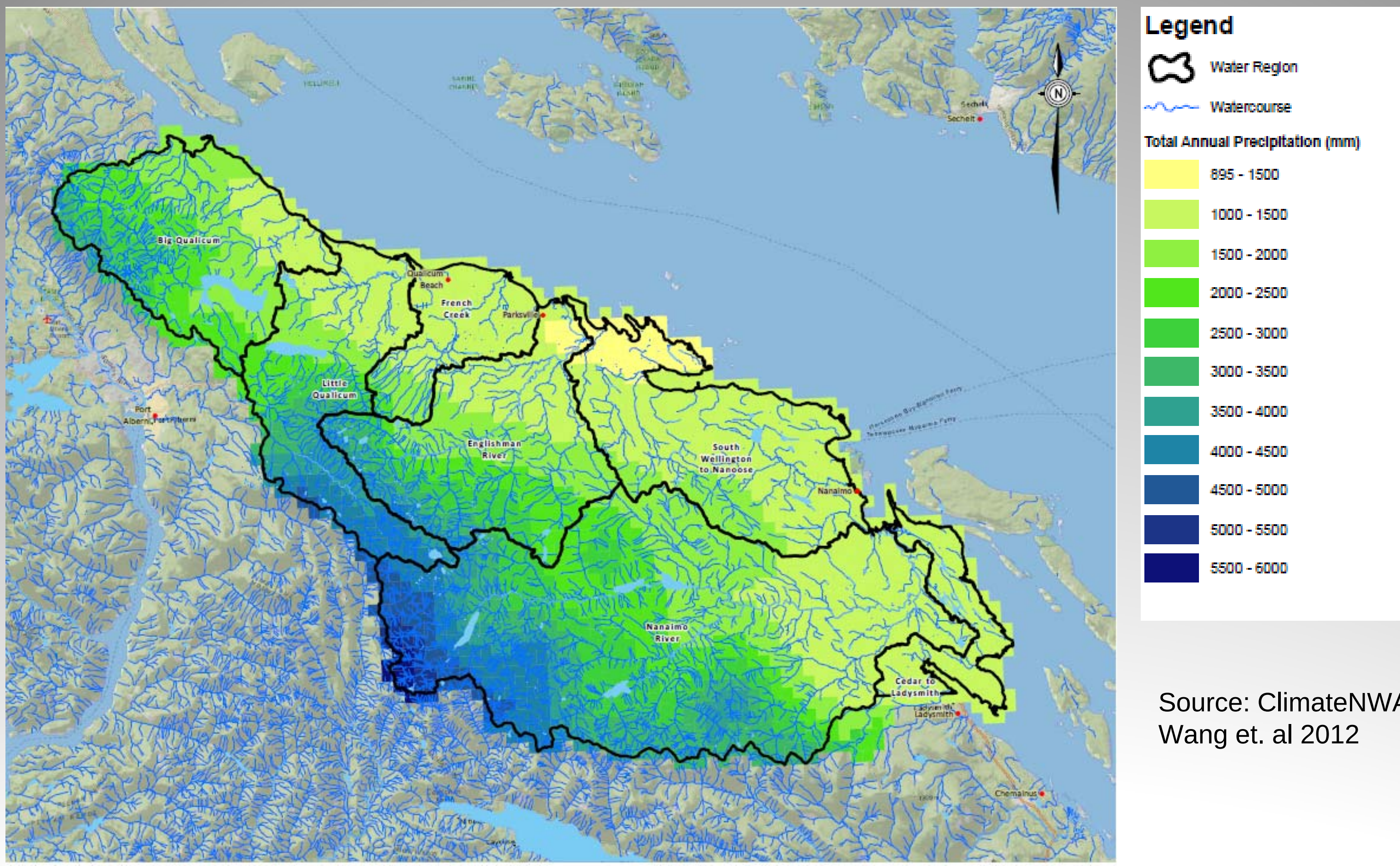
RDN Precipitation



Source: ClimateNWA Model
Wang et. al 2012

- Total annual precipitation:>5000 mm Mtns, <1250 mm on coast;
- 70-80% of precipitation from Oct-Mar

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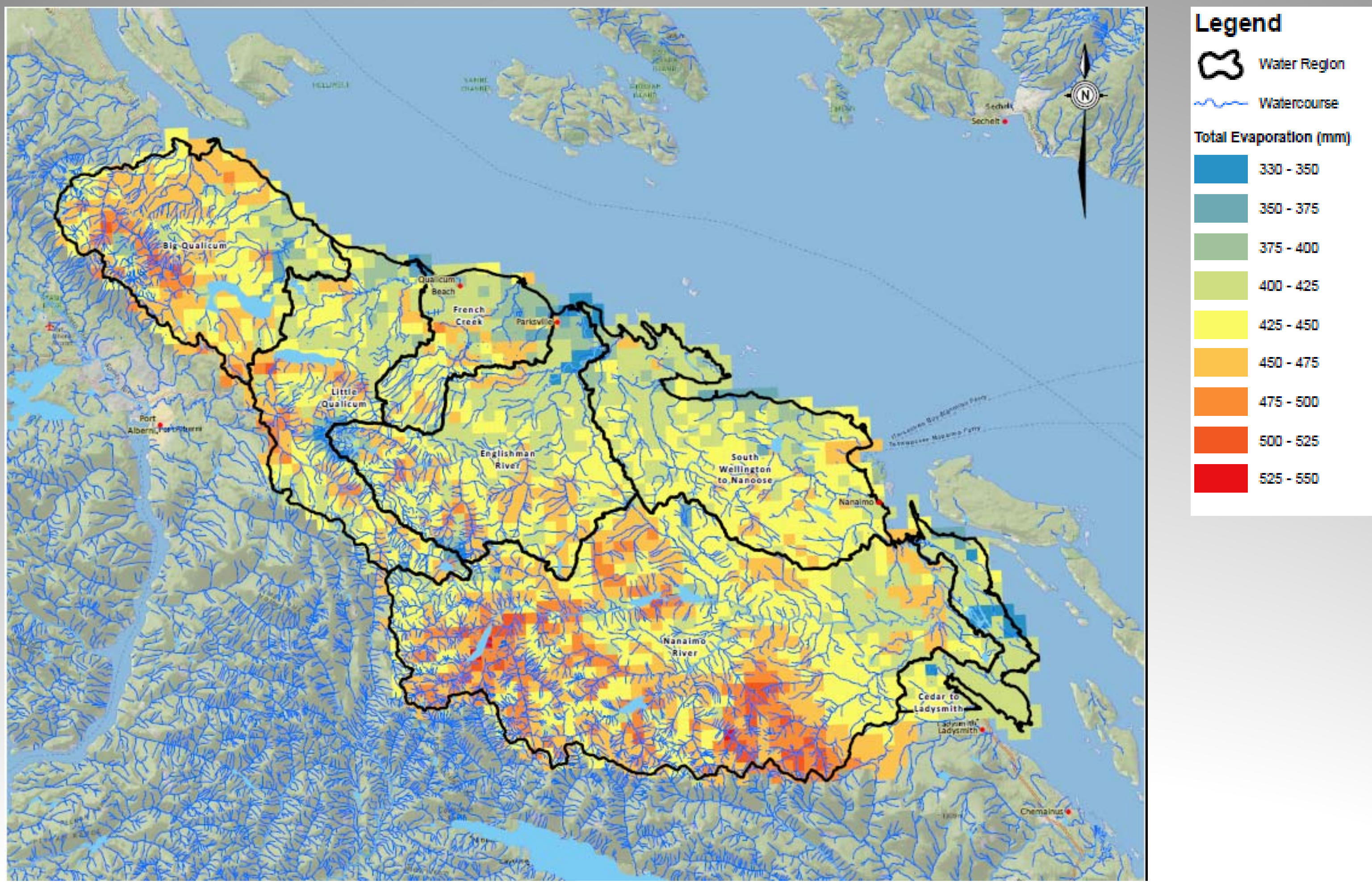
RDN Evapotranspiration



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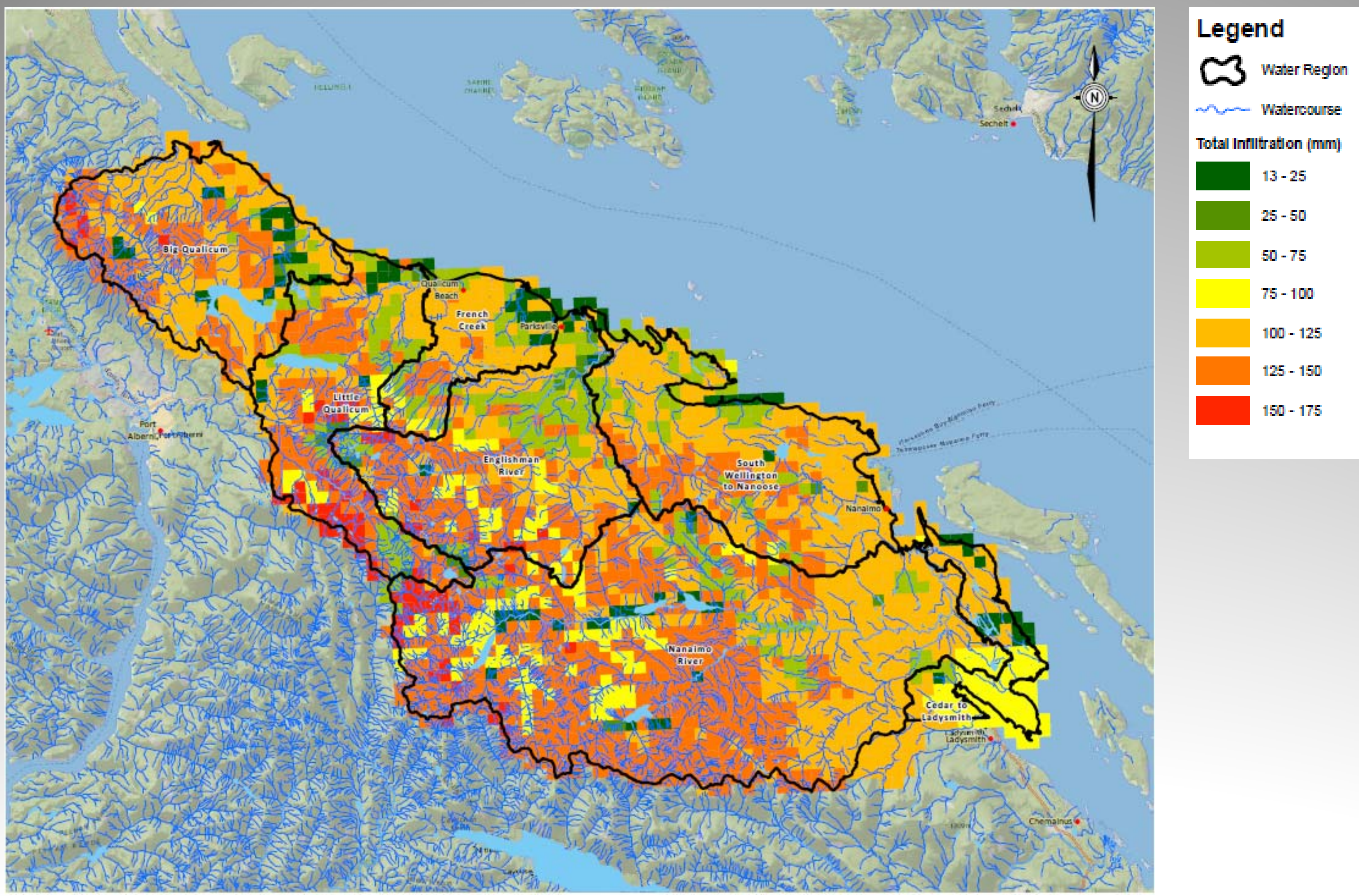
RDN Infiltration



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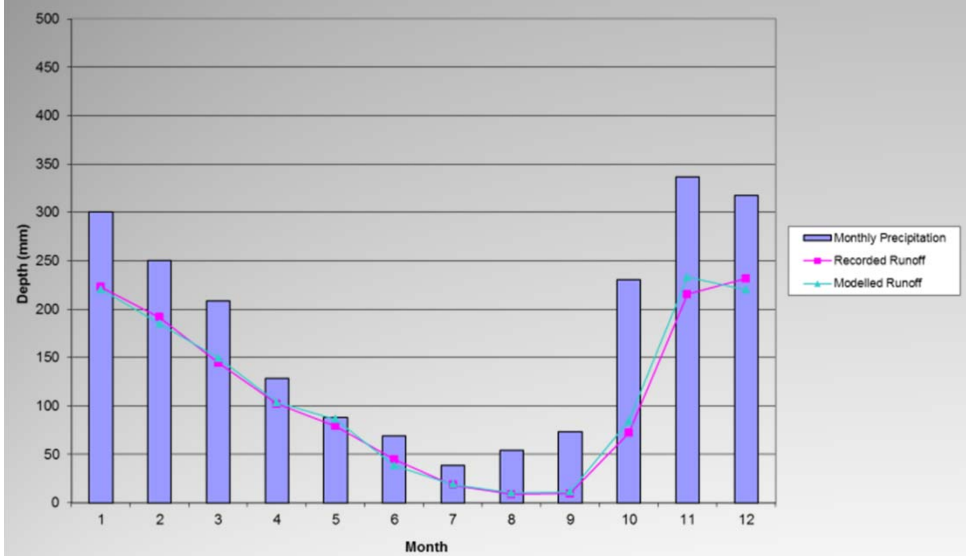
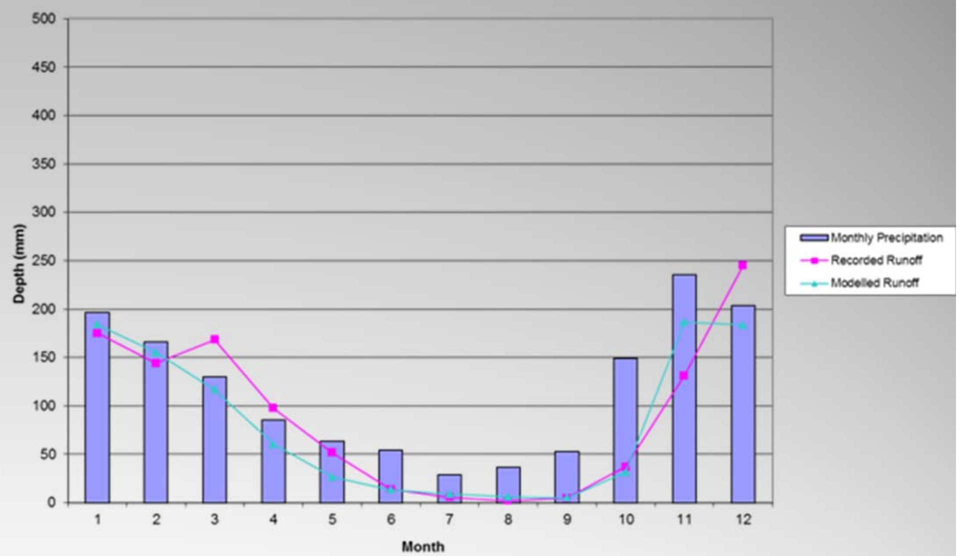
Stream Flow Comparisons

Englishman River
(1971-200 Normal)



French Creek
(1971-200 Normal)



Recorded Discharges from 1971 to 1990 (Prior to Construction of AWS Dam)
Total Annual Vol Error = 1.5%
Summer Vol. Error = 12%

6 years of recorded summer flows
2 years of recorded winter flows
(1990 to 1996)

Summer Vol. Error = 63%

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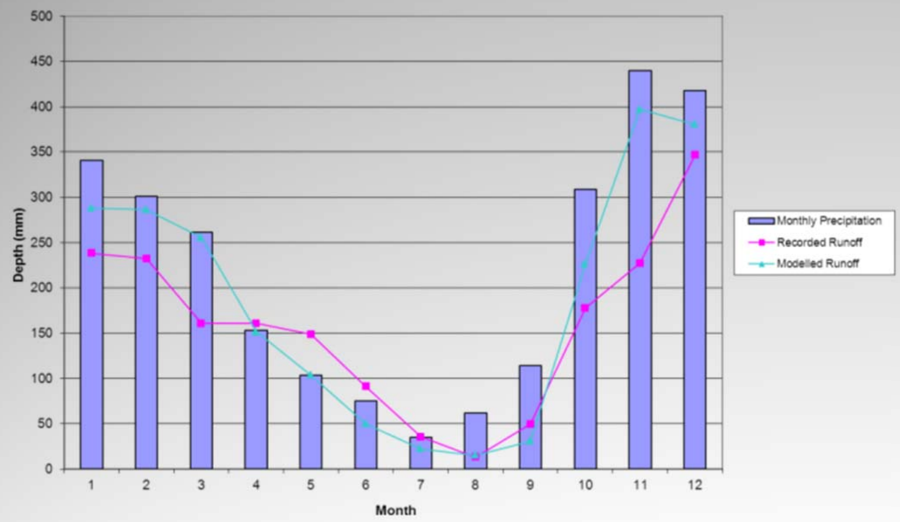
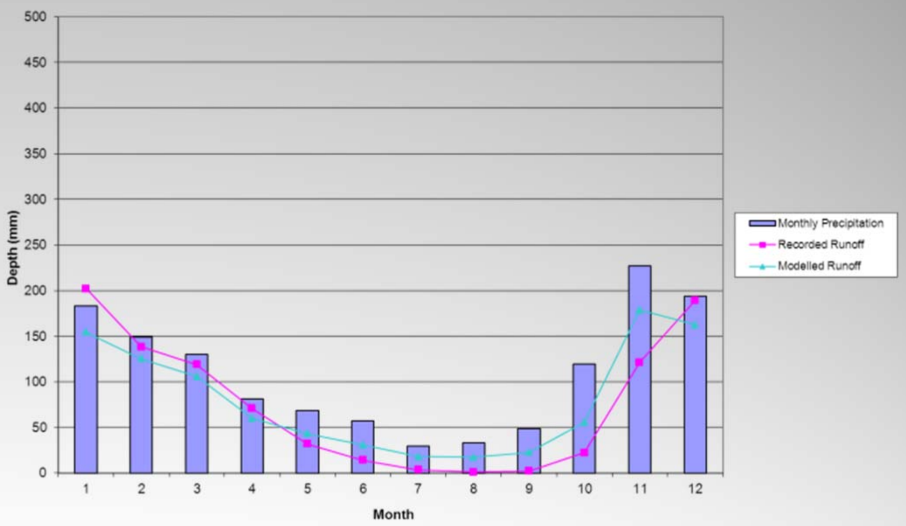
Stream Flow Comparisons

Nanaimo River
(1901-1930 Normal)



Millstone River
(1971-200 Normal)



Prior to construction of dams

Total Vol. Error 17.4%

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Water Balance Model Calibration Summary

- Positive Model Performance:
  - ✓ Good calibration to watersheds with little to no lake storage;
  - ✓ Good summer calibration;
- Model Performance needing improvement:
  - ✓ Improved accounting for surface water storage features;
  - ✓ Improved snow-melt response.
  - ✓ Detailed routing and reservoir assessments

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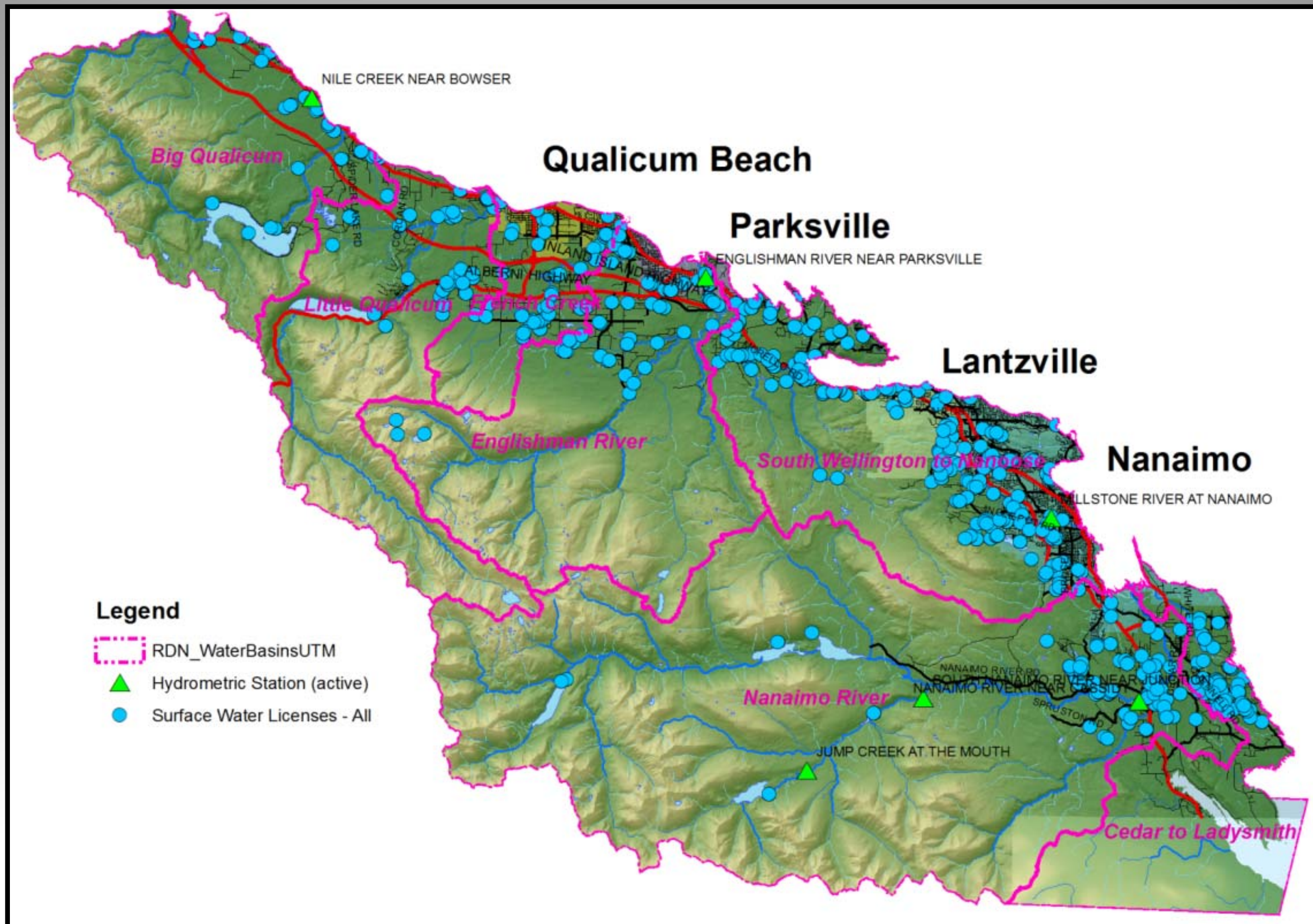
RDN Surface Water Extraction



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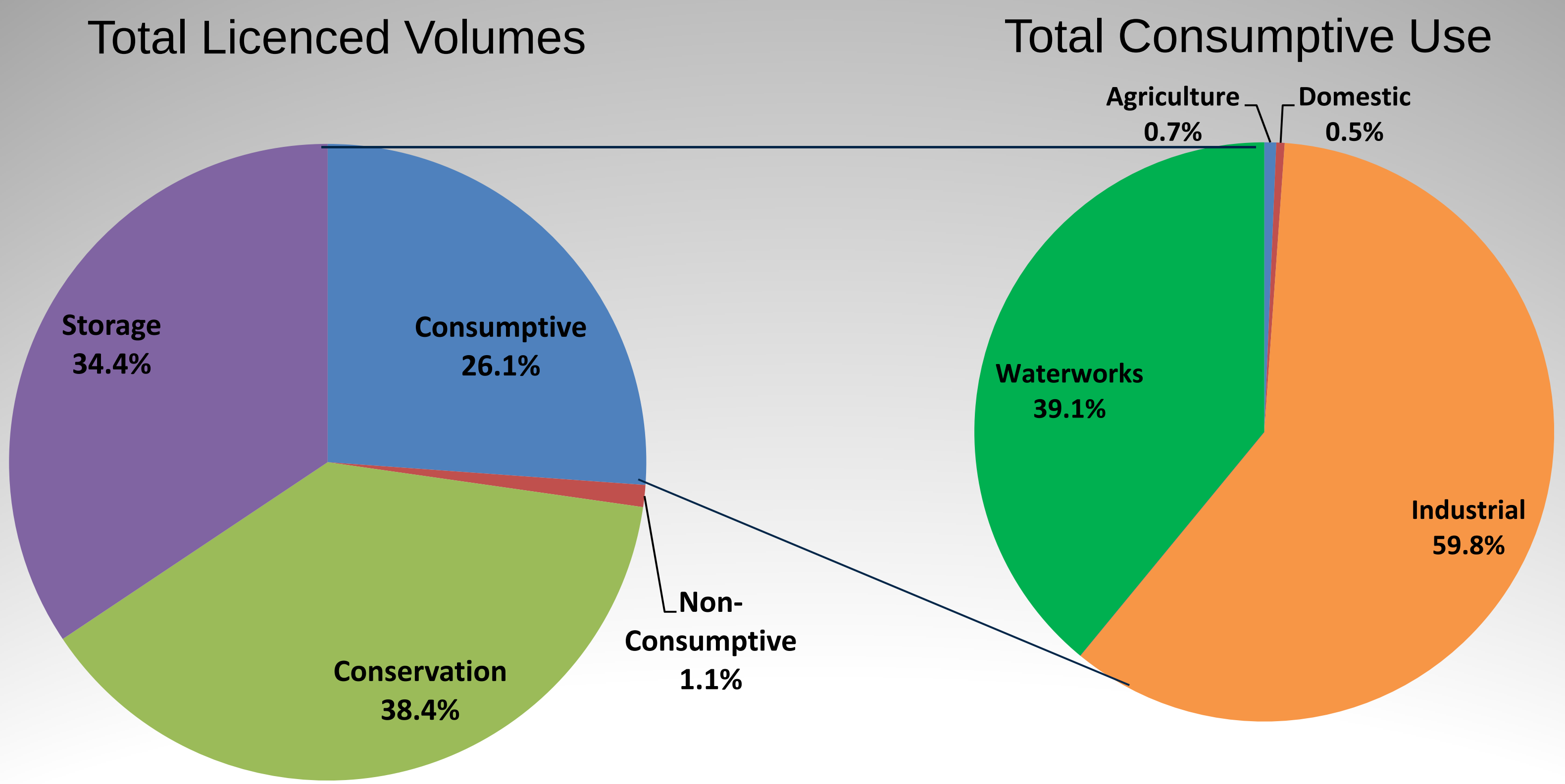
RDN Licenced Surface Water Use

Monthly Licenced Consumptive Demand = 16,391,000 m^3/month



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Surface Water Stress Analysis

Stress =

$$\frac{Consumptive\ Demand + Min.Conservation\ Flow}{\text{Avg. } Natural\ River\ Flow + Storage}$$

Consumptive Demand (Agriculture, Waterworks, Industrial, Domestic)

Min. Conservation Flow = 10% of Mean Annual Discharge

Natural River Flow = Average Modeled River Flow

Storage = Total Licenced Storage

Provides RELATIVE comparison of surface water stress.

Does not account for variability of river flow (only average)

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Relative Stress Analysis

Watershed	Water Region	Average Natural River Flow Supply	Storage	Conservation Flow (10% of MAD)	Licensed Demand	Allocation Stress	Stress Level	Actual (2010) Demand	Actual (2010) Stress
French Creek	3	1.40	0.11	1.75	0.10	**123%**	High	0.07	**121%**
Nanoose Creek	5	0.6	0.0	0.7	0.02	**107%**	High		
Nanaimo River	6	40.7	64.2	45.8	51.5	**93%**	Moderate to High	15.5	**58%**
Chase River	5	0.6	0.5	0.6	0.3	**77%**	Moderate to High		
Englishman River	4	14.4	9.1	13.2	2.7	**68%**	Moderate	0.6	**8%**
Little Qualicum River	2	18.9	4.8	13.5	0.2	**58%**	Moderate		
Millstone River	5	2.21	3.27	2.21	0.31	**46%**	Low to Moderate		
Nile Creek	1	1.90	0.00	0.26	0.07	**18%**	Low		
Big Qualicum	1	3.7	175.2	6.2	0.1	**4%**	Low		

Total Summer (Jun to Sept) Volumes in Million m^3

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Data Gaps and Recommendations
Surface Water

Reactivate discontinued Water Survey of Canada Gauges

- ✓ French Creek
- ✓ Haslam Creek
- ✓ Little Qualicum

Lake and Wetland Water Level Monitoring

Continue Summer Low-flow Spot Measurements

Consistent Format and Units for Surface Water Demand Reporting

Reporting of Summer Flow Releases from Surface Storage Reservoirs

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Groundwater Budget Components

Extraction

1 Precipitation and vertical leakage

5 Large municipal well fields

6 RDN water services

7 Private utilities

8 Private non-serviced rural groundwater users

Recharge – Discharge = Annual Aquifer Water Budget

2 Lateral through-flow and mountain block recharge

3 Discharge to creeks and rivers

4 Discharge to Down Grad. aquifers & ocean

Natural Discharge

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Conceptual Groundwater Budget

8

- Water Demand Assessment - Non-Service Areas
  - ✓ RDN provided parcel water use data from metered RDN and municipal water service areas;
  - ✓ We removed all forest and vacant land parcels (no water use);
  - ✓ Retain agricultural parcels & lots already approved for development (primarily residential) and assigned Okanogan agricultural water use values;
  - ✓ Check against 2011 air photos and civic addresses outside municipal service areas;
  - ✓ Assume all water use in non-service areas get supply from wells (verify on GIS with airphoto and wells Layer);
  - ✓ Calibration Check: aggregate parcel water use within service areas against measured water use values.

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Stress Assessment

- Aquifer Stress = GW Out (Creeks, Down Grad aquifers & Anthropogenic use) divide GW input (Precip. and MBR) x 100%:
  - ✓ 0-25% = Low Stress
  - ✓ 25-50% = Low to Moderate Stress
  - ✓ 50-75% = Moderate Stress
  - ✓ 75-100% = Moderate to High Stress
  - ✓ 100-150% = High Stress
  - ✓ >150 % = Very High Stress
- Caution: Analytical method provides crude approximation due to the lack of GW data:
  - ✓ Try to represent heterogeneous aquifers with average values;
  - ✓ Stress assessment is qualitative for comparison only (not absolute).

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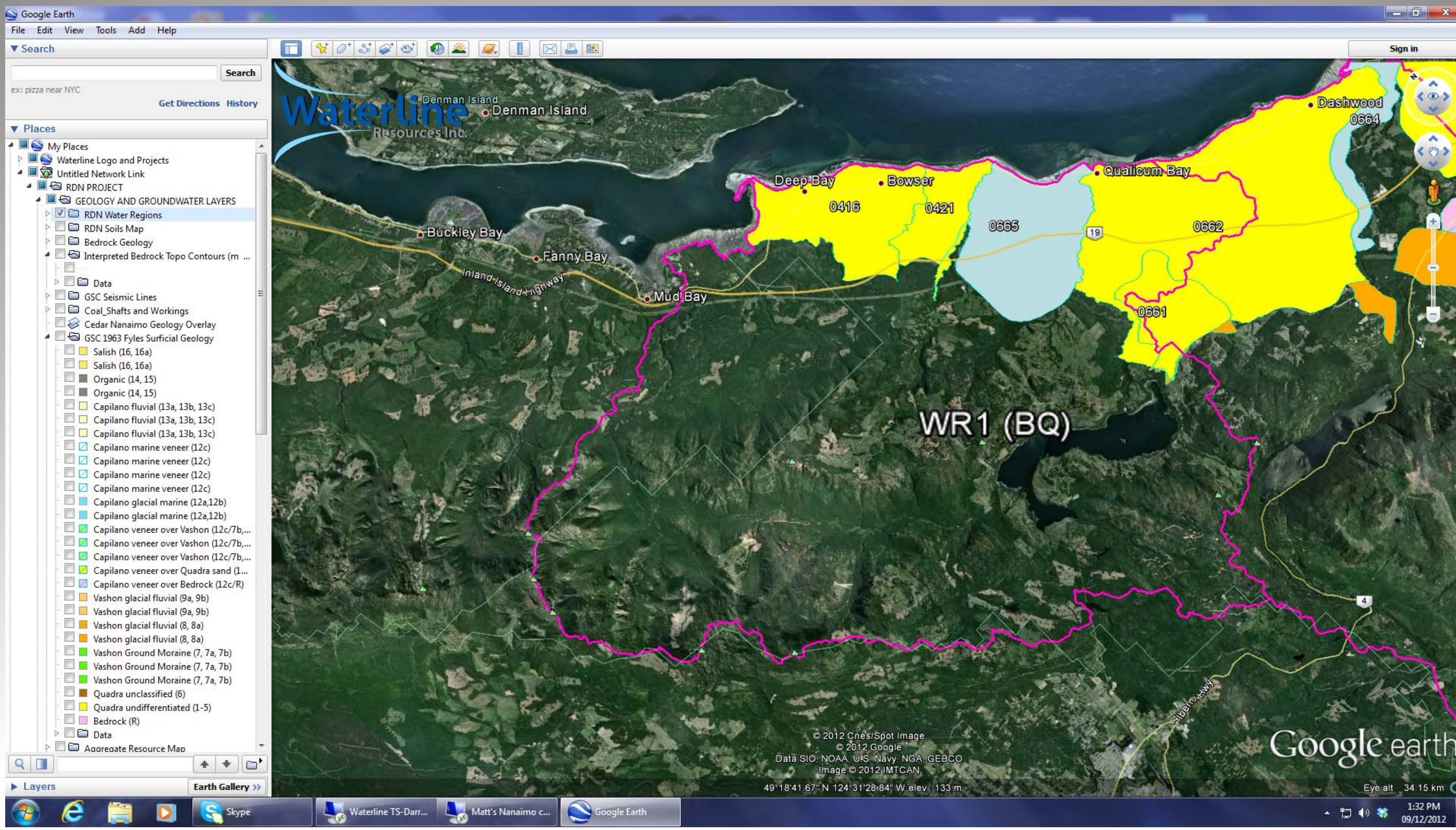
Aquifer Water Budget/Stress – WR1 (BQ)



Aquifer Water Budget/Stress – WR1 (BQ)

Aq #	Lith.	GW-SW interact.	MOE Obs Well	Seas. Fluc.	Long Term / PDO Fluc.	WL Trend (up, down, level)	T. Est. AQ. Rec. (TRin) (Rp/l + Rmb)	Est. Ann Disch. to Cr. & Down Grad. Aquifer (Tc&o out)*	Mun. Qual. B & H. Lk. Imp. Dist. @ Nile Creek (1 Well)	Mun. Qual. B & H. Lk. Imp. Dist @ Thames Cr. (1 Well)	Bowser WW (2 wells)	Deep Bay Imp. Dist. (11 Wells)	Other Private Wells (From RDN Water Use Est. & Zoning) **	T_{out} [T. $C\&O_{out}$ + $ANTH_{out}$	GW Balance (T_{out} / T_{in} x 100%) (Use VS Avail. Rec. = Est. Stress)	Relative Stress Assess.
			ID	(m)	(m)	U/D/L	m^3/yr	m^3/yr	m^3/yr	m^3/yr	m^3/yr	m^3/yr	m^3/yr	m^3/yr	(%)	Lo, Mod, Hi
416	Quad	Ocean	310, 331	2.5	4.4	U	5.1E+06	0.0E+00	---	?	9.2E+04	1.7E+05	5.4E+04	3.11E+05	6	Lo
421	Quad	Ocean, Nile	?	?	?	?	1.7E+06	1.3E+06	?	---	---	---	0.0E+00	1.33E+06	78	Mod-Hi
665	Cap	Ocean, Qual., Nile Cr.	?	?	?	?	9.8E+08	3.3E+08	---	---	---	---	7.0E+00	3.26E+08	33	Lo-Mod
662	Quad	Ocean	?	?	?	?	1.2E+07	4.1E+06	---	---	---	---	6.7E+05	4.81E+06	41	Lo-Mod

Notes: Quad means Quadra Sand Aquifer, Cap means Capilano Aquifer, BQ means Big Qualicum, LQ means Little Qualicum, NA means not applicable, ? Means not available, * means discharge to ocean was ignored, , ** estimated from GIS data for non-service areas, AQ means aquifer, lith mean lithology, GW-SW Interact. means groundwater surface water interaction, Prec. means precipitation, Pump. Inter. means pumping interference, Seas. means seasonal, fluc. means fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, T means total, Est.means estimated, Disc. means discharge, Rec. means recharge , Cr. means creek, O. means ocean, Qual. B. means Qualicum Beach, H.Lk. means Horne Lake, Imp. means Improvement, Dist. means District, Util. means utility, Priv. means private, ANTH mean Anthropogenic.

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Conclusions & Recommendations

- WR1 (BQ):
  - ✓ Aquifers in BQ generally stable and exhibit low-mod stress overall
  - ✓ 4.4 m WL drop in MOE Obs Well in Aquifer 416;
  - ✓ Aquifer 421 Mod-Hi stress and maybe due to significant groundwater discharge to Nile Creek (Supported by conceptual model (Quadra Exposed) and SW & GW Budget Calcs.);
  - ✓ GW levels and use need to be monitored to ensure water demand doesn't exceed recharge and creek flows are maintained at required rates.

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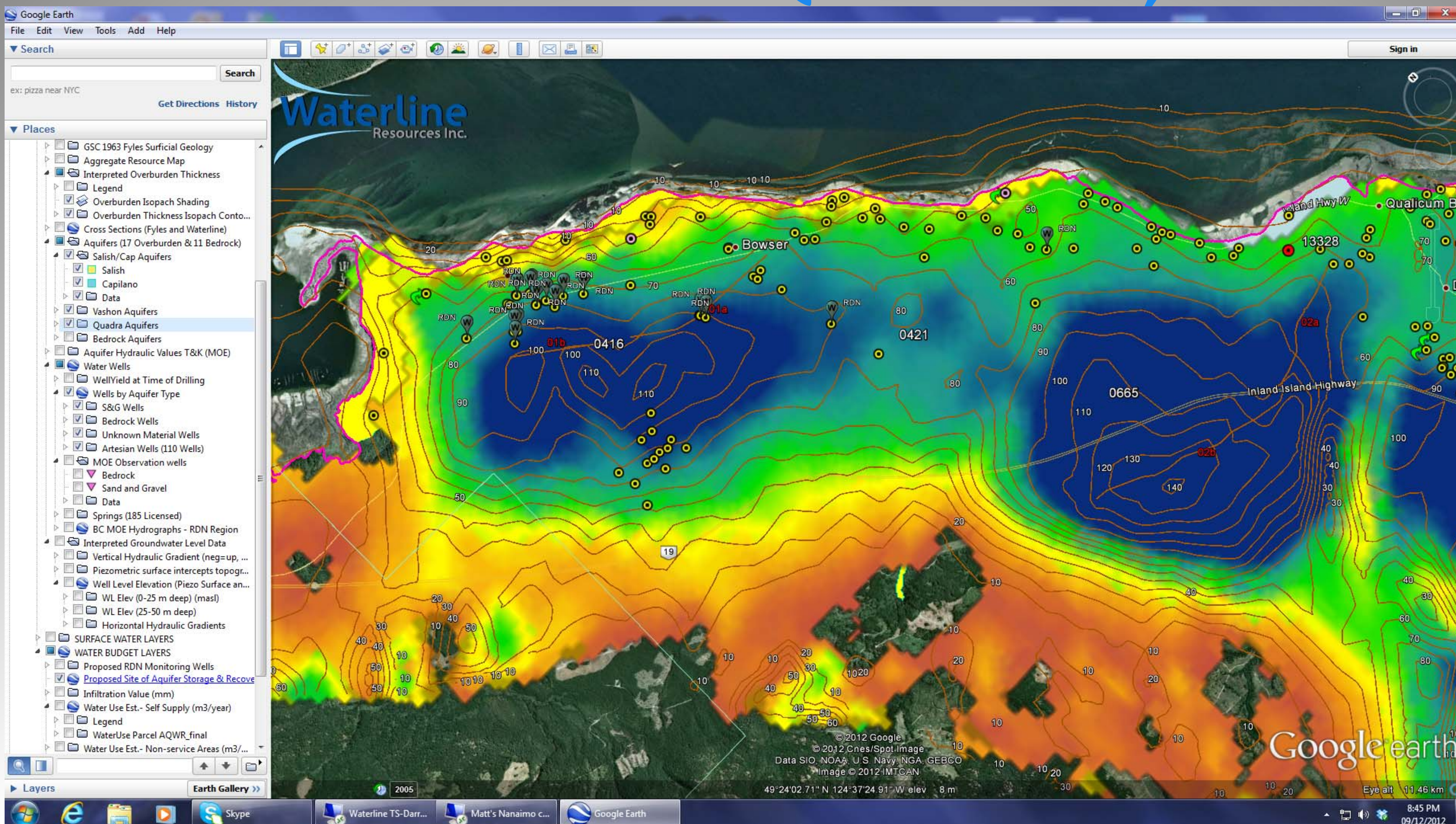
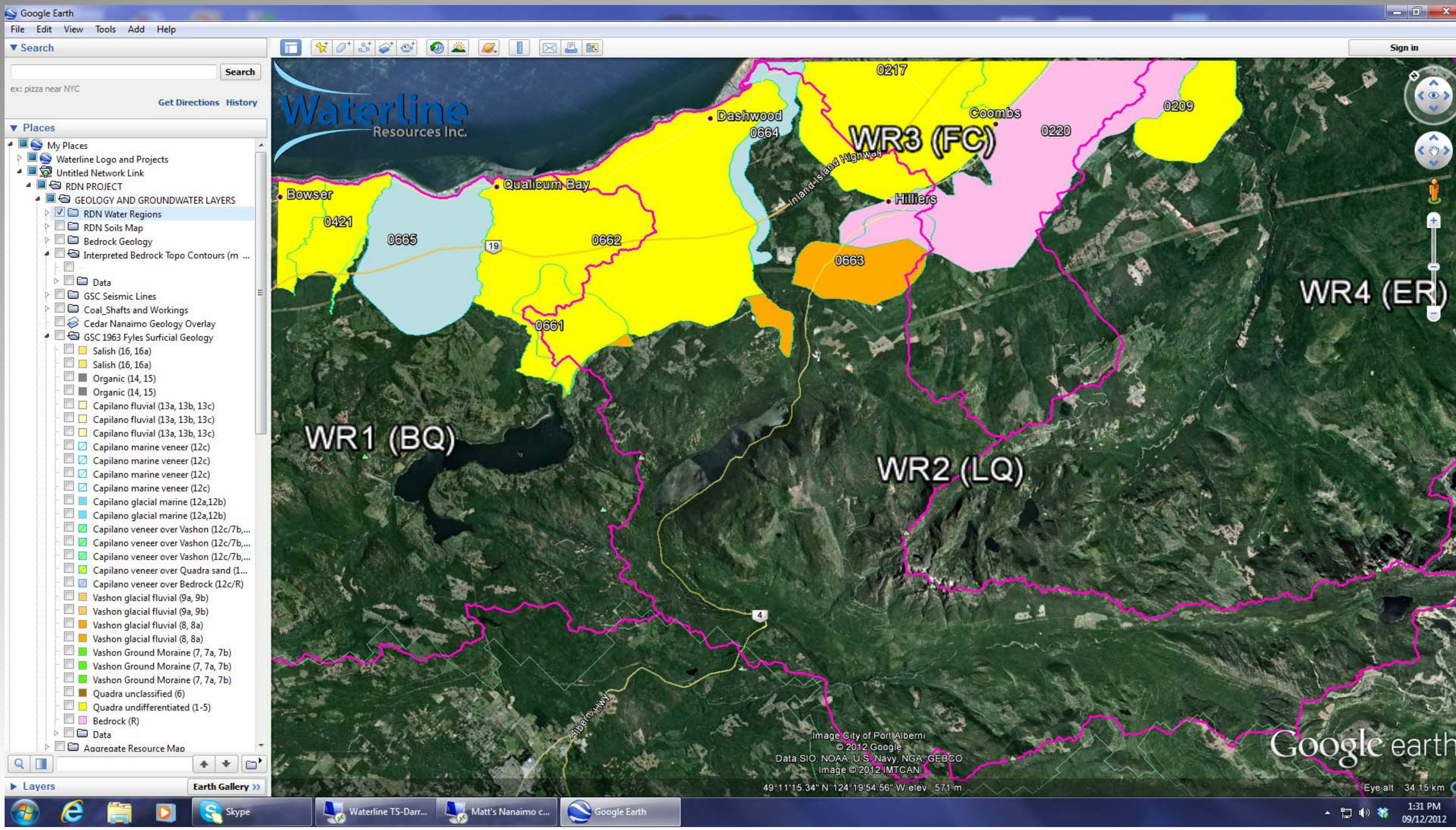
Overburden Thickness Quadra 416, 421 & 665



Aquifer Water Budget/Stress – WR2 (LQ)



12/12/2012

Aquifer Water Budget/Stress – WR2 (LQ)

Aq #	Geo.	GW-SW interact.	MOE Obs Well	Seas. Fluc.	Long Term / PDO Fluc.	WL Trend (up, down, level)	T. Est. AQ. Rec. (TRin) (Rp/l + Rmb)	Est. Ann Disch. to Cr. & Down Grad. Aquifer (Tc&o out)*	T. of Qual. B. (R. Wells Tof Q)	Surfside (2 wells, 37 conn.) (Aq 664)	RDN Melrose Sys. (1 well, 28 Conn.) (Aq. 663)	Whisk. Cr. Water Sys.	LQ Riv. Vill.	West. Estat.	Other Private Wells (From RDN Water Use Est. & Zoning)**	T_{out} [T. $C\&O_{out}$ + $ANTH_{out}$	GW Balance (T_{out} / T_{in} x 100%) (Use VS Avail. Rec. = Est. Stress)	Relative Stress Assess.
			ID	(m)	(m)	U/D/L	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	(%)	Lo, Mod, Hi
662	Quadra	Ocean	391	2.50	0.80	U	3.2E+07	0.0E+00	---	---	---	---	---	---	1.2E+06	1.22E+06	4	Lo
661	Kame	Spider LK, Horne	?	?	?	?	1.9E+07	1.2E+07	---	---	---	---	---	---	4.1E+04	1.17E+07	65	Mod
664	Salish	Ocean, LQ	389	3.00	?	D	3.7E+07	0.0E+00	8.2E+05	1.1E+04	---	---	---	---	5.7E+05	1.39E+06	4	Lo
663	Kame (Vashon Gf) top of Whiskey Cr.	Whiskey Cr., LQ	?	?	?	?	3.8E+07	2.9E+07	---	---	8.0E+03	8.0E+03	3.4E+04	---	5.8E+04	2.92E+07	81	Mod-Hi
217	Quadra	LQ and Ocean	?	?	?	?	7.2E+06	4.9E+06	---	---	---	---	---	---	4.4E+05	5.32E+06	87	Mod-Hi
220	Haslam	Whisky Cr.?	**NA**		**9.1**	**?**	1.1E+06	1.7E+05	---	---	---	---	---	---	4.1E+05	5.77E+05	146	V. Hi

Notes: Quad means Quadra Sand Aquifer, Cap means Capilano Aquifer, BQ means Big Qualicum, LQ means Little Qualicum, NA means not applicable, ? Means not available, * means discharge to ocean was ignored, , ** estimated from GIS data for non-service areas, AQ means aquifer, lith mean lithology, GW-SW Interact. means groundwater surface water interaction, Prec. means precipitation, Pump. Inter. means pumping interference, Seas. means seasonal, fluc. means fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, T means total, Est.means estimated, Disc. means discharge, Rec. means recharge , Cr. means creek, O. means ocean, Qual. B. means Qualicum Beach, ANTH mean Anthropogenic.

Conclusions & Recommendations

- WR2 (LQ):
  - ✓ Kame (Aq. 661) Spider Lk. reported declining levels but no Obs data;
    - WL in aquifer depends on up gradient recharge from Horne Lk.;
    - GSC drilling confirms aquifer is perched and limited extent.
  - ✓ Quadra (Aq. 662) reported declining levels but MOE 391 WL up and stress assessment indicates low;
  - ✓ Haslam (Aq. 220) stress assessment indicates high stress.
    - Reported water level decline (9.1 m over 15+ yrs).....
    - May be related to climate variability affecting recharge and overuse;
    - Larger part of Aq. 220 in upper FC (next),
    - More monitoring and cumulative effects analysis needed to assess well interference.
  - ✓ Kame Aq. 663 water budget indicates its moderately stressed, need Obs well data.

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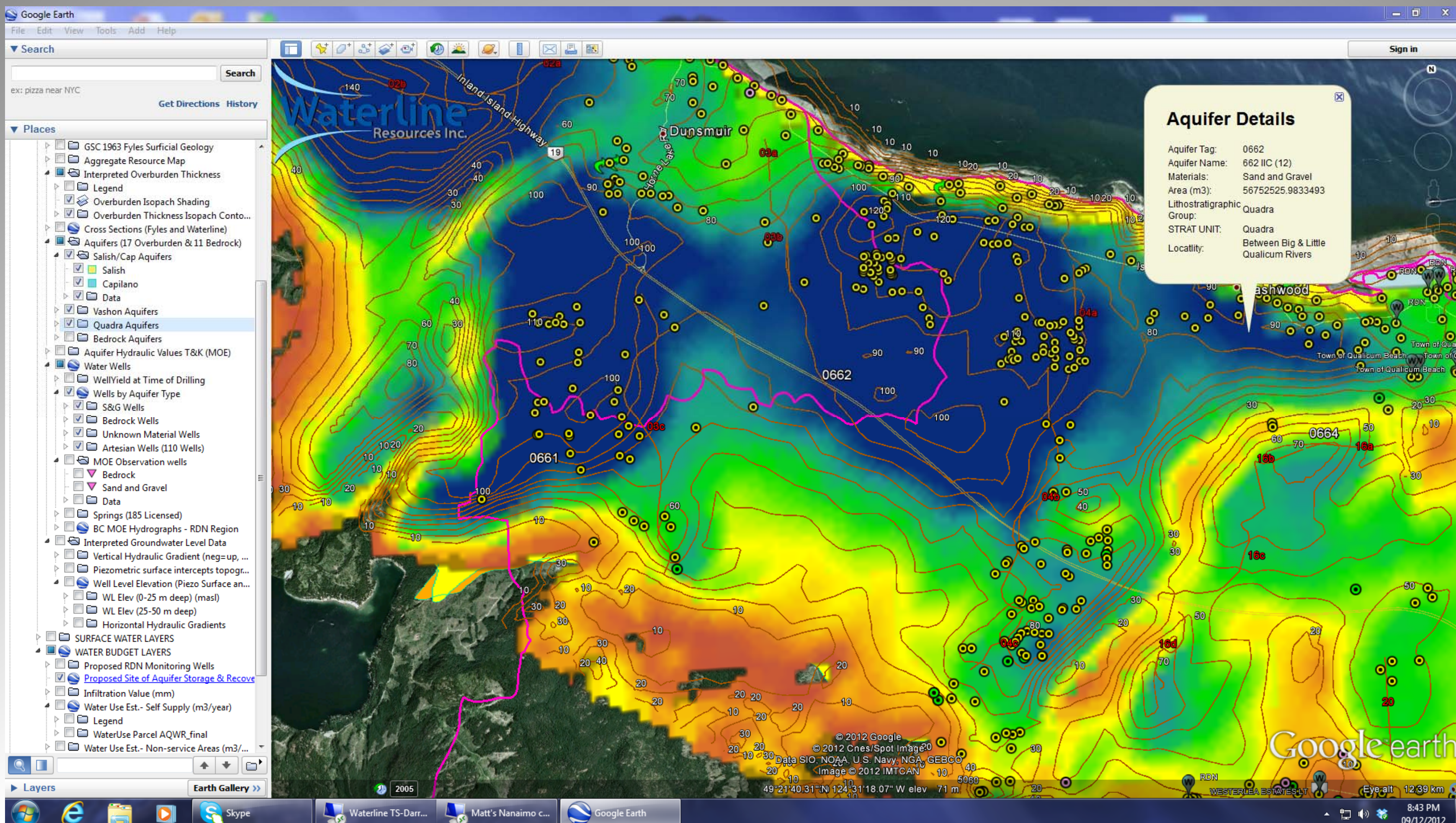
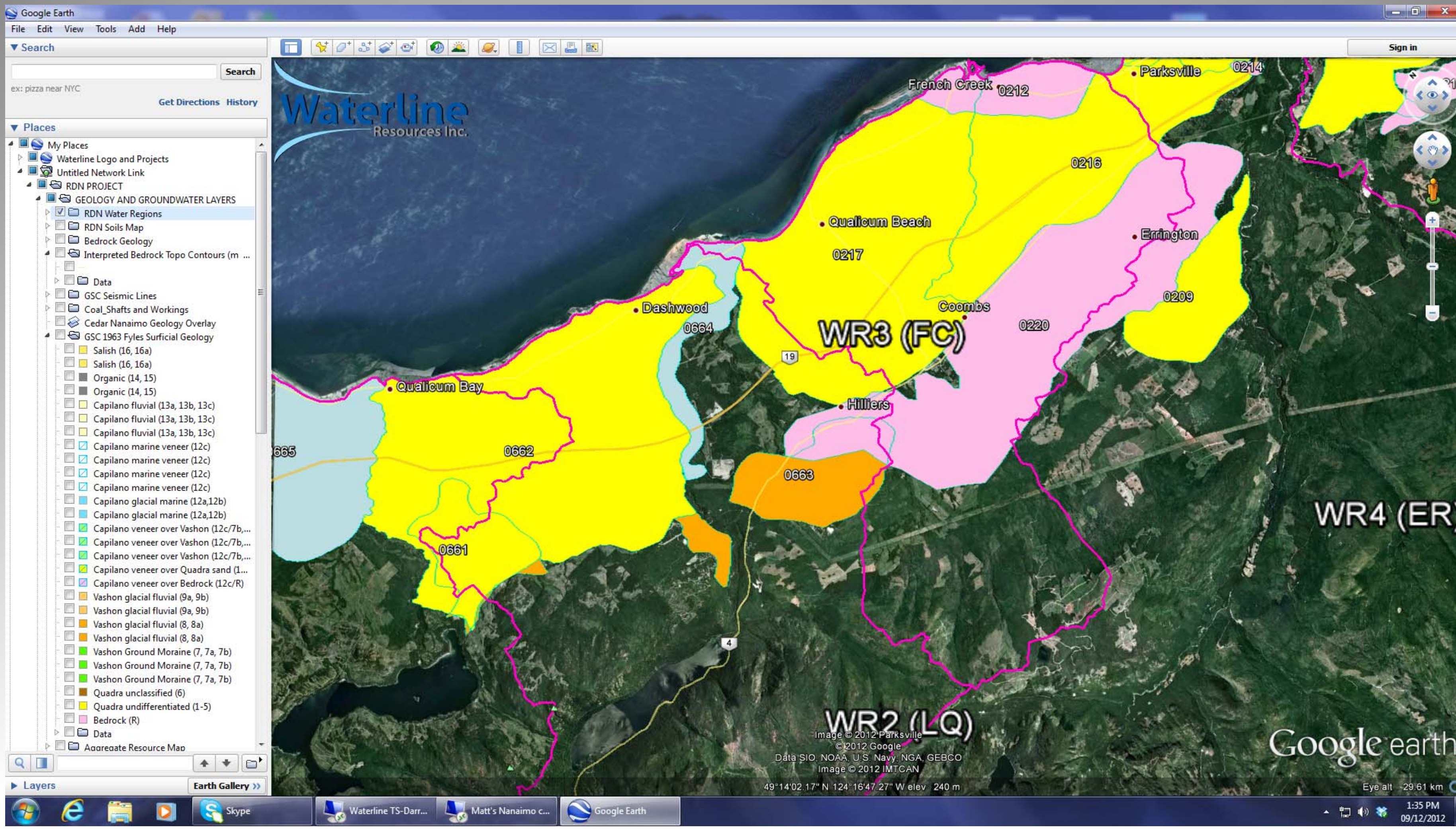
Overburden Thickness - Quadra 661 & 662



Aquifer Water Budget/Stress – WR3 (FC)



Aquifer Water Budget/Stress – WR3 (FC)

Aq #	Geo.	GW-SW interact.	MOE Obs Well	Seas. Fluc.	Long Term / PDO Fluc.	WL Trend (up, down, level)	T. Est. AQ. Rec. (T_{in}) (R_{p}/l + R_{mb})	Est. Ann Disch. to Cr. & Down Grad. Aquifer (Tc&o out)*	Parks ville Spring wood Field (8 wells)	T. of Qual. B. Ber Wick Wells	T. of Qual. B. River Wells	FC Water Sys. (6 wells, 236 conn. in Aq. 217)	Epcor (8 wells)	Epcor (FC Estat.)	Other Private Wells (From RDN Water Use Est. & Zoning**	T_{out} [T. $C\&O_{out}$ + $ANTH_{out}$	GW Balance (T_{out} / T_{in} x 100%) (Use VS Avail. Rec. = Est. Stress)	Relative Stress Assess.
			ID	(m)	(m)	U/D/L	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	(%)	Lo, Mod, Hi
220	Haslam	FC	287		9.1	D	6.4E+06	5.13E+05	---	---	---	---	---	---	2.2E+06	2.69E+06	42	Lo-Mod
216	Quadra	FC	314	1.60	3.60	D/L	4.5E+07	3.79E+07	2.8E+06	NA	NA	NA	2.0E+05	---	1.1E+06	4.52E+07	100	Hi
217	Quadra	FC & O.	321, 325, 303	5	12	D/L	8.3E+06	2.52E+06	---	8.2E+05		8.0E+04	2.0E+05	1.9E+06	1.7E+06	1.10E+07	133	Hi
212	NG	O.	?	?	?	NA	8.8E+05	0.00E+00	---	---	---	---	2.0E+05	---	3.1E+05	5.04E+05	58	Mod

Notes: Quad means Quadra Sand Aquifer, Cap means Capilano Aquifer, FC means French Creek, NA means not applicable, ? Means not available, * means discharge to ocean was ignored, ** estimated from GIS data for non-service areas, Q means aquifer, lith mean lithology, GW-SW Interact. means groundwater surface water interaction, Prec. means precipitation, Pump. Inter. means pumping interference, Seas. means seasonal, fluc. means fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, T means total, Est. means estimated, Disc. means discharge, Rec. means recharge, Cr. means creek, O. means ocean, Qual. B. means Qualicum Beach, ANTH mean Anthropogenic.

Conclusions & Recommendations

- WR3 (FC):
  - ✓ Smallest watershed in RDN and limited catchment for recharge,
  - ✓ GW-SW interactions with FC likely significant (Quadra exposed),
  - ✓ Quadra 217 stressed, 216 slightly less stressed:
    - MOE Obs well indicates 12 m decline in 15 years,
    - Overburden thickness thins and may affect geometry and limit extent of aquifer (216 more pronounced),
    - Dense development with increased water supply demand,
    - Recommend well testing to determine aquifer boundaries, long-term monitoring and cumulative impact assessment,
    - Will require numerical modelling to develop more accurate water budget for development planning.

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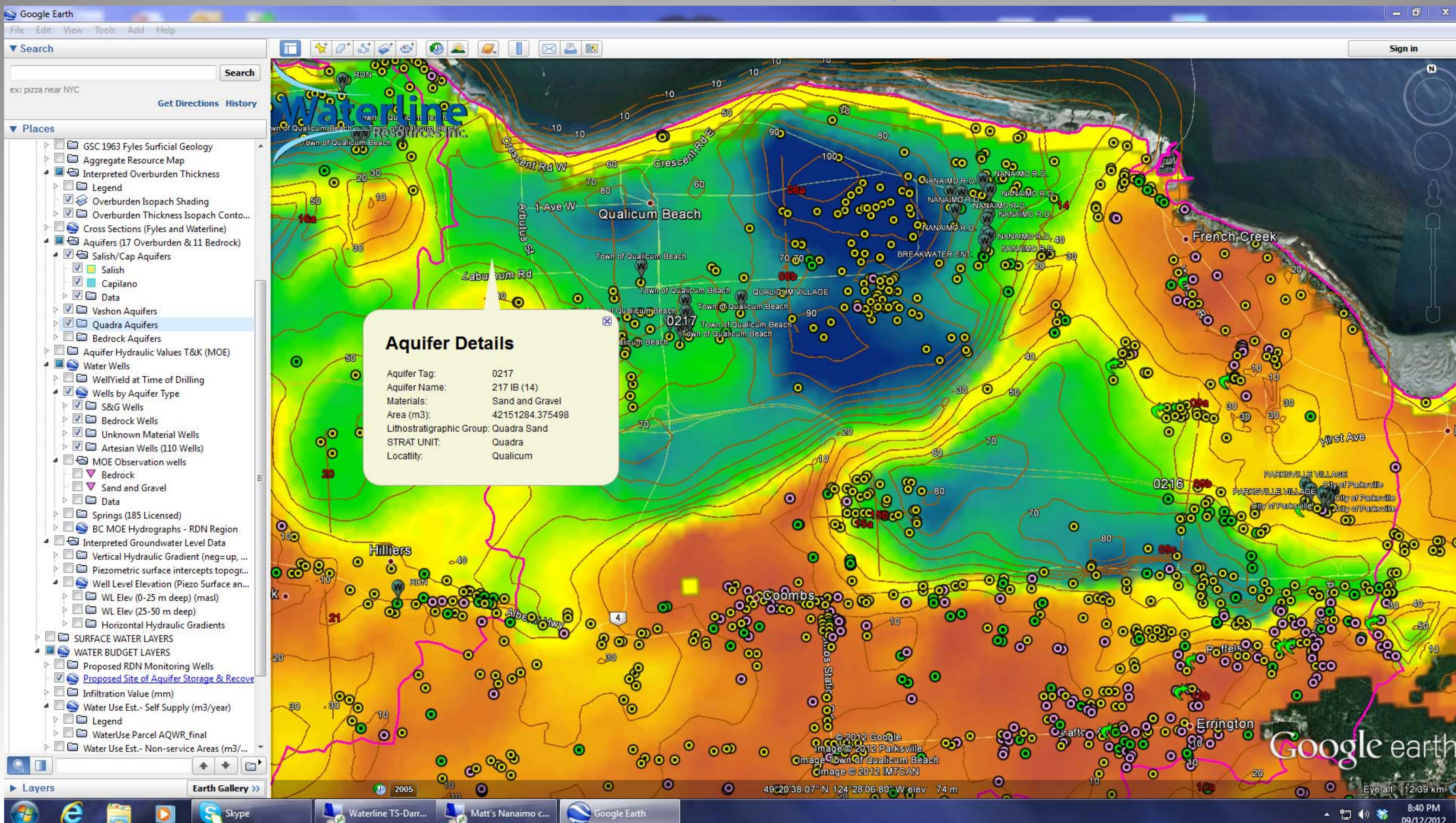
Overburden Thickness Quadra 216 & 217



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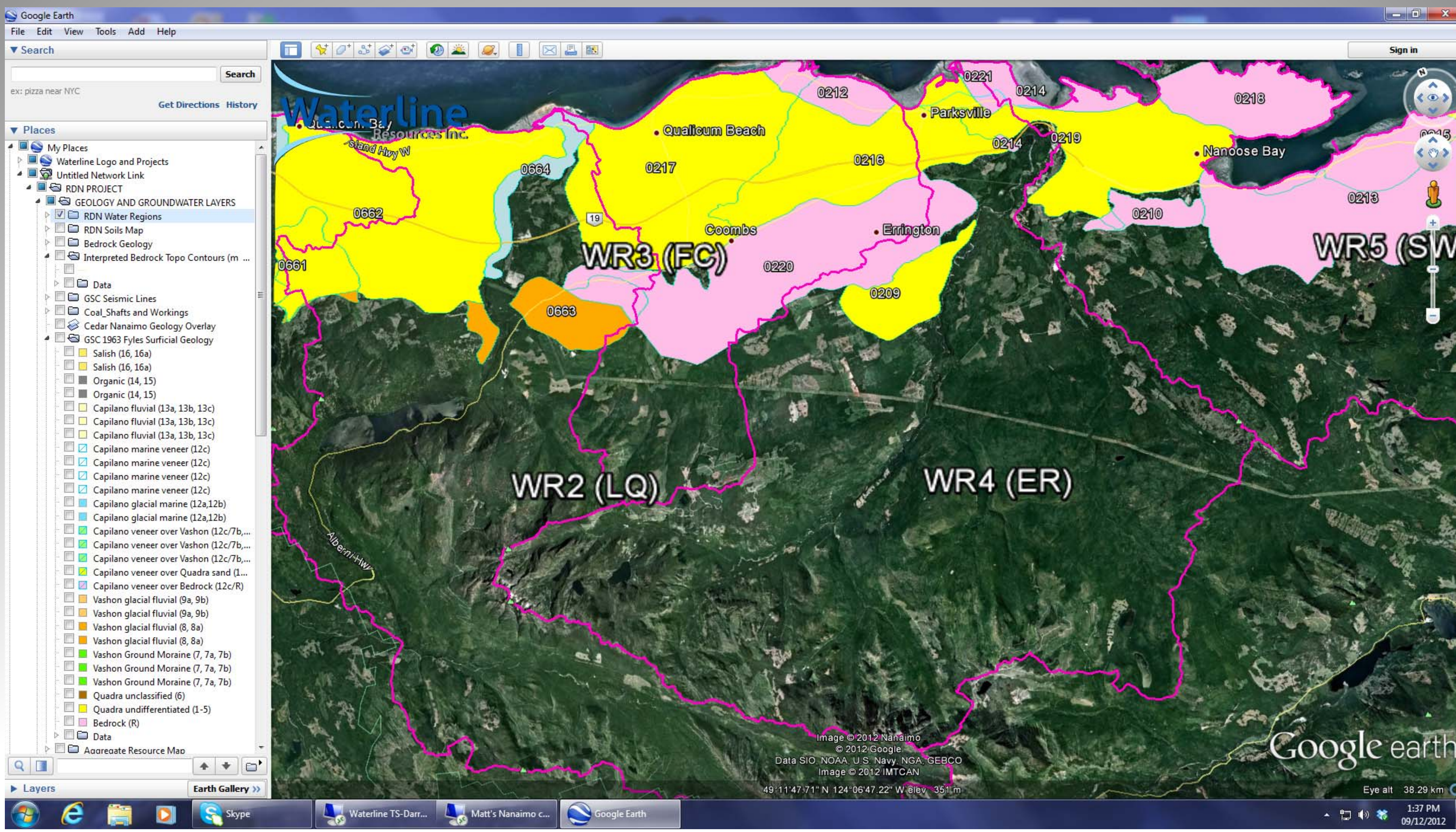
Aquifer Water Budget/Stress – WR4 (ER)



Aquifer Water Budget/Stress – WR4 (ER)

Aq #	Geo.	GW-SW interact.	MOE Obs Well	Seas. Fluc.	Long Term / PDO Fluc.	WL Trend (up, down, level)	T. Est. AQ. Rec. (T_{in}) (R_p/l + R_{mb})	Est. Ann Disch. to Cr. & Down Grad. Aquifer (Tc&o out)*	Parks ville Rail Way Field Aq. 216	San Pareil (4 wells, 280 conn. Aq 214)	Other Private Wells (From RDN Water Use Est. & Zoning	T_{out} [T. C&O_{out} + $ANTH_{out}$	GW Balance (T_{out} / T_{in} x 100%) (Use VS Avail. Rec. = Est. Stress)	Relative Stress Assess.
			ID	(m)	(m)	U/D/L	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	(%)	Lo, Mod, Hi
209	Quadra	Aq. 220	?	?	?	?	2.2E+07	8.67E+06	---	---	1.1E+06	1.84E+07	86	Mod-Hi
220	Haslam	ER	287	?	9.1	D	9.7E+05	1.72E+04	---	---	1.2E+06	1.24E+06	128	Hi
216	Quadra	ER	314, 304, 313	1.60	3.60	D/L	6.0E+06	4.00E+06	?	---	7.6E+05	8.76E+06	145	Hi
219	Quadra	O., ER	?	?	?	?	2.2E+07	6.04E+06	---		8.3E+03	1.81E+07	99	Mod-Hi
214	NG	O.	?	?	?	?	6.2E+05	0.00E+00	---	---	1.4E+05	1.38E+05	22	Lo
221	Salish	O., ER	?	?	?	?	2.9E+05	0.00E+00	---	8.0E+04	9.5E+04	1.75E+05	122	Hi

Notes: Quad means Quadra Sand Aquifer, ER means Englishman River, ? Means not available, * means discharge to ocean was ignored, ** estimated from GIS data for non-service areas, AQ means aquifer, lith mean lithology, GW-SW Interact. means groundwater surface water interaction, Prec. means precipitation, Pump. Inter. means pumping interference, Seas. means seasonal, fluc. means fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, T means total, Est. means estimated, Disc. means discharge, Rec. means recharge, Cr. means creek, O. means ocean, ANTH mean Anthropogenic.

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Conclusions & Recommendations

- WR4 (ER):
  - ✓ Groundwater contribution to ER baseflow appears significant;
  - ✓ Suspect bedrock controls/faulting is major contributor from large upgradient Mountain Block (MBR);
  - ✓ High Stress on Aquifer 216:
    - Dense development with increased water supply demand (Eg: RDN, City of Parksville, Epcor, private wells),
    - Conceptual model indicates overburden thickness thins and may affect geometry and limit extent of aquifer ,
    - Recommend well testing to determine aquifer boundaries, long-term monitoring and cumulative impact assessment,
    - Will require numerical modelling to develop more accurate water budget.

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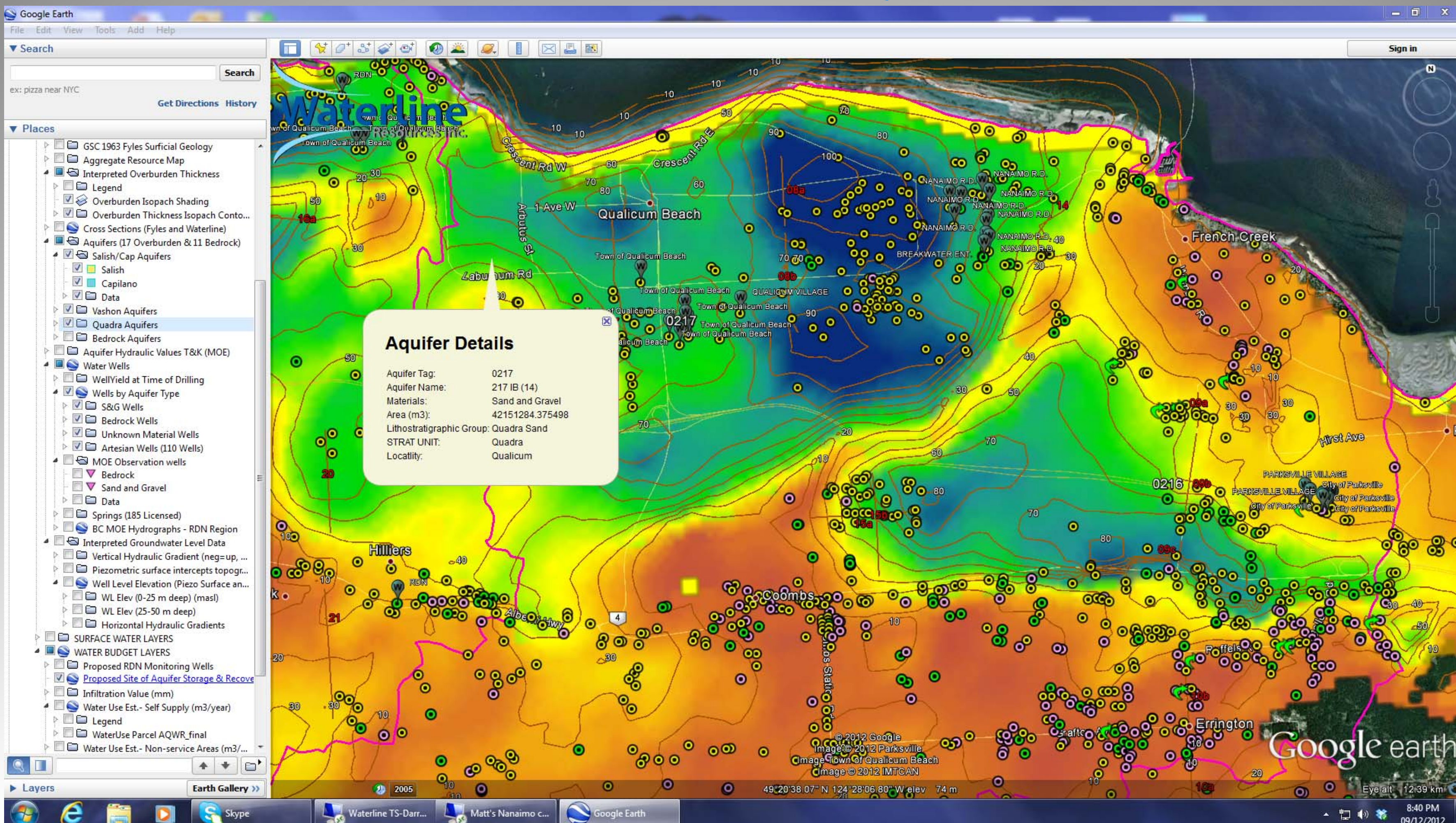
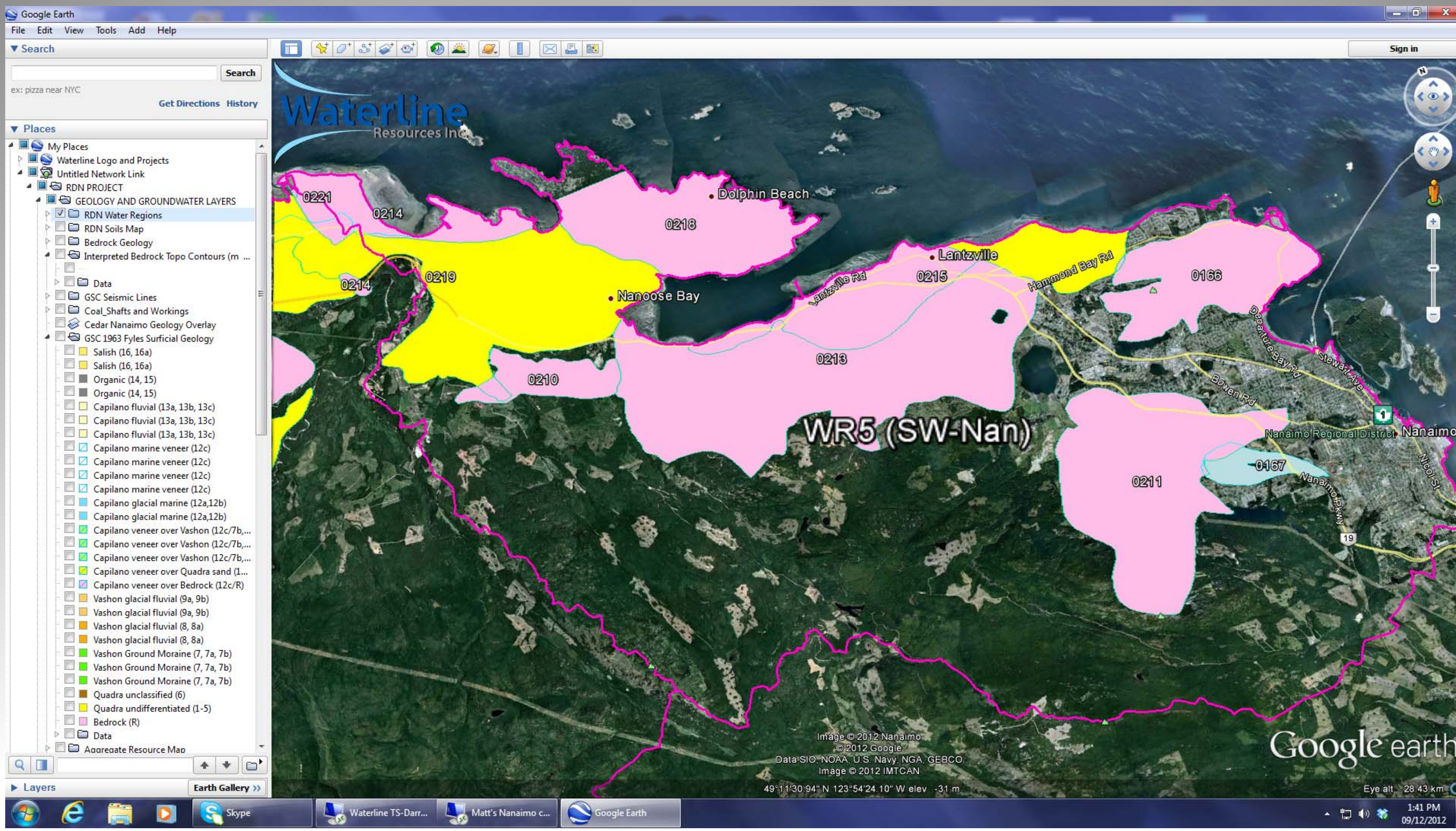
Overburden Thickness Quadra 216 & 217



Aquifer Water Budget/Stress – WR5 (SW-N)



Aquifer Water Budget/Stress – WR5 (SW-N)

Aq #	Geo.	MOE Obs Well	Seas. Fluc.	Long Term Fluc. PDO or Pump.	WL Trend (up, down, level)	T. Est. AQ. Rec. (T_{in}) (R_p/l + R_{mb})	Est. Ann Disch. to Cr. & Down Grad. Aquifer (Tc&o out)*	Lantz Ville (5 wells, Harby Rd)	ER (R.'s Edge), 4 wells, 135 conn.)	Nan. Bay Wat. Ser. (Wall Brook wells).	Nan. Bay Wat. Ser. Madrona Aq 219	Nan. Bay Wat. Ser. (Nan. Fair winds., West bay)	Fair winds Arbut. (Aq 218)	Lantz ville Imp. Dist. (1 ww)	Nan. Res.	Other Private Wells (From RDN Water Use Est. & Zoning**	T.GW Out [Tc&oOut + ANTHout	GW Balance (T_{out} / T_{in} x 100%) (Est. Stress)	Relative Stress Assess.
		ID	(m)	(m)	U/D/L	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	(%)	Lo, Mod, Hi
219	Quadra	392, 393	?	?	L	1.6E+08	1.56E+07	---	5.5E+04	?	1.0E+05	5.8E+04	1.5E+05	---	---	2.4E+06	1.84E+07	11	Lo
214	NG	?	?	?	?	6.2E+05	0.00E+00	---	---	---	?	---	---	---	---	4.4E+02	4.38E+02	0	Lo
210	Buttle Lk. , Fth Lk. Fm, Mt H Gab.	?	?	?	?	3.1E+06	2.45E+06	---	---	---	---	---	---	---	---	3.2E+05	2.76E+06	88	Mod-Hi
218	Benson Fm, IP, VG	394	?	?	?	2.0E+06	4.06E+06	---	---	---	---	---	1.5E+05	---	---	1.2E+05	4.32E+06	212	V. High
213	VG	?	?	?	?	1.4E+07	4.12E+05	?	---	---	---	---	---	?	?	7.2E+05	1.13E+06	8	Lo
215	Quadra	340, 232	1.6, 3.0	5, 7	D/L	6.3E+07	6.05E+07	---	---	---	---	---	---	---	---	4.4E+05	6.09E+07	97	Mod-Hi
166	VG & NG	?	?	?	?	2.2E+06	0.00E+00	0	---	---	---	---	---	---	---	0.0E+00	0.00E+00	0	Lo
211	VG & NG	388	10.0	?	precip	3.8E+06	9.18E+06	---	---	---	---	---	---	---	---	2.3E+06	1.15E+07	306	V. High
167	Cap.	?	?	?	?	3.6E+07	1.77E+07	---	---	---	---	---	---	---	---	0.0E+00	1.77E+07	49	Lo-Mod

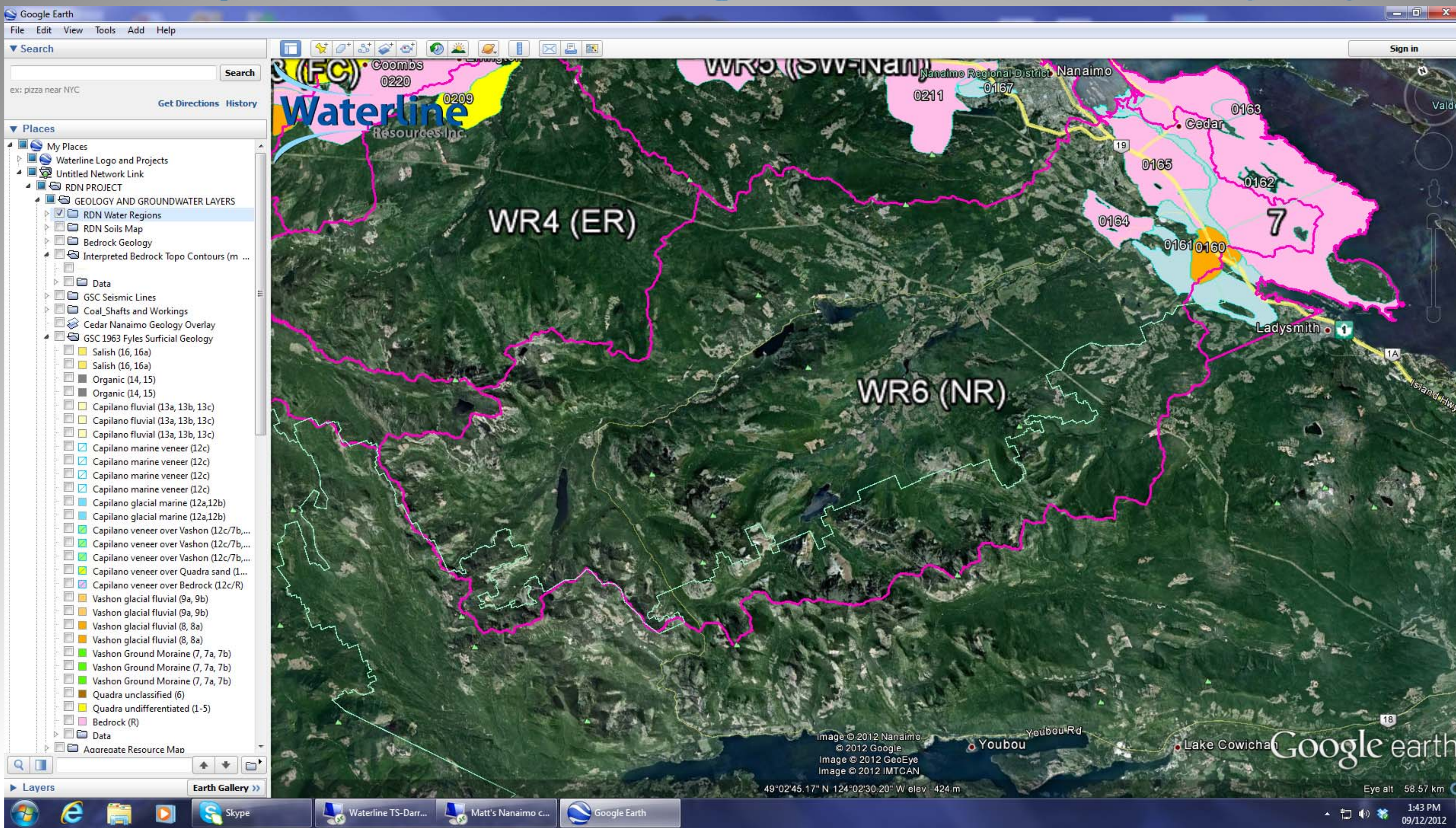
Notes: Quad means Quadra Sand Aquifer, Cap means Capilano Aquifer, SW-N means South Wellington to Nanoose, ? Means not available, * means discharge to ocean was ignored, ** estimated from GIS data for non-service areas, AQ means aquifer, lith mean lithology, GW-SW Interact. means groundwater surface water interaction, Prec. Off. means precipitation offset, Pump. Inter. means pumping interference, Seas. means seasonal, fluc. means fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, T means total, Est.means estimated, Disc. means discharge, Rec. means recharge , Cr. means creek, O. means ocean, ANTH mean Anthropogenic.

Conclusions & Recommendations

- WR5 (SW-N):
  - ✓ NG Aq. 213 reported to be locally stressed (Superior Rd) but not reflected in GW budget due to large size of aquifer.
  - ✓ Benson Fm. Aq. 218, Nan. Peninsula indicating stress:
    - Hydrograph shows tidal influence.
  - ✓ Quadra Aq. 215 Lantzville also stressed;
    - Catchment area is small and little/no MBR,
    - Well to well density high,
    - Recommend well testing, long-term monitoring and cumulative impact assessment.
  - ✓ VG/NG Aq. 211 also showing stress:
    - Located high in watershed with limited catchment for recharge,
    - Many surface water licences diverting aquifer recharge,
    - High well density so well to well interference affecting WL's,
    - Down gradient coal workings may also be a GW sink?
    - Recommend long-term monitoring and cumulative impact assessment.

Overburden Thickness - Quadra 215

Aquifer Water Budget/Stress – WR6 (NR)



Aquifer Water Budget/Stress – WR6 (NR)

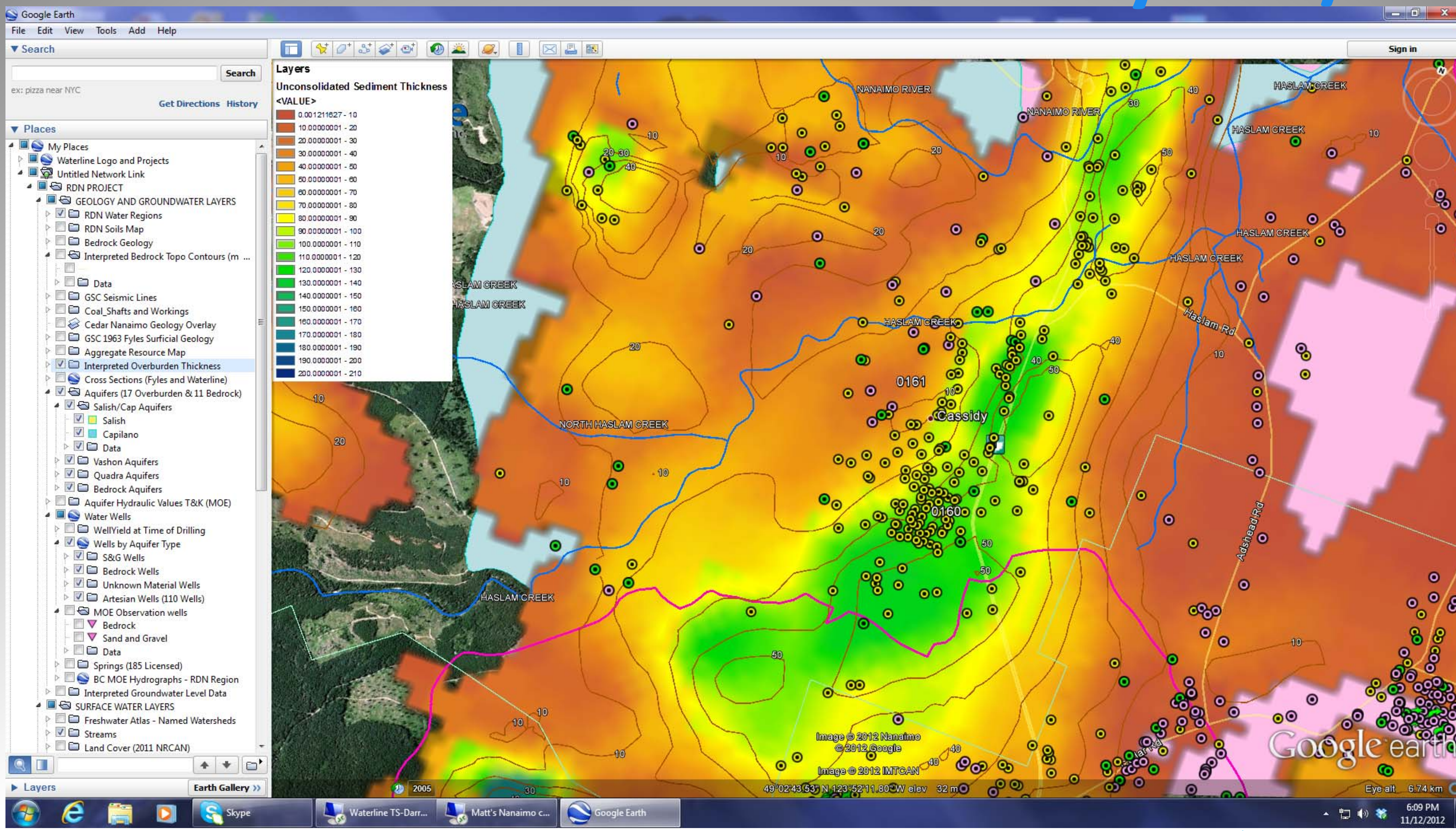
Aq #	Geo.	GW-SW interact.	MOE Obs Well	Seas. Fluc.	Long Term Fluc. PDO or Pump.	WL Trend (up, down, level)	T. Est. AQ. Rec. (T_{in}) $(R_{p/l}$ + $R_{mb})$	Est. Ann Disch. to Cr. & Down Grad. Aquifer (Tc&o out)*	N. Cedar W.W. DIST	RDN De Courcy	Pylades	Sun. First Nation	Nan. Airpt.	Harmac	Other Private Wells (From RDN Water Use Est. & Zoning**	T.GW Out [Tc&oOut + ANTHout	GW Balance $(T_{out}$ / T_{in} x 100%) (Est. Stress)	Relative Stress Assess.
			ID	(m)	(m)	U/D/L	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	m³/yr	(%)	Lo, Mod, Hi
160	Vash.	NR	228	4, 4.5	0	L	1.3E+07	7.84E+06	---	---	---	---	2.7E+03	---	2.2E+06	1.0E+07	80	Mod-Hi
161	Cap.	NR	330, 312	0, 3.5	9, 6	Aban., D/L	1.3E+08	1.05E+08	4.5E+05	---	---	?	2.7E+03	1.8E+07	2.0E+06	1.2E+08	99	Hi
162	NG	NR, O.	337, 315, 390	7, 15	5, 10	D/L	1.3E+07	3.31E+06	---	1.0E+03		---	---	---	1.1E+07	1.4E+07	110	Hi
163	Quad.	O.	?	?	?	?	2.9E+05	1.14E+06	---	---	---	---	---	---	3.1E+05	1.4E+06	502	V.Hi
164	NG	NR	?	?	?	?	1.1E+06	5.05E+03	---	---	---	---	---	---	8.5E+05	8.6E+05	77	Mod-Hi
165	NG	NR	?	?	?	?	3.2E+06	4.13E+05	---	---	---	---	---	---	1.8E+06	2.2E+06	68	Mod

Notes: Quad means Quadra Sand Aquifer, Cap means Capilano Aquifer, NR means Nanaimo River, ? Means not available, * means discharge to ocean was ignored, ** estimated from GIS data for non-service areas, AQ means aquifer, lith mean lithology, GW-SW Interact. means groundwater surface water interaction, Prec. Off. means precipitation offset, Pump. Inter. means pumping interference, Seas. means seasonal, fluc. means fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, T means total, Est. means estimated, Disc. means discharge, Rec. means recharge , Cr. means creek, O. means ocean, ANTH mean Anthropogenic.

Conclusions & Recommendations

- WR6 (NR):
  - ✓ Capilano Aq. 161 (Cassidy) indicates High stress:
    - Aquifer 161 connected to Haslam Creek and NR,
    - Harmac has several high capacity river wells which can affect river base flow seasonally,
    - 1.4 m^3/s critical low flow in late summer and early fall in NR identified by MOE and DFO and therefore need to define minimum head in aquifer 161 to ensure flows are maintained,
    - Moderate density of domestic wells causing cumulative impact,
    - Recommend gauging Haslam Creek, well testing, long-term monitoring and cumulative impact assessment,
    - Numerical modelling needed to refine water budget estimates.
  - ✓ Vashon Aq. 160 (Lr. Cassidy)
    - Moderate to High stress indicated, although not much use,
    - Evidence that Aquifer 161 and 160 are connected,
    - Recommend well testing, long-term monitoring and cumulative impact assessment.

Overburden Thickness – Cassidy 160/161



Conclusions & Recommendations

- WR6 (NR):
  - ✓ Quadra Aq. 163 indicates stress in water budget:
    - Isolated, small aquifer area with limited recharge.
  - ✓ Nanaimo Group Aq. 164 and 165 indicates moderate to high stress:
    - Discharges to NR must be maintained,
    - High well density in a low K aquifer,
    - Recommend well testing, long-term monitoring and cumulative impact assessment.
  - ✓ NG Aq. 162 (Yellow Pt Aq.):
    - Water budget calcs indicates high stress,
    - 10 m WL drop over 10 yrs,
    - Problem related to V. high well density in a low K aquifer with limited recharge,
    - Recommend well testing, long-term monitoring and cumulative impact assessment.

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Data/Knowledge Gaps – Wells DB

- **Mandatory submission of WW logs to MOE database, …..interim measure by RDN:**
  - ✓ Identify possible missing wells using civic addresses on air photo overlay and mapped MOE wells;
  - ✓ Recommend field verification survey with public participation (lead by local groups, Eg: Galiano I.).
- Standards of Practice (hydrogeology):
  - ✓ Require full analysis of pump tests (T, S);
  - ✓ Cumulative effects analysis, well to well interference calculations.

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Data/Knowledge Gaps – GW Monitoring

- Need more MOE/RDN Obs wells with data loggers;
- Regional water level monitoring in private wells;
- Reactivate discontinued Water Survey of Canada gauges;
- Report system needed to track surface water use;
- GW-SW interactions to assess summer baseflow:
  - Multi-level wells, seepage meters, thermal imaging, EC surveys.

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Data/Knowledge Gaps – Water Use

- Need consistent Well ID's and locations for major groundwater users (RDN, Municipal, Private Utility wells)… use WPN and/or WTN;
- Analysis needed on consumptive versus non-consumptive use in non-serviced areas.
- Separate irrigation (recharge) from septic (waste water to ocean) in service areas.

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RDN Priorities – Near Term

- RDN Beta Testing of Waterline System:
  - ✓ Need to deal copyright and privacy issues.
- Consideration for RDN Water Portal:
  - ✓ Construction of secure user interface.
- Consistent Electronic Data Format Input:
  - ✓ Recommend stream keepers, drillers, pump installers, water practitioners be given format for data submission to RDN.

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RDN Priorities – Near Term

- Focus on Areas of stress:
  - ✓ French Creek, Lantzville, Cedar.
- Select 1 or 2 WRs for Tier 1 or 2 Water Budget:
  - ✓ Allows RDN to develop complete template for Water Management Planning in all Water Regions;
  - ✓ Select area in Nanaimo Lowland so that numerical modelling by GSC can refine aquifer water budget estimates (ie: French Creek?).

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RDN Priorities – Medium Term

- Other important potential data sources:
  - ✓ Septic suitability studies;
  - ✓ Geotechnical investigations;
  - ✓ Contaminant/environmental investigations;
- Remote Sensing Data (Land Cover & LAI)
  - ✓ Phase 1 RDN Water Budget study accurate to 1 km^2;
  - ✓ Possible to get 10 m^2 accuracy;
  - ✓ Improves knowledge of significant recharge areas.
- LIDAR Data

Questions?