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Regional Climate and Hydrometric Monitoring Network Scoping Study

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Prepared for:

Regional District of Nanaimo

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Executive Summary

One of the goals identified in the Regional District of Nanaimo's (RDN) Drinking Water and Watershed Action Plan (Action Plan) is to:

> *Improve information about the Region's water resources in terms of both quality and quantity, in support of better land use decisions and public understanding.*

To meet this goal, the Action Plan recommends implementation of a Water Resource Inventory and Monitoring Program. In addition, the RDN Regional Water Budget Phase 1 project completed in 2013 recommended collection of additional climate and hydrometric data at key location to fill identified data gaps to better understand available surface and ground water resources. The purpose of this study is to move beyond the general recommendation of these plans and to identify, prioritize locations and identify potential partnerships to support additional climate and hydrometric (streamflow) stations within the region to improve the existing climate and hydrometric monitoring networks.

Some of the key purposes for collection of climate and hydrometric data include:

- Assessment of available surface water and ground water supplies for land development and community planning
- local watershed scale hydrological evaluations for habitat conservation measures, design of water supply or other development;
- interpreting water quality data to provide estimates of total loading rather than only concentrations of pollutants;
- design flood estimates and rainfall intensities for drainage, stream crossings or flood protection design;
- operational hydrology for seasonal water supply forecasting,
- flood forecasting and warning,
- watershed health tracking,
- fire weather monitoring (for forestry operations and forest fire safety),
- baseline monitoring for climate change impact assessment; and
- other currently unknown future uses.

Currently, the climate and hydrometric monitoring stations in the region are operated by a variety of agencies and stakeholders, ranging from Federal and Provincial Government to local Stewardship groups. The currently active stations in the RDN include:

- Twelve hydrometric stations
  (most of which are on regulated streams and are used for monitoring of water supplies)
- Seventeen climate stations
  (most of which are located along the coastal lowlands at elevations below 200 m)
- Two active snow monitoring sites
  (one automated snow pillow and one manual snow course)

Through review of the currently available hydrometric and climate data key gaps have been identified in the network, most notably:

- a lack of hydrometric data for smaller coastal watersheds, smaller mountain headwater streams and larger natural or unregulated watersheds;
- a gap in the coastal climate monitoring network in the Nanoose region and on Gabriola Island as well as limited climate data available in the mountain headwater region (above elevation 200 m); and
- a lack of continuous snow data in the central and northern portion of the region.

Although the RDN has a reasonably good network of existing monitoring stations which provide sufficient data to assess region wide water availability, the lack of data at the key locations identified limits the ability to predict available water supplies at local scales. The following tables outline the recommended sites:

Recommended Hydrometric Stations

Watershed	Priority$_1$	Potential Partner$_2$	Comments
Primary Permanent Baseline Stations (on-going long term operation)			
French Creek	**First (Continuous)**	WSC/Friends of French Creek/BCCF/DFO (Seasonal since 2014)	Establish year-round continuous station. High surface and groundwater stress French Creek watersheds
Nanoose Creek	**First**	WSC	Baseline Station for Nanoose Area/High Surface Water Stress and Mod-Hi Ground Water Stress region
Haslam Creek	**First**	WSC	Baseline Station for southern RDN watersheds/moderate-high stress aquifers. Historical WSC gauge station. Nanaimo Airport Precipitation.
Goodhue Creek	**Second**	WSC or local Stakeholder Group	Baseline Station for Gabriola Island surface water balance.
Thames Creek	**Third**	NCES or other Stakeholder Group	Baseline station for lowlands watersheds in northern RDN.
Cameron River	**Third**	WSC	Upper Elevation Mountain watershed for assessment of high elevation runoff in region
Secondary Short Term or Seasonal Stations (operate for two or three years)			
Morningstar Creek	**First**	BCCF or other	Review surface water availability for High Groundwater Stress region
Hokkanen Creek	**First**	BCCF or other local stewardship group	Review surface water availability for High Groundwater Stress region
Kinkade Creek	**Second**	BCCF, NCES or other	As part of groundwater/surface water study for Spider/Illusion Lakes
Annie Creek	**Second**	BCCF, NCES or other	As part of groundwater/surface water study for Spider/Illusion Lakes.
Whiskey Creek	**Second**	BCCF or other	Review surface water availability for Mod-High Groundwater stress
Morrison Creek	**Second**	BCCF or MVIHES	Review surface water availability for Mod-High Groundwater stress

In addition to the longterm and secondary short-term hydrometric stations outlined above, several smaller streams within municipalities have been identified for streamflow measurement to track watershed health.

Recommended Climate Stations

Location	Priority1	Potential Partner2	Comment
Nanoose Climate Station	**First**	RDN	Provide climate data for Nanoose/Fairwinds areas
Gabriola Island Climate Station	**First**	RDN/Gabriola Volunteer Fire Department	Provide Climate Data for Gabriola/Mudge DeCourcy Island Water Region
Mt Cokeley/Mt Arrowsmith Automated Snow Pillow	**First**	Parksville/AWS/DFO/MFLNRO/ MABRRI	Snow Pillow to collect snow data for Cameron River and Englishman River watersheds
Upper Little Qualicum/ Cameron River Watershed	**Second**	MoTI (Climate Station on Highway 4)/ Island Timberlands	Additional Data for western portion of region with high annual rainfall
Horne Lake or Cameron Lake Climate Station	**Second**	DFO	Additional Collect data in highland/plateau region and to assist with forecasting for Storage at Horne Lake and Cameron lake
Upper Qualicum Watershed	**Third**	Unknown	Additional Data for northwestern portion of region with high annual rainfall
Upper Nanaimo River Watershed/ Fourth Lake Dam/Labour Day Lake	**Third**	Harmac/Timberwest/Island Timberlands	Additional Data for western portion of region with high annual rainfall

Note: 1 - **First Priority** implement within 1 to 2 years, **Second Priority** implement within 5 years, **Third Priority** implement after 5 years.
2- Potential partner (capital funding, operation, in-kind, etc) identified for initial discussion with regard to station installation (AWS- Arrowsmith Water Service, BCCF – BC Conservation Foundation, DFO – Department of Fisheries and Oceans, MABRRI – Mt Arrowsmith Biosphere Reserve Research Institute, MoTI – Ministry of Transportation and Infrastructure, MFLNRO – Ministry of Forest, Lands and Natural Resource Operations, MVIHES – Mid Vancouver Island Enhancement Society, NCES – Nile Creek Enhancement Society, RDN – Regional District of Nanaimo, WSC- Water Survey of Canada

The capital cost for installation of hydrometric and climate station range based on specific site conditions (site access, power supply, site preparation, etc). However, typical costs are:

Hydrometric stations	$15,000 to $25,000
Climate Stations	$13,500 to $35,000
Automated Snow Pillow	$40,000 to $60,000

On-going maintenance cost for stations also varies but is typically between $10,000 to $20,000 depending on site access and complexity of the station.

Section 1

Introduction

1. Introduction

1.1 Introduction

Kerr Wood Leidal Associates Ltd. (KWL) was retained by the Regional District of Nanaimo (RDN) to complete the following scoping study for a hydrometric and climate monitoring in the region. The goal of the scoping study is to provide a framework for a regional hydrometric and climate monitoring network expansion as part of implementation of the RDN Drinking Water and Watershed Protection (DWWP) Action Plan (Action Plan). Collecting, cataloguing and distributing information on water quantity and water quality is one of the seven key programs to be implemented as part of the Action Plan. The goal of Water Resource Inventory and Monitoring (Program 2 of the Action Plan) is to:

> *Improve information about the Region's water resources in terms of both quality and quantity, in support of better land use decisions and public understanding.*

The monitoring network is also key in supporting other programs outlined in the Action Plan including public education and awareness (Program 1), watershed management planning (Program 3), water quality management (Program 6) and climate change adaptation (Program 7)

In addition to the programs outlined in the Action Plan, the Regional District of Nanaimo Water Budget Study – Vancouver Island (Water Budget) prepared in June 2013 recommended implementation of a regional surface water quantity monitoring program. The Water Budget study identified collection of additional baseline data as one of the data gaps that would need to be filled to support future detailed surface water and ground water modelling for higher risk watersheds and aquifers.

The purpose of this study is to move beyond the recommendations in the RDN Water Budget Project. This involves a review of potential for the Regional Network to collect both baseline data for future phases of the Water Budget Project as well as a wider regional hydrometric and climate data program to fulfill the needs of the broader community and stakeholders. In addition, a systematic framework has been developed to assist with prioritizing the stations and to consider capital and on-going costs.

1.2 Project Scope

The purpose of this Regional Hydrometric and Climate Network Scoping Study is to:

- Develop overall goals and objectives for a regional hydrometric and climate monitoring network in the context of the Action Plan, the Water Budget Study and other regional strategic plans;
- Develop a framework to assess potential monitoring sites in relation to these goals and objectives;
- Recommend hydrometric and climate data standards to be used in the network;
- Prepare a ranked list of monitoring sites (including both existing and proposed sites) using the framework;
- Develop an implementation plan for the network focused on the highest ranked locations including budget estimates for installation, on-going maintenance and training requirements; and
- Identification of potential stakeholder involvement and partnerships to support on-going monitoring program.

1.3 Project Team

The members of the project team for this study are:

Regional District of Nanaimo

Mike Donnelly, Manager of Water Services

Julie Pisani, Drinking Water and Watershed Protection Program Co-ordinator

Kerr Wood Leidal Associates Ltd.

Craig Sutherland, P.Eng. - Project Manager/Project Engineer

David Sellars, P.Eng – Senior Technical Review

1.4 Acknowledgements

The project team would like to thank the members of the Regional Hydrometric and Climate Monitoring Working Group technical advisory committee for their input and guidance, including:

Rosie Barlak, Ministry of Environment

Linda Brooymans, Mt Arrowsmith Biosphere Reserve Research Institute

David Campbell, River Forecast Centre

Tony Cheong, Ministry of Environment

Chris Cole, Timberwest

Brian Epps, Ministry of Forest Lands and Natural Resource Operations

Ken Epps, Island Timberlands

Kristen Fagervik, Ministry of Transportation and Infrastructure

Bill Floyd, Ministry of Forest Lands and Natural Resource Operations

Alan Gilchrist, Vancouver Island University

Neil Goeller, Ministry of Forest, Lands and Natural Resource Operations

Russ Greogory, Water Survey of Canada

Heather Johnstone, Ministry of Environment

Peter Law

Rob Mathewson, Water Survey of Canada

Bill Sims, City of Nanaimo

Mike Squire, City of Parkville/Englishman River Water Service

Fred Spears, District of Lantzville

Shawn Stenhouse, BC Conservation Foundation

Gilles Wendling, GW Solutions

Section 2

Hydrometric and Climate Network

2. Hydrometric and Climate Monitoring Network

2.1 Need for Hydrometric and Climate Monitoring

As outlined in the Action Plan, the primary focus of the proposed regional hydrometric and climate monitoring network is to support the goals and objectives of the Action Plan with regard to the actions related to the Regional Water Inventory and Monitoring goals. In addition, the network should provide baseline data for future phases of the Regional Water Budget Project. The baseline data will be used in the future for surface water and groundwater modelling to better understand surface water/ground water interaction in higher risk watersheds in the region.

Most importantly from the RDN perspective is having good quality surface water data through which information regarding water availability can be assessed for land use planning and land development approvals.

In addition to RDNs specific identified goals for quantifying impacts to water resources with respect to land use planning, the regional hydrometric and climate monitoring network could also provide information to support a variety of other purposes which could include:

1. local watershed scale hydrological evaluations for habitat conservation measures, design of water supply or other development;
2. interpreting water quality data to provide estimates of total loading rather than only concentrations of pollutants;
3. design flood estimates and rainfall intensities for drainage, stream crossings or flood protection design;
4. operational hydrology for seasonal water supply forecasting,
5. flood forecasting and warning,
6. watershed health tracking,
7. fire weather monitoring (for forestry operations and forest fire safety),
8. baseline monitoring for climate change impact assessment; and
9. other currently unknown future uses.

Hydrometric and climate monitoring networks are often designed to support a specific purpose. However, the RDN network is intended to serve as a baseline network which could support the wide variety of purposes listed above in the future. Therefore, the network design will have to reflect the variation in climatic and hydrologic conditions across the region but at the same time provide sufficient good quality data at key locations to assist the RDN with their primary goal of assessing water impacts from land use planning.

The purpose of this study is to provide a framework to select appropriate locations for hydrometric and climate monitoring stations which can support the goals of the Action Plan and the recommendations from the Regional Water Budget Study Phase 1. At the same time, the network design must consider both the capital cost limitations of installing stations, the logistical constraints of sites (such as access for maintenance) to limit on-going operation and maintenance costs and potential partnerships with other agencies or stakeholders to support on-going costs and operation.

2.2 Existing Hydrometric and Climate Monitoring Networks

Currently, there are several sources of hydrometric and climate data across the RDN. These come from Federal, Provincial and Local Government as well as from industry. The available data sources across the region are listed below.

Hydrometric Data

- Water Survey of Canada
- Department of Fisheries and Oceans
- City of Parksville/Englishman River Water Service
- City of Nanaimo
- BC Conservation Foundation
- Harmac

Climate Stations

- Environment Canada
- BC Ministry of Environment
- BC Ministry of Forest Lands and Natural Resource Operations
- BC Ministry of Transportation and Infrastructure
- City of Parksville
- City of Nanaimo
- Timberwest
- Island Timberlands (still to be confirmed)
- School Climate Monitoring Network (developed by University of Victoria and supported by Vancouver Island School Districts)

Maps showing the locations of the existing active and discontinued stations are shown in Figure 1-1 and Figure 1-2, respectively. Although there is a good network of existing data, there are still key gaps in the existing data set which will require installation of new climate stations or hydrometric stations.

Hydrometric Monitoring

Hydrometric monitoring in BC has traditionally been undertaken by the Water Survey of Canada (WSC) through the BC/Canada Agreement. The WSC operates an "integrated" program that includes a network of about 450 stations across the province. Most of the WSC operated stations serve the needs of a large number of organizations sharing the use of common data. The number of stations in BC has dropped from around 800 in the 1980s and a good portion of the ongoing historical data record has been lost. International standards would estimate the required size of the hydrometric network in BC to be in the order of 1200-1500 stations. Much of the Provincial attention on flow monitoring is related to flooding on large river systems where significant infrastructure (such as highways and hydro facilities) and public safety are at risk.

Within the RDN, the WSC continues to operate seven hydrometric stations of which three are located in the Nanaimo River watershed. These are located predominantly on larger watercourses and often in relation to operation and monitoring of water resource management systems. For instance, two WSC gauges within the Nanaimo River watershed are used to monitor conservation flows downstream of the Jump Creek Reservoir, used by the City of Nanaimo for municipal water supply and the Nanaimo Lakes reservoirs used by Harmac for industrial process water.

Many of the WSC stations are operated in partnership with other organizations. For instance, the Arrowsmith Water Service supports on-going operation of the Englishman River near Parksville Gauge (08HB002) while the City of Nanaimo supports on-going operation of the Millstone River at Nanaimo (08HB032).

Water survey of Canada data can be accessed via the following link:

http://www.ec.gc.ca/rhc-wsc/

Climate Monitoring

In British Columbia, climate monitoring is undertaken by a wide range of government agencies and industry. The data is used for many purposes ranging from long term monitoring of climate trends for climate change assessment to providing information on initial watershed conditions for operation forecasting such as flood forecasting, water supply forecasting or fire weather forecasting.

One of the key sources of climate data is the Climate Data Portal developed by the Pacific Climate Impacts Consortium (PCIC). This program provides a single portal to access data from a range of agencies including Environment Canada, Ministry of Forest, Lands and Natural Resource Operations, Ministry of Transportation and Infrastructure, Ministry of Agriculture, Ministry of Agriculture, Rio Tinto Alcan and BC Hydro. Much of the data relating to current climate stations within the RDN has come from this source. It can be accessed via the following link:

http://www.pacificclimate.org/data/bc-station-data

Snow Monitoring

Snow and snow pack monitoring stations within the region are operated by the Provincial Snow and Groundwater Survey and the data is reported by the River Forecast Center. The data can be found here:

http://bcrfc.env.gov.bc.ca/data/index.htm

Water Quality Monitoring

Although the focus of this scoping study is surface water quantity, one of the goals of the Regional Water Resource Inventory and Monitoring Network is to collect, catalogue and distribute regional water quality data. The RDN are currently implementing a regional water quality monitoring program, the Community Watershed Monitoring Network which engages and trains local stewardship groups to collect water samples at key locations on streams throughout the region. This data will become part of the Regional Water Resource Inventory and Monitoring program.

Ground Water Monitoring

The scope of this study is to review surface water monitoring and climate network. However, groundwater monitoring is also a key component in understanding of the regional water resources. The key source of groundwater data is the Provincial Groundwater Observation Well network. This data can be accessed via the following link:

http://www.env.gov.bc.ca/wsd/data_searches/obswell/map/

Sixteen BC Observation Wells within the RDN have been added to the network since 2011 through a partnership between the DWWP program and the MFLNRO, enabled by grant funding. There are also volunteer observation wells (private residential wells) that are being monitored in the RDN. For more information see www.dwwp.ca

Figure 2-1: Locations of Existing Active Climate and Hydrometric Stations

Regional District of Nanaimo - Drinking Water and Watershed Protection

Climate Legend (See below for Parameters)

- City of Parksville Climate Station
- City of Nanaimo Climate Station
- BC MoE - Air Quality
- Environment Canada - Climate Station
- BC MFLNRO - Snow Course
- BC MFLNRO or Timberwest - Fire Weather Climate Station
- BC MoTI - Climate Station
- School Climate Monitoring Sites (Hourly Temp., Rain, Wind, Humidity)

Climate Station Parameters Description:
HW - Hourly Wind
HT - Hourly Temperature
HP - Hourly Precipitation
HRh - Hourly Relative Humidity
HAtm - Hourly Atmospheric Pressure
DT - Daily Temperature
DP - Daily Precipitation
DR - Daily Rain
DS - Daily Snow Depth
DSWE - Daily Snow Water Equivalent
DHr - Daily Relative Humidity
MS - Monthly Snow Depth
MSWE - Monthly Snow Water Equivalent

Hydrometric Legend

- WSC Hydrometric Sites - River Discharge and Water Level
- WSC Real-Time Hydrometric Sites - River Discharge and Water Level
- DFO Monitoring Site
- City of Parksville Hydrometric Site - Daily Water Level
- Harmac Hydrometric Site - Spot Water Level Measurements
- BCCF/Stewardship Group Flow Site - Seasonal Spot Flow and/or Continuous Monitoring
- Community Watershed Monitoring Sites (Water Quality)

General Legend

- Watercourse
- Lake
- Water Region

List of Label Abbreviations:
MoE - Ministry of Environment
MFLNRO - Ministry of Forests, Lands and Natural Resource Operations
MoTI - Ministry of Transportation and Infrastructure
DFO - Department of Fisheries and Oceans

Basemap: NRCAN 1:50,000 Topo

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Kilometers
5 0 5
1:150,000

Project No.	Date	Drawn By
536-010	April 2015	MS

Active Stations - Regional Hydometric and Climate Monitoring Scoping Study

Fig. 2-1

Regional District of Nanaimo - Drinking Water and Watershed Protection

Legend

- Miscellaneous Spot Flow Measurements (MoE Water Allocation Plans)
- Private
- Discontinued Community Watershed Monitoring Sites
- Discontinued Water Survey of Canada Hydrometric Sites
- BC Ministry of Environment - Air Quality
- Environment Canada
- Lake
- Watercourse
- Water Region

Climate Station Parameters Description
HW - Hourly Wind
HT - Hourly Temperature
HP - Hourly Precipitation
HRh - Hourly Relative Humidity
HAtm - Hourly Atmospheric Pressure
DT - Daily Temperature
DP - Daily Precipitation
DR - Daily Rain
DS - Daily Snow

Basemap: NRCAN 1:50,000 Topo

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Kilometers
5 0 5
1:150,000

Project No.	Date	Drawn By
536-010	February 2015	Name

Discontinued Stations - Regional Hydrometric and Climate Monitoring Scoping Study

Fig. 2-2

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Section 3

Hydrometric and Climate Network Review

3. Hydrometric and Climate Monitoring Network Review

3.1 Review Framework

In order to prioritize potential locations for additional hydrometric and climate monitoring sites, a framework has been developed to compare potential sites against a set of criteria. These criteria reflect both the specific Regional Water Inventory and Monitoring goals as well as the potential for data to be used by other stakeholders as data sources. The following sections outline the framework developed for both hydrometric and climate stations and presents a list of recommended sites.

Hydrometric

As previously outlined, the regional hydrometric and climate network should function to both provide specific data to support RDN land use planning, as baseline data for the Water Budget Project as well as to support other uses for hydrometric and climate data throughout the region.

A list of watershed parameters has been developed to provide a selection of criteria to first identify and then prioritize potential hydrometric site locations. The priorities for the recommended sites are based on the surface water and ground water stress levels, followed by availability of previous data sets, relationship to existing community water quality monitoring point, watershed size and dominant physiographic region.

The watershed parameters used in the framework for selection of hydrometric stations, in no particular order are:

1. Watershed Area which provides scale of the watershed, the network should cover a range of watershed scales.
2. Dominant physiographic region (ie: Coastal Lowlands (less elevation than 200 m), highlands/plateaux (200 m to 1000 m), interior mountains with elevations greater than 1000 m, The network should provide representative climate and hydrometric data within each of these dominant regions.
3. Large Lake – Is there a relatively large lake in the watershed which would dampen/store runoff? In order to estimate discharges in ungauged watersheds, it is important that the baseline station not have influence of large lakes or other storage which can increase baseflow above what would be seen in watersheds without large storage.
4. Regulated – Is flow in the watershed regulated by means of a storage reservoir or significant flow diversion?
5. Is there a currently a hydrometric station installed within the watershed?
6. Was there a discontinued hydrometric station installed within the watershed? How long did it operate?
7. Is there an active climate station near the watershed that would be representative of watershed precipitation and temperature?
8. Is there a Community Watershed Water Quality monitoring point in the watershed?
9. What was the surface water stress level calculated for the watershed in the Regional Water Budget Study?

10. What groundwater aquifers are associated with the watershed?
11. What was the water stress level calculated for the aquifers in the watershed?

A summary of all watersheds within the region is provided in Appendix A.

Climate

The primary objective of the climate station network is to provide sufficient coverage of the region to characterize the variation in climatic conditions. The total annual rainfall in the region varies dramatically from less than 1,000 mm in some regions along the coast to more than 4,000 mm in the mountainous area in the region. In addition, temperatures also vary depending on elevation with typically a 5°C to 10°C reduction in temperature for every 1,000 m elevation gain depending on relative humidity. However, at times of inversion, temperatures at higher elevations can sometimes be higher than those at lower elevation. Therefore, to best represent climate conditions in the region, there should be a representative distribution of climate station locations distributed throughout the region at varying elevations.

Currently, the majority of climate stations are located within the coastal lowlands area at elevations typically less than 200 m. There is good coverage of climate stations within the coastal lowland areas except for the Nanoose region. This area is located within the rain shadow of Mount Arrowsmith, the highest peak in the southern Vancouver Island ranges, and is therefore drier than other coastal areas in the region.

The only climate station data available in this region is the School Weather Network station located at Nanoose Bay Elementary. Although the school network stations provide a reasonable representation of climate conditions, they are not highly accurate climate stations. Therefore, an additional climate station in the Nanoose Area is recommended. There are several potential locations for this climate station in Nanoose including providing more accurate climate monitoring equipment for the Nanoose High School, at the Fairwinds Golf Course or at the RDN Nanoose Wastewater Treatment Plant.

There are a small number of climate stations located in the highlands/plateau physiographic region (between 200 m to 1000 m elevation). These are primarily fire weather stations operated by MFLNRO and the larger timber companies in the region including Timberwest. The fire weather stations record precipitation, temperature and relative humidity as input to fire condition models for forest operations.

Finally, there are currently only two stations in the region which provide data for conditions in the upper mountain elevations of the region, the Jump Creek Automatic Snow Pillow (ASP) site operated by MFLNRO and the L8 Weather Station operated by the City of Nanaimo. These are both located in extreme southern portion of the region (Jump Creek station is located in the Cowichan Valley Regional District).

Snow depth and snow water equivalent (estimate of the volume of water available in the snow pack) are recorded at the Jump Creek ASP as well as at a manual snow course site on Mt Cokely (above Cameron Lake).

Unlike screening of hydrometric stations, which has been based on physiographic and hydrologic conditions in the watersheds, selection of potential climate station locations have been based more on logistics including ease of access, conjunction with other stations and potential operational partners.

3.2 List of Recommended Sites

Hydrometric Sites

The list of recommended hydrometric station sites, their intended purpose (long term baseline reference station, short term station used to characterize and relate to baseline stations, or seasonal spot flow measurements) and relative priority are included in Table 3-1. The locations of the recommended hydrometric sites are shown in Figure 3-1.

The relative priority of stations (First, Second, Third) provides relative priority for implementation. The priority has been based on parameters outlined in the framework with a focus on first priority for the watersheds and aquifers with the highest relative water stress levels as well as those stations where a potential partner is identified.

In addition to the primary baseline stations and short term/seasonal stations, collection of spot flow measurements in smaller watersheds during summer baseflow period. This can provide better understanding of relative differences between summer stream baseflows which are dependent on groundwater conditions which can vary significantly from one watershed to the next. The locations of summer streamflow monitoring should be based on:

1. Recommendations in integrated rainwater/stormwater management plans prepared for municipalities for the purposes of watershed health monitoring; and
2. the outcome of the Community Watershed Monitoring Network water quality monitoring program.

A detailed scoping of small urban watersheds stream monitoring is outside the scope of this study. A follow-up detailed assessment should be completed as a follow-up and supplement to the more regional overview of this document

Climate Stations

Climate station locations are recommended based on review of the available climate station data and to compliment proposed hydrometric network. The list of recommended climate station sites and their priorities based on implementation timing are included in Table 3-2. The locations of the recommended hydrometric sites are shown in Figure 3-2.

Table 3-1: Preliminary Recommended Hydrometric Station List

Watershed	Watershed Area (km²)	Dominant Physiographic Region	Neighbouring Climate Station	Community Water Monitoring Program Site	Surface Water Stress[1]	Ground Water Stress[1]	Priority[2]	Potential Partner[3]	Comments
Primary Permanent Baseline Stations									
French Creek	69.7	Highlands/Plateau	Qualicum Beach Airport	Yes	High	High	**First**	WSC/ Friends of French Creek/BCCF/DFO (seasonal in 2014)	Convert seasonal station to continuous station. High surface and groundwater stress French Creek watersheds
Nanoose Creek	34	Highlands/Plateau	Currently None (Recommended Nanoose Climate Station)	Yes	High	Moderate/High	**First**	WSC	Baseline Station for Nanoose Area/High Surface Water Stress and Mod-Hi Ground Water Stress region
Haslam Creek	129	Highlands/Plateau	Nanaimo Airport	No	Moderate/High (as part of Nanaimo River Watershed)	Moderate/High	**First**	WSC	Baseline Station for southern RDN watersheds/moderate-high stress aquifers.
Goodhue Creek	10.5	Lowlands	Currently None (Recommended Gabriola Climate Station)	No	Not Calculated	Moderate*	**Second**	WSC or local Stakeholder Group	Baseline Station for Gabriola Island surface water balance.
Thames Creek	8.8	Lowlands	Bowser/Mud Bay	Yes	Not Calculated	Low	**Third**	WSC, NCES or other Stakeholder Group	Baseline station for lowlands watersheds in northern RDN. Summer baseflows in Nile Creek not representative of smaller lowland watersheds. Linkage with Community Water Quality monitoring station on Thames.
Cameron River	112	Mountains	Currently None	No	Not Calculated	Not Calculated	**Third**	WSC, Island Timberlands	Upper Elevation Mountain watershed for assessment of high elevation runoff in region and inflow to Cameron Lake for storage forecasting
Secondary Short Term or Seasonal Stations (operate for two or three years)									
Morningstar Creek	15.1	Lowlands	Qualicum Beach Airport	No	Not Calculated	High	**First**	BCCF or other	Review surface water availability for High Groundwater Stress region
Hokkanen Creek	15	Lowlands	Nanaimo Airport	No	Moderate/High (as part of Nanaimo River Watershed)	High	**First**	BCCF or other local stewardship group	Review surface water availability for High Groundwater Stress region
Whiskey Creek	26.8	Highlands/Plateau	Little Qualicum Hatchery	Yes	Moderate (as part of Little Qualicum)	Moderate/High	**Second**	BCCF or other	Review surface water availability for Mod-High Groundwater stress
Morrison Creek	38.1	Highlands/Plateau	City of Parksville	Yes	Moderate (as part of Englishman River Watershed)	Moderate/Low	**Second**	BCCF or MVIHES	Review surface water availability for Mod-High Groundwater stress and Water Quality Monitoring Network
Kinkade Creek	39.6	Highlands/Plateau	Horne Lake Road/Hwy 19 - MoTI Station	No	Moderate/High (as part of Little Qualicum Watershed)	Moderate/High	**Second**	BCCF, NCES or other	As part of groundwater/surface water study for Spider/Illusion Lakes
Annie Creek	5.4	Lowlands	Qualicum Fish Research	Yes	Not Calculated	Moderate/Low	**Second**	BCCF, NCES or other	As part of groundwater/surface water study for Spider/Illusion Lakes.

Note: 1 - Groundwater and Surface Water Stress as reported in Regional District of Nanaimo Water Budget Study Phase 1 (Vancouver Island)(Waterline, 2013) or Water Budget Study Phase 1 (Gabriola, Mudge and DeCourcy Islands)(SRK, 2013)

2 - **First Priority implement within 1 to 2 years**, **Second Priority implement WITHIN 5 years**, **Third Priority implement AFTER 5 years**

3 – Potential partner (capital funding, operation, in-kind, etc) identified for initial discussion with regard to station installation (AWS-Arrowsmith Water Service, BCCF – BC Conservation Foundation, DFO – Department of Fisheries and Oceans, , MABRRI – Mt Arrowsmith Biosphere Reserve Research Institute, MoTI – Ministry of Transportation and Infrastructure, MFLNRO – Ministry of Forest, Lands and Natural Resource Operations, MVIHES – Mid Vancouver Island Enhancement Society, NCES – Nile Creek Enhancement Society, RDN – Regional District of Nanaimo, WSC-Water Survey of Canada

Regional District of Nanaimo - Drinking Water and Watershed Protection

Legend

- Existing Active Hydrometric Station

Preliminary Recommended Hydrometric Station

- Primary Baseline Station
- Secondary Seasonal/Short Term Station
- Lake
- Watercourse
- Water Region

Basemap: NRCAN 1:50,000 Topo

KERR WOOD LEIDAL consulting engineers

Kilometers
5 0 5
1:150,000

Project No.	Date	Drawn By
536-010	February 2015	MS

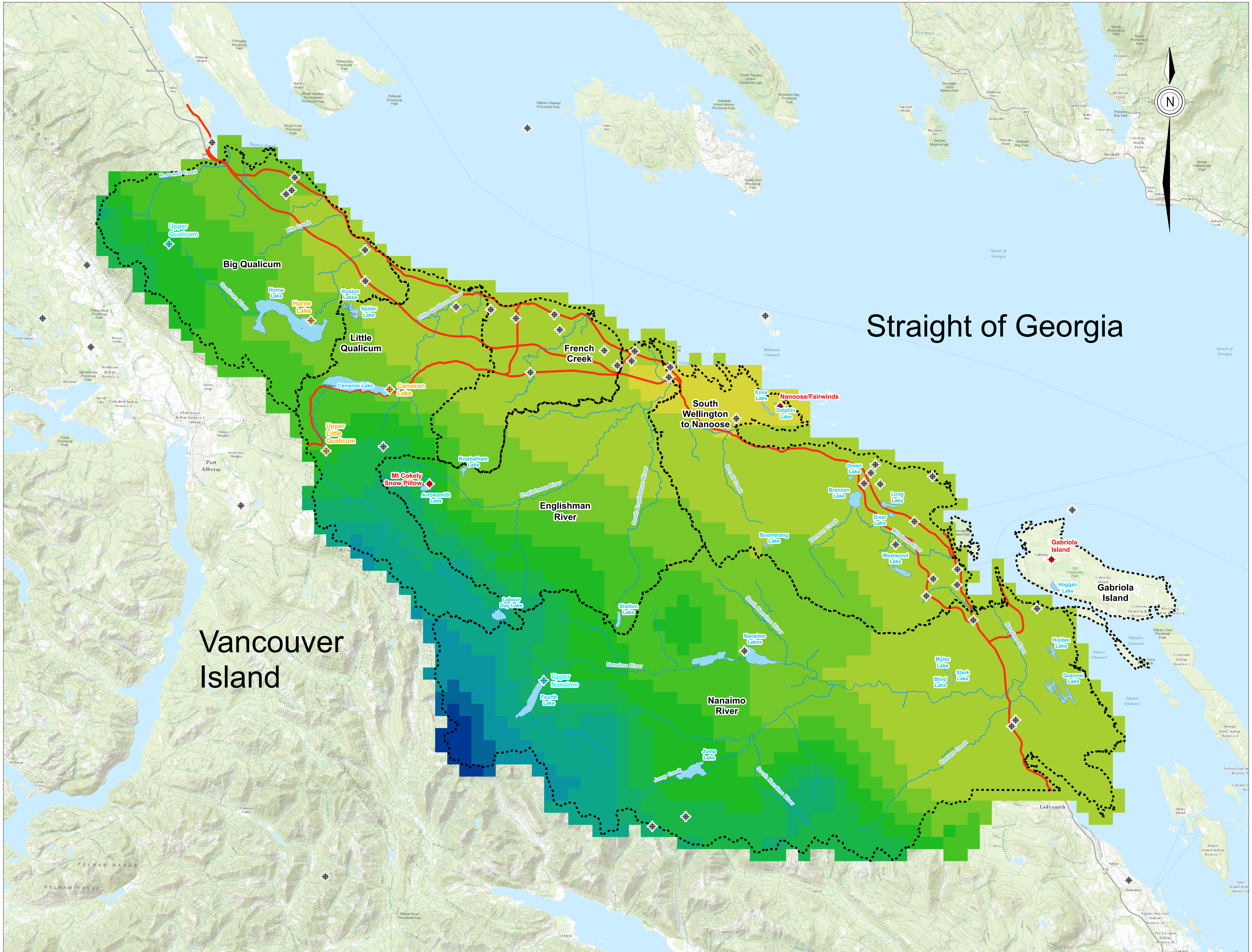
Proposed Hydrometric Stations - Regional Hydometric and Climate Monitoring Scoping Study

Fig. 3-1

Table 3-2: Preliminary Recommended Climate Station List

Location	Purpose	Potential Partner[2]
First Priority (install in 1 to 2 years)		
Nanoose Region (Nanoose Elementary, RDN Treatment Plant or Fairwinds Golf Course Climate Station)	Provide climate data for Nanoose/Fairwinds areas	RDN, Fairwinds, School District 69
Mt Cokely/Mt Arrowsmith Automated Snow Pillow	Snow Pillow to collect snow data for Cameron River and Englishman River watersheds	City of Parksville/AWS/DFO/MFLNRO/MABRRI /VIU
Gabriola Island Climate Station	Provide Climate Data for Gabriola/Mudge DeCourcy Island Water Region	RDN/Gabriola Volunteer Fire Department
Second Priority (install up to 5 years)		
Upper Little Qualicum/Cameron River Watershed	Additional Data for western portion of region with high annual rainfall	MoTI (Climate Station on Highway 4)/ Island Timberlands
Horne Lake or Cameron Lake Climate Station	Additional Collect data in highland/plateau region and to assist with forecasting for Storage at Horne Lake and Cameron lake	DFO
Third Priority (install more than 5 years)		
Upper Qualicum Watershed	Additional Data for northwestern portion of region with high annual rainfall	DFO (inflow to Horne Lake)
Upper Nanaimo River Watershed/Fourth Lake Dam/Labour Day Lake	Additional Data for western portion of region with high annual rainfall	Harmac/Timberwest/Island Timberlands

1 - **First Priority implement within 1 to 2 years**, **Second Priority implement WITHIN 5 years**, **Third Priority implement AFTER 5 years**
2 – Potential partner (capital funding, operation, in-kind, etc) identified for initial discussion with regard to station installation (AWS- Arrowsmith Water Service, BCCF – BC Conservation Foundation, DFO – Department of Fisheries and Oceans, , MABRRI – Mt Arrowsmith Biosphere Reserve Research Institute, MoTI – Ministry of Transportation and Infrastructure, MFLNRO – Ministry of Forest, Lands and Natural Resource Operations, MVIHES – Mid Vancouver Island Enhancement Society, NCES – Nile Creek Enhancement Society, RDN – Regional District of Nanaimo, WSC- Water Survey of Canada



Regional District of Nanaimo - Drinking Water and Watershed Protection

Legend

- Existing Active Climate Station

Preliminary Recommended Climate Station

- High Priority
- Medium Priority
- Low Priority
- Highway
- Lake
- Watercourse
- Water Region

Estimated Annual Precipitation (mm)

- 895 - 1000
- 1000 - 1500
- 1500 - 2000
- 2000 - 2500
- 2500 - 3000
- 3000 - 3500
- 3500 - 4000
- 4000 - 4500
- 4500 - 5000
- 5000 - 5500
- 5500 - 6000

Basemap: NRCAN 1:50,000 Topo

KERR WOOD LEIDAL consulting engineers

Kilometers
5 0 5
1:150,000

Project No.	Date	Drawn By
536-010	April 2015	MS

Proposed Climate Stations - Regional Hydrometric and Climate Monitoring Scoping Study

Fig. 3-2

Section 4

Hydrometric and Climate Station Summary

4. Hydrometric and Climate Station Summary

4.1 Hydrometric and Climate Station Descriptions

Hydrometric Station

The components of a hydrometric station include:

1. Data logger (including batteries for power and possibly solar panel)
2. Water Level sensor (pressure transducer, radar, etc.)
3. Manual water level gauge (staff gauge)
4. Benchmarks

The water level sensor and data logger are used to collect a continuous record of water level at the site. Water levels are converted to flow using a water level flow relationship known as a rating curve. Rating curves can either be based on known hydraulics (such as a weir, culvert or other structure) or based on a series of manual water level and discharge measurements recorded in the field. Once a rating curve is established, it requires to be monitored to confirm that conditions in the channel have not changed resulting in a change in the water level-discharge relationship at the site.

The flow in a river can be calculated by the average flow velocity multiplied by the cross sectional area of the flow. Manual discharge measurements are most often recorded using the velocity-area method. It is relatively easy to measure the cross sectional area. However, the flow velocity varies across the channel (ie: slower velocity at the channel edge versus high velocity in the middle). A method known as the Manual discharge measurements are most often recorded using the velocity-area method. This method can be used to calculate discharge by estimating the average velocity using a series of flow velocity measurements across the channel.

In this method, a channel cross section perpendicular to the flow is established. This section is then divided into smaller sub-sections or panels, often 10 or more panels across the width of the channel. The velocity is measured in each panel using a flow velocity meter. The discharge in each panel is calculated by multiplying the recorded velocity by the area of the panel. The total discharge in the stream is then calculated as the sum of the discharges in each panel.

Often the velocity area method is difficult to implement in smaller streams or at low flows. This is because traditional flow velocity meters (essentially propellers) have difficulty measuring velocity in relatively shallow flow depth and the slow velocities. Alternative methods can be used in these instances such as diverting the flow into a small structure with a known water depth vs flow relationship (Parshall Flume), collecting flow downstream of a drop (small waterfall) or a culvert outlet in a bucket of known volume and timing how long it takes to fill or using new Doppler technology which uses radar (Doppler effect) to measure the velocity of the surface of the flow.

Climate Station

The components of a Climate Station include:

1. Air Temperature/Relative Humidity Sensor
2. Wind Speed and Wind Direction Sensor
3. Rainfall Gauge (Total volume or Tipping Bucket)
4. Solar Radiation (Optional)
5. Data logger and Telecommunication for Real-time stations

6. Power Source (120V mains power or 12 V battery/Solar Panel)

Often recording rainfall or precipitation can be challenging at certain climate stations. For lower elevation stations where temperatures do not fall below freezing regularly or there is significant snowfall, a tipping bucket rain gauge can be used to monitor precipitation on hourly basis. However, tipping buckets do not function well in freezing conditions due to freezing of the tipping mechanism and bridging/capping of snow over the collection cone. Therefore, at higher elevations other tools are used to record precipitation such as standpipe/total volume gauges or weighted rainfall gauges. These gauges measure the total precipitation (either rain or snow). The gauges are filled with an anti-freeze water mixture which melts falling snow such that either the depth of precipitation or the weight of precipitation can be measured.

Automatic Snow Pillow

The component of Automatic Snow Pillow Station include:
1. Air Temperature/Relative Humidity Sensor
2. Snow Depth Sensor
3. Rainfall Gauge (Standpipe/Total volume)
4. Snow Pillow and Manometer or Snow Scale
5. Data logger and Satellite Telecommunication
6. Power Source (12 V battery/Solar Panel)

Snow pillows are used to measure the snow water equivalent or the amount of water available in the snow pack. They are essentially a scale used to measure the weight of the snow. They consist of a flexible bladder placed on the ground filled with an antifreeze solution. A standpipe manometer is plumbed into the bladder. As snow falls on the bladder, the level of the fluid in the standpipe rises and falls depending on the weight of the snow lying on the bladder. The water level is either measured using a float system (shaft encoder) or a pressure transducer.

Snow depth is also measured at the sites using an ultrasonic sensor which measures the vertical distance from the sensor mounted above the ground on a tower to the surface of the snow below. Total precipitation is also measured using a standpipe total precipitation gauge as described in the climate station section above.

Manual Snow Course

Snow water equivalent can also be measured at a manual snow course site. This methodology involves a manual measurement of the snow depth and the water volume in the snow pack. Snow depth is measured using a graduated aluminum tube, known as a Standard Federal Snow Sampler, which is driven through the snow to ground. The sampler is then carefully withdrawn, extracting a core of snow. The tubes and the core of snow are then weighed using a scale calibrated to centimeters of water. The difference between the weight of the full tubes and the weight of the empty tubes is then calculated as the water equivalent of the snow. Several measurements are taken across a specific area known as a snow course and the average of the samples is reported as the SWE for the station. These measurements are often recorded once or twice a month and require staff to travel to the sites for measurements.

4.2 Preliminary Site Reconnaissance

Mr. Rob Mathewson of WSC, Ms. Julie Pisani of RDN and Mr. Craig Sutherland of KWL completed a preliminary site reconnaissance in the afternoon of February 12, 2015. The reconnaissance included visiting the site of two discontinued WSC stations, one located on Nanoose Creek and one located on Haslam Creek. The purpose of the visit was to review current site conditions to assess viability of re-establishing hydrometric stations at these locations. A summary of the findings are below:

<u>Nanoose Creek (08HB039) – located downstream of Highway 19 bridge crossing</u>

The Nanoose Creek channel downstream of the Highway 19 bridge is approximately 10 m wide. There is evidence of gravel deposition at the bridge crossing indicating that the channel maybe unstable at higher flow events. Approximately 60 m downstream of the bridge the channel becomes straight with potential for a relatively stable gauging section. It is likely that streamflow measurement at all stages would have to be carried out either by wadding or tethered boat. Streamflow measurement from the bridge would not likely be possible due to unstable channel conditions at the bridge crossing.

Property ownership and access will need to be confirmed.

Overall it is considered that this location would be suitable for installation of a gauging station; however, it may require higher level of effort to maintain and confirm water level-discharge relationship due to unstable nature of the channel.

Nanoose Creek looking downstream at potential hydrometric gauging location.
Photo Credit: Rob Mathewson, WSC

<u>Haslam Creek (08HB003) – located near western end Timnberlands Road</u>

The original location of the Haslam Creek Water Survey of Canada gauge was not located during the reconnaissance. However, a location with very good potential was found at the forest road bridge crossing located on private forest road off the end of Timberlands Road.

The Haslam Creek channel in this location is approximately 15 m wide. Downstream of the bridge the channel is straight and appears to be stable. It would provide a good location for measuring flow by either wadding or tethered boat. A pool with a stable outlet is located upstream of the bridge with a bedrock outcrop which could be used to attach the pressure transducer logger.

Overall this site is considered to be a very good candidate to install hydrometric station.

Haslam Creek looking upstream at potential hydrometric gauging location.
Photo Credit: Rob Mathewson, WSC

Copies of the field reconnaissance reports prepared by Mr. Mathewson are included in Appendix A.

4.3 Hydrometric and Climate Station Costs

Costs for climate and hydrometric stations include equipment, installation and on-going maintenance. In addition, hydrometric stations require at least five and preferably ten manual streamflow measurements to be collected throughout the first one or two years of station operation to develop a rating curve. Once the rating curve is developed, on-going streamflow measurements (two or three a years) are required to check and update the rating curve as necessary. Typical costs for climate station and hydrometric stations are shown in Table 3.

Table 3: Budgetary (Class C) Cost Estimates for Climate and Hydrometric Stations

Item	Budget Cost
Hydrometric Station (Local, small stream – Mobile Network Communication)	
Equipment (Data Logger, Pressure Transducer, Misc. station equipment)	$5,000
Co-ordination and Installation (recon, co-ordination and installation)	$10,000
Total Installation Costs	*$15,000*
Rating Curve Development (including manual discharge measurements)	$15,000 (in first year)
On-going maintenance (Maintenance Visits, Telemetry, Monthly Data Quality Review, etc.)	$10,000/year to $15,000/year on going
Hydrometric Station (Remote, or large stream – Satellite Communication)	
Equipment (Data Logger, Pressure Transducer, Misc. station equipment)	$10,000
Co-ordination and Installation	$15,000
Total Installation Costs	*$25,000*
Rating Curve Development (including manual discharge measurements)	$15,000 (in first year)
On-going maintenance (Maintenance Visits, On-going flow measurements, Telemetry, Data Quality Reviews)	$15,000/year to $20,000/year on going
Climate Station (Local – Mobile Data Network Communication)	
Equipment (Data Logger, Temperature, Precipitation, Relative Humidity, Misc. station equipment)	$6,000
Equipment co-ordination and Installation (recon, co-ordination and installation)	$7,500
Total Installation Costs	*$13,500*
On-going maintenance (Maintenance Visits (2 per year), Telemetry, Monthly Data Quality Review, etc.)	$6,000/year to $8,000/year
Climate Station (Remote – Satellite Communication)	
Equipment (Data Logger, Temperature, Precipitation, Relative Humidity, Misc. station equipment)	$20,000
Equipment co-ordination and Installation (assume 3 day equipment co-ordination , 1 day installation including travel)	$15,000
Total Installation Costs	*$35,000*
On-going maintenance (Maintenance Visits (4 per year), Telemetry, Monthly Data Quality Review, etc.)	$6,000/year to $8,000/year

Snow Pillow Site	
Equipment (data logger, snow pillow, temperature, total precipitation gauge, solar panels, etc.)	$25,000
Co-ordination and Installation (assumes 3 person crew over 4 days plus travel and initial co-ordination to test equipment, construction of instrument shed, etc.)	$25,000
Total Installation Costs	*$50,000*
On-going Maintenance (assumes 2 visits per year)	$10,000
Notes: Local stations assume mobile/cellular network coverage, relatively simple access and installation. Example: local climate station installed in Municipal Public Works Yard or other existing facility. Remote stations assume satellite telemetry, more difficult access and installation conditions. Example: remote climate station in the mountains Costs assume installation within lands or at facilities that are provided free of charge. Installation and maintenance costs assume ground access. Helicopter access is approximately $1500/hr The costs included in the table are based on cost estimates prepared for previous similar projects and discussion with other climate and hydrometric station operators in the region. They reflect approximate costs at time of preparation (2015). They are considered suitable for budgetary purposes and should be revised after site reconnaissance.	

4.4 Data Collection, Cataloguing and Distribution

Once stations are installed, data needs to be collected, catalogued and distributed to end users. Although development of a full data model is beyond the scope of this study, some of the key elements to consider are:

1. Data Transfer - Real-time versus Manual

In real-time stations, data collected at the monitoring station is transferred via telemetry to a central database. Depending on the location of the station, telemetry can be either via satellite, mobile data (cellular) network, radio (SCADA) systems, or hard wired through internet connection. This has the advantage that data can be monitored continuously. However, there are costs associated with initial station set-up and on-going communication costs.

In manual stations, data is collected by a data logger at the station which consists of a digital memory platform that records digital data from the sensors. The data is then manually downloaded periodically by field staff during maintenance visits. Often there can be a significant delay in getting data from these stations because of the manual download. However, there are both initial and on-going cost savings in not having real-time data.

2. Data Storage – Central Database versus Network of Databases.

Once the data is collected and transferred, it needs to be stored in a database. There are two broad categories with a central database operated by a single agency which pulls together data from various sources into a single database or a network of databases in which each agency continues to collect and store data individually but there is an overarching database which links the data to each other.

Some of the key items to consider in development of database are:

- Is there an agency that is already collecting and storing data such as WSC?
- Is there a need to extract data from existing databases or link to existing databases?
- What is the data format?
- How is data to be collected by local stakeholders to be incorporated into the database?
- Who will be responsible for on-going maintenance and costs of operating the database?

Data collected and stored in database need to be reviewed to confirm data quality and remove any erroneous data. This typically involves a skilled technologist who understands data collection methodology and can interpret if data requires adjustment or complete removal from the database. Prior to review, data is often considered to be “Provisional Data” while after this process the data is often considered to be “published data”.

3. Data Retrieval – Online Access vs. Manual

Given the wide range of stakeholders that may be interested in the data, there may be a need for a user-friendly online interface to access the data. Some agencies have already developed on-line portals for access of data while others provide an online map showing locations of stations and information about the station and a contact person to access data.

4. Data Information - Metadata and Data Quality

The final piece of data cataloguing and retrieval is the collection and cataloguing of information about the collected data. This includes such information as location, elevation, type of equipment, date of installation, photographs, field visit notes, maintenance logs, agency contact information and if the data is provisional or published.

One very important piece of information about the data is the relative quality of the data. Providing information on data quality is essential for stakeholders understanding of how the data should be used. Data quality can be affected by many different factors including monitoring site conditions, frequency of data records, accuracy of monitoring equipment, methodology used for measurements and instrument calibration, etc. The Resource Information Standards Committee (RISC) have developed standards for hydrometric monitoring and snow measurement which provide guidelines on how to assess data quality. Environment Canada also provides guidance on standards to be used for collection of climate data. These standards can be used to assess the relative quality of the data which should be included with the metadata.

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Section 5

Recommendations and Submission

5. Recommendations and Submission

5.1 Recommendations

Based on the results of the hydrometric and climate monitoring network assessment, we recommend that:

1. Further field reconnaissance be carried out to review field conditions for the recommended sites starting with high priority sites;
2. Initiate discussion with potential partners identified regarding cost sharing, operation or in-kind assistance with implementation of stations;
3. Initiate discussion with land owners at sites to obtain access permission and land tenure for the stations;
4. Identify streamflow data collection locations for smaller urban streams within municipalities based on findings of the community watershed monitoring network report;
5. Continue streamflow measurement training for interested stewardship groups to assist with on-going summer low flow spot measurements in smaller coastal watersheds; and
6. Conduct a review of data collection, cataloguing and retrieval to develop a regional water monitoring database which can provide access to collected data.

5.2 Report Submission

Prepared by:

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Water Resources Engineer

Reviewed by:

David Sellars, P.Eng.
Senior Technical Review

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Appendix A

Hydrometric and Climate Monitoring Network Assessment Framework and Analysis

Regional District of Nanaimo
Regional Hydrometric and Climate Monitoring Scoping Study

Appendix A - Hydrometric/Climate Network Analysis Table Jan-15

Water Region	Water Region Name	Watercourse	Watershed Area	Regulated	Large Lake	Dominiant Physigraphic Region	Hydrometric Station: Active	Hydrometric Station: Discontinued	Active Representative Climate Station	Community Watershed Water Quality	Surface Water Stress	Aqufier	Groundwater Stress
WR-1	Big Qualicum	Rosewall Creek	43.6	No	No	Mountains	BCCF Flow Gauge (Seasonal Spot Flow)	1968-1978	Bowser/Mud Bay	No	Not Calculated	416	Lo
WR-1	Big Qualicum	McNaughton Creek	9.5	No	No	Highlands/Plateau	No	Single Point Flow July 1985$_1$	Bowser/Mud Bay	No	Not Calculated	416	Lo
WR-1	Big Qualicum	Cook Creek	19.7	No	No	Highlands/Plateau	BCCF Flow Gauge (Seasonal Spot Flow)	Summer 1985$_1$	Bowser/Mud Bay	No	Not Calculated	416	Lo
WR-1	Big Qualicum	Chef Creek	8.1	No	No	Lowlands	No	Summer 1992$_1$	Bowser/Mud Bay	No	Not Calculated	416	Lo
WR-1	Big Qualicum	Sandy Creek	3.9	No	No	Lowlands	No	Single Point Flow August 1985	Bowser/Mud Bay	No	Not Calculated	416	Lo
WR-1	Big Qualicum	Whitman Creek	1.3	No	No	Lowlands	No	No	Bowser/Mud Bay	No	Not Calculated	416	Lo
WR-1	Big Qualicum	Thames Creek	8.8	No	No	Lowlands	No	Summer 1985$_2$ and 2010$_1$	BowserMud bay	Yes	Not Calculated	421	Mod-Hi
WR-1	Big Qualicum	Nile Creek	16.9	No	No	Highlands/Plateau	WSC 1959 - Ongoing	No	Bowser/Qualicum Fish Research	No	Low	421	Mod-Hi
WR-1	Big Qualicum	Nash Creek/Norene Spring	4.1	No	No	Lowlands	No	2010 Only$_2$	Bowser/Qualicum Fish Research	No	Not Calculated	665	Lo-Mod
WR-1	Big Qualicum	Black Brook	1.3	No	No	Lowlands	No	No	Bowser/Qualicum Fish Research	No	Not Calculated	665	Lo-Mod
WR-1	Big Qualicum	Qualicum River	145.6	Yes	Yes	Mountains	DFO	WSC 1913-22, 1956-74	Qualicum Fish Research (No data for upper watershed)	Yes	Low	665/662	Lo-Mod
WR-1	Big Qualicum	Annie Creek	5.4	No	No	Lowlands	No	Summer 1985, Summer 1992$_2$	Qualicum Fish Reseach/Highways	Yes	Not Calculated	662	Lo-Mod
WR-2	Little Qualicum	Kinkade Creek	39.6	No	Yes	Highlands/Plateau	No	Summer 1985, Summer 1992$_2$	Horne Lake Road/Hwy 19 - MoTI Station	No	Moderate (as part of	661/662	Lo-Mod
WR-2	Little Qualicum	Whiskey Creek	26.8	No	No	Lowlands	No	No	Little Qualicum Hatchery	Yes	Moderate (as part of	Little Qualicum)	Mod-High
WR-2	Little Qualicum	Little Qualicum River	252	Yes	Yes	Mountains	DFO	WSC 1913-2001	Little Qualicum Hatchery (No data for upper watershed)	Yes	Moderate	664	Lo
WR-2	Little Qualicum	Cameron River	112	No	No	Mountains	No	Summer Season (5 years) 1958 to 1966	None	No	Not Calculated	Unkown	Not Calculated
WR-2	Little Qualicum	Lockwood Creek	14.3	No	No	Mountains	No	No	No Data	No	Moderate (as part of	NA	NA
WR-2	Little Qualicum	McBey Creek	11.5	No	No	Mountains	No	No	No Data	No	Moderate (as part of	NA	NA
WR-3	French Creek	Grandon Creek	7.2	No	No	Lowlands	BCCF	No	Qualicum Beach Airport	Yes	Not Calculated	217	Hi
WR-3	French Creek	French Creek	69.7	No	No	Highlands/Plateau	WSC 2014-Ongoing	WSC 1969-1996	Qualicum Beach Airport	Yes	High	216	Hi
WR-3	French Creek	Morningstar Creek	15.1	No	No	Lowlands	No	No	Qualicum Beach Airport	No	Not Calculated	216	Hi
WR-3	French Creek	Carey Creek	8.9	No	No	Lowlands	No	August 1986$_2$	Parksville Rain Gauges	No	Not Calculated	216	Hi
WR-3	French Creek	Romney Creek	6.4	No	No	Lowlands	No	No	Parksville Rain Gauges	Yes	Not Calculated	216	Hi
WR-3	Englishman River	Shelley Creek		No	No	Highlands/Plateau	BCCF Flow Gauge	No					
WR-4	Englishman River	Morison Creek	38.1	No	No	Highlands/Plateau	No	No	Parksville Rain Gauges	Yes	Moderate (as part of	209/220	Mod-Lo/High
WR-4	Englishman River	Centre Creek		No	No	Lowlands	BCCF Flow Gauge	No			Moderate (as part of	220/221	Mod-Lo/High
WR-4	Englishman River	Englishman River	316	Yes	Yes	Mountains	WSC	No	Parksville Rain Gauges (no Data for upper watershed)	Yes	Moderate (as part of	220/221	Hi/Mod
WR-4	Englishman River	South Englishman River	100	No	Yes	Highlands/Plateau	BCCF Flow Gauge	No	Parksville Rain Gauges	Yes	Moderate (as part of	NA	NA
WR-5	SouthWellington-Nanoose	Craig Creek	11.7	No	No	Lowlands	No	Misc Spot Flow (1985 to 1993)	Parksville	Yes	Not Calculated	219/214	Low
WR-5	SouthWellington-Nanoose	Enos Creek	2.7	Yes	Yes	Lowlands	No	WSC 1962-1976, Private Water Levels at Enos Lake	No Station	No	Not Calculated	218	High
WR-5	SouthWellington-Nanoose	Strudwck Brook	5.5	No	No	Lowlands	No	No	No Station		Not Calculated	219/214	Low
WR-5	SouthWellington-Nanoose	Nanoose Creek	34	No	No	Highlands/Plateau	No	WSC 1970-72, Misc Spot Flow (1992 to 1993)$_2$		Yes	High	219/214/210	Mod-Hi
WR-5	SouthWellington-Nanoose	Bonell Creek	51.2	No	No	Highlands/Plateau	No	WSC 1991	No Station	No	High	219/214/213	Low
WR-5	SouthWellington-Nanoose	Williams Creek	1.8	No	No	Lowlands	No	No	No Station	No	Not Calculated	213	Low
WR-5	SouthWellington-Nanoose	Stewart Creek	4.2	No	No	Lowlands	No	No	No Station	No	Not Calculated	213	Low
WR-5	SouthWellington-Nanoose	Dublin Gulch	8.1	No	No	Lowlands	No	Misc Spot Flow (1975 to 1980)	No Station	No	Not Calculated	213	Low
WR-5	SouthWellington-Nanoose	Indian Reserve Creek	1	No	No	Lowlands	No	WSC Spring/Summer 1974-1979	No Station	No	Not Calculated	213	Low
WR-5	SouthWellington-Nanoose	Knarston Creek	7.6	No	No	Lowlands	No	WSC Summer Only 1970-1971	Nanaimo Station	No	Not Calculated	213	Low
WR-5	SouthWellington-Nanoose	Bloods Creek	4.2	No	Yes	Lowlands	No	Misc Spot Flow Measurements 1989$_2$	Nanaimo Station	No	Not Calculated	213	Low
WR-5	SouthWellington-Nanoose	Cottle Creek	3.8	No	Yes	Lowlands	No	No	Nanaimo Station	Yes	Not Calculated	166	Low
WR-5	SouthWellington-Nanoose	Departure Creek	2.4	No	Yes	Lowlands	No	No	Nanaimo Station	Yes	Not Calculated	166	Low
WR-5	SouthWellington-Nanoose	Millstone River	100	Yes	Yes	Highlands/Plateau	WSC 1961 - Ongoing, DFO Water Level and Outflow at Westwo	WSC 1961 to 1974 at Oulet of Brannen Lake	Nanaimo Station	Yes	Moderate	167/211	High
WR-5	SouthWellington-Nanoose	Chase River	28.7	Yes	Yes	Highlands/Plateau	No	WSC Seasonal 1976 to 1978	Nanaimo Station	Yes	Moderate High	Not mapped	NA
WR-5	SouthWellington-Nanoose	Richards Creek	11.5	No	No	Lowlands	No	No	Nanaimo Station	No	Not Calculated	Not mapped	NA
WR-6	Naiamo River	Nanaimo River	830	Yes	Yes	Mountains	WSC 1965-Ongoing	WSC 1913-1927, 1948-1962	Nanaimo Airport/Nanaimo First Lake	Yes	Moderate High	161/165/162	High
WR-6	Naiamo River	Haslam Creek	129	No	No	Highlands/Plateau	No	WSC Continous 1949 to 1962, Seasonal 1994 to 1998	Nanaimo Airport	No	Moderate High (as p	161/160	Mod/High
WR-6	Naiamo River	Hokkanen Creek	15	No	Yes	Lowlands	No	WSC Water Levels Quennel Lake	Nanaimo Airport	No	Moderate High (as p	162	High
WR-6	Naiamo River	South Nanaimo	213	Yes	Yes	Mountains	WSC		City of Nanaimo L8 Weather	No	Moderate High (as p	Not mapped	N/A
WR-6	Naiamo River	Jump Creek	62	Yes	Yes	Mountains	WSC	No	City of Nanaimo L8 Weather	No	Moderate High (as p	Not mapped	N/A
WR-6	Naiamo River	Sadie Creek	29	Yes	Yes	Mountains	Harmac Fourth Lake Water Levels		No Station	No	Moderate High (as p	Not mapped	N/A
WR-6	Naiamo River	Beck Creek	14	No	No	Lowlands	No	No	Nanaimo Station	No	Moderate High (as p	165	Moderate
WR-6	Nanaimo River	Berkley Creek	9.2	No	No	Lowlands	No	No	Nanaimo Airport	No	Moderate High (as p	163	High
WR-6	Nanaimo River	Boulder Creek	12	No	No	Mountains	No	No	No Station	No	Moderate High (as p	N/A	N/A
WR-6	Nanaimo River	Stark Creek	14	No	No	Lowlands	No	No	Nanaimo Airport	No	Moderate High (as p	164	Mod/High
WR-7	Gabriola,Mudge,DeCourcy	McCormack Creek	0.2	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Sands Region	High
WR-7	Gabriola,Mudge,DeCourcy	Fransesco Brook	0.6	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Sands Region	High
WR-7	Gabriola,Mudge,DeCourcy	Ike Creek	0.3	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Sands Region	High
WR-7	Gabriola,Mudge,DeCourcy	Castell Brook	3.3	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Lock Bay Regio	Moderate
WR-7	Gabriola,Mudge,DeCourcy	Mallet Creek	0.7	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Descanso Bay	Low
WR-7	Gabriola,Mudge,DeCourcy	GoodhueCreek	10.5	No	Yes	Lowlands	No	No	Entrance Island	No	Not Calculated	Hogan Lake	Moderate
WR-7	Gabriola,Mudge,DeCourcy	Jenkins Creek	3.7	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Gabriola	Moderate
WR-7	Gabriola,Mudge,DeCourcy	Stoney Creek	1.7	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Gabriola	Moderate
WR-7	Gabriola,Mudge,DeCourcy	Jaquelin Brook	1.2	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Gabriola	Moderate
WR-7	Gabriola,Mudge,DeCourcy	Dick Brook	4.4	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	Gabriola	Moderate
WR-7	Gabriola,Mudge,DeCourcy	Martin Brook	0.6	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	West Degnen B	High
WR-7	Gabriola,Mudge,DeCourcy	Degnen Brook	0.9	No	No	Lowlands	No	No	Entrance Island	No	Not Calculated	West Degnen B	High
WR-7	Gabriola,Mudge,DeCourcy	Mudge Island	No Streams Identified			Lowlands	No	No	Entrance Island/Nanaimo Airport	No	Not Calculated	Mudge	High
WR-7	Gabriola,Mudge,DeCourcy	DeCourcy Island - Unnamed Brook	0.1	No	No	Lowlands	No	No	Entrance Island/Nanaimo Airport	No	Not Calculated	DeCourcy	Moderate

Sources: 1. MoE Water Allocation Reports 2. LGL, 2011

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Appendix B

Field Reconnaissance

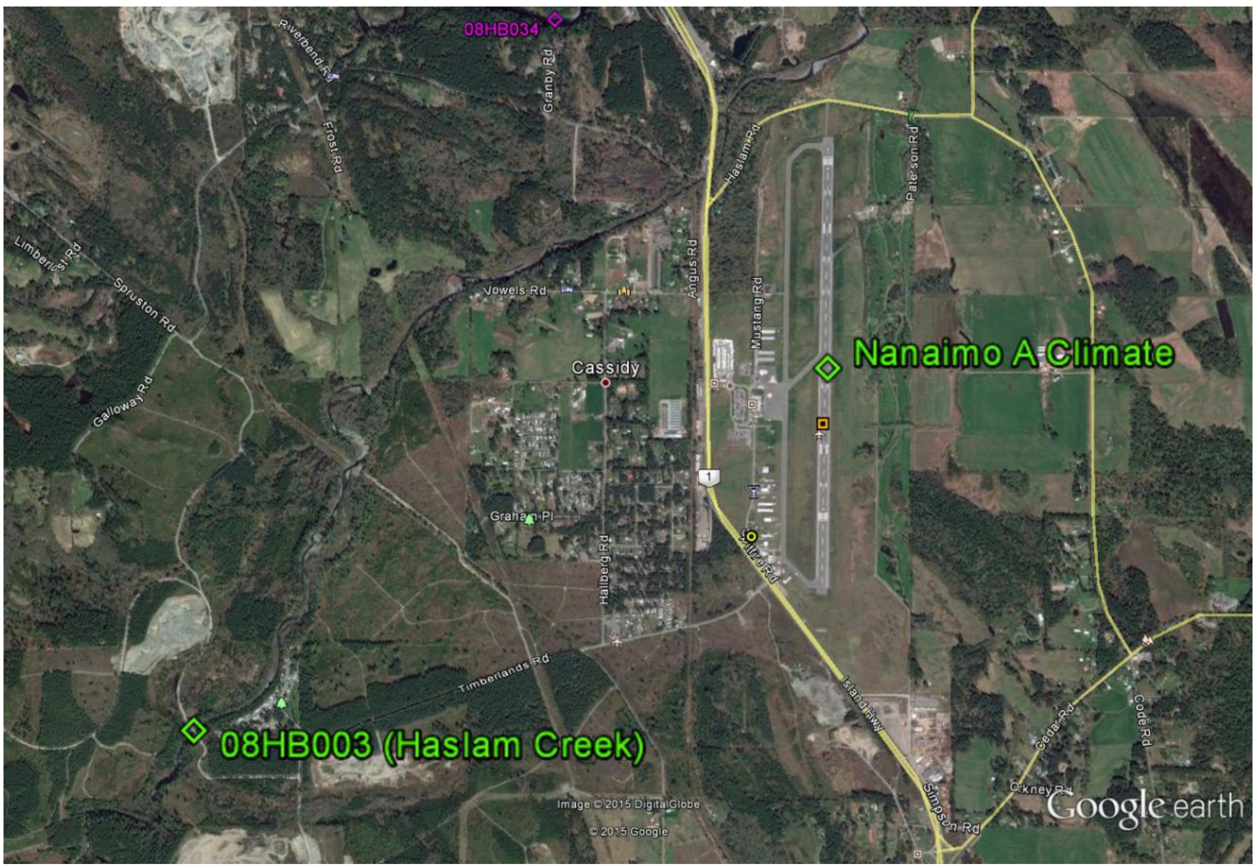
Water Survey of Canada - Site Reconnaissance

Location Information

River: Haslam Creek
Address/Location:
Latitude: 49° 2'23.18"N Longitude: 123°54'32.94"W
Station Name: Haslam Creek near Cassidy (former WSC station 08HB003)
Date Completed: February 12, 2015
Company: Rob Mathewson (WSC), Craig Sutherland (KWL), Julie Pisani (RDN)
Analysis Completed By: Rob Mathewson

Detailed Site Information

West on Timberlands Road. Forestry road takes off to right just after Rondalyn Resort Campground/RV Park at 1350 Timberlands Road. Station could be near bridge roughly 650 m beyond gate at Timberlands Road.



Control Type:

Riffle / constriction ~ 40 m upstream from bridge across Haslam Creek

Streambed Type:

Fairly stable cobble boulder bed similar to Jump Creek or South Nanaimo River

Stream Banks:

LB – high bedrock & moss; RB - cobble & vegetation (trees & shrubs). Both banks would need clearing at measurement sections of minor sweepers and overhangs but work could easily be done at low water

Stream Channel:

Good gauge pool ~ 40 m u/s from bridge (centre of photo above) All flow in 1 channel under bridge, u/s & d/s, straight for at least 5 x width

Measurement Sections:

Low: wading just below bridge

Medium: wading or bridge – photo above is mid-stage

High: bridge and/or tethered ADCP

Accessibility:

Road - Good road to site; need key for gate on Timberlands Road;

Parking - not really a good parking spot, but could be developed

Traffic- Active logging road – signage & traffic control may be necessary for bridge measurements or they should be coordinated to occur outside logging traffic hours.

Services Available:

While electricity and telephone lines are both likely available within 500 m of potential location, it is recommended that satellite transmitter (GOES) be installed with a solar power system to maintain independence and allow data to be available in realtime

Benchmarks:

Bedrock and bridge abutments both available depending on station location

Backwater Considerations:

Beaver evidence noted during visit, banks overflow into forest. Logs could potentially jam under bridge

Ice Considerations:

High energy stream in a relatively warm climate so conceivable for short periods only between say December and April

Additional Comments:

Summary/Conclusion:

This would be an ideal location for a gauge. There was formerly a WSC gauge at this site and discharge data are available from 1914-1915; 1949-1962; and seasonally from 1993-1998. As well as having all the attributes necessary to develop a sound stage-discharge relationship, the station is easily accessible and could be measured through most of its range effectively with existing infrastructure. Additionally the station is located within 3 km of Nanaimo Airport meteorological station (CID 1025365) compounding the value of any hydrological data collected.

Signature____

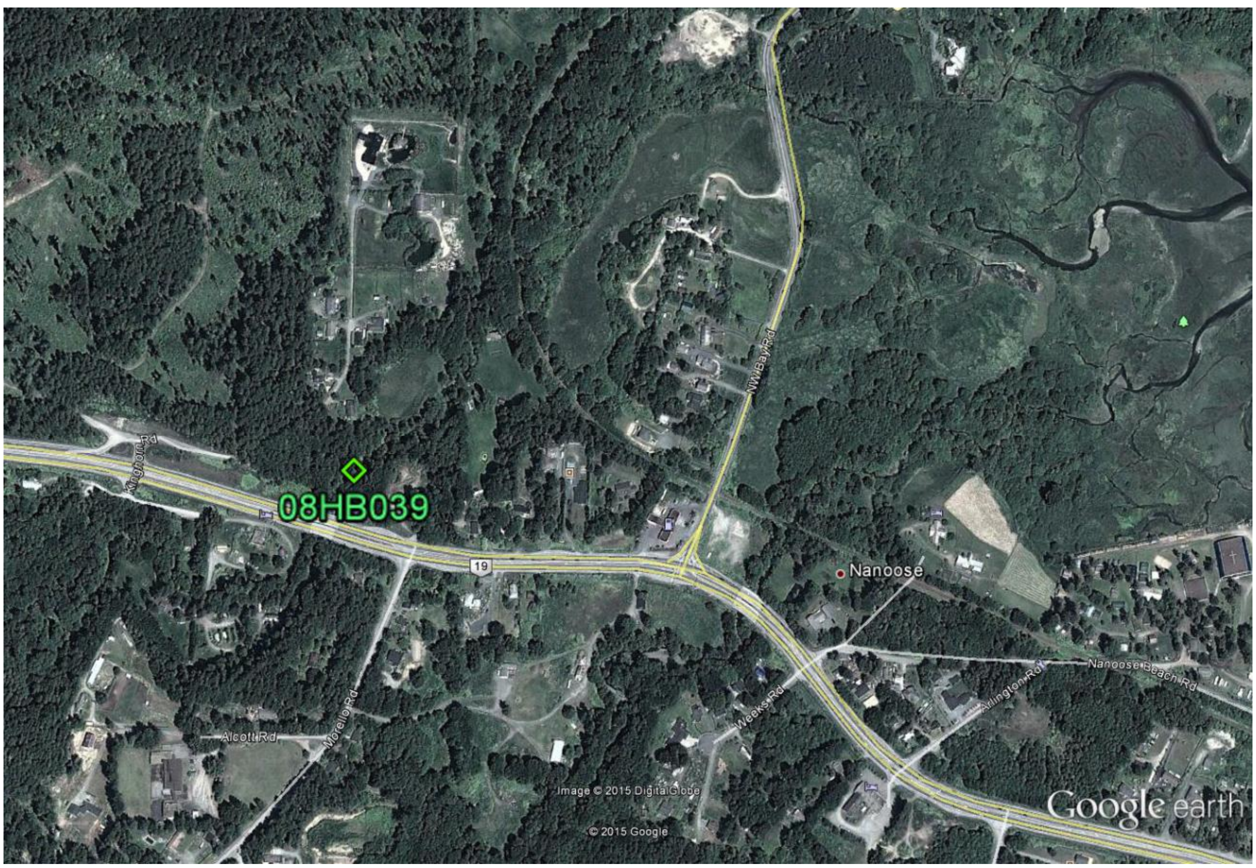
Date____

Water Survey of Canada - Site Reconnaissance

Location Information

River: Nanoose Creek
Address/Location: 19.0 km N of Northfield Road on Nanaimo Parkway BC-19N, where Inland Highway crosses Nanoose Creek, 400m WNW of intersection of Northwest Bay Road and Inland Island Highway, 100 m W of Morello Rd Intersection
Latitude: 49 15’52.94” N **Longitude: 124 12”17.72” W**
Station Name: Former WSC Station Nanoose Creek at the Mouth (08HB039)
Date Completed: February 12, 2015
Company: Rob Mathewson (WSC), Craig Sutherland (KWL), Julie Pisani (RDN)
Analysis Completed By: Rob Mathewson

Detailed Site Information



Control Type:

Channel control to roughly 2 m depth, then bank control with significant vegetation on RB overflow– d/s riffle noted at mid-stage. Also likely interference from d/s vegetation

Streambed Type:

Unstable sand/gravel likely moving with large scale events. Sandy loam on RB overflow bench.

Stream Banks:
Comments: *(height/erosion/weeds)*

0~1.5m gravel channel with clay/sand/loam banks; low slope on RB with small to mid-sized riparian vegetation; Steep slope on LB with larger trees

Stream Channel:
Comments: *(gauge pool/straightness)*

Width during visit roughly 10 m. Channel straight for roughly 50 m above potential gauge pool at measurement location roughly 60 m below bridge. Potential pool perhaps u/s of bridge as well, though control will be shifty.

Measurement Sections:

Low: Wading ~ 50 m below bridge
Medium: Wading ~ 50 m below bridge
High: Tethered boat ADCP ~ 50 m below bridge

Accessibility:
Comments: *(Road/parking/traffic)*

Station location has good pull out, however high traffic volume at higher speed (posted 60, but 90 km/h shortly after crossing bridge, so traffic is accelerating). If station located on LB d/s side of bridge, short access trail will be required through the brambles (~150-200m), however location would be easily accessible at all stages. LB will allow location above maximum anticipated WL

Services Available:
Hydro: Available close by, but recommend staying off-grid
Solar: Fairly clear shot to South
Phone: Rogers cellular coverage, and Shaw cable close by
GOES: Fairly clear shot to South

Benchmarks:
Comments: *(locations/bedrock)*

Good location in concrete bridge abutments

Backwater Considerations: *(vegetation/beavers/obstructions)*

Downstream vegetation would cause backwater at higher flows

Ice Considerations:

Little to no chance of ice (very close to sea-level)

Additional Comments:

Summary/Conclusion: *(Ideal/not suitable)*

This would be a suitable location for a stream gauge. Previous location of station was not located during this reconnaissance; however there is evidence of a concrete sump on d/s LB, close to matching the location and description of one referenced in the previous station description. No bench mark was found during visit.

Signature____

Date____

Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
A	March 27, 2015	DRAFT	Submitted for Review	CS
0	April 13, 2015	FINAL		CS

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