Photo: Living Lakes Canada

Water Monitoring in British Columbia: Scanning the Data Landscape Public Report

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For Water Monitoring Working Group of the BC Water Funders Collaborative

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Executive Summary

Freshwater is a finite resource essential for human existence and maintaining functioning ecosystems. Monitoring and reporting on freshwater quality and quantity is a fundamental tool for managing freshwater ecosystems and supplies.

Over the last several decades there have been significant changes in who is monitoring what freshwater quality and quantity indicators and where. These changes, along with the recent implementation of the *Water Sustainability Act* in British Columbia in 2016, provide an opportune time for inclusive discussions on water monitoring and reporting. In 2017, members of the BC Water Funders Collaborative's Working Group on Water Monitoring commissioned a Water Monitoring Landscape Scan to inform discussions on a shared vision for water monitoring and reporting in British Columbia.

Water monitoring is conducted to:

- determine baseline conditions;
- assess status and trends over time;
- ensure laws and regulations are upheld;
- determine whether policies and decisions are having their intended effect; or
- address specific questions or unknowns, such as information to support operations or resource management decisions.

This Scan collected information on surface and groundwater quality and quantity monitoring and reporting in British Columbia, providing examples of who is collecting what data at which locations – and if and how data are shared. It did not include monitoring information on other environmental components needed to fully understand the state of water resources such as information on land use, wetlands, aquifers, glaciers, snowpack, climate, and water withdrawals.

This scan, while not intended to be comprehensive, identified over 125 water monitoring initiatives that represent a range of types of monitoring that vary in scope from monitoring at a single site to province-wide networks. Over 40 diverse data hubs, portals or databases that are sharing and/or summarizing data were also identified. **Because of different monitoring objectives and organizational capacities there is no one-size-fits-all approach to water monitoring and reporting.**

Water monitoring data are collected and shared - to varying extents - by all levels of government (local, provincial, federal, First Nations), community-based monitoring groups, water purveyors, industry, academia, and other non-government organizations. **Over half of**

the monitoring and reporting initiatives identified in this Scan involved partnerships. This highlights the need to support and facilitate collaboration.

The provincial and federal governments have province-wide monitoring networks collecting data on river flows, surface water quality, benthic invertebrates as an indicator of water quality, ground water quality and quantity, and lake conditions. Data from these networks are generally available through open-source data platforms. Typically, the spatial and temporal resolutions of the data collected by these networks are not sufficient to address smaller scale regional or issue-specific needs (nor are they designed to).

Regional and issue-specific monitoring programs are conducted by a variety of different levels of governments and non-government organizations. Many of the newer monitoring initiatives focus on data to support maintaining and restoring fish habitat; managing groundwater quantity and quality; developing thresholds for environment flows and their management; addressing climate change and cumulative effects; and source water protection and watershed planning. **Regions that have made the most headway in identifying and filling regional data gaps also had the following:**

(1) **a distinct issue, problem, or question that needs to be addressed;**

(2) **champions to lead;**

(3) **networks for collaborations (including networks to access funding and technical support); and**

(4) **sufficient capacity (in particular funding).**

In general, data are available (data custodians are willing to share data). However, apart from the major province-wide networks with open-source data platforms, data are generally difficult to access and in particular meta-data (e.g. monitoring location coordinates, information on data collection methods and data quality) are generally difficult to access without directly contacting data custodians. In some cases, the data are proprietary and not available publicly or they are difficult to find because they are housed in reports. This Scan found that data provided on websites or portals are often not up-to-date, in formats that are not useable to multiple users, and lacking meta-data. There is an increasing trend for open-source data and during the time of this research several new data hubs were developed or are being planned.

Water monitoring across British Columbia is like a weaving of fabric, where some regions are detailed, or patterned, or more ornately woven together, with multiple layers and connecting threads, while others remain vague, threadbare, or missing entirely, like holes in a fabric. Jurisdictional and watershed boundaries combined with varied capacity and regulatory requirements, and the collection of different parameters for different purposes create a complex landscape.

Several initiatives have compiled data and information from multiple sources for a given geographic area for various purposes including to determine baseline conditions and data gaps. Open-source data and new technology are making these data compilations more feasible. However, they are still time consuming and expensive. **There is little incentive for data collectors to collect, manage, and share data in formats that make the data easily useable to others.** However, most programs are collecting data using standard protocols, and there are efficiencies that can be realized by sharing data across jurisdictions and using data for multiple purposes.

Photo: Okanagan Nation Alliance

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1. Introduction

1.1 Background

Over the last two decades there have been significant changes that affect water monitoring and reporting in British Columbia, including:

- Decreases in the number of monitoring stations maintained by major government agencies;
- Increases in community-based monitoring[i];
- Changes in technology for collecting, managing, and sharing data;
- Changes in monitoring drivers (e.g. needs to address climate change, cumulative impacts, and determine environmental flow needs); and
- Legislative and policy changes such as the *Water Sustainability Act.* [ii]

These changes in the water monitoring landscape, as well as current opportunities for new governance structures[iii], and the need for new whole ecosystem management approaches to address pressing issues such as cumulative effects and climate change, make it an opportune time for an inclusive discussion on water monitoring. In 2017, a landscape Scan of water monitoring and reporting in British Columbia was undertaken with support of members of the Water Monitoring Working Group of the BC Water Funders Collaborative, a project of Tides Canada.

1.2 Goals and Objectives

The overall goal of this Scan is to inform a shared vision for water monitoring and reporting in B.C. The objectives of the Scan are to identify who is collecting which data where and how, and if and how data are being shared.

1.3 Methods

The general approach for this Scan was to identify current water monitoring and reporting initiatives through a literature review, internet research, and interviewing personnel in the freshwater community and investigating their professional networks. The Scan was guided by a Steering Committee of leaders in the freshwater community and supported by staff and members of the B.C. Water Funders Collaborative's Working Group on Water Monitoring.

The Scan collected information on monitoring and reporting of fresh surface and groundwater quality and quantity. It did not include other data that are necessary to fully understand the state of water resources such as information on wetlands, aquifers, water withdrawals, glaciers, snowpack, and climate.

In total, over 50 people were contacted by either email or phone to identify initiatives and collect associated meta-data (monitoring locations, parameters, methods, sampling

frequency) as well as to determine data availability (*are data available to the public?*) and accessibility (*how easy is it to access the data?*).

This report provides a summary of the results. It is not a comprehensive inventory but rather a high-level view of the current state of the water monitoring and reporting landscape in British Columbia.

Photo: Okanagan Nation Alliance

2. Results

Water monitoring data are being collected and shared – to varying extents – by all levels of government (local, provincial, federal, First Nations), community-based monitoring groups, water purveyors, industry, academia, and other non-government organizations. This Scan identified over 125 water monitoring initiatives that represent a range of types of monitoring that vary in scope from monitoring at a single location to large province-wide networks. Several recent reports have indicated there are insufficient accessible data to assess the health of freshwater and to effectively support water management in British Columbia[iv].

Different types of data are collected by different organizations for different purposes. Who is collecting what data and where – and if and how data are shared – depend on the capacity of the monitoring or reporting organization. **Because of different objectives and capacities there is no one-size-fits-all approach to water monitoring and reporting.**

Geographically, some areas have more comprehensive monitoring, while others are almost threadbare. Several recent projects have compiled data from various sources to determine base-line conditions or state of the knowledge reports for defined geographic areas[v]. Drawing on data from multiple sources can be challenging – especially if associated meta-data (such as monitoring locations) are not available or data are housed in reports.

This Scan identified over 40 data hubs, portals or databases that are sharing and/or summarizing data on-line. This Scan found that many of these data sharing platforms were difficult to navigate not up-to-date, and/or lacking meta-data. There is an increasing trend for open-source data and during the time of this research several new data hubs were developed or are being planned.

Water monitoring in the province is dynamic- both spatially and temporally, with on-going changes in which groups are collecting what data in which locations. These changes are mostly because of capacity issues, especially lack of staff or funding and in many cases both; and the desire to respond to current issues.

2.1 Types of Monitoring

Monitoring is conducted for a variety of different purposes (Table 1). *Status and trends* monitoring typically generate the longest and most standardized data sets. *Regulatory and compliance, applied research*, *effectiveness*, and *baseline* monitoring tend to have shorter durations.

This Scan focused primarily *on status and trends* monitoring, but also includes other monitoring types to help identify where efficiencies can be gained through data sharing. For example, water treatment plant operators collect source water data at their intakes for operational and regulatory purposes. However, these data can also provide valuable

baseline and *status and trends* data[vi]. There are opportunities to share data that are collected for different purposes. However, there needs to be incentives for data collectors to manage and share data in formats that make it available to others.

Data associated with *effectiveness*, *regulatory and compliance*, and *applied research* were much harder to find as these data are often housed in reports or academic journals, which are difficult to identify and access or they are collected for proprietary purposes and not always readily shared, even under the terms of data-sharing agreements. Although this Scan did not focus on *regulatory and compliance* monitoring, information collected suggests there has been a decrease water monitoring since British Columbia's transition to a professional reliance model in the natural resources sectors.[vii]

Table 1: Types of Monitoring

Baseline	The collection of data over a specified time period with which to compare future conditions. Baseline monitoring is typically designed to assess variability to make statistically sound comparisons with future data sets.
Status & Trends	The systematic collection of data in a standardized manner to assess conditions over time.
Regulatory & Compliance	Monitoring to ensure laws and regulations are upheld.
Effectiveness	Monitoring to determine whether policies and decisions are having the intended effect. Effectiveness monitoring is an integral part of adaptive management.
Applied Research	Monitoring to address a specific question or unknown. Applied research can be used to inform resource management decisions.

2.2 What Parameters are being Monitored?

There are many parameters that can be measured to assess water quality and quantity. The National Long-term Water Quality Monitoring Network Database typically analyzes 115 parameters for each site and has 725 potential variables (analysis of same parameter by different methods is considered a separate variable)[viii].

The parameters analyzed in any given program depend on monitoring objectives. Parameters can be grouped in various ways including physical parameters (e.g. pH, turbidity, total and dissolved solids, suspended sediment), ions, nutrients, carbon content, microorganisms, organic and inorganic contaminants, and water quantity parameters such as flow rates and water levels. This Scan did not find many examples of initiatives or individual sites being monitored for "emerging" contaminants such as pharmaceuticals.

It is costly to have standardized monitoring programs that measure all variables across large geographic areas and in every watershed– hence the need for custom-designed issue or region-specific monitoring programs and representative studies to generate information to inform precautionary management decisions across different watersheds.

While many of the water parameters have been standard for some time -with standard protocols developed by various agencies and organizations - there are several new and cost-effective monitoring techniques that are currently being developed. For example, the National Water Research Institute, researchers at the University of Guelph, WWF-Canada, and Living Lakes Canada are assessing the use of environmental DNA (eDNA) as an indicator of water quality[ix]. Similarly, the City of Vernon, is collaborating with GenomeBC and University of Victoria on genome-based water quality testing[x]. The *Decolonizing Water Project* is developing a low-cost alternative to commercially available data loggers for First Nations communities to monitor water quality and identify locations of contamination[xi]. The BC Ministry of the Environment and Climate Change Strategy is assessing the use of turbidity as a surrogate for other water quality parameters in the Vancouver Island region.

2.3 Province-wide Monitoring Networks

There are several province-wide networks that are managed by the provincial government or jointly with the federal government. These include the:

- Federal-Provincial Hydrometric Monitoring Network,
- Federal-Provincial Water Quality Monitoring Network,
- Provincial Groundwater Observation Well Network,
- Provincial Lake Monitoring Program, and
- Canadian Aquatic Biomonitoring Network (CABIN).

These networks provide a “backbone” of monitoring in the province and the data sets are used for various purposes including water management operations and for research such as assessing long-term trends and developing models to forecast future conditions. However, the parameters analyzed, and the spatial and temporal scopes of the province-wide monitoring networks are not sufficiently comprehensive to address smaller scale regional or issue specific needs (nor are they designed to). Data from these networks are generally available through open-source platforms.

These main provincial networks provide standardized monitoring approaches and mechanisms for partnerships. Various organizations contribute to the province-wide networks through different agreements. For example: BC Hydro and some municipalities have cost sharing agreements to fund some of the hydrometric stations in the Federal-Provincial Hydrometric Monitoring Network; the BC Ministry of Environment and Climate Change Strategy is partnering with the BC Lake Stewardship Society to collect data for

Provincial Lake Monitoring Program, and the CABIN database is populated with data from studies conducted by government, industry, community groups, First Nations, and academia.

2.4 Regional & Issue-specific Monitoring Programs

Regional and issue-specific monitoring programs are conducted by all levels of government, First Nations, industry, community-based monitoring groups, academia, and other non-government organizations. Currently, newer monitoring initiatives focus on ground water quantity and quality, thresholds for environment flows and their management, maintaining and restoring fish habitat, addressing climate change and cumulative effects, and monitoring to support source water protection and watershed planning. Many of these programs are collaborative (see Appendix B for examples).

Regional and issue-specific monitoring programs vary greatly in what parameters they collect, on what scales of time and place. These programs typically follow standard protocols and rely on tools and guidance from other established programs and agencies such as the Canadian Council of Ministers of the Environment (CCME).

This Scan revealed that the regions that have made the most headway in identifying and filling regional data gaps are those that have: (1) a distinct issue, question, or problem to be answered; (2) champions to lead; (3) networks for collaborations (including networks to access funding and technical support); and (4) sufficient capacity (in particular funding. **Over fifty percent of the initiatives identified in this Scan had some kind of partnership with other organizations- they were either directly collaborating, collecting and sharing data as part of a network, or sharing data on a hub or portal that was collected by others.** This highlights the need to support mechanisms and provide capacity to facilitate collaboration.

2.5 Initiatives Supporting Monitoring

This Scan identified initiatives that are not directly collecting water monitoring data but fill important roles in the freshwater monitoring community such as identifying data gaps, securing funding, providing training, and facilitating collaboration. These "facilitators" include watershed planning roundtables, community-based monitoring networks, organizations that focus on a particular region or issue, and informal collaborations among organizations.

"Facilitators" play a key role in storing, organizing, managing, accessing, distributing, analyzing, interpreting, communicating, and planning, water monitoring as well as applying data for various purposes. Regions that have facilitators have made the most headway in identifying and filling regional and issue-specific data gaps. For example, in the Okanagan, the Okanagan Basin Water Board (OBWB) does not collect data itself, but it has been able to support water monitoring and reporting initiatives to address specific local issues, and to be a data host and aggregator[xii]. The OBWB also participates in water science projects such as

a surface-groundwater interaction study, hydrometric monitoring to support environmental flow needs, groundwater monitoring, monitoring evaporation rates, and the development of a database to house locally-collected hydrometric data.

The BC Ministry of Environment and Climate Change Strategy identifies six components of a data knowledge framework, held together by a governance structure, that are needed for effective management and use of data: (1) Collection and acquisition, (2) Storage, organization and management, (3) Access and distribution, (4) Analysis and interpretation, (5) Business use, communication and reporting, and (6) Planning[xiii]. This Scan found that across the spectrum of water monitoring and reporting initiatives, there are few incentives and resources for components 2 through 6. This limits identification and filling of data gaps, and the extent to which data are shared and used effectively. This Scan found that regions with "facilitators" have made the most progress towards identifying and filling data gaps. **"Facilitators" - including both non-government and government organizations - play critical roles in identifying and filling data gaps and generating resources and collaborations to do so.**

Photo: REFBC

3. Who is doing what?

3.1 Provincial and Federal Governments

The main province-wide networks (see Appendix A for descriptions) are managed by the provincial or federal governments or jointly between them. These networks typically collect data on the large mainstem systems and do not necessarily provide the detail needed to address smaller-scale and region-specific issues.

Both the provincial and federal government conduct various other monitoring programs that collect *baseline*, *status and trends*, and *applied research* monitoring data. These programs vary in scope and in their capacity to meet data needs for various purposes (e.g. assessing freshwater health, informing policy and resource management, and generating data that can be applied to different watersheds). Some examples of these programs include:

- Programs for developing watershed-specific **Water Quality Objectives (WQO)** [xiv] and at assessing WQO attainment to assess variation in water quality related to climate cycles, landscape alteration due to human activities, and natural disturbances such as forest fire, mountain pine beetle effects in smaller drainages. The WQO attainment programs collect water quality data on a roving schedule about once every 5 to 7 years in key watersheds and data are collected for other applied research to support WQO development.
- The Provincial **Fish-Forestry Interaction Research Program** that has been researching impacts of forestry on fish bearing streams for over 35 years at 6 sites (Bowron River, Carnation Creek, Prince George, Queen Charlotte Islands (Haida Gwaii), Slim-Tumuch, Stuart-Takla)[xv].
- The **Environment Canada Pacific-Yukon Region Transboundary Aquifer Program** which has been collecting ground water levels and water quality data- in particular nitrate and nitrite concentrations - in the Canadian portion of the Abbotsford-Sumas aquifer since the early 1990s[xvi].
- **The Environmental Monitoring and Surveillance Program for the Federal Chemical Management Plan** focuses on emerging chemicals of concern such as bisphenol A (BPA), siloxanes, chlorinated paraffins, metals (including platinum group elements, PGEs), perfluorinated compounds (PFCs), polybrominated diphenyl ethers (PBDEs), and other flame retardants. Priorities for monitoring are reviewed annually[xvii]. There are only four sites in B.C. that are part of this program and these are located in the southern Fraser and Columbia Basins.
- The **Fraser River water quality monitoring and surveillance buoy** is a partnership between Environment Canada and the BC Ministry of Environment and Climate Change Strategy to collect water quality and quantity and meteorological information

in the Main Arm of the Fraser River[xviii]. Real-time data are collected and transmitted via cellular telemetry and are available on Environment Canada's website.

- The **Osoyoos Lake Water Quality Buoys** are operated by Environment Canada who collect and share real-time data during the summer months on Environment Canada's website[xix].
- Part of the provincial **Northeast Strategy** is to enhance water monitoring and reporting in Northeast B.C. The Provincial Government has partnered with or funded various agencies, local governments, First Nations, industry, GeoScience BC and academic institutions to increase monitoring in the area. For example, the Murray River Cumulative Effects Assessment project has compiled existing historical and baseline data in the Murray River watershed and identified data gaps (among other objectives). The Province is working on monitoring to fill those data gaps.

Typically, *regulatory and compliance* monitoring is conducted by industry and reviewed by government. There are *regulatory and compliance* data that are publicly available and stored in the provincial Environmental Management System (EMS)[xx], but this database is cumbersome to search and extract data. This Scan did not explicitly search for or assess the extent of *regulatory and compliance* or *effectiveness* monitoring. It did find one example of effectiveness monitoring in the forestry sector, the **Forest and Range Evaluation Program**[xxi]. This program uses a qualitative approach to asses impacts of forestry-disturbed sites on water bodies. In 2016, the Auditor General of British Columbia conducted an audit to determine whether the regulatory compliance and enforcement activities of the Ministry of Energy, Mines and Petroleum Resources and the Ministry of Environment and Climate Change Strategy pertaining to mining, are protecting the province from significant environmental risks and found that monitoring and inspections of mines were inadequate[xxii].

Effectiveness Monitoring in the Forestry Industry

Forest and ranges practices are regulated through the *Forest and Range Practices Act*[xxiii] (FRPA) and its associated regulations. The Act defines the forest and range management framework which relies on a professional reliance model. Since the transition to a professional reliance model it appears that there has been a decrease in water monitoring associated with forestry and range practices.

The Forest and Range Evaluation Program (FREP) currently evaluates the effectiveness of forest and range practices[xxiv]. Their water quality effectiveness evaluation protocol (QEEP) uses a qualitative approach to evaluate forestry-disturbed sites that generate and transport fine sediment to natural water bodies (fish streams and/or drinking water sources). As of 2015, 6,040 sites were assessed qualitatively for the potential impact of sediment generation potential at 1,205 cutblocks and associated road networks/stream crossings since the program began in 2008[xxv]. The FREP program also qualitatively evaluated the impact of free-ranging cattle at 194 sites from 2008-2012 sites where there was a known water source downstream. For this evaluation, 15 simple indicators were considered, including vegetation, condition of ground and stream channel, presence of livestock feces, and range management techniques. When an indicator threshold was reached, the site was considered likely to have negative impacts on water quality[xxvi].

Regulatory and Compliance Monitoring in the Mining Sector

In 2016 the Auditor General of British Columbia conducted an audit to determine whether the regulatory compliance and enforcement activities of the Ministry of Energy, Mines and Petroleum Resources (MEM) and the Ministry of Environment and Climate Change Strategy (ENV), pertaining to mining, are protecting the province from significant environmental risks. The auditor general found that expectations for a robust compliance and enforcement program within the MEM and the ENV were not met, monitoring and inspections of mines were inadequate to ensure mine operators complied with requirements, and there are too few resources, infrequent inspections, and lack of enforcement. In British Columbia, there are 13 major coal and metal mines in operation, over 160 temporarily or permanently closed mines, and several mines moving through the permitting approvals process. Fourteen mines currently have water treatment facilities. The Ministry of Energy and Mines has ranked 45 additional mines as having moderate to high potential of acid rock drainage and/or leaching and has estimated that 12 of these mines will require perpetual water treatment.[xxvii]

3.2 Water Purveyors and Health Authorities

Water purveyors collect water data to help manage operations and to meet regulatory requirements. There are approximately 2,800 points of diversion for drinking water systems in BC that are licensed under the *Water Act*. Typically, water system operators collect water quality samples many times per month at their distribution system (post-treatment samples), and several times per year at source water locations (pre-treatment samples). Pre-treatment (source water) samples tend to be collected by large system water purveyors (> 500 people served) while very few small to medium size water purveyors (<500 people served) tend to collect source water samples.

Source water quality data is a valuable dataset that could contribute to the overall understanding of the state of surface and groundwater quality in B.C. For example, in the Peace River Regional District data compilation, the Northern Heath Authority (NHA) had the largest number of datasets, as well as the oldest samples found within the Peace River Regional District. Over 280 groundwater quality samples from 85 (source) sampling stations from the NHA were included in the water quality database.

Regional health authorities, of which there are six in BC (Northern, Fraser, Interior, Vancouver Island, Vancouver Coastal and First Nations), review data collected by water purveyors to ensure compliance with the *Drinking Water Protection Act and Regulations.* Health Authorities may also conduct monitoring themselves, fund monitoring, and conduct inspections and audits of water treatment systems.

With the exception of Northern and First Nations Health Authorities, the regional health authorities also review and/or may fund beach and recreational water quality sampling, primarily for *Escherichia coli* ("E. coli") and other microorganisms such as *Enteroccocal* bacteria. Health Authority data sets for bacteriological testing for beaches and recreational waters are not necessarily comprehensive. Some towns and municipalities report recreational water monitoring themselves on their own websites, while others report through the Health Authorities.

All of the Health Authorities (with the exception of the First Nations Health Authority) compile compliance monitoring data from small and medium size water treatment systems in publicly available databases available on line. However, the data are not geo-referenced, and the formats are set up to search data for a particular water treatment system. It is difficult to extract bulk data or identify the source of the water data. Audits are typically not available to anyone external to the Health Authorities.

Health Authorities can also be involved in source water protection initiatives. For example, Interior Health (IH) is working on guidance for Source Water Protection Plans for Small Water Suppliers which may lead to more ambient (source) water sampling. Interior Health is

currently focusing on assisting water suppliers with Emergency Management Systems and plans to follow this work with monitoring programs and additional source water protection work which may also lead to more source water monitoring.

Source Water Quality Data Consolidation Pilot Project

In 2011, a project was initiated to assess the feasibility of consolidating water quality data collected by water system operators by archiving source water monitoring data results into the provincial Environmental Monitoring System (EMS). The project identified key challenges which included: the fees charged by laboratories to upload the data into EMS (average of $16.25 per sample); the time requirements to set up the process in EMS (average of 25.25 hours per water system); the complexity for laboratories to establish EMS upload capabilities; and finding committed staff to set up and maintain the process. The Project recommended that resources need to be evaluated and re-allocated from existing positions/funding to support data consolidation. This project highlights the cost and personnel requirements to effectively manage and share data.[xxviii]

3.3 Local & Regional Governments

Local and regional governments collect various types of water data including:

- Source water, drinking water, and wastewater treatment effluent as owners and operators of water treatment and wastewater treatment systems;
- Water quality (bacteriological) monitoring for beaches and recreational waters;
- Municipal hydrometric monitoring for flood control and water management;
- Water monitoring to inform watershed management; and
- Collaborative region-specific projects with other levels of government, First Nations, universities, industry or other partners.

Most large-scale wastewater treatment facilities and drinking water treatment facilities in British Columbia are owned and operated by municipalities or regional governments and conduct monitoring as required by regulations. The Municipal Waste Water Regulation requires dischargers to monitor the quality and quantity of municipal effluent at least for the first two years of discharge. After two years, alternate monitoring requirements may be authorized. Some municipalities monitor ambient water quality near wastewater discharge points (e.g., MetroVancouver Testing of Receiving Waters[xxix]).

This Scan identified several examples of monitoring by local government. Many of these programs are collaborative, involving several partners and data are collected to fill gaps. For

example, the hydrometric gauge network used for flood forecasting on the lower Fraser River includes municipal, provincial and federal gauges[xxx]. Other example of local government montoring programs include (See Appendix B for descriptions):

- Regional District of Nanaimo Community Watershed Monitoring Network[xxxi];
- City of Dawson's Creek Kiskatinaw River Watershed Stewardship Program Monitoring[xxxii], and
- Mission Creek Groundwater and Surface Water Interaction Study[xxxiii].

Several local and regional governments are also compiling data. For example, the Okanagan Basin Water Board is developing a database to house locally collected hydrometric data that is not stored elsewhere. It uses the same software (Aquarius) used by the province to manage hydrometric data. The Peace River Regional District (PPRD), in collaboration with the Treaty 8 Tribal Association, compiled, sorted, formatted, and organized all publicly available data on surface water and groundwater quality in the PRRD[xxxiv]. The City of Dawson Creek conducted a 3-year watershed baseline research in partnership with its regional district and the University of Northern BC[xxxv].

In general, the data collected by regional and local governments is difficult to find. Some programs are sharing data online or in other databases. For example, the Regional District of Nanaimo uploads results from its community watershed monitoring into the Provincial Environmental Management System (EMS). Further research is needed to determine the extent of water monitoring by municipalities and regional governments.

3.4 First Nations

First Nations are collecting traditional ecological knowledge and western science data for various purposes including managing ancestral lands according to traditional laws and values and to support First Nation government departments and specific projects such as treaty negotiations, environmental assessments, resource management, fisheries protection, water management plans, and source water protection.

> "There is great diversity in Indigenous communities and water stewardship across Canada. No two Indigenous communities are the same and as such, the relevance of water and climate monitoring will vary among Indigenous communities, in large part based on their assets and capacities."- Cave *et al*., Centre for Indigenous Environmental Resources[xxxvi]

Some First Nations share data online and others have data sharing agreements with other First Nations and third parties. However, the extent of First Nations monitoring was difficult to assess in this Scan as the availability and accessibility to the public of data collected by First Nations are variable and influenced by many factors, including capacity, data ownership, legal considerations including rights and title, and basic trust that government

and third parties are using data effectively and transparently to make informed policy and management decisions. Ownership-Control–Access-Possession (OCAP) is specific protocol for working with Indigenous communities in relation to data[xxxvii]. It implies that ownership of data rests with communities, who retain control and have prescribed protocols for access and possession.

Some examples of water monitoring and data sharing by First Nations include:

- First Nations on the Central and Northern BC Coast have developed collaborative programs for monitoring and restoring fisheries including the Coastal Stewardship Network Regional Monitoring System[xxxviii];
- The Fort Nelson First Nation, are or are planning to collect data to support its Community Watershed Plan and cumulative effects monitoring program[xxxix]. The Fort Nelson First Nations has recently completed a State of Knowledge Report for the Liard Basin[xl] and shares data on the Mackenzie DataStream[xli];
- the Okanagan Nation Alliance who are monitoring water quality and supply as part of their work to restore salmon fisheries in the Okanagan[xlii];
- The *Decolonizing Water Project* is developing cost effective data loggers to monitor electrical conductivity and temperature and bioassay tools for communities to independently detect spills from natural resource extraction, monitor industrial development close to human settlements, or monitor changes to important water sources[xliii]; and
- The Indigenous Observation Network is a collaborative water quality monitoring project between the US Geological Survey (USGS), Yukon River Inter-Tribal Watershed Council (YRITWC), and Yukon River Basin communities (although the majority of the sampling sites are in the Yukon River Basin, there are a few sites in British Columbia)[xliv].

A number of First Nations in BC have invested significant resources in the development and use of information portals for managing referrals[xlv]. While these portals are not specific to water monitoring data, Shared Decision Management agreements and the associated portals highlight the emergence of non-treaty agreements and data sharing related to the management of land and resources which have been developed through negotiations between the Province of British Columbia and individual or groups of First Nations.

First Nations are leaders or collaborators in various watershed management roundtables, monitoring trusts and other initiatives that conduct or support water monitoring and/or data management or have initiated water monitoring through government to government negotiations (e.g. Nechako Watershed Roundtable[xlvi], Morice Water Monitoring Trust[xlvii],

Skeena Knowledge Trust[xlviii]). Research by the Centre for Indigenous Environmental Resources indicates strong First Nation interest in monitoring programs, data collection, and data sharing agreements[xlix] and the First Nations Fisheries Council has recently highlighted the importance of monitoring as a gateway to effective watershed governance[l].

3.5 Community-based Monitoring

Community-based monitoring (CBM) is extremely dynamic and variable, depending on available capacity and citizen engagement. This Scan identified 48 community monitoring programs (excluding First Nations discussed separately above).

The majority of the community-based monitoring programs are collecting *status and trends* surface water quality data. However, some programs are conducting other types of monitoring such as the Slocan River Streamkeepers who developed a sampling program following a Jet-A fuel spill in a local creek. Some programs are also collecting water quantity information and recently Living Lakes Canada has initiated a community-based groundwater monitoring program. Most programs are following standard protocols such as CABIN. A research project on stewardship activities in Northeastern BC concluded that water stewards rely on various provincial programs and tools to help interpret information and provide context and guidance for decision making[li].

Groups that are part of a network and that have support for data management are most effective in sharing data and ensuring data are used in decision making. There are several organizations helping to coordinate and provide support to citizen science groups such as:

- Columbia Basin Watershed Network,
- Columbia Basin Water Quality Project,
- Regional District of Nanaimo Community Watershed Monitoring Network,
- Pacific Streamkeepers Federation,
- BC Lake Stewardship Society, and
- Living Lakes Canada.

A survey of CBM organizations conducted in 2016 indicates that CBM programs are filling information gaps on watershed health, informing decision-making at various levels of government, and fostering environmental stewardship in communities across Canada. Furthermore, the majority of CBM programs are following scientifically-rigorous protocols, having their data analyzed by professional scientists, and addressing a diversity of community concerns relating to the health of freshwater resources. However, ongoing challenges for CBM include inadequate or unpredictable funding, inconsistent monitoring protocols, and difficulty in translating diverse and regionally-specific data to coherent recommendations for decision-makers.[lii]

Most CBM groups investigated in this Scan had websites and many were attempting to share data, although recent data (within the last two years) were rarely available and most CBM websites appear out-of-date. Information on number and locations of monitoring sites could generally not be compiled without personal communications with members of the community groups. Data was most easily accessed for groups that are part of a larger body providing data management support such as the Columbia Basin Water Quality Project and the Regional District of Nanaimo Community Watershed Monitoring Network.

3.6 Industry

Data are collected by industry for a variety of reasons including exploration, project scoping, environmental assessments, operational purposes, and as required by orders, permits and regulations. This Scan did not specifically seek out sources of industry data. Typically, industry data are housed in reports that are difficult to access or they are proprietary and held in internal databases.

The BC Environmental Assessment Office (EAO) has a website that provides information on environmental assessments, including status, contact information, and associated documents (e.g. Certificate Decision, Compliance Oversight) for individual environmental assessments. This Scan did not search through these documents to identify water monitoring data. The BC Water Portal has some data from the EAO, but there are only 7 sites with historical water quantity from 2007 to 2012 data[liii].

In the mining industry, when companies are bought and sold, data are typically not passed on to new owners, or they are passed on in formats that do not facilitate effective data management. The Canadian Mining and Innovation Council is currently working on a Mining Industry Knowledge Hub to create open-source and open data platforms for industry data[liv].

This Scan identified some examples of industry-collected data that are shared publicly:

- In the Elk Valley, Teck Coal Ltd.'s permit requires them to have surface and groundwater monitoring programs to assess progress towards its Water Quality Plan (see description in Appendix B)[lv]. Surface water and groundwater quality samples are collected, and the data are summarized in public reports and available in the Provincial Environmental Management System (EMS).
- GeoScience BC is an independent non-profit organization that generates earth science information to support industry needs. Projects are funded and conducted in collaboration with the provincial government, First Nations, local communities, academia, and the resource sector. For example, GeoScience BC coordinated a collaborative project to conduct hydrogeological investigation of potential aquifers in the Horn River Basin (see description in Appendix B) in order to quantify and map reservoir capacity and productivity/injectivity potential. Data from GeoScienceBC projects are typically available in reports. Data from GeoScience BC's 2015 Horn

River Surface Water Monitoring Program are accessible on the Flow-works online data platform[lvi].

BC Hydro's hydrology group manages a network of over 150 automated, real-time reporting climate, snow and surface water stations for reservoir management. The majority of surface water stations in this network are operated by the Water Survey of Canada and paid for by BC Hydro. Additional stations are operated by BC Hydro and its subcontractors. BC Hydro provides recent real-time hydrology data for these additional stations and reservoir level data online[lvii].

3.7 Academia

Water monitoring by academia is typically focused on *applied research* and the data sets are generally shorter term (2-5 years consistent with masters and PhD program lengths). However, there are also longer data sets that have been collected by academia through long-term projects and research centers. For example, the Quesnel River Research Center (QRRC) associated with the University of Northern British Columbia has been taking regular conductivity-temperature-depth observations in Quesnel Lake and other water bodies for several years. The QRRC provided baseline data prior to the 2014 Mount Polley Mine tailings pond breach and is facilitating collaborative research aimed at understanding the immediate and longer-term environmental and ecological implications of this event[lviii].

Academic institutions are partnering with other players in the freshwater community on large water monitoring and reporting initiatives. For example, the Integrated Watershed Research Group at the *University of Northern British Columbia* works collaboratively on integrated watershed-based research with an emphasis on the Fraser River Basin and other Northern B.C. watersheds including the Nechako River Basin (*e.g.,* the Netchako Watershed Portal[lix]). The Pacific Water Research Centre at *Simon Fraser University* promotes and mobilizes research that addresses water issues focusing on research coalition building, resource mobilization and bridging science and policy. The Northeast B.C. Project is a joint initiative between *Simon Fraser University* and the B.C. Ministry of Forest, Lands, Natural Resource Operations and Rural Development whose goal is to characterize aquifers in the Northeast Region to create regional and specific knowledge about groundwater.

It was beyond the scope of this Scan to identify all current and past academic water monitoring projects in the province. However, it is important to recognize that academia plays an important role in water monitoring and reporting and is a significant contributor to the freshwater community in a variety of ways. These include, but are not limited to:

- producing data;
- providing scientific and technical services;
- providing analyses that allows data to be communicated in effective ways to inform policy, adaptive management, and decision making;
- facilitating collaboration; and

- sharing and managing data through data-hubs and providing expertise on the management of data.

Academia is playing an increasing role in the management of data. For example, the Straight of Georgia Data Centre is a joint initiative between the University of British Columbia Fisheries Centre and the Pacific Salmon Foundation. The Pacific Climate Impact Consortium (PCIC) at the University of Victoria is a service centre providing practical information, including a data portal and modeling on the physical impacts of climate variability and change in the Pacific and Yukon Region. Although the PCIC does not house water quality or quantity data, it or similar consortiums, could be a potential portal for water data. KEY at Simon Fraser University (SFU) is a "big data" initiative that offers consulting services, workshops and events, academic programs and partnerships. The federal government uses KEY services and stores data on SFU servers.

3.8 Non-government Organizations

This Scan revealed that Non-Government Organizations (NGOs) are typically more involved in sharing data rather than collecting it (with the exception of Community Based Monitoring Groups discussed separately). Many NGOs are facilitators- identifying data gaps, securing funding, providing training, and facilitating collaboration. In this Scan, some examples of NGOs that are directly involved in water monitoring are the Buckley Valley Research Centre, Babine Watershed Monitoring Trust, Coquitlam River Watershed Roundtable, Morice Water Monitoring Trust, and the Shuswap Watershed Council.

Through roundtables and watershed assessments, NGOs are playing a role in identifying data gaps and opportunities (e.g., *Nechako Watershed Roundtable, Nicola Basin Collaborative, World Wildlife Fund State of Watershed Reporting)*. NGOs are also playing a role in managing and sharing data (e.g. *Mackenzie Data Stream, Pacific Salmon Explorer, Skeena Data Centre, Nechako Watershed Health Atlas*). These initiatives demonstrate how non-governmental organizations can be a vehicle for monitoring and data sharing within a defined region. Further research is needed to determine the types and levels of monitoring by NGOs such as fish and wildlife clubs and stewardship organizations.

4. Data Availability and Accessibility

In general, the majority of water monitoring data in the province are available (data custodians are willing to share data) but not accessible (it is difficult to access and often requires personal communications with the data custodian). For most monitoring initiatives identified in this Scan, data custodians must be contacted to obtain meta-data (information on monitoring locations, sampling protocols, lengths of data records, and data quality).

For this Scan, the coordinates of monitoring locations could be downloaded from the internet for just five of the monitoring initiatives identified in this Scan (Federal-Provincial Water Quality Monitoring Network, Provincial Groundwater Observation Well Network, Water Survey of Canada Hydrometric Network, Osoyoos Lake Water Quality Buoys, Indigenous Observation Network). For all other monitoring initiatives, the monitoring location coordinates had to be requested through personal communications with the data custodians or extracted from tables in reports. Many monitoring programs and data hubs had maps on-line showing monitoring locations (e.g Mackenzie Data Stream, CABIN monitoring, Federal Contaminants Program, BC Hydro Monitoring, Indigenous Guardian Program, Vancouver Island Hydromet Stations). However, the coordinates of monitoring locations could not be downloaded and had to be requested from the relevant agencies or organizations.

Data from three of the province-wide networks (Federal-Provincial Hydrometric Monitoring Network, Federal-Provincial Water Quality Monitoring Network, and Provincial Groundwater Observation Well Network) are available through open-access data portals. CABIN requires training to access the models and data from individual studies need to be requested from the study proponents. Recently, some CABIN data has been made available through the Government of Canada Open Data Portal[lx]. The Provincial Lake Monitoring Program is relatively new and plans for storing and sharing data are still being developed.

The majority of the provincial *status and trend* and more recent *compliance and regulatory* monitoring data are stored in the province's Environmental Management System (EMS)[lxi] while data from other regional studies and specific programs are typically held in regional offices. The EMS has been described as "clunky" and "difficult to use". A user guide[lxii] is available and the Shuswap Watershed Council has developed a 5-page simplified user manual[lxiii]. In general, it is difficult to find data without the EMS IDs, which are unique IDs for each monitoring site. Some data that are housed in reports can be found in the Ecological Reports Catalogue[lxiv]. The catalogue can be searched using a map which allows for identification of reports associated with a specific geographic area. However, determining what data are available and extracting data from reports are challenging.

Currently, there are many efforts underway to share data more effectively. New data sharing initiatives developed in the last year include the provincial government's Real Time Water

Data Portal[lxv] and the Kootenay-Boundary Water Tool[lxvi] and the South and Coast Area Water Tool[lxvii] developed by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development, together with Foundry Spatial Ltd. and the BC Oil and Gas Commission. The Ministry of the Environment and Climate Change Strategy's Knowledge Management Branch is working on a multi-agency Water Information Systems Project to improve water information systems and how data and information from regional offices and stakeholders can be integrated into an information system.

The data portals that were identified in this Scan are listed in Table 2. The ease with which data can be retrieved from these portals, the extent of meta-data presented, and the comprehensiveness varies significantly- with many portals not providing the most current data or necessary associated meta-data. New data portals that are being developed include:

- Columbia Basin Data Hub[lxviii];
- Nechako Watershed Portal[lxix];
- Mining Industry Knowledge Hub[lxx]; and
- NSERC Canadian Lake Pulse Network Database[lxxi].

Managing data is a large, time-consuming task. Data and public portals are not useful if the data are not in formats that are accessible to the end-users and the appropriate meta-data are not included. Typically, organizations are importing data into their own data management and analysis platforms for use (e.g. Geographic Information Systems). In some cases, data does not necessarily have to be public to be useful - what matters is that the right people have access to the data they need to make decisions. As described elsewhere in this report, various organizations are compiling data from multiple sources in order to identify and fill data gaps.

Table 2: Examples of Publicly Available Data Sharing Portals Identified in this Scan

Federal Government	Health Authorities	Other/Collaborations
Government of Canada Open Data Portal	Fraser Health Beach Conditions	Columbia Basin Water Quality Monitoring Project
Water Survey of Canada - HYDAT	Fraser Health Drinking Water Quality	FreshWater Watch
National Pollutant Release Inventory (NPRI)	Interior Health Recreational -Water Sampling Beaches	Mackenzie Data Stream
Provincial Government	Interior Health-Drinking Water Samples	Nechako Watershed Health Atlas
BC Data Catalogue	Island Health-Drinking Water	Nechako Watershed Portal
BC Environmental Management System (EMS)	Island Health-Recreational Water Samples	Pacific Climate Impact Consortium (PCIC)
BC Real-Time Water Data (Aquarius)	Northern Health Drinking Water Chemical Samples & Results	Pacific Salmon Explorer
Groundwater Level Data Interactive Map	Vancouver Coastal Health Beach Water Quality Reports	Peace River Water Quality Database & Analysis (Report available)
BC WELLS Database	Vancouver Coastal Health Drinking Water Quality	Regional District of Nanaimo-Community Watershed Monitoring Network
Fisheries Information Summary System	**Water Tools**	Skeena Salmon Data Centre
First Nations	BC Water Portal	Straight of Georgia Data Centre
Indigenous Observation Network (Yukon & Alaska)	Cariboo Water Tool	Streamkeeeper Database
Okanagan Nation Alliance Data Portal	Kootenay Boundary Water Tool	Vancouver Island Hydromet Stations
Okanogan Basin Monitoring and Evaluation Program	NorthEast Water Tool	Water-Quality Data from the Yukon River Basin in Alaska and Canada
	NorthWest Water Tool	
	Omineca Water Tool	
	South and Coast Area Water Portal	

5. Data Gaps

In general, the province-wide water monitoring networks provide a "backbone" of water monitoring in the province but do not necessarily meet the needs of regional and local issues or reflect the parameters and data needed to address current monitoring drivers. For example, the provincial-federal hydrometric monitoring network typically collects water flow data on main-stem systems, while data from smaller streams and tributaries are needed to address current monitoring drivers such as protection and restoration of fish habitat and addressing environmental flow needs and adaptation to climate change.

Data summaries and gap analyses are being conducted on various geographic scales throughout the province. Reports that were identified during this Scan that summarize large watershed scale reviews of data and monitoring program reviews are listed in Appendix C. Data summaries and gap analyses are being conducted at smaller watershed scales to address specific regionally-based concerns. These types of local data compilations and assessments provide a strategic and targeted approach to filling data gaps. It was beyond the scope of this research Scan to identify all available regional studies. Some examples of local and regional data compilations and data needs assessments include:

- Towards a Healthy Nechako: Nechako Watershed Strategy[lxxii];
- Hydrometric Network Requirements for the Okanagan Basin[lxxiii];
- Regional District of Nanaimo Regional Climate and Hydrometric Monitoring Network Scoping Study[lxxiv];
- Water Monitoring and Climate Change in the Upper Columbia Basin: Summary of Current Status and Opportunities[lxxv];
- Peace River Regional District Water Quality Database and Analysis[lxxvi]; and
- Liard Basin Monitoring Initiative Year 1 State of Knowledge Report[lxxvii].

Local governments, First Nations, non-government organizations, watershed planning roundtables and other collaborative initiatives are compiling data from multiple sources and identifying data needs. **Regions that have sufficient capacity, champions to lead, and networks for collaborations have made the most progressive headway towards identifying and filling data gaps.**

There are opportunities to fill data gaps to address current issues such as maintaining fish habitat, developing thresholds for environment flows and their management, drought and flood management, protecting groundwater quantity and quality, addressing climate change and cumulative effects, source water protection, and watershed planning. Data gaps can be filled by increasing resources for data management; sharing existing data more efficiently; increasing the amount of monitoring; and facilitating collaboration.

Endnotes and References

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[vii] See recommendations 116-118 of BC Professional Reliance Review Report: https://engage.gov.bc.ca/app/uploads/sites/272/2018/06/Professional_Reliance_Review_Final_Report.pdf

[viii] https://open.canada.ca/data/en/dataset/67b44816-9764-4609-ace1-68dc1764e9ea

[ix] http://www.wwf.ca/?25921/Faster-better-freshwater-monitoring-through-new-citizen-scientist-program

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[xi] http://decolonizingwater.ca/

[xii] http://www.obwb.ca/projects/

[xiii] Tesch, David. (2017). "Provincial Data Systems and Monitoring Collaborations" presented at the Water Data Hub Conference, Invermere. November 29, 2017.

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[xxxix] http://www.fortnelsonfirstnation.org/our-projects.html

[xl] http://www.fortnelsonfirstnation.org/news.html

[xli] https://mackenziedatastream.ca/#/

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Examples of Information Portals:
Ktunaxa Referrals Management System: https://github.com/ktunaxa/rms
Stó:lō Connect: http://summit.sfu.ca/item/13816
Tsilhqot'in Stewardship Planning Portal: http://www.tngportal.ca/

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[lvii]https://www.bchydro.com/energy-in-bc/operations/transmission-reservoir-data/hydrometeorologic-data.html

[lviii] http://www.unbc.ca/quesnel-river-research-centre/mount-polley

[lix] https://ecohealthkta.net/the-nechako-watershed-portal/

[lx] https://open.canada.ca/data/en/dataset/13564ca4-e330-40a5-9521-bfb1be767147

[lxi] https://a100.gov.bc.ca/pub/ems/indexAction.do

[lxii] https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/reporting/reporting-documents/environmental-monitoring-docs/ems_wr_present.pdf

[lxiii] Shuswap Watershed Council. (2017). *How to Retrieve Water Quality Data from the British Columbia Environmental Monitoring System-User Guide.* https://www.fraserbasin.bc.ca/_Library/TR_SWC/WQ_Data_User_Guide.pdf

[lxiv] http://a100.gov.bc.ca/pub/acat/public/welcome.do

[lxv] https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/real-time-water-data-reporting

[lxvi] https://news.gov.bc.ca/releases/2018FLNR0205-001541

[lxvii] https://news.gov.bc.ca/releases/2018FLNR0206-001542

[lxviii] https://livinglakescanada.ca/projects/columbia-basin-water-data-hub-and-framework/

[lxix] https://ecohealthkta.net/the-nechako-watershed-portal/

[lxx] http://cdn.geosciencebc.com/pdf/SummaryofActivities2016/SoA2016_Flynn.pdf

[lxxi] http://lakepulse.ca/national-lake-pulse-database/

[lxxii] Fraser Basin Council. (2016). *Towards a Healthy Nechako: Nechako Watershed Strategy – Version 1*. https://www.fraserbasin.bc.ca/_Library/UFR/Nechako_Watershed_Strategy-31Oct2016-FINAL.pdf

[lxxiii] Okanagan Hydrometric Network Working Group. (2008). *Hydrometric Network Requirements for the Okanagan Basin*. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=15045

[lxxiv] Sutherland, C. (2015). *Regional Climate and Hydrometric Monitoring Network Scoping Study (Regional District of Nanaimo).* http://www.rdn.bc.ca/dms/documents/dwwp-reports/region-wide-reports/rdn_regional_hydrometric_and_climate_monitoring_scoping_study_-_2015.pdf

[lxxv] Carver, M. (2017). *Water Monitoring and Climate Change in the Upper Columbia Basin: Summary of Current Status and Opportunities*. https://ourtrust.org/wp-content/uploads/downloads/2017-02_Trust_WaterMonitoring-ClimateChange_Web.pdf

[lxxvi] GW Solutions. (2016). *Peace River Regional District Water Quality Database and Analysis*.

[lxxvii] Fort Nelson First Nation. (2017). *Liard Basin Monitoring Initiative Year 1 State of Knowledge Report.* Fort Nelson First Nation Liard Basin Monitoring Initiative. http://www.fortnelsonfirstnation.org/news.html

Photo: Living Lakes Canada

APPENDIX A: Descriptions of Province-Wide Monitoring Networks

Joint Federal-Provincial Hydrometric Network

Provincial and federal hydrometric stations in British Columbia are managed jointly under the Canada-BC Hydrometric Agreement which was renewed in 2013. Hydrometric data are collected and compiled by the Water Survey of Canada and is housed in two centrally-managed databases: HYDEX and HYDAT. HYDEX is the relational database that contains inventory information on the various streamflow, water level, and sediment stations (both active and discontinued). This database contains information about the stations themselves such as; location, equipment, and type(s) of data collected. HYDAT is a relational database that contains the actual computed data for the stations listed in HYDEX. These data include: daily and monthly means of flow, water levels and sediment concentrations (for sediment sites). For some sites, peaks and extremes are also recorded. Real-time and historical hydrometric data and hydrometric station and network meta-data metadata (such as station name, location, drainage area, data type, gauge type, stream order) are available online[1].

There are currently 477 active hydrometric monitoring stations in the Provincial-Federal Network in British Columbia. Many of the active hydrometric stations were constructed to serve a specific water management purpose at specific sites, while others were strategically located to document hydrological characteristics and processes to understand regional hydrology[2]. The lengths of the data records are variable, depending on the site. The average record length for the active sites is 54 years. The longest record is for the Fraser River at Mission which has been monitored for 141 years. To help address low flow concerns the number of sites with water temperature monitoring has increased to 126 compared to 22 in 2008. In order to improve access to real-time hydrometric information the number of sites with telemetry has increased to 383, compared to 194 in 2008.

Over the last several years, the Province has purchased equipment to conduct hydrometric monitoring at regional priority sites for both annual and seasonal (low flow) monitoring. Over 100 sites are either established or being planned. Currently gauge height data are available from 76 sites on the BC Real-time Water Data Portal[3].

[1] https://wateroffice.ec.gc.ca

[2] http://www.ec.gc.ca/rhc-wsc/default.asp?lang%20=En&n=E228B6E8-1

[3] http://aqrt.nrs.gov.bc.ca/Data/Map/Parameter/Stage/Statistic/LATEST/Interval/Latest

Joint Federal-Provincial Water Quality Network

Monitoring for the Federal-Provincial Water Quality Network assesses water quality status and long-term trends, detects emerging issues, is used to establish water quality guidelines, and track the effectiveness of remedial measures and regulatory decisions. There are currently 45 active sites in British Columbia and these are located in the Fraser River Basin, Columbia River Basin, Okanagan-Similkameen River Basin, Pacific Coastal Basin, and there is one site in the Peace-Athabasca River Basin. There are no sites in the Yukon, Taku, or Nass drainage basins.

Samples are analyzed for various physical-chemical parameters, nutrients, major ions, and total and extractable metals. Sampling protocols specific to the operations of the Federal and Federal- Provincial Water Quality Networks in BC and the Yukon have been developed including: sampling from bridges; sampling from shore; collecting air and water temperature measurements; filling in the data card; quality assurance for sample collection; dissolved metals filtering; and for using the dissolved oxygen meter. There are also protocols for data approval and the data are reported as validated or non-validated. Lengths of data records and frequency of testing depend on site location.

Provincial Groundwater Observation Well Network

The Provincial Groundwater Observation Well Network program collects, interprets, and reports information about groundwater quantity and quality. The network was established in 1961 and this long-term dataset allows for the monitoring of ground water patterns and trends.

In 2009, a review of the Network[4] was conducted, the results of which have been used to guide changes and additions to the network. In 2009, there were 144 wells in the Network and this has been increased to 219 in 2017. The province is anticipating increasing the number of wells in the network by two to three wells annually over the next few years (on average).

Almost two-thirds of the observation wells in the network transmit water level information through satellite telemetry. Ground water samples are collected and analyzed for nutrients, metals and general water chemistry. The sampling frequency for each observation well is based on the classification of the aquifer being monitored, the age of the well within the network, and long-term analytical trends. Data are available on the BC Real-time Water Data Portal[5].

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[4] Hodge Hydrogeology Consulting, Azar & Associates, & Hy-geo Consulting. (2009). *Provincial Observation Well Network Review- British Columbia (Vol.I & II).* http://a100.gov.bc.ca/appsdata/acat/documents/r20489/ObsWellNetworkReviewVol1_1292876648183_8691bd33a0340692500d37fb4a445e7ed50dda2e2a5107fdc65fb54918231a94.pdf

[5] https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/real-time-water-data-reporting

Canadian Aquatic Biomonitoring Network

The Canadian Aquatic Biomonitoring Network (CABIN) is a nationally standardized biomonitoring approach developed by Environment and Climate Change Canada (ECCC) to assess the health of freshwater ecosystems. CABIN relies on sampling benthic macroinvertebrate communities. Data from reference sites that are minimally impacted by human activities are used to build predictive models to evaluate ecosystem health at sites where water quality is a concern. The Provincial Ministry of the Environment and Climate Change Strategy (ENV) has partnered with ECCC over the past decade to expand the CABIN program across B.C., with various agencies including ENV and Parks Canada collecting data to populate the database. There are currently predictive models available for the entire province, with the exception of portions of Northeast B.C. However, there has been sampling conducted in the Northeast B.C., and models are expected to be completed soon.

Parameters typically collected at each CABIN site include site descriptor data (monitoring location, basin name, stream order, etc…), field habitat data (flow, channel measurements, substrate size, etc…), benthic taxonomy data, and water quality data and some landscape-level Geographic Information System (GIS) data. Data collection requirements are specified in the CABIN Field Manual[6].

As of December 2017, there have been 129 studies in BC that have used CABIN. The total number of samples analyzed include 686 potential reference site samples, 956 reference site samples, and 4939 test samples from 3304 sites in BC. A potential reference site is the same as a reference site but has yet to be incorporated into a predictive model. The BC Ministry of the Environment has identified 8 “sentinel” sites that it attempts to monitor annually to look at long-term changes to aquatic ecosystems.

CABIN can be used as a decision-making tool for water quality objectives monitoring, environmental impact assessment, cumulative effects monitoring, regulatory effectiveness evaluations, and state of the environment monitoring. Individuals can take training to access the CABIN database and compare test sites (samples) to predictive models to assess ecosystem health. The existing CABIN models have been used by approximately 350 different CABIN users, including various levels of government, academic institutions, First Nations and industry. CABIN data from individual studies need to be requested from the study proponents. Recently, CABIN data has been made available through the Government of Canada Open Data Portal[7].

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[6] http://publications.gc.ca/site/archivee-archived.html?url=http://publications.gc.ca/collections/collection_2012/ec/En84-87-2012-eng.pdf
[7] https://open.canada.ca/data/en/dataset/13564ca4-e330-40a5-9521-bfb1be767147

B.C. Lake Monitoring Program

The B.C. Lake Monitoring Program is planning to collect *status and trends* water quality data for 140 sites in 102 lakes throughout the province. The goals of the program are to:

- Determine background water quality of B.C. lakes to provide a baseline for environmental assessment and assess the status and trends in response to watershed and climate change, pollution control, and other management actions;
- Assess the potential cumulative risks to B.C. lakes and to evaluate the effectiveness of regulations around high priority initiatives that are underway in the province (e.g., LNG, mining, and built communities);
- Evaluate water quality status to established Water Quality Objectives for key parameters and determine trophic status;
- Provide accessible, accurate and timely water quality data for BC lakes to inform decision makers within government, industry, and the public; and
- Develop partnerships with stewardship groups and other programs to provide a strategic coordinated approach to provincial lake sampling.

Sites were selected using a priority ranking tool based on values, risks, and impacts and ensuring that the lakes selected cover all eco-provinces and span wide gradients of lake characteristics including area, depth, and trophic status. Sampling is conducted in late-winter/spring and late-summer/fall every year (depending on where in the province the lakes are located) by Ministry of Environment staff, partners, stewardship groups and volunteers. Parameters to be analyzed include a variety of physical, chemical and biological parameters, with additional biological parameters if funds allow.

In 2017, samples were collected at 87 of the 140 sites and the program is working on developing plans and obtaining capacity to monitor all of the desired sites. Currently the B.C. Ministry of the Environment and Climate Change is developing a framework with the B.C. Lakes Stewardship Society and Living Lakes Canada on how stewardship groups can support the B.C. Lake Monitoring Program. Although the program is relatively new, it builds on longer-term water quality data sets that exist for some of the lakes. The program is still in its infancy, and plans for how the data will be stored, analyzed and shared are not yet fully developed.

APPENDIX B: Examples of Monitoring Collaborations

Review of monitoring and reporting collaborations indicate that regions that have: (1) a distinct issue, problem or question that needs to be solved; (2) champions to lead; (3) networks for collaborations (including networks to access funding and technical support); and (4) sufficient capacity (in particular funding) have made the most headway in identifying and filling regional data gaps. Below are some examples of collaborative monitoring and data sharing efforts identified in this Scan.

Coastal Stewardship Network Regional Monitoring System[8]

The Coastal Stewardship Network Regional Monitoring System is a network of Local Guardian Watchmen from nine First Nation communities on the central and northern BC Coast. Although most data in this program are marine-based and related to fish stocks, some water quality and quantity data for salmon spawning streams are collected. Water quality and quantity data are recorded using a mobile device application following Fishery and Oceans Canada's stream inspection log protocols (SIL cards). Data are compiled in a centralized database. Each First Nation owns their data and has data sharing agreements with other First Nations. Members can access the data through the centralized database which has access and privacy controls based on data sharing agreements. Some First Nations in the Network have created data sharing agreements with outside third parties.

Columbia Basin Water Quality Monitoring Project[9]

The Columbia Basin Water Quality Project (CBWQ) is a citizen scientist project made up of non-profit partner groups who monitor their local watersheds in the Columbia Basin. CBWQ has been administered and coordinated by Mainstreams Environmental Society in Kimberley since the inception of the project in 2007. The purpose of this project is to build the capacity of citizen-scientists in local watershed groups to monitor their water. CBWQ monitoring protocols are based on Environment Canada's Canadian Aquatic Biomonitoring Network standards (CABIN). The CBWQ has a website whose purpose is to provide public access to project data. The data provided on the website includes water chemistry, velocity and flow, temperature graphs and reports. The CBWQ has been primarily funded by Columbia Basin Trust since 2007. This project would not be possible without the continuing funding from the Trust. The purpose of the CBWQ website is to provide public access to project data.

[8] http://coastalfirstnations.ca/our-environment/programs/regional-monitoring-system/

[9] http://cbwq.ca

Columbia River Treaty Hydrometeorological Committee[10]

The Columbia River Treaty (the Treaty) Hydrometeorological Committee (CRTHMC) was formed in 1968 under the Columbia River Treaty and was given the responsibility for planning and monitoring the operation of data collection facilities to support the Treaty. The Committee is comprised of members from B.C. Hydro in Canada and the U.S. Army Corps of Engineers Northwest Division and Bonneville Power Administration in the United States. The Committee works with many other data collection and water supply forecasting groups around the Pacific Northwest and has provided the necessary support to help preserve hydrometeorological stations through times of shrinking networks. A data exchange system was developed by the Corps to manage the exchange of information across the Columbia Basin to report on and support planning of the operation of Treaty projects on the Columbia River.

Decolonizing Water Project[11]

The long-term goal of the Decolonizing Water Project is to create a self-sustaining water and ecological monitoring program that will enhance protection of water resources and fulfill the promise of Indigenous water governance. The Project engages in interdisciplinary, and Indigenous-led co-research on water including its ecological, socio-economic, cultural, and spiritual dimensions. The Decolonizing Water Project, in partnership with Environmental Bio-Detection Products Inc (EBPI) and the UBC Ecohydrology Lab, are developing a low-cost, open-source, do-it-yourself alternative to commercial water quality loggers that can be used to use to monitor water quality and identify locations of contamination. The logger can be pulled across lakes or rivers behind a canoe or boat and, at programmed time intervals, record electrical conductivity, temperature, and GPS position, to an SD data storage card.

Environment and Climate Change Canada Meteorological Service of Canada Network of Networks

Environment Canada's Meteorological Service of Canada (MSC) is developing a "Network of Networks" initiative. It is a principles-based, multi-participant, collaborative approach to monitoring that encourages and facilitates access to observations from a variety of network operators, within a structured national framework. It includes data policies and technical standards to encourage and facilitate timely and open exchange of data among many contributors – supported by a modern data management system. Pilot projects for weather stations in British Columbia and Ontario were identified. Data sharing agreements will be formalized with third party data providers through Memorandums of Understanding. Although MSC's "Network of Networks" initiative is for weather data, similar frameworks could be applied to freshwater monitoring. Currently, the Provincial-Federal Hydrometric

[10] https://westernsnowconference.org/sites/westernsnowconference.org/PDFs/2008Smith.pdf

[11] http://decolonizingwater.ca/

Monitoring and Water Quality Networks and the Canadian Aquatic Biomonitoring Network have various types of data and cost sharing agreements with multiple different partners.

Fort Nelson First Nation Liard Basin Water Monitoring Initiative[12] & Community Based Monitoring[13]

The Liard Basin Water Monitoring Initiative (LMBI) is a 3-year pilot initiative led by the Fort Nelson First Nation (FNFN) to develop a cumulative effects monitoring program for the Liard Watershed based on FNFN cultural and ecological values. The LBMI's focus on water quantity includes both surface and groundwater. Overall, surface and groundwater monitoring are currently not adequate to monitor cumulative effects across the Liard Watershed. The Water Survey of Canada has 9 active hydrometric stations on larger rivers in the Watershed. In 2017, Fort Nelson First Nation took over the operation of 4 hydrometric stations from Geoscience BC that were formerly part of the Horn River Basin Aquifer Project. The FNFN have identified 17 proposed hydrometric station locations that should be monitored on smaller rivers. FNFN have also identified priority places where monitoring should occur for baseline water quality, aquatic ecosystem health, and sedimentation. The FNFN is also preparing a community watershed plan and is currently piloting monitoring to support the plan. Monitoring data are shared on the Mackenzie Data Stream[14].

Horn River Basin Aquifer Project[15]

The Horn River Basin Aquifer Characterization Project was a cooperative effort between GeoScience B.C. and the Horn River Basin Producers Group (HRBPG). In 2008, Geoscience B.C. secured $5 million in funding from the B.C. Ministry of Energy, Mines and Petroleum Resources for geoscience studies to support the timely and efficient appraisal and development of the Horn River Basin shale gas resource. The objectives of Phase I of the project were to: (1) Synthesize available geological information to produce a stratigraphic framework for hydrogeological / aquifer analysis; (2) Facilitate collection of aquifer and fluid data from new Producer Group wells, particularly those being drilled for water supply and disposal and (3) Undertake a systematic hydrogeological investigation of potential aquifers in the Horn River Basin in order to quantify and map reservoir capacity and productivity/injectivity potential. In phases 2 and 3, the project was expanded to undertake baseline surface and ground water hydrological research and to collect and share water data in the Horn River Basin and South Peace region to improve industry practices and to provide the information required to make informed decisions about water and natural gas extraction.

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[12] http://www.fortnelsonfirstnation.org/uploads/1/4/6/8/14681966/fnfn_sok_year_1_summary_jan_5_2018_web.pdf

[13] http://wildsight.ca/wp-content/uploads/2016/11/BB2.2-Lowe.pdf

[14] https://mackenziedatastream.ca/#/

[15] http://www.geosciencebc.com/s/HornRiverBasin.asp

Indigenous Observation Network - Yukon River Basin[16]

The Indigenous Observation Network is a collaborative water quality monitoring project between the US Geological Survey (USGS), Yukon River Inter-Tribal Watershed Council (YRITWC), and Yukon River Basin communities. Since 2006 the USGS and YRITWC have been partnering to collect water-quality samples from the Yukon River and tributaries with the assistance of trained community members living in the Yukon River Basin. The YRITWC provides support for this project through sample collection, sample processing and shipment logistics with communities and to the USGS. The USGS provides water analysis and data interpretation support. Through this partnership over 300 community members have been trained in water sample collection, which has resulted in over 1,500 samples collected at more than 50 sites covering the entire 2,300 mile reach of the Yukon River since the program began. This program has allowed the USGS to create and maintain a baseline record (long-term at some sites) of water-quality in the river basin, critical for understanding climate change impacts.

Kiskatinaw River Watershed Stewardship Program[17]

The City of Dawson Creek has a Watershed Stewardship Program (WSP) that is committed to understanding groundwater recharge, flow forecasting, water quality and water supply demands. A 3-year watershed baseline research program was conducted in partnership with the University of Northern BC and the Regional District. In April of 2015, the WSP partnered with the University of Alberta's Foothill Research Institute (FRI) to complete the Kiskatinaw Watershed Management Strategy. Through the North East Water Strategy, the WSP secured partners and funding to establish two Water Survey of Canada Hydrometric Stations in the Kiskatinaw River Watershed. The WSP works with the Dawson Creek Watershed Society Board and the Pacific Streamkeepers Federation Program on training, outreach, and monitoring. The WSP prepares an annual report summarizing water monitoring activities.

Living Lakes Canada Columbia Basin Groundwater Monitoring Program[18]

Living Lakes Canada's Columbia Basin Groundwater Monitoring Program works with local, regional, First Nation and provincial governments, local citizens, landowners, and community groups to identify and monitor priority aquifers and increase awareness about groundwater stewardship in the Upper Columbia Basin. Currently, twelve priority aquifers have been identified by the province based on vulnerability and relevance for future water

[16] https://www.sciencebase.gov/catalog/item/573f3b8de4b04a3a6a24ae28

[17] http://www.dawsoncreek.ca/departments/infrastructure/water-environmental/watershed-stewardship-program/

[18] http://livinglakescanada.ca/projects/columbia-basin-community-based-groundwater-monitoring-program/

management, and water level monitoring data are being collected. The program supplements the Provincial Groundwater Monitoring Well Observation Network (PGOWN) as there are limited PGOWN wells in the Upper Columbia Basin.

Mission Creek Groundwater and Surface Water Interaction Study[19]

The Okanagan Basin Water Board is working with the Okanagan Nation Alliance, City of Kelowna, UBC Okanagan, and the South East Kelowna Irrigation District on hydrometric and groundwater monitoring to support studies to understand the interactions between groundwater and surface water flow for Mission Creek. Ultimately, information from the study will help determine whether new well licenses should be issued near Mission Creek.

Upper Morice Water Quality Objectives Development[20]

Through Government to Government negotiation during the Morice Land and Resource Management Planning process, the Office of the Wet'suwet'en (OW) and the Provincial Government established the Morice Water Management Area (MWMA) to help protect water quality and fish stocks that are vital to First Nations health and culture. In 2008, the Environmental Protection Division, Skeena, and the OW partnered to create a water quality monitoring framework and Multi-Year Operational Plan for the MWMA. One objective of the plan is establishing site specific water, sediment, and/or biological quality objectives related to potential cumulative effects from gas and oil pipelines, mining and forestry. One year of baseline data was collected toward the development of water quality objectives (WQOs) in 2008 and at additional sites associated with a proposed gas pipeline in 2013. Between September 2015 and October 2016, up to 17 water quality samples were collected from each of 5 sites.

Peace Region Groundwater Monitoring Network Installation Project[21]

Thirty new groundwater monitoring wells will be installed across the Peace Region in northeast B.C. as part of a collaboration among the University of British Columbia, B.C. Oil and Gas Commission, Geoscience B.C., Simon Fraser University, and the University of Calgary. The project will address knowledge gaps in ground water conditions in areas of resource development in B.C., including levels of methane and other hydrocarbons close to oil and gas wells. This new research project will generate high quality scientific data to address concerns related to resource development in the Peace Region. The first eight monitoring wells will be installed in 2018 with the project concluding in spring 2020. It is

[19] http://www.obwb.ca/water-board-to-study-groundwater-flows-in-mission-creek/

[20] https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/land-water-use/crown-land/land-use-plans-and-objectives/skeena-region/morice-lrmp/morice_water_management_area_multi_yr_op_plan.pdf

[21] http://eeri.ubc.ca/current-research-projects/peace-region-monitoring-network-installation-project/

anticipated that the infrastructure will allow ongoing monitoring of ground water trends and cumulative effects in northeast B.C. for decades to come.

Provincial Lake Monitoring Program

The B.C. Ministry of the Environment and Climate Change Strategy's (ENV) B.C. Lake Monitoring Program is planning to collect status and trend water quality data for 140 sites in 102 lakes throughout the province. In 2017 samples were collected at 87 of the 140 sites and there is limited capacity to be able to monitor all of the sites. Currently, the ENV is working with the B.C. Lake Stewardship Society and Living Lakes Canada on an Integrated Lake Monitoring Framework for B.C. that outlines how the province and stewardship groups can work together to monitor sites in the B.C Lake Monitoring Program. Although the program is relatively new, it builds on longer-term water quality data sets that exist for some of the sites.

Regional District of Nanaimo- Community Watershed Monitoring Network[22]

The Community Watershed Monitoring Network is partnership among the Regional District of Nanaimo's (RDN) Drinking Water and Watershed Protection program, the Ministry of the Environment and Climate Change Strategy (ENV), Island Timberlands LP, and community watershed stewardship groups. The RDN has the capacity to facilitate the Network through a parcel tax that supports the Drinking Water and Watershed Protection Program.

The RDN provides the equipment and works with the ENV to complete annual training and data analysis. The ENV contributes expertise in water quality testing, deciphering gathered data and guidance in program direction. Island Timberlands sponsors the lab analysis costs for Quality Assurance and Quality Control, loans volunteers' safety gear and provides access to the upper watersheds. Community groups donate their time, attending annual training sessions, calibrating equipment and getting out on their local streams to collect water quality data. After three years of sampling, each site's results are reviewed and testing at sites with consistently good water quality is suspended for three to five years. This allows resources to be used to expand the network, adding sampling at new sites where needed.

Upper Fraser Fisheries Conservation Alliance Water Monitoring Program

The Upper Fraser Fisheries Conservation Alliance (UFFCA) are working with the University of Northern British Columbia and First Nations in the Upper Fraser Watershed to fill data gaps on small hydrometric systems that are needed to: compile baseline data; address environmental flow needs; and support habitat restoration. Hydrometric, water quality and time lapse photography monitoring are conducted at 21 stations in small sub-watersheds in the upper Fraser Basin.

[22] http://www.rdn.bc.ca/community-watershed-monitoring

Water Quality Monitoring in Elk Valley[23]

Teck Coal Limited (Teck), who operate six coal mines in the Elk Valley, has surface and ground water quality monitoring programs to support its Elk Valley Water Quality Plan. The development of the Water Quality Plan, as well as a Water Quality Assessment to inform the Plan, and the associated monitoring are requirements of a ministerial order and permit from the provincial government which authorizes effluent discharges from Teck's mining operations. The permit also required the establishment of an Environmental Monitoring Committee (EMC) to strengthen the design of monitoring programs and ultimately support the Plan's objectives. The EMC consists of: BC Ministry of Environment and Climate Change Strategy; BC Ministry of Energy, Mines and Petroleum Resources; Ktunaxa Nation Council; Interior Health Authority; Teck; and an independent scientist. The EMC has face to face meetings, produces an annual public report, and hosts an annual public meeting that presents results from permit-related monitoring.

The Water Quality Plan sets out methods and phased site-specific performance objectives and compliance limits to address elevated selenium and nitrate concentrations in the Elk and Fording Rivers which were routinely elevated above water quality guidelines and were generally increasing in many areas. Water monitoring is conducted at:

- Eight authorized discharge Compliance Points (stations that capture and reflect all or most direct and indirect discharges from a mine site);
- Seven Order Stations (stations used to monitor water quality in the Elk Valley more generally and provide information on the implementation success of the Elk Valley Water Quality Plan); and
- 88 authorized discharge, receiving environment, and other sampling sites;
- 36 ground water wells and one background well that form the Regional Groundwater Monitoring Program; and
- Ground monitoring wells for site-specific monitoring at each mine operation.

[23] https://www.teck.com/media/Environmental-Monitoring-Committee-Report-2017.pdf

APPENDIX C: Annotated bibliography of large watershed scale data reviews, monitoring program reviews, and data needs & opportunities that were identified in this Scan

Region/Watershed	Report
Large Watershed Scale Data Compilations and Assessments of Data Gaps	
National	World Wildlife Fund. (2017). ***Watershed Reports – A National Assessment of Canada's Freshwater***. A national health assessment of major watersheds and sub-watersheds based on currently accessible and available data that aligns with selected indicators, e.g. water flow, water quality, fish, and benthic invertebrates. Results indicated there was insufficient data to assess overall health and specific indicators for many of BC's watersheds and sub-watersheds. For the Pacific Coastal and Mackenzie watersheds in B.C. there were insufficient data to assess health. In other watersheds and sub watersheds throughout the province there were insufficient data for one or more of the indicators (water flow, water quality, fish, and benthic invertebrates).
Upper Columbia Basin	Carver, M. (2017). ***Water Monitoring and Climate Change in the Upper Columbia Basin: Summary of Current Status and Opportunities***. January 2017. Columbia Basin Trust. Provides an overview of the current state of water monitoring and associated scientific understanding in the Upper Columbia Basin, examines the expected effects of projected climate change, and identifies opportunities to improve the understanding of Basin water resources.

Peace River Regional District	GW Solutions. (2016). ***Peace River Regional District Water Quality Database and Analysis***. Peace River Regional District and Treaty 8 Tribal Association. Publicly available surface and groundwater data were compiled, sorted, formatted, organized, and analyzed to provide groundwater-surface water baselines. Revealed the absence of adequate temporal and spatial monitoring of both surface water and groundwater prior to and concurrent with human activities that may impact water. Identified urgent need for a proper surface water and groundwater monitoring plan, supported by adequate planning and funding.
Northeast BC	Northeast Water Strategy (NEWS). (2017) **Northeast Water Strategy Progress Report-2017**. Of the 52 current and historic Water Survey of Canada hydrometric stations in Northeast B.C., 31 stations are active, recording real-time data. Eighteen additional current and historical hydrometric stations in Northeast B.C. are managed by GeoScience BC, local government, Oil and Gas industry, and/or universities. The *Surface Water Quality Data Summary for Northeast B.C.* project's main goal was to summarize the available data, characterize it and identify trends in water quality so an appropriate enhanced monitoring program could be established for the region. It was found that only 21 of the 69 watersheds had data from within the last 10 years and 35 watersheds have no data.
Northeast BC	Lapp, S., Redding, T., Ronneseth, K., & Wilford, D. (2015). ***Research and Information Needs Assessment to Support Sustainable Watershed Management in Northeast British Columbia***. Information needs assessment based on survey of key people involved in water research and management in Northeastern B.C. In total, 65 respondents completed the survey and identified priority topics for research, monitoring, tools, and policy. Includes on-line database[24] of data, information sources, and relevant research.
Northeast BC	Adelaide Consulting. (2013). ***Summary of Water Stewardship Activities in Northeast BC***. Catalogues information sources, programs, initiatives, tools and activities undertaken by the Province and its partner organizations to support water stewardship in Northeast B.C. Supports gap analysis and planning for future studies and monitoring programs.

[24] http://www.bcwatertool.ca/info-sources/northeast-bc/

Program Reviews	
Provincial	Office of the Auditor General of British Columbia. (2016). ***An Audit of Compliance and Enforcement of the Mining Sector*.** Goals of the audit were to determine whether the regulatory compliance and enforcement activities of the Ministry of Energy and Mines (MEM) and the Ministry of Environment (ENV), pertaining to mining, are protecting the province from significant environmental risks. The auditor general found that expectations for a robust compliance and enforcement program within the MEM and the ENV were not met, monitoring and inspections of mines were inadequate to ensure mine operators complied with requirements, and there are too few resources, infrequent inspections, and lack of enforcement.
Provincial	Saarinen, E. (2012). *Review of the 2011- 12* ***Source Water Quality Data Consolidation Pilot Project*.** Victoria. Review of how source water data from health authorities can be consolidated into the provincial Environmental Management System (EMS). Main challenges associated with consolidating data include time, complexities of establishing upload capabilities, gaining participation, costs, and staffing.
Provincial	Office of the Auditor General of British Columbia. (2010). ***An Audit of the Management of Groundwater Resources in British Columbia*.** Victoria. Concluded information on groundwater is insufficient to ensure sustainability of groundwater resources. Recommended that MOE lead coordination of consolidating groundwater monitoring information collected by provincial ministries and other agencies to reduce duplication of effort and to ensure the best use of limited resources.
National	Environment Canada. (2010). ***Audit of the National Hydrometric Program***. Identified sub-watersheds with no coverage or insufficient hydrometric monitoring based on program objectives.

Provincial	Hodge Hydrogeology Consulting, Azar & Associates, & Hy-geo Consulting. (2009). ***Provincial Observation Well Network Review- British Columbia*** **(Vol. I&II)**. The 2009 Review recommended an additional 50-75 new observation wells in the next 10 to 15 years. Review is being used to guide changes and additions to the Provincial Observation Well Network. In 2009 there were 144 monitoring wells in the network and in 2017 there are 219.
Provincial	BC Ministry of Sustainable Resource Management. (2003). ***Water Quantity Monitoring in British Columbia: A Business Review of the BC Hydrometric Programs*****.** Assessed ability of existing network to provide data needed by users to make important business decisions. Informed the user community of challenges faced in maintaining the network and assessed how they can participate in obtaining and paying for their data requirements. Institutional and organizational options for the management of the program were also assessed.
Provincial	Cui, Y., & Wei, M. (2000). ***Ambient Groundwater Quality Monitoring and Assessment in BC: Current Status and Future Directions*****.** Proposes a strategic framework for expanding ambient groundwater quality monitoring in BC. Recommendations for improving existing ambient groundwater quality monitoring activities, including QA/QC measures, sampling strategies, collection of background information, data compilation, data quality, database design, data analysis, reporting and information dissemination.
Provincial	Office of Auditor General of British Columbia. (1999). ***Protecting Drinking Water Sources - Auditor General Report*****.** Recommended that one agency should be assigned the role of "voice of water" within government. Highlights challenges of inter-agency responsibilities related to water.
Other Research, Reports, and Guidelines	

Provincial	Nelitz, M., Smith, R., & de la Cueva, P. (2015). ***Surface Water Allocation in a Changing Climate: Data Gaps, Needs, and Priorities*.** Provincial water managers were surveyed to understand their most pressing needs/demands and to assess data gaps, needs, and priorities to improve water management and decision making in the context of climate change in BC. Short and long-term priorities were identified including improved harmonization of hydrometric data from multiple organizations with existing data portals, and collection of continuous hydrometric data at new locations.
Provincial	Rathfelder, K. (2016). ***Modelling Tools for Estimating Effects of Groundwater Pumping on Surface Waters*.** Supports implementation of the Water Sustainability Act and groundwater licensing by investigating surface water-groundwater interactions and evaluating modelling approaches and tools for quantifying impacts of groundwater withdrawals. Recommends that studies and monitoring activities should be supported to improve understanding of surface water-ground water connectivity.
Provincial	Hy-Geo Consulting. (2015). ***Development of Preliminary Water Budgets for Two Aquifer Areas in British Columbia.*** Tests the previous established water budget methodologies on two aquifers in BC. Provides prioritized recommendations for collecting more accurate information to assist with future groundwater licensing initiatives.
Provincial	Lewis, A., Hatfield, T., Chilibeck, B., & Roberts, C. (2004). ***Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia*.** Defines assessment methods for identifying impacts from water withdrawals on aquatic habitat. Recommends hydrology information submitted by water license applicants should meet or exceed the standards published by the Resources Inventory Standards Committee. Strongly recommends that it is in the interest of all project proponents to establish new gauging stations when none exist on the affected streams.

Federal	Canadian Council of Ministers of the Environment. (2015). ***Guidance Manual for Optimizing Water Quality Monitoring Program Design*.** Water quality management benefits from optimized, effective and cost-efficient water quality networks because they support sound decision-making and provide insight into how various ecosystem components interact. Well-designed monitoring systems should result in lower costs for implementation and increased monetary benefits associated with environmental improvement. Five main steps in water quality monitoring design are described in this guidance and an overview of systematic tools to evaluate and optimize each of these five steps is provided. In addition, a number of statistical tools are discussed for key aspects of monitoring program design optimization including tailor-made monitoring objectives, spatial and temporal monitoring design considerations (number of samples and station selection; sampling frequency). A step-by-step flowchart including a support toolbox based on systematic rational criteria is presented to strengthen monitoring programs by becoming more effective and cost-efficient, while promoting Canada-wide consistency in program design.
Reports Specific to Jurisdictions	
First Nations	Cave, K., McKay, S., Nelitz, M., & Switzman, H. (2016). ***Indigenous Involvement in the Network of Networks: Enhancing Access and Use of Hydrometeorological Data for Water Management*.** Outlines what is needed to ensure that indigenous communities can participate in and derive value from Environment and Climate Change Canada's Network of Networks. Includes key findings and other observations relevant to the structure and nature of Indigenous engagement in addressing gaps in water and climate monitoring information.
First Nations	Evans, B., & Carlick, S. (2014). ***Workshop Summary Report: On the Ground Indigenous Stewardship in Canada.*** Identifies priority needs and strategies for indigenous stewardship including the need for data collection to be linked to resource management and community learning.

First Nations	Cave, K., Ko, J., Layton-Cartier, G., & McKay, S. (2016). ***Indigenous Watershed Initiatives and Co-Governance Arrangements: A British Columbia Systematic Review*.** Systematic review of indigenous watershed initiatives and co-governance arrangements to identify capacity gaps and to contribute to shaping the future of water/watershed planning and a new watershed governance regime in BC. Survey extended to 200 First Nation communities and 27 First Nations' organizations; 63 submissions received. Results included information about community-based monitoring and data collection capacities and needs.
Community-Based Monitoring	Carlson, T., Cohen, A., & Hartwig, K. (2016). ***A Snapshot of Community Based Monitoring in Canada*.** Nation-wide survey of community-based monitoring (CBM) programs. CBM programs are filling information gaps on watershed health, informing decision-making at various levels of government, and fostering environmental stewardship in communities. Majority are following scientifically-rigorous protocols, having data analyzed by professional scientists, and addressing a diversity of community concerns relating to the health of freshwater resources. On-going challenges include inadequate or unpredictable funding, inconsistent monitoring protocols, and difficulty in translating diverse and regionally- specific data to coherent recommendations for decision-makers.
Community-Based Monitoring	Our Living Waters, (2016). ***Realizing the Potential of Community Based Monitoring in Assessing the Health of Our Waters*.** Identifies core challenges for CBM: (1) Ensuring credible data; (2) Connecting indigenous traditional knowledge and western science; (3) Engaging and motivating citizens; (4) Informing decision makers; and (5) Data accessibility and aggregation. Provides five case studies for overcoming these challenges.

Photo: Okanagan Nation Alliance