Data Management System Options for Community-Based Water Monitoring Groups

A Collaborative Monitoring Initiative Guide

Collaborative Monitoring Initiative

JUNE 2022

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EXECUTIVE SUMMARY

A survey of British Columbia community-based water monitoring data management systems and their capabilities was carried out to assist Indigenous and non-Indigenous groups and their partners in taking steps to improve how they store, share, and use western science and Indigenous Knowledge related data.

The project was conceived to fill a need among over 100 community-based water monitoring (CBM) groups in the province to better coordinate, plan for and manage water related data so that it is of higher value for use in existing and emerging watershed level planning and decision making.

The qualitative survey was conducted using a telephone interview format with individuals representing 12 CBM related data management systems. These systems were chosen to represent a sliding scale of capabilities described as:

BASIC DATA SYSTEM → **INTERMEDIATE DATA SYSTEM** → **ADVANCED DATA SYSTEM**

Six themes of information were discussed as part of the 12 interviews, including:

Project Purposes, Data Types, System Attributes, Data Management Plan/Functions/Attributes, Communication Pathways For Users And Decision Makers, Access Through Web Link(s) And Other Means.

These six themes were then further reorganized into 20 data system attributes.

The information was summarized and qualitatively analyzed to provide the following 3 outcomes:

1. **Characterization of each data system in terms of capabilities inherent in each of the six themes of information obtained, as well as in aggregate.**
   This helps CBM groups understand where a given data system may fit in terms of capabilities relative to each system in the group of 12 (note that there is no global ideal set of data system capabilities, as they are entirely dependent on a group's purposes for the data).

2. **20 data system attributes were defined using aggregated capability information gathered for all 12 data systems.**
   Each were depicted on a sliding scale of complexity (basic to advanced). This provides a broad range of possible capabilities to explore when considering data system improvements.

3. **A graphic illustration of the sliding scale of data system capability.**
   See Figure 1 (pg 28). This may further help CBM groups see where they may "stand" and possible incremental data management system enhancements that may be chosen to follow.

The introductory background information and these three outcomes were then used as the basis of recommendations regarding how a broad collaborative approach may assist CBM groups to incrementally evolve in the direction of more advanced data management systems.

RECOMMENDATIONS:

1. **Collaborate on best practices to harmonize the use of Indigenous Knowledge and western science data management systems where possible**
2. **Create a CBM focused community of practice for data system development and management**
3. **Foster regional coordinated data system collaboratives**
4. **Create a provincial data catalogue/directory as a single source of information about available water data**
5. **Explore creation of a non-profit software advisor/provider for CBM groups**

1. INTRODUCTION

This survey of 12 data management systems and their capabilities is meant to assist CBM groups and their partners in improving how they store, share, and use water data, including western science and Indigenous Knowledge.

First, the case is made for an integrated, rigorous approach. Then some examples of systems in BC are described in terms of capabilities, including purposes, data types, system attributes, data management plans, functions, communication pathways and data access. This is followed by some recommendations for CBM groups to incrementally enhance their data management capabilities.

"Data is the "life blood" of an organization, for as it flows between systems, databases, processes, and departments, it carries with it the ability to make the organization smarter and more effective."[1]

For the purposes of this document and its focus on data management systems, both western science information and Indigenous Knowledge are referred to as "data." In addition, CBM groups are broadly defined as Indigenous and non-Indigenous groups engaged in watershed-related monitoring, exclusive of provincial and federal governments (although these governments may be funders and/or partners of these groups).

PROJECT AND DATA MANAGEMENT PLANNING

Project planning must include data management and associated systems. Manuals and templates for this component are available online.[2] However, except for the simplest applications, data system development requires expertise to find the right solutions for the given circumstances.

Low cost solutions may be found in "off the shelf" institutional systems (e.g., BC's Environmental Monitoring System (EMS), Government of Canada Open Maps platform, and Gordon Foundation's DataStream). Use of open-source software and standards can also reduce overall costs for desired capabilities (e.g. Columbia Basin Water Hub, and Skeena Knowledge Trust Salmon Data Centre[3]). Commercial products such as Aquarius Time Series for a range of real time water data are often highly functional, but come with significant subscription costs. If there are multiple collaborators or data types, more than one platform and/or a custom approach may be needed, sometimes at significant cost. No matter what the capital cost of a given data system, there will be ongoing system maintenance, and operational costs and ongoing enhancements that must be included in the plan.

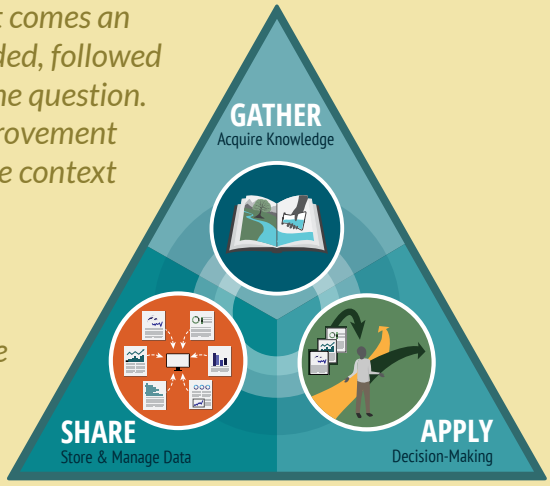
Water Knowledge Mobilization Framework

The triangle represents three discrete activities, that together form key ingredients in any watershed related monitoring project.

The three corners represent all of the ways water information (data) is acquired, ways in which it is managed (e.g., organize, store, share, interpret, analyze, communicate, report), and applied in a variety of decision-making processes (watershed or monitoring planning, restoration, advocacy, regulatory, cumulative effects assessment, etc.).

Generally, a monitoring project plan starts with a question related to a decision that needs watershed related information as part of the answer (note: a project may have multiple questions related to multiple decisions). Next comes an evaluation of what types and amounts of data may be needed, followed by acquiring, managing, and applying the data to answer the question. Often, this process requires an iterative, or continuous improvement approach to ensure that uncertainties are understood in the context of the decision.

In looking for the maximum leverage in capacity building among CBM groups, it is likely that improvements in data management, and associated systems will not only increase the value and overall use of monitoring data but will also foster improvements in data acquisition and use in decision making.



THE CASE FOR AN INTEGRATED, RIGOROUS APPROACH TO WATER DATA MANAGEMENT

British Columbia is in lockstep with the global trend of growing community involvement in monitoring aspects of watershed management. This is evident from a scan of recent documents and CMI experience in 2021. The scan provides a compelling picture of the demand for, and rigorous approach to water data management in BC.

Elements of the Scan

2018

- A **2018**, BC Water Funders Collaborative scan of the water data landscape in BC documented over 125 water monitoring initiatives involving a wide range of people and partnerships among governments (local, regional, provincial, federal, and Indigenous), community-based water monitoring groups (Indigenous and non-Indigenous organizations), individuals and industries. These initiatives varied widely in geographic scope and objectives, and "over 40 diverse data hubs, portals or databases that are sharing and/or summarizing data" were also identified.[4]
- In **2019**, POLIS Water Sustainability Project published a Watershed Governance Dispatch titled *Pooling Shared Information and Knowledge Governance*. It described examples of how multi-party collaborations are pooling and integrating various forms of water related data.[5]
- In **2021**, the Healthy Watersheds Initiative (HWI), funded by the BC government, and administered by the Real Estate Foundation of BC and Watersheds BC provided $27M to over 60 community-based watershed related projects. At least 10 of these projects had water monitoring as a focus, while an additional 34 had water monitoring components as part of a restoration focus.[6]
- In **May 2021**, a bioscience article titled *The Use of digital platforms for Community-Based Monitoring*[7] provided a global perspective on the necessary evolution of CBM data systems.
- In **2021 & 2022**, CMI conducted three CBM focused water data management webinars, which attracted over 200 participants each, demonstrating the importance of this topic to a broad range of interested groups.[8]

2022

What Was Learned From the Scan

- **Knowledge and data governance is the foundation of data management and needs further exploration and emphasis in monitoring planning.** This includes decision making and coordinative processes, collaborative arrangements and structures, and rules/guidelines for data collection, ownership, sharing, integration, storage, deletion, and use in watershed planning, management, and decision making.

- **Data management needs to be central to the design of CBM programs.** There is a compelling need to increase the role of CBM groups, especially Indigenous communities, in digital platform design, implementation, and use through participatory approaches during all stages of program development and implementation.

- **The move toward a balance of interoperability and data sovereignty, along with data standardization will support the use of CBM data across multiple scales of planning and decision making.** In achieving this, there needs to be a better understanding of how western science and Indigenous Knowledge can be used in concert for better watershed management. This includes respecting Indigenous groups' rights to exercise data and knowledge sovereignty at their discretion through the use of OCAP[9] principles (Ownership, Control, Access, and Possession), while emphasizing open data concepts typified by FAIR[10] principles for western science (Findable, Accessible, Interoperable, Reusable).

- **Trust in CBM generated water related data is often lacking, which limits its use in planning and decision making. Mistrust may be the result of:**

    - **Poor information management:** Data and information is often un-consolidated, and is difficult to access across organizations, reports, websites, or databases.
    - **Inconsistency of data integration:** Data collection methods are inconsistent, and data is not easily integrated, quality assured, shared, and used.
    - **Data and knowledge gaps:** This impedes the many types of data uses.

There needs to be a better understanding of how western science and Indigenous Knowledge can be used in concert for better watershed management. This includes respecting Indigenous groups' rights to exercise data and knowledge sovereignty.

What Was Learned from the Scan cont'd...

- **Industries need to be provided with opportunities and incentives to contribute relevant data to participate more fully in watershed management processes.**

- **Feedback during the CMI water data management webinars demonstrated a general atmosphere of curiosity and interest** in networking and coordinating various data storage platforms, opportunities to share data, how to support integration of data, and the importance of Indigenous Knowledge in watershed management. In addition to mirroring much of the content above, webinar outcomes included needs for:

    - **Concrete "next steps" for an accessible, coordinated approach to data management** for community-based monitoring/stewardship groups, including a community of practice for water monitoring data management.

    - **Enabling CBM groups to grow by creating more approachable data management practices, training opportunities and tools.**

    - **More funding and funding proposal criteria integration** to better reflect the strategic value of the range of CBM data.

    - **A data catalogue** to identify and access data residing on a range of data systems, and to provide opportunities for CBM groups to contribute data to these systems.

    - **Explore opportunities to collaborate** with industries on data management.

    - **Challenges and successes related to incorporating various forms of data,** including Indigenous Knowledge and quantitative measurements, into data sets and links to decision making.

2. SURVEY OF CBM DATA MANAGEMENT SYSTEMS IN BC

METHODS

All methods used in the survey were subjective in nature. Twelve CBM related water data management systems were chosen to illustrate the diversity of data system attributes across BC. This led to recommendations for CBM groups on how they may progress along a spectrum of data system capabilities based on evolving needs. (e.g., accelerating climate change and growing human footprint). A "question and answer" telephone interview format was used that had six themes (Project purposes; Data types; System attributes; Data Management Plans/Functions/Attributes; Communication Pathways for Users and Decision Makers; Access through web links or other), and a question regarding desired future system enhancements. Information for each of 12 data systems surveyed included originating organization and contact information, project summaries and possible future enhancements.

This information was summarized as follows:

1. **A master spreadsheet was used to organize and describe interview content, and illustrate qualitatively derived capability ratings (Basic, Intermediate, or Advanced) for each of the six Q&A themes. Then average ratings for all themes for a given data system were recorded.**
2. **Results for the six themes were then reorganized to better represent the range of data system attributes that could be of value to CBM groups looking to evolve their data systems. This was presented in a tabular summary of "sliding scales" of data system capability for each of 20 new attributes aggregated for the 12 surveys.**
3. **Integration of 1 and 2 above resulted in a graphic illustration of possible incremental data management system enhancements that any CBM group may choose to follow, given their plans for the future.**

These steps in analysing the survey provide a picture of a sliding scale of capabilities that matches the scales and levels of complexity among the 12 CBM groups, so that any CBM group may see where it currently fits on the sliding scale. From this, recommendations were made regarding how a collaborative approach may assist CBM groups to incrementally evolve in the direction of more advanced data management systems.

RESULTS

All survey results are provided in Appendix 1. A summary of the survey results including content on the six capability themes used for the interviews is provided as follows:

- **Aggregated Ratings of Data system Capability: BASIC, INTERMEDIATE, ADVANCED** *(pg 13)*
- **Summary of Selected CBM Data Management Attributes of the 12 Data Systems Surveyed** *(pg 14)*
- **Each System's Capability to Meet FAIR and/or OCAP Principles** *(pg 26)*
- **Range of Variation of Capabilities Among Data Systems** *(pg 27)*
- **Illustration of Possible Incremental Data Management System Capability Enhancements** *(pg 28)*

Aggregated Ratings Of Data Systems Capability

In aggregate, data system capability ratings among the 12 systems surveyed were:

BASIC DATA SYSTEM	INTERMEDIATE DATA SYSTEM	ADVANCED DATA SYSTEM
3	5	4
systems rated **BASIC**	*systems rated* **INTERMEDIATE**	*systems rated* **ADVANCED**
(few intermediate or advanced ratings among individual themes)	*(mostly intermediate ratings among individual themes)*	*(almost all advanced ratings among individual themes)*

Summary Of Selected CBM Data Management System Attributes of the 12 Systems Surveyed

1

BASIC SYSTEM

BC LAKE STEWARDSHIP SOCIETY

Water Quality Monitoring Program

BCLSS

Water quality information is for education, outreach, and lake/basin water quality management. Three monitoring program levels are used by BC lake stewardship groups to create field and lab generated water quality data.

a. Data Types: Water quality data typifying lake health using an escalating three level system.

b. Most data are collected by volunteers and transferred to BC Ministry of Environment and Climate Change Strategy (MOECCS) databases (EMS, Algae Watch).

c. Data analysis is through use of downloaded data in MS Excel spreadsheets.

d. Templated reports are produced by BCLSS with assistance from MOECCS staff, and available online.

e. Future enhancements will include MOECCS upgrades to its data systems.

2

BASIC SYSTEM

BC INVESTMENT AGRICULTURE FOUNDATION (IAF)

Bertrand Creek Water Quality Monitoring Program

Water monitoring for agricultural areas supports the development of source water protection and improvement through a coordinated Group Environmental Farm Plan.

a. Data types: Water quality data is used for contaminant source identification, suitability for agricultural use, and planning. Multiple water quality parameters and metadata (including information on farm operations, problem areas related to water quality, and likely degradation sources) are documented.

b. Microsoft products are used to collate data, then data is transferred to a commercial (Virtual Solutions) database.

c. A contractor does data analysis (comparisons of existing water quality with provincial guidelines), and riparian management and irrigation planning upon request.

d. Data is shared among participants, but not public.

e. Reporting is to participants and the BC Ministry of Agriculture Food and Fish (MAFF).

f. Future enhancements may include wider sharing of riparian health assessment data.

3 BASIC SYSTEM

SKEENAWILD CONSERVATION TRUST

Willow Creek Restoration Project

Establish baseline conditions, develop prescriptions for treatment, and begin treatments.

a. Data types: water quality (turbidity, temperature), beaver dam occurrence (active, inactive), dam removal treatments, plant species locations/abundance, fish passage occurrence.

b. Data on paper field forms is transferred to MS Excel spreadsheets. Descriptive information is documented in MS Word.

c. Files are stored in email and local hard drive(s). Reports and data will be stored in Skeena Knowledge Trust Salmon Data Centre for public access and distribution.

d. There is limited reporting to funders in Year 1.

e. Future data management enhancements will arise from growing experience (7-10 year project). Future data collection to include flow and smolt occurrence.

INTERMEDIATE SYSTEM

4 FRASER BASIN COUNCIL (FBC)

Nicola Watershed Low Tech Process Based Restoration Project

Collaborate with farmers and ranchers to restore critical salmon and trout habitat, regulate water flows, stabilize flood affected sediment wedges, build beaver dam analogues (BDAs) to moderate water flows and temperature.

a. Data types: elevation, GIS mapping, drone footage/other imaging for construction of BDAs. Consultant implementing effectiveness monitoring program, using these and other water related variables.

b. Data is stored on the consultant's hard drives.

c. Basic plan is to collect, store and share data; includes data gathering, management and use in restoration choices.

d. Data to be shared with the Research and Technical Committee through private web sharing (80 participants from multiple organizations).

e. Website reports on the project but there is no public access to raw data.

f. Hydrometric monitoring is planned. Year 2 plan will be built on year 1 results.

5

INTERMEDIATE SYSTEM

FRASER BASIN COUNCIL (FBC)

Shuswap Lakes Water Quality Monitoring Project

Monitor and report on lake health with a focus on eutrophication and suitability for primary contact recreation. Partners include Indigenous, Federal, Provincial, Local governments and organizations, industries and CBM groups.

a. Lake water quality parameters include nutrients, water clarity, dissolved oxygen, chlorophyll *a* (12 lakes), bacteriology (10 beaches), invasive species (Zebra and Quagga mussel watch program). MOECCS augments this data with a water chemistry monitoring program including, pH, temperature, turbidity/total suspended solids (TSS), hardness, sulphate, alkalinity.

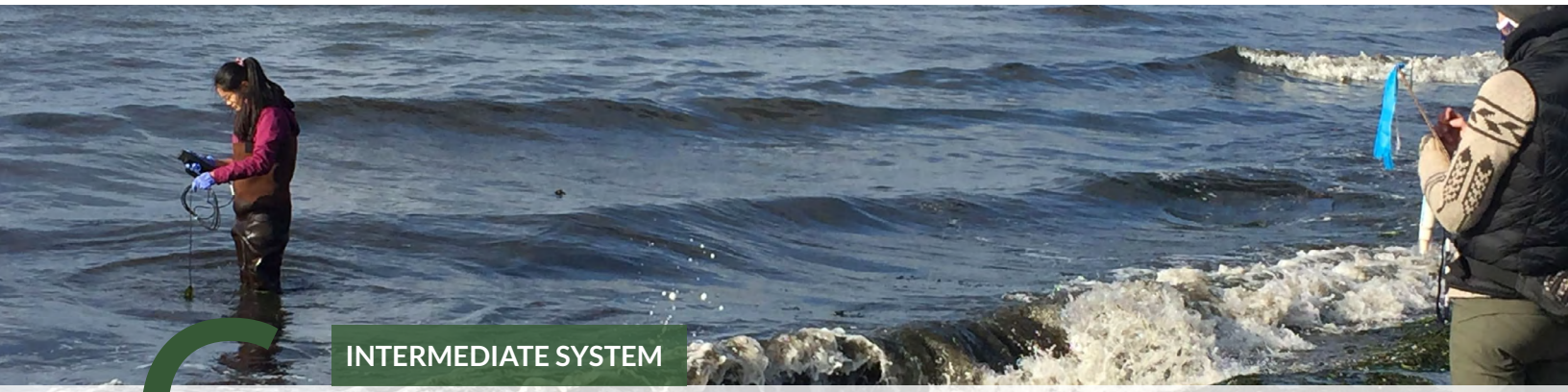
b. Data sharing occurs among partners. Analysis and interpretation are part of templated regular reporting.

c. The provincial EMS database houses lake data, and Interior Health database houses beach data. Some field data is first collated on MS Excel spreadsheets and stored on private hard drives, prior to uploading to the databases.

d. Shuswap Water Quality Monitoring Group Terms of Reference describes data governance. Includes sampling, data management and templated reporting protocols.

e. Shuswap Watershed Council collaborators share and use the data for planning and decision making. Council meets twice a year to discuss the monitoring program, including needs and gaps. Interior Health Authority web link to beach data is publicly available. Lake reports are available through the Fraser Basin Council website.

f. Will implement the MOECCS Algae Watch program, and any new provincial data management systems enhancements.



6

INTERMEDIATE SYSTEM

A ROCHA CANADA

Water Quality Restoration & Monitoring in Boundary Bay

CANADA A ROCHA Environmental Stewardship

Identify contamination sources, develop a water quality action plan, and restore water quality to resume shellfish harvest. The Shared Waters Alliance includes A ROCHA, Semiahmoo Nation, DFO, Fraser Health, BC municipalities, Whatcom County, Washington State Department of Health, agricultural landowners, stewardship groups.

a. Data types: bacteriology, pH, dissolved oxygen, temperature, conductivity, turbidity, plants, fish, shellfish. Contaminant source data provided by Fraser Health, Department of Fisheries & Oceans (DFO), municipalities and observations.

b. Initial data management is through MS Excel spreadsheets stored on local hard drives. Longer term data management plan mirrors Whatcom County monitoring and assessment plan.

c. Analyses: trend assessment and attainment (or lack of attainment) of Puget Sound Indicator guidelines. U.S. remedial actions are required if there is non-attainment of indicator thresholds. For BC, DFO can use trend data to alter the existing shellfish sanitary closure order once/if contamination is sufficiently reduced.

d. Communication is by email and meetings. Annual reports are generated for internal and external communications - posted on A ROCHA website and provided to Shared Waters Alliance members.

e. Planning is ongoing with Whatcom County to create a web based data management system including internal and public reporting. Enhancements may include a GIS based discovery tool. Semiahmoo First Nation is planning a traditional use survey component which will likely involve OCAP principles.

7

INTERMEDIATE SYSTEM

SKEENA FISHERIES COMMISSION (SFC)
GITKSAN WATERSHED AUTHORITY
Gitxsan Surface Water Temperature Project

Surface water temperature monitoring as part of salmon habitat assessment.

a. Data type: Continuous water temperature data at up to 150 sites.

b. Data storage and sharing uses Google Drive. Data is then transferred to Skeena Knowledge Trust Salmon Data Centre (SKT SDC) and Gitxsan Lax'yip interactive website.

c. Data is formatted, analysed, and interpreted using "R" and GitHub (open-source tools).

d. A data management plan includes data capture, storage and searchability functions. Data is initially for internal use, prior to publication. For external users, there will be long term data storage, spatial query function and reports through the SKT Salmon Data Centre. Internal users access the same information on Gitxsan Lax'yip website.

e. In the future, temperature data may be stored on a new Pacific Salmon Foundation water temperature specific database. SKT is building new visualization functions.

8

INTERMEDIATE SYSTEM

SKEENA FISHERIES COMMISSION (SFC)

Climate Change Effects on NW BC Lakes Monitoring Project

Climate change related lake trend monitoring.

a. Data types: lake bottom profiles and multiple remotely monitored lake characteristics and weather.

b. Data stored on Hakai Institute database (Hakai Data) and a private commercial server for large datasets. Profiles and metadata are manually entered to the Hakai database. Lake station (buoy) data is uploaded via satellite to the private server. Permanent data storage options are being considered.

c. A data management plan is in place, which includes QA/QC protocols developed by data type, analysis, and visualization scripts (stored and accessed in GitHub).

d. Partners communicate directly and have access to stored data. There is no external web access at present.

e. A communications and reporting strategy is pending. Details on data analysis methods are being developed.

9

ADVANCED SYSTEM

BC WILDLIFE FEDERATION

Wetlands Workforce

Collaborating with First Nations and conservation organizations to restore, stabilize, and monitor BC's wetlands to improve wetland inventories, management, restoration, and other decision making. Project includes development and calibration of a new regional Wetlands Ecosystem Services Protocol – WESP, and inventory.

a. Data types: Vegetation - species present, wetland classification (CWS, BC, species, and plant communities at risk), Water quality (conductivity, pH), water level, benthic macroinvertebrate communities, soil types, canopy cover, photos, drone imagery, landscape level stressor variables, terrestrial wildlife occurrence, amphibians, reptiles, birds (nests, eggs), browsing, stubble height, planning data including site restoration prescriptions. There are 185 monitoring sites throughout BC, 395 field verification points, and 35 remote cameras.

b. A comprehensive data management plan includes data sharing agreements with private landowners.

c. A custom data management system uses existing software and hardware components. Initial field data from tablets using ArcGIS Survey 123 smart forms, is collated in MS Excel and stored on hard drives and MS OneDrive cloud platform. An ArcGIS database provides full service GIS mapping, analysis, query, and discovery functions.

d. Amphibian and reptile data is uploaded to the BC Conservation Data Centre. ArcGIS data is uploaded to the provincial EcoCat database. Columbia basin specific data is uploaded to Columbia Basin Water Hub. Metadata is tied to attribute tables. Data quality assurance checks are done manually. Project partners share data, but it is not publicly available at present.

e. Internal communications and data access is through personal communication and the ESRI ArcGIS platform. External communications are through BCWF communications coordinators and published report(s) on the state of wetlands.

f. Regionally based recommendations will be communicated to Canadian Wildlife Service (CWS) for further WESP development. Project plan includes finding other region specific data hubs and future CWS open data platform to upload to. Considering adding an Indigenous values component to the WESP protocol, finding new partners to expand the program and use of the data in the BCWF Wetlands Education Program. Data gathering will be improved (error reduction, efficiencies).

10

ADVANCED SYSTEM

LIVING LAKES CANADA (LLC)

Columbia Basin Water Data Hub & Collaborative

Host, link, and share any kind of water data generated by CBM groups, local and regional governments and the private sector in the Columbia Basin. Make a wide range of water data available and useful to help manage 10 Columbia sub-basins. An outreach and education approach includes videos, webinars, and direct communications.

a. Data types: >225 datasets spanning many water data types from 40 organizations in the Collaborative. Data uploading is templated. Hydrometric data is key to using an established water balance approach to sub-basin water management.

b. A custom CKAN open data platform (Comprehensive Knowledge Archive Network) with a variety of extensions, (e.g., custom schema, mapsearch, and xlsload) was developed and is maintained in-house, and is run on a Carl Data Solutions server.

c. Each organization controls who can access and download specific datasets. Datasets can be accessed directly through the web, or through a map based search function.

d. A data management plan sets out data standards (provincial, federal, international), and includes structure, QA/QC, organization of data, data grading, governance (ownership, control, functions), and continuous improvement approach. A water balance data plan for the 10 sub-basins is in place.

e. The Hub links to federal, provincial, and ENGO systems (DataStream, Pacific Climate Impact Consortium, SKT, Streamkeepers), and there are plans to integrate with them. The Hub is a host for the Foreshore Integrated Management Planning (FIMP) program in collaboration with the Department of Fisheries and Oceans. A formal database governance system is in development, and there are data sharing agreements with Indigenous governments and the private sector.

f. New partners are welcome.

11

ADVANCED SYSTEM

TRAILMARK SYSTEMS

Trailmark Cloud & Mobile is Software-as-a-Service Platform

Designed to collect, manage, store, analyze, interpret, and report Indigenous Knowledge. The data system aids Indigenous Nations in using Indigenous Knowledge with other data sets in planning, monitoring, and resource decision making, and it makes GIS data more accessible to mobilize knowledge in community-based research programs.

a. Data types: Recorded qualitative and quantitative information upload-able or directly inputted -includes audio, video, photo, transcript, text, map/geospatial and other numeric or descriptive files.

b. Features include an engagement survey builder with mapping function, mobile data collection app with custom form builder, direct-to-digital interview mapping, digital archive with place name geo-referenced, and GIS upload and query capabilities.

c. All data can be searched, geo-referenced, and filtered. The system allows integration of data types by geospatial search and category theme.

d. Trailmark Cloud runs on AWS infrastructure in Canada, and uses Mapbox as the spatial component (geolocation, query, and data visualization). Trailmark Mobile data collection is based on Flutter.

e. Using Trailmark Cloud, administrators can create fully customizable mobile data collection forms and push them out to Trailmark Mobile (supports iOS and Android OS).

f. Staff assisted users can develop data sharing agreements compatible with the system, honoring data sovereignty and governance. A manual describes use of technical components. Private community sub-groups for a region are possible under one account/Cloud for data pooling by a central body while maintaining privacy at the community level. Cloud accounts can share data/knowledge gathering forms posted to a common library. Data can be shared across accounts to create regional networks. Account administrators can control sharing, through a range of permissions. Communities share data/knowledge by curating and sharing links to interactive maps with query and visualization capabilities.

g. A public portal is planned for curated information. Other enhancements planned include: a portal to track data requirements for use by leadership, data quality analysis and reporting tools, more visualization, search and geospatial analysis functions, and linking with other geospatial data sources, so shared layers are current through time.

12

ADVANCED SYSTEM

SKEENA KNOWLEDGE TRUST (SKT)

Salmon Data Centre & Skeena Map Portal

Skeena Knowledge Trust

Complementary systems (SDC & SMP) are a source for salmon ecosystem information for the Skeena watershed. SKT works with many organizations as a data bridge, organizer, and amplifier of information by archiving and integrating data sets provided by anyone willing to share. The platform provides services that ensure long term custody of the data and enhances its value through visualization tools that present it in more digestible forms.

a. Data types: audio, video, photo, transcript, map/geospatial and any other numeric or descriptive files. SKT also finds, curates, and uploads historic datasets.

b. The SDC is a CKAN implementation - an open-source data management system for data hubs and portals - with compatible add-ons. The accompanying SMP is housed on a Docker GeoNode/ GeoServer. Metadata accompanies datasets through use of metadata templates tailored to the client.

c. The system plan includes process documentation, and annual upgrades. The inter-connected SDC and SMP provide data accessibility, discovery, query, and visualization capabilities. SKT is open to all under its terms of use. Data standards are customized to the client (there is a wide range of data types and volumes across clients). SKT provides training and data management advice on request.

d. All data is open-source, although data sets can be initially password protected. SKT does all data uploading. Data is owned by the contributor, who is responsible for maintaining and removing data.

e. Communities share data by curating and sharing links to interactive maps, downloading and processing data for sharing. A reporting tool uses basic analysis and map visualization software.

f. Data can be published to a public portal, exported, or shared via weblink by the administrator. Ongoing enhancements are done in-house: including a project registry, shared community mapping network, integrate with DataStream on water quality data management, more data visualization tools and expanding services to others (long range plan is to expand the data registry to BC and Yukon).

Each System's Capability to Meet FAIR & OCAP Principles

Table 1 shows each data system's capability to meet FAIR principles (Findable, Accessible, Inter-operable, Reusable) and/or Indigenous focused OCAP principles (Ownership, Control, Access, Possession). Some systems focus strictly on open data (FAIR principles) or Indigenous proprietary data (OCAP principles), while others may have provisions for some principles from both types (e.g., password protected, ensuring adherence to Ownership, Control and Access principles on an advanced platform that houses both open, and proprietary data).

Table 1 - System Capacity to Meet FAIR & OCAP Principles

Organization & Project Name	FAIR[11] Principles Met	OCAP[12] Principles Met
BC Lake Stewardship Society (BCLSS) *BC Water Quality Monitoring Program*	Partly: EMS stored water quality data meet most FAIR principles criteria	Not discussed in the survey
BC Investment Agriculture Foundation (IAF) *Bertrand Creek Water Quality Monitoring Project*	All data is private. Some data meet most I, R principles criteria	Not discussed in the survey
SkeenaWild Conservation Trust *Willow Creek Restoration Project*	All data is private. Some data meet most I, R principles criteria	Not discussed in the survey
Fraser Basin Council (FBC) *Nicola Watershed Low Tech Restoration Project*	All data is private. Some data meet most I, R principles criteria	Not discussed in the survey
Fraser Basin Council (FBC) *Shuswap Lakes Water Quality Monitoring Project*	Partly: EMS and Interior Health data systems water quality data meet FAIR principles	Not discussed in the survey
A ROCHA Canada *Water Quality Restoration & Monitoring Boundary Bay*	All data is private. Some data meet most I, R principles criteria	Not discussed in the survey
Skeena Fisheries Commission (SFC) *Gitksan Watershed Authorityperature Project* *Gitxsan Surface Water Temperature Project*	All data is private. Some data meet most I, R principles criteria	Gitksan Watershed Authority owns and controls public access to water temperature data
Skeena Fisheries Commission (SFC) *Monitoring Climate Change Effects in NW BC*	All data is private. Some data meet most I, R principles criteria	Skeena Fisheries Commission owns and controls public access to data. Data housed on commercial/ institutional systems
BC Wildlife Federation (BCWF) *Wetlands Workforce Project*	All data is private. FAIR principles generally apply, but on a restricted access basis	Indigenous partners own and control public access to data specific to their territories (O, C, A). Data housed by BCWF
Living Lakes Canada (LLC) *Columbia Basin Water Data Hub & Collaborative*	All data Findable and Accessible online unless password protected. FAIR principles may vary across the collaborative	O, C, A principles may be invoked by an Indigenous organization through password protection. Data housed by LLC
Trailmark Systems *Cloud & Mobile Indigenous Knowledge/Data System*	All data is private. FAIR principles generally apply, but on a restricted access basis	O, C, A principles are the default. Data housed by Trailmark Systems
Skeena Knowledge Trust (SKT) *Salmon Data Centre and Skeena Maps Portal*	Generally, data meet F, A principles, but I, R principles may vary across the many users	O, C principles apply. Access is open by default. Data housed by SKT.

Range of Variation of Capabilities Among Data Systems

It became apparent that additional theme categories were needed to better explain the kinds of variation among data systems. The overall survey results are described in terms of a sliding scale of capability among 20 re-organized data system attributes. Table 2 summarizes the findings for the 12 data systems surveyed. Descriptions in the table illustrate the "bookends" of the sliding scale, and in some cases, a continuum of increasing capabilities is described. In all cases, there are likely other intermediate aspects that could be identified and explored.

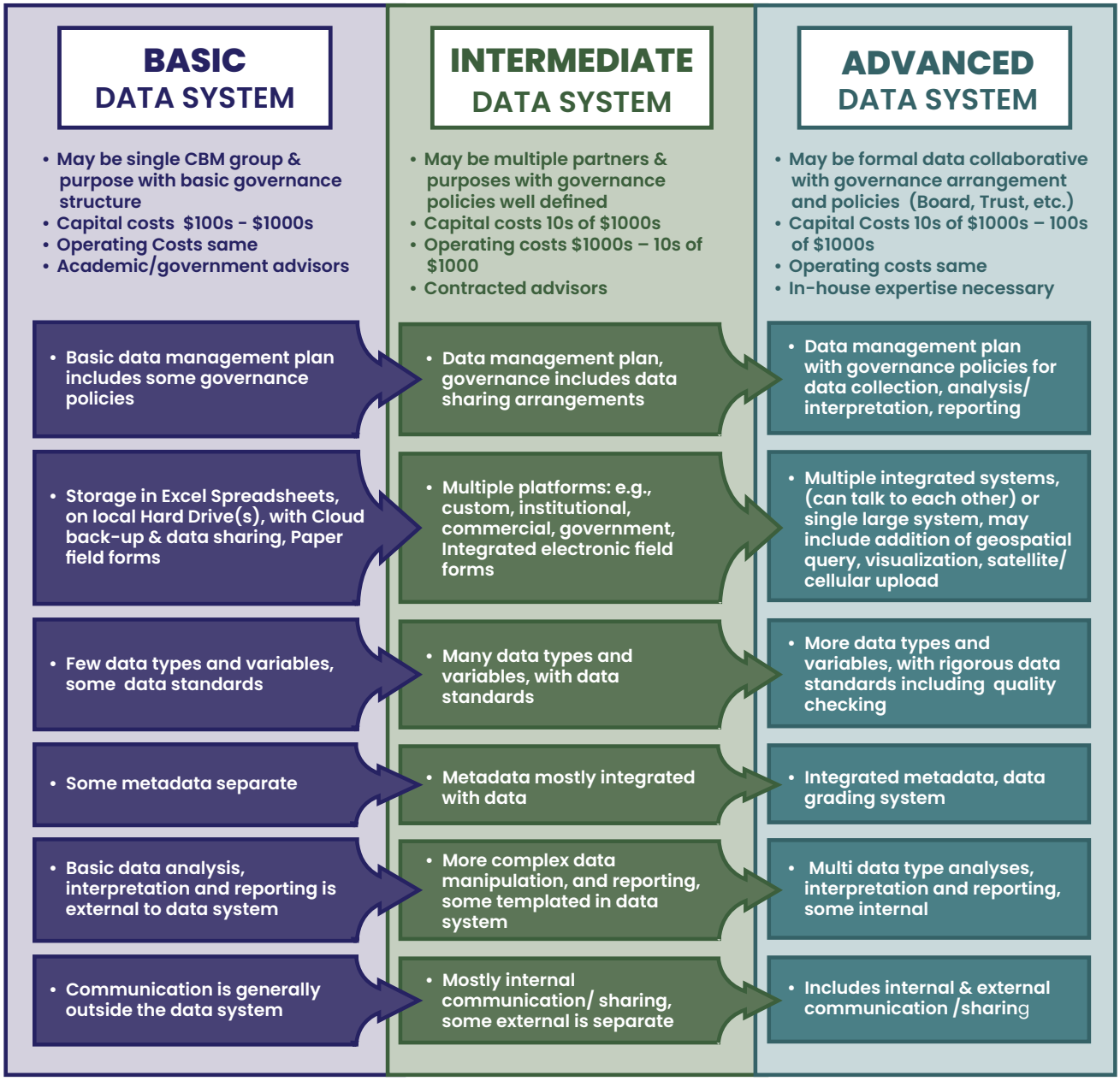
Table 2 - Sliding Scales of Data System Capability

Aspects of Data Management	Sliding Scale of Capability
Project Purposes	• 1 purpose or data use➔ multiple purposes, data uses
Number of Collaborators	• 1 entity ➔ multiple entities
Collaborative Governance	• basic ➔ comprehensive (data sharing agreements)
Number of Data Types and Variables	• few variables of same type ➔ many variables, different types
Data System, Types/Sources	• "off the shelf" ➔ custom built (can be commercial or open-source)
Number of Data Systems Used	• 1 system for 1 function➔ multiple systems integrated for multiple functions
Number of System Functions/ Capabilities	• archive ➔ sharing ➔ analysis, interpretation ➔ visualization, reporting • metadata separate➔included ➔ tied to other data for integration
Analysis/Interpretation	• downloaded to other software ➔integrated within system • basic (MS Excel) ➔ relational (R, MS Access, other) • Alphanumeric data imaged (e.g., PDF) ➔ extractable in raw form • raw data ➔ tabular summaries, graphics ➔ basic analysis, summary stats ➔ detailed analyses and summary stats ➔predictive modeling • no geospatial capability➔ full geospatial analytical, query, visualization
Field/Desktop Data Gathering Tools	• paper forms, manual transfer ➔ electronic templates, auto transfer ➔ real time upload (cell or satellite link)
Backup of Data, Reports	• manual/separate ➔ built-in/automatic
Communication Pathways	• Internal only ➔ internal and external • single audience/decision maker ➔ multiple audiences/decision makers • direct (email, meeting) ➔web based, integrated • no FAIR principles ➔F, A, but not necessarily I, R➔ all FAIR principles • no OCAP principles ➔ O, C, A, but not P➔ all OCAP principles

Illustration of Possible Incremental Data Management System Capability Enhancements

CBM plans need a data management component that can be modified as data system capability requirements evolve over time. Figure 1 illustrates sliding scales of data system capability and the differences between them, and may help CBM groups to navigate this evolution.

Figure 1 - Possible Incremental Data Management System Capability Enhancements



FAIR principles applied may vary across the spectrum of data systems capability: data may not be Findable or Accessible by web search and data quality issues may limit use of Interoperable/ Reusable principles

OCAP principles are specific to First Nations Ownership, Control, Access and Possession of data. These principles may be used in whole, or in part at the discretion of the Indigenous organization depending on circumstances. Indigenous generated western science data may be treated differently than Indigenous Knowledge in terms of OCAP application, depending on the circumstances, and data governance system (e.g. data sharing agreements).

3. DISCUSSION

Recent documentation of the CBM data "landscape" has demonstrated that trusted, shared information is the foundation of watershed management processes and decisions, which ultimately leads to better outcomes. Key issues affecting current processes and decisions include poor/inconsistent data management and integration, data and knowledge gaps, and lack of coordinated, standardized approaches to data management and governance. This means that all participants in watershed related monitoring, including CBM groups should find opportunities to improve and evolve their data management capabilities to best fit individual monitoring program objectives and desired outcomes. This does not mean that all data systems need to progress to an advanced level of capability, as incremental capital and operating costs may outweigh some added system capability benefits.

Results from the 12 CBM data system surveys provide CBM groups with a means to see where they stand in terms of a continuum or "sliding scale" of capabilities by comparing their data system attributes with those shown on the sliding scales represented in three ways in Table 1 (FAIR and OCAP principles adherence) and Table 2 (sliding scales of capabilities), and Figure 1 (graphical synthesis of capabilities identified in the survey). The next step for a CBM group would then be to determine how other capabilities shown in Figure 1 beyond what they currently have could match their aspirations for generating more trusted, shared data. This cannot be done without first having a solid monitoring program plan and companion data management plan containing system development, use and maintenance information. These plans, if coordinated at watershed scales will lay the foundation for collecting, managing, and applying the necessary data in appropriate ways and amounts for specified watershed planning and management purposes.

In general, large shifts in data system capabilities are expensive, and it is unlikely that most CBM groups throughout BC will find the funds to make desired shifts happen quickly. This means that with a long-term vision and knowledge of existing compatible systems, a collaborative and incremental approach to funding and tackling the evolution of data management system capabilities at local and regional levels may be the best option for many CBM groups. This would allow these groups to also incrementally grow their monitoring capabilities at a reasonable pace.

4. RECOMMENDATIONS

These recommendations are meant to promote scalable local and regional data management system planning based on collaboration among CBM groups, governments and funders. This includes ways to link and integrate with other data systems to increase the value and use of CBM generated data in planning and decision making.

1 **Foster formal and peer learning, and development of best practices to harmonize the use of Indigenous Knowledge and western science data management systems and processes where possible.**

This includes applying FAIR and OCAP principles in ways that provide broad opportunities for data sharing where appropriate, while understanding, respecting, and applying Indigenous data governance and sovereignty requirements.

a. **Given that there is a range of understanding among some CBM groups as to exactly what FAIR and OCAP principles actually are, and how they may apply in a variety of situations, considerable effort will be required to broaden this understanding.**

2 **Develop a provincial scale Community of Practice and expert advisory services for CBM groups to:**

a. **collectively focus on data systems governance, planning and implementation approaches,**

b. **make the best use of existing well managed data systems that are compatible with specific objectives (e.g., consider using existing provincial, federal and other institutional data systems as part of local CBM plans),**

c. **explore what incremental data system improvements would create the most benefits for CBM groups (e.g., data integration standards that link data systems together may be of great benefit in comparison to other capability improvements).**

3 **Create or participate in regional monitoring and data management collaboratives to create cost advantages, increase capabilities and coordination, and the prospect of long term CBM success in partnership with others at provincial, regional and watershed scales.**

(e.g., Skeena Knowledge Trust's "off the shelf" CKAN platform that others can use as a foundation, Fraser Basin Council Shuswap Lakes platforms serving multiple objectives, BC Wildlife Federation Wetlands Workforce data system that includes a wide variety of Indigenous and non-Indigenous collaborators across the province).

a. ensure that these collaboratives are inclusive of local, regional, and Indigenous governments, industries, environmental non-government organizations (ENGOs) and other community organizations, and that they are well coordinated with senior governments (provincial and federal).

4 **Create and continually update a provincial data catalogue/directory so that all participants, including CBM groups, can share a single source of comprehensive information regarding what types and amounts of water data are available, and how to access this data.**

This will greatly reduce duplication of efforts, increase data discoverability, and use in planning and decision making and move overall data system integration efforts forward.

5 **At a provincial level, explore the concept of creating a non-profit entity that could act as a Software as a Service (SAAS) provider to CBM groups.**

This entity could provide advisory services and could design, build, operate and maintain data systems at a reasonable cost to CBM groups, using open-source software.

APPENDIX 1 COMMUNITY-BASED DATA MANAGEMENT SURVEY RESULTS

CBM Data Management Survey Results

Click here for larger view

BC CBM Data Management Systems Survey Results

Organization Contact(s)	Project Purposes	Data Types	System Attributes	Data Management: Plan / Functions / Attributes	Communication Pathways for users, public, decision makers	Access through web Link(s), other	Overall Level of Capability Basic->Intermediate->Advanced	Future Enhancements
BC Lake Stewardship Society Dawn Romieu info@bclss.org	BC Lake Stewardship Water Quality Monitoring Program. Water quality information is for education, outreach, and lake/basin water quality management. 3 levels of monitoring programs are in use. Rated: Basic	Field and lab geneRatedd water quality (phys/chem), Algae Watch Program (BC MOECCS). Some metadata. Rated: Basic	BCLSS developed field forms, data spreadsheet formats and reporting templates. MOECCS EMS database is used for lab results. Rated: Basic	Majority of monitoring and data collating done by volunteers. Field forms or excel spreadsheets provided to BCLSS staff by volunteer samplers. For level 2 and 3 monitoring, provincial contracted lab uploads results to EMS - meets FAIR principles, open by default. BCLSS staff download EMS data for reporting. Data saved/analysed/interpreted in excel spreadsheets on BCLSS hard drive, Google Drive back-up. Algae Watch data uploaded to MOECCS portal. Rated: Basic	Data analysis follows reporting templates. Each monitoring level includes training. Level 3 monitoring includes oversight by MOECCS staff. Level 3 data and reports include a QA/QC step, and MOECCS technical review. Monitoring reports are reviewed by BCLSS staff. Rated: Intermediate	Lab data available through MOECCS EMS database. https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/environmental-monitoring-system. Algae Watch program data viewed @ BC MOECCS Algae Watch portal. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/algae-watch. Reports are produced and published by BCLSS. See: https://www.bclss.org/document-library. Rated: Intermediate	**Basic**	An MOECCS app for meta data archiving and connection to measured data is under development. EMS soon to be replaced with ENMODS.
Investment Agriculture Foundation Michelle Redekopp mredekopp@iafbc.ca	Bertrand Creek Water Quality Monitoring Program: Water monitoring for agricultural areas along Bertrand Creek to support the development of source water protection and improvement through a Group Environmental Farm Plan. Using water quality data for contaminant source identification (e.g. livestock waste storage, commerical, industry, waterfowl, huuman) and suitability for agricultural use (e.g. irrigation). Rated: Intermediate	Multiple water quality parameters. Metadata (e.g. information on farm operations, problem areas related to water quality, likely degradation sources etc.). Rated: Basic	Water quality data is first shared by EFP participants using PDF, MS Word or image files on Google Drive, then transferred to a custom Virtual Solutions database. Data is uploaded by planning advisors for farmers. Rated: Basic	Basic data management plan: use water data and metadata as context for planning decisions related to agricultural water use. Data gathered by farmers or their consultants. Data analysis: comparisons of existing water quality to guidelines for agricultural use. Templated approaches are used for some analyses (e.g. riparian health assessment). Individual farm planning processes and plan documents are proprietary - plan documents are not public. These documents cannot be shared as they contain client information. Data outputs are integRatedd into specific plans requiring contractor involvement (e.g. riparian management or irrigation plans). Rated: Basic	All aspects of data use and reporting are proprietary. Some data is shared among participants, and broader access to some data may be considered on request. Group plan participants communicate among themselves and with Plan Advisor through online meetings Some community consultation occurs through personal communication. Reporting is internal, and to the Ministry of Agriculture, Food and Fish. Complete report contains client information, so approval is needed for limited external summary reporting). Rated: Basic	No external web access Partners communicate directly (email, phone, face to face) Rated: Basic	**Basic**	Long term data management enhancements could, with participant approvals, include sharing riparian health assessment data and results to highlight areas for restoration funding
Skeenawild Conservation Trust Sarah Railton: contractor Naiad Stewardship Solutions sarah_railton@naiadstewardshipsolutions.com	Willow Creek Restoration Project - a 7-10 year project. Year 1: Establish baseline conditions, Develop prescriptions for treatment, begin treatments, including beaver dam removal, invasive plant remediation, plant species of Indigenous cultural significance protection, encourage riparian conifer regeneration (shade), inventory existing mature conifer trees in proximity to stream riparian area (seed trees). Rated: Intermediate	Variables measured: water quality (turbidity, temperature), beaver dam occurrence (active, inactive), dam removal treatments used, invasive plant species locations/abundance, plants of Indigenous importance locations in vicinity of treatments, presence of existing mature conifer trees adjacent to the stream riparian area that are capable of dispersing conifer seed into the project area, fish passage occurrence above beaver dam removal locations. Rated: Basic	Paper field forms. Data transferred to Excel spreadsheets. Descriptive information documented in MS Word. Spreadsheet and Word documents stored in email and local hard drive(s). Reports/data to be stored in Skeena Knowledge Trust Salmon Data Centre for access and distribution. Data is Interoperable and Re-useable, but only Findable and Accessible through personal communication and permission. Rated: Basic	Basic data management plan. Manual analyses (includes Beaver Dam Assessment Protocol). Data quality control is done manually by project lead. Metadata documented and stored along with pressure/state and prescription data. Rated: Basic	Project contributors communicate and share data by email and SKT Salmon Data Centre. External sharing through SKT Salmon Data Centre is by permission only (password protected), and is currently restricted to project team. Year 1 reporting is to project team and select organizations as part of efforts to secure future funding opportunities (ie. Terrace Community Forest). Rated: Basic	Project team access to data is through personal communication and SKT Salmon Data Centre access password. External access to data is currently not available. Rated: Basic	**Basic**	Using a "starting small" approach, with year 1 experience leading to more robust 7-10 year project and data management plans. Future data management enhancements will arise from growing experience. Future data collection to include flow, smolt occurrence.
Fraser Basin Council Mike Simpson msimpson@fraserbasin.ca	Nicola Watershed Low Tech Process Based Restoration Project CollaboRated with farmers and ranchers to restore critical salmon and trout habitat, regulate water flows Nicola River - stabilize sediment wedges impacted by flooding, build beaver dam analogues (BDAs) to modeRated water flows and temperature Rated: Intermediate	Data includes: elevation, GIS mapping, drone footage/other imaging for construction of BDAs; Consultant implementing effectiveness monitoring program, using these and other water related variables. Rated: Intermediate	Monitoring data and metadata is stored on consultant's hard drive(s) Rated: Basic	Basic plan to collect, store and share data Includes data gathering, management and use, in ongoing watershed restoration decision making. Rated: Basic	Data to be shared with Research and Technical Committee on private web sharing. Includes many organizarions (e.g. Indigenous, DFO, Fraser Basin Council, academic, community, etc.) Others may access data through permission from committee Electronic communications occur among 80 participants. Reporting is via website www.nicolaplan.ca Rated: Intermediate	Website notes projects but not raw data access www.nicolaplan.ca Rated: Basic	**Intermediate**	Data management improvements will be folded into ongoing project planning. Future years will include hydrometric monitoring. Planning of next phase will use year 1 data.
Fraser Basin Council Shuswap Watershed Council (SWC) Mike Simpson msimpson@fraserbasin.ca	Shuswap Lakes Water Quality Monitoring Project. Monitor and report on lake health with focus on eutrophication and suitability for primary contact recreation. Monitoring occurs at beach, river and lake locations. Partners include Federal, Provincial, Local governments, Indigenous government and organizations, industries and CBM groups. Rated: Intermediate	Lake water quality parameters include nutrients, water clarity, dissolved oxygen, chlorophyl a (12 lakes), bacteriology (10 beaches), invasive species (Zebra and Quagga mussel watch program). MOECCS augments this data with a water chemistry monitoring program- a suite of lab and field analysed water constituents, including pH, temperature, turbidity/total suspended solids (TSS), hardness, sulphate, alkalinity. Rated: Intermediate	Data sharing occurs among participants as needed. Analysis and interpretation is part of templated regular reporting. Provincial EMS database for lake monitoring, and Interior Health database for beach monitoring. Some data spreadsheets stored on private hard drive(s), prior to uploading. Rated: Intermediate	Data management plan in place. Shuswap Water Quality Monitoring Group Terms of Reference describes data governance. Sampling, data management and templated reporting protocols are in place. SWC collaborators share and use the data for planning and decision making. Rated: Intermediate	Shuswap Watershed Council meets twice a year to discuss program, including needs and gaps. Interior Health Authority web link to beach data. Five years of annual reports. Rated: Intermediate	Provincial EMS database for some data - has permanent archive, data discovery and download functions. https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/environmental-monitoring-system. Beach data stored in, and accessed from Interior Health Authority data system. https://www.interiorhealth.ca/health-and-wellness/environmental-health-and-hazards/drinking-water/water-samples. Reports available at https://www.fraserbasin.bc.ca/Shuswap_Water.html. Rated: Intermediate	**Intermediate**	Looking to Province for data management systems enhancements: pending replacement of EMS. Will implement new provincial Algae Watch program: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/algae-watch,
A Rocha Canada Christy Juteau christi.juteau@arocha.ca	Water Quality Restoration and Monitoring in Boundary Bay. Identifying contamination sources through monitoring, developing a water quality action plan and restoring water quality in Boundary Bay so Semiamhoo Nation can resume the harvest of shellfish. Rated: Advanced	Water quality - bacteriology, pH, 02, temperature, conductivity, turbidity, plants, fish, shellfish biotoxins. Contaminant source data provided by Fraser Health, DFO, municipalities (e.g. Whiterock), Watcom county, and derived from field observations. Rated: Intermediate	Lab reports, instrument measurements and field sampling/observations data documented on MS Excel spreadsheets. Data stored on local hard drive(s). Rated: Basic	Data management plan mirrors Watcom County monitoring and assessment plan. Analyses focus on trend assessment and attainment of thresholds (e.g. Puget Sound Indicator guidelines, DFO shellfish closure allowable limits). Comparisons may be made with year 2000 and 2009 data. Annual Report to be posted on AROCHA website, and with the Shared Waters Alliance members. Data is interoperable and re-useable through standard monitoring and assessment methods. Rated: Intermediate	Partners: Shared Waters Alliance - AROCHA, Semiamhoo Nation, DFO, Fraser Health, BC municipalities (Whiterock), Watcom County, Washington State Department of Health, agricultural landholders. Project partner interactions are by email and meetings. Data application: For Watcom county: actions are required if results demonstRated non-attainment of indicator thresholds. For BC, DFO has authority to alter shellfish sanitary closure order once/if contamination is below allowable limits. Annual reports for both internal and external communications Rated: Intermediate	Project partners have access to all data upon request. No current provisions for sharing data beyond partners. Annual report(s) will be public. https://arocha.ca/what-we-do/conservation/. Rated: Basic	**Intermediate**	Working towards a data management system and web link to it. Planning with Watcom county to provide web link to distribute data widely as it becomes available. Planning for data management enhancements will be based on this year's experience and will occur prior to next year's activities. Looking to create a GIS based discovery tool. Semiamhoo First Nation is planning a traditional use survey component which will likely involve OCAP principles.
Skeena Fisheries Commission (SFC) and Gitksan Wadershed Authorities Allison Oliver, Aquatic Ecologist allisonoliver@skeenafisheries.ca as contractor to Gitksan Watershed Authority	Gitxsan Surface Water Temperature Project: Water temperature monitoring to be integRatedd as part of salmon habitat assessment. Rated: Intermediate	Continuous water temperature data at up to 150 sites. Rated: Intermediate	Data storage and sharing on Google Drive & Skeena Knowledge Trust Salmon data Centre & Gitksan Lax'yip interactive web site. Data formatted, analysed and interpreted using R and GitHub. Gitksan Watershed Authority controls what data is placed on external web site. Temperature data will be publicly available on SKT. Rated: Intermediate	Data management plan includes built-in storage and searchability functions. Temporary Cloud storage of metadata and raw temperature data files (Google Drive). For external users: long term data storage and spatial query function at SKT Salmon Data Centre. For internal users: long term storage and spatial query function at Gitksan Lax'yip interactive web site. R and GitHub for data analysis and visualization. Code for data analysis and visualization on Github (R) but actual visualizations will be in SKT SDC system. Reports stored at SKT SDC and Gitksan Lax'yip site. Rated: Advanced	Data is initially for internal use, prior to publication. Shared data and reports are placed on external web site. Gitksan personnel may use data in collaboration with other decision makers. Rated: Intermediate	SKT SDC is an external access link. Internal access to data and reports is through two other web links. Rated: Intermediate	**Intermediate**	May store temperature data on a future Pacific Salmon Foundation water temperature specific database. SKT data system will include visualizations as well as reports.
Skeena Fisheries Commission (SFC) Allison Oliver, Aquatic Ecologist allisonoliver@skeenafisheries.ca in collaboration with Hakai Institute (https://hakai.org/), and NW BC First Nations	Monitoring Climate Change Effects on NW BC Lakes. Climate change related lake monitoring (lake bottom profiles and multiple remotely monitored lake characteristics). Rated: Advanced	lake profiles, remotely monitored lake characteristics variables - weather, depth profiles. Rated: Advanced	Hakai Institute database (Hakai Data). Additional private commercial server for large datasets. Profiles and metadata manually entered to database. Lake station (buoy) data uploaded via satellite to private server. Permanent data storage options being considered. Rated: Advanced	Data management plan in place, and will advance as project progresses. QA/QC protocols developed by data type, generally following advice in https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/bc_field_sampling_manual_part_a.pdf . Analysis and visualization scripts are stored in GitHub. Rated: Intermediate	Partners communicate directly. Publications and communications stRatedgy pending. Rated: Basic	No external web access at present. Partners have direct access to stored data on multiple platforms. Rated: Basic	**Intermediate**	Detail on data analysis methods and external reporting being developed.
BC Wildlife Federation Wetlands Workforce Kyla Rushton kyla.rushton@bcwf.bc.ca Christina Borring-Olsen Christina.Borring-Olsen@bcwf.bc.ca	Wetlands Workforce Project: BC Wildlife Federation is collaborating with First Nations and conservation organizations to restore, stabilize, and monitor BC wetlands. These activities will improve wetland inventories, management, restoration and other decision-making. Further develop and calibRated a new regional Wetlands Ecosystem Services Protocol - WESP (e.g. regional calibration for Skeena wetlands). Additional general information at: https://bcwf.bc.ca/initiatives/wetlands-workforce/. Rated: Advanced	Wetlands Ecosystem Services Protocol (https://wetlandsworkforce.ca/2021/08/14/the-workforce-calibrating-b-c-s-wetlands/) and Wetland Inventory. Vegetation: species present, wetland classification (CWS, BC, species and plant communities at risk). Water quality - conductivity, pH, water level, benthic macroinvertebRated community, soil type(s), canopy cover, photos, drone footage, landscape level stressor variables. Terrestrial wildlife occurrence, amphibians, reptiles, birds (nests,eggs), browsing, stubble height. Field data: 185 monitoring sites throughout BC, 395 field verification points, 35 remote cameras. Planning data including site restoration prescriptions. Rated: Advanced	ArcGIS database - full service GIS mapping, analysis and discovery platform. Electronic field data collection with ArcGIS Survey 123, including smart forms. See ESRI ArcGIS Online system capabilities. https://www.esri.com/en-us/arcgis/products/arcgis-online/overview. Tabular data in Excel, stored on hard drive(s) and Microsoft OneDrive cloud platform. Amphibian and reptile data uploaded to provincial database (BC Conservation Data Centre). Rated: Advanced	Data management plan in place. Custom data management system built using existing software and hardware components. Digital components throughout (survey 123 spatial forms, electronic data gathering). Data gathering forms were modeled on previous work by others. Upload ArcGIS data to provincial database: EcoCat. Columbia basin specific data uploaded to Living Lakes Canada Columbia Basin Water Hub. Metadata tied to attibute tables. Manual data quality assurance. Data sharing agreements with private landowners. Project partners share data, but it is not generally available at present. Data is interoperable and reuseable, but discovery (Findable) and Access is currently limited to project team and Indigenous partners. Rated: Advanced	Internal communications and data access is through personal communication and ESRI platform. Geospatial data to be transferred to EcoCat: https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat . External communications are through BCWF communications coordinators and published report(s) on state of wetlands. This will include a broad invitation for others to join the Wetlands Workforce. Regionally based recommendations will be communicated to CWS re: citizen science protocols (WESP). Rated: Intermediate	No external web access at present. Partners communicate and share data directly, and through internal data platforms. Rated: Basic	**Advanced**	Will look for other region specific data hubs to upload to, and explore uploading to CWS open data platform. Continue to find new partners to expand the program to other wetlands. Will transfer field data to Wetlands Education Program as part of continuing program, and Columbia specific data to Living Lakes Canada Columbia Water Data Hub. Data gathering can be improved (error reduction) and become more efficient. Considering adding Indigenious values component to the WESP protocol (OCAP principles would apply to this data).
Living Lakes Canada (LLC) Columbia Basin Water Data Hub Santiago botero santiago@livinglakescanada.ca	Columbia Basin Water Data Hub and Collaborative. Host, link, and share any kind of water data geneRatedd by community water monitoring groups in the Columbia Basin. Make a wide range of water data available and useful to help manage 10 Columbia sub-basins, or for any other purpose. Rated: Advanced	>150 datasets spanning many water data types from >30 organizations. Hydrometric data is key to using an established water balance approach to sub-basin water management. Rated: Advanced	CKAN open data platform (Comprehensive Knowledge Archive Network) details at: https://data.cbwaterhub.ca/ColumbiaBasinWaterHubDataManagementPlanandFramework.pdf. Customized by LLC: variety of custom extensions, (e.g. custom schema, mapsearch, and xlsload). Runs on Carl Data Solutions server. Built and maintained by LLC. Meets all FAIR and OCAP principles. Rated: Advanced	Data management plan sets out data standards (provincial, federal, international): includes structure, QA/QC, organization of data, data grading system, ownership/ governance and control by each organization in the collaborative, and how the hub functions. See more details at https://data.cbwaterhub.ca/ColumbiaBasinWaterHubDataManagementPlanandFramework.pdf. Water balance data plan in place. Hub links to many federal and provincial data systems, as well a other ENGO systems - DataStream, Pacific Climate Impact Consortium, Skeena Knowledge Trust, Streamkeepers, DFO's Foreshore IntegRatedd Management Planning platform. Each organization can specify who can access and download specific datasets. Data uploading is accomplished through upload templates. Rated: Advanced	Outreach and education approach includes instructional videos, webinars and direct communications (email, phone). Database governance communications occur through personal communication and group meetings. Datasets can be accessed directly, or through a map based search function. Rated: Advanced	Web access to data: https://data.cbwaterhub.ca/dataset. https://data.cbwaterhub.ca/map_search. Rated: Advanced	**Advanced**	Continuous improvement approach to data system enhancement. Water Data Collaborative welcomes expansion to new partners. Need to further develop Hub's governance structure and functioning. A range of data systems are currently linked to, and efforts are underway to integRated them so they can "talk to each other".
Trailmark Systems Beth Keats beth.keats@trailmarksys	Trailmark Cloud and Mobile is a Software-as-a-Service platform with an Indigenous focus, designed to collect, manage, store, analyze, interpret and report Indigenous Knowledge. Purpose: Aid Indigenous Nations in using Indigenous knowledge with other data sets in planning, monitoring, and resource decision making, and make GIS data more accessible to mobilize knowledge in community based research programs. Rated: Advanced	Recorded qualitative and quantitative information uploadable or directly inputed to Trailmark includes: audio, video, photo, transcript, text, map/geospatial and any other numeric or descriptive files. Features include an engagement survey builder with mapping function, mobile data collection app with custom form builder, direct-to-digital interview mapping, digital archive with placename georeferenced, and an easy to use GIS with shapefile upload and query capabilities. All data can be searched, georeferenced, and filtered. Allows integration of data types by geospatial search and category theme. Rated: Advanced	Trailmark Cloud runs on AWS infrastructure physically located in Canada. Trailmark Cloud uses Mapbox (https://www.mapbox.com/) as the spatial component (geolocation, query and data visualization). Trailmark Mobile is used for mobile data collection and is based on the development framework Flutter. Using Trailmark Cloud, administrators can create customizable mobile data collection forms and push them out to Trailmark Mobile (supports iOS and Android OS). Meets all FAIR and OCAP principles. Rated: Advanced	Trailmark staff assist in developing data sharing agreements that fit with systems architecture and functionality. Software is structured to reflect the principles of data sovereignty and governance. A data system user manual identifies the technical components and how to use them. The system allows for the creation of private community sub-groups for a region under one account/Cloud. This allows for data pooling by a central body while maintaining privacy at the community level when required. Cloud accounts can share data/knowledge gathering forms by posting them to a library accessible by others. Data can be shared across accounts to create regional networks. Each Cloud account administrator can control what is shared. Each Cloud account has permissions det to user type withing the system, from full admin privileges to guest and participant accounts. Rated: Advanced	Communities share data/knowledge by curating and sharing links to interactive maps with query and visualization capabilities inside the system. A reporting tool uses basic analysis and map visualization software. Outputs can be tailored to the specific report, and exported. Rated: Advanced	Trailmark website: https://www.trailmarksys.com/. Clients access their data through: https://trailmarkapp.com/tm/?client=ykdfn. Rated: Advanced	**Advanced**	A public portal is planned for publishing cuRatedd information. Enhancing internal portal to handle and track data requirements to be used/reviewed by leadership by querying a password protected data catalogue. Building data quality analysis and reporting tools. Creating more visualization, search and geospatial analysis functions (integration of data types by area and theme). Linking with other geospatial data sources (federal, provincial, territorial) so that shared layers remain current through ongoing updates.
Skeena Knowledge Trust (SKT) Johanna Pfalz johanna@ skeenatrust.ca	Skeena Knowledge Trust includes a Salmon Data Centre (SDC) and a Skeena Maps Protal (SMP). SKT and its data systems is a deinitive source for salmon ecosystem information across the Skeena Watershed. SKT works with a broad range of organizations as a data bridge, organizer and amplifier of information by archiving and integrating data sets provided by anyone willing to share. The platform provides services that ensure long term custody of the data, and enhances its value through visualization tools that present it in more digestible forms. Rated: Advanced	Data types uploaded include audio, video, photo, transcript, map/geospatial and any other numeric or descriptive files. SKT finds, cuRateds and uploads historic datasets, as well as current data. Rated: Advanced	The SDC is a CKAN implementation, which is an open-source data management system for powering data hubs and portals. The platform also incudes other compatible add-ons. The accompanying Skeena Map Portal is housed on a Docker GeoNode/GeoServer. Metadata accompanies datasets through use of metadata templates tailored to the client. Rated: Advanced	There is an overall system plan that includes internal process documentation, with annual updates including focused upgrading projects. The SDC and SMP are inter-connected to provide data accessibility, discovery, basic query and visualization capabilities to the user. SKT is open to any and all data providers, under its terms of use. Data standards are customized to the client, their data and needs (there is a wide range of data types and volumes across clients). At present, SKT does all data uploading, but the data is owned by the contributor, who is responsible for maintaining and removing data (help with this is available on request). All data is open source by default, although data sets can be behind a password for a period of time. SKT provides training and data management advice on request. Rated: Advanced	Communities share data by curating and sharing links to interactive maps, downloading and processing data for sharing, sending a login to the system, or publishing to a public page. A reporting tool uses basic analysis and map visualization software. Outputs can be tailored to the specific report and exported. Rated: Advanced	Data can be published to a public portal, exported to CSV, or shared via weblink by administrator. Rated: Advanced	**Advanced**	Upgrades to mapping portal and Salmon data Centre (rebuilds in-house) have begun. Improve data visualization tools. Create a Skeena wide project registry and a community mapping network, then expand the registry to BC and Yukon. CollaboRated with DataStream on water quality data management. Expand services to more groups across the watershed.

Capability Rantings under each heading were chosen qualitative judgements that considered the range of data system capabilities in the survey as a whole.

ENDNOTES

[1]UNESCO, 2018. The Handbook on Water Information Systems Administration, Processing and Exploitation of Water Related Data https://www.inbo-news.org/sites/default/files/_HB-2018-SIE-BAT_web.pdf

[2]Examples include:

1) Kroetsch, Nicola Carmen, 2021. Improving Environmental Monitoring Collaborations Through Co-development of Data Management Plans: A guide for Resource Management Agencies and Environmental Stewardship Groups https://mcusercontent.com/389657c8f0bdbc7fc5e9dc59d/files/c4ffd2a6-0325-ad04-53d0-4cc8ea2b9466/Nicola_Kroetsch_Guide_for_Environmental_Monitoring_Collaboration.pdf&sa=D&source=docs&ust=1647278907389961&usg=AOvVaw2SzoLNjFmsBV6-AfNOiygi

2) Keats, Wong, Evans and Michel, 2021. Mobilizing Indigenous Knowledge in Resource Management Settings: A Practical Guide. https://cbmtoolkit.trailmarksys.com.

3) Internet of Water: Sharing and Integrating Water data For Sustainability. 2017. Aspen Institute. https://www.aspeninstitute.org/wp-content/uploads/2017/05/Internet-of-Water-Report-May-2017.pdf

4) Internet of Water: Water Data Assessment Tool and Data 101: A Guidebook for Water Data Users and Decision Makers https://internetofwater.org/resources/learning-center/

5) Columbia Basin Water Hub Data Management Plan, v. 1.2 2021 https://data.cbwaterhub.ca/ColumbiaBasinWaterHubDataManagementPlanandFramework.pdf

[3]Columbia Basin Water Hub: https://data.cbwaterhub.ca/, Skeena knowledge Trust Salmon data Centre: https://data.skeenasalmon.info/

[4]Luttmer, Carol, 2018. Water Monitoring in British Columbia: Scanning the Data landscape. Report prepared for the Water Monitoring Working Group of the BC Water Funders Collaborative. https://www.obwb.ca/bc_water_monitoring_scan/

[5] Pooling Shared Information and Knowledge Governance: https://poliswaterproject.org/2019/12/13/pooling-shared-information-and-knowledge-governance/

[6]Information extracted from https://healthywatersheds.ca/projects/

[7]Noor Johnson, Druckenmiller M.L., Danielsen F., Pulsifer P.L., 2021. The Use of Digital Platforms for Community-Based Monitoring Bioscience May 2021 Bioscience vol 71, No. 5. P. 452-456. https://academic.oup.com/bioscience/article/71/5/452/6236037

[8]Webinar recordings are available at https://www.cmibc.ca/events/

[9]OCAP Principles. See: https://fnigc.ca/ocap-training/

[10] FAIR Principles. See: https://www.howtofair.dk/what-is-fair/ and https://www.go-fair.org/fair-principles/

[11]The criteria behind meeting FAIR principles are sometimes used loosely (e.g., dictionary definitions of the words), or more specifically. This is apparent in the use of "should", as opposed to "must" in the following definitions:

Findable: Data and supplementary materials should have sufficiently detailed descriptive metadata as well as a unique and persistent identifier such as a digital object identifier (DOI).

Accessible: Metadata and data should be understandable to both humans and machines, and data should be stored in a trusted repository.

Interoperable: Metadata should use a formal, accessible, shared, and broadly applicable language for knowledge representation, such as agreed-upon controlled vocabularies.

Re-useable: Data and collections should have a clear usage license and provide accurate information on provenance"

The more general approach has been used in this survey.

Adapted from https://library.cumc.columbia.edu/insight/what-are-fair-data-principles#:~:text=The%20FAIR%20Data%20Principles%20(Findable,the%20reusability%20of%20digital%20assets).

[12]The criteria behind meeting OCAP™ principles are summarized as follows:

Ownership refers to the relationship of First Nations and their communities to cultural knowledge, data, and information, and states that a community or group owns information collectively in the same way that an individual owns personal information.

Control affirms that First Nations, their communities and representative bodies have rights to seek control of all aspects of research and information management processes that impact them, including all stages of a project e.g. resources, review and planning processes, and information management, among others.

Access refers to First Nations and their communities' rights to access information and data about themselves, regardless of where it is currently held, and to manage and make decisions regarding access to their collective information. This may be achieved through standardized, formal protocols.

Possession refers to the physical control of data. Possession is a mechanism by which ownership can be asserted and protected.

Adapted from https://fnigc.ca/wp-content/uploads/2020/09/2be8f15f2eff14b1f122b6a26023836a_fnigc_ocap_brochure_en_final_0.pdf

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