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CANADIAN GEOSPATIAL DATA INFRASTRUCTURE
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CANADIAN GEOSPATIAL DATA INFRASTRUCTURE (CGDI) USER NEEDS ASSESSMENTS

Hatfield Consultants

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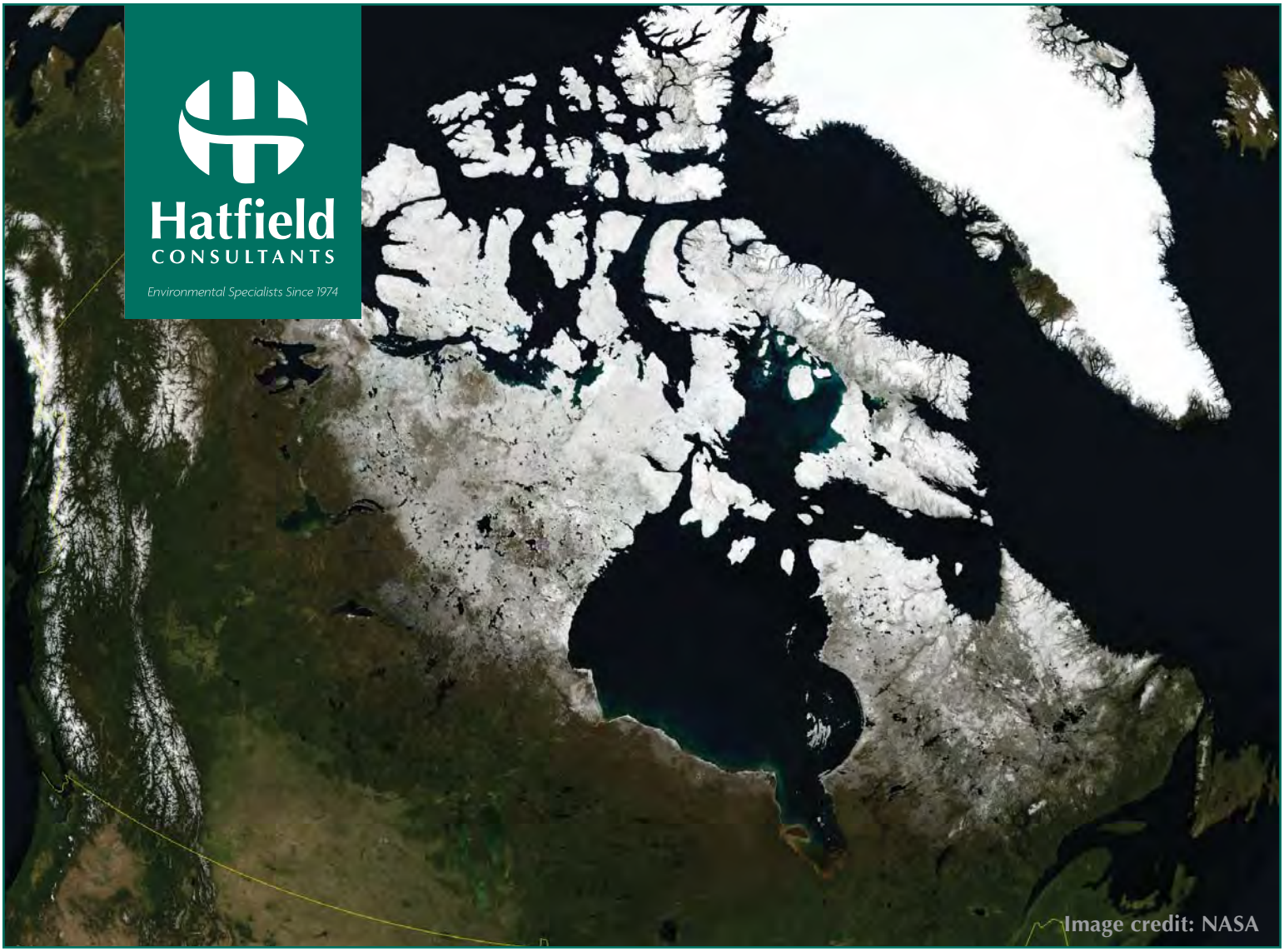

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Part A – Canadian Stakeholders
Part B – Indigenous Communities and Spatial Data

CANADIAN GEOSPATIAL DATA INFRASTRUCTURE (CGDI) USER NEEDS ASSESSMENTS

File No. - NRCan-5000034704

September 2018

Prepared for:

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Part B – Indigenous Communities and Spatial Data

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LIST OF ACRONYMS

AAFC	Agriculture and Agri-Food Canada
ADIwg	Alaska Data Integration working group
AOOS	Alaska Ocean Observing System
ARD	Analysis Ready Data
API	Application Programming Interface
AI	Artificial Intelligence
BC	British Columbia
CCOG	Canadian Council on Geomatics
CDM	Canadian Drought Monitor
CGDI	Canadian Geospatial Data Infrastructure
CSW	Catalogue Services for the Web
CIER	Centre for Indigenous Environmental Resources
CEOS	Committee on Earth Observation Satellites
EO	Earth Observation
FGP	Federal Geospatial Platform
GEODE	Geoanalytics Earth Observation Data Environment
IGAC	Geographic Institute Agustín Codazzi (Columbia)
GUI	Graphical User Interface
HAL	Hickling Arthurs Low
ITI	Industry, Tourism and Investment (Northwest Territories)
ICT	Information and Communication Technology
ILRR	Integrated Land & Resource Registry (British Columbia)
IoT	Internet of Things
MMI	Man–Machine Interface
NRCan	Natural Resources Canada
NDVI	Normalized Difference Vegetation Index
ODC	Open Data Cube
OGC	Open Geospatial Consortium
PaaS	Platform as a Service
RCM	Radar Constellation Mission
SDI	Spatial Data Infrastructure
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TEK	Traditional Ecological Knowledge
UCD	User-centered Design
UNA	User Needs Assessment
WFS	Web Feature Service
WMS	Web Map Service
WPS	Web Processing Service

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AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of UNA Report	20180326	Andy Dean Project Director	Olivier Tsui Project Manager
2	Second version of UNA Report	20180329	Andy Dean Project Director	Olivier Tsui Project Manager
3	Final version of UNA Report	20180914		
			Andy Dean Project Director	Olivier Tsui Project Manager

EXECUTIVE SUMMARY

The Canadian Geospatial Data Infrastructure (CGDI) began in the late 1990s with the aim to help Canadians gain new perspectives into social, economic and environmental issues, by providing an online network of resources to improve the sharing, use, and integration of spatial data across Canada. With recent developments in information and communications technology, geomatics technology, and availability of spatial data, there are new opportunities and challenges for Canadians. The needs and capacity of existing and new users of the CGDI have changed over time. In this context, Natural Resources Canada (NRCan) commissioned a research team to conduct a User Needs Assessment (UNA) and User-centered Design (UCD) study for the CGDI to gather, build upon previous work and understand the current requirements of Canadian stakeholders, including data users and suppliers. Led by Hatfield Consultants, the research team comprised companies and organizations from across Canada: Strata360, Hickling Arthurs Low (HAL), RHEA, Thorpe Consulting Services, BigSky Consulting, Acosys Consulting Services, and the Centre for Indigenous Environmental Resources (CIER).

The study was structured in two parts, to enable the research team to provide sufficient attention to major stakeholder groups for the CGDI. As a result, the study consisted of two concurrent studies:

- **Part A** – Canadian stakeholders, including federal, provincial, territorial, and municipal governments, academia, private sector, and non-government organizations; and
- **Part B** – Indigenous (First Nations, Inuit, Métis) organizations in Canada, including Indigenous governments, Tribal Councils, Treaty Organizations, Indigenous NGOs/Non-profits, and Indigenous-owned private companies.

This report provides a synthesis of consultation results, an assessment of user needs, and presents recommendations to help identify future phases of stakeholder engagement and communication that responds to the needs of the different communities and foster the adoption and implementation of the CGDI.

Study Methods Used

The UNA and UCD approach comprised of four methods, beginning with a review of existing materials as a first step. Subsequently, the study developed profiles of current and potential CGDI users, developed and implemented an online survey, and conducted structured interviews with selected users.

- Literature review: The literature review covered existing literature by national and international organizations concerning SDIs and user needs for spatial data.
- User Profiles: User profiles were developed to help understand and characterize the stakeholders that are current and potential users of the CGDI.
- Online Survey: An online survey was developed to explore the needs of the user groups profiled, including government and non-governmental organizations, and Indigenous governments, communities, and organizations in Canada.
- Interviews: Structured and semi-structured interview were conducted with stakeholders and organizations willing to participate to gain deeper and more detailed insights into user needs.

Part A – Key Findings and Recommendations

Thematic Data Requirements

Users expressed a need for a huge range of thematic spatial data that would enable them to fulfill their mandates and to respond to challenges across a range of environments, health, and economic areas of interests. Open data is a key requirement and provides many perceived benefits to users. Remote sensing datasets derived from remotely sensed imagery appear to be highly valued. A common theme was the need to centralize all image datasets acquired by Federal and Provincial departments and make them accessible to all through a common location/map service. Access to an authoritative base map dataset through the CGDI was a priority and users also expressed interest in accessing datasets at a finer scale and with local significance.

Recommended initiatives for the CGDI focus on stimulating the development of the most needed data and supporting access to realize the value-adding potential where data can be re-used multiple times. Users noted the following:

- Provincial/national LiDAR to generate high-quality elevation data and to enable assessment of vegetation structure;
- Land use and land survey;
- Road networks; and
- Definitive base map of Canada – standardized.

Technology, Applications, and Tools

Most users access spatial data by downloading data from external sources; however, awareness of web services is growing. Users also show interest in programmatic access to data through Application Programming Interfaces (APIs). While understanding that it would be a challenge to develop, users surveyed and interviewed mentioned the benefit of a single geoportal – based on federated data sources – to enable users to more easily discover data. The use of cloud computing is being increasingly adopted and the concept of Platform as a Service (PaaS) is gaining in awareness and interest, with users expressing interest in moving from geo-portals to geo-platforms.

Recommended CGDI activities related to new technology, applications, and tools are:

- Support key data suppliers to be standards compliant, especially those with relatively limited experience interacting with the CGDI such as smaller municipalities, regional districts, and non-government organizations;
- Review the opportunity to develop a CGDI geoportal based on federated data sources;
- Review technological trends identified in this study and identify how they may impact and benefit the CGDI;
- Promote the provision of access to spatial data and metadata through web services and APIs;

- Explore potential CGDI collaboration with existing and proposed geo-platforms such as the Polar Thematic Exploitation Platform (TEP), Earth Data Store (supported by the Digital Technology Supercluster), and Open Data Cube; and
- Review how the CGDI could support the development of marketplaces for spatial data and analytical services.

Policy, Standards, and Governance

Open data is a key requirement for users of spatial data and spatial data infrastructure. Where data cannot be made available free of cost, users still want to be able to discover the data easily and understand its accessibility, license, and costs. The largest barrier to sharing geospatial data is confidentiality and intellectual property issues, with restrictive licenses frequently mentioned. It is important to address perceived issues from potential suppliers that participation in the CGDI may negatively affect intellectual property and privacy/confidentiality. Despite metadata standards existing, users still commented on the benefit to metadata standards to make data search and discovery easier.

Recommended CGDI activities related to policy, standards, and governance are:

- Continue to develop and promote open data as a fundamental component of the CGDI;
- Provide guidance on policies and approaches to become a CGDI data provider, including metrics regarding the use of hosted data;
- Develop mechanisms to bring commercial data providers into the CDGI, through metadata discovery, marketplaces; and
- Help to improve users' ability to use and produce metadata. Consider a compliance testing service for CGDI components.

Training and Capacity Building

The GeoConnections program and the development of the CGDI have clearly enhanced the capacity of many users of spatial data to access, manage, use, and share spatial data. Despite this, almost half of respondents were not aware of CGDI tools and endorsed standards. Some users could not differentiate between CGDI and related government initiatives, such as GeoBase, which may suggest a potential branding issue for CGDI. There is a sense of confusion about how these different resources and initiatives contribute and co-exist within the same broad ecosystem. Several users indicate that technical capacity is not necessarily an issue for their organization, rather the availability of personnel and resourcing is an issue for users in accessing, processing, and producing data.

Recommended CGDI activities related to training and capacity-building are:

- Address a potential CGDI awareness and branding issue. The CCOG recently undertook a rebranding and developed a clear website to communicate its purpose and vision. A similar effort is needed to clarify the purpose and mandate of CGDI, GeoConnectons, GeoBase, and GeoGratis;

- Develop a communication and engagement plan to further develop the user base of the CGDI to expand the benefits to Canadians. Priorities include Indigenous organizations, communities, and governments in Canada (see Part B of this report), municipalities and regional districts, and the private sector;
- Create fact sheets in English, French and in Indigenous languages to raises awareness of the CGDI and participation. Conduct presentations at conferences and to relevant committees, as well as webinars to expand potential participation in presentations; and
- Collaborate more with regional data providers, e.g., regional districts and municipalities, to address the need to provide or link users to the datasets they value most. Promote collaboration with private industry to innovate and grow the geospatial marketplace (e.g., linkages to Innovation Superclusters).

Part B – Key Findings and Recommendations

Future Engagement

There is considerable interest among Indigenous organizations to increase their use of geospatial data and to participate in geospatial initiatives, for example in UNA and UCD initiatives. Further engagement with Indigenous communities and organizations is imperative to validate the findings presented here to gain a more complete picture of Indigenous user needs and to explore alternative viewpoints.

Thematic Data Requirements

Examples of key thematic datasets include: natural resource data; community use and occupancy studies; land use and cover; imagery - satellite, LIDAR, aerial photographs; and climate change related data. Prioritizing and providing these data will better enable Indigenous communities and governments to participate meaningfully in decision-making within and beyond their asserted territories. Like other users of geospatial data, Indigenous organizations need up-to-date spatial data to enable them to make informed decisions about land use and other issues in relation to their territory and Aboriginal rights and title.

Recommended CGDI activities related to thematic data requirements are:

- Increase availability of, and ease of access to, thematic datasets to better meet the needs of Indigenous communities and organizations;
- Engage more with Indigenous communities and organizations to better understand needs and access to framework and thematic datasets;
- Work to make sure relevant data sets are as up-to-date as possible; and
- Support and facilitate Indigenous collection of geospatial data that they identify as relevant and important.

Technology, Applications, and Tools

Bandwidth limitations are especially a problem for Indigenous organizations, in the north, parts of rural BC and other 'remote' locations. Standardized methods, tools, protocols, and systems were identified as key for Indigenous organizations to be able to build on their existing work. These include best practices or guidelines for data collection and sharing sensitive information. Indigenous organizations identified mobile applications and technologies, including tablets and smartphones, and use of drones/Unmanned Aerial Vehicles (UAV) as important geospatial tools that could improve capacity for natural resource management and environmental monitoring.

Recommended CGDI activities related to new technology, applications, and tools are:

- Develop improved methods to ensure Indigenous communities and organizations have access to key framework and thematic datasets for their areas of interest, which could include data packages, virtual machines with data and software, and addressing concerns over cloud storage[1];
- Where possible, increase bandwidth and improve the consistency and reliability of internet access to improve data sharing and use of geospatial data and CGDI;
- Develop and implement jargon-free, user-friendly tools to facilitate Indigenous organizations use and engagement with CGDI;
- Explore lessons from virtual reality and gaming to better actualize oral traditions tethered to maps; and
- Research and engage Indigenous organizations to better understand priorities and to identify cost-effective ways to improve access to technology, applications, and tools.

Policy, Standards, and Governance

Indigenous organizations note that it is often difficult to locate needed datasets and to navigate ever-changing discovery portal interfaces. Several organizations noted that a "one-window" approach would simplify data discovery and improve Indigenous access to, and use of, geospatial data. Results suggest that few organizations have data management policies or standards in place to guide how geospatial data is catalogued. Indigenous communities and organizations are most concerned about the security of geospatial data related to traditional knowledge and use.

Recommended CGDI activities related to policy, standards, and governance:

- Make data discovery easier and more user-friendly. Efforts to establish more standardized and stable interfaces to geodata discovery portals would help the data discovery aspect of Indigenous CGDI/SDI use;

[1] Implementations of data access services for SDI can include, in addition to online data services: brokered access services; offline packaging and physical delivery of data; and direct delivery of data via FTP (GSDI 2012).

- Consider the feasibility of establishing regional geospatial databases to help standardize and improve data access and governance. Databases could include baseline cartographic information, scientific information, remote sensing imagery, and other data that users upload or is acquired by different levels of government;
- Designate knowledgeable government contacts to be available to support Indigenous organizations to help address questions or challenges with these databases;
- Support Indigenous organizations to increase cataloguing capacity to help with data distribution and sharing;
- Work with Indigenous communities and organizations to develop and establish clear policies and standards around data ownership, storage, sharing, and access. These are especially important with respect to confidentiality and intellectual property concerns, and should include guidance on how communities can protect sensitive information; and
- Develop and distribute guidance documents and instructions manuals that outline best practices and help organizations to implement data management policies and practices.

Collaboration and Institutional Arrangements

Indigenous communities and organizations have differing and often low levels of network bandwidth, geomatics technical capacity, and varied adoption of data distribution governance policies. CGDI was built working across levels of government and involving the private sector in collaborative processes and partnerships. Indigenous communities and organizations need to be afforded the same opportunities for collaboration. Equitable participation by Indigenous organizations must be understood in the context of community resources, as lack of funding was identified as a key barrier for Indigenous aspirations around the use of geospatial data. Geospatial data generated or used for the purposes of consultation should be readily available to Indigenous communities and organizations.

Recommended CGDI activities related to collaboration and institutional arrangements:

- Indigenous communities and governments must be able to choose their levels of participation and be supported in ways that enable their engagement with CGDI in line with their own aspirations and goals;
- Collaboration between current CGDI participants (government and other groups) and Indigenous organizations must be encouraged to help raise understanding, build trust, and increase the capacity of Indigenous organizations to interact with CGDI;
- Work with Indigenous communities and organizations to ensure they have adequate funding and resources to collaborate and participate in data partnerships; and
- Resource development and project proponents should be compelled to share geospatial data pertinent to Indigenous issues and concerns that are (or may be) collected during project initiation, permitting, and beyond.

Training and Capacity Building

Capacity building was a commonly expressed need amongst Indigenous organizations, regardless of their size, location, or existing GIS capabilities. Although not the only dimension of capacity building, funding, and education and training are the two pillars of capacity that emerged most consistently throughout the UNA. The need for funding was a consistent theme raised by all interview and survey participants. Funding is a major requirement for Indigenous organizations to be able to continue to build their capacity to interact with geospatial data.

Recommended CGDI activities related to training and capacity building:

- Explore funding potential for Indigenous organizations to continue to build their capacity to interact with geospatial data;
- Raise awareness about training and employment opportunities in geomatics and other fields related to the use, collection, management, and application of geospatial data;
- Explore opportunities to incorporate lessons and modules on geospatial technology into the educational curriculum as early as possible;
- Shift from reliance on outside consultants for training and expertise to Nation to Nation training and mentoring. One interviewee from a relatively well-resourced community suggested a “pay it forward” model such that members of the community could train others in both in and outside of their communities;
- Promote and support the use of more contemporary and accessible training and capacity building tools. For example, while guidance documents and manuals have a role in training and capacity building, the use of video/video gaming appeals to a youth-centred approach prioritized by many Indigenous organizations and aligns with Indigenous oral tradition; and
- Build training programs grounded in Indigenous cultural norms and ways of learning to ensure more effective initiatives. For example, create an advisory group comprised of Indigenous representatives from across the country who could provide key guidance on capacity building initiatives and other aspects related to spatial data use, access, storage, and management.

1.0 INTRODUCTION

Using geographic information, we are able to better understand our environment and address the challenges society faces, including climate change, public health, and resource management. Improving access to geospatial data can help us better predict, understand and react to changes in our environment. Spatial data is information that identifies the geographic location of features and boundaries on Earth, including the natural, built or perceived environment. Put simply, spatial data is information that can be represented on a map. Spatial data can be as simple as drawing or writing on an existing map, or it can include digital location and descriptive information.

In the early 1990s, spatial data was identified as a high-value asset in the emerging information economy (NRC 1993). Over this period, spatial data has become almost entirely digital, which has opened new opportunities to maximize value to stakeholders and realize significant efficiencies. Sharing of data and accessing datasets is supported by **spatial data infrastructure** (SDI), which encompasses technologies, policies, standards, and tools. The concept of SDI emerged in the early 1990s. The United Nations Strategy for Developing and Implementing a UN SDI (2007) identifies SDI as a concept tying geographic information to common standards for information exchange.

Spatial Data Infrastructure informs the decision-making process

An SDI increases efficiencies by allowing for re-use of components including data, technical capacity, skills, and intellectual effort. This reuse is enabled by infrastructure policies and standards including protocols and specifications and is contingent on sharing of these components between stakeholders. Information is expensive, and SDI helps avoid failure to discover data or the re-capturing of already existing data. There is an additional opportunity to reuse data incidentally captured for other purposes, and compatibility across jurisdictions is important in this regard. Common conventions and agreements can also limit duplication of tool development, which can be shared between cooperating parties (GSDI 2009).

The **Canadian Geospatial Data Infrastructure** (CGDI) helps users of spatial data to access and share data and to collaborate. The process to establish the CGDI began in the late 1990s with the aim to help Canadians gain new perspectives into social, economic and environmental issues, by providing an online network of resources that improve the sharing, use, and integration of information tied to geographic locations in Canada (GeoConnections 2012). The CGDI encompasses the technology, standards, access systems and protocols necessary to make spatial data available through the Internet.

With the recent proliferation of location-enabled devices and sensors, there is an increased awareness of the value of spatial data and it has become more commonplace. SDI's are responding to demand for spatial data and the variety of sources available. At the same time, users, their needs, and capacities also change over time. In this context, Hatfield Consultants (Hatfield) led a team of researchers to conduct a **User Needs Assessment (UNA) and User-centered Design (UCD) study** for the CGDI to gather build upon previous work and understand the current requirements of Canadian stakeholders, including data users and suppliers.

Scope and Structure of the Study

The study was completed for Natural Resources Canada (NRCan) under contract no. 3000659567 by a team of researchers led by Hatfield. The research team comprised companies and organizations from across Canada: Strata360, Hickling Arthurs Low (HAL), RHEA, Thorpe Consulting Services, BigSky Consulting, Acosys Consulting Services, and the Centre for Indigenous Environmental Resources (CIER). Financial support was provided by GeoConnections, a national collaborative initiative led by Natural Resources Canada. GeoConnections supports the integration and use of the CGDI.

The study was structured in two parts, to enable the research team to provide sufficient attention to major stakeholder groups for the CGDI:

- **Part A** - Canadian stakeholders, including federal, provincial, territorial, and municipal governments, academia, private sector, and non-government organizations; and
- **Part B** – Indigenous organizations in Canada (First Nations, Inuit, Métis), including Indigenous governments, Tribal Councils, Treaty Organizations, Indigenous NGOs/Non-profits, and Indigenous-owned private companies.

A focus on Indigenous organizations in Canada was intended to ensure that the important, unique needs and requirements of Indigenous organizations and communities are captured as an important current and future user of the CGDI. As a result, the study consisted of two concurrent studies. Each with a focus to gather requirements from each of the stakeholder communities across Canada – a Pan-Canadian and a Pan-Aboriginal consultation. Part B presents a unified discussion of Indigenous user needs across Canada, however, does explore and report on distinct regional differences that might be important to know about for future refinement of CGDI and improvement of its utility and accessibility in Indigenous contexts.

This report provides a synthesis of consultation results, an assessment of user needs, and presents recommendations to help identify future phases of stakeholder engagement and communication (e.g., awareness and capacity building) that responds to the needs of the different communities and foster the adoption and implementation of SDIs. This report highlights the value of spatial data in supporting effective decision-making and how SDIs are contributing to innovation and open science. It also confirms the value and benefits of using geospatial data and SDIs for efficient monitoring and decision making in Canada.

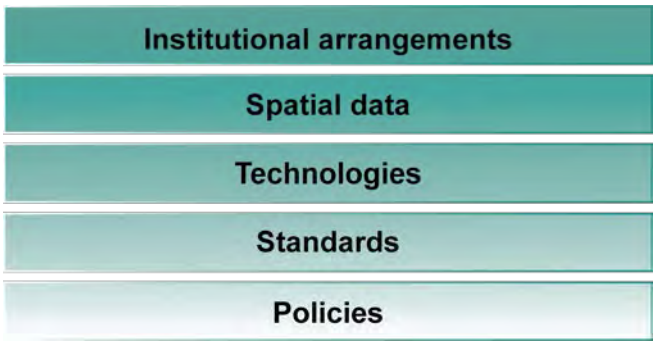
Following this introduction, chapter 2 provides background and context on SDI components that are relevant to Part A and Part B of the study. Subsequently, Part A summarizes the Pan-Canadian and Park B the Pan-Aboriginal consultation

2.0 BACKGROUND AND CONTEXT

2.1 Components of Spatial Data Infrastructure

Key components of an SDI include governance, technology, standards, and data, which are summarized in the figure below. An SDI is about spatial data, but it is also about infrastructure. “Infrastructure” suggests a reliable supporting environment, in which common technologies, policies, and institutional arrangements exist. SDI supports applications using geographically-related data through a minimum set of practices, protocols, and specifications (GSDI 2009). Spatial infrastructure must provide access to spatial data in a reliable, consistent and well-defined manner so that it can support functions addressing end-user needs.

Spatial Data Infrastructure Architecture



Source: Spatial Data Infrastructure Manual for the Arctic (GeoConnections 2017).

SDI is also about the community of users. Datasets identified as having high value may differ from user to user and is dependent on the application. For example, professional and non-professional users may have distinct needs. Professional users expect standards-compliant data delivery that can be integrated with other datasets. Non-professional users will not have as strict a requirement for authoritative data, which can often be provided by “Mass Market Geomatics” services such as Google Maps and related products. (CP-IDEA 2013). SDI can provide for these and other use cases, but fundamentally, use cases are driven by the users. Hence, understanding the users and their needs is important to the uptake and utility of SDI as a good for the community. User needs must be understood, and mechanisms put in place to evaluate if they are being met.

The Global Spatial Data Infrastructure Association is an international organization of academics, researchers, government agencies and others. It released a “Cookbook” in 2009, which provided information on the components of an SDI including a selection of case studies (GSDI 2009). The cookbook deals with data issues in depth, including: multi-user data; metadata; data discovery and visualization; and access and delivery. A distinction is often made between “framework” or “core” data and “thematic” data, where framework data provides commonly reused base map features as a foundation for other data (CPIDEA 2013). The cookbook also describes outreach and capacity building, calling these *community-building* functions.

2.2 GeoConnections Initiative and the Canadian Geospatial Data Infrastructure

GeoConnections was founded in 1999 through a $60 million five-year investment (Goss Gilroy Inc. 2012), as a national partnership between federal government and Canadian stakeholders in the geomatics sector. The program's mandate is to lead the CGDI to provide endorsed standards-based access to shared national geospatial data as a common public asset. In the five years of this Phase I, activities focused on building connections with partners and stakeholders and to collectively lay the foundation of the CGDI.

Phase II of GeoConnections began in 2005 with additional funding for five more years. In this phase, activities were focused on four identified priority goals: public health; safety/security; environment, and matters of importance for aboriginal peoples.

After a two-year extension, GeoConnections funding was renewed to cover a total of five years in Phase III. In this phase, GeoConnections focused on continual updates to align with the evolving nature of internet policies. Goss Gilroy Inc., 2012 states:

> The CGDI is intended to improve decision making within all levels of government, the private sector, non-governmental organizations, and academia. The CGDI enables users to access and easily integrate the most current and accurate geospatial information in databases distributed across Canada, as well as around the world. The CGDI does not house or store this content. Rather, it provides an infrastructure that allows a diverse community to access and share information directly from authoritative sources by capitalizing on common standards.

A key stakeholder in CGDI is the Canadian Council on Geomatics (CCOG). This body was formed in 1972 as a consultative body with representation from federal, provincial and territorial governments. It addresses common issues and concerns and makes recommendations regarding future programs and technologies, and relevant legislation. The Council promotes adoption of international geomatics standards; the CGDI is a strong mechanism through which the Council can promote cooperation and exchange of information using recognized web-centric data exchange mechanisms.

CCOG oversees the GeoBase initiative, approved in 2001 to provide national framework spatial data. GeoBase has been promoted and facilitated through GeoConnections, which has provided funding and direction to prepare framework data and a user portal aligned with the principles of CGDI. In May 2014, the GeoBase framework data was absorbed into the GeoGratis portal; however, the initiative continued to be active. GeoGratis began as an initiative by NRCan's Canada Centre for Remote Sensing in 2000. Currently, GeoGratis and GeoBase data are being actively incorporated into the open.canada.ca portal.

2.3 Indigenous Communities and Spatial Data

Indigenous peoples have used geographic information for millennia to understand and live in relationship with the world around them, for example, carefully building mental maps of key harvesting areas or safe travel routes. Today Indigenous people, through their governments, associations and nations may use spatial data in new ways and with new technologies.

Through land claim settlements and rulings in the courts, Indigenous communities across Canada have progressively gained new powers and authority over their lands. Spatial data is an increasingly relevant and powerful tool in the process of re-asserting Indigenous rights to traditional lands and resources, in articulating their visions for how these lands are to be developed and conserved (Makivik 2008a), and in helping to preserve and maintain cultural knowledge and transfer it to younger generations. Land use planning is increasingly used by Indigenous communities for reconciling community vision with third-party interests for which geospatial data is a central and strategic tool.

An important emerging mandate for Indigenous communities is anticipating and planning for the effects of climate change. Geospatial data and technology needs range from predicting potential impacts of climate change on communities, to monitoring and surveillance of changing terrestrial and marine ecological conditions and from understanding vulnerability and resilience, to adaptation planning and building adaptive capacity.

Indigenous-owned business participation in resource development, fisheries, and forestry will also benefit from geospatial data. For example, Indigenous participation in the east coast fisheries has grown substantially since the Marshall decisions of 1999, and First Nations desire growth in their role and decision-making capacity in fisheries management (APCFNCS 1999).

The geospatial data needs and technological challenges associated with data management for Indigenous communities and organizations are likely to be similar in many ways to the issues that affect Canadian communities and users of geospatial data in general. It is expected, however, that discovering, accessing, and using geospatial data will also present unique opportunities and challenges for Indigenous users. Addressing both sets of issues in an appropriate and conscientious manner will not only help make geospatial data easier to find and use for Indigenous communities and organizations, it will in turn, also help build capacity and support reconciliation.

PART A – CANADIAN STAKEHOLDERS

CANADIAN GEOSPATIAL DATA INFRASTRUCTURE (CGDI) USER NEEDS ASSESSMENTS

Part A – Canadian Stakeholders

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1.0 INTRODUCTION

This is Part A of the **Canadian Geospatial Data Infrastructure User Needs Assessment (UNA) and User-centered Design (UCD) study**. This document addresses users from Canadian federal, provincial, territorial, and municipal government, academia, private sector, and non-government organizations. A companion Part B document focuses on Indigenous organizations and spatial data.

Part A aims to provide Natural Resources Canada (NRCan) with insight into needs and priorities of Canadian organizations regarding spatial data, including: thematic requirements; policy and governance; technology and tools; standards and protocols; and capacity. Subsequently, it aims to generate recommendations to frame how issues and needs can be meaningfully integrated to strengthen the Canadian Geospatial Data Infrastructure (CGDI).

This UNA and UCD study builds upon previous work, a significant amount of which was completed through GeoConnections, a national program with three phases (1999-2005, 2005-2010, and 2010-2015) with a mandate to lead the CGDI and to help Canadian citizens, groups, businesses, and communities manage the complex social, economic, cultural, and environmental issues of the 21st Century. This UNA and UCD study is a continuation of efforts to expand and deepen the accessibility and use of geographic information through the CGDI. It presents the findings of a rapid assessment carried out with government and non-government organizations across Canada between January and March 2018. This document is structured into the following sections:

- Methodology for the study;
- Review of previous studies and best practices;
- Analysis of user profiles;
- Analysis of user survey and interviews results, built around broad themes that emerged from the primary research; and
- Key findings and recommendations, synthesized and reframed in context to acknowledged *aspects* of UNA as defined in the Spatial Data Infrastructure Manual (GeoConnections 2017) and *components* of SDI (GeoConnections 2007).

2.0 METHODOLOGY

The UNA and UCD approach comprised four methods, beginning with a review of existing materials as an important first step. Subsequently, the study developed profiles of current and potential CGDI users, developed and implemented an online survey, and conducted structured interviews with selected users.

Literature Review

The literature review covered existing material concerning SDIs and user needs for spatial data. This included literature on spatial data infrastructures by national and international organizations that are concerned with spatial data, such as GeoConnections, Open Geospatial Consortium (OGC), Global Spatial Data Infrastructure Association (GSDI), Arctic SDI, and INSPIRE. Areas where existing materials and current initiatives contribute include learning from existing UNAs and UCDs, identifying SDIs and SDI component systems, and identifying key stakeholders and user needs.

The UCD review was placed on the initial stages of the UCD process, which consists of capturing business and user requirements. In addition, the UCD review included a summary of main geoportal design trends, which aimed to summarize the main user design aspects for geoportals that are being driven by new technological trends.

User Profiles

User profiles enable researchers to understand and characterize the stakeholders that are current and potential users of a service or system. User profiles support the development of survey and interview questions and provide a framework for the UNA. In the context of the CGDI, user profiles consider roles as suppliers, developers, marketers, enablers, and end-users (based on the GeoConnections *Understanding Users' Needs and User-Centered Design publication* (GeoConnections 2007).

Online Survey

A survey was developed to explore the needs of the user groups profiled. An online survey was selected as the most efficient option for user engagement and requirements gathering. As part of our adaptive approach respondents were segmented according to their level of knowledge of spatial data and CGDI (i.e., enable more detailed, technical questions to stakeholders with extensive SDI knowledge and experience). Our approach was designed to balance the timeline of the study and our commitment to respectful and effective engagement with government and non-governmental organizations.

The survey comprised 44 questions aimed at federal, provincial, and municipal governments, academic institutions, public organizations, NGOs, and private companies across Canada (a full list of survey questions is available in Appendix A1). The survey utilized multiple choice and Likert rating questions to characterize the following:

- Characteristics of user and organization;
- Overall capacity and knowledge of organizations to produce, utilize, acquire, and share spatial data and spatial data products;

- Main activities performed by users in the context of using and sharing spatial data;
- Key spatial data requirements and needs of the organizations;
- Current use of spatial technologies;
- Data management, distribution, and sharing policies and practices;
- Familiarity with CGDI, associated tools, and policies; and
- Key barriers and challenges to acquiring, using, and integrating spatial data into users' key activities.

The survey was developed on the Survey Monkey platform and delivered via an e-mail link with an introductory letter explaining the objectives of the study, composition of the research team, what spatial data is, and how organizations might benefit from participating. Invitees received reminders either via phone or email to encourage their participation.

The project team approached a total of 201 individuals to complete the survey. Stakeholders were selected to complete the online survey based on the network and professional experience of the project team and from recommendations from NRCan. Further outreach was completed using GoGeomatics Canada's Canadian Spatial Times newsletter. The online survey was not intended to capture a statistically representative sample of all organizations in Canada. This was due firstly to the study's limited timeline, and secondly, to the complexity in identifying the overall study population and sampling for proportionality among different types of organizations. Rather, the survey provides an exploratory examination of user needs to inform future phases of stakeholder engagements and CGDI development.

Interviews

Structured and semi-structured interviews were conducted with stakeholders willing to participate to gain deeper and more detailed insights into user needs (an example of an interview is available in Appendix A2). Building on data collected in the online survey, the semi-structured interviews focused on the following elements:

- Validate user profiles identified in the literature review and online survey results;
- Validate user knowledge and capacity in context to CGDI and spatial data sharing;
- Gain further details on an organization's barriers and challenges to acquiring, using, integrating, or sharing spatial data;
- Gain further details on the organization's future use and sharing of spatial data; and
- Acquire insights and subtleties not captured in the online survey.

Stakeholders who completed the online survey and indicated a willingness to be interviewed were contacted via telephone. For the UCD component of the study, the target for interviews was users and developers of relevant geoportals, primarily focused on the Arctic. The purpose here was to gather lessons learned from

the design of other geoportals of relevance to Canada, with the aim of presenting these considerations to the attention of NRCan, for possible future implementations of CGDI portals, or updates of existing ones.

Research Limitations

The timeframe of the project presented constraints in terms of identifying and screening participants, developing and testing research tools, and collecting and analyzing primary data. Most significantly, the project's timeline limited the research team's ability to engage with organizations in a manner that accommodates varying schedules and resources, availability, and timelines. As such, the results of the needs assessment are not statistically significant, nor does it comprehensively represent the diverse user groups and organizations across Canada. Secondly, the project team was not able to comprehensively validate the online survey results with stakeholder groups. For the UCD component of the study, the project team could only get limited feedback from the interviews of persons involved in Arctic geoportals.

3.0 REVIEW OF PREVIOUS STUDIES AND BEST PRACTICES

3.1 USER-CENTERED APPROACH

UNA and UCD are methods of involving end-users in system design and delivery. They facilitate gauging how well goals and needs align, taking guidance from end-users themselves. Treasury Board of Canada guidelines for Phase II of GeoConnections stipulated a user-driven process to ensure the system meet requirements (GeoConnections 2007). UNA has been at the core of the development of the CGDI. For example, framework data updates are driven by continual consultation. GeoConnections guidelines include user needs as priorities for meeting requirements and require that design must be user-centric.

GeoConnections 2007 describes UNA as meeting user needs by accounting for their ideas, attitudes, wants and preferences, assisting in priority setting and decision making regarding the system (GeoConnections 2007). The UNA process has three phases:

- Planning the assessment;
- Conducting the assessment; and
- Interpreting and reporting the assessment results.

Planning involves setting objectives and constraints, identifying the resources and methods needed, and profiling users to determine who will be contacted in the assessment.

GeoConnections UNA includes community identification of content, technology, and policies necessary to address requirements. Subsequent UCD focuses on the implementation of applications and systems. GeoConnections recommends that an independent research professional conduct the UNA and UCD. This ensures impartiality among other advantages. GeoConnections 2007 describes UCD as soliciting user inputs at various design stages to ensure ease of use and that user requirements are met (GeoConnections 2007). UCD considerations include:

- How an application or system is used;
- How users want or need to work;
- How users think about their tasks; and
- How often users do particular tasks.

3.2 CASE STUDIES IN USER NEEDS ASSESSMENT AND USER-CENTERED DESIGN FOR SPATIAL DATA INFRASTRUCTURE DEVELOPMENT

This section reviews selected UNA studies implemented for the development of SDI in Canada and internationally:

1. The Global SDI UNA (1998);
2. GeoConnections UNA (2006);
3. Canadian Aboriginal Land Use Geospatial UNA (2008);
4. Colombian Spatial Data Infrastructure (2009);
5. DataBC Concept of Operations (2012);
6. GeoNOVA (2014);
7. GeoDiscover Alberta (2016);
8. City of Nanaimo Needs Assessment GIS Report (2017); and
9. Arctic SDI / INSPIRE.

A range of UNA methods were employed. Identification of stakeholders and end-users was sometimes implicit (Case Studies #1, #3, and #8). In many cases, the initial stakeholder list drew from previously identified groups (Case Studies #2, #4, #6 and #7). In Case Study #5, "oversight stakeholders", i.e., groups that ensure alignment to government priorities and objectives, are mentioned but not specifically identified.

Structured questionnaires were employed in two of the UNAs (Case Studies #1 and #2). Telephone interviews were also employed in two of the UNAs (Case Studies #2 and #3). Most information-gathering appeared to be by in-person interviews or through workshops, focus groups, or the work of committees (Case Studies #3, #4, #6, #7, #8, and #9).

GeoConnections 2006 (Case Study #2) is the most comprehensive UNA. An initial group of stakeholders was invited to participate in focus groups in which other potential stakeholders were identified. These groups were approached by telephone to confirm their willingness to participate, and a questionnaire was mailed to them. After responses were received, a follow-up telephone interview allowed for clarification and amplification of responses. Survey responses were quantitatively analyzed.

The approach in Makivik 2008b (Case Study #3) is interesting, in that important land use plans for the Indigenous Communities involved were reviewed to identify high-value datasets. Summaries were provided to originating communities for comment, and follow-up workshops were held. Internet search and telephone inquiries were used to determine custodian information for each dataset. Quantitative and qualitative reporting and qualitative assessment of priority datasets (rankings) were provided.

City of Nanaimo 2017 (Case Study #8) reviews data needs from civic departments, evaluating each, not only in terms of effort and cost, but also alignment with corporate goals. GeoNOVA 2014 (Case Study #6) similarly seeks to align their initiative with the provincial Technical and Information Management Strategy, including the Chief Information Officer as a key partner.

GeoConnections (2007) provides an overall description of UCD methods applied to geoportals. It proposes a methodological framework consisting of 5 steps: (1) Business Requirements Analysis, (2) User Requirements; (3) User Interaction design; (4) Development; (5) Deployment. Depending on the overall

context of the development and planned usage of the geoportal, this cycle may be implemented once (similar to a 'waterfall' approach in software development terminology) or, at the extreme, may be iterated many times on very short timescales (Agile development methodology). After the geoportal is placed in service and operated, UCD approaches to continuous software design and development must be iterative, so that the resulting software can be continuously developed, tested, and improved upon. For example, one UCD approach to software development is the "DevOps" approach, which closely integrates development and operations of software, so that new software releases are regularly issued to add software features, correct bugs reported by users, and improve the user experience based on user feedback. By releasing new software on a rapid lifecycle, not only user experience can be rapidly improved, but also the ability to adapt software quickly considerably reduces the risk on software development projects.

Finally, another aspect to UCD methodologies needs to consider the paradigm of centralized versus decentralized development. An open source software development approach can create the conditions for a vibrant ecosystem of multiple contributors to the software, resulting in a decentralized software development framework. Usually, this adds values to the product, as each contributor enriches software features, functionality, or robustness, in response to needs expressed by their end-users. For that reason, an open source approach, combined with a large development community, can be considered as one way to achieve a UCD approach. Examples include the Arctic SDI geoportal (Case Study #9) based on the open source Oskari[2] toolkit. Additionally, DataBC (Case Study #5) and GeoDiscover Alberta (Case Study #7) use the CKAN web-based open source system, which incorporates modern web design elements and a faceted search mechanism. This system is also being employed by the Government of Canada's Open Data Portal (open.canada.ca).

The Global SDI UNA (1998)

Harlan Onsrud of the University of Maine's School of Computing & Information Sciences conducted a UNA in 1998 to support the development of a global SDI (Onsrud 1998). The results were presented at the GSDI 3 meeting in Canberra, Australia in November of that year. Web documents of this age become hard to reference, but the questionnaire and a partial archived copy of the UNA results are available through archive.org[3]. The survey was specifically for national-level infrastructures; hence, the respondents, in this case, represented government entities.

The survey focused on how similar or different various national approaches were, and what case might exist for global coordination between systems. Some of the questions clearly identify *citizens* and *businesses* as potential end-users. Questions regarding public domain or commercial data, end-user costs, and access mechanisms were included. With reference to the conceptual architecture, the survey asks if components will include metadata, a clearinghouse, data standards, and core data (elsewhere referred to as "framework" data). Canada did not return a response to this UNA. There was a response from Columbia's Geographic Institute Agustín Codazzi (IGAC), foreshadowing the Colombian SDI (ICDE) – details of this system were collected in 2009 (CP-IDEA 2013). 27 nations responded in total, with two separate respondents from Germany and Japan, representing different organizations within those countries.

[2] http://www.oskari.org/

[3] https://web.archive.org/web/19990127090413/http:/www.spatial.maine.edu:80/harlan/gsdi/GSDI.html

GeoConnections UNA (2006)

Environics Research Group conducted the Survey of Geographic Information Decision-Makers for GeoConnections in 2006 (Environics 2006). The original UNA is available through Library and Archives Canada[4], or online through archive.org[5].

GeoConnections sought to ensure a user-driven approach and to help achieve this, mechanisms were put in place to allow users of spatial data in priority areas/themes to communicate their needs to the CGDI implementation teams. Information was sought from *current* and *potential* end-users. Environics Research Group was commissioned to conduct a national level UNA for this purpose. End-user key business requirements were collected across four thematic areas: public health; public safety/security; sustainable development; and the environment and aboriginal concerns.

GeoConnections was interested to know what CGDI could offer to become the service of choice for users. This involved assessing desired data types, themes, and attributes and methods of delivery. Current constraints on use were also addressed in the survey, including policy and technological limits.

An initial qualitative scan (Phase 1) was followed by an extensive survey of current and potential users nation-wide (Phase 2). Phase 1 involved 13 focus groups of CGDI users and non-users who were stakeholders in the four thematic areas, held in communities across the country. These stakeholders were pre-identified by Natural Resources Canada. Phase 2 involved a quantifiable survey with the aim of extrapolation to the full CGDI user population. Those results were covered in Environics 2006. Participants were first contacted by telephone to confirm their interest and that they were *users of geographic information*. GeoConnections material and the survey questions were then mailed to the participant, and an appointment was scheduled for a follow-up telephone call, in which the participant's responses and elaborations were collected.

The report included summary information about end-user types, data use by thematic area, etc., is given in great detail. Decision makers often had prior awareness of GeoConnections and saw the CGDI as able to meet the stated needs and bring benefits to their organizations. CGDI was well positioned to lead in the adoption of guidelines and standards, and to promote the utility of metadata to bring confidence to end-users. It was noted that technical experts view metadata as more important than did decision makers. The report found that costs and resource limitations were the most frequent impediments to access, especially for Aboriginal Peoples.

Key recommendations included:

- CGDI identifies high-value datasets in each thematic area but could focus on cross-cutting datasets;
- Users of the "discovery portal" should be asked if they are willing to be participants in future studies, so that end-user groups can be more accurately determined;

[4] http://www.bac-lac.gc.ca/eng/CollectionSearch/Pages/record.aspx?app=laccat&IdNumber=33460629

[5] https://web.archive.org/web/20071015180135/http:/www.geoconnections.org/publications/reports/CGDI_UNA/Environics_GeoConnections_Report_E.pdf

- The CGDI website must provide a *prominent link* to the discovery portal; and
- The discovery portal website *should be re-designed* to facilitate data discovery – many organizations used data across the thematic areas, so organizing the data by theme may be a limitation to discovery.

Canadian Aboriginal Land Use Geospatial UNA (2008)

This UNA explored the spatial data requirements for indigenous peoples in Canada. Information regarding geospatial data use was summarized and analyzed from ten land use plans (Makivik 2008b). Summaries were distributed back to the community contacts for review, and follow-up workshops were conducted. Participant inputs from the workshops were used to identify missing and needed datasets. Internet research and telephone inquiries sought to determine authoritative custodian information on each dataset. The analysis involved summarizing the frequencies of characteristics for the datasets.

Priority datasets were identified, with more than 95% of framework datasets coming from governmental sources, and 46% of thematic data coming from Aboriginal sources.

Items reviewed, with a brief synopsis include:

Data Property	Synopsis
Currency	Datasets require update on a yearly to 5-year cycle
Formats	Shapefile was the most frequently provided and requested. The infrequent use of web services was noted.
Access	Most non-community owned datasets were available for local download, and this was the preferred mechanism. A small proportion of data was provided as web services.
Confidentiality	Community-owned datasets such as Traditional Ecological Knowledge (TEK) and use and occupancy is highly confidential. These comprised 18 % of the datasets. Framework data was generally public information with few access restrictions; however, provincial and territorial datasets often required membership access, an information sharing request, or a usage fee.
Cost	Natural Resources Canada introduced no-fee access after most of the land-use plans were reviewed for this UNA. Thus, most framework datasets are now free to access. At the time of writing, many provincial datasets still required fees to access. Access fees were prohibitive for LiDAR, digital elevation models, and satellite imagery.
Metadata	Most framework datasets (94%) shipped with metadata. Only 12% of thematic datasets had metadata. Most community-based data did not have accompanying metadata. It was recommended that GeoConnections support organizations in meeting CGDI endorsed metadata standards.
Missing or inaccessible	78% of participants had issues accessing desired datasets. These largely either had access restrictions or were for purchase at significant cost. Other issues included incompatible formats, data size, and convoluted processes for obtaining access permission. Some desired datasets simply did not exist. Cost and security/confidentiality were noted as the largest barriers to access.

Colombian Spatial Data Infrastructure (2009)

This SDI was foreshadowed by Colombia's response to the Global SDI UNA (presented above). It is described in detail in GSDI 2009, and as a report[6] (DANE, IGAC, 2009) from Colombia's Department of Statistics (DANE) and its primary mapping agency (IGAC). This review is primarily based on GSDI 2009.

The SDI grew out of multiple Columbian agencies' production and use of spatial data, and presidential decrees to modernize systems. The National Development Plan for the period 2006 – 2010 sought to strengthen the use of spatial data while promoting the interchange of data between these agencies (23 in total).

The IGAC (the responding agency to the 1998 Global SDI UNA), took an early lead through development in 1995 of an Integrated GIS system specification which included: an integrated data model; a spatial database implementing the model; data exchange formats; and standards. The national oil company, ECOPETROL, was implementing geographic data standards and metadata around the same time. These initiatives led to the creation of a national committee for geographic standards.

As a result of the formation of the 1998 Inter-Institutional Committee, government GIS producers agreed to create joint policies, guidelines, and strategies. These included organizational strategies and roles for the Columbian Geographic Information System (ICDE) and to build the National Geographic Information Network. As such, the Columbian SDI combined direction from the executive level of government, initiatives by individual agencies, and policies developed through inter-agency meetings and consultation.

No formal UNA appears to have been conducted. Other issues included: no formal mandate existed, and no lead organization had been identified for the initiative; issues of privacy, access, use, pricing, and liability had not been addressed; and no cost-benefit study had been performed. GSDI 2009 recommended that the SDI seek *high-level government support* (through presidential decree or Ministerial Council Order for example) in order to succeed, noting that the efforts of individual government agencies alone would not suffice.

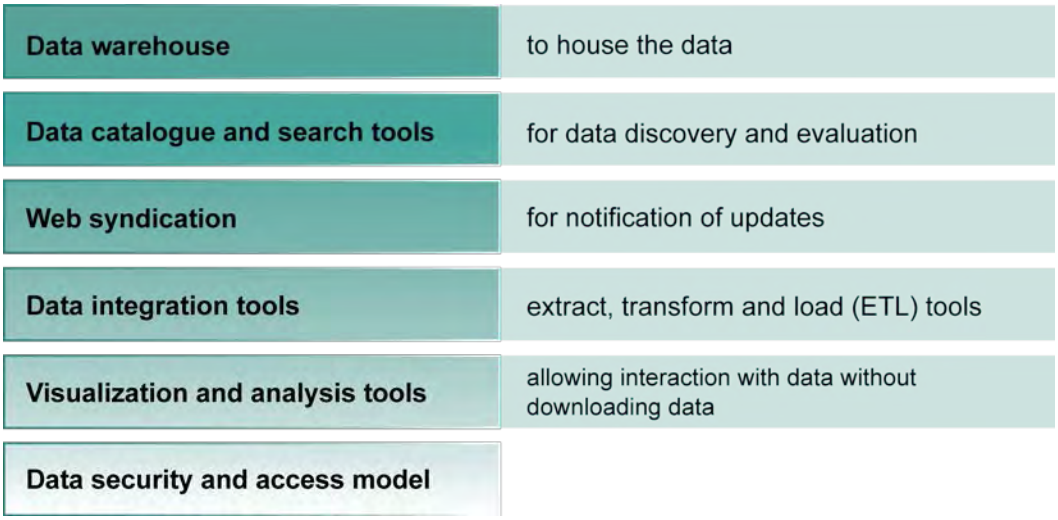
DataBC Concept of Operations (2012)

British Columbia (BC) has been a pioneer in Canada of making open data accessible and available to the public. While not a UNA, the concept of operations document provides the justification, goals and conceptual framework for the larger DataBC system, and the BC Geographic Warehouse, which contains its spatially enabled data (Ministry of Labour, Citizens' Services and Open Government 2012). Components of DataBC are presented in Figure 1.

BC desires to manage data as a strategic asset. It is of value to both the government and the public. Technology within government is seen as a future enabler, with automated processes assisting with continuity as staff retire. DataBC can have an integrating function, bringing public and government users closer to the data and each other. Several brief case studies are provided illustrating how data awareness and automation increases efficiencies and leads to additional opportunities.

[6] http://www.icde.org.co/sites/default/files/8.CONPES%203585%20de%202009_0.pdf

Figure 1 Components of DataBC and their purpose.



Major DataBC outcomes include:

- Licensing – minimal restrictions on access and use of data;
- Discovery – improved access through visual interfaces such as maps;
- IT automation – data management activities through IT infrastructure tools; and
- Community engagement – opportunities to submit and share data.

Stakeholder engagement efforts include promotion of the data portal, opportunities for the community to submit and share data, and code sharing and collaborative development initiatives such as the BC Developer's Exchange.

To leverage the utility of their service, DataBC believes data literacy must be promoted. Management of the asset through its entire lifecycle requires the maintenance of accuracy and lineage metadata and implementation of data governance policies.

Interface design efforts involve the adoption of the Open Knowledge foundation's CKAN open source tools. CKAN tools help with data website creation and include faceted search functions including previewing through maps, graphs, and tables. Select spatial portals using CKAN tools include:

Federal Government	Canadian Provinces	Large Cities
data.gc.ca (Canada)	open.alberta.ca (AB)	data.ottawa.ca (Ottawa)
data.gov (USA)	catalogue.data.gov.bc.ca (BC)	donnees.ville.montreal.qc.ca (Montreal)
data.gov.uk (UK)		datahub.cmap.illinois.gov (Chicago)
data.gov.au (Australia)		data.london.gov.uk (London, UK)

GeoNOVA (2014)

The GeoNOVA program was developed to respond to new opportunities for leveraging spatial data as a corporate asset across provincial departments in Nova Scotia (GeoNOVA 2014). 21 different departments and agencies were engaged as stakeholders in an advisory group to develop a strategy aligned with the provincial Technical and Information Management Strategy.

The program seeks to become an integrated single authoritative source for spatial data in Nova Scotia. Identified benefits include improved planning, decision making, and service delivery by enabling a government that effectively uses location-based information. The program promotes increase geomatics awareness across government.

GeoNOVA notes that millions of dollars have been spent on spatial data, but it is underutilized. Barriers that have been identified include lack of awareness, difficulty of access and limited user technical knowledge. GeoNOVA feels that with new technology, spatial data can now be easily placed in users' hands. Additionally, GeoNOVA wishes to bring spatial data to groups beyond traditional users.

The program identifies the need for strong governance mechanisms, and proposes a strong governance framework:

- Recognition of location-based holdings as a corporate-wide resource;
- Accountability and clear roles and responsibilities;
- Driven by business needs; and
- Sustained through regular evaluation and adjustments.

GeoNOVA strives for continuous progress through realistic target setting. A Provincial Location-Based Information Forum will draw insights from the business community and geomatics specialists. Pilot projects will be encouraged within departments, e.g., management of roads and bridges. Targeted training and awareness building activities will be performed, and a skills development program created.

The program is guided by a strategic council, including deputy ministers from several departments. Special working groups may also be formed for priority corporate tasks.

Data does not only come from the Province. For example, there are high-value municipal datasets. The program will be a single authoritative source by managing infrastructure, standards, technology, licensing and data discovery. Departments will act as data custodians, with a quality assurance program to monitor integrated systems.

GeoDiscover Alberta (2016)

Alberta Environment and Parks formed a steering committee and produced a strategy document based on feedback from clients and industry best practices. It will be the basis for Alberta's geospatial data infrastructure, promoting open design, quality data, and improved governance. Stakeholder ideas and requirements were gathered to guide a three-year strategy.

Spatial literacy and data accessibility were recognized as essential to increasing government effectiveness.

The listed stakeholders represent various provincial departments and cities and include both geomatics technical staff and managers. It is not clear how requirements gathering was done. The user interface employs the CKAN open data distribution system (see DataBC above).

City of Nanaimo Needs Assessment GIS Report (2017)

The City of Nanaimo seeks to update its Vision and Mission Statement to reflect a more holistic and enterprise-wide view. Guiding principles of the City's GIS units will influence the updates to seek improvements to efficiency and to increase value. The City identifies implementation of structures that will allow staff to maintain and use geospatial data and allow the general public to find and access data efficiently.

In a lengthy report, the City of Nanaimo identifies internal departments as users and details the spatial data needs of each. Lists of specific datasets are given including their source or likely source. Three user categories are identified: Flagship, Analytical, and Browser, including the primary spatial tools these users employ (e.g., desktop GIS, web application). A companion document outlines the conceptual design of the system.

GIS goals and objectives are identified at the enterprise-wide and individual departmental level. Individual needs are assessed by category (governance, data, software, training, processes, IT infrastructure), pervasiveness, estimated level of effort and cost, and how well they fit with organizational imperatives. Additionally, City engineering department staff conducted on-site interviews with departmental employees. A Strengths, Weaknesses, Opportunities, and Threats (SWOT) table was compiled to guide efforts towards improvements to the City's GIS.

Arctic SDI & INSPIRE Data Specifications Methodology

The Arctic SDI Geoportal is a tool for searching, visualizing, analyzing, and sharing distributed geographic information about the Arctic region (A-SDI 2017). It is one of the outcomes of the Arctic SDI initiative launched in 2014 by National Mapping Agencies of Norway, Sweden, Denmark, Finland, Iceland, Canada, Russia, and the United States. Recognizing the need to share and harmonize geospatial data for the Arctic regions worldwide, the Arctic SDI set out to define and achieve 6 strategic objectives (A-SDI 2015):

- Objective 1: User and Stakeholder Needs and Requirements
- Objective 2: Reference Datasets
- Objective 3: Thematic Datasets
- Objective 4: Data and Technical Interoperability
- Objective 5: Spatial Operational Policies
- Objective 6: Communications

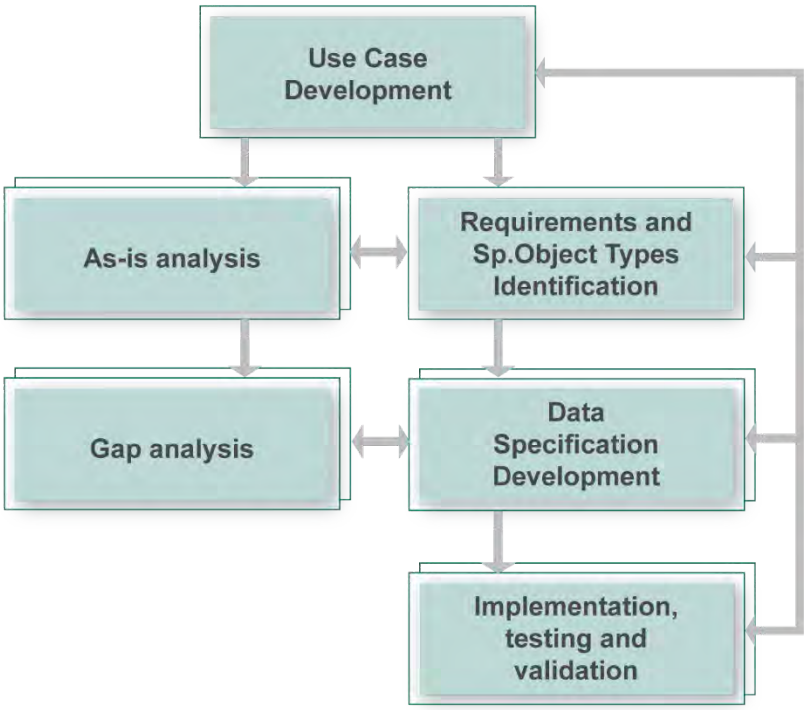
Strategic objective 1 (User Needs and Requirements) is focused on understanding the needs and role in the Arctic SDI of relevant stakeholders and on the evaluation and prioritization of available, relevant datasets and services for inclusion into the Arctic SDI. (A-SDI 2015b). For that purpose, the UNA follows a process of (1) developing questions to be used to document user needs, (2) capturing these needs from various stakeholders (including, but not limited to, Arctic Council Working Groups), and (3) analyzing and prioritization of the user requirements. This process is ongoing, iteratively, and will likely be an ongoing process for the foreseeable future, to continue adding or improving new features as needs, technologies, and priorities evolve in time.

The build-up of the Arctic SDI geoportal is ongoing in parallel with the UNA process outlined above. The development of the core infrastructure of the platform is based on existing open source tools (Oskari open source software), on which map layers are added. The data underlying the map visualizations are provided by each of the National Mapping Agencies involved in the Arctic SDI initiatives.

The Arctic SDI (GeoConnections 2017) seeks to build on foundational work from the Geographic Information Technology project in the Barents region (GIT Barents). This project integrated data from Finland, Norway, Russia and Sweden and provided it through internet-based infrastructure complying with the EU INSPIRE Directive.

The INSPIRE Methodology for the Development of Data Specifications (INSPIRE 2007) formalizes a process for creating data specifications that meet user requirements, including the identification of gaps. The INSPIRE approach first models user requirements conceptually, then creates formalized specifications at the implementation level (Figure 2). Steps are not necessarily sequential but involve rapid feedback in an iterative manner.

Figure 2 INSPIRE methodology for data specification meeting user requirements.



While this model specifically addresses data, it is conceptually valuable for the SDI as a whole. Identification of implementation gaps helps with continual improvement and fits with ongoing measuring and monitoring efforts. These efforts assess (GeoConnections 2017):

- Achievement of objectives;
- Efficiency of operation;
- Positive effects on the community; and
- Required improvements.

An independent review of the Arctic SDI Geoportal is conducted in a separate report "*Environmental Scan on User Needs Assessment for the International Arctic Spatial Data Infrastructure*" (Hatfield 2018). The objective of the Arctic SDI UCD review was to establish what the Arctic SDI Geoportal does well, and what it does not do well, and establish the implication of both for design considerations that could be relevant to the CGDI.

3.3 UNA LESSONS-LEARNED AND EMERGING TRENDS IN INFORMATION TECHNOLOGY

Open Data

The Government of Canada is committed to the concept of Open Data[7]. Open Data is seen as supporting innovation and development of consumer and commercial products based on public sector information. DataBC (2012) describes data as a *non-rival* good, whereby the use by one party does not diminish the asset for use by others. A resultant goal is that data should be deployed and utilized as widely as possible – management of the asset is not an issue of fair allocation between users, as with traditional assets.

Under the framework of open access standards, open data can be repackaged, transformed and distributed widely through production of custom applications. For example, DataBC provides the BC Developer's Exchange. Another example is Google Maps consuming civic transit data to allow trip planning with a smartphone (DataBC 2012). These are cases where the SDI has drawn previously untapped, unidentified end-users. Early efforts at understanding SDI users included not only government departments and academia, but *citizens* and *businesses* as end-users (e.g., GSDI 1998). Application development of this kind also supports community engagement and the potential for a marketplace linking suppliers, developers and service providers, and end-users.

Makivik 2008b surveyed geospatial data needs within Aboriginal Communities for Natural Resources Canada. End-users identified the cost of data as an impediment to access of high-value datasets, including satellite imagery, and provincial government datasets. Respondents appeared to desire access to the data but were not interested in advanced data delivery or value-added services. They appeared to want a data warehouse, not an SDI. Responses within this user community be a microcosm for perceptions at that time.

The situation has evolved since this UNA was completed, most notably in terms of data access and costs. The preference for local download of datasets could be an advocacy/education issue, especially if still prevalent today. Modern paradigms such as cloud-based infrastructure (Data as a Service, cloud-computing, etc.), coupled with cheaper high-speed internet access, may alter user preferences (even in remote communities). Ingestion of web services or access online through a web GIS portal is especially useful for very large datasets, such as satellite imagery.

Costs have also changed since 2008. For example, most provincial spatial datasets within BC are now provided as open data through DataBC, with GeoDiscover Alberta appearing to be following this example. Additionally, satellite imagery has undergone significant change with the opening of the historic Landsat archive (available since January 2009) and all new Landsat imagery, and the growing collection of European Sentinel series satellite imagery being offered as open data. Landsat-8 (Launched February 2013) has a 15 m panchromatic band, which doubles the resolution available in 2008, and Sentinel-2 (the first of two satellites, launched June 2015) provides 10 m multi-band (including true colour) imagery. Also, medium-resolution commercial imagery in the 5 m range has become very cost effective.

[7] Cf. https://open.canada.ca/en/open-data-principles

Growth in Potential End-Users

The prior GeoConnections UNA (2006) sought information on both *current* and *potential* users; however, these groups were drawn from existing users of geographic information. A qualitative scan identified user groups, and consultation was done to gain quantifiable insight into the needs of these groups through survey and interview. This is a sound approach; however, it could be argued that today citizens, in general, are important users of geospatial information – i.e., non-professional users are regularly consuming geographic information. While the needs of professional and general public users are different, there appears to be an opportunity to be more inclusive and extend the range and vision of what geographic information can provide as a common good. Entrepreneurial developers can bring geospatial information to a broader public through web and smartphone apps, for example

User Interface and Branding

Data discovery and access mechanisms are critical to opening spatial data to a larger public. Many SDI initiatives have embraced modern web-based discovery and delivery designs such as CKAN[8] (including open.canada.ca). The 2006 GeoConnections UNA recommended that GeoConnections redesign their portal to facilitate data discovery and that prominent page links be made from the CGDI website to the portal. Currently, the CGDI web pages contain a lengthy collection of policy documents, assessments, and background information, but do not provide a prominent link to a CGDI portal, or to the Open Government Portal (open.canada.ca). Consistent branding is also important, as potential users may be confused as to the relation between GeoConnections, CGDI, GeoGratis and the Open Government Portal.

Organizational Approach for SDI Development

GSDI (2009) provided background regarding typical development histories of SDIs. Individual projects at departmental levels often lead to a legacy of data. As more data is collected by more agencies, a critical point is reached where SDI becomes an obvious solution. The Columbian SDI (2009) was an excellent example, where some 23 different agencies sought to integrate data. In Canada, GeoNova (2013) appears to have followed a similar path. In both cases, no stand-alone UNA appears to have been performed, with goal setting coming out of working group and committee activities. User needs can additionally be addressed through ongoing measuring and monitoring efforts. In the Columbian case, there was a strong recommendation that the SDI seek high-level governmental support (i.e., at the ministerial level or higher) to ensure ongoing success. GeoNOVA, by contrast, is guided by an oversight group composed of deputy ministers from various stakeholder departments.

Innovations Superclusters

Canada's Innovations Supercluster Initiative aims to spark business-led innovation to build world-leading innovation ecosystems, secure Canada's future as an innovation leader, and accelerate economic growth. Superclusters in this context are very dense associations of business, academic and research entities that foster collaboration to provide competitive advantages. The Innovations Supercluster Initiative is being led

[8] https://ckan.org

by Innovation, Science and Economic Development Canada through matching funding with industry. Applications from industry consortia are made to secure these matching funds through a formal process[9].

The Digital Technology Supercluster[10] was awarded to a British Columbia consortium in February 2018 and will share part of $950 million in federal funding, with the addition of over $500 million committed by private industry[11]. This supercluster will focus on big data, employing advanced cloud computing, machine learning, and visualization technologies. The needs of the natural resources sector are identified as one of three service areas the supercluster will address.

The Digital Technology Supercluster will respond to the critical nature of data as a strategic resource. It is recognized that the Canadian economy must adapt to increasing volume and complexity of data to create value – the Digital Technology Supercluster will address the increasing importance of data by providing cutting-edge tools and resources to Canadian businesses while attracting research and talent through a focus on business expenditures on research and development. The Digital Technology Supercluster initiative will have a core of over 500 members and associates from export-oriented firms, supporting creation of cross-cutting collaboration and industry solutions[12].

The Digital Technology Supercluster will provide a Data Commons in which participants can exchange and discover high-value digital assets. One project already identified for the Digital Technology Supercluster that will contribute to the Commons is the Earth Data Store. This project seeks to "twin" 85% of the world's landmass daily through extensive mining of Earth data. Amongst partners are Urthecast, who provide daily satellite image coverage of the entire globe, and D-Wave, who are pioneers in quantum computing development. Both are Canadian firms operating in the Vancouver area whose activities have global reach. Earth Data Store seeks to become a single source of geographic information to the resource sector and will provide advanced analytics and visualization tools to extract value from the enormous data repository it will host.

3.4 USER-CENTERED DESIGN APPROACHES AND TRENDS

In general terms, UCD in the context of geospatial data portals addresses all layers of a portal architecture. There are different ways to represent architectures of a geospatial data portal, but in generic terms, they all typically have four layers (Figure 3).

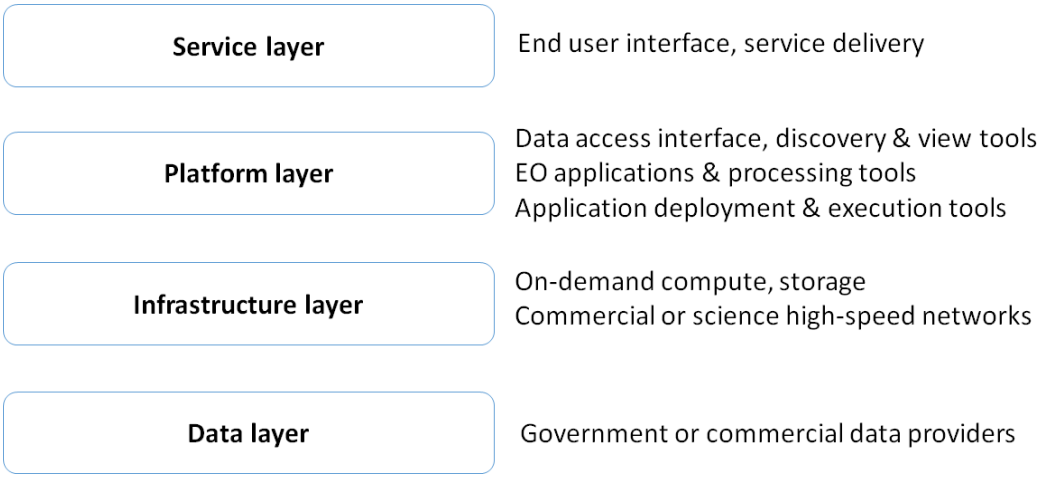
[9] https://www.ic.gc.ca/eic/site/093.nsf/eng/00003.html

[10] See https://www.digitalsupercluster.ca

[11] See https://news.gov.bc.ca/releases/2018JTT0006-000212

[12] See https://www.digitalsupercluster.ca/wp-content/uploads/2018/02/FAQs-Canadas-Digital-Technology-Supercluster.pdf

Figure 3 Architectural Layers of a geospatial data portal.



- **Service layer**: This delivers EO-derived products or services to end-users, offered by geospatial information service providers building on the capabilities of the lower layers;
- **Platform layer**: this layer delivers software tools for geospatial data access and analytics and integration of multiple geospatial datasets, for the production of value-added information that supports the delivery of services to end-users. This includes, for example, data services (e.g., ingestion, catalogue, discovery, dissemination) and processing services (e.g., standard libraries, toolkits, orchestration, workflow, analytics);
- **Infrastructure layer**: this provides the Information and Communication Technology (ICT) necessary to store, compute and disseminate geospatial data and products; and
- **Data layer**: this layer encompasses the provision of the geospatial datasets of interest.

While UCD methodologies are sometimes associated only (or mostly) to the 'service layer' in terms of user interface or user experience (e.g., the web user interface of a geoportal), in fact UCDs must consider the entirety of the geoportal architectural elements, and a successful user-centric implementation of a geospatial portal will need to address all four layers outlined above. Referring to those layers, below are some examples of how UCD methodologies consider the design of each element of a geoportal:

- A UCD-oriented design of the infrastructure layer will consider user needs and constraints related to data storage, computer resource needs, scalability, security, privacy, or cost. These user needs and constraints will be key considerations in design aspects associated with IT architecture (e.g., in-house servers, cloud services) and security architecture. The trend now is for IT infrastructure to be considered as an external commodity, and many geoportals benefit from public clouds (commercial offering or government-funded infrastructure).

- UCD considerations for the data layer deal with questions such as data confidentiality and standardization. Regarding data confidentiality, while there is a general trend (with government-funded programs) towards open data policies, segregation of data and data access restrictions still often exist in geoportals to respond to needs of commercial stakeholders or to public sector strategic or sovereignty requirements. These user needs typically have a significant impact on the design and architecture of the data layer. Regarding standardization, there is a clear consensus that standards for data, metadata, and geospatial web services, to name a few, must be a central consideration in the design of any geoportal. With a general trend towards the combination of multiple data sources for the extraction of meaning and the generation of value to end-users, data quality and traceability also becomes a standardization issue.

- The platform layer is perhaps the area where there is the most variability in terms of user-centric designs. Depending on the targeted users, UCDs for data access and management, or for software tools for analytics, workflow support, data presentation, will vary significantly. The next section presents a summary of the main trends in UCDs for the platform layer.

- UCD approaches for the service layer are the most intuitive and perhaps the most developed, as they deal in large part with data presentation, interface usability, user experience, for which design methodologies are well developed in the software industry (e.g., use cases, personas, wireframes, stakeholder interviews, storyboards, etc.).

To support their target communities and fulfill their initial requirements, SDI must follow UCD-related requirements, which can be broadly classified into two categories:

- User's expectations of the SDI's functional capabilities; and

- User's expectations of non-functional aspects relating mainly to the SDI's usability, such as performance, security and reliability, i.e., the Quality of Service.

The following sections address some of the main design trends for geoportals, driven by common UCD requirements falling into one or both categories.

New Data Access Paradigms: Big Data, Open Data Cube, and Analysis Ready Data (ARD)

Earth Observation (EO) instruments are increasingly complex and capable of collecting new types of data in ever-growing volumes. EO data supply is likely to dramatically increase in the coming years, due to publicly funded programs such as Copernicus in Europe or Radar Constellation Mission (RCM) in Canada, but also due to commercial initiatives: several constellations exist or are planned which offer higher resolutions, higher revisit rates, and lower costs compared to previous generations of EO satellites. Examples include Sentinels 1, 2 & 3 (two spacecraft each), Planet, DigitalGlobe, Airbus-DS EO constellation, NorthStar system, and many others. In addition, numerous government-funded networks for in-situ data collection and many initiatives collecting regional & local data using UAVs, also contribute to the massive increase in geospatial data.

UCD designs for current and future geoportals that aim to leverage these massive datasets must consider user concerns for data access, data preparation (pre-processing), and data analytics in support of end-user applications. Common concerns that users of geoportals have include:

- As much as possible, and to the extent that it satisfies user requirements, access to free and open EO data and to processing algorithms;
- Consistent architectures that allow sharing of data, code, tools, and algorithms;
- Access to specialized knowledge required to access and prepare satellite data;
- Efficient time series analytics to support land change applications;
- Combination of multiple datasets, which itself calls for data interoperability and complementarity; and
- Solutions that reduce dependency on commercial suppliers ('vendor lock-in' situation).

For example, one of the solutions that aim to address these UCD requirements is the Open Data Cube (ODC) initiative, which seeks to provide a data architecture solution that has value to its global users and increases the impact of EO satellite data. It is promoted currently by the Committee on Earth Observation Satellites (CEOS). The Open Data Cube architecture framework is 100% free, open and available to everyone. A data cube refers to a four-dimensional (space and time) range of values that are generally used to explain the time sequence of an image's data. It is a data abstraction to evaluate aggregated data from a variety of viewpoints. It allows the storage of any dataset in a database, derived product and time series analysis output. One of the advantages of a data cube is the standardized data infrastructure which removes the need for difficult and time-consuming pre-processing of the data for individual applications.

The Open Data Cube (ODC) initiative is one possible implementation of a data cube. It provides a data architecture solution that lowers the technical barriers for users to exploit EO data and addresses issues of data accessibility and usage.

As part of the ODC initiative, there is a strong push for the generation and standardization of Analysis Ready Data (ARD). CEOS defines ARD as "satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis without additional user effort". ARD products typically come with the following requirements: (1) metadata description; (2) radiometric calibration; (3) geometric calibration; (4a) solar and atmospheric calibrations (for optical sensors) or (4b) speckle filtering (for radar sensors). ARD data lower the barrier to data access, facilitate data preparation, and offer analytics in support of the implementation of user applications. Systematic and regular provision of ARD will significantly reduce the burden on EO data users.

The use of Open Data Cube initiative, in conjunction with ARD data and Big data analysis platforms in future SDIs, will increase visibility and usability of future portals and will provide users with a much-needed tool and extract value from the existent datasets. ODCs can scale with increases in data supplies and can offer in parallel the needed tools and technologies to mine and preserve these massive datasets. Consequently, the need to capture metadata is also becoming essential. Growing groups are focusing on making machine-readable metadata, so that search engines can utilize machine learning systems.

Cloud Computing

Historically, data providers and value-added service providers have relied on proprietary data storage and computing solutions, which have led to an inefficient and costly use of computing resources. Indeed, this is still the case for many geoportals in operations today. With the increasing availability of affordable cloud-based ICT resources offered as a commodity, more and more data providers and value-added service providers are now migrating to cloud architectures to serve their clients. The past, inefficient way of moving large amounts of data to processing infrastructures and to the user, is now replaced by an inverse trend in which users access and process data in the cloud. This trend responds to a UCD requirement to allow wider access to adequate IT infrastructure at an affordable price.

Cloud computing is used when applications, services, and datasets are no longer located on individuals' computers, but distributed over remote facilities operated by third-party providers (e.g., AWS, Azure, Google). In cloud environments, users can allocate computational resources without requiring human interaction with a resource provider (on-demand self-service). Examples of such resources include storage, processing, memory, network bandwidth, and virtual machines.

These resources and their capabilities are available over the network via standard mechanisms and simple web service interfaces. The providers of resources (physical and virtual resources) have to cope with multiple users and their dynamically changing demands. From the user's perspective, the availability of resources in the Cloud often appears to be unlimited.

For SDIs, the adoption of cloud computing allows organizations and governments to better plan their SDI infrastructures; for example, a project can start small with 1 or 2 servers and with a limited storage capacity and grow on demand, provided the overall architecture of the SDI allows this scalability. Cloud resources can also grow on demand more dynamically, e.g., to keep good performance during IT resources demand peak times.

Cloud computing helps mitigate usual issues with SDI users related to performance, availability, or reliability, since everything can be fully backed up and automatically deployed. The main benefits of cloud computing are simplified deployment and maintenance of SDI services and reduced costs of providing content and applications with a high quality of service.

User-Centered Design Impacts of Open Data

The policies around open data policies in Europe, US and Canada means that users are expecting the access to data via the traditional data download and access to data via web map services (WMS, WMTS, WCS). In Canada, USA, Australia and elsewhere, government organizations are in various stages of implementing geospatial platforms, with a general trend towards open access. SDIs are expected to deliver and comply with standards around open data. The Open Geospatial Consortium (OGC) is the foremost provider of open geospatial standards. It has a wide membership and has defined many standards. However, some of the OGC standards (e.g., for catalogues) are not regarded as being good enough, are too ambiguous and, as with many standardization bodies, the standardization process is rather slow. Therefore, other standards (de facto or de jure) might have to be used and it is unclear which standards will emerge as the main ones in use. This is not likely to be clear for several years. Whatever technical

solutions are developing for SDIs, constant monitoring of how standardization evolves is necessary, to keep providing relevant tools to the geo-industry.

3.5 INDIGENOUS COMMUNITIES AND SPATIAL

Research and documenting current use of and future needs for geospatial data in Indigenous communities in Canada has been sporadic. Work has been done in this context, but much documentation focuses on specific projects, mandates, or concerns for Indigenous groups. This section provides an overview of the key needs for geospatial data in Indigenous communities. Further detail is provided in "Part B – *Indigenous Communities and Spatial Data"* of the "Canadian Geospatial Data Infrastructure (CGDI) User Needs Assessment" report.

The most thorough study directly focused on geospatial data user needs of Indigenous communities/organizations in Canada is the Makivik (2008a; 2008b; 2008c) assessment of Aboriginal geospatial data needs for land and resource management. This sampled land use plans from ten Métis, Inuit, and First Nations communities from Atlantic, eastern, central, western and northern Canada. The project aimed to determine key geospatial datasets required and determine closest-to-source custodians for these.

In addition to recording data priorities among the communities, the project team also documented a set of broader topics related to geospatial data use in the study communities. Topics important to the understanding Indigenous use of geospatial data and CGDI are summarized in Table 1.

Table 1 Topics important to understanding Indigenous use of geospatial data and CGDI.

Topic	Summary of Past Needs Assessment Findings
Geomatics Capacity	Most communities did not maintain internal geomatics capacity because of difficulties putting in place long-term committed funding, training and retaining staff. The report found a heavy reliance on outside expertise.
Use of Web-Based Mapping	Internet technologies such as WMS and WFS were not being used, nor did communities report any need or desire to use these. This was thought to be a result of lack of access to reliable high-speed Internet and limited fluency with computer-based applications.
Locating and Downloading Geospatial Data	Only about half of participants had working knowledge of data discovery portals. Those who did found it difficult to locate and download the data they needed.
Access to Data	Communities reported that up-to-date information from government and industry on resource development was difficult to obtain on a routine basis.
Data Confidentiality and Protocols	Communities were hesitant to release data in absence of information sharing agreements, consultation protocol agreements, and agreements on intellectual property rights.
Cultural Data Inventories	All communities relied heavily on cultural data to inform land use decision-making. Participants indicated the cost of collecting and maintaining the data was high. The report noted wide discrepancies in approaches in methodologies used for the research resulted in studies having differing value for resource management.

Topic	Summary of Past Needs Assessment Findings
Satellite Imagery	Satellite imagery was desired by a number of participants to depict and understand changes in land cover, but was not widely used because of cost and because most groups did not have the technical capacity to analyze raw imagery to identify changes.
Data Format and Standards	ESRI software was used by all participants, and thus shapefile and other ESRI file formats were preferred. [CIER reported similar findings of preferred software platforms in surveyed Indigenous communities (2010).]
Frequency of Updates (Data Currency)	The study found that most of the datasets had not been updated on a regular basis, especially in the communities where GIS capacity is an issue.
Limited bandwidth capacity	Bandwidth limitations represent a real issue and were identified as a barrier to accessing existing geospatial data.

Managing and making decisions about land and marine areas is a core function for many Indigenous communities across Canada. At the same time, Indigenous organizations have other mandates that will or may benefit from geospatial data such as the duty to consult, commercial participation in the resource sector, and education. Other activities for Indigenous organizations that may benefit from geospatial data include Indigenous-owned business participation in resource development, fisheries, and forestry. For instance, Indigenous participation in the east coast fisheries has grown substantially since the Marshall decisions of 1999, and First Nations desire growth in their role and decision-making capacity in fisheries management (APCFNCS 1999). The geographic data needs for such activities and roles are likely to be very similar to non-Indigenous organizations, but discovering, accessing, and using data may present challenges that could be addressed using CGDI.

One key emerging mandate for Indigenous communities is anticipating and planning for climate change impacts. Some observations on geospatial data and technology needs associated with this are:

- Monitoring and surveillance of land and marine ecological conditions;
- Utility of information for climate change prediction;
- Predicting and mitigating climate change impacts-northern communities; and
- Predicting and mitigating climate change-east and west coast communities.

Lastly, there has been increasing attention paid to using Indigenous Traditional Knowledge as a complement to scientific knowledge.

4.0 USER PROFILES

Five user profiles are identified by GeoConnections (2007), namely suppliers, developers, marketers, enablers, and end-users (Figure 4). Important stakeholders for SDI can belong to any or more than one of these categories.

Figure 4 User Categories.

For this study, a simpler grouping of users was applied in the following three user types:

- **Publishers** act as curators of geospatial data of specific interest to their constituency and can develop and share geospatial content and tools within their mandate. They have the right to share geospatial data within their organizations, or among a group of organizations, or with the public, or a combination thereof. The method of publishing data varies and may include the development of web applications.
- **Enablers/Facilitators** encompass organizations providing frameworks that promote or facilitate the wide utilisation of geospatial information by user groups. Such frameworks may be of technical nature (e.g., a web-based application that enables users to access geospatial information), of regulatory nature (e.g., guidelines on geospatial data standardisation, or open data policies), of administrative nature (e.g., acting as a moderator of users, or as manager of user privileges), or of financial nature (e.g., provision of funding to support the development or use of geospatial information).
- **End-users** utilize geospatial data in decision making or in business and rely on applications to produce usable outputs. For example, end-users for soil information could include farmers, gardeners, researchers, scientists, municipal government officials, and staff responsible for preparing soil reports.

Users are also defined in broad categories based on their type of organization. All types of users will not be present in all types of organizations. The following organization types are defined:

- **Government** – all levels of government, with potential differences due to resource and capacity (e.g., Federal department compared to a medium-sized municipality). Government is a major supplier, developer, marketer, and enabler of geospatial data users. All levels of government are major users of geospatial data and applications.

- **Academic institutions** – mainly researchers that require access to spatial data to address research questions. A research objective may be to share spatial data that is the output of research.
- **Private Sector** – companies require access to spatial data to provide services to government or other private sector clients in economic sectors such as forestry, mining, tourism, and oil & gas. A business objective may be to share spatial data with customers, clients, and regulators.
- **Non-government organizations** – require access to spatial data based on their mandate, for example in conservation or public health. An objective may be to share spatial data with the public, businesses, Indigenous communities, or government.

Table 2 to Table 5 provide examples of user types and user categories based on the professional judgment of the research team. The allocation of users to different categories is not definitive and is designed to be illustrative of the complex range of users of the CGDI.

Table 2 Example government CGDI user types.

Example	Publisher	Enabler/Facilitator	End-user
NRCan – CCMEO	✓	✓	✓
Canadian Space Agency	✓	✓	-
Environment and Climate Change Canada	✓	-	✓
Fisheries and Oceans	✓	-	✓
National Defence and the Canadian Armed Forces	-	-	✓
Statistics Canada	-	✓	✓
Agriculture and Agri-Food Canada	✓	✓	✓
Elections Canada	✓	-	✓
Public Safety Canada	-	-	✓

Table 3 Provinces and Territories CGDI user types.

Example	Publisher	Enabler/Facilitator	End-user
GeoDiscover Alberta, Alberta Open Government, GeoBC, Manitoba Land Initiative, GeoNB, Newfoundland and Labrador Open Data, Northwest Territories Centre for Geomatics, NWT Discovery Portal, GeoNova, Canada-Nunavut Geoscience Office, Land Information Ontario, Ontario Open Data, PEI GIS Data Layers, Québec géographique, Données ouvertes, GIS Saskatchewan, Geomatics Yukon	✓	✓	-
Provincial and Territorial sectoral ministries,	✓	✓	✓
Municipal government engineering departments	✓		✓
Municipal government planning and services departments			✓

Table 4 Academic institutions CGDI user types.

Example	Supplier/Developers	Enabler/Facilitator	End-user
Researchers requiring authoritative geospatial data (e.g., census, physical environment)	-	-	✓
Researchers using and generating geospatial data	✓	-	✓

Table 5 Private sector and non-government organization CGDI user types.

Example	Supplier/Developers	Enabler/Facilitator	End-user
MDA, Urthecast, Planet	✓	✓	✓
Environmental engineers, social science consultants, planning consultants, Ducks Unlimited, WWF Canada, Sierra Club	✓		✓

The following boxes provide an overview, persona, and scenario descriptions for potential user groups and user types of the CGDI. These overviews are based on desktop research and do not reflect the direct contribution of the user organizations.

Agriculture and Agri-Food Canada (AAFC) – Government supplier, enabler, and user

Overview – Agriculture and Agri-Food Canada (AAFC) works with farmers and food producers to support the growth and development of the agriculture and agri-food sector. AAFC policies, programs, research, and technology help farmers and food producers succeed in Canadian and global markets. Among its responsibilities, AAFC produces interactive agriculture-related maps, geospatial data, and tools, including annual crop inventory, agroclimate data, and soils of Canada

Persona – Expert level of knowledge on geospatial data standards and the CGDI. AAFC publishes data and information on areas of Canada related to agricultural resources, production, and climate. They consume data published by other government departments and have a high level of experience in sourcing, integrating, modelling, and producing data and information.

Scenario (story) – a researcher at AAFC publishes information on the impacts of drought across Canada monthly. The Canadian Drought Monitor (CDM) brings together AAFC's drought monitoring capabilities with data and expertise from external agencies to produce analysis and consolidation of multiple indices and indicators. An easily understood comprehensive national drought severity map and report is published each month following CGDI endorsed standards.

GeoBC – Provincial enabler

Overview – GeoBC produces and maintains a diverse roster of tools and applications that can be used to discover, view and manipulate spatial information.

Persona – Expert level of knowledge on geospatial data standards and the CGDI. GeoBC offers consultation services across natural resource sector agencies to create and manage geospatial information and products to help better manage natural resources in British Columbia.

Scenarios – based on a provincial mandate, GeoBC managers want to provide a single source of reliable information on B.C. Crown land legal interests and land status. It also wants to provide information on land and resource restrictions and reservations, and locations of private land. The Integrated Land & Resource Registry (ILRR) must consolidate tenures, rights, and interests electronically and output in a consistent and credible format following published standards.

Public health university research – end-user

Overview – University research department hosts researchers with expertise in geography and epidemiology. The institute addresses important research questions in spatial health analysis, infectious disease, and environmental change.

Persona – Experience using GIS software and completing geospatial analysis, but limited knowledge of spatial data infrastructure and the CGDI.

Scenarios – Researcher wishes to have access to information regarding available authoritative data on demographics, environment, climate, and scenarios of climate change. Once they have learned about the data, they want to be able to access and use the data with clear information on license, access, quality, and currency.

Forestry & landscape management university research – Role as supplier, enabler, and end-user (e.g., geoscientist, forest management.)

Overview – University research department hosts researchers with expertise in geography, forestry, remote sensing, and modelling. The institute addresses important research questions in sustainable resource management, assessing the impacts of forestry operations, human settlements, mining, and oil & gas development on ecosystem integrity, recovery, and biodiversity.

Persona – Expert level of knowledge on geospatial data integration, modelling, and development of integrated information to support vegetation and wildlife research. Develops products useful for other researchers but may not have the tools or experience to publish to the CGDI.

Scenarios – a forest scientist develops a geospatial product on landscape dynamics through "big data" processing of satellite image time series. Following rigorous evaluation of the product and peer-reviewed publication, there is an opportunity to share the product with Canadian users to address further questions and to address natural resource management challenges. The research wants information on the CGDI.

Planet commercial remote sensing – supplier/developer, enabler, and end-user

Overview – Planet designs, builds, and launches satellites, completes mission control, and processes and delivers imagery to users in several formats and delivery mechanisms.

Persona – Planet engineers have a high level of expertise in cloud computing, data management, web development and provide web applications and application programming interfaces to provide users with access to Planet's imagery and archive.

Scenarios – Planet is a commercial company and engineers want to ensure that Planet data are available following accepted standards to enable customers to access only the imagery and associated metadata needed for an application. Planet wishes to ensure that users can easily integrate imagery into tools and workflows.

Ducks Unlimited Canada, environmental NGO – end-user

Overview – Ducks Unlimited Canada conserves, restores and manages wetlands and grasslands to benefit waterfowl, wildlife, and people.

Persona – Most staff and volunteers are biologists and ecologists, with some internal expertise in geospatial data management and remote sensing analysis for wetland identification and classification.

Scenarios – Ducks Unlimited Canada wishes to plan activities in the conservation of wetlands and waterfowl habitat across Canada. This requires access to the best available information from different provinces and territories on the distribution of wetlands. To supplement existing data, Ducks Unlimited will use remote sensing to refine the inventory and classification of wetlands. Ducks Unlimited wishes to make the data available to the Canadian public to further support wetland conservation.

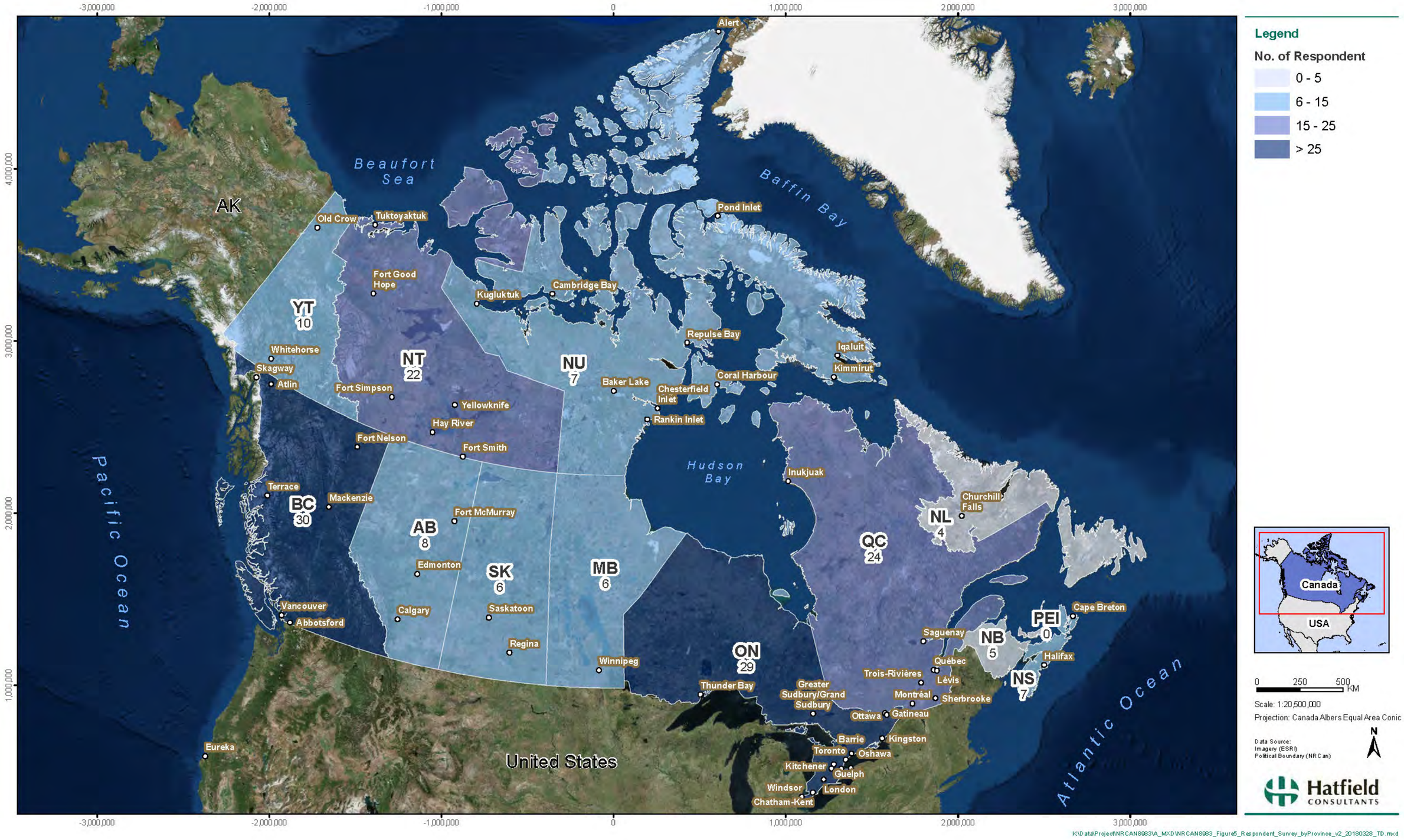
5.0 ANALYSIS OF SURVEY AND INTERVIEW RESULTS

The online survey was completed by 60 organizations/individuals across Canada. Further insights into user needs were garnered through semi-structured interviews with survey respondents. Some respondents only agreed to participate through the interview process. Due to the project's short timeline and small sample size, the results of the survey are not statistically representative. Nevertheless, there are many strong and consistent messages and themes that emerge from the online survey and the interviews and around which the discussion is organized: the profile and characteristics of users, their current knowledge and use of spatial data and technologies, key barriers and challenges, policies and governance around sharing of spatial data, and requirements for enhancing use of spatial data in the future.

Figure 5 presents a national map illustrating the number of combined (Part A and B) respondents to the online survey aggregated by province/territory. Overall, except for Prince Edward Island, all provinces and territories are represented, however as a result of the sample size insights into regional differences is not possible.

From the total of 60 survey respondents, the project team conducted semi-structured telephone interviews with 21 individuals. For the UCD, the project team contacted eight stakeholders involved in Arctic geoportals to request an interview with two completed interviews.

Figure 5 Combined (Part A and B) survey responses aggregated by province/territory.

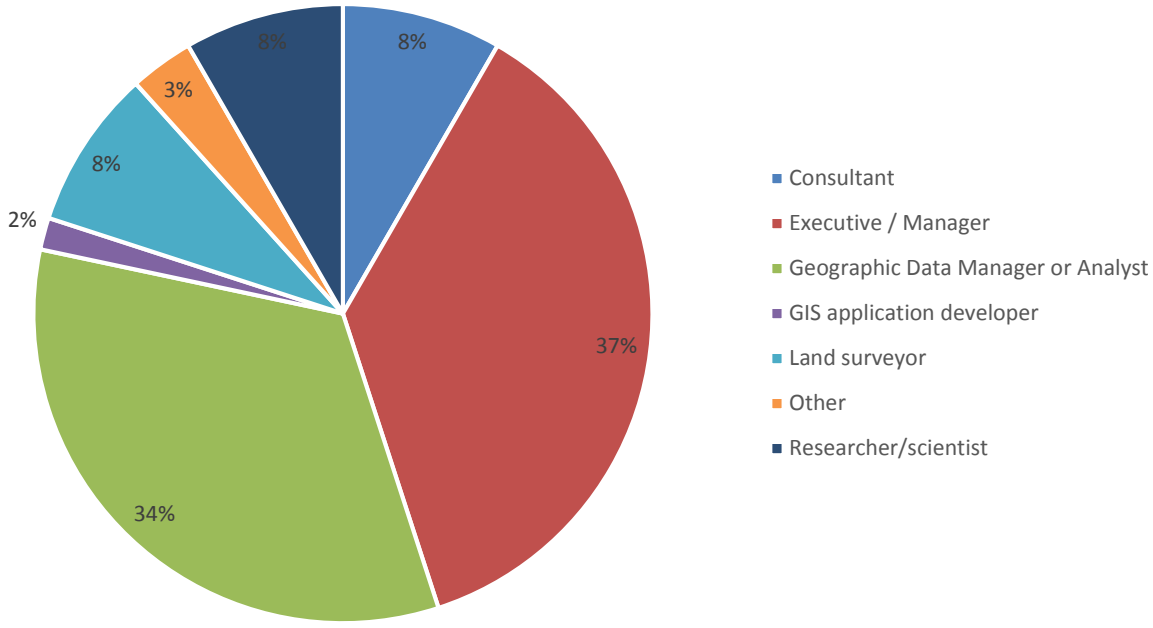


5.1 USERS AND USES OF SPATIAL DATA

Survey results indicate that a large majority of users (70%) are employed as either Executive / Manager, or Geographic Data Manager or Analyst, with responses close to evenly split (36% and 33%). Researcher / Scientist and Consultant were also evenly represented, with an additional equal number of responses indicating Land Surveyor (8% in each category) (Figure 6). Within these occupations, 54% of respondents worked for the federal or a provincial government with 34% working for an external or private company. A large majority (43%) of respondents fit the three roles of end-users, publishers / developers, and enablers, based on aggregation of answers to various survey questions.

Out of the 42 respondents listing their occupation as either Executive / Manager or Geographic Data Manager or Analyst, 27 respondents worked for the federal or a provincial government (64%), and 9 worked for an external or private company (21%). Representation from Academia was very small (4%).

Figure 6 Roles of respondents.



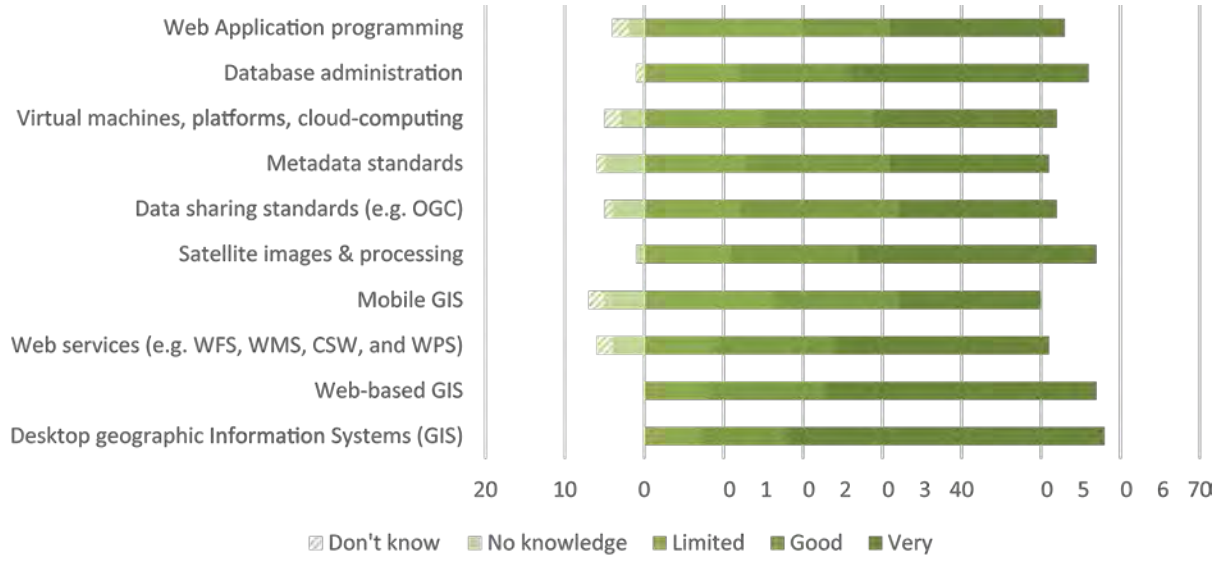
Regarding completed interviews, Table 6 summarizes the user profiles and user groups (see Section 4.0 for a definition of user groups). The numbers in the table indicate the number of times a certain combination of user profile / user group pair was encountered in the pool of interviewees. Note that in some cases one interviewee fit into more than one user profile / user group pair, so the overall total obtained by adding the numbers in the table below is higher than the number of people interviewed (21).

Table 6 User profiles and user groups interviewed.

		User Profiles		
		Publisher	Enabler/Facilitator	End-User
User Groups	Government	7	5	3
	Academia			1
	Private sector	2	1	3
	NGO	1	1	1

While desktop GIS is the most extensively employed geographic technology (69% of respondents), all the listed technologies are extensively used (nearly 50% or more of respondents across most categories). Mobile use, data sharing and metadata standards, web application programming, and virtual machines show noticeably lower use (between 32 and 40% for very extensive use); however, when combining extensive and very extensive use, these technologies are listed by 58 to 70% of users. For comparison, web services, database administration, satellite images and processing, web-based GIS and desktop GIS are listed by 74 to 88% of users (Figure 7). All users stated having some knowledge of desktop GIS, web-based GIS, and database administration, perhaps reflecting the relative maturity of these technologies. Respondents indicated limited knowledge of web application programming more frequently than for other technologies (35%).

Figure 7 Use of geospatial technologies.

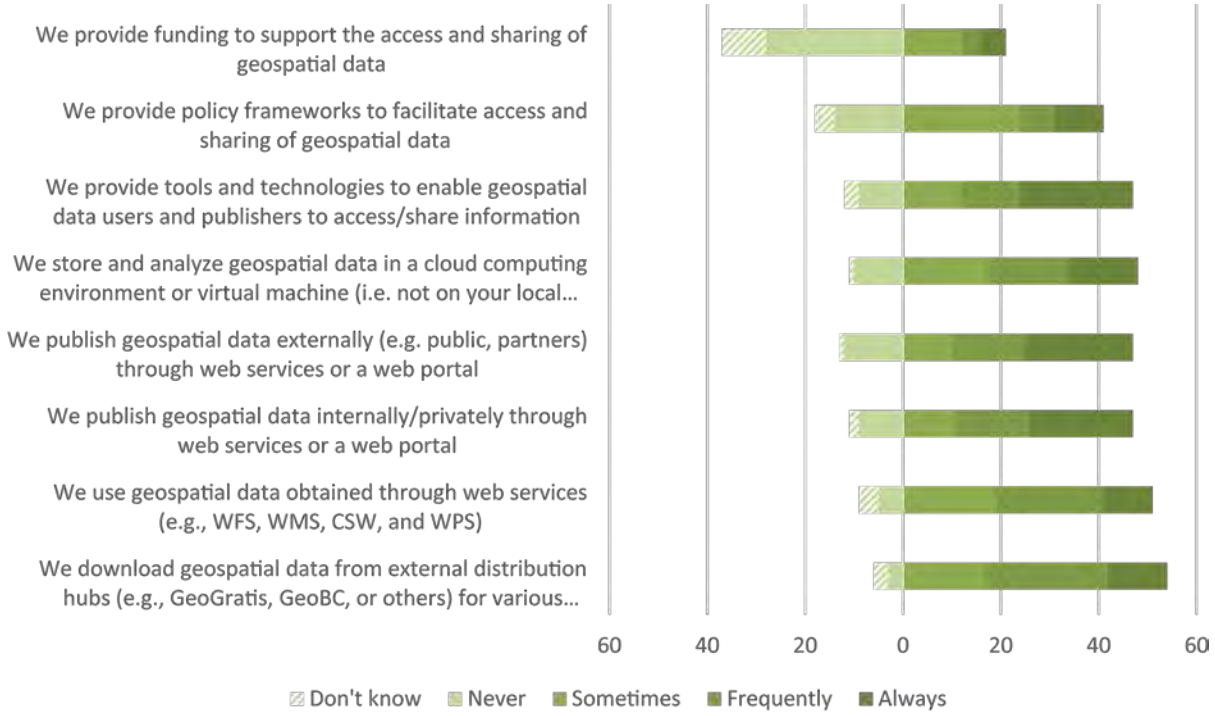


* Graphed on the Likert scale. X-axis is in counts of respondents, with the right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

90% of respondents report downloading geospatial data from external distribution hubs, with 62% reporting they do so frequently or always. Users provide tools or technology to access and share geospatial information to some degree (80%), with 59% of users listing frequently or always. 40% of users indicate they use web services never or sometimes, while 53% indicate using them frequently or always. Many

users (47%) indicate they never fund supporting access and sharing of geospatial data, while 15% indicate they don't know if they do so, and 36% stating they do sometimes or more frequently. All users report using external service providers of geospatial data and services, with 68% doing so sometimes and 24% doing so rarely (Figure 8).

Figure 8 Use of geospatial data.



* Graphed on the Likert scale. X-axis is in counts of respondents, with the right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

Land use planning data is used or shared to some extent more frequently than other datasets (96%) with security / sovereignty data being the least frequently used or shared (42%). 46% of users state they never use security / sovereignty data (Figure 9). Data supporting other activities listed on the survey were all generally listed as used or shared (44% or more stating use frequently or always used / shared for all types except culture / heritage and security /sovereignty).

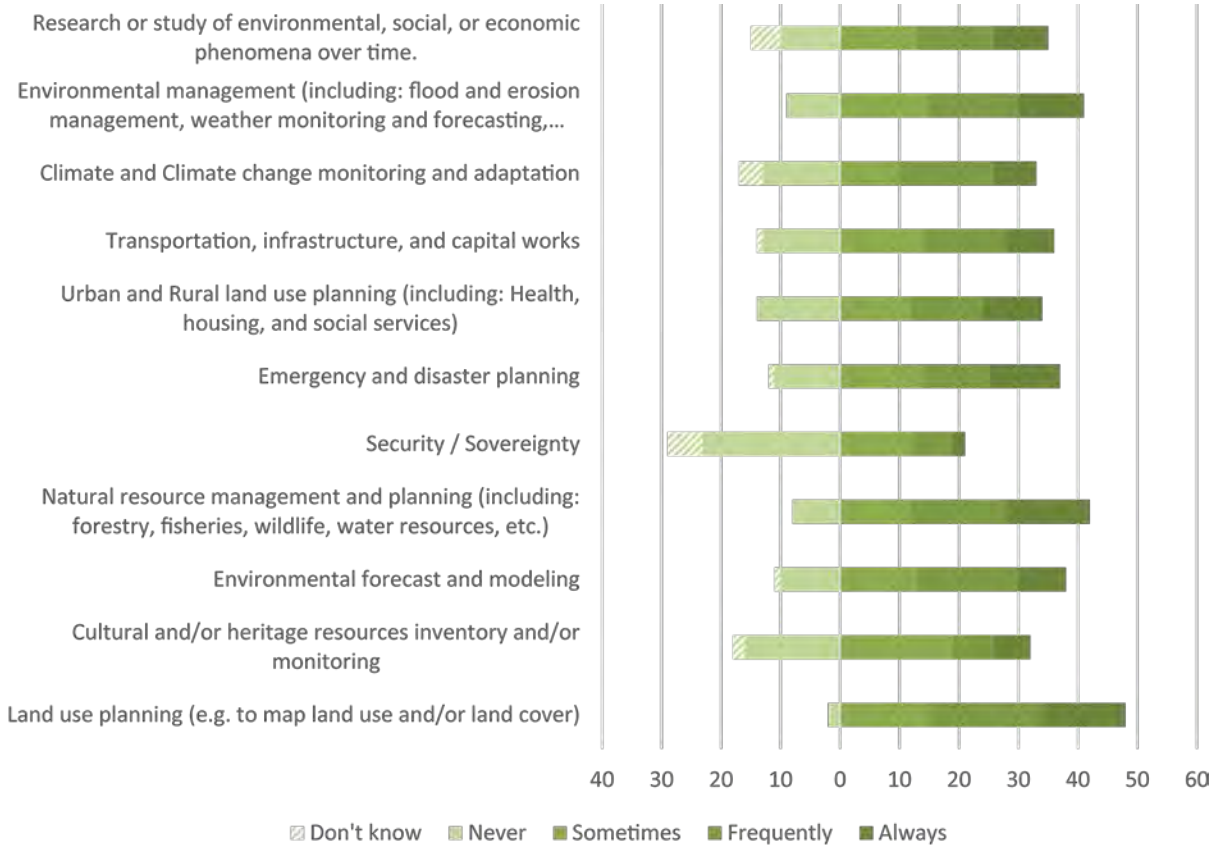
Importance of spatial data generally increases at a finer scale, with scales above 1:100,000 being not useful to 22% and somewhat useful to 31% of respondents (Figure 10). It is interesting that scales 1:5,000 to 1:50,000 and less than 1:5,000 had similar response numbers for being useful or very useful (82 and 84% respectively).

> Interviewees expressed a wide range of data usage which covered a broad range of applications, including surveying, construction, meteorology, emergency management, ocean and coastal mapping, vegetation land cover.
>
> Interview respondents

Geospatial data from other organizations is used frequently by 47% of respondents, while 37% always produce data for internal use. The most frequently listed activities never done are share or sell geospatial data or services, facilitate access to geospatial data or services, and develop geographic applications (20%, 18%, and 16% respectively). Interestingly, frequencies for always performing these same three activities are similar (25%, 25%, and 27% respectively), perhaps suggesting a bimodal split in the sample group based on primary producers and primary consumers of geospatial data and services.

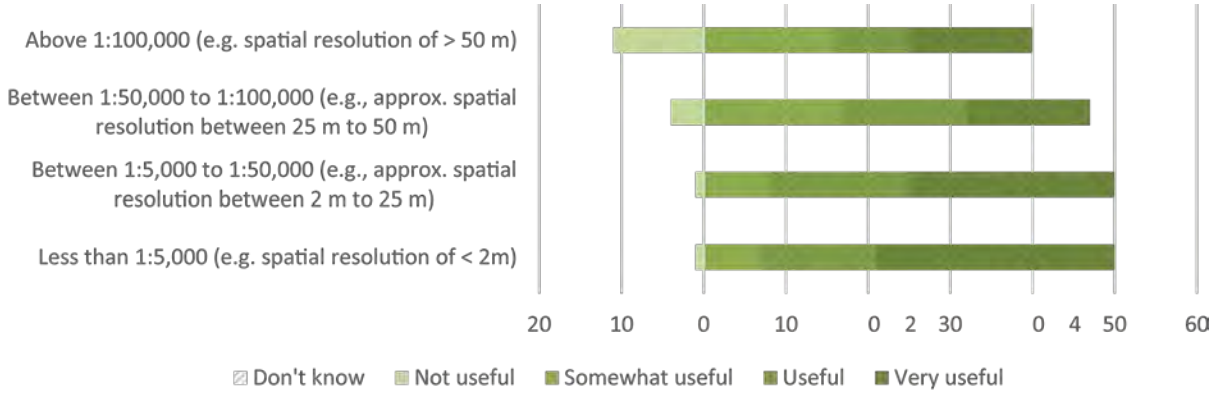
In terms of geospatial analysis activities, obtaining and processing regional scale data was listed as very important to 43%, and as important or very important to 88% of respondents (Figure 11). Daily or weekly tracking of change was listed as not important to 22% of users, and also had the lowest response for being important or very important (39%).

Figure 9 Activities where geospatial data is used.



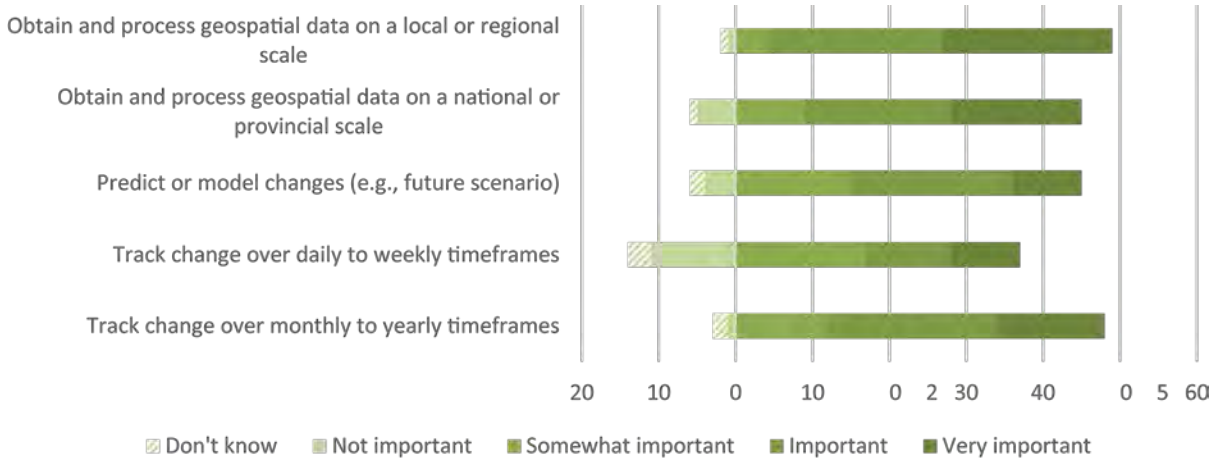
* Graphed on the Likert scale. X-axis is in counts of respondents, with right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

Figure 10 Different mapping scales.



* Graphed on the Likert scale. X-axis is in counts of respondents, with right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

Figure 11 Importance of different spatial analysis.



* Graphed on the Likert scale. X-axis is in counts of respondents, with right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

5.2 THEMATIC DATA REQUIREMENTS

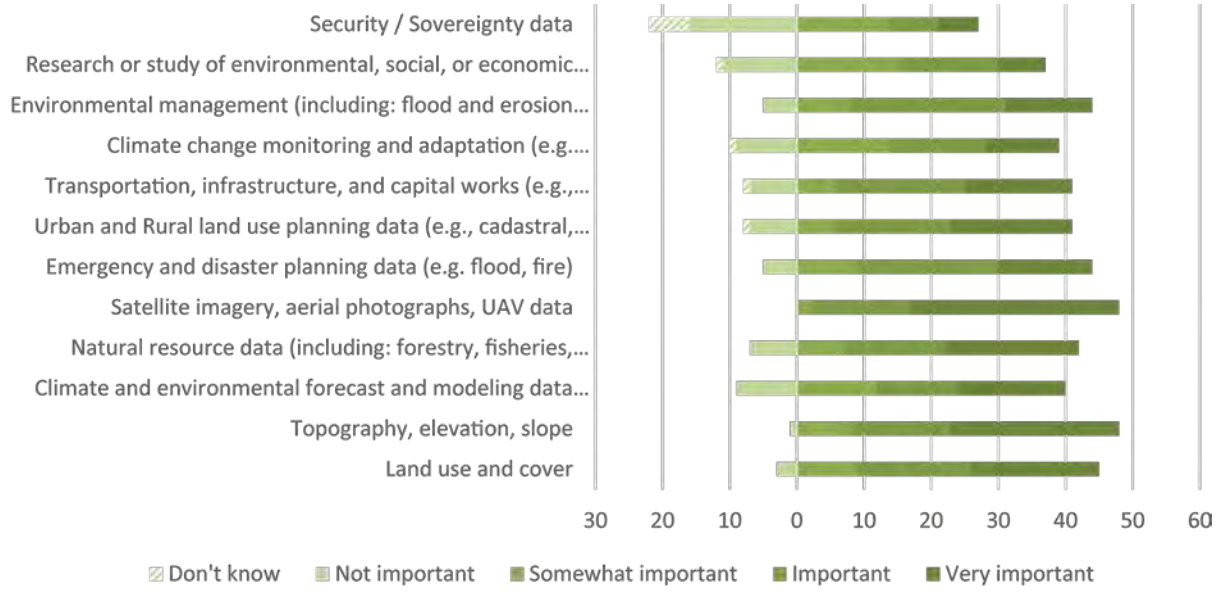
Satellite and aerial imagery was very important for 65% of respondents, with topographic products very important to 51%. Land use and cover was very important to only 40% of users but was important or very important to 75%. These are the most traditional raw and derived remote sensing products. These needs were validated by interviews, especially the need for satellite imagery and the ability to have access to derived data from available remote sensing datasets (e.g., NDVI, elevation). A common theme from interviews was the need to centralize all image datasets acquired by Federal and Provincial departments and make it accessible to all through a common location/map service.

Security and sovereignty data were less important with 33% saying it is not important and 60% saying it is not important or somewhat important. A fairly large number (16%) of respondents did not know if this data was important. 46% of users never use or share security and sovereignty data, while 42% use or share it in some way (sometimes or more frequently). Research or study of environment, social or economic data was also of low importance (not important to 22%, not important or somewhat important to 53%). 18% of respondents said climate and environmental forecast and climate change monitoring data was not important (Figure 12).

> "Federal and Provincial Governments acquire many image datasets, but these are not centralized in a common location/map service accessible to all."
>
> Interviewee response

It should be noted that these results may reflect the types of users in the survey more than the general population of spatial data users.

Figure 12 Importance of different geospatial datasets.



* Graphed on the Likert scale. X-axis is in counts of respondents, with right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

With regards to desired attributes of geospatial data and systems used, trustworthiness or quality of data was the most frequently listed by users (96%). That data be up to date or the most recent available was similarly valued (92% of users), while ease of search and discovery was also frequently listed (86% of users). Visual attractiveness of maps or user interface was relatively unimportant, only being listed by 39%

of users, while a visually intuitive interface was valued significantly more (57% of users). Each of the geospatial attributes in the survey was listed by more than half of users except visual attractiveness.

> "Government can also play a central role in better publicizing availability of open data and promoting mechanisms for exploiting them – including funding."
>
> Interviewee response

Users were mostly able to find metadata that permits evaluation of data fitness and quality. 92% of respondents stated that suitable metadata was available or sometimes available, with 49% stating it was sometimes available. Only 4% of respondents found such metadata to be unavailable. Users also state that they themselves provide metadata with products they share (95%), with a respondent from the Province of Nova Scotia stating that the province is working on populating ISO 19115 compliant metadata for their spatial holdings.

Nonetheless, 78% of respondents listed metadata as a documentation type they find to be lacking. User manuals and quantitative and qualitative data quality representations were found to be lacking by between 52 to 59% of respondents. The findings may reflect that metadata is a more established and expected component of geospatial data delivery than are the other sources of documentation.

Some survey responses regarding spatial data are also reflected in the interview results. Most Interview correspondents noted that key features of the data system would be as important as the actual datasets, namely:

- Make the most important datasets open and available to the public;
- Ensure reliable availability of timely and accurate data;
- Standardization of some datasets for the entire country; and
- Agreement of metadata and data standards.

Both survey and interview results directly indicate the value of data reliability and timeliness. The wish of interviewees for agreed-upon metadata and standards is reflected in a large number of survey respondents identifying ease of data search and discovery as important, and the large number identifying missing metadata as an issue.

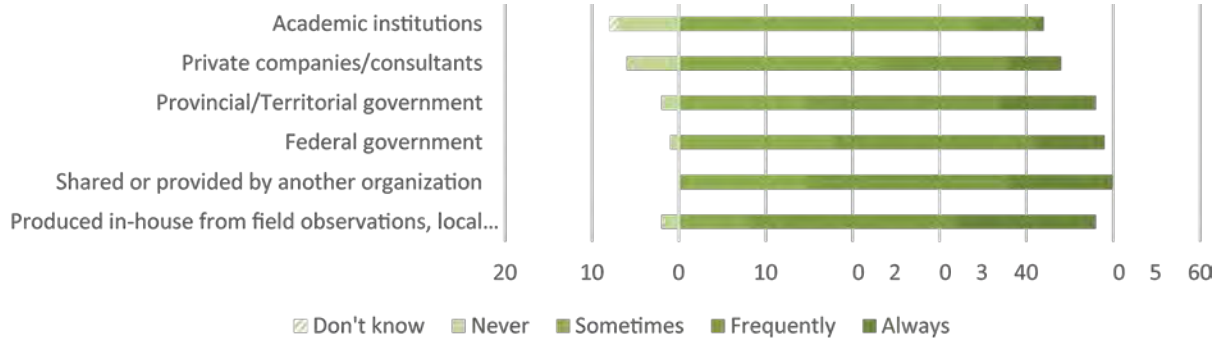
5.3 KNOWLEDGE AND CAPACITY

Users employ the full range of data sources (84 - 100% sometimes or more frequently used for each). Private and academic sources are less-often employed, listed as frequently or often used by 42% and 16% of respondents versus other sources at 66% to 80% (Figure 13). Private and academic sources are never used by 14% and 12% of respondents. Users indicate that international and municipal data sources are also employed.

All users employ desktop systems, with 94% employing a GUI, and 92% using commercial systems rather than open source (at 58%). This is the most traditional use model. Scripting and API use is high, at 72% and 62%, while the use of external services is quite low (28%). Users indicate an increasing desire to use

APIs in the future relative to scripting (68% versus 58%), which is a reversal of how they indicate current use (66% API and 72% scripting). There is a small indication of a desire to increase use of external services (30% in future versus 28% currently out of 43 respondents).

Figure 13 Data sources.



* Graphed on the Likert scale. X-axis is in counts of respondents, with right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

Users indicate they also employ tablets or portable devices (75%) and smartphones (50%), while 63% continue to use hard copy printouts. GPS and web mapping are listed as other devices and systems used. A desire for web-based activity is indicated by 76% use of public web-based software, and 70% employment of computer and web programming tools. The latter finding also supports the indicated desire to use APIs and scripting.

> "The CGDI is providing standards for Canadian practitioners for data management and interoperability. Working towards common goal of data provision and data discovery "
>
> Interviewee response

Respondents were almost evenly split on awareness of CGDI endorsed tools and standards (56% aware, 44% not aware). As designed, those selecting they were unaware of CGDI were not asked follow-up questions, which reduced the number of respondents to those questions by about half. A large number (77%) of remaining respondents state they use CGDI data content, tools, and endorsed standards. This result may also reflect the fact that CGDI employs standards with scope beyond itself, including international ones. Additionally, users may associate older initiatives such as GeoBase and GeoGratis with CGDI. It would be useful to know if users, in general, were aware of these standards and other initiatives outside the context of CGDI.

In comparison to survey respondents, a minority of interview respondents (22.7%) did not know anything at all about the CGDI or the associated projects and initiatives (e.g., GeoConnections). Most interviewees knew of the CGDI but did not describe themselves as users of the system – "I am aware of the CGDI but don't really know what it does" was quite a typical response. Many had heard of GeoConnections, GeoGratis, and the Federal Geospatial Platform (FGP). However, there was a sense of confusion about how these different resources contributed and co-exist within the same broad ecosystem.

Asked specifically about the CGDI, one response was "*The CGDI is providing standards for Canadian practitioners for data management and interoperability. Working towards common goal of data provision and data discovery* "; however, another replied "*There is no clear distinction if CGDI is a business entity or unit and/or a collection of standards*"; This pair of responses illustrates a lack of clarity about what CGDI is, or what it is supposed to be to some users. Some commented on the fact that CGDI, and other federal resources, are often difficult to use. Others noted that many/most CGDI datasets can be accessed via other sources, generally more easily.

Most of the users interviewed are long-time experienced users of geospatial data, mostly working in organizations that recognize the value of geospatial data and the need for systems that enable the use of the data. As such, most of them have access to internal systems which they use in preference to CGDI. In some cases they have no choice since the use of internal systems is mandated. In others, they prefer the internal systems that are available to them. In yet other cases, they have no internal systems, yet have chosen an external system other than the CGDI (for varying reasons). One survey respondent noted that the department wishes to link to CGDI (GeoBase) data on an internal system. A priority for the CGDI is to understand and address the barriers so that the CGDI meets user needs.

Most correspondents described themselves as data consumers and publishers but most stated that they did not share data very much. These interview results partially match survey results in which user profiles indicate 67% identify as end-users, and 84% as publishers (users could belong to more than one profile); however, 88% of survey users indicated they share spatial data, with a large number indicating they provide tools or technology to access or share information.

Interviewees indicated that most data sharing is internal to their department (survey results corroborate with 83% sharing within their departments or organizations). In some of these cases they are not allowed to share their data for internal reasons (undisclosed), but some are in the situation where they do not share data even though the organization supposedly has an open data policy. Where data is shared, organizations have their own way of doing so, with no two correspondents describing the same way of sharing data. The CGDI should prioritize understanding and countering the various reasons why so many people still do not share data, including understanding how standardization and capacity building can help with this goal.

5.4 BARRIERS AND CHALLENGES

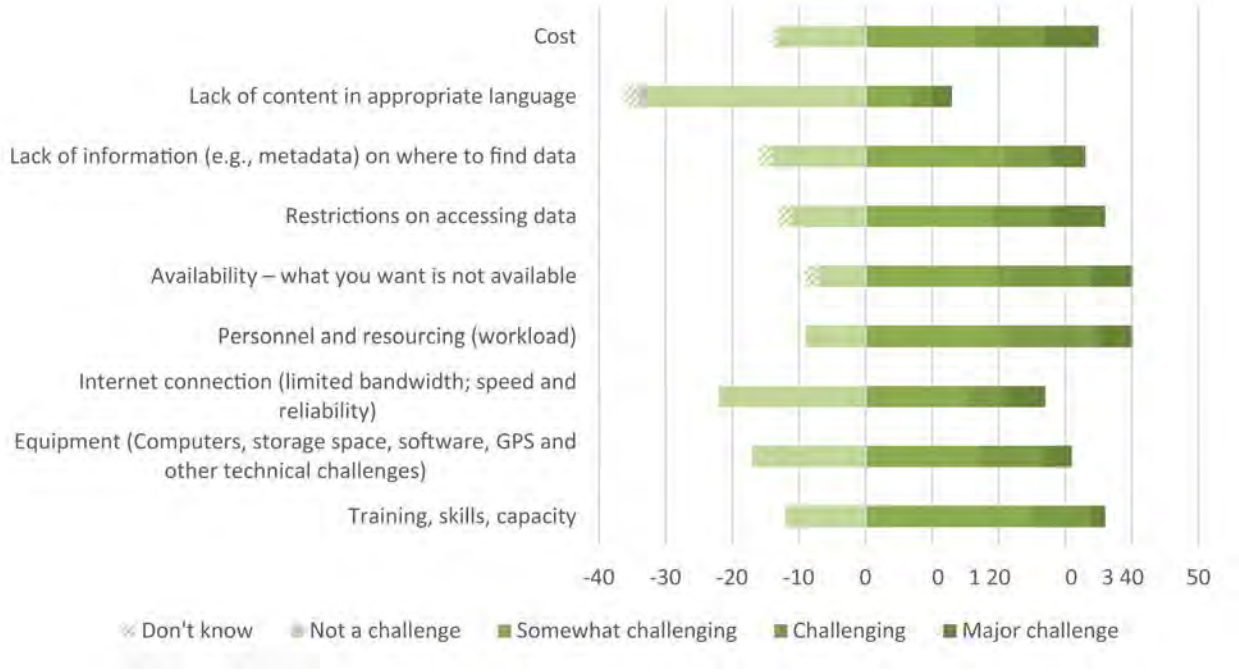
Few survey respondents found major challenges with acquiring important geospatial datasets, with only 16% indicating that each of the cost and access restrictions were major issues (Figure 14). In contrast, 41% stated that availability of desired data was challenging or a major challenge. Similarly, 39% stated that each of data cost and personnel and resourcing requirements were challenging or a major challenge, with 35% stating the same for data access restrictions.

No respondents found major challenges integrating geospatial data. 33% of users stated there was no challenge from lack of integration information (with 52% stating they did not know), while 48% stated that incompatible file formats were not a challenge (46% stating they did not know). The largest difficulty users indicated was personnel and resourcing, with 46% finding this somewhat challenging or challenging. 35% of users found missing or unclear metadata to be somewhat challenging or challenging (Figure 15). In

answer to an open question (#41), some users stated staff resourcing is a significant barrier where agencies are responsible for large areas but draw funding from a small tax base (e.g., the Northwest Territories). Internal restrictions on the use of non-Canadian cloud resources were noted in one case, as was the burden of relatively narrow, restrictive licenses on some commercial datasets.

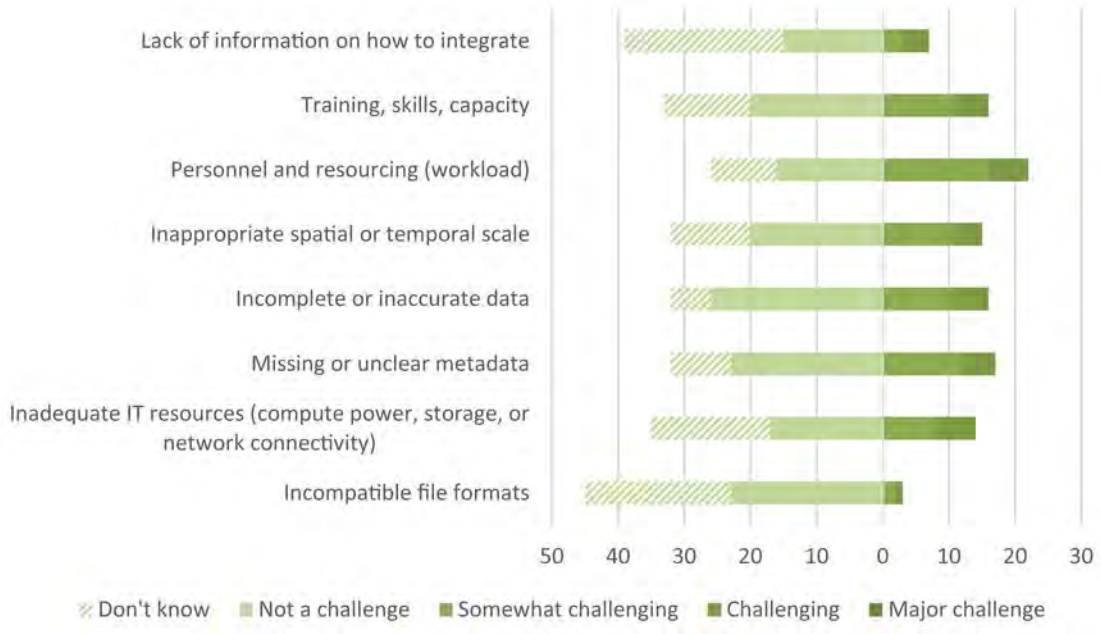
While responses to the survey indicate a sophisticated user-base with knowledge of SDI-related standards and of the utility of the data SDI can provide, there were multiple challenges to the adoption of CGDI data and endorsed tools and standards. 38% of respondents indicated that a lack of internal capacity was a barrier, with 33% indicating barriers from each of the cost of change, and it not being the right time for their organization. Similar numbers responded that there was an insufficient business case and a lack of compatibility with existing systems (24 and 19%, respectively). As a follow-up question to awareness of CGDI, the number of respondents reduced to about half of the total pool.

Figure 14 Challenges in acquiring and using spatial data.



* Graphed on the Likert scale. X-axis is in counts of respondents, with right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

Figure 15 Challenges in integrating spatial data.



* Graphed on the Likert scale. X-axis is in counts of respondents, with right of zero representing agreement or affirmative response, and left of zero representing disagreement or negative response.

The main challenges highlighted during the interviews related to:

- **Data management**: storage, curation and downloading of large amounts of data is seen as problematic, or time-consuming, which takes away valuable time from limited resources, in data analysis and the extraction of geospatial information. Some correspondents reported technical barriers: e.g., poor connectivity in remote regions, older systems unsuited to contemporary issues. Others reported technological problems, such as issues migrating to cloud technology, license issues, firewall issues.
- **Data multiplicity**: interviewees indicated that their challenge is to know what data is available and the conditions of access, mainly due to the multitude of data sources. Many reported data problems, e.g., discovery, access, and quality issues. In principle, a CGDI system would be designed from the bottom up to fundamentally resolve problems of this type by being a single resource which makes all its datasets readily searchable and findable, and then retrievable, and ensures that the data provided is accurate, recent, up-to-date, consistent, etc. On the same topic, users also noted the growing need to integrate multiple data sources, which today requires much human involvement and little automation.

- **The "silo culture"**: each community, department, industry uses geospatial data in their own way, with still yet very little interaction and understanding of how other communities address similar challenges. This provides for a fragmented landscape, which comes with inefficiencies, duplications of effort, and an overall sense of missed opportunity for creating synergies. On a related topic, many interviewees reported internal workplace cultural issues, with the difficulty of persuading older senior management figures to buy-in to an entirely new approach to architecture and infrastructure.

- **Cost**: issues reported include purchase cost of datasets, cost of maintaining servers and systems, and of training personnel. Some groups have invested heavily relatively recently in systems that are becoming obsolete quicker than expected and repeating such an investment may not be possible.

Interviews were conducted with two experts working on existing Arctic geoportals: One involved with the Alaska Ocean Observing System – AOOS and the other the Alaska Data Integration working group – ADIwg, part of the AOOS program. From those interviews, it appears that metadata standardization is the biggest concern for the people involved on these Arctic-related geoportal projects, as it is a pre-requisite to make data searchable and to integrate them in the SDI. Initial efforts in the AOOS development was related to metadata harmonization. The adoption of ISO standards for metadata would help in addressing a wide audience beyond the USA and Canada. In addition, limitations in the availability of suitable infrastructure (lack of a scalable storage strategy and computer power) made it difficult to scale up the initiative as the projects grew in scope and number of users.

5.5 POLICIES AND GOVERNANCE

Record Keeping

A large majority of survey respondents indicate that they keep past records or archives of geospatial data (84%), with 71% indicating they keep these records indefinitely. 7% indicate they keep the records for 5 years, with a large 22% indicating they do not know (or perhaps do not have a policy). In contrast, 27% never access these archives with another 27% accessing them yearly (54% combined). Only 10% access these archives daily, with 12% accessing them each of weekly and monthly (34% combined). Reflecting the results for data retention, 12% indicate they do not know how often they access archived data.

An interesting contrast exists given that 38% of users (by far the largest proportion) indicate updating shared geospatial datasets monthly – data is updated far more frequently than it is accessed. This proportion is similar to the combined responses indicating updates yearly, every one to three years, and every five to ten years (40%). Only 2% of respondents indicate shared data is never updated, with a large 19% indicating they do not know.

Splitting responses based on those who keep historical geospatial data and those who do not suggest that those who store data are more likely to engage in data modelling, predictions, or tracking changes over time. The most frequent responses vary with indication of storing past data. 46% of those who store data are frequently involved with prediction or modelling activities, while 38% of those who do not store data only perform these activities sometimes (where these are the most frequent responses in the two groups).

Similarly, for tracking change on a monthly or yearly timeframe, 46% of archivers perform this activity frequently, with 38% of non-archivers performing it sometimes. For tracking change daily or weekly, the responses are 34% for sometimes from archivists, and 38% for never from non-archivists.

Sharing Policies

Data sharing appears to be a well-established practice amongst respondents, with 71% indicating they have sharing policies or procedures. 63% indicate they also have a data management policy which includes metadata, with only 8% indicating they do not know. A large majority (88%) share geospatial data, listing internal sharing as the most common scenario (83% for each of within the department and within the organization). Other sharing scenarios are also common, with sharing outside of Canada and with indigenous government or communities being the least common (57 and 55% respectively). Other responses include sharing with municipalities and with allied nations.

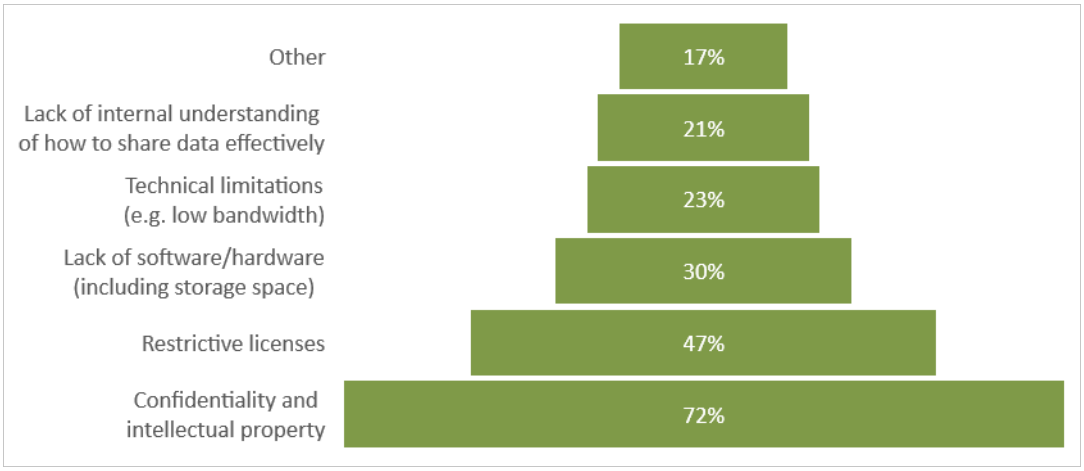
The clear majority (95%) of respondents include metadata with their shared geospatial data. In terms of data status, 45% indicate the data they share is partially complete and either up-to-date or requiring an update (19 and 26% respectively). 33% indicate data is complete but requires an update, with only 14% indicating data is both complete and up-to-date. Only 7% of respondents did not know about the status of their shared data.

Sharing Mechanisms

82% of respondents provide geospatial products to end-users as digital / electronic datasets, which is the most traditional method (i.e., as ESRI Shapefiles, Google Earth KMZ, etc.); however, all distribution methods were frequently listed (between 53 and 82% of respondents). The least-frequently listed was distribution tailored to mobile devices. Paper maps are still distributed by 63% of respondents, but a larger number of users (73%) also distribute data as web services (WMS, WFS or API access). One user included Web Processing Service (WPS) as a delivery method. This may be reflected in 38% of users indicating they were willing to share analytical capabilities with others. Surprisingly, 50% of users state they do not know if they would be so willing, perhaps indicating that the idea is relatively new to users.

By far the largest barrier to sharing geospatial data is confidentiality and intellectual property issues (72%), with restrictive licenses being the next most frequently listed (47%). The three other items listed (lack of technical understanding, technical limitations, and lack of software or hardware) were each in the range of 21 to 30% (Figure 16). Other answers were provided by 17% of respondents (8 out of 47), with three of these indicating internal policy restrictions, and one indicating supplier restrictions. These results indicate that legal or competitive concerns are the biggest issues impeding data sharing.

Figure 16 Barrier to sharing geospatial data.



Users indicated that each of the strategies listed on the survey for improving geospatial data production and sharing was viewed as helpful (57% answering "All"). Of the remaining responses improved data posting, discovery and evaluation mechanisms were the most frequently identified as helpful **(20%).**

5.6 TRENDS AND REQUIREMENTS

Most users in the survey employ Web Mapping (WMS) or Web Feature (WFS) Services, with an equal number employing metadata standards (81% for each). Web Processing Service (WPS) and Catalogue Services for the Web (CSW) were employed fairly frequently (38 and 29%, respectively), indicating a strong awareness of OGC standards amongst the user base.

All interview correspondents agreed that geospatial data and information are already fundamentally important to contemporary society, and that this influence will only increase. Many potential opportunities and advancements that could arise, from open data generally and the CGDI specifically, were identified, along with current and future examples of innovation from Canadian institutions and industry.

Open data makes a huge contribution to the economy at all scales from municipal to federal, in both rural and urban areas, and via both public and private funds. Examples from forestry, agriculture, aquaculture/fisheries, and tourism were given where geospatial data is increasingly being used routinely to improve performance, yields and efficiencies. Emergency services and disaster management depend critically on geospatial data, with the 2013 flooding in Calgary repeatedly cited as an example of an event that has led to industry-wide review of practices and adoption of geospatial data, which in turn has led to such advances in forecasting and modelling that flood data is now a commercially valuable commodity. The potential for following the same general approach to mitigate against wildfires is being investigated. Geospatial data is central to urban planning, with systems being developed to identify the suitability of areas for major investment and development before

> "Senior-level government support for open data is a result of efforts by initiatives such as CGDI."
>
> Interviewee response

committing substantial amounts of money. Some specific recent examples of Canadian geospatial-enabled services are:

- Native-land.ca
- First Story app
- Land Disposition Data (Northwest Territories)
- Industry, Tourism and Investment (ITI, Northwest Territories)
- VALTUS (WMS enabled LIDAR data)
- BC Data Catalogue
- ParcelMap BC
- ReCollect.net

The CGDI can play a key role in defining and providing the infrastructure needed to enable and facilitate the broader uptake of geospatial data in Canada. The underlying infrastructure and enabling systems will lead to developments and opportunities in hugely diverse areas, for example:

- Big data techniques for enhanced validation of datasets, and change detection;
- Better networks and integration – sensors, networks, Internet of Things (IoT) – optimised for user mobility;
- Widespread utilization of cloud infrastructure and artificial intelligence for data storage, curation, and processing, enabling interconnectivity to optimize access to data and services;
- Development of tools that allow processing and consuming of data and making it available – especially graphical user interfaces (GUI) and man–machine interfaces (MMI) – leading to further commercialization opportunities;
- Parallel developments more generally in software development and programming/coding and broaden opportunities for graduates and skilled workers; and
- Development of secondary economic sectors beyond strictly resource/ goods-based (e.g., blockchain), the knowledge economy, services, and experience-based purchasing.

Contributions such as the above combine to provide better information to individuals at all levels, which in turn helps inform and improve decision-making. Examples of domains in which this process is already beginning to influence decisions include: energy and utilities; smart cities; health; mitigating climate change; societal 'big issues' – e.g., homelessness, crime, disaster relief.

Designing and developing a system that can support these advances and innovations will be a complex process that will impose significant requirements; some examples that were identified include:

- Data authorities must be willing to share data, for free when the data is obtained via public funds;

- Ensure adequate network and internet bandwidth (e.g., via web services and APIs);
- Ensure sufficient capacity everywhere at the correct cost;
- Standardization, accuracy, reliability, latency, and availability of datasets;
- Easy access point with good GUI/MMI; and
- Modular design to encourage further take up and development, and integration, by nimble developers, embracing modern technologies and techniques such as big data, Artificial Intelligence (AI), and blockchain.

The CGDI should aim to be the Go-To directory for whatever it provides. It doesn't necessarily need to be solely responsible for the update and maintenance, but it must provide, and ensure, access at all times. To achieve this, it will be necessary to take a top-to-bottom look at legislation, business processes, and policy/regulation governing the creation and publication of data, likely on a domain-by-domain basis.

Most stakeholders interviewed were positive about the future of the CGDI, and most were open to potential future involvement. Specific areas where they felt they could offer expertise include: promoting broader engagement; liaison with Federal government; engagement with domain-specific groups; defining data and metadata standards; tools (e.g., web services), analytics, big data; technology (e.g., cloud, computing, blockchain).

6.0 KEY FINDINGS AND RECOMMENDATIONS

6.1 THEMATIC DATA REQUIREMENTS

Spatial data are a fundamental component of the CGDI. Users expressed a need for a huge range of framework and thematic spatial data that would enable them to fulfill their mandates and to respond to challenges across a range of environment, health, and economic areas of interests. **Open data** is a key requirement and provides many perceived benefits to users – this is discussed in relation to policy, standards, and governance below.

Remote sensing data and datasets derived from remote sensing appear to be highly valued, perhaps reflecting the improvements in these datasets in terms of spatial detail, frequency of acquisition, and information content. A common theme was the need to centralize all image datasets acquired by Federal and Provincial departments and make it accessible to all through a common location/map service. There is a desire for ongoing update and distribution of national and provincial aerial images, LiDAR, and satellite imagery. Several datasets can be derived from the remote sensing, such as precise elevation data, land use and land cover, and indexes such as the normalized difference vegetation index (NDVI). Most users see monthly or yearly updates of data to be more important than daily or weekly data (for monitoring purposes).

Current and potential users of the CGDI wish to access **Authoritative Data** through an SDI with high numbers of users citing authoritative data and ease of search and discovery as priorities, with the implied expectation of complete metadata. Users frequently expressed that data quality and trustworthiness is paramount. Users require geospatial data in both English and French. They also indicate there is a need for additional language support, including indigenous languages and those supporting the tourism industry.

Users want to access datasets at a finer scale and with local significance, suggesting that the CGDI could further develop partnerships with regional and local data producers, such as provincial governments, municipalities, and regional districts. Users value a long archive of data but do not necessarily create or provide adequately complete or up-to-date products themselves. Access to historical data is occasional for many users but appears to be of value to them, suggesting external hosting would be appealing.

Recommended initiatives for the CGDI focus on stimulating the development of the most needed data and supporting access to realize the value-adding potential where data can be re-used multiple times. Users noted the following:

- Provincial/national LiDAR to generate high-quality elevation data and to enable assessment of vegetation structure;
- Land use and land survey;
- Road networks; and
- Definitive base map of Canada – standardized.

6.2 TECHNOLOGY, APPLICATIONS AND TOOLS

SDIs are typically driven by governmental organizations and thus follow top-down approaches. While this provides for a concerted and harmonized framework for SDI implementations, the drawback is that it can make SDIs less able to evolve at the same speed as new technological trends. The ways that users interact with data and applications are changing, which was reflected in the survey responses and interviews, especially when placed in the context of previous UNA and UCD studies.

Most users still access spatial data by downloading data from external sources if data are not already available internally within their organization's systems. Some users acquire data via web services or other forms of direct access. Awareness of web services is growing, and, in some cases, users are distributing their data through web services. Value-added services, such as **web processing services** appears to have some appeal, but users may lack awareness of this option and its implications.

Users also show interest in programmatic access to data through **Application Programming Interfaces** (APIs). The growth of API usage and relatively high use of provincial and federal datasets suggests that the CGDI should encourage access to government open data through web services and APIs. Organizations also indicated an interest in accessing data through mobile applications and technologies such as using tablets and smartphones as geospatial tools.

One of the most important functions SDI provides is to allow users to discover datasets they are seeking and to confirm that they will meet their needs (CP-IDEA 2013, 112-113). Users see value in improved discovery, evaluation and exchange mechanisms, which are important components of SDI. While understanding that it would be a challenge to develop, users surveyed and interviewed mentioned the benefit of a **single geoportal** – based on federated data sources – to enable users to more easily discover data. Efforts to establish more standardized and stable interfaces to geodata discovery portals would help data discovery. Users frequently expressed that search/discovery portals should be intuitive.

Availability and use of cloud-based ICT resources appear to be increasing, including for users in the private sector and data suppliers. SDIs can be seen as an integral part of the overall information infrastructure, driven by experts and stakeholders from the geospatial domain. These ICT trends do not affect existing SDI-specific standards or agreements that have a wide acceptance in the community. The use of Cloud computing is already being increasingly adopted. However, taking advantage of Cloud infrastructure to migrate from spatial data portals to more robust platforms will require a shift in thinking on the purpose and role of SDI by those involved in their design and development. **Cloud computing** may simplify deployment and maintenance of SDI services, and reduced costs of providing content and applications with a high quality of service. The concept of **Platform as a Service (PaaS)** is gaining in awareness and interest, with users expressing interest in moving from geo-portals to geo-platforms. This platform concept provides users with the ability to conduct processing analysis at the location of the data, rather than having the data brought to the location where the user conducts the processing/analysis. This concept has been stimulated by the development of big data and particularly the challenges and opportunities of approaches to work with big satellite EO data. For example, NRCan has explored the development of a Geoanalytics Earth Observation Data Environment (GEODE), a centralized repository holding a valuable and long timeline of public domain satellite data.

In the CGDI survey and interviews, Internet connectivity does not appear to be a major issue, which reflects the location and type of organizations who responded. Government suppliers and enablers are aware of the need to ensure that CGDI services can be used in remote locations. Users recognize with the eventual release of 5G technology, there will be better networks and integration of data – sensors, networks, Internet of Things (IoT) – optimized for user mobility.

Recommended CGDI activities related to new technology, applications, and tools are:

- Support key data suppliers to be standards compliant, especially those with relatively limited experience interacting with the CGDI such as smaller municipalities, regional districts, and non-government organizations.
- Review the opportunity to develop a CGDI geoportal based on federated data sources.
- Review technological trends identified in this study and identify how they may impact and benefit the CGDI.
- Promote the provision of access to spatial data and metadata through web services and APIs.
- Explore potential CGDI collaboration with existing and proposed geo-platforms such as the Polar Thematic Exploitation Platform, Earth Data Store (supported by the Digital Technology Supercluster), and Open Data Cube. Review how the CGDI could support the development of marketplaces for spatial data and analytical services.

6.3 POLICY, STANDARDS, AND GOVERNANCE

Open data is a key requirement for users of spatial data and SDIs. The benefits of open data include higher utilization of data in a range of areas considered to deliver many benefits to Canadians, e.g. flood risk management, environmental management, resource development, and innovation through data integration (e.g. application development by third parties). Where data cannot be made available free of cost, users still want to be able to discover the data easily and understand its accessibility, license, and costs. These findings support the case for SDI.

Commercial data costs, intellectual property, privacy/confidentiality, and narrow license restrictions were identified as barriers to wider employment of high-value datasets. The largest barrier to sharing geospatial data is confidentiality and intellectual property issues, with restrictive licenses frequently mentioned. It is important to address perceived issues from potential suppliers that participation in the CGDI may negatively affect intellectual property and privacy/confidentiality.

The online survey and interviews generated conflicting information around **metadata standards** and the usefulness of metadata. Many users suggested the completeness, usefulness, and usability of metadata were important. User manuals and quantitative and qualitative data quality representations were found to be lacking by users. Despite metadata standards existing, users still commented on the benefit to metadata standards to make data search and discovery easier.

Recommended CGDI activities related to policy, standards, and governance are:

- Continue to develop and promote open data as a fundamental component of the CGDI;
- Provide guidance on policies and approaches to become a CGDI data provider, including metrics regarding the use of hosted data;
- Develop mechanisms to bring commercial data providers into the CDGI, through metadata discovery, marketplaces;
- Help to improve users' ability to use and produce metadata. Consider a compliance testing service for CGDI components.

6.4 TRAINING AND CAPACITY BUILDING

The GeoConnections program and the development of the CGDI have clearly enhanced the capacity of many users of spatial data to access, manage, use, and share spatial data. Despite this, almost half of respondents were not aware of CGDI endorsed tools and standards. Of those who were aware, a large majority use spatial web services of some kind and metadata standards. Users may not differentiate between CGDI and related government initiatives such as GeoBase, which may suggest a branding issue for CGDI. Many users aware of CGDI endorsed tools and standards identify challenges adopting CGDI data, tools and standards, while another group did not know if their organization faced such challenges. Lack of internal capacity was the most identified challenge to adoption.

Depending on the type of user, many users see the CGDI as a supplier of authoritative spatial data, rather than understanding the CGDI's role in governance, policy, standards, and applications. Users may associate older initiatives such as GeoBase and GeoGratis with CGDI. It would be useful to know if users, in general, were aware of these standards and other initiatives outside the context of CGDI. There is a **sense of confusion** about how these different resources contributed and co-exist within the same broad ecosystem. There is some confusion among users in the status of the CGDI, and its relationship to Geconnections, Federal Geospatial Platform (FGP), and Open Data Canada. CGDI stakeholders would like to understand how the different resources and/or initiatives contribute or co-exist with each other.

Several users indicate that technical capacity is not necessarily an issue for their organization, rather the **availability of personnel and resourcing** is an issue for users in accessing, processing, and producing data. This speaks to a need for improved discovery processes and the potential benefits are providing authoritative, analysis-ready data.

Recommended CGDI activities related to training and capacity-building are:

- Address a potential CGDI awareness and branding issue. The CCOG recently undertook a rebranding and developed a clear website to communicate its purpose and vision. A similar effort is needed to clarify the purpose and mandate of CGDI, GeoConnectons, Geobase, and GeoGratis.
- Develop a communication plan and engagement plan to further develop the user base of the CGDI to expand the benefits to Canadians. Priorities include Indigenous Communities (see Part B of this report), municipalities and regional districts, and the private sector.

- Create fact sheets in English, French and in Indigenous languages to raises awareness of the CGDI and participation. Conduct presentations at conferences and to relevant committees, as well as webinars to expand potential participation in presentations.
- Collaborate more with regional data providers, e.g., regional districts and municipalities, to address the need to provide or link users to the datasets they value most. Promote collaboration with private industry to innovate and grow the geospatial marketplace (e.g., linkages to Innovations Superclusters).

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APPENDICES

Appendix A1

Online Survey Questionnaire

User Needs Assessment for Canadian Spatial Data Infrastructure

INTRODUCTION

Thank you for agreeing to fill out our survey about your organizations knowledge and use of geospatial data and the Canadian Geospatial Data Infrastructure (CGDI).

This survey is part of a User Needs Assessment, the goal of which is to make geospatial data more useful and more accessible for all Canadians. By completing this survey, you will be helping us better understand the needs for data, associated tools, training, standards, policies, and governance.

You do not need to be an expert in mapping, geographic information systems, or policy to contribute to this user needs assessment and your participation is entirely voluntary.

* 1. General

Name	
Name of Organization	
Location (City)	
Approximate staff size	

* 2. Which of the following best describes your occupation?

- ◯ Executive / Manager
- ◯ GIS application developer
- ◯ Researcher/scientist
- ◯ Consultant
- ◯ Geographic Data Manager or Analyst
- ◯ Other (please specify)

* 3. Which of the following describes your organization? (Check all that apply)

- [ ] Government (federal, provincial/territorial)
- [ ] Local government (municipal)
- [ ] External services provider or Private company
- [ ] NGO or non-profit
- [ ] Research organization
- [ ] Academia
- [ ] Other (please specify)

4. How extensively do you or your organization use the following geographic technologies?

	Don't know	No knowledge	Limited	Good	Very
Desktop geographic Information Systems (GIS)	○	○	○	○	○
Web-based GIS	○	○	○	○	○
Web services (e.g. WFS, WMS, CSW, and WPS)	○	○	○	○	○
Mobile GIS	○	○	○	○	○
Satellite images & processing	○	○	○	○	○
Data sharing standards (e.g. OGC)	○	○	○	○	○
Metadata standards	○	○	○	○	○
Virtual machines, platforms, cloud-computing	○	○	○	○	○
Database administration	○	○	○	○	○
Web Application programming	○	○	○	○	○

Other (please specify)

5. Please identify the degree to which the following tasks align with your activities?

	Don't know	Never	Sometimes	Frequently	Always
We download geospatial data from external distribution hubs (e.g., GeoGratis, GeoBC, or others) for various purposes	○	○	○	○	○
We use geospatial data obtained through web services (e.g., WFS, WMS, CSW, and WPS)	○	○	○	○	○
We publish geospatial data internally/privately through web services or a web portal	○	○	○	○	○
We publish geospatial data externally (e.g. public, partners) through web services or a web portal	○	○	○	○	○
We store and analyze geospatial data in a cloud computing environment or virtual machine (i.e. not on your local computer)	○	○	○	○	○
We provide tools and technologies to enable geospatial data users and publishers to access/share information	○	○	○	○	○
We provide policy frameworks to facilitate access and sharing of geospatial data	○	○	○	○	○
We provide funding to support the access and sharing of geospatial data	○	○	○	○	○

6. Do you use external service providers and consultants to meet your organization's needs for geospatial data and/ or services?

- ◯ We don't use external providers and don't have in-house capacity
- ◯ We only use in-house resources to meet our needs
- ◯ Sometimes use external support (e.g. for specific tasks to complement internal resources)
- ◯ We use external support about half the time
- ◯ We always use external support
- ◯ Don't know

WHAT ARE YOUR PRIORITIES FOR GEOSPATIAL DATA?

7. Which of the following activities does your organization currently use or share geospatial data for? (Check all that apply)

	Don't know	Never	Sometimes	Frequently	Always
Land use planning (e.g. to map land use and/or land cover)	○	○	○	○	○
Cultural and/or heritage resources inventory and/or monitoring	○	○	○	○	○
Environmental forecast and modeling	○	○	○	○	○
Natural resource management and planning (including: forestry, fisheries, wildlife, water resources, etc.)	○	○	○	○	○
Security / Sovereignty	○	○	○	○	○
Emergency and disaster planning	○	○	○	○	○
Urban and Rural land use planning (including: Health, housing, and social services)	○	○	○	○	○
Transportation, infrastructure, and capital works	○	○	○	○	○
Climate and Climate change monitoring and adaptation	○	○	○	○	○
Environmental management (including: flood and erosion management, weather monitoring and forecasting, coastal zone management, etc.)	○	○	○	○	○
Research or study of environmental, social, or economic phenomena over time.	○	○	○	○	○

Other (please specify)

8. When using geospatial data to support your activities, how often does your organization do the following?

	Don't know	Never	Sometimes	Frequently	Always
Use geospatial data or services provided by other organizations (for example, downloading maps and datasets)	○	○	○	○	○
Produce geospatial data or services for internal use (for example, collecting geospatial data in the field and mapping them electronically)	○	○	○	○	○
Share or sell geospatial data or services (for example, contribute geospatial data to a communal database, sell maps, or provide spatial or geographic services)	○	○	○	○	○
Facilitate access to geospatial data or services (for example, help other groups or organizations access and use geospatial data, administer/coordinate a database to share data with selected individuals or groups)	○	○	○	○	○
Develop geographic applications (online, mobile, or desktop)	○	○	○	○	○

9. Are the following geospatial analysis important for your department, organization, or business?

	Don't know	Not important	Somewhat important	Important	Very important
Track change over monthly to yearly timeframes	○	○	○	○	○
Track change over daily to weekly timeframes	○	○	○	○	○
Predict or model changes (e.g., future scenario)	○	○	○	○	○
Obtain and process geospatial data on a national or provincial scale	○	○	○	○	○
Obtain and process geospatial data on a local or regional scale	○	○	○	○	○

10. When using geospatial data, are the following mapping scales useful to your activities?

	Don't know	Not useful	Somewhat useful	Useful	Very Useful
Less than 1:5,000 (e.g. spatial resolution of < 2m)	○	○	○	○	○
Between 1:5,000 to 1:50,000 (e.g., approx. spatial resolution between 2 m to 25 m)	○	○	○	○	○
Between 1:50,000 to 1:100,000 (e.g., approx. spatial resolution between 25 m to 50 m)	○	○	○	○	○
Above 1:100,000 (e.g. spatial resolution of > 50 m)	○	○	○	○	○

User Needs Assessment for Canadian Spatial Data Infrastructure

HOW DO YOU ACCESS AND USE GEOSPATIAL DATA?

11. What are the main sources of geospatial data used by your organization? (Rate how often you access geospatial data from these sources)

	Don't know	Never	Sometimes	Frequently	Always
Produced in-house from field observations, local knowledge	○	○	○	○	○
Shared or provided by another organization	○	○	○	○	○
Federal government	○	○	○	○	○
Provincial/Territorial government	○	○	○	○	○
Private companies/consultants	○	○	○	○	○
Academic institutions	○	○	○	○	○

Other (please specify)

12. Based on your organizational priorities, how do the following geospatial datasets serve your requirements? (Check all that apply and rate importance)

	Don't know	Not important	Somewhat important	Important	Very important
Land use and cover	○	○	○	○	○
Topography, elevation, slope	○	○	○	○	○
Climate and environmental forecast and modeling data (e.g., weather, SWE, etc.)	○	○	○	○	○

	Don't know	Not important	Somewhat important	Important	Very important
Natural resource data (including: forestry, fisheries, wildlife, water resources, etc.)	○	○	○	○	○
Satellite imagery, aerial photographs, UAV data	○	○	○	○	○
Emergency and disaster planning data (e.g. flood, fire)	○	○	○	○	○
Urban and Rural land use planning data (e.g., cadastral, building footprint, etc.)	○	○	○	○	○
Transportation, infrastructure, and capital works (e.g., resource roads, bridges, etc.)	○	○	○	○	○
Climate change monitoring and adaptation (e.g. permafrost, ice cover, soil moisture)	○	○	○	○	○
Environmental management (including: flood and erosion management, weather monitoring and forecasting, coastal zone management, etc.)	○	○	○	○	○
Research or study of environmental, social, or economic phenomena	○	○	○	○	○
Security / Sovereignty data	○	○	○	○	○

Other (please specify)

13. Which of the following attributes do you value in the geospatial data and systems you are using? (Check all that apply)

- [ ] Most recent, up-to-date, data sets
- [ ] Data trustworthiness / quality
- [ ] Visually attractive maps or user interface
- [ ] Ease of search and discovery of data sets
- [ ] Intuitive interface and easy navigation in the user interface
- [ ] Ability to manipulate data, perform operations / run algorithms on it
- [ ] Other (please specify)

14. What systems or devices does your organization currently use to work with geospatial data? (check all that apply)

- [ ] Desktop computer
- [ ] Smartphone
- [ ] Tablet or other portable device
- [ ] Print-outs
- [ ] None
- [ ] Don't know
- [ ] Other (please specify)

15. How do you currently interact with geospatial data? (Check all that apply)

- [ ] Graphical User Interface(GUI)
- [ ] Scripting (e.g. Python)
- [ ] Application Program Interface (API)
- [ ] Don't know
- [ ] Services by an external provider
- [ ] Other (please specify)

16. How would you prefer to interact with geospatial data in the future (e.g. push factors)? (Check all that apply)

- [ ] Graphical User Interface(GUI)
- [ ] Scripting (e.g. Python)
- [ ] Application Program Interface (API)
- [ ] Services by an external provider

17. What software programs does your organization currently use to work with geospatial data? (Check all that apply)

- [ ] Public web-based software (For example: Google Maps, Google Earth, OpenStreetMap)
- [ ] Open source desktop software (For example: QGIS, gvSIG, GRASS GIS)
- [ ] Commercial geospatial software (For example: ArcGIS, Global Mapper, PCI Geomatica, ENVI)
- [ ] Computer and web programming tools (For example: Python; C#)
- [ ] None
- [ ] Don't know
- [ ] Other (please specify)

18. What challenges does your organization face in using and acquiring important geospatial datasets?

	Don't know	Not a challenge	Somewhat challenging	Challenging	Major challenge
Training, skills, capacity	○	○	○	○	○
Equipment (Computers, storage space, software, GPS and other technical challenges)	○	○	○	○	○
Internet connection (limited bandwidth; speed and reliability)	○	○	○	○	○
Personnel and resourcing (workload)	○	○	○	○	○
Availability – what you want is not available	○	○	○	○	○
Restrictions on accessing data	○	○	○	○	○
Lack of information on where to find data	○	○	○	○	○
Lack of content in appropriate language	○	○	○	○	○
Cost	○	○	○	○	○

Other (please specify)

19. What challenges do you face in integrating geospatial data or spatial datasets into your organization's activities? (Check all that apply and rate)

	Don't know	Not a challenge	Somewhat challenging	Challenging	Major challenge
Incompatible file formats	○	○	○	○	○
Inadequate IT resources (compute power, storage, or network connectivity)	○	○	○	○	○
Missing or unclear metadata	○	○	○	○	○
Incomplete or inaccurate data	○	○	○	○	○
Inappropriate spatial or temporal scale	○	○	○	○	○
Personnel and resourcing (workload)	○	○	○	○	○
Training, skills, capacity	○	○	○	○	○
Lack of information on how to integrate	○	○	○	○	○

Other (please specify)

20. Do documents and metadata usually allow you to evaluate the fitness or quality of geospatial data and/or service available?

- ○ Yes
- ○ Sometimes
- ○ No
- ○ Don't know

21. What kind of documentation is lacking?

- [ ] Up-to-date user manuals
- [ ] Accurate metadata containing vintage and accuracy information
- [ ] Quantitative representations of data quality
- [ ] Qualitative representations of data quality (e.g., confidence in the process that was used to generate the data)
- [ ] Other (please specify)

22. Does your organization have a need to keep records (archives) of past outdated geospatial data?

- ( ) Yes
- ( ) No

23. How many months (or years) of data do you need to keep?

- ○ 1 month
- ○ 6 months
- ○ 1 year
- ○ 5 years
- ○ All available history
- ○ Don't know

24. How often do you need to access these past data sets?

- ○ Daily
- ○ Weekly
- ○ Monthly
- ○ Yearly
- ○ Rarely
- ○ Never
- ○ Don't know

25. In what language(s) do you need your geospatial data to be represented?

- ☐ English
- ☐ French
- ☐ Other (please specify)

26. Do you have a policy or procedure that governs the sharing and/or distribution of geospatial data?

- ◯ Yes
- ◯ No
- ◯ Don't know

27. Do you have a data management policy, including standards for cataloguing (metadata) and storing your geospatial data?

- ◯ Yes
- ◯ No
- ◯ Don't know

28. Does your organization share geospatial data?

- ◯ Yes
- ◯ No

29. How would you describe the status of the geospatial data that you share?

- ◯ Complete spatial coverage and up-to-date
- ◯ Complete spatial coverage but some areas needs to be updated
- ◯ Partial spatial coverage but up-to-date
- ◯ Partial spatial coverage but some areas needs to be updated
- ◯ Obsolete (now considered historical)
- ◯ Don't know

30. In general, what is the update cycle for your shared geospatial datasets (how frequently do you update your geospatial data)?

- ◯ Once every 5-10 years
- ◯ Once every 1-3 years
- ◯ Yearly
- ◯ Monthly
- ◯ Never
- ◯ Don't know

31. Who do you share data with?

- [ ] Internally within your department
- [ ] Internally within your organization/company
- [ ] Federal or Provincial/Territorial Government
- [ ] Indigenous government / communities
- [ ] Academia
- [ ] Private companies (e.g. mining and forestry companies)
- [ ] NGOs
- [ ] General public (e.g. drivers, farmers)
- [ ] Organizations/companies/individuals outside Canada
- [ ] Other (please specify)

32. Do you include metadata with the geospatial data that you share?

- ( ) Yes
- ( ) No

33. What prevents you from sharing geospatial data with others?

- [ ] Confidentiality and intellectual property
- [ ] Restrictive licenses
- [ ] Technical limitations (e.g. low bandwidth)
- [ ] Lack of internal understanding of how to share data effectively
- [ ] Lack of software/hardware (including storage space)
- [ ] Other (please specify)

34. How do you communicate or distribute geospatial data to your end users (audience)?

- [ ] Paper or digital maps (e.g. PDF maps)
- [ ] Digital/electronic datasets (e.g. Google KMZ, ESRI Shapefile)
- [ ] Using the Internet / Internal network (map services; WMS; WFS; API)
- [ ] Digital /electronic maps and datasets for use on mobile devices
- [ ] File Transfer Protocol (FTP)
- [ ] Other (please specify)

35. Which solution would help improve efficiency and reduce redundancy in your geospatial data production and/ or sharing?

- ( ) Better mechanisms for posting, discovering, evaluating, and exchanging existing geospatial resources
- ( ) Providing essential building blocks for authoring and managing content, publishing services, discovering and exchanging geospatial information, networking services
- ( ) Simplify access to countrywide geographic data and reduce the average time for processing data
- ( ) All of the above

36. Would your organization be willing to contribute analytical capabilities (e.g. data processing algorithms) to for others to benefit from?

- ( ) Yes
- ( ) No
- ( ) Don't know

37. Are you familiar with the Canadian Geospatial Data Infrastructure (CGDI) tools and standards?

- ◯ Yes
- ◯ No

38. Do you use any CGDI data content, tools or standards in your GIS?

- ( ) Yes
- ( ) No

39. If Yes, check all CGDI data content, tools or standards you use:

- [ ] Web Mapping Services (WMS) and/or Web Feature Service (WFS)
- [ ] Web Processing Service (WPS)
- [ ] Catalogue Services for the Web (CSW)
- [ ] Metadata standards (e.g., FGDC or ISO19115)
- [ ] Other (please specify)

40. Do you face any of the following challenges that may prevent your organization from adopting CGDI data, tools, or standards: (check all that apply)

- [ ] Cost of change
- [ ] Insufficient business case
- [ ] Lack of internal capacity
- [ ] Lack of compatibility with existing systems
- [ ] Not the right time for the organization
- [ ] Don't know
- [ ] Other (please specify)

41. If you have any additional comments about how you currently use geospatial data or about what limits your use, please type in the box below.

42. Are there any other organizations who you think we should consult to better understand the needs for geospatial data? Please type in the box below.

* 43. May we contact you for a follow-up interview? It will take no more than 30 minutes.

- ( ) Yes
- ( ) No

44. Please enter your contact details.

Name	
Company	
Email Address	
Phone Number	

Thank you for completing the survey!

Appendix A2

Interview Questions

INTERVIEW PROCESS AND GUIDE

1.0 INTRO SCRIPT

Thank you for agreeing to participate in this interview. We will make every effort to ensure the information you provide is kept anonymous. We will not quote you without obtaining your written consent in advance. We will only report on the information gathered for this project in regional or organizational summaries.

You may stop the interview at any time or ask to have your responses removed from the survey. If you wish, you will have the opportunity to review notes taken during the interview and make any comments or corrections.

Do you have any questions?

2.0 INTERVIEW GUIDE (AND NOTES)

1. Name of interviewee:

Enter before interview

2. Name of organization:

Enter before interview

2.1 INTERVIEWEES THAT HAVE NOT COMPLETED THE ONLINE SURVEY

If the respondent has completed the survey, skip to Section 2.2.

3. Tell me about your organization's core objectives and/or its mandate.

4. Can you further describe to me how your organization interacts with spatial data? (E.g., Do you publish or share spatial data on the internet or offline? Do you promote access to spatial data by providing services or maintaining a database? Do you simply download spatial data and use it only for internal purposes?)

2.2 INFORMATION TECHNOLOGY

5. Are you familiar with GeoConnections and the Canadian Geospatial Data Infrastructure (CGDI)?

   - If so, in your own words how would you describe the what the CGDI is?

6. Have you used CGDI tools and resources? (e.g., GeoGratis, Open.Canada.ca, DataBC, GeoYukon, etc.)
7. How, and for what purpose?
8. Currently, is it easy/simple to find the geospatial data sets you need?
9. If yes, what portals/ sources do you use?
10. If no, why?
11. What potential training or awareness raising activities are needed to promote assess and discovering spatial data and products?

2.3 DATA

12. Please describe, in a perfect world, what spatial data would you like to obtain about the Canadian landscape that would support your organizations' mandate?

2.4 CHALLENGES

13. What is your biggest challenge to storing, accessing **or** updating **your** geospatial data?
14. For example: cost of personnel with the right skills, cost of acquiring data, cost of software to analyze manipulate, cost of equipment and hardware
15. Technology?
16. Data policies?
17. Do you share geospatial data with other organizations or publicly? If yes, what sorts of roadblocks and/or challenges do you face in trying to share this data?
18. Privacy / IP?
19. Loss of control of data/anonymity?

2.5 FUTURE USE OF SPATIAL DATA

20. What opportunities and advancements do you see with regards to the CGDI and Open Data? (e.g., enriching Business intelligence, Open Innovations, Open Cities, etc.)

21. Successful SDIs are based on adopting open standards and policies for publishing data. What are the next steps or changes your organization needs to make to be able to work more closely with CGDI's web-based infrastructure?

22. Would you or your organization consider being involved in the future developments and improvement of the CGDI?

23. If so, what role do you see your organization play in the CGDI as it evolves? (e.g. as a 'beta tester', or involved in future consultations, or involved in future communication / engagement activities, etc.)

2.6 CLOSING

24. How is the sharing of geospatial information contributing to Canadian innovation and open data science? Can you give an example of new users, integrators of spatial data? (e.g., Polar Data Catalogue, Lake Winnipeg Basin Information Network, etc.)

25. Please describe your top three business/organizational needs and requirements with regards to an operational Spatial Data Infrastructure?

26. Do you have any other points or messages you would like to convey to NRCan in regards of the CGDI (with the understanding that this feedback would be anonymised)? (Use this question to summarize the stakeholder's priorities and wrap up the interview.)

Thank you for participating. Over the next several weeks we will be collating and analyzing the results and will submit a report to NRCan. Please feel free to contact us with questions or comments at any time.

SUPPLEMENTARY QUESTIONS ON THE ARCTIC SDI "LESSONS LEARNED"

1.0 QUESTIONS FOR END-USERS OF THE ARCTIC SDI

1) How often do you use the Arctic SDI?

    a) Annually

    b) Monthly

    c) Weekly

    d) Daily

    e) Never

    f) Don't know

2) Does the Arctic SDI allow you to accomplish tasks that would otherwise be very difficult or impossible to carry out?

    a) YES

    b) NO

3) Do you find that you use any particular products predominantly?

    a) Biota, Farming and Oceans maps

    b) Boundaries, Elevation and Location maps

    c) Economy and Health maps

    d) Imagery/Base Maps/Earth Cover and Geoscientific Information maps

    e) Climatology/Meteorology/Atmosphere and Environment maps

    f) Society, Infrastructure and Transportation maps

4) Do you find that you use any particular services predominantly?

   a) Map views

   b) Map legends and metadata reports

   c) Map layer transparency

   d) My data/embedded maps

   e) Map publishing

   f) Map distance/area measurements

   g) Coordinate view

   h) Search

5) Are there any missing products and services that you would like to see provided?

   a) If so can you please list them

   b) If so, do you already use them, via a source other than Arctic SDI

   c) If so, would they make a noticeable difference in support of your daily tasks if available via Arctic SDI

   d) If so, would you be prepared to pay for certain high-value missing products and/or services

   e) Were you previously consulted about the Arctic SDI for example during the design phase

   f) If so, did you request any products and services at that time

   g) If so, were they implemented and are they currently available

6) How would you describe your user experience when using the Arctic SDI User Interface? (1 = very difficult to use, difficult to navigate, 2 = hard to use, 3 = not hard to use, 4 = easy to use, 5 = very easy to use, logical design and navigation, and robust links)

   Add specific comments if you like

7) Is the Arctic SDI User Guide and supporting documentation helpful? (1 = poor, 2 = insufficient, 3 = adequate, 4 = good, 5 = excellent)

   Add specific comments if you like

8) In your routine work do you encounter any of the following technical problems when accessing via Arctic SDI or other source(s):

   a) Access to a network

   b) Access to/availability of the system

   c) Bandwidth limitations for use of the system

   d) Bandwidth limitations for use of any particular products/services

   e) Latency/timeliness problems

   f) Security restrictions

   g) License restrictions

   h) Blocking of any products/services

   i) Graphical rendering of any products/services

   j) Other (please specify):

9) Does your organization offer any products that you feel would be of interest or use to other users?

   a) Yes

   b) No

      If so, have you investigated how to make it available via Arctic SDI?

         If so, have you encountered any limitations, either technical or logistical?

2.0 FOR ENABLERS/FACILITATORS AND PUBLISHERS (IN ADDITION TO MANY/MOST OF THE ABOVE)

1) Is the Arctic SDI system "easy for developers to work with" (1 = very difficult, 2 = challenging, 3 = similar to many other distributed systems, 4 = easier than most equivalent systems, 5 = very easy)

2) Does the Arctic SDI system design impose restrictions in terms of developing products for the system?

   a) Format requirements on the data to be provided

   b) Metadata requirements

   c) Integration to the system, protocols, etc.

   d) Standards to observe

   e) Other (please specify)

3) Does the Arctic SDI system design impose restrictions in terms of providing its products/services to the users?

    a) Timeliness or latency

    b) Data resolution

    c) Processing needs

    d) Bandwidth and connectivity needs

    e) Other (please specify)

4) Is the Arctic SDI API an asset in terms of developing products/services? (1= poor, 2 = insufficient, 3 = adequate, 4 = good, 5 = excellent)

    a) If so, are there missing API features that you think should be provided

        a. If so, would you be able to develop (some of) the missing features

5) Is the Arctic SDI data model an asset in terms of developing products/services (1 = poor, 2 = insufficient, 3 = adequate, 4 = good, 5 = excellent)

    a) If so, are there missing data model and metadata features that you think should be provided

6) Does your organization offer additional products/services that you feel would benefit the Arctic SDI and its users? (Yes / No)

    a) If so, are there significant barriers that might prevent you offering them via Arctic SDI?

        a. Technical

        b. Regulatory

        c. Political

        d. Commercial

        e. Other: Please specify

b) If so, do you consider that some of these products/services are potentially commercially valuable? (yes / no / maybe)

    a. If so, would you consider offering these products/services under a subscription model? (yes / no / maybe)

PART B – INDIGENOUS COMMUNITIES AND SPATIAL DATA

CANADIAN GEOSPATIAL DATA INFRASTRUCTURE (CGDI) USER NEEDS ASSESSMENT

Part B – Indigenous Communities and Spatial Data

File No. - NRCan-5000034704

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1.0 INTRODUCTION

Geographic information, also known as spatial data, is information about the natural environment, society, and the economy. We need spatial data to help us better understand, plan, and live within our world, from local communities to the global scale. Spatial data help us understand land, water, and natural resources, conduct disaster risk planning, adapt to climate change impacts, and care for the environment. Indigenous peoples have used geographic information for millennia to understand and live in relationship with the world around them, for example, carefully building mental maps of key harvesting areas or safe travel routes. Today Indigenous people, through their governments, associations, and nations may use spatial data in new ways and with new technologies.

The **Canadian Geospatial Data Infrastructure** (CGDI) helps users of spatial data to access and share data and to collaborate. The process to establish the CGDI began in the late 1990s with the aim to help Canadians gain new perspectives into social, economic and environmental issues, by providing an online network of resources that improve the sharing, use and integration of information tied to geographic locations in Canada (GeoConnections 2012).

GeoConnections, a national collaborative initiative led by Natural Resources Canada. GeoConnections supports the integration and use of the CGDI. GeoConnections aims to make spatial data and analysis as widely available as possible to help Canadian citizens, groups, businesses and communities manage the complex social, economic, cultural, and environmental issues of the 21st Century. Phase II of GeoConnections (2005-2010) was mandated to evolve and expand Canadian Geospatial Data Infrastructure (CGDI) by engaging a broad range of end-users across four priority areas including, “matters of importance to Indigenous peoples” (NRCan 2012).

In this context, Hatfield Consultants (Hatfield) led a team of researchers to conduct a **User Needs Assessment (UNA) and User-centered Design (UCD) study** for the CGDI to build upon previous work and understand the current requirements of Canadians who depend on, use or supply geospatial data. This UNA is a continuation of the effort to expand and deepen Indigenous communities’, organizations’, and people’s access to, use of, and engagement with geographic information and CGDI for their benefit.

Study Objectives and Purpose

The objective of the project is to conceptualize, document, frame and develop detailed UNA and UCD studies in terms of:

- Data and services – including land and marine areas.
- Standards – harmonization of standards is fundamental to ensuring the efficient exchange of location-based information.
- Technologies – e.g., applications such as smart agriculture or citizen data.

- Operational policies – practical instruments such as guidelines, best practices, procedures and manuals that address topics related to the lifecycle of geospatial information (i.e., collection, management, dissemination, and use) and help facilitate delivery, access and use of relevant geospatial data.
- Consideration of the context of Indigenous roles and relationships around governance and reconciliation.
- Collaboration, leadership, and governance – complex issues such as Spatial Data Infrastructure (SDI) require collaborative partnerships, leadership, and governance structures.

This study focused on a UNA of Indigenous communities, organizations, and people across Canada. It aims to support the Government of Canada's commitments to Indigenous reconciliation through engagement, communications and capacity building around GDI and Arctic SDI.

The purpose of this report is to provide Natural Resources Canada with insight into the needs and priorities of Indigenous communities, organizations, and people and recommendations for meaningfully integrating Indigenous needs and priorities into the broader effort to strengthen the accessibility and use-ability of CGDI/Arctic-SDI.

Scope and Structure of the Study

The study was completed for Natural Resources Canada (hereafter “NRCan”) under contract no. 3000659567 by a team of researchers led by Hatfield. The research team comprised companies and organizations from across Canada: Strata360, Hickling Arthurs Low (HAL), RHEA, Thorpe Consulting Services, BigSky Consulting, Acosys Consulting Services, and the Centre for Indigenous Environmental Resources (CIER). Financial support was provided by GeoConnections.

The study was structured in two parts, to enable the research team to provide sufficient attention to major stakeholder groups for the CGDI:

- **Part A** – Canadian stakeholders, including federal, provincial, territorial, and municipal governments, academia, private sector, and non-government organizations; and
- **Part B** – Indigenous (First Nations, Inuit, Métis) organizations in Canada, including Indigenous governments, Tribal Councils, Treaty Organizations, Indigenous NGOs/Non-profits, and Indigenous-owned private companies.

This report, “Part B – Indigenous Communities and Spatial Data”, is a companion document to “Part A – Canadian Stakeholders”. This report uses the terms “geospatial” and “spatial” interchangeably with regards to data, services, technologies, practices, and policies.

The report presents the findings of a rapid UNA carried out with Indigenous communities, organizations, and people between January 2018 and March 2018. The report includes a summary of current research and understanding of Indigenous user needs in Canada (Section 2) and an overview of the primary research methods used to gather firsthand information about the specific needs of Indigenous users and uses of geospatial data (Section 3).

Section 4 presents a discussion of research findings and is built around the broad themes that emerged through the course of the research, including:

- Indigenous users and uses of spatial data;
- Indigenous knowledge of, and capacity to use or interact with, CGDI;
- the barriers and challenges that Indigenous communities, organizations, and people face in accessing and using geographic information; and
- Indigenous ideas and priorities with respect to future needs and aspirations to make better use of spatial data.

While much of the report presents a unified discussion of Indigenous user needs across Canada, Section 5 takes a regional approach to explore the geographic breadth and diversity of Indigenous communities, organizations, and people across Canada and to help identify possible regional differences.

Section 6 summarizes key findings and recommendations that emerged from the UNA, which, it is hoped, will help to inform future refinement of CGDI and improvement of its utility and accessibility in Indigenous contexts.

2.0 BACKGROUND AND CONTEXT

Research and documenting current use of, and future needs for, geospatial data in Indigenous communities in Canada has been sporadic. Work has been done in this context, but much documentation focuses on specific projects, mandates, or concerns for Indigenous groups. Since these often involve management and administration of land or marine areas, and undertaking or responding to activities on them, this literature points to information required for decision making even if it is not directly focused on documenting it.

The most thorough study directly focused on geospatial data user needs of Indigenous communities/organizations in Canada is the Makivik (2008a; 2008b; 2008c) assessment of Aboriginal geospatial data needs for land and resource management. This sampled land use plans from ten Métis, Inuit, and First Nations communities from Atlantic, Eastern, Central, Western and Northern Canada. The project objectives were to determine key geospatial datasets required and determine closest-to-source custodians for these.

In addition to recording data priorities among the communities, the project team also documented a set of broader topics related to geospatial data use in the study communities. Topics important to understanding Indigenous use of geospatial data and CGDI are summarized Table 1.

Table 1 Topics important to understanding Indigenous use of geospatial data and CGDI.

Topic	Summary of Past Needs Assessment Findings
Geomatics Capacity	Most communities did not maintain internal geomatics capacity because of difficulties putting in place long term committed funding, training and retaining staff. The report found a heavy reliance on outside expertise.
Use of Web-Based Mapping	Internet technologies such as WMS and WFS were not being used, nor did communities report any need or desire to use these. This was thought to be a result of lack of access to reliable high-speed Internet and limited fluency with computer-based applications.
Locating and Downloading Geospatial Data	Only about half of participants had working knowledge of data discovery portals. Those who did found it difficult to locate and download the data they needed.
Access to Data	Communities reported that up-to-date information from government and industry on resource development was difficult to obtain on a routine basis.
Data Confidentiality and Protocols	Communities were hesitant to release data in absence of information sharing agreements, consultation protocol agreements, and agreements on intellectual property rights.
Cultural Data Inventories	All communities relied heavily on cultural data to inform land use decision-making. Participants indicated the cost of collecting and maintaining the data was high. The report noted wide discrepancies in approaches in methodologies used for the research resulted in studies having differing value for resource management.
Satellite Imagery	Satellite imagery was desired by a number of participants to depict and understand changes in land cover, but was not widely used because of cost and because most groups did not have the technical capacity to analyze raw imagery to identify changes.

Topic	Summary of Past Needs Assessment Findings
Data Format and Standards	ESRI software was used by all participants, and thus shapefile and other ESRI file formats were preferred. [CIER reported similar findings about preferred software platforms in surveyed Indigenous communities (2010).]
Frequency of Updates (Data Currency)	The study found that most of the datasets had not been updated on a regular basis, especially in the communities where GIS capacity is an issue.
Limited bandwidth capacity	Bandwidth limitations represent a real issue and were identified as a barrier to accessing existing geospatial data.

Land use planning and land management are key mandates for many Indigenous organizations in Canada, so the focus of the Makivik needs assessment was valuable. At the same time, Indigenous organizations have other mandates that will or may benefit from geospatial data, hence the broader mandate of the current UNA is an important next step.

Closely related to land use planning and management is preparing responses to requests from the Crown arising from the constitutional duty to consult and accommodate when Aboriginal rights may be infringed (Watts 2014).[13] Accommodations arising from consultations are fact specific (Newman 2009). Because title and rights relate to lands and resources, responses to these consultation requests benefit greatly from the community reviewing geospatial data and understanding potential impacts so that measures allowing them to be avoided, mitigated, and the community to be compensated ("Impact and Benefit Agreements") can be negotiated (pp.9-10). Geospatial data required are similar to themes useful for land use planning including for example: wildlife location, habitat, and migration; fish locations and spawning areas; hydrographic information to predict potential runoff effects; cultural use and harvesting areas; travel routes; and archaeological, ceremonial, and sacred sites. Because time available to respond to consultation requests normally is very limited, and some communities in areas of intense resource development receive a great number, communities need geospatial data to be easily accessible and updatable, and in forms amenable to very quick use.

A key emerging mandate for Indigenous communities is anticipating and planning for climate change impacts. Some observations on geospatial data and technology needs associated with adapting to climate change are summarized in the Table 2. Many of these observations may apply more broadly to communities in Canada, but they are particularly germane to Indigenous people, communities, groups, and organizations.

[13] This process is often referred to by practitioners and staff of Indigenous organizations as "referrals". In this report, we similarly refer to this process as "referrals" or "the referrals process".

Table 2 Summary of climate change related Indigenous geospatial data needs & issues

Issue	Geospatial data Needs and Issues
Monitoring and surveillance of land and marine ecological conditions	There is increasing attention to the value of community-based participatory research in Indigenous communities as a critical complement to scientific and technical knowledge. Some practitioners advocate use of GIS as one platform to synthesize and communicate both forms of knowledge. To advance this, community stewardship of data, access to technology, and training are important (McGetrick et al 2015). Community-based monitoring programs have used GIS to gather and communicate impacts of resource development on species (see, for instance, Herrmann et al 2014).
Utility of information for climate change prediction	An assessment of climate change research projects found that less than half connected objectives with use for decision-making, making it “usable science” (see Ford et al 2013). Climate change modelling information regarding climate change consequences (e.g., permafrost changes or changes in species abundance and migration are important for northern Indigenous communities) but require high technical capacity to undertake. (See, for instance, Castro de la Guardia et al 2013; Nicolson et al 2013; Streletskiy et al 2012.)
Predicting and mitigating climate change impacts-northern communities	Data required for predicting climate change and adaptation planning includes: geophysical information (climate; geology and geomorphology; permafrost and ground ice; sea ice; waves and storm surges); changes in conditions and processes (temperature and precipitation; sea ice; storm intensity; sea level and extreme water levels; permafrost); vulnerability (built environment; semi-permanent trails; health and wellbeing; business and economy; culture and education; subsistence harvesting) (Ford et al 2016). Community knowledge can be a valuable input to understanding local changes to reduce impact (see Andrachuk and Pearce 2010; Carter et al 2017). Traditional knowledge is key to adaptation to changing conditions in the Canadian Arctic, including flexibility, hazard avoidance, and emergency preparedness (Pearce et al 2015). Less ice in the north could make access to Inuit communities easier and create longer shipping seasons. More marine traffic may result in increased economic opportunities for some communities, but it will also increase environmental hazards through oil spills and other pollution incidents. Current climate changes are likely to lead to an increase in exploration and industrial activities. Oil and mineral resource development in the north are expected to increase. Key datasets: mining, oil and gas development, monitoring of impacts Climate change may also impact the tourism industry resulting in a longer tourism season and increased tourism activity. This is likely to result in increased cruise ship activities bringing challenges in the form of impacts on communities, historic resources, and the environment in general.
Predicting and mitigating climate change-east and west coast communities	Sea-level rise is a critical consideration for planning activities in coastal floodplains. In BC, provincial guidelines recommend planning for a 1m se-level rise by the year 2100. LIDAR data and other digital orthophoto data are valuable for estimating local changes such as potential flooding, but these are not available to all communities. (Vadeboncoeur 2016)

Issue	Geospatial data Needs and Issues
	Geographic data on factors affecting slope stability and the impact of intense precipitation events is important, as is information on shoreline stability that may be impacted by extreme storms.
	Pacific Indigenous communities where primary incomes are based on salmonid fisheries are expected to be affected both economically by climate-related declines in commercial catches, culturally and socially by declines in subsistence harvests. Information monitoring tends is important for managing socio-economic impacts.

In a survey conducted by CIER in 2010, respondents identified the following five needs for mapping as the most important motivation to set-up a geographic information system (GIS):

- cultural inventories such as use and occupancy mapping (traditional use mapping);
- consultations with industry and government;
- land use planning
- treaty or land selection; and
- forestry or resource management planning.

Other activities for Indigenous organizations that may benefit from geospatial data include Indigenous-owned business participation in resource development, fisheries, and forestry. For instance, Indigenous participation in the east coast fisheries has grown substantially since the Marshall decisions of 1999, and Indigenous peoples and communities desire growth in their role and decision-making capacity in fisheries management (APCFNCS 1999). The geographic data needs for such activities and roles are likely to be very similar to non-Indigenous organizations, but discovering, accessing, and using data may present challenges that could be addressed by improving CGDI to make geospatial data easier to find and use.

3.0 METHODOLOGY

3.1 USER NEEDS ASSESSMENT APPROACH

The Indigenous UNA involved a literature review and primary research including an online survey (Section 3.1.2) and a series of key-informant, semi-structured interviews (Section 3.1.3). User profiles (Section 3.1.1) were developed to characterize Indigenous communities, groups, organizations, and people that might be current or potential users of geographic information.

To support the primary research and ground the study in broader UNA practice, secondary sources were reviewed including a review of literature with a specific focus on, or related to, Indigenous peoples, communities, issues, and concerns. A fulsome literature review of UNA resources is presented in Part 1 – Canadian Geospatial Data Infrastructure. Highlights from a review of UNA literature that related specifically to Indigenous themes is presented above in Section 2.

3.1.1 User Profiles

User profiles enable researchers to understand and characterize the stakeholders that are current and potential users of a service or system. User profiles were based initially on review of the literature, specifically those described in the GeoConnections publication *Understanding Users' Needs and User Centered Design* (NRCan 2007). User profiles supported the development of survey and interview questions.

Subsequently the user profiles were reconsidered in light of results of the online survey and key informant interviews. Three overarching user profiles were identified:

- **Publishers** act as curators of geospatial data of specific interest to their constituency and can develop and share geospatial content and tools within their mandate. They have the right to share geospatial data within their organizations, or among a group of organizations, or with the public, or a combination thereof. The method of publishing data varies and may include development of web applications.
- **Enablers/Facilitators** encompass organizations providing frameworks that promote or facilitate the wide utilisation of geospatial information by user groups. Such frameworks may be of technical nature (e.g., a web-based application that enables users to access geospatial information), of regulatory nature (e.g., guidelines on geospatial data standardisation, or open data policies), of administrative nature (e.g., acting as a moderator of users, or as manager of user privileges), or of financial nature (e.g., provision of funding to support the development or use of geospatial information).
- **End-users** utilize geospatial data in decision making or in business and rely on applications to produce usable outputs. For example, end-users for soil information could include farmers, gardeners, researchers, scientists, municipal government officials, and staff responsible for preparing soil reports.

3.1.2 Online Survey

Quantitative user needs information was captured in a 34-question online survey aimed at Indigenous organizations across Canada.[14] The survey utilized multiple choice and Likert rating questions to characterize the following (the survey questions are presented in Appendix B1):

- Characteristics of users and organizations
- Overall capacity of organizations to produce, utilize, acquire, and share spatial data and spatial data products
- Key activities performed by users, using spatial data
- Current use of spatial technologies
- Current sources of spatial reference data and primary spatial data
- Data management, distribution, and sharing policies and practices
- Familiarity with CGDI and associated tools and policies
- Key barriers and challenges to acquiring, using, and integrating spatial data into users' key activities
- Anticipated future uses of spatial data

In order to accommodate a diverse population of potential respondents with varying knowledge and capacity regarding CGDI and SDI, the survey questions referred to spatial data and/or geospatial data as "geographic information". These terms are used interchangeably in this report.

The project team approached a total of 200 organizations using purposive and snowball sampling. Organizations were first selected to participate based on the research team's network and professional experience. Organizations were then added based on recommendations from those who filled out the survey and/or participated in the interview. A total of 99 surveys were completed.

The survey did not, and was never intended to, capture a representative sample of Indigenous organizations in Canada. This was due firstly to the project's limited timeline, and secondly, to the complexity in identifying the overall study population and sampling for proportionality among different types of Indigenous organizations. The survey results are indicative but should not be regarded as statistically significant.

The survey was developed on the Survey Monkey platform and delivered via an e-mail link with an introductory letter explaining the objectives of the project, composition of the research team, what spatial data are, and how organizations might benefit from participating (see Appendix B2). Invitees received reminders either via phone or email to encourage their participation. Personal/professional connections were used as much as possible to increase participation. Two-days before the survey was to be closed a

[14] The project team has deep understanding and experience in consultation and engagement with Indigenous people/communities/organizations across Canada. Indigenous communities in Canada have unique rights, interests and circumstances. Our approach was designed to balance the timeline of the project and our commitment to respectful and effective engagement with Indigenous governments, communities, and organizations.

blanket email was sent to all potential respondents in the assembled database. The blanket email elicited both positive and negative results as it prompted some people to complete the survey before its impending closure. Others retracted prior agreement to participate in the study citing insufficient time to contemplate the value of this project in relation to their interests and internal resourcing or capacity constraints.

3.1.3 Interviews

Based on an initial assessment of key communities and organizations and past experiences conducting UNAs, the research team developed semi-structured interviews to gain deeper and more detailed insights into user needs (Appendix B2). Building on data collected in the online survey, semi-structured interviews focused on the following elements:

- Validating user profiles identified in the literature review and survey results;
- Gaining further details on an organization's barriers and challenges to acquiring, using, integrating, or sharing spatial data;
- Understand the spatial data, tools, policies, and processes that would add value to the organization's work; and
- Identify opportunities for collaboration and capacity building.

Interviewees self-selected by indicating their interest in doing an interview and providing contact details in the online survey. In total, 44 interviews were conducted. In one case, an interviewee was contacted for a survey reminder and opted to partake in the interview instead of the survey.

3.1.4 Research Limitations

The research process for this UNA was limited by a number of factors. We discuss these in further detail and provide recommendations for next steps in Section 6.0.

The short timeline of the project presented substantial constraints for identifying and screening participants, developing and testing research tools, and collecting and analyzing primary data. For efficiency the project team focused recruitment efforts on Indigenous communities and governments with whom there were pre-existing relationships or contacts. Some cold calls were made, but in the end the assessment the assessment had very limited participation by certain groups, for instance Indigenous businesses, non-profits, and associations. Most significantly, the project's timeline limited the team's ability to engage with Indigenous organizations in a manner that accommodates varying schedules and resources, availability, timelines, and engagement protocols. As such, the overall response rate was 48%. The results of the assessment are not statistically significant, nor are they representative of diverse Indigenous organizations across Canada.

The needs of Indigenous organizations related to SDI are wide ranging and diverse – as are the sizes, jurisdictions, and technical and administrative capacities of the organizations themselves. The scope and timeline of the project was not conducive to fully characterizing the variation among Indigenous organizations who might engage with the CGDI, and how that variation may influence the way they interact with spatial data, technologies, services, and policies. While the findings provide general insights into user

needs and consolidate and build upon past work in this area, the project team was not able to validate findings via workshopping or review by study participants. As noted in the recommendations in Section 7, this is a crucial next step in fully understanding the needs of Indigenous organizations and communities as CGDI users.

Finally, the project team notes that the awareness and conceptual understanding of CGDI among participants was low. Therefore, fully capturing how CGDI might contribute to fulfilling the mandates of Indigenous organizations was challenging. Rather, the assessment focused in on specific aspects of CGDI such as production and consumption of spatial data, technologies and technical capacity, data sources, services, and data management and sharing policies.

4.0 ANALYSIS AND RESULTS

4.1 HOW ANALYSIS IS ORGANIZED

Many strong and consistent messages emerged from the online survey and the interviews. The analysis is organized around four themes as follows:

- profile and characteristics of Indigenous users (Section 4.2);
- current knowledge and use of spatial data and technologies of Indigenous groups (Section 4.3);
- key barriers and challenges to the use of geospatial data and CGDI (Section 4.4); and
- future aspirations and plans of Indigenous users that require spatial data (Section 4.5).

These sections focus on what was said, what the research team heard and learned from their engagement with Indigenous groups and representatives, unfiltered (as much as possible) by the technical language and assumptions of CGDI. In Section 4.6 many of these findings are revisited in a thematic summary in accordance with a series of recognized aspects of CGDI/SDI as presented in NRCan (2017).

4.2 INDIGENOUS USERS AND USES OF SPATIAL DATA

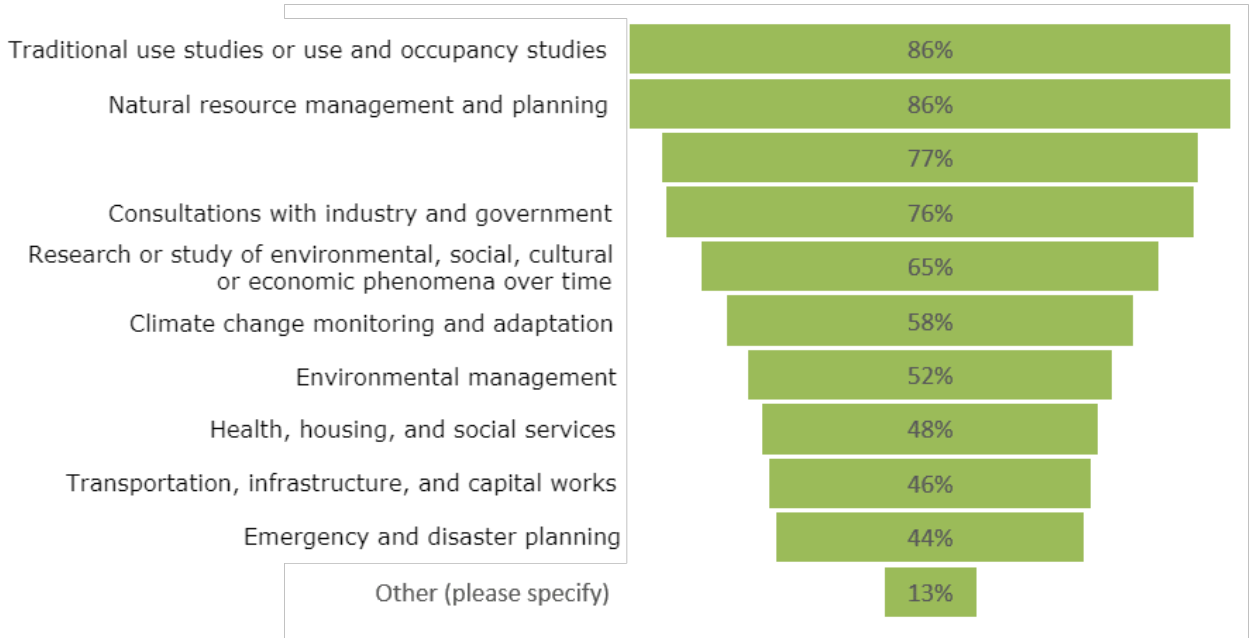
Characteristics of Potential Users

Survey respondents consisted mainly of individuals in Land, Environment, or Natural Resource Management roles. These accounted for more than half of respondents, followed by GIS or Geographic technicians (approx. 25%) and Managers or Coordinators of Geographic information (14%).

There is substantial variation in Indigenous organizations, communities, and groups that use geospatial data in terms of size, type, jurisdiction, treaty status, and other. The size of Indigenous organizations that were engaged with varied widely, ranging from 5 to 600 staff members. Most respondents identified as an Indigenous Community and/or Government, as a Tribal Council, or Treaty Organization. Other types of organization, including, NGO/Non-profit, Association, or Indigenous-owned company accounted for only 7% of the sample, although this has as much (or more) to do with the limitations of the research rather than being representative of the full range of types of Indigenous organizations using geospatial data in Canada.

Organizations typically perform multiple functions and represent a variety of members. In general, the work of organizations was broad and encompassed several overlapping and interrelated subject areas. For example, as outlined in Figure 1, most organizations indicated that they were involved in traditional use or use and occupancy studies, natural resource management, land use planning, consultations and referrals with industry and government, and research. Over half of the organizations indicated they were involved in climate change monitoring and environmental management activities (such as flood, erosion and coastal zone management, and weather monitoring). To a lesser extent, organizations were also involved in, health, housing, and social services, transportation and infrastructure, and emergency and disaster planning.

Figure 1 Activities that organizations are involved in (Survey Q1)[15].



Indigenous users are also diverse in their overall capacity for working with geographic information and technologies. When asked to self-identify their organization's capacity for working with spatial data, 41% indicated basic capacity, 28% indicated advanced capacity, and 30% indicated that their organization had little or no capacity, as shown in Figure 2 below. Further, nearly all (approx. 85%) of responding organizations indicated that they used external service providers/consultants for geographic information and services to some degree, to complement internal capacity and fill gaps (Figure 3).

[15] Categorical survey questions typically asked respondents to "check all that apply" as a means to capture the full range of organizations' activities and other features.

Figure 2 Overall capacity of organizations for working with spatial data, self-identified (Survey Q3).

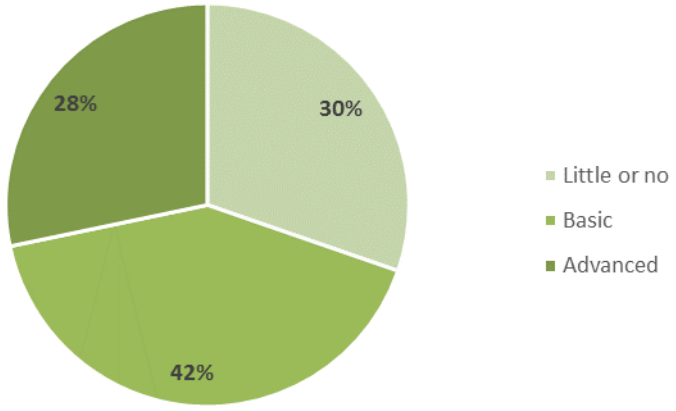
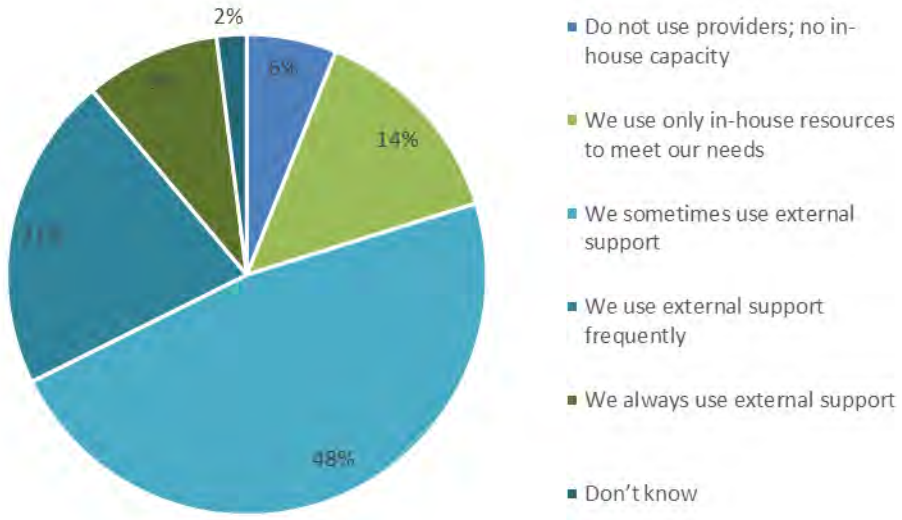


Figure 3 Organizations' use of external service providers for spatial data and services (Survey Q7).



The range in capacity of organizations that were interviewed spanned from those with high capacity with dedicated GIS departments and who rarely use external consultants to those having no dedicated GIS department or GIS staff and limited capacity to meet their spatial data needs in-house. Personnel who worked with spatial data came from a variety of backgrounds: forestry, fisheries, community Traditional Knowledge, administration, Native studies, geography and natural resources, as well as formal GIS training.

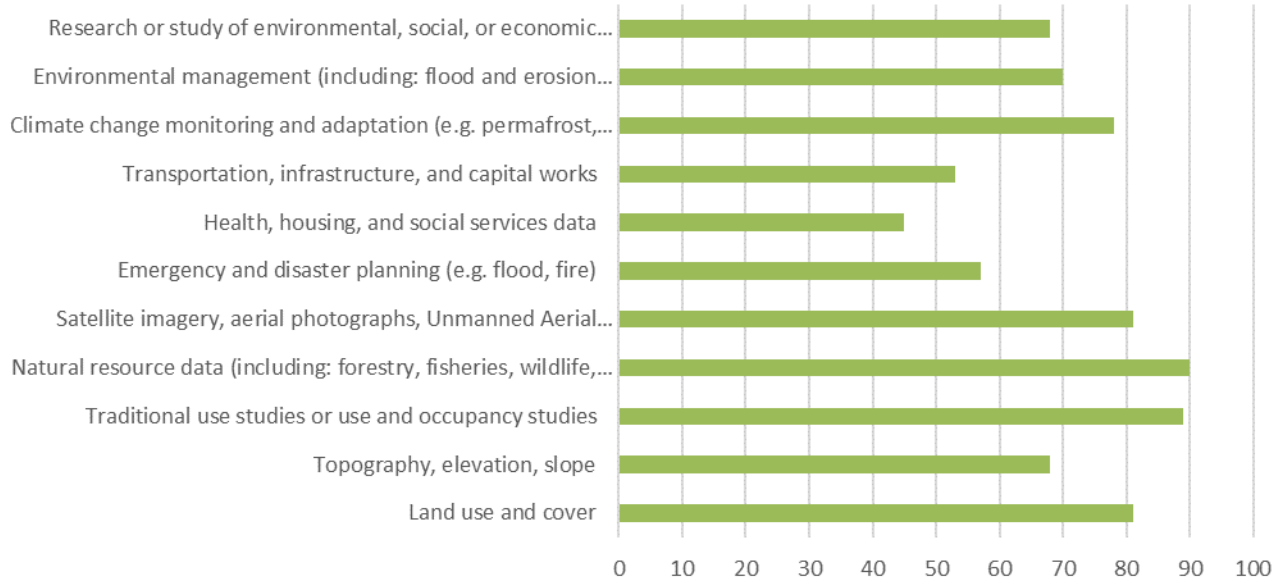
There were extreme differences in capacity between larger organizations with access to more funding and smaller organizations with limited operating bugets. Some organizations emphasized that they often retain external contractors to supplement their geomatics capacity. Where internal geomatics capacity was in

place, it frequently suffered from a lack of personnel, funding, and training to manage the demand for spatial services. Organizations with in-house capacity typically were those that represented multiple Indigenous communities, and Indigenous groups with larger administrations such as Tribal Councils or Indigenous Associations. These organizations sometimes provided spatial data collection, processing, and management services to members and communities. In the case of Treaty Nations where there is often more capacity in general, resourcing for geomatics nevertheless competes with other budget priorities.

Spatial Data Priorities

Respondents were also asked to identify the importance of different types of geographic or spatial information that would add value to their organization's work. This is summarized in Figure 4 below. Most organizations indicated that all types of geographic information would add value. Information on natural resources (forestry, fishers, wildlife, water, etc.), traditional use and occupancy studies, land use and cover, satellite imagery, climate change monitoring and adaptation (such as permafrost, ice cover, and sea level rise), and environmental management were most frequently identified as important or very important. In contrast, geographic data on health and housing, social services, and transportation/infrastructure were of less importance.

Figure 4 Types of geographic information identified as *important* or *very important* (Survey Q2).



Interviewees provided further detail on the activities for which they frequently use spatial data. These activities are aligned with the findings of past UNAs conducted in 2010 (CIER, 2010), and included:

- Consultations and referrals for proposed developments that overlap with traditional lands and territories.
- Treaty negotiations and court cases.

- Traditional use and occupancy studies or internal documentation of Traditional Knowledge.
- Primary or 3rd party environmental field data collected by community members or contractors to support environmental monitoring and management and climate change adaptation. Specific reference was made to habitat and species assessment and ecological restoration by several interviewees.
- Creating and implementing land use plans.
- Natural resource management.
- Community planning.

Importantly, several interviewees also indicated that the consultation and referral processes with government agencies and/or project proponents consume a substantial amount of their spatial capacity and staff time. With industry and government beginning to place more emphasis on the duty to consult, some Nations are facing overwhelming pressure on their administrative and land management departments to respond to consultation requests. This leads to the bulk of spatial expert's resources being used for reactive activities, such as responding to referrals, rather than proactive activities such as engaging with their own data and addressing other priorities such as land use and environmental management planning.

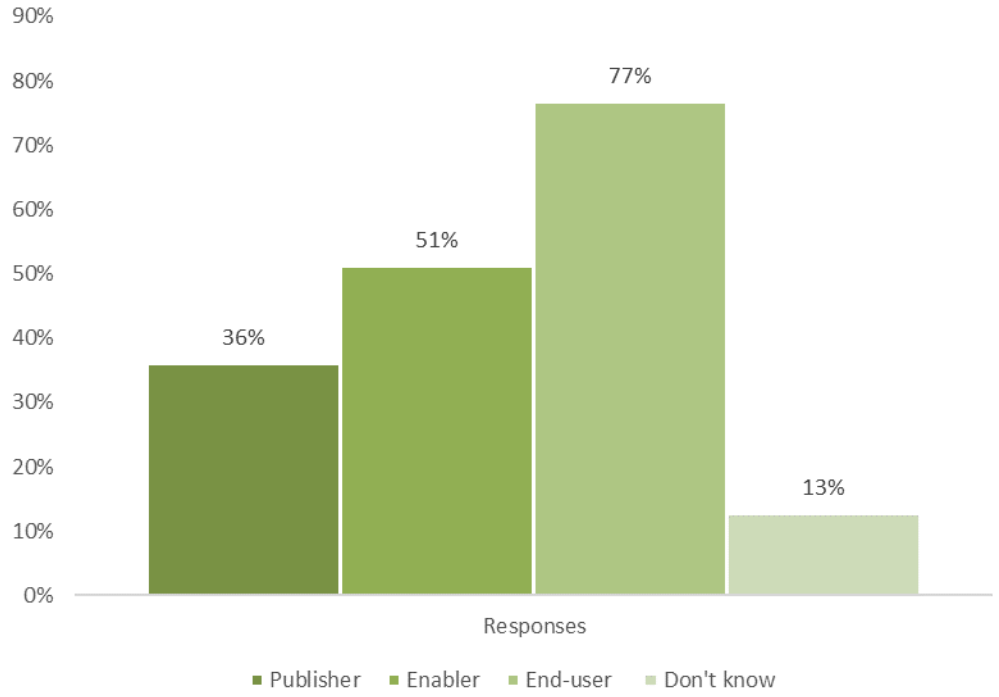
When asked about specific types of data that were important to organizations at this point, interviewees mentioned: baseline land use and environmental inventories to help communities make decisions and understand different interests involved in land use; locations of emergency services and associated transportation routes, as well as residential address information to help locate members in the event of an emergency; and cultural information produced and maintained by community members.

User Profiles

One of the priorities of this UNA is to better understand the CGDI user profiles of Indigenous organizations. While the scope of this assessment does not involve characterizing the proportions of different types of Indigenous users across Canada in a representative manner, it does provide insight into how often organizations perform activities that are associated with different user profiles, and therefore builds a deeper understanding of the needs of different user types.

In the survey, respondents were asked to identify their organization as end-users, who primarily download and consume geographic information, enablers/facilitators, who support or promote access to and use of geographic information, and/or publishers, who produce and share spatial data. While many organizations identified as more than one type of user, most identified themselves as end-users (76%), followed by enablers/facilitators (51%), and publishers (36%), as outlined in Figure 5 below.

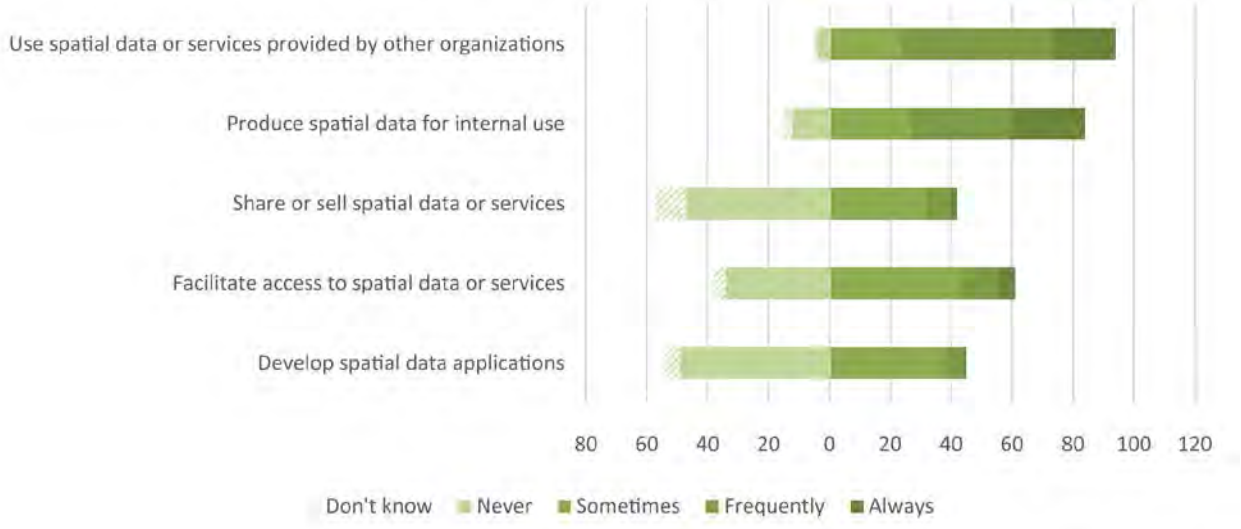
Figure 5 Self-identified User Profiles (Survey Q27).



In terms of different types of user activities, organizations indicated that they most often used spatial data or services provided by other organizations (for example, downloading maps and datasets) or produced their own spatial data or services. In addition, some respondents indicated that they sometimes facilitate access to spatial data or services (for example, by administering or coordinating a database). Few organizations reported that they were involved in sharing or selling spatial data or developing spatial applications for online, mobile, or desktop use (Figure 6).

These findings were echoed during interviews, with many interviewees indicating that they download and consume third party data for use in-house and also produce data for sharing with limited external parties. Interviewees did not often identify as publishers because the data they produced and shared was typically project-based or made available only to a specific audience (such as community or band members, consultants, or Provincial/Federal governments). While several interviewees reported that their organization maintained a spatial database in some form, it was often only for internal use.

Figure 6 Frequency of different user activities (Survey Q6).



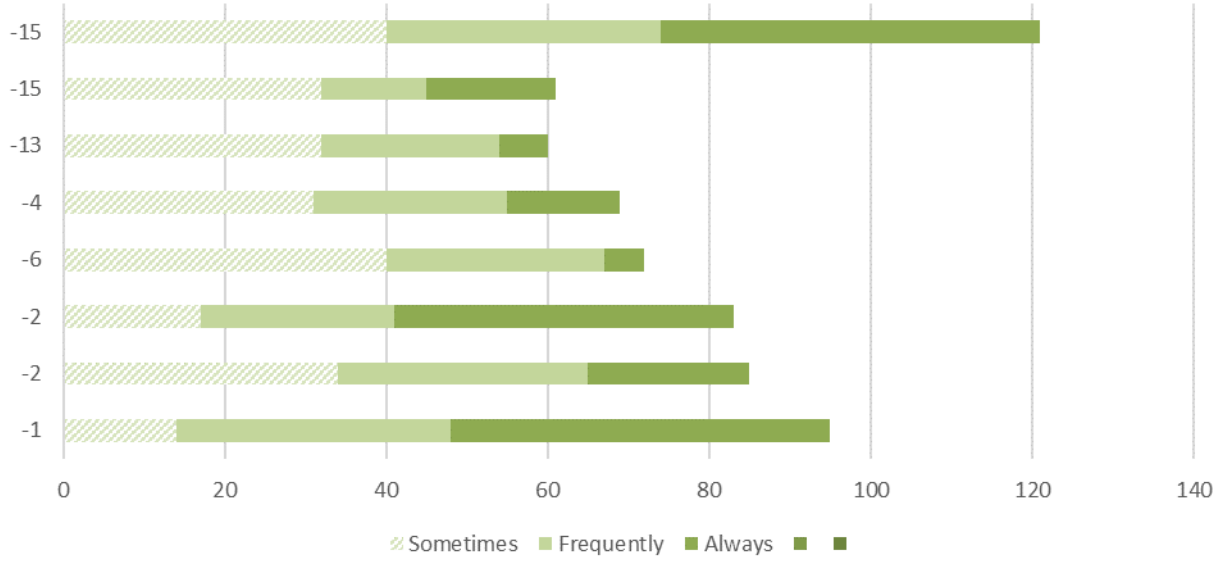
4.3 KNOWLEDGE AND USE OF SPATIAL DATA AND TECHNOLOGY

In the survey, organizations were asked to describe the spatial data, technologies, and data management and sharing practices that they currently utilize to support their work.

Technology

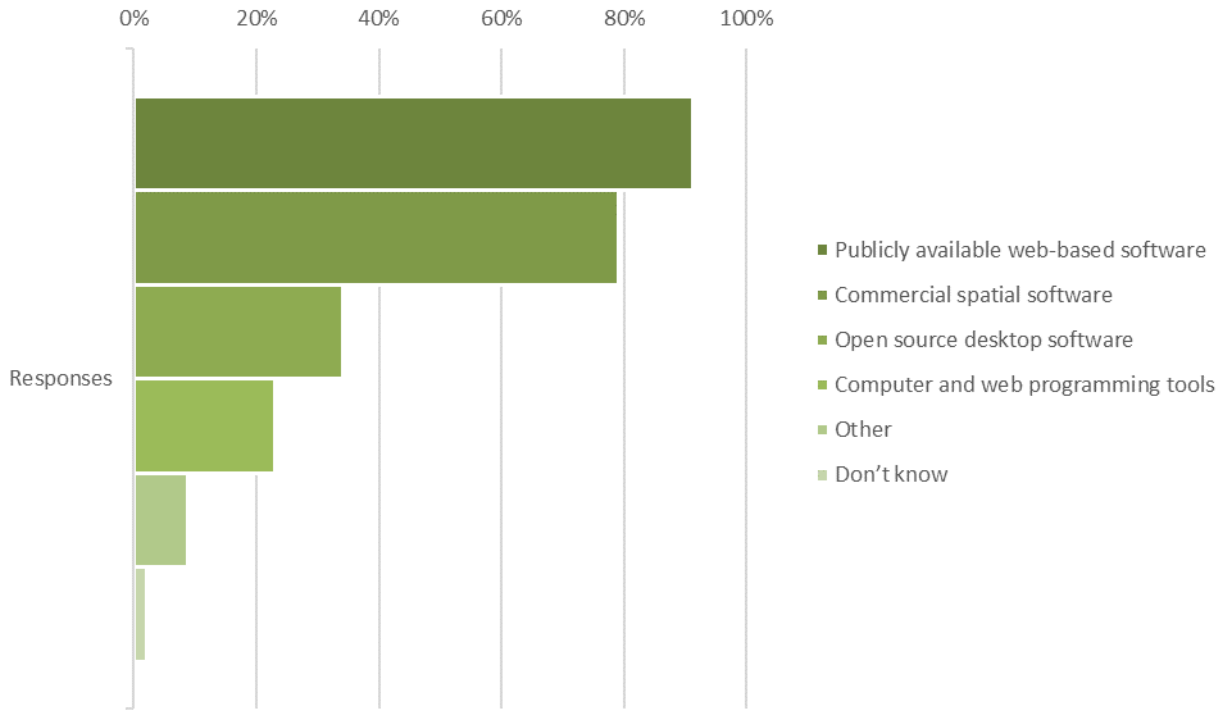
Most responding organizations indicated that they *frequently* or *always* use spatial technologies such as digital maps, global positioning systems (GPS), and GIS, as shown in Figure 7. Organizations use remote sensing technologies and are involved with administering spatial databases less frequently. Few are involved with programming or creating web mapping applications often. Interestingly, nearly half of respondents indicated that they utilize SDI at least sometimes, while in interviews, many respondents found it difficult to conceptualize SDI or describe how they interact with it. We discuss this finding further in Section 6.0.

Figure 7 Use of Spatial Technologies (Survey Q4).



The survey asked respondents to indicate the type of software systems they use to work with spatial data (Figure 8). Most organizations use a combination of publicly available web-based software such as Google Maps, Google Earth, Bing Maps, Open Street Map, or Apple maps (over 90%), and commercial spatial software such as ArcGIS, PCI Geomatica, Global Mapper, Erdas Imagine, Trailmark, or ENVI. (79%). Other less-frequently utilized software systems were open-source desktop systems such as QGIS, Grass, and SAGA. Few respondents indicated that they used computer or web programming tools such as Python or C# for working with spatial data.

Figure 8 Use of spatial software programs and systems (Survey Q12).



Sources of Data

Indigenous organizations use spatial data from a variety of sources, focusing mainly on downloading or accessing spatial data from free, publicly-available sources. About 30% of organizations indicated that they sometimes purchased data. Interviews revealed that datasets that are purchased are typically specialized remote sensing data such as LIDAR and UAV photography for specific areas at specific spatial resolutions as they are typically more current than publicly available data.

The most frequently used sources, as shown in Figure 9, were data obtained from Provincial data repositories (for example, Data BC) or Territorial government databases, followed by data produced in-house from field observations or local/traditional knowledge. Organizations also accessed spatial data from Federal government repositories such as Open Data. Where important datasets are not available, some organizations obtain them via specific requests to government agencies. In some cases, Indigenous organizations have formed reciprocal arrangements with municipalities or other governments to share or access data, but this largely depends on a strong working relationship between the parties.

Respondents also indicated that they sometimes obtain spatial data from private companies and consultants and academic institutions. Most organizations reported that they sometimes obtained data that was shared by other Indigenous organizations.

Figure 9 Sources or providers of spatial data (Survey Q8).

Interviewees were also asked about what documentation and metadata was important in relation to the datasets that they accessed or acquired. For organizations that produced much of their own spatial data through primary collection and in-house analysis and processing, documentation was not a major concern as they were familiar with the datasets. Other organizations that relied more heavily on third party data cited the importance of accompanying documentation and metadata, including:

- Date of collection or currency of datasets
- Data dictionaries or other appended coding documents
- Attribute table field name and value descriptions
- Contact information to field inquiries about the dataset

Data Management and Sharing

As part of assessing knowledge and capacity in relation to SDI and CGDI, the survey and interviews inquired about organizations' data management and sharing policies and practices. Nearly 70% of organizations indicated they share some spatial data that they have collected or otherwise own. This data was shared internally (with member communities – e.g., in the case of Tribal Councils – and within the organization), with other Indigenous organizations and communities, and externally with non-Indigenous parties.

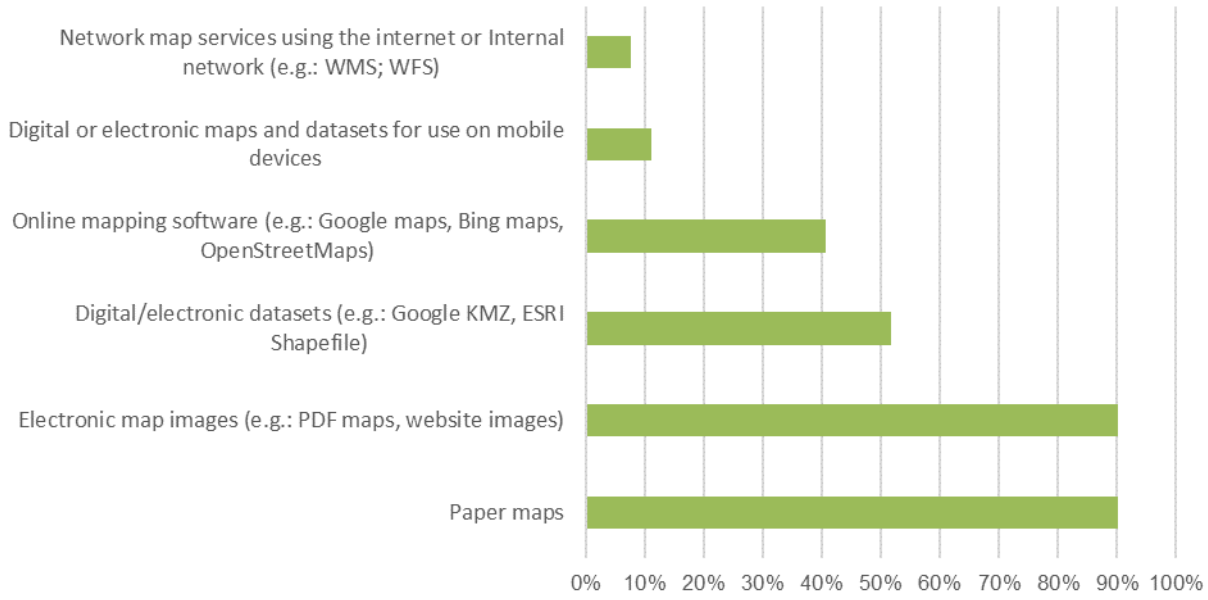
Organizations indicated that they shared spatial data and information with a variety of parties. Most often, data were shared with decision-makers within Indigenous governments, Indigenous Elders and community members, and consultants hired by or working with the organization. Information was also frequently shared with Federal, Provincial, or Territorial governments, partners and collaborators (such as NGOs and

conservation organizations); and sometimes shared with Indigenous or band-owned businesses and other (external) Indigenous organizations. Respondents indicated that they least frequently shared information with private companies and academic institutions.

Several survey respondents and interviewees noted that their practices for sharing geographic information depended on the type of information and the party with whom they were sharing. For example, some organizations stated that they would openly or on request, share non-sensitive spatial data such as land use plans or environmental monitoring data. However, data pertaining to Traditional Ecological Knowledge or Traditional Uses were not often shared or distributed outside of the band or organization. This was mainly linked to concerns about privacy and confidentiality. Some interviewees indicated their willingness to share sensitive information with government as part of broader negotiations and assertions related to Aboriginal rights and title issues. They were typically much less inclined to share sensitive information with industry.

Approximately half of survey respondents indicated that their organization had a policy or procedure to govern the sharing or distribution of spatial data. Some interviewees noted that their organization employed data sharing agreements when working with external parties or agencies. In general, data sharing agreements were perceived as important to organizations maintaining sovereignty and control over information, and in turn, their willingness to distribute or share spatial data.

Figure 10 Methods of communicating or distributing spatial data to intended audiences (Survey Q21).



Spatial data were most frequently shared as a finished product, using paper and electronic map images (e.g.: PDF maps, website images) by over 90% of organizations (Figure 10). About half of organizations also shared spatial data as full electronic datasets, such as KMZ or shapefiles; and about 40% also shared via online platforms such as Google maps, Bing maps, or Open Street Maps. However, few organizations reported that they shared digital maps and datasets formatted for use on mobile devices. Less than 10%

indicated that they used online or internal networked services such as Web Mapping Services (WMS) and Web Feature Services (WFS).

Nearly all interviewees reported that they use ESRI compatible formats (i.e., shapefiles, geodatabase, file geodatabases) for storing and sharing spatial data. Other commonly used formats were Google Earth KML or KMZ files, and GeoTIFF. Interviewees from some rural and northern areas indicated that in some cases, final product paper maps, PDFs or electronic data tables were the only means of distributing spatial data due to limitations in their access to the internet, adequate bandwidth, and/or suitable computer hardware and software.

Knowledge and Use of CGDI

Most survey respondents (77%) were not familiar with CGDI tools and standards. Of the small group that had some familiarity with CGDI, several organizations indicated that they currently used some CGDI data content, tools, or standards as part of their GIS, including metadata standards, Google KML, and WMS/WFS.

Interviews echoed this finding, revealing a general lack of knowledge and understanding of CGDI/SDI and associated standards and policies. Some interviewees indicated that they saw value in having standards and sharing data. They recognize that CGDI/SDI is a potentially valuable tool but nevertheless see developing local capacity as a higher priority. There is a basic knowledge of different websites "out there" where spatial data can be uploaded or accessed, but in general the lack of detailed knowledge of what is available appears to remain a barrier to greater use of CGDI/SDI. Similarly, the dispersed nature of many data sources is also seen as a persistent barrier to wider use by Indigenous groups. Nonetheless, several organizations did report taking steps to integrate some form of external data standards already, including the Vegetation Resources Inventory data standards (BC), the Open Geospatial Consortium standards, and the Canadian Geographic Information Standard.

Interviewees were generally enthusiastic about the implementation of stronger and more streamlined data standards for the data they consume, and about adopting standards for their own spatial data works moving forward. However, interviewees noted that several barriers remain, for example: (i) transitioning current policies and practices and bringing existing data into compliance was perceived as a difficult and daunting task; (ii) many organizations lack the budget, personnel, and training necessary to make such a transition; (iii) resistance to transitioning spatial data resources to cloud-based servers due to concerns about data sovereignty and confidentiality; and (iv) challenges faced by communities with limited internet access and/or very low bandwidth such as those in remote rural locations, particularly in the north. These are elaborated in greater detail in the following section.

4.4 BARRIERS/CHALLENGES

Multiple overlapping and interconnecting barriers/challenges face Indigenous communities when accessing, acquiring, integrating, using, and sharing spatial data. These hurdles can frustrate and preclude Indigenous peoples' meaningful engagement in managing lands and resources within and beyond their asserted territories. For many Indigenous people, cultural identity is tethered to "the land" (a term broadly used to mean the environment as a whole). This connection to place should be the ideal foundation for a

strong relationship with geospatial data. Indigenous peoples could be contributing to the national and international enhancement of spatial data in unique ways, for example, by contributing thousands of years of traditional knowledge to long-term climate monitoring.

Generally, the barriers/challenges that Indigenous organizations face as CGDI/SDI users are centred around the following key themes:

- Cost
- Capacity
- Data Discovery, and Access
- Data Quality and Usability
- Data Sharing
- Technology Issues

These themes align with what survey respondents and interviewees report as major barriers/challenges including lack of funding, cost, workloads, training, skills and capacity, technology limitations (e.g., equipment, internet issues), data access (e.g., data are unavailable, lack of information on where to find data, restrictions on accessing datasets, lack of content in appropriate language).

4.4.1 Costs

Interviewees frequently stated that costs can be prohibitive when it comes to purchasing data, licenses, equipment (computers, servers, printers, drones, etc.) as well as acquisition and maintenance of geomatics software, hardware, training, salaries and consultant fees.

> *Training, funding, equipment, projects to collect data. Having the ability to stop being reactive and move towards a proactive approach. Definite will and interest in community but a lack of skills, equipment, programs, funding. (Misty Ireland, IRMA Land and Resources Co-ordinator, West Point First Nation, March 9, 2018)*

Data and Software

While most organizations indicated that they could access geospatial data free of charge from government agencies, many indicated that they had limited access to LIDAR, geomagnetic data, satellite imagery, orthophotos, and drone/UAV data, as these are costly to produce or acquire. Organizations also found that the cost of geospatial software and tools was hard to justify. Communities that have commercial software are also using open-source tools. One interviewee explained that basic tools and software often allow communities to meet their needs for viewing geospatial information, running simple queries, and making maps. However, even with free or low-cost, publicly available tools, the need remains for affordable and current data.

> *Satellite imagery. We would access more. I recently explored this and it is very expensive to pull up archival imagery or to get future acquisition. I know there is Landsat stuff but at too [coarse] resolution and communities want a better resolution. Price can get too expensive. Communities would love to have more of that if it weren't for cost (Pano Skrivanos, Senior Manager and Mapper, Inlailawatash Limited Partnership, March 9, 2018)*

Equipment

Most interviewees indicated that cost was a barrier to keeping equipment current. As technologies and spatial data programs evolve, Indigenous communities need funding to stay both relevant and functional. Several interviewees explained that they need new computers and were lacking basic equipment such as printers, and that this challenged their ability to engage with spatial data. Rural and remote Indigenous communities face high shipping costs, which can be prohibitive, in addition to the expense of the equipment itself.

> *Our barrier there is that we don't have a printer. Nobody in town has a printer we can access. We have a hard time printing out large maps to look at. We can only print paper size [letter or legal] or look on computer. We're hoping we can get funding for a printer [plotter] this year to improve our resources better. (Misty Ireland, IRMA Land and Resources Co-ordinator, West Point First Nation, March 9, 2018)*

Personnel

In addition, funding the salary and ongoing training for a person with geomatics skills from the community or recruiting a skilled person to relocate to a remote location with relatively poor salary and benefits were repeatedly cited as significant barriers. Some interviewees expressed deep frustration with this seemingly insurmountable challenge.

4.4.2 Capacity

Interviewees shared that their organizations faced systematic capacity issues that prevented them from developing or scaling up geomatics programs. These were often centred around a lack of long-term funding or appropriate funding schemes, lack of training opportunities, and heavy workloads of personnel who are already required to manage a broad array of tasks.

Funding

According to most survey respondents and interviewees, the root cause of the many cost-related barriers they face is a consistent lack of funding available to Indigenous communities for spatial data initiatives. Despite many recent funding commitments and injections related to spatial data in Indigenous communities ongoing lack of funding and/or predictable funding has been a significant barrier for Indigenous communities. Multiple interviewees shared that when communities are not sure of their budgets from one year to the next, it is difficult to implement long-term strategies for spatial data management. Lands and resource department members, already plagued with heavy workloads and low staff numbers, take time away to prepare funding proposals or report on grant spending, only to begin the process again the next fiscal year. Ironically, these tasks detract from what could be productive time engaging directly with spatial data and furthering Indigenous priorities around land and resource management. Further, when individuals have no idea whether their database will be funded from one year to the next, it makes it difficult to implement a long-term, proactive, innovative and forward-thinking program. When funding is offered late in a fiscal year with the requirement that it is spent in a narrow window, long-term planning becomes even more unobtainable.

> *There is a huge cost that is prohibitive. There aren't many funding sources. I convinced our Board to support the Community Mapping Initiative, but we are limited in what we can provide. Our constraints finance-wise are largely capacity constraints. We don't have the personnel to even work on proposals, reports, etc. We can't even wrap up projects because we don't have the technical people. Not enough who are community engaged types. Those people are super in demand and then they get burned out. (Deb Simmons, Executive Director, Sahtu Renewable Resources Board, March 14, 2018)*

The majority of interviewees and survey respondents spent significant amounts of time elaborating on the challenges associated with lack of funding. Many interviewees explained that often funding for geomatics related work was project based, creating situations wherein significant geomatics capacity could not be maintained long term. This encourages the use of contractors and creates "patchwork datasets" that are not integrated, in some cases not even managed by the Indigenous organization and not directly accessible.

Training Opportunities

Although cost and lack of funding are reported to be barriers to training, there are several additional challenges to training staff in Indigenous organizations. Meaningful engagement with spatial data necessitates that users are trained on an ongoing basis. Indigenous organizations need to keep current with ever-changing software and hardware as well as data sharing and management protocols. Thus, even when cost is not a barrier to acquiring equipment or technology, it can still be a challenge if training funds are not allocated to support ongoing and long-term capacity building.

> *Sometimes communities have licences, but don't use them: no time or capacity. Many times I go somewhere, and people have been paying licence fees for years but are not using them. Other times it is skills or capacity that is the biggest barrier. I do a lot of training and try to promote the easier use tools like Google Earth and iMap BC because people can pick them up quicker and greater chance they will still with it. If you train in ArcMap you quickly forget unless you are using the program all the time. People getting trained don't have the background in GIS and don't necessarily understand the intricacies in GIS. It takes years to be trained to be a GIS person. People want to use these data and don't have this background. (Pano Skrivanos, Senior Manager and Mapper, Inlailawatash Limited Partnership, March 9, 2018)*

Several interviewees report that it is difficult to find qualified staff to work full time and willing to travel for training because there are few capacity building opportunities available in rural locations. Online training can be a solution, but one that can sometimes be isolating, lonely and frustrating for the users.

> *Finding the time to sit down and learn about the licence, how to use it to the best of our ability. At the same time, I am busy doing a hundred other things. It's hard to sit down and focus on just learning. Nice to take a course once in a while but you don't get the hands-on training. I can take a one-week course and show me data I would use the spatial analyst for and sure I can use it. But I don't have five years experience and make that transition to learning it. I'm the GIS guy and if I leave in five years, all of that is gone. Would be nice having somebody training with me. I have nobody here to fall back on to smash two heads together to come up with a solution. Primarily me just finding a solution. If somebody else here had the knowledge, two of us together would be a lot easier. (Henry Tambour, GIS Technician, K'atl'odeeche First Nation, March 12, 2018)*

When trained staff leave, so too does their capacity. Where funding is long-term and access to training is prioritized, Indigenous communities can plan for fail-safe and sustainable capacity-building.

Heavy workloads

Many respondents lamented the heavy workloads faced by staff members in Indigenous organizations. Often, staff are required to carry out multiple diverse tasks and hold various responsibilities, sometimes beyond their training or job descriptions.

> *People aren't doing this kind of work as their only job sometimes. Making maps off the side of their desk. Internal capacity is a real challenge. (Pano Skrivanos, Senior Manager and Mapper, Inlailawatash Limited Partnership, March 9, 2018)*

> *Without core funding, it is difficult. I'm the whole Lands and Resource Department and I work 30 hrs/week. I'm it! We are really under-resourced, especially here. (IRMA Land and Resources Co-ordinator, West Point First Nation, March 9, 2018)*

Often there are troves of historic information that has yet to be digitized. Traditional knowledge and land use data remain on cassette tapes and brittle mylar overlays in the storage rooms of Indigenous organizations across the country. Many respondents cited the need to process information into a usable geomatics format, but the inability to find the time, funding, and personnel to do so.

4.4.3 Data

Data Discovery and Access

Accessing desired geographic information is difficult for several reasons. In many cases, interviewees suggested that they don't know what is available or what exists. It is challenging to know who holds, owns and has access to data. In the words of one interviewee, "we don't know what we don't know."

> *The other barrier is not knowing what our needs are. For example, mapping programs compatible and skills to use those types of programs. Not knowing what we need is most significant. (Misty Ireland, IRMA Land and Resources Co-ordinator, West Point First Nation, March 9, 2018)*

Many interviewees complained that there are many datasets but a lack of information on where to find the data and too many competing repositories. Interviewees well versed in spatial data explained that even with their training, it was difficult to keep up with understanding all the data available to communities.

> *There are 1000s of datasets in a system but you have to know what you are looking for first before you go there. Otherwise there is just so much information. I wish there was a better system, an index of something, so they could look up a theme and have a list of all the datasets associated with forestry and then pick and choose what they want. (Pano Skrivanos, Senior Manager and Mapper, Inlailawatash Limited Partnership, March 9, 2018)*

While some interviewees praised NRCan and other federal, provincial/territorial and municipal governments for their online systems and the ease at which they were able to access and download data, other individuals lamented the lack of a one-window approach and staff that were not knowledgeable about available data even within their own organization. One interviewee was particularly frustrated that systems for accessing data kept changing on federal websites requiring the users to repeatedly learn a new system.

Several interviewees mentioned that some data relevant to both marine and terrestrial ecosystems simply did not exist.

As elaborated earlier, many interviewees do not have the capacity or resources to access data. Further, they may have limited or no knowledge of CGDI/SDI.

> *We are nowhere near the point of accessing data. We are barely able to keep on top of incoming applications. This is where our program is at today. Struggling to connect with funding agencies and researchers who would work with us to do the other things we want to do (e.g., baseline data on water quality, monitor well heads). The dream is to have three people on the land overseeing these kinds of things. There is a resurgence of mining near Pine Point, mining activities are winding up, concerns about the flow of groundwater and the quality of the water flowing under, near and past us. Is it going to change? Will it remain healthy? This is a community priority right now. They want data set up in their areas of interest now so that 10-15 years from now when mining is winding down we can cross reference to that data. (Misty Ireland, IRMA Land and Resources Co-ordinator, West Point First Nation, March 9, 2018)*

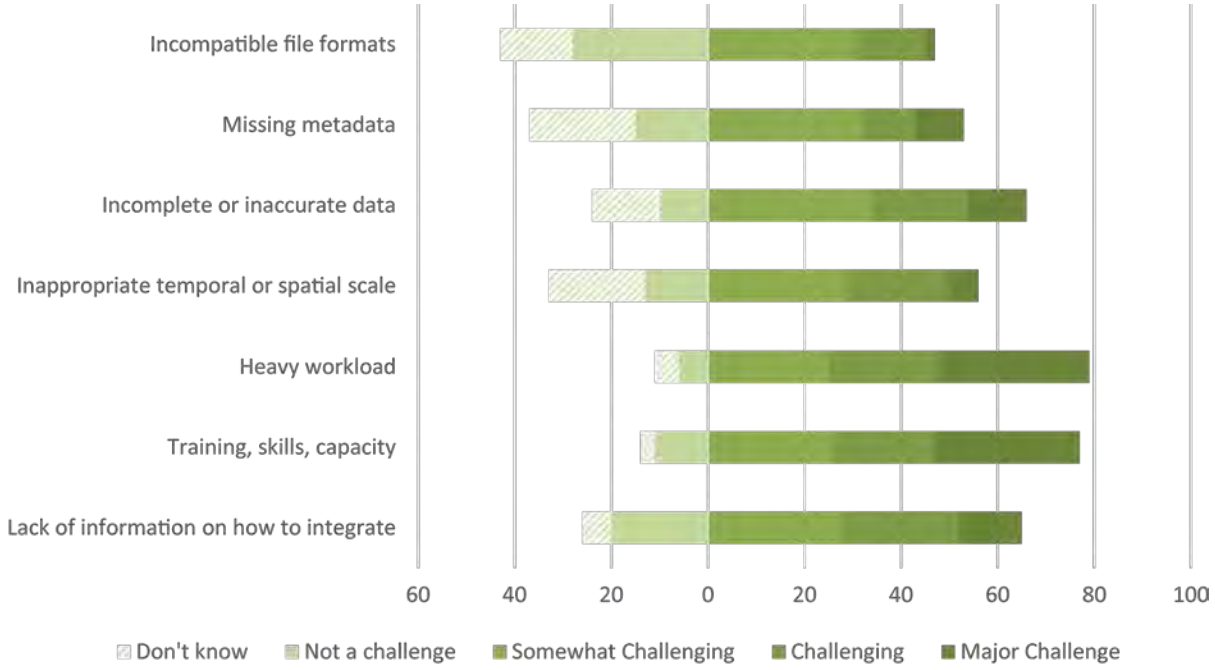
Organizations also sometimes struggle to obtain data that is relevant to – or in some cases, owned by - them from the private sector can. Several interviewees spoke of frustrations with this. In some cases, data collected by industry has not been returned to or shared with the community. This can happen when a proposed project runs out of capital or decides not to proceed with an environmental assessment and thus fails to follow through with commitments around data sharing negotiated at the outset of the work. In cases where a project or development moves forward, several interviewees spoke about difficulties in accessing spatial data (e.g., baseline data) related to privately-held lands. Industry can hold proprietary information that is relevant to Indigenous organizations but may not share it at all or in a useful format. Currently, there are no regulatory imperatives that require this. Some interviewees explained that the lack of cooperation on both sides leads to information typically being exchanged in PDF format rather than spatial format. Others stated that government or other stakeholders sometimes use data sharing as a negotiating lever to demand community data.

> *We have access to Crown Land and Toquaht-owned land but not for private property. It is harder to get that information. If we are doing a referrals response, it would make it easier. Some of the privately-owned forestry companies don't like to share their data. That can be a challenge. (David Johnsen, Manager of Resources and Public Works, Toquaht Nation, March 12, 2018)*

Data Quality and Usability

Finding authoritative, current and complete information is often a challenge for Indigenous users. Publicly accessible data can sometimes be considerably outdated, generally more than private data. Survey results indicated that incomplete or inaccurate data was challenging for them (Figure 11). In particular, interviewees cited provincial data and orthographic imagery as outdated. Data that do not reflect current resources, roads, trails, etc. undermines Indigenous organizations ability to carry out tasks that depend on accuracy (e.g., land use or community planning, referrals, etc.).

Figure 11 Challenges to integrating spatial data into projects or activities (Survey Q11).



Several interviewees commented that spatial coverage is often limited or, in instances where the coverage is considered complete the resolution is too poor to be useful.[16] One interviewee elaborated that there may be an agreement with government for parcel fabric with PID numbers, and although an organization will receive land disposals, there are no PID numbers provided with disposals.

> *Metadata is also difficult to access. There is a crisis of metadata in the world when it comes to GIS. What is the story about the data? . . . It has been a huge challenge how to interpret that map. It is a guessing game in some cases. (Deb Simmons, Executive Director, Sahtu Renewable Resources Board, March 14, 2018)*

A frequent problem cited in interviews was that thematic data, when obtained, collected, or inherited, were in a "raw" form which would require significant processing to turn into useful information for decision makers. Barriers to accomplishing such analysis (discussed in detail in the Capacity section above) include in many cases a lack of expertise in the thematic subject. One respondent for example, trained in wildlife biology and geomatics, needed to assess the possible impacts of climate change on marine stocks and behaviour in the Hudson Strait. He was able to access a large amount of raw historical data on sea ice coverage, but unable to process the raw data into sea ice coverage projections as this was not his field of expertise. In this case and many others, respondents pointed out that the problem was not the lack of data but rather the lack of useful processed data and/or opportunities to collaborate with subject matter experts to help support decision making.

[16] One interviewee elaborated that there may be an agreement with government for parcel fabric with PID numbers, and although an organization will receive land disposals, there are no PID numbers provided with disposals.

Sharing Data

Sharing data either internally or externally can be fraught with challenges. These include: technical barriers such as lack of capacity to integrate spatial data, incompatible file formats or limited bandwidth; institutional barriers such as poor communications between departments, siloed teams/infrastructure, or over-worked staff; and, more intangible barriers such as lack of trust or a legacy of external parties appropriating and misusing data.

Several interviewees suggested that while there may be an interest, sharing data requires administration overhead and time, thereby adding strain where resources are already limited. Sharing data between Indigenous groups can also be frustrated by the fact that not all nations have the same capacity or technical skills. Sharing within and between Indigenous communities and organizations is a challenge in some areas as oral traditions require in-person meetings to share data and information (even when using digital technologies), which comes at substantial costs, especially in the north.

Many interviewees reported that there is a general lack of capacity for understanding, accessing, and using spatial data and systems at the community or band level. Lack of capacity is linked to lack of education and training on spatial technologies, remote locations, and poor internet access. Capacity at the band level is generally only sufficient in larger Nations with more funding or, as is more often the case, falls to tribal councils or treaty organizations who represent multiple communities and tend to have more resources at their disposal. Sharing data may require time for the giving party to address technical challenges or, in some cases, provide capacity building sessions to the receiving party.

Success in data sharing often is attributable to the strength of relationship between parties. Trust, which is built up over time and in the absence of one party taking advantage of another greatly facilitates data sharing.

> *"Networking is key for First Nations. Sometimes we have issues with sharing and confidentiality based on things happening in the past. We need to overcome that." (Chrystal Nahanee, GIS and Research Officer, Squamish Nation, March 2, 2018)*

In general, interviewees explained that the primary limitation on sharing of data with other communities is confidentiality policies and sensitivity of data. While some are willing to share resource data, they will not share data related to rights/title/culture. Almost all Indigenous organizations play a role as guardians of traditional knowledge, culture, and way of life. Indigenous communities are cautious about sharing data about their traditional knowledge. It is generally stored and managed in-house and protected by confidentiality agreements. Sharing with government and industry is on a need-to-know basis. Such data are usually only shared with external parties on a project-by-project basis.

Communities spoke of challenges finding the balance between protecting and sharing data, particularly for traditional knowledge and traditional land use data. It can be challenging for regulators and industry to accommodate the protection of information such that it is not made public or posted on the internet. Interviewees further mentioned that partner organizations (including project proponents, NGOs, researchers) do not always understand the complexity of privacy and confidentiality. Typically, Indigenous organizations prefer not to share data with government or industry. This in turn, creates challenges for planning processes: "on one hand, communities want to protect sensitive cultural sites from the public by

keeping their locations secret, but on the other, if cultural data are not shared in public planning processes, sites important to the community won't be recognized and protected," (CIER 2010).

Data Sharing Policies and Agreements

Lack of data sharing agreements or data sharing agreements that are poorly drafted can limit access to data. In some cases, data sharing agreements may not be in place. This is often a problem when organizations are limited in capacity and have not been able to prioritize the development of data sharing policies. For others the time-consuming nature of putting agreements in place means that, "it is easier not to share data than to share" (anonymous, February 28, 2018). Without data sharing agreements, Indigenous communities may be reticent or refuse to share data. Interviewees spoke to their concerns about confidential data, particularly cultural information, and the need to assert control over how their data are used.

One interviewee from a well-funded Indigenous group explained that she felt lucky to have legal services in-house to assist. The agreement was in place, which made it easier when she was asked to share data or wanted to acquire data and was asked to sign a data sharing agreement.

Good data sharing agreements, according to interviewees, must be designed with the best interest of the community or organization in mind. They must address the valid concerns that communities have around intellectual property, confidentiality, appropriation and misuse of data – concerns that are grounded in a legacy of mistrust between Indigenous groups and non-Indigenous organizations. As such, Indigenous groups insist that the data that they share are protected, remain accessible to them, and ultimately under their control. All parties should understand that that is the objective of data sharing agreements.

> *Indigenous communities have little access to their own data. [Traditional Knowledge] gathered for development projects is in cabinets, locked, or whatever. Not only is this inaccessible, but also there are issues around intellectual property rights that actually hamper community access itself. Need to respect ownership and support communities to have the confidence to demand their data from the institutions that are … protecting their Intellectual Property. (Deb Simmons, Executive Director, Sahtu Renewable Resources Board, March 14, 2018)*

4.4.4 Technological Barriers

Bandwidth Limitations

Particularly in the north and to a lesser extent in the west and east, rural/remote communities face significant bandwidth limitations and data caps. Although improvements have been made in many communities, many still face profound challenges in this regard:

> *There are times I go home and come back in the evening because if one/two people are researching on the internet, I have to wait about 15 minutes for a hyperlink to open. Sometimes I wait until the office closes and people go home. We desperately need better internet. There is a potential possibility for sat internet, but it is really new. We have a tech looking into that for us right now. Our time could be so much more efficient. We'd have more time to work on our research and projects. That is a huge barrier. It takes forever. It is beyond snail-mail. On average I get 30-40 resource related emails/day. Each email will take 5-10 minutes to scan to see if it is relevant or not. Of those, about 10 will be relevant but I still need to sort through the other 20. (Misty Ireland, IRMA Land and Resources Co-ordinator, West Point First Nation, March 9, 2018).*

Sharing data can be hampered by the combination of large file size associated with geospatial data and low bandwidth. Data can be too large to download from a central repository such as a government website. Where bandwidth is not strong, it can be difficult to even email files. In such cases, FTP sites or open source software (e.g., Dropbox) may be used. Ultimately this can mean that servers are housed outside the community which raises concerns about data security and protection. Many interviewees in the north commented that the most reliable way to share data in their region was to load it onto a hard drive and mail it.

Concerns about Cloud Storage

Most interviewees – ranging from basic to experienced users – expressed concerns about storing community data such as traditional knowledge in the cloud. Issues around bandwidth compound with fears that data may be used or copied without permission and ultimately used against the Indigenous organizations.

To address and ameliorate concerns about confidentiality and storage in the cloud, many interviewees talked about how their organizations maintain an internal database.

> *Our Nation has its own spatial database in-house. We store everything in-house. We do not like to store in a cloud. We prefer local storage on a server. Some of our information we share publicly while some is confidential. For example, place names are highly confidential and not shared with the public or posted on any social media. (Anonymous, March 2, 2018)*

In a few cases, interviewees did suggest that the cloud storage was a good alternative for keeping data backed up and sync'd. This helps organizations avoid having multiple copies of data in different locations and in turn, losing track of which is the most current or complete.

> *We have a good information management system that runs well. We have a centralized system with information synced on our individual devices, all data are backed up in the cloud, we share easily through FTP sites. There are concerns about storing data in the cloud that is culturally sensitive. Public data are okay. (Pano Skrivanos, Senior Manager and Mapper, Inlailawatash Limited Partnership, March 9, 2018)*

Data Management Systems

Many interviewees spoke to the fact that they do not have data management systems in-house that meet their current needs. Both technical and management support were identified as being needed to develop these systems. Formal data management protocols are lacking such that when knowledgeable staff leave, they often take their capacity and knowledge of the data (and sometimes their computers containing data) with them. The project-based nature of many geospatial initiatives, often requiring temporary personnel or the use of outside consultants, frequently results in the production of datasets that are not compatible with each other in scale, attribute table fields, or collection methodology.

The first step towards an integrated data management system can be daunting. Information is often described as siloed in various departments in incompatible formats. An initial and time-consuming stage of data discovery, consolidation, and analysis is typically necessary before the architecture of a data management system could be designed.

I am looking at our map system right now. If I could take a picture and send it to you, you would laugh. Even a map cabinet would be amazing. I need some funding to do that. They [maps] are all stored in two cardboard boxes, full and over-flowing. That is our data management system at this time. (Misty Ireland, IRMA Land and Resources Co-ordinator, West Point First Nation, March 9, 2018)

A significant struggle for communities trying to digitize and organize their traditional knowledge and traditional land use databases is that data are often missing, erroneous or incomplete, specifically, the metadata from historic work. Data description and organization may not be recognized as being critical in current initiatives simply because individuals may not have the training, understanding or capacity to realize that metadata provides necessary context and detail to map features for future users.

Proper archiving is really important… People don't always understand the gold mine they have. Lots of stuff ends up in the dump. Hand-written maps end up in the dump while the nicely printed ones get saved… Keeping maps alive through stories and presentations, engaging communities in a living way… then people understand why all this deadly killer technical work is needed. (Deb Simmons, Executive Director, Sahtu Renewable Resources Board, March 14, 2018)

We lack a process to archive that data and make it accessible on a regular basis and share it with communities. We'd like to have a system that is easy to use, visual. (George Low, AAROM Coordinator, Dehcho First Nations, March 8, 2018)

4.5 ORGANIZATION PLANS AND FUTURE GOALS AND ASPIRATIONS

As part of the research, organizations were asked to comment on how they may want to produce, use, access or share geospatial information in the future. They were asked what would be required to do this, and what plans or aspirations they have that would require collection and/or use of geospatial data.

Participants identified multiple areas of their work in the near or medium term requiring geospatial data. There was strong recognition of the value of geospatial data and understanding that the use of geospatial data is "the way of the future". Research participants understood geomatics capacity as a valuable and effective tool, and one that enhances their communities' standing in a variety of planning and negotiating contexts.

Plans and Initiatives

The interviews indicate that some Indigenous organizations have specific new plans or initiatives in mind, while others plan to continue and expand what they are currently doing with better systems in place, more trained staff, more data, better and newer technology, and covering greater areas of their territory. Some respondents identified a wish list of what they would like to achieve should everything be put in place for them to do so. As one interview participant said, "the sky's the limit".

Interviewees highlighted a range of topics/issues that could be supported with geospatial data. These include:

- consultations and referrals with government and industry;

- land use planning and land code processes;
- federal and provincial environmental assessment processes;
- cumulative effects monitoring;
- community planning;
- climate change related planning;
- emergency response planning;
- title and rights court cases; and
- negotiations with the federal government.

Data Collection and Mapping

Indigenous organizations identified several needs associated with traditional knowledge and use information. While we found that most already have such information documented, those without it understand collecting and documenting it as important to supporting their communities' interests. Most information of this sort is associated with geospatial locations, and current research on it almost inevitably includes creating geospatial datasets. Many that already have such data aspire to map and record additional traditional use and traditional knowledge information. For some communities, data collection has been limited to study areas defined by industry projects, leaving parts of their territories undocumented. These expressed a desire to collect and map information across broader areas of the territory to fill existing gaps. Some identified the need to digitize information from their traditional use and traditional knowledge studies done in the past, and archaeological data that were collected when geomatics software was unavailable outside large government, corporations, and academic institutions. Place name mapping was also of interest, not only for internal purposes, but also to educate others about Indigenous cultures. Interviewees indicated that collection and recording of cultural information supports a range of activities, including consultation and negotiations, land use planning, environmental management and protection, and identification of cumulative impacts on the territory.

Many interview participants indicated that they would like to make use of mobile GIS products (for use on tablets, cellphones, or other hand-held devices) and data collector systems for field data collection by staff, environmental monitors, or community members. Some communities are successfully using these types of tools, while others are still seeking tools that more fully meet needs such as ability to take photos, record audio or video, or are simply able to withstand cold temperatures.

In addition to cultural information, Indigenous organizations expressed an interest in digitizing population and demographic data and having up-to-date data on resources (e.g., fish, wildlife, habitat, areas of significance for cultural keystone species) for different land uses (e.g., forestry, mining, fish farms, urban development) and from different sources (e.g., community monitoring data; data collected for environmental assessments).

While some organizations largely work with information at a territory wide scale, others perceive a need for finer details at the scale of parcel boundaries and reserves, through use of UAV imagery.

Some communities are also exploring creative ways of working with geospatial information. For example, one interviewee expressed the possibility of using it to learn Indigenous languages. Another interviewee explained that their organization is considering new ways of linking maps and stories. Their staff are looking to the gaming industry and virtual reality as a means for sharing traditional knowledge and traditional land use, engaging people and helping express their story. Still another commented about utilizing mapping capabilities similar to those in the popular game app, “Pokemon Go”, where maps showed the details of the buildings and infrastructure which could be used for emergency planning and infrastructure projects in the community. Thinking creatively about how people learn about their landscapes may give rise to new ways of using geospatial data for Indigenous communities.

Data Publishing and Sharing

Some Indigenous organizations expressed an interest in publishing and sharing data using thematic web-maps or other web-based applications. These would be used for internal work and to make data accessible to communities. For example, community members could access data identifying cultural sites and add to or correct existing information. Some indicated that they would like to share data within their communities first, and then eventually share some of it more widely.

Interview results indicate there is a growing interest in sharing information with other Indigenous organizations to develop relationships, support mentoring of one group by another, and reduce duplication of effort.

Some Indigenous organizations also indicated that they have begun to consider the business opportunities their geospatial data might present (e.g. producing maps).

Standardized Systems, Methods and Tools

Many interviewees expressed an interest in developing or enhancing existing systems related to storing and managing geospatial data. Currently, many Indigenous organizations do not have data management procedures that ensure consistency and quality over time and across departments and staff members. Research participants expressing this goal often indicated that they would require support to put systems in place to address this need.

Key areas participants flagged speaking about desires to develop standardized methods and tools include:

- data storage;
- data management systems;
- standardized methods, tools, and protocols for data collection;
- protocols for data sharing;
- standards for working with sensitive information;

- protocols for protection of intellectual property;
- documentation of best practices and guidelines.

When asked if they envisioned storing, organizing, and sharing geospatial data using SDI standards and tools in the future, Indigenous organizations had varied responses. Few interviewees indicated that they were already using SDI standards and tools. Many were unable to answer as they were not sure of the meaning of SDI standards. Others indicated they would like to use SDI standards, as they see standards in general as important. Some expressed interest in using SDI standards at some point in the future but that this would require more internal capacity and greater understanding of SDI, stating that "we're just not there yet."

Community Engagement and Capacity Building

Several research participants envisioned using geospatial data to better support their community engagement efforts in the context of land use planning, environmental monitoring, environmental assessments, and information sharing. A variety of ways of engaging communities were identified, including:

- involve citizens directly in data collection and mapping activities to map and document their traditional use;
- set up interactive technologies and web-based tools to share community heritage and other information;
- use web-maps to validate traditional use information with members.

One interviewee expressed that geospatial data can be a powerful tool for engaging community members and passing on oral histories from one generation to the next:

> *"I would say that in my department we have some people on staff that are very knowledgeable about the land. There are less and less people like that as we move through the generations. Geographic information can play an important role in documenting oral history on maps. That is probably the most important use [of geographic information] so that oral history is not lost. We have a PhD going out with elders and recording where plants are on maps and then documenting how they are used for medicine. We can then hold and share that information. Maps are something people can understand more than a report." (anonymous, February 28, 2018)*

Many interviewees indicated they would like to enhance the capacity of their community members with respect to geomatics. Some wish to further train current staff and hire GIS technicians, and indicated a keen interest in hiring from within the community. However, they noted it is challenging to find members who are interested in or understand GIS, or who know of GIS-related careers. The importance of encouraging youth to consider careers in geospatial data was raised by several interviewees.

> *"Offering summer training programs in high school for students. There is a trades centre at Squamish Nation with training opportunities in carpentry or rebar or administration. Why not offer something to do with GIS? You never know. There may be teenagers that would be interested in mapping." (Chrystal Nahanee, GIS and Research Officer, Project Negotiation and Development, Squamish Nation, March 14, 2018).*

"We would like to build capacity in the community – train youth in the community to build people up … Younger kids are interested in technology – we would like to mentor up someone – that would be beneficial to us in the future". (Katherine Capot-Blanc, Acting Director, Department of Lands and Resources, Fort Nelson First Nation, March 12, 2018)

Others reflected on their desire to increase capacity of community members to understand geospatial data to improve their ability to participate in decision-making and their understanding of what band administration is doing.

"I was thinking about the jargon around GIS itself – it is pretty intimidating, and it can be hard even to explain it to community members. It is a challenge relaying information to community members. Explaining the limitations of data (e.g., it is only as good as data coming in) – explaining what data can be used for, their limitations. I want to explain to people what we do here. How can people feel reflected when they don't know what it means?" (Katherine Capot-Blanc, Acting Director, Department of Lands and Resources, Fort Nelson First Nation, March 12, 2018)

Use of Geospatial Data in Regulatory Processes

Several Indigenous organizations spoke about their interest in using geospatial data more effectively in regulatory and referrals processes. One participant explained that:

"We use [spatial data] within regulatory processes] but government is not using them. You need a common language to be [able to] receive information on the other end. We are stuck conveying results from analyses in PDF format when there should be an exchange of geospatial information. That is where metadata is important. Some are using outdated datasets to look at the current state of a resource. We need to enhance processes and standards and have a consistent methodology so that QAQC can be performed to inform the analysis that informs decisions" (David de Wit, Natural Resources Manager, Office of the Wet'suwet'en, March 15, 2018).

Another interviewee indicated that enabling shared access to geospatial data through a database on a web portal would greatly simplify the work involved with responding to referrals and participating in environmental assessment processes. For meaningful engagement and consultation to occur, Indigenous organizations also identified the need for the private sector to make its data more accessible (see Section 4.2.3.3). This is, of course, dependent on good relationships between parties, and willingness to enter into data sharing agreements.

Collaboration with Others

Interview results suggest that many Indigenous organizations view the use of geographic information as an opportunity to work together, share information about valued resources, develop shared tools, and collectively build their capabilities.

When asked who they would like to collaborate with in the future, Indigenous organizations identified a range of entities – government, industry, academic institutions, other Indigenous organizations, external consultants, and GIS-related companies.

Indigenous organizations appear to have more interaction with the provincial government and municipalities than with federal departments and therefore have a better understanding of the type of geographic information held at the provincial level. Some expressed a desire to work more with federal agencies.

4.6 SUMMARY OF USER NEEDS ASSESSMENT RESULTS

The following table summarizes our research findings in relation to aspects of UNA enumerated in the SDI Manual for the Arctic (2016).

Aspect of UNA	Findings
Key activities	Communities that participated in the research indicated their mandates included the following activities: ▪ 86%: Natural resource management and planning (including: forestry, fisheries, wildlife, water resources, etc.) ▪ 77%: Land use planning ▪ 76%: Consultations with industry and government (including: Treaty or land selection, court cases, negotiations, environmental assessments) ▪ 58%: Climate change monitoring and adaptation ▪ 52%: Environmental management (including: flood and erosion management, weather monitoring and forecasting, coastal zone management, etc.) ▪ 48%: Health, housing, and social services ▪ 46%: Transportation, infrastructure, and capital works ▪ 44%: Emergency and disaster planning 13% listed other mandates, including: environmental impact assessment; water quality and fisheries management; stewardship and guardian program; project monitoring; and land management. Most participants conduct research on topics with a geospatial component. 86% have undertaken traditional use/ use and occupancy studies. 65% have researched environmental, social, economic, or cultural phenomena.
User characteristics (function of organization)	Organizations that participated in the research largely (68%) classified themselves as community administration/government. 35% were tribal councils or treaty organizations. 6% were NGOs, and less than 5% classified themselves as Indigenous associations, resource councils, academic institutions, or private companies.
User characteristics (size of organization)	The organizations were widely divergent in size. Of 51 organizations that answered, staff levels varied between 2 and 600. 18% had less than 10 staff, 16% had 10-19 staff, 33% had 20-39 staff, and 33% had 40 staff or more.
User characteristics (capacity to use geospatial data)	The organizations were widely divergent in capacity to use geospatial data: ▪ Only 14% of organizations used only in-house resources for data analysis, reporting, cartography, and other geospatial data needs. 9% used external service providers exclusively, 21% used them frequently, while 47% used them occasionally. ▪ Of organizations that provided the information, 66% considered themselves end-users of geospatial data, 36% publishers of data, and 51% facilitators of access and use of data. However, 13% indicated they did not know. ▪ Follow up interviews clarified that the majority publish information through paper or electronic maps, and those who distribute data often use non-network methods such as mailing physical devices because of network bandwidth and reliability constraints.

Aspect of UNA	Findings
User characteristics (means of communicating geospatial information and recipients)	Over two-thirds (68%) of individuals participating in the research responded that their organizations share geospatial data. Of those who provided more detailed breakdowns: ▪ 92% share information with Indigenous government decision-makers; ▪ 82% with elders/community members; ▪ 79% with consultants working for the organization; ▪ 71% with government (federal, provincial/territorial); ▪ 68% with partners/collaborators such as conservation NGOs ▪ 65% with other Indigenous organizations; ▪ 54% with Indigenous business; ▪ 40% with academic institutions; and, ▪ 35% with private companies. Most organizations (90%) use paper maps and electronic maps to communicate/distribute geospatial data. 52% use electronic datasets (e.g., ESRI shapefile, Google KMZ). 41% use online mapping software (e.g., OpenStreetMaps, Bing maps, Google maps). 11% use digital products targeted at mobile devices. 8% use network map services (e.g., WMS, WFS, ArcGIS Online).
Data access (current sources of geospatial data)	Organizations secured or produced geospatial data from a variety of sources. ["Don't know" responses omitted, thus percentages may not add to 100%]: ▪ **provincial/territorial governments:** 62% secured data from this source frequently; 33% occasionally; and only 3% never. ▪ **federal government:** 46% secured data from this source frequently; 42% occasionally; and only 7% never. ▪ **field observations and local knowledge:** Almost 60% produced geodata from field observations and local knowledge; 30% did occasionally; only 10% of organizations did not produce any geospatial data from this source ▪ **data shared with or provided by another Indigenous organization:** 24% secured data from this source frequently; 45% occasionally; and 26% never. ▪ **academic institutions:** 20% secured data from this source frequently; 48% sometimes; and 25% never. ▪ **private companies/consultants:** 19% secured data from this source frequently; 45% occasionally; and 21% never.

Aspect of UNA	Findings
Data access (technology issues); **Web services and tools**	Of the organizations participating in the survey, 42% rated limited Internet bandwidth, speed, or reliability as challenging or a major challenge; 24% considered this somewhat a challenge; and 34% not a challenge. Follow up interviews confirmed that this issue is directly related to proximity of the organization's office to urban concentrations where data infrastructure is varied and well-developed. Organizations with offices in the urban south considered network data access to be unproblematic. To the contrary, even large, well-resourced organizations in smaller communities in the Canadian north indicated that they could not rely on Internet connections for large datasets such as satellite imagery, and preferred mail or courier shipping of hardware storage devices containing datasets. In the survey, when asked for any additional comments on use of geospatial data, several participants flagged bandwidth as a key issue: "Please increase our internet speed in our communities and the entire NWT." "Low bandwidth limitations in Nunavut mean that even if we develop a wonderful tool for our public website, there are real limitations to ability to use in communities." This is the likely reason that only a small number of participants make use of OGC web services such as WMS and WFS, and very few indicated that using these is in their plans for future use of geospatial data.
Data needs	Research participants required a broad spectrum of geospatial data, much covering large areas. Examples of the key data types/parameters that were identified, with percentage of survey participants indicating they were important or very important, include: <u>Framework Data</u> ▪ 69%: topography, elevation, slope, digital elevation models ▪ 54%: transportation, infrastructure, capital works <u>Thematic Data</u> ▪ 91%: natural resource data (forestry, fisheries, wildlife, water resources, population surveys, migration routes, genetic stock locations, etc.) ▪ 90%: traditional use studies or use and occupancy studies (harvesting, place names, travel routes, etc.) ▪ 82%: land use and cover ▪ 79%: climate change related data (e.g., permafrost, ice cover, sea level) ▪ 71%: research data on environmental, social, or economic phenomena ▪ 58%: emergency and disaster planning data (e.g., flood, fire) ▪ 45%: health, housing, social services data <u>Remote Sensing Data</u> ▪ 82%: satellite imagery ("true colour", multi-spectral, etc.), LIDAR, aerial photographs, UAV photos In interviews, a substantial number of participants indicated that their organizations found desired LIDAR and satellite imagery cost-prohibitive.

Aspect of UNA	Findings
Data quality and usability	Research participants indicated that geospatial datasets were needed at a variety of geographic scales--local, regional and broader. Time scales included a range from current (e.g., land ownership and permitting; petrochemical development; forest cutting) to historical (e.g., seasonal average temperatures). Frequently, transforming large thematic datasets to actionable information was cited as a challenge during interviews. Thematic data that were accessible to users was generally described as "raw" and in need of significant manipulation to be useful. This post-processing was beyond the internal capacity of almost all respondents because of unavailability of time or expertise.
Data enhancements required	Organizations using external geospatial data pointed to several challenges that could be addressed by data enhancements. [“Don’t know” responses omitted, thus percentages may not add to 100%]: ▪ **incompatible file formats:** 18% found this challenging or very challenging; 34% somewhat challenging. ▪ **missing metadata:** 23% found this challenging or very challenging; 36% somewhat challenging. ▪ **incomplete or inaccurate data:** 36% found this challenging or very challenging; 38% somewhat challenging. ▪ **inappropriate spatial or temporal scales:** 31% found this challenging or very challenging; 33% somewhat challenging.
Distribution formats required	Seventy-nine (79) percent of organizations participating in the research used commercial geomatics software. Another 34% indicated that open source desktop software was used, and 23% web programming tools. However, every user of open source software or web programming tools also used commercial software. 91% of organizations used web-based software such as Google Maps or Open Street Maps, but only 12% did not also use commercial software. Follow up interviews made it clear that ESRI ArcGIS software is the commercial software used in almost all organizations that have geomatics software, and respondents expressed a strong desire for geospatial data distribution formats compatible with this software.
Data and service documentation required	Interview participants indicated that having information on a range of metadata topics is important for evaluating fitness of geospatial data for use. Topics noted include: ▪ information on data attributes (“Knowing what the attributes are, what exactly each field means, is important.”) ▪ an indication of data accuracy ▪ temporal currency (dates collected) ▪ source(s) ▪ publication notes describing data collection/generation, quality, etc. ▪ Some participants noted that metadata formats for geospatial data they receive are cryptic, and that standardized, straightforward information would be useful.
Scope of knowledge (SDIs and geoportals)	Seventy-seven (77) percent of organizations participating in the research indicated that they were not familiar with CGDI tools and standards. Of the 23% that were, over a third indicated that they do not use CGDI data content, tools, or standards. In sum, only 13% of organizations stated that they use CGDI data, tools and standards. However, in follow up interviews, organizations regularly indicated that they made some use of spatial discovery portals and downloaded datasets. It appears that these elements of CGDI are not understood as being part of spatial data infrastructure or what SDI is.

Aspect of UNA	Findings
Scope of knowledge (information management policies)	Only twenty-one (21) percent of research participants indicated that their organization had a data management policy or standards for cataloguing. 69% did not have such a policy. (9% were not sure.) Forty-eight (48) percent of respondents indicated that their organizations had policies and procedures governing sharing and distribution of geospatial data; 40% did not; and 12% did not know.
Legislation, policies, procedures, standards required to participate in SDI	Most research participants (almost 85%) rated confidentiality and intellectual property concerns as a very important reason their organizations are prevented from sharing geospatial data with others. In interviews, some indicated that even though they were willing to share information, the time-consuming nature of putting agreements in place means that "it is easier not to share data than to share." Almost 40% indicated that their organization does not have a policy or procedure governing distribution and sharing of geospatial data.
Future aspirations	When asked what ways their organizations would like to use or collect geospatial information that they are not currently, interview participants suggested several priorities (listed in general order of how frequently they were mentioned): ▪ create online atlases, interactive web maps, or regional data portals to allow community members to access information; ▪ implement GIS access on mobile devices (phones, tablets) for community data access, field data collection, education; ▪ begin collecting environmental data internally instead of using third parties; ▪ map traditional land use and place names. When asked what would be required to use geospatial data in ways they currently are not, organizations listed a variety of needs. These are listed below in general order of how frequently they were mentioned: ▪ funding (to purchase technology, software, hire staff, train staff) ▪ education/training ▪ improved data sharing agreements with provinces/territories that allow creation and distribution of information products ▪ organizational agreements on data sharing ▪ new software (e.g., ArcGIS Online) ▪ improved bandwidth ▪ robust technology (e.g., GPS devices capable of operating in extreme cold)

5.0 REGIONAL SUMMARIES

Three regions within Canada were established for the purpose of the UNA: east, west, and north. Overall, survey and interview results were similar among the three regions. In this section, we provide regional summaries and highlight any differences that emerged between the different regions.

While Indigenous organizations in each of these regions may share some geographic characteristics, the regional distinctions that emerge from this study are primarily administrative. To assess regional differences across the country would require a larger sample and methodology designed specifically to capture the intricacies and diversity of Indigenous people, communities, groups, and organizations in these regions.

5.1 EAST

A total of 23 organizations that agreed to participate in the research were located in eastern Canada. These represented communities in Nova Scotia, New Brunswick, Newfoundland and Labrador, Quebec, and Ontario. The organization staff sizes ranged from 10 employees to over 600. A majority of participants (10) were Tribal Councils, Secretariats, and other bodies representing multiple communities; almost half (8) were Indigenous community government/administrations, while one (1) was an Indigenous NGO.

Like other communities surveyed across Canada, almost all were involved in natural resource management, and in consultations with government and industry. As well, most had conducted cultural land use and occupancy research. Eastern communities were also engaged widely in planning for climate change; environmental management; and research on environmental, cultural, or economic phenomena. Half or more engage in land use planning; emergency planning; and managing transportation and other infrastructure.

Like other regions, most organizations in the east described themselves as *end-users* of geospatial data. A third described themselves as *publishers* of geospatial data. One in five described themselves as *enabler/facilitators*. (All enabler/facilitators also were publishers.)

One in five had advanced geomatics capacity in-house, and the rest were evenly split between describing themselves as having basic capacity or having little or no capacity. Almost all with basic or advanced in-house capacity indicated that they use external support for specific tasks as a complement to internal resources. Of those with little or no capacity, three-quarters used external geomatics support frequently, while a quarter (around one in ten organizations surveyed) did not use any external geomatics support, thus lacked any geomatics capacity except for that provided by other organizations.

In organizations with geomatics software, surveys showed that all except one—which used open source software only—employed commercial software. All participants who participated in follow up interviews indicated that their organization used ArcGIS. One in three complemented the commercial software with open source software. A large proportion of eastern research participants used publicly available web-mapping software such as OpenStreetMap, Google Earth, or Bing Maps.

Almost all eastern organizations used desktop computers to work with geospatial data. Somewhat less than half made use of tablets, and a quarter smartphones. Most participants indicated that their organizations made use of GPS, about half *frequently* and half *sometimes*, and only 16% never made use of it.

Key geospatial information for organizations in the east were most frequently sourced from provincial governments (about three-quarters *frequently* and a quarter *sometimes*), and the federal government (about half *frequently* and half *sometimes*). A large number (half *frequently*, a quarter *sometimes*) indicated that they produced their own data from field observations and local knowledge. Fewer received data from private sources (a fifth *frequently*, less than half *sometimes*). For data and data shared by other Indigenous communities or from academic sources, over half indicated *sometimes*, and somewhat more than one in ten *frequently*). Use of remote sensing datasets was split – around a quarter used them *frequently,* a third *sometimes*, and the rest *never*.

Like other regions, around three-quarters of survey participants were not familiar with the CGDI endorsed standards and tools. However, during interviews it became clear that some organizations use CGDI technologies such as standards compliant data discovery portals but do not identify these as part of CGDI.

When asked what geospatial information would add value to their organizations' work if more readily available, nearly all survey participants in eastern Canada indicated that land cover data were *important* or *very important*. Natural resource data (information on forestry, fisheries, location of species, etc.),) traditional land use and occupancy data, climate change data (such as sea level rise, and information predicting precipitation and runoff changes), and data from independent research of environmental, social, or economic phenomena were ranked *important* or *very important* by more than three-quarters.

Satellite imagery, aerial photographs, and UAV data and disaster planning information (such as flood or fire) were ranked *important* or *very important* by more than two-thirds of respondents. In follow up interviews, some participants indicated that such changes have already affected shoreline and infrastructure in their communities, and that planning and mitigation strategies were important.

Topography/elevation/slope data, imagery, environmental management data, and transportation infrastructure information were also identified as priority areas by around two-thirds of organizations.

Relative to other regions, few research participants in the east indicated that network connectivity and bandwidth limitations were problems when accessing or sharing geospatial information or using online services. This is probably attributable to relative lack of representation of isolated boreal forest and other remote communities in the east.

For some organizations, cost and ongoing funding were considered important barriers to improving geomatics capacity. Others indicated that funds were available in the organization, but administration considered it too risky to hire and train people, and the challenge was convincing management in the organization of the value of geomatics.

When asked about factors that prevent sharing geospatial information with others, most organizations in the east indicated that confidentiality agreements were problematic. In interviews, some organizations elaborated that what they perceived as excessively restrictive provincial data sharing agreements, prevented them from using data or derived products for maps or other information products. Some interviewees attributed to provincial desires to derive funds from detailed scale framework data.

In interviews, study participants mentioned several future projects they would like to undertake to improve use and access to geospatial information:

- Creating an atlas of community information, for distribution both in paper and digital form.
- Centralized geospatial data storage and storage management. Bring sister organizations together to cooperate and share datasets.
- Mobile GIS product that would allow information to be downloaded and accessed by members.
- Collecting traditional knowledge, current use areas, areas that are significant as inputs for Chief and Council for decision making, informing decisions on protected areas, etc.

5.2 NORTH

The UNA online survey reached 33 organizations from northern Canada (including Yukon, Northwest Territories, Nunavut, northern Quebec, and Labrador). The varied scale and scope of land claims agreements in the north has resulted in Indigenous organizations with spatial data needs that vary widely in both the geographic scope and the nature of mandates. Northern Indigenous organizations include individual communities, regional land management organizations (e.g., Kivalliq Inuit Association), organizations focused on particular responsibilities (e.g., Nunavik Marine Region Wildlife Board), and regional co-management organizations (e.g., Yukon Land Use Planning Council). Each deal with barriers unique to their situations, but they often also share common needs, challenges, and goals for the future use of geospatial data.

Just under three-quarters of survey respondents in the north were not familiar with CGDI, although interviews revealed that the majority of organizations interacted with CGDI (through data download portals, and the following of OGC or ISO standards) but were unaware of doing so. There was an uncertainty about the nature and definition of the CGDI. As well interviews revealed that, in the north, both individual communities and regional Indigenous organizations play a role, or wish to play a role, in the CGDI. A large number of the organizations contacted are less than 25 years old. Many are still establishing how fulfilling their mandate best requires the use of geospatial capacity, while others have established some form of geospatial capacity but are still developing geospatial data policies.

The activities undertaken by northern organizations as identified in the online survey (n=33) vary widely. Traditional use and occupancy studies and natural resource management and planning were most commonly cited as important activities. A common theme in survey responses was the dynamic nature of data needs for Indigenous organizations. Over half of respondents also indicated they used geospatial data for climate change monitoring and adaptation, consultations with industry and government, and research projects.

A large majority of northern Indigenous users see their function as *end-users* of the CGDI. Half of northern organizations surveyed envisioned a secondary role for themselves as custodians and *publishers* of geospatial datasets, as well as facilitators of data access. However, many lacked the capacity to share data or are only able to do so in ad hoc manners such as by email, Dropbox or on hard drives delivered by mail due to limited internet quality.

Information on traditional land use and environmental knowledge, climate change, ice, wildlife and satellite imagery were frequently identified as data priorities by interviewees.

Geomatics capacity varies widely in the north, from non-existent to expert but over-burdened. Over three-quarters of survey respondents in the north rated their organizational capacity for working with geospatial data and technology as either *basic* or *little to no*. A third of northern organizations reported using outside consultants *frequently* or *all the time* to meet their geospatial needs. Most respondents in the north reported making use of outside consultants to bridge the gap between geospatial needs and internal geospatial capacity.

Human capacity is seen as a major barrier amongst Indigenous organizations in the north. Over half of northern survey respondents reported *training, skills, and capacity* as a challenge or major challenge to acquiring and making use of geospatial information. Organizations without internal geomatics capacity see it as a need, while those with geospatial capacity typically cite the need for more funding, time, personnel, and expertise. Many interview respondents indicated that the uneven distribution of geomatics capacity in partner or constituent organizations is a barrier to being able to share data. Lack of funding to hire specialists and develop staff geospatial capability was also frequently discussed as a barrier.

Indigenous organizations often found geospatial data were not useful for decision making in raw format. Raw spatial datasets are often large and complex, and refining this into useable data requires expertise both in the subject matter and GIS. Many organizations remark that they have access to large datasets of raw thematic data, such as traditional land use, sea ice flow, or biological information, but do not have the capacity, be it time or expertise, to refine these large raw datasets into useful outputs to direct decision making and analyze trends.

Four-fifths of northern survey respondents rated remote sensing imagery as important or very important to their organizations work if it were more readily available. Access to remote sensing imagery was frequently mentioned in interviews as prohibitively expensive. Such data were linked specifically to needs in land use planning, referrals management, identification of wildlife habitat, and change monitoring, including climate change and project monitoring.

Computer hardware was mentioned as a barrier in a small number of interviews, but many stated that the expense of professional GIS software limited their capabilities. Many organizations cited the poor quality of the internet service in the north as a major barrier to discovering, accessing, and sharing data.

The lack of defined geospatial data policies was cited as a barrier to sharing data by many interviewees, specifically with respect to traditional knowledge. Less than half of northern survey respondents reported having a data sharing policy in place. Sharing of traditional knowledge with outside organizations would require explicit limitations to data use.

In their plans and aspirations for the future, respondents generally saw the need for better access to information, improved methods of data sharing internally and with the public, the usefulness of developing mobile data collection apps and drones, and the need for better data refinement and management.

Many interviewees expressed the need for a regional data portal co-managed by different levels of government, in which all relevant thematic data for a region could be visualized and downloaded. This would include academic and governmental datasets and be designed with the bandwidth limitations of the north in mind.

A similar goal expressed by many interviewees is for the development of a data visualization portal that would allow an organization's constituents who do not have a geomatics background to see data easily and be able to create and download maps themselves. These portals would be managed by the organization with access controlled by sign-in. The ways in which these portals were organized and indexed would have to carefully planned to ensure search and access functions were intuitive.

Many northern organizations collect data for internal use. Seventy-nine percent of northern survey respondents reported their organizations being involved in traditional land use studies. The development of data collection apps for mobile devices is seen as a means to reduce data collection costs while improving the consistency of location precision and attribute detail with the goal of developing a large and consistent dataset. These initiatives support the growing interest in community guardianship / community - based monitoring initiatives.

A frequent goal mentioned in interviews is the centralization and refinement of geospatial data within the organization to make it easier to search and so that it may better serve decision making.

5.3 WEST

The UNA online survey reached 31 organizations from western Canada (including BC, Alberta, Saskatchewan, and Manitoba). As in other regions, organizations in western Canada were extremely diverse in size, mandate, and capacity. Nearly all organizations identified as Indigenous communities or governments, Tribal Councils, Treaty organizations, or a combination of the three. This was intentional, as the project team approached multiple tribal councils and organizations that represented groups of communities with common heritage or interests in effort to be as inclusive as possible of the hundreds of Indigenous communities in western Canada. Most organizations were involved in multiple activities, ranging from managing lands and resources to providing health services. Organizations most frequently cited traditional use or occupancy studies, natural resource and land use planning, consultations with government, research, environmental management and climate change monitoring as their key activities. However, close to half were also involved with health, housing and social services; transportation and infrastructure; and emergency planning.

As with other parts of the country there is a broad spectrum of both capacity and dependence on outside resources. A fifth of organizations indicated they had little or no capacity for working with spatial data and technology and close to half stated that they had basic or advanced capacity. The majority of organizations reported that they relied on external service providers or consultants for spatial services *sometimes* or *frequently*; but very few reported that they *always* relied on external support. Interviews revealed that most in-house geomatics capacity was housed in Lands or Natural Resource departments, and that the bulk of these resources were used for responding to referrals or consultation requests from industry and government.

Organizations in the west typically identified themselves with more than one user profiles, with two-thirds categorizing themselves as *end-user*. Many also identified as being a combination of End-User, Enabler/Facilitator, and Publisher.

Organizations in the west were aligned with those in other regions when describing what kinds of spatial data would add value to their work if it was more readily available. Natural resource data, traditional use studies, and satellite imagery were most frequently identified as *important* or *very important.* Topography/elevation/slope, land use and cover, climate change monitoring data (such as permafrost, ice cover, and sea-level rise), environmental management, emergency and disaster planning, and health, housing and social services were also identified as priority areas by close to two-thirds of organizations in the west.

When using spatial technologies, organizations in western Canada had similar results to other regions, stating that they used digital maps, GPS, GIS, spatial databases most frequently. Use of software systems was also similar to other regions. Most organizations relied on a combination of publicly available web-based software (Google Maps, Google Earth, Bing Maps, OpenStreetMap, Apple Maps), and commercial software (ArcGIS, Global Mapper, PCI Geomatica, ERMapper. ENVI, Erdas Imagine, Trailmark). About 10% relied on open source desktop software (QGIS, Grass, SAGA).

Key sources of spatial data for organizations in the west were similar to those identified by organizations in other regions. Organizations most frequently identified that they produced their own data from field observations and local knowledge or obtained third party data from provincial/territorial governments, and to a lesser extent, the federal government.

Interviewees further described that their organizations would benefit from better access to specialized data and technologies, such as LIDAR, up-to-date and high-resolution aerial and satellite imagery, and drone/UAV imagery. A key barrier for organizations was that publicly available data did not always meet their needs in terms of spatial resolution and currency, and that cost of acquiring these themselves was prohibitive. Thematically, organizations perceived that better access to data created by these technologies would improve their ability to model and manage climate change, digitize human, population and cultural data, or understand the interests or impacts of external parties on traditional territories.

Many interviewees cited that their work was hindered by ineffective user interfaces on some online data repositories. In general, organizations in the west relied most heavily on provincial portals and repositories and did not interact with federal portals such as Open Data as much. Interviewees had difficulties searching for the datasets they needed efficiently and found the process of navigating federal portals to be especially time-consuming. Some interviewees reported that metadata was not always standardized or missing for older datasets.

As with other regions it is common in the west to share spatial data produced or otherwise owned by the community. Data were most commonly shared with decision-makers within Indigenous governments, Indigenous Elders and community members, consultants, and provincial or federal governments. In the west, over half of organizations indicated that they had a policy to govern the sharing or distribution of spatial data. Interviewees provided further insight into the complexities of data sharing and the policies that govern it. Generally, organizations that had developed data sharing agreements were more willing to share certain types of information with external parties. Like in other regions, western organizations were hesitant or unwilling to share data relating to traditional knowledge and used outside of the organization. Key barriers to sharing spatial data included: confidentiality, the need for stronger policies that prevent the misuse of

data, the time required to develop and implement effective data sharing agreements, and lack of trust in utilizing cloud-based servers for sharing.

When speaking to barriers to accessing, using, and integrating spatial data in their work, interviewees in western Canada cited several challenges related to skills and training, personnel, technology, and costs. Organizations frequently said that that they had difficulties recruiting and retaining local people with GIS and spatial data skills. In addition, lack of capacity and skills in GIS among community remembers can be a limiting factor in spatial data being used effectively by community members. In rural and northern areas of western Canada, there are limited opportunities for training. Developing or upgrading skills often requires travelling to a city centre, which can be cost prohibitive for staff and community members. In terms of technology, organizations working in remote areas struggle with internet connection and low bandwidth, especially when downloading large datasets or trying to share data with smaller communities. Costs associated with licensing fees for software (ESRI) and equipment (GPS, plotters) were also mentioned as financial barriers. Perhaps one of the most frequently cited barriers was the heavy workload involved with responding to referrals for consultation with industry or Provincial/Federal government for natural resource development projects. With limited GIS resources and personnel, organizations struggle to find time for important proactive work, such as land use planning and climate change monitoring when their time is consumed by processing referrals.

Like Indigenous organizations across Canada, most western organizations were not familiar with CGDI endorsed tools and standards. Organizations had limited knowledge of what CGDI and its associated standards and policies were. Some organizations had internal data standards and policies that they found effective. Others stated that implementing standards and policies was difficult for them due to the workload involved with standardizing all existing data, a lack of IT skills, and high turnover of staff with geomatics skills.

Interviewees discussed a variety of issues and future projects that would be enhanced by better access to spatial data and associated standards and resources. These include:

- Making the referral process more efficient;
- Better internal coordination between departments that use or need to use spatial data;
- Acquiring more data to enhance decision making and extend spatial analysis to other activities such as public works, housing, and health and social services;
- More efficient and detailed collection of environmental field data;
- Map or digitize traditional knowledge and use (for internal use only);
- Better integration of remote sensing data and technologies, such as drones/UAVs and up-to-date high-resolution aerial or satellite imagery;
- Incorporating traditional place names and languages into existing web mapping platforms;
- Introducing mobile technologies such as tablets into communities for viewing and collecting spatial data;
- Undertaking effective and collaborative Cumulative Impact Assessments; and

- Developing online portals for increasing and controlling access to sensitive spatial data.

6.0 KEY FINDINGS AND RECOMMENDATIONS

6.1 SUMMARY OF KEY FINDINGS AND IMPORTANT ISSUES

The survey and interviews revealed several important observations and key challenges faced by Indigenous organizations with regards to use of geospatial data and interaction with CGDI/SDI as follows:

- There is enormous diversity among and between Indigenous organizations and communities in terms of their histories, cultures, size, jurisdictions, mandates, and funding structures. Many organizations are performing a variety of functions, from managing lands and resources, to liaising with government and industry for development projects, to providing health and social services. Their needs for geospatial data in all areas, particularly in terms of maintaining traditional knowledge, varies widely. It is therefore difficult to group Indigenous organizations into "types" of organizations in a way that is useful for understanding their user needs for geospatial data infrastructure.

- **Organizations varied greatly in their capacity for utilizing geospatial data, products, and services**. Some organizations employed several full-time geomatics personnel; others had geomatics projects and tasks undertaken on an ad-hoc basis by any personnel that had the time and skills to do so. Nearly all organizations were using some form of geomatics or mapping software, using a combination of free and licensed applications. Funding challenges, rapidly advancing open source and commercial software and technology, and the predominant need for organizations to produce simple maps are leading organizations to seek free applications where possible.

- **Survey respondents and interviewees shared a general lack of understanding of specifically what CGDI/SDI is or does**. Many organizations could speak to certain elements of CGDI/SDI, such as data discovery options, user interfaces, and data standards. In fact, many organizations interacted with CGDI/SDI on some level without being aware of it. For example, geomatics personnel working with Indigenous organizations were often familiar with online portals such as Open Data, and aware that certain data standards and guidelines existed. However, few responding organizations had heard of CGDI/SDI or thought of their geospatial activities and needs in the context of an overarching infrastructure. Many interviewees saw CGDI/SDI as beneficial, but dependent on further enhancement of internal capacity.

- Indigenous communities and organizations have significant concerns over data protection and confidentiality, especially with regard to cultural and traditional knowledge. Concerns exist around how shared data will be used to the benefit of the Indigenous organization and the potential for traditional use data to be exploited. This concern spills over into many of the ways in which organizations interact with spatial data. Though some organizations are open to experimenting with cloud computing, most were hesitant to upload or store data on a cloud-based server or contribute their data to open databases. For the most part, geospatial data are shared on a "need-to-know" basis and is dependent on a strong relationship between parties. In addition, organizations want access to geospatial data generated by other public and private organizations (for example, project proponents, or public utilities such as Hydro Quebec).

- **Most interviewees expressed a need for more geomatics personnel within their organization**. In general, they struggled to recruit, retain, and develop personnel with geomatics skills. This was due to training opportunities being unavailable outside of city centres, as well as a lack of dependable long-term funding for these positions. There is strong interest in recruiting from within their communities, but this too is challenging given the limited awareness of, or interest in, geomatics-related careers. Many organizations also reported that responding to referrals from government or industry (i.e., being reactive) consumed the bulk of their geomatics staff time, leaving little capacity for long-term proactive geospatial projects identified as priorities of their organizations (e.g., land use planning, community-based monitoring).

- Cost is a substantial barrier to many Indigenous organizations that prevents or severely limits their access to and use of geospatial data and services. These included: acquiring timely, high-resolution geospatial data; paying licencing fees on geospatial software; accessing high-speed internet in remote locations; information technology maintenance; purchasing equipment; funding and training geomatics personnel; organizing, digitizing, and standardizing existing internal data; and developing and maintaining internal database management systems.

- There is a great deal of interest within the Indigenous community across the country in undertaking geospatial initiatives in the future. Such initiatives included: digitizing and organizing archived, current and future traditional use and knowledge data; using drone and UAV technology; employing mobile technologies to enhance data collection and management, and increase capacity for working with geospatial data among community members (ranging from referrals management to community-based/guardianship programs); incorporating Indigenous place names into publicly available geospatial datasets; developing community atlases; advancing regional data storage and management systems; and exploring new technologies such as virtual reality and gaming to bring spatial data alive and relevant, particularly for youth and in a way that aligns with oral tradition and an Indigenous world view.

- **In many organizations, Indigenous peoples want and need a more prominent role in their use and access to geospatial data.** Community members need/want to lead or have key roles in data collection and mapping their traditional knowledge and use of the land, and in building and managing their internal databases. In part this is seen as a critical pathway to enhance their capacity in data collection, analysis, and spatial data management; and to support asserted land claims. It is also a reflection of their desire to adapt technology and data to support and uphold their responsibility for the care and long-term health of their lands and waters. The capacity to undertake, or even consider, such roles and leadership varies substantially. As such, they must be empowered through guardianship programs founded on systematic data collection, analysis and sharing protocols. In this era of rights and reconciliation, Indigenous communities are "guardians" and not "monitors."

6.2 RECOMMENDATIONS

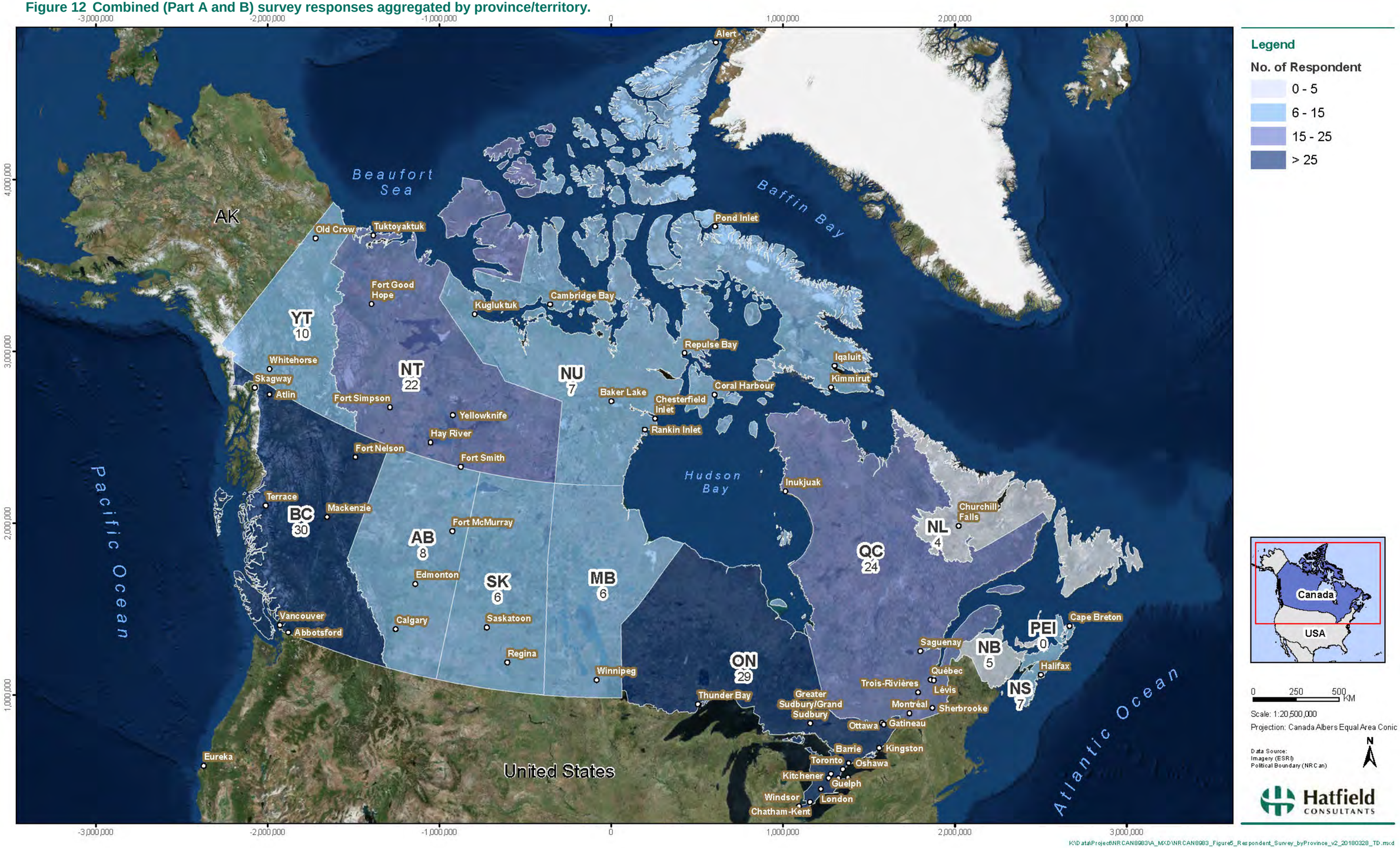
The needs of Indigenous organizations related to CGDI/SDI are wide ranging and diverse – as are the sizes, jurisdictions, and technical and administrative capacities of the organizations themselves. This study is one step along a path to characterizing the variation among Indigenous organizations who might engage with the CGDI. It increases understanding of how that variation may influence the way Indigenous organizations interact with spatial data, technologies, services, and policies. The findings provide additional insights into user needs and consolidates and builds upon past work in this area.

The following recommendations should be verified through further research and engagement with Indigenous communities and organizations, in part to help Indigenous users come to a clearer understanding of where and how CGDI/SDI fits within the broader universe of geospatial data and the multitude of roles it might play in the context of Indigenous applications.

6.2.1 Future Engagement

Further engagement on Indigenous user needs is necessary to fill gaps and verify some of the findings of this report which should be seen as preliminary. There are several things to consider in planning future engagement, most of which indicate a need for a longer timeframe for engagement and careful consideration of the timing of engagement. First, Figure 12 shows the distribution across Canada by province of responses to the survey for both parts A and B. The distribution does not reveal anything in particular about regional differences in levels of interest in the subject matter of this research, rather it is most likely a reflection of the purposive sampling approach wherein the team first contacted organizations where they had existing relationships. The distribution of respondents does provide a benchmark that will be a useful guide as to where additional time and effort is needed to engage a wider sample of Indigenous communities and organizations.

Figure 12 Combined (Part A and B) survey responses aggregated by province/territory.



Second, cold-calling was, understandably, less successful. Several organizations declined to participate in the survey due to heavy workloads associated with fiscal year-end reporting requirements. Similarly, interviews had to be declined because the prospective interviewee was unavailable until the first week of April. Third, several survey respondents identified other organizations that they believed would be interested in participating in the UNA process, but there was insufficient time to effectively engage these referred organizations in an effective and respectful manner.

There is considerable interest among Indigenous organizations to increase their use of geospatial data and to participate in geospatial initiatives, for example in UNA and UCD initiatives. Further engagement with Indigenous communities and organizations is imperative to validate the findings presented here to gain a more complete picture of Indigenous user needs and to explore alternative viewpoints.

Key processes recommended for Phase II of this work include: timeframe and scheduling that accommodates seasonal and fiscal year-end priorities; further survey/interview work with a larger and more representative sample size; engagement through a variety of vehicles including regional workshops and/or larger gatherings with opportunities for regional collaboration, webinars and presentations, and facilitating review by study participants.

6.2.2 Thematic Data Requirements

Increase availability of, and ease of access to thematic datasets to better meet the needs of Indigenous communities and organizations. Examples of key thematic datasets include:

- natural resource data – forestry, fisheries, wildlife population surveys, migration routes, etc. (95%);
- community use and occupancy studies – lifeways, harvesting, place names, travel routes, etc. (94%);
- land use and cover (87%);
- imagery – satellite, LiDAR, aerial photographs (86%);
- climate change related data – permafrost, ice cover, sea level, etc. (84%).

Prioritizing and providing these data will better enable Indigenous communities to participate meaningfully in decision-making within and beyond their asserted territories.

Engage more with Indigenous communities and organizations to better understand needs and access to framework and thematic datasets. The survey research found that several types of thematic dataset were more often rated *important/very important* than framework dataset themes. However, interview responses suggest that some organizations already have access to satisfactory framework datasets and simply assume that framework data are adequate and available, which may not always be the case.

Work to make sure relevant thematic datasets are as up-to-date as possible. Like other users of geospatial data, Indigenous organizations need up-to-date spatial data to enable them to make informed decisions about land use and other issues in relation to their territory and Aboriginal rights and title.

6.2.3 Technology, Applications, and Tools

Develop improved methods to ensure Indigenous communities have access to key framework and thematic datasets for their areas of interest, including data packages or virtual machines with data and software. Policies, standards, and governance surrounding data storage should address concerns about the security of cloud storage.[17] Bandwidth limitations are especially a problem for Indigenous organizations in the north, in parts of rural BC, and in other 'remote' locations. As well, for organizations with small staff numbers and technical capacity, this approach allows key framework or thematic data to be accessed that Indigenous groups have indicated are most familiar to them. Increasing bandwidth into these areas is a long-term solution. Issues related to concerns about cloud storage need to be addressed through appropriate policies, standards, and governance and awareness raising regarding how data can be secure in a cloud environment (Section 6.2.4).

Where possible, increase bandwidth and improve the consistency and reliability of internet access to improve data sharing and use of geospatial data and CGDI. Indigenous organizations face challenges in transferring files and working with web-based applications due to the widespread problem of weak internet access and inadequate bandwidth.

Develop and implement jargon free, user friendly tools to facilitate Indigenous organizations use and engagement with CGDI. Standardized methods, tools, protocols and systems were identified as key for Indigenous organizations to be able to build on their existing work. These include best practices or guidelines for data collection and sharing sensitive information.

Research and engagement are needed to better understand priorities and to identify cost-effective ways to improve access to technology, applications and tools. Indigenous organizations identified mobile applications and technologies, including tablets and smartphones, and use of drones/UAVs as important geospatial tools that could improve capacity for natural resource management and environmental monitoring. Lessons from virtual reality and gaming can further be explored to better actualize oral traditions tethered to maps. Facilitating better access to these technologies through subsidies, grants, or training will help Indigenous users improve their geospatial capacity.

6.2.4 Policy, Standards, and Governance

Make data discovery easier and more user friendly. An important function of CGDI/SDI is to allow users to discover datasets they are seeking and to confirm that they will meet their needs (CP-IDEA 2013). Indigenous organizations note that it is often difficult to locate needed datasets and to navigate ever-changing discovery portal interfaces. Efforts to establish more standardized and stable interfaces to geodata discovery portals would help the data discovery aspect of Indigenous CGDI/SDI use. Several organizations noted that a "one-window" approach would simplify data discovery and improve Indigenous access to, and use of, geospatial data.

Consider the feasibility of establishing regional geospatial databases to help standardize and improve data access and governance. Databases could include baseline cartographic information,

[17] Implementations of data access services for SDI can include, in addition to online data services: brokered access services; offline packaging and physical delivery of data; and direct delivery of data via FTP (GSDI 2012).

scientific information, remote sensing imagery and other data that users upload or is acquired by different levels of government. Bandwidth limitations would need to be taken into account in processing the data (tiled by region and sub-region and compressed). New, and non-confidential data collected as part of research/studies, or as part of regulatory processes could be added to this database. One of the aims of such regional databases would be to minimize the replication of effort. Maintaining a well-organized, user-friendly and searchable index of available datasets within the database would be critical.

Designate knowledgeable government contacts to be available to support Indigenous organizations to help address questions or challenges with these databases. Ideally, each community should have a designated contact within the federal government with specialist knowledge in geospatial data, its use and availability, and a good understanding of Indigenous issues related to CGDI/SDI. Such a relationship-based approach would help to build trust and bridge cultural differences.

Support Indigenous organizations to increase cataloguing capacity to help with data distribution and sharing. Survey results suggest that only 21% of organizations have data management policies or standards in place to guide how geospatial data are catalogued. Implementing some form of cataloguing compatible with publishing of metadata using Open Geospatial Consortium standards (see GSDI 2012) will help Indigenous communities that want to share data through CGDI.

Work with Indigenous communities and organizations to develop and establish clear policies and standards around data ownership, storage, sharing, and access. These are especially important with respect to confidentiality and intellectual property concerns. Indigenous communities and organizations are most concerned about the security of geospatial data related to traditional knowledge and use. Establishing clear policies and standards are critical to building trust and improving opportunities for data sharing. A framework for defining sensitive geospatial data prepared for NRCan includes the principles that the data custodian decides whether data are to be classified as sensitive and defines conditions under which sensitive data can be shared (AMEC 2010). This imperative should be applied to information held by Indigenous organizations and could include requirements for data sharing agreements and guidance on how communities can protect sensitive information.

Develop and distribute guidance documents and instructions manuals that outline best practices and help organizations to implement data management policies and practices. Indigenous organizations are amenable to complying with strong data standards and streamlined data management practices, however most do not have the resources in terms of funding and personnel to bring all existing datasets into compliance. Others simply do not know where to begin. Some interviewees suggested a "SWAT team" approach wherein a roving data expert would provide continuous and ongoing support to help implement new standards.[18] Such an approach would also reduce the need for people in remote communities to "go outside" to get training and, at the same time, would build capacity among more individuals and organizations within the community.

[18] Advocated in recent Indigenous forums centre around spatial data (e.g. Tides Canada Northern Guardian / Community-Based Monitoring Data Tools Solutions Workshop in Yellowknife, NT held from March 7-8, 2018).

6.2.5 Collaboration and Institutional Arrangements

Indigenous communities must be able to choose their levels of participation and be supported in ways that enable their engagement with CGDI in line with their own aspirations and goals. Indigenous communities and organizations have differing and often low levels of network bandwidth, geomatics technical capacity, and varied adoption of data distribution governance policies. All of these will affect the degree to which a community can participate in CGDI and reaffirms that the voluntary model for SDI development is most appropriate for Indigenous communities.[19]

Collaboration between current CGDI participants (government and other groups) and Indigenous organizations must be encouraged to help raise understanding, build trust, and increase the capacity of Indigenous organizations to use CGDI. CGDI was built working across levels of government and involving the private sector (CP-IDEA 2013) in collaborative processes and partnerships. Indigenous communities and organizations need to be afforded the same opportunities for collaboration.

Work with Indigenous communities and organizations to ensure they have adequate funding and resources to collaborate and participate in data partnerships. CGDI Principles for Data Partnership include the idea that partners should contribute equitably to costs of collecting and managing data and should be allowed to integrate information into their own databases and distribute it to their own internal stakeholders (CP-IDEA 2013). [20]

Resource development and project proponents should be compelled to share geospatial data pertinent to Indigenous issues and concerns that is collected during project initiation, permitting, and beyond. Geospatial data generated or used for the purposes of consultation should be readily available to Indigenous communities and organizations. Interviewees spoke of frustrations accessing data when a proposed project runs out of capital or decides not to proceed with an environmental assessment and fails to follow through with commitments around data sharing negotiated at the outset of the work. In cases where a project or development moves forward, several interviewees spoke about difficulties in accessing spatial data (e.g., baseline data) related to privately-held lands.

6.2.6 Capacity Building

Capacity building was a commonly expressed need amongst Indigenous organizations, regardless of their size, location, or existing geomatics capabilities. Although not the only dimensions of capacity building, funding and education and training are the two pillars of capacity that emerged most consistently throughout the UNA.

[19] There are two SDI development models: mandatory and voluntary (CP-IDEA 2013, 34). CGDI uses the voluntary model, in which use is on a purely voluntary basis.

[20] Given that lack of funding was identified as a key barrier to Indigenous aspirations around the use of geospatial data, the idea of principle of equitable participation by Indigenous organizations must be understood in the context of community resources.

Funding

Funding is a major requirement for Indigenous organizations to be able to continue to build their capacity to interact with geospatial data. Funding is recommended in the following areas to support Indigenous organizations:

- capacity building of staff and members through training and accessible tools;
- consistent long-term funding of GIS technician positions;
- funding for technology and equipment (e.g., bandwidth, computers, software);
- development and support for standardized systems, methods and tools;
- support for implementation of and training on use of data storage and data management systems;
- funding for data collection and mapping initiatives, it should be recognized that different Indigenous organizations may require different levels of funding to carry out similar work because of differences in circumstance that affect research cost (e.g., location, size, geographic extent of territory); and
- support for Indigenous organizations to turn mapping services into business opportunities.

Education and Training

Raise awareness about training, employment, and business opportunities in geomatics and other fields related to the use, collection, management, and application of geospatial data. There is a desire to further train current staff and hire GIS technicians. The preference is to be able to hire from within the community, but it is often a challenge to find members who are interested in or understand GIS, or who know of GIS-related careers. There is also potential to support the development of small businesses in rural areas who can offer data processing or other services desired by rural and remote Indigenous organizations.

Explore opportunities to incorporate lessons and modules on geospatial technology into the educational curriculum as early as possible. Encourage youth to consider careers in geospatial data was suggested by several interviewees.

Where possible, shift from reliance on outside consultants for training and expertise to Nation to Nation training and mentoring. One interviewee, from a relatively well-resourced community, suggested a “pay it forward” model such that members of the better-off community could train others with fewer resources at their disposal. Regional forums were another example where Indigenous users could be compensated to share their experience and teach others.

Promote and support the use of more contemporary and accessible training and capacity building tools. For example, while guidance documents and manuals have a role in training and capacity building, the use of video/video gaming appeals to a youth-centred approach prioritized by many Indigenous organizations and aligns with Indigenous oral tradition. Similarly, “learning by doing” is an ethic often advocated by Elders and community leaders that would lend itself well to many aspects of training around the use, collection and management of geospatial date.

Building training and capacity building programs grounded in Indigenous cultural norms and ways of learning will ultimately lead to more effective initiatives. To this end, one suggestion is to create an advisory group comprised of Indigenous representatives from across the country who could provide key guidance on capacity building initiatives and other aspects related to spatial data use, access, storage, and management. Through this current research, several individuals stood out as ideal candidates that could bring substantial value to such a group.

6.2.7 User-Centred Design (UCD)

Engage with Indigenous communities and organizations to introduce the concept of UCD and identify key Indigenous perspectives that should be incorporated. While this study is still early in the process of properly understanding Indigenous user needs, steps should be taken in subsequent stages of engagement to raise awareness of what UCD is and identify relevant Indigenous partners that should be involved in designing an approach appropriate for Indigenous organizations.

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APPENDICES

Appendix B1

Online Survey Questionnaire

Thank you for agreeing to fill out our survey about your organization's knowledge and use of geospatial data and spatial data infrastructure. The survey should only take about 15 minutes to complete.

Geographic information (also called "spatial data") is any information that identifies, or can be identified by, a geographic location on the Earth's surface. It is any data or information that can be mapped.

This survey is part of a User Needs Assessment, the goal of which is to make geographic information more useful and more accessible for Indigenous people and for all Canadians.

By completing this survey, you will be helping us to better understand Indigenous people's needs for data, tools, training, standards, policies, and governance related to geographic information. Your responses will help improve the way geographic information is organized and made available to different users and decision makers, including Indigenous nations, communities, governments, and organizations.

You do not need to be an expert in mapping, geographic information systems, or policy to contribute to this user needs assessment.

Your participation in this survey is entirely voluntary. Your responses will be kept anonymous and the findings will only be published as regional summaries.

1. Which of the following activities is your organization involved with?
Select all that apply.

- [ ] Land use planning
- [ ] Traditional use studies or use and occupancy studies
- [ ] Natural resource management and planning (including: forestry, fisheries, wildlife, water resources, etc.)
- [ ] Emergency and disaster planning
- [ ] Health, housing, and social services
- [ ] Transportation, infrastructure, and capital works
- [ ] Climate change monitoring and adaptation
- [ ] Environmental management (including: flood and erosion management, weather monitoring and forecasting, coastal zone management, etc.)
- [ ] Consultations with industry and government (including: Treaty or land selection, court cases, negotiations, environmental assessments)
- [ ] Research or study of environmental, social, cultural or economic phenomena over time
- [ ] Other (please specify)

2. What kind of geographic information would add value to your organization's work if it were more readily available?

Select all that apply and rate how important.

	Don't know	Not important	Somewhat important	Important	Very important
Land use and cover	◯	◯	◯	◯	◯
Topography, elevation, slope	◯	◯	◯	◯	◯
Traditional use studies or use and occupancy studies	◯	◯	◯	◯	◯
Natural resource data (including: forestry, fisheries, wildlife, water resources, etc.)	◯	◯	◯	◯	◯
Satellite imagery, aerial photographs, Unmanned Aerial Vehicle (UAV) data	◯	◯	◯	◯	◯
Emergency and disaster planning (e.g. flood, fire)	◯	◯	◯	◯	◯
Health, housing, and social services data	◯	◯	◯	◯	◯
Transportation, infrastructure, and capital works	◯	◯	◯	◯	◯
Climate change monitoring and adaptation (e.g. permafrost, ice cover, sea level rise)	◯	◯	◯	◯	◯
Environmental management (including: flood and erosion management, weather monitoring and forecasting, coastal zone management, etc.)	◯	◯	◯	◯	◯
Research or study of environmental, social, or economic phenomena	◯	◯	◯	◯	◯

Other (please specify what and how important)

3. Which of the following best describes your organization's capacity for working with geographic information and technology?

- ◯ We have little or no geographic capacity in-house
- ◯ We have basic geographic capacity in-house
- ◯ We have advanced geographic capacity in-house
- ◯ Don't know

4. How extensively does your organization use the following geospatial technologies?

	Don't know	Never	Sometimes	Frequently	Always
Maps (digital)	◯	◯	◯	◯	◯
Global Positioning Systems (GPS)	◯	◯	◯	◯	◯
Geographic Information Systems (GIS)	◯	◯	◯	◯	◯
Remote Sensing (e.g. satellite images, drone images)	◯	◯	◯	◯	◯
Spatial database administration (e.g.: managing environmental monitoring data)	◯	◯	◯	◯	◯
Web mapping application programming	◯	◯	◯	◯	◯
Spatial Data Infrastructure (e.g. tools, resources, standards, and policies needed to use spatial data)	◯	◯	◯	◯	◯

Other (please specify)

5. Do you have a data management policy, including standards for cataloguing (metadata) and storing your geographic information?

- ◯ Yes
- ◯ No
- ◯ Don't know

6. If/when using geographic information to support activities, how often does your organization do the following?

Please rate the following:

	Don't know	Never	Sometimes	Frequently	Always
Use geographic information or services provided by other organizations (for example, downloading maps and datasets)	○	○	○	○	○
Produce geographic information or services for internal use (for example, collecting geographic information in the field and mapping them electronically)	○	○	○	○	○
Share or sell geographic information or services (for example, contribute geographic information to a communal database, sell maps, or provide spatial or geographic services)	○	○	○	○	○
Facilitate access to geographic information or services (for example, help other groups or organizations access and use geographic information, administer/coordinate a database to share data with selected individuals or groups)	○	○	○	○	○
Develop geographic applications (online, mobile, or desktop)	○	○	○	○	○

7. Do you use external service providers and consultants to meet your organization's needs for geographic information and services?

- ○ We don't use external providers and don't have in-house capacity
- ○ We use only in-house resources to meet our needs
- ○ We sometimes use external support (e.g. for specific tasks to complement internal resources)
- ○ We use external support frequently
- ○ We always use external support
- ○ Don't know

8. Where does your organization get geographic information or data from?

Please rate the following:

	Don't know	Never	Sometimes	Frequently	Always
Produced in-house from field observations and local/traditional knowledge	○	○	○	○	○
Shared or provided by another Indigenous organization	○	○	○	○	○
Federal government	○	○	○	○	○
Provincial/Territorial government	○	○	○	○	○
Private companies/consultants	○	○	○	○	○
Academic institutions	○	○	○	○	○

Other (please specify)

9. How often does your organization use the following methods to access geographic information?

	Don't know	Never	Sometimes	Frequently	Always
Download or access geographic information from free, publicly-available sources (e.g.: government repositories; web-based catalogues)	○	○	○	○	○
Purchase geographic information	○	○	○	○	○

10. What challenges does your organization face in acquiring and making use geographic information and data?

Please rate the following:

	Don't know	Not a challenge	Somewhat challenging	Challenging	Major challenge
Training, skills, capacity	○	○	○	○	○
Heavy workload	○	○	○	○	○
Equipment (computers, software, GPS and other geographic data collection tools)	○	○	○	○	○
Internet issues (limited bandwidth, speed, and reliability)	○	○	○	○	○
The data we want is unavailable	○	○	○	○	○
Restrictions on accessing datasets (privacy, licensing etc.)	○	○	○	○	○
Lack of content in appropriate language	○	○	○	○	○
Lack of information on where to find data	○	○	○	○	○
Lack of funding	○	○	○	○	○
Cost	○	○	○	○	○

Other (please specify what and how challenging)

11. What challenges does your organization face in integrating important datasets into your organization's activities?

Please rate the following:

	Don't know	Not a challenge	Somewhat challenging	Challenging	Major challenge
Incompatible file formats	○	○	○	○	○
Missing metadata	○	○	○	○	○
Incomplete or inaccurate data	○	○	○	○	○
Inappropriate temporal or spatial scale	○	○	○	○	○
Heavy workload	○	○	○	○	○
Training, skills, capacity	○	○	○	○	○
Lack of information on how to integrate	○	○	○	○	○

Other (please specify what and how challenging)

12. What software programs or systems does your organization use to work with geographic information?

Select all that apply.

- ☐ Publicly available web-based software (For example: Google Maps, Google Earth, Bing Maps, OpenStreetMap, Apple Maps)
- ☐ Open source desktop software (For example: QGIS, Grass, SAGA)
- ☐ Commercial spatial software (For example: ArcGIS, Global Mapper, PCI Geomatica, ERMapper. ENVI, Erdas Imagine, Trailmark)
- ☐ Computer and web programming tools (For example: Python; C#)
- ☐ None
- ☐ Don't know
- ☐ Other (please specify)

13. What devices does your organization currently use to work with geospatial data?
Select all that apply.

- [ ] Desktop computer
- [ ] Smartphone
- [ ] Tablet or other portable device
- [ ] GPS
- [ ] Print outs
- [ ] Don't know
- [ ] Other (please specify)

14. What methods do you *currently* use to interact with geographic information?
Select all that apply.

- [ ] Graphical User Interface(GUI)
- [ ] Scripting (e.g. Python)
- [ ] Application Program Interface (API)
- [ ] Services by an external provider
- [ ] Don't know
- [ ] Other (please specify)

15. What methods would you *prefer* to use to interact with geographic information and spatial data in the future?
Select all that apply.

- [ ] Graphical User Interface(GUI)
- [ ] Scripting (e.g. Python)
- [ ] Application Program Interface (API)
- [ ] Services by an external provider
- [ ] Don't know
- [ ] Other (please specify)

Geographic information can be **shared** by a number of means, including paper maps, electronic maps, data files, online mapping systems, and many more.

16. Does your organization share geographic information it has collected or otherwise owns?

- ◯ Yes
- ◯ No

17. How do you share geographic information?
Select all that apply.

- [ ] Internally within your community/organization
- [ ] With other Indigenous Nations/organizations
- [ ] Externally, with other non-indigenous groups

18. Who do you share geographic information with?
Select all that apply.

- [ ] Indigenous government /decision makers
- [ ] Indigenous Elders and community members
- [ ] Other (external) Indigenous organizations
- [ ] Federal or Provincial/Territorial government
- [ ] Band or nation owned businesses or other Indigenous business
- [ ] Private companies (e.g. mining and forestry companies)
- [ ] Consultants (e.g. working for your organization)
- [ ] Partners or collaborators (e.g. conservation NGOs)
- [ ] Academic institutions
- [ ] Other (please specify who and how often)

19. What prevents you sharing geographic information with others?
Select all that apply.

- [ ] Confidentiality and intellectual property
- [ ] Restrictive licenses
- [ ] Technical limitations (e.g. low bandwidth or connection speed)
- [ ] Limited understanding of or awareness about geographic information systems
- [ ] Lack of software/hardware (including storage space)
- [ ] Other (please specify)

20. Do you have a policy or procedure that governs the sharing and/or distribution of geographic information?

- ( ) Yes
- ( ) No
- ( ) Don't know

21. How do you communicate or distribute the geographic information to your end users (audience)?
Select all that apply.

- [ ] Paper maps
- [ ] Electronic map images (e.g.: PDF maps, website images)
- [ ] Online mapping software (e.g.: Google maps, Bing maps, OpenStreetMaps)
- [ ] Digital/electronic datasets (e.g.: Google KMZ, ESRI Shapefile)
- [ ] Network map services using the internet or Internal network (e.g.: WMS; WFS)
- [ ] Digital or electronic maps and datasets for use on mobile devices
- [ ] Other (please specify)

22. Are you familiar with the Canadian Geospatial Data Infrastructure (CGDI) tools and standards?

- ( ) Yes
- ( ) No

23. Do you use any CGDI data content, tools or standards in your GIS?

- ( ) Yes
- ( ) No

24. If Yes, select all that apply

- [ ] Web Mapping Services (WMS) and/or Web Feature Services (WFS)
- [ ] Web Processing Services (WPS)
- [ ] Google KML
- [ ] Metadata Standards
- [ ] Other (please specify)

* 25. About your organization

Name of organization

Location

Approximate size

26. Type of organization:
Select all that apply.

- [ ] Indigenous community or government
- [ ] Tribal council
- [ ] Treaty organization
- [ ] Private company
- [ ] Indigenous Association (for example: hunters and trappers association)
- [ ] NGO
- [ ] Resource Council
- [ ] Indigenous-owned company
- [ ] Academic institution
- [ ] Other (please specify)

27. With respect to geographic information, is your organization a(n):
Select all that apply.

- [ ] Publisher of geographic information
- [ ] Enabler/facilitator that supports or promote access and use of geographic information
- [ ] End-user of geographic information
- [ ] Don't know

28. Which of the following best describes your role?

- ◯ Manager of environment, natural resources, lands, etc.
- ◯ Manager of geographic information
- ◯ Technician (e.g.: GIS)
- ◯ Consultant
- ◯ Other (please specify)

29. If you have any additional comments about how you currently use geographic information or about what limits your use of geographic information, please let us know below.

30. Are there any other organizations who you think we should talk to? Please let us know below:

31. Please provide your contact information below if you would be willing to do a 30 minute follow-up interview with us.

Name	
Organization	
Email Address	
Phone Number	

Thank you for completing the survey!

Appendix B2

Interview Questions

INTERVIEW PROCESS AND GUIDE

1.0 INTRO SCRIPT

Thank you for agreeing to participate in this interview. Your insights will help us to better understand Indigenous people's needs for data, tools, training, standards, policies, and governance related to geographic information.

We will make every effort to ensure the information you provide is kept confidential. We will not quote you without obtaining your written consent in advance. We will only report on the information gathered for this project in regional summaries.

You may halt the interview at any time or ask to have your responses removed from the study. If you wish, you will have the opportunity to review notes taken during the interview and make any comments or corrections.

If there are specific interviewing protocols within your community I should be following, please let me know now.

Do you have any questions? May we begin the interview?

2.0 INTERVIEW GUIDE (AND NOTES)

1. Name of interviewee:

Enter notes here

2. Name of organization:

Enter notes here

Ice-breaker questions:

3. Please tell me your job title or position

…

4. How long have you been with the organization/working in this field?

…

5. What sort of background or training do you have that prepared you for this position?

2.1 PROTOCOL FOR HAVE NOT COMPLETED THE ONLINE SURVEY

If the respondent has completed the survey, skip to Section 2.2.

A. Tell me about your organization's core objectives and/or its mandate.

B. Can you further describe to me how your organization interacts with geographic information? (PROMPT: Confirm which user profiles this org belongs to. Do you publish or share spatial data on the internet or offline? Do you promote access to spatial data by providing services or maintaining a database? Do you simply download spatial data and use it only for internal purposes?)

C. How would you describe your organizations capacity to work with and use geographic information?

Proceed to Section 2.3.

2.2 ABOUT YOUR ORGANIZATION

6. Can you further describe to me how your organization interacts with geographic information? (PROMPT: Confirm which user profiles this org belongs to. Do you publish or share spatial data on the internet or offline? Do you promote access to spatial data by providing services or maintaining a database? Do you simply download spatial data and use it only for internal purposes?)

…

(Q25, ADDED 2018-02-28) What geographic information is most important to your organization right now?

…

2.3 BARRIERS TO USING GEOGRAPHIC INFORMATION/SDI

For the following question, useful to have the interviewees survey responses available in front of you.

7. In the survey, you said your organization does … … ….
What geographic information that you can't access now would help you do this better?

8. Tell us (more) about barriers/challenges related to cost (for example: cost of personnel with the right skills, cost of acquiring data, cost of software to analyze manipulate, cost of equipment and hardware)

…

9. Tell us (more) about barriers/challenges related to accessing data that is relevant (for example: can't find it, completeness/appropriateness, inconsistencies, availability on the right spatial scale, etc.)

…

(Q26, ADDED 2018-02-28): What type of documentation for geographic data or applications is useful to your organization? [Examples for prompting: metadata; feature catalogue; attribute table entities description; publication notes; distribution formats; file name identification; manuals on how to use.]

…

(Q27, ADDED 2018-02-28): What geographic data formats are most useful for your organization? [Examples for prompting: shapefile; file geodatabase (ESRI); KML (Google Earth); DNG (Autocad); GeoTIFF (satellite imagery).]

…

10. Tell us (more) about barriers/challenges related to data policies and governance (for example: privacy and confidentiality; not willing to share information in a central database, lack data management policies, etc.)

…

11. Tell us (more) about barriers/challenges related to technology (for example: ….)

…

12. Can you give me any examples of issues or needs of your community or organization that would be easier to manage if you had better access to geographic information?

…

13. Do you share geographic information with other communities or organizations? If yes, what sorts of barriers and challenges do you face in trying to share geographic information?

…

The following Question is for FACILITATORS/PUBLISHERS:

…

14. Tell us more about barriers/challenges related to getting the right information and products to your audience

2.4 FUTURE USE OF GEOGRAPHIC INFORMATION/SPATIAL DATA

15. In what ways would you like to be producing, using, accessing, or sharing geographic information that you currently are not? (Prompt: for example, this could include collecting field data, producing maps and products, getting more training, doing spatial analysis, GIS processing, storage management services, creating or using mobile apps?)

…

16. What might be required to do this? (Prompt: For example, think of training and capacity building; and standards/guidance (e.g.: user manuals), additional funding). Alternate or additional wording: What needs to be enhanced in order to do that in terms of: technology and tools, standards and policies, access, training, cost reductions, etc.

…

17. Who might your organization need or want to collaborate with to increase or improve your access to and ability to make use of geographic information?

…

18. What kinds of information/tools/services would be most useful? (Prompt: For example, more/better web services)

…

19. . What future plans might you have that require use of or collection of spatial data?

…

20. Do you think you might need to store, organize, and share spatial data (internally/externally) using SDI standards, tools, etc. in the future?

…

21. Are you aware of any reports or documents on user spatial information needs that might be useful for our study? Do you know how we might obtain a copy or gain access to those?

2.5 CLOSING

22. Before we close, is there anything else you'd like to share about your experience with geographic information?

…

23. We are always trying to improve this interview. Are there questions we asked and shouldn't have? Are there questions we should have asked?

…

24. Is there anyone else, or other organization, that you think it would be important for us to talk to?

…

(ADDITIONAL QUESTIONS ADDED 28 FEBRUARY 2018 as additions to Q6 and Q9 although they have been numbered 25 – 28 for tracking purposes.)

…

…

…

Thank you for participating. Over the next several weeks we will be collating and analyzing the results and will submit a report to NRCan. Please feel free to contact us with questions or comments at any time.