SPATIAL DATA INFRASTRUCTURE (SDI) MANUAL FOR THE ARCTIC

A collective work by the national mapping agencies of the eight Arctic countries: Canada, Finland, Iceland, Norway, Russia, Sweden, United States of America and the Kingdom of Denmark

Version 1.0

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Document History and Version Control

Document Version Number	Brief Description of Change
0.9	Initial document created by Intelli3 and delivered to Canada.
1.0	Revised based on comments from the national mapping agencies of the eight Arctic countries. The following sections were updated: Executive Summary, Data Models, Data Specification, Thematic Data, Standards and Conclusions.

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Executive Summary

Understanding and responding to the impacts of climate change and human activities in the Arctic, a unique area among the Earth's ecosystems, require accessible and reliable data to facilitate monitoring, management, emergency preparedness and decision making. Often it is difficult and costly to find, access and combine useful datasets for a project since they are stored in many different organisations. The Arctic Spatial Data Infrastructure (Arctic SDI), launched by representatives from the eight participating national mapping agencies of the Arctic countries, was established to address this need for readily available spatial data in the North.

The Arctic SDI is currently under development. Stakeholders from various groups have identified the need for the creation of a SDI Manual for the Arctic aiming at providing guidance and information management good practices through the adoption of commonly accepted SDI operational policies and standards. This manual addresses the needs of 3 different audiences: the high-level strategic decision makers, the Arctic data providers and distributors, and the end users of Arctic data.

The key components of a SDI include institutional arrangements and collaboration between participating organisations, data (including framework and thematic spatial data), technologies covering all aspects of the SDI, standards allowing for diverse data sources, services, applications, and systems to operate with each other, and policies covering the whole spatial data lifecycle and enabling users to exchange data effectively and efficiently. These components are described in details in the manual. Additional considerations such as the open SDI concept, community engagement, communications, and monitoring and measuring impacts and benefits of the SDI are also discussed.

The goal of this manual is to provide information and guidance on the planning, management, development and maintenance of the Arctic SDI to the various involved groups, to provide best data management practices, to identify policy and guideline requirements and to demonstrate the value and benefits of using a SDI for efficient monitoring and decision making in the Arctic. It is inspired by and building on the United Nations *SDI Manual for the Americas* (CP-IDEA, 2013) and other references.

This SDI manual (version 1.0) is a living or dynamic document, which is expected to be continually edited and updated to reflect the evolution of SDI components and also the changing information requirements of the Arctic stakeholders. It does not necessarily reflect all policies of each of the participating national mapping agencies.

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List of Acronyms

Table 1 presents the meaning of acronyms used in this document.

Acronym/abbreviation	Meaning
ABDS	Arctic Biodiversity Data Service
CAFF	Conservation of Arctic Flora and Fauna
CGDI	Canadian Geospatial Data Infrastructure
CSS	Cascading Style Sheets
EBSA	Ecologically or Biologically Significant Marine Area
EU	European Union
GIT	Geographic Information Technology
GML	Geography Markup Language
GSDI	Global Spatial Data Infrastructure
HTML	Hyper Text Markup Language
HTTP	Hyper Text Transfer Protocol
ICAO	International Civil Aviation Organization
IHO	International Hydrographic Organization
INSPIRE	Infrastructure for Spatial Information in the European Community
ISO	International Organization for Standardization
KPI	Key Performance Indicator
MOU	Memorandum of Understanding
NCP	National Contact Point
NMA	National Mapping Agency
NSDI	National Spatial Data Infrastructure
OGC	Open Geospatial Consortium
OWL	Web Ontology Language
PBM	Performance-Based Management
PDC	Polar Data Catalog
PI	Performance Indicator
SDI	Spatial Data Infrastructure
SKOS	Simple Knowledge Organization System
SIMF	Spatial Information Management Framework
TC	Technical Committee
URI	Uniform Resource Identifier
VGI	Volunteered Geographic Information
W3C	World Wide Web Consortium
WMS	Web Mapping Service
XML	Extensible Markup Language

1. Introduction to the Manual

The Arctic is the region surrounding the North Pole and consists of the Arctic Ocean and parts of the Arctic countries: Alaska (United States), Canada, Finland, Greenland (Denmark), Iceland, Norway, Russia, and Sweden. The Arctic region is a unique area among the Earth's ecosystems and is considered the world's barometer for climate changes. It includes the largest freshwater resources (with Antarctic) and it presents unique and diverse Indigenous cultures.

Understanding and responding to the impacts of climate change and human activities in the Arctic require accessible and reliable data to facilitate monitoring, management, emergency preparedness and decision making. For example, the Ecosystem-Based Management (EBM) approach proposed by the Arctic Council Expert Group on EBM for the Arctic Environment requires seamless sharing of data across jurisdictions and organisations (Arctic Council, 2013). However, it is often difficult and costly to discover, access and combine useful datasets for a project since they are stored in many different organisations. The Arctic Spatial Data Infrastructure (Arctic SDI) was established to address this need for readily available spatial data in the North.

The **Arctic SDI is currently under development**. Stakeholders from various groups have identified the need for the creation of a SDI Manual for the Arctic aiming at providing guidance and information management good practices through the adoption of commonly accepted SDI operational policies and standards.

This first chapter presents an overview of basic spatial data infrastructure (SDI) concepts, and the specific context of the Arctic SDI. It describes the intended audience and the objectives of the document. It presents an illustrated case study that will be used throughout the manual to picture the various elements that will be discussed. It also introduces the reader to the contents of this SDI Manual for the Arctic.

1.1 The SDI Concept

The **SDI concept appeared in the early 1990's** (CP-IDEA, 2013) and its first adoption at the national level occurred in the United States in 1994, with the establishment of the National Spatial Data Infrastructure (NSDI) (Robinson, 2008). Among other Arctic countries, Canada initiated the development of its Canadian Geospatial Data Infrastructure (CGDI) in 1999 (GeoConnections, 2005). The Russian Federation, on its side, started the development of its NSDI in 2006 (Russian GIS Association, 2006). In May 2007, the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive was adopted. This directive included a mandatory requirement for the implementation of national SDIs, made compatible with common implementation rules, by all European Union Member States (European Parliament, 2007), which comprises the other Arctic countries (Finland, Denmark, Iceland, Norway, and Sweden). Similarly, various communities are working on Data Centers (e.g., the Canada's First Nations Data Center), GeoData Portals (e.g., the Arctic Biodiversity Data Service of the Arctic Council's Conservation of Arctic Flora and Fauna Working Group) and Geospatial Data Catalogues (e.g., the Polar Data Catalogue of the Canadian Cryospheric Information

Network and of ArcticNet Canadian Network of Centers of Excellence for the coastal Canadian Arctic). In fact, when a group of organisations have interests and conduct activities in a common region, they build a common infrastructure to facilitate data discovery and exchange, while implementing policies to state their responsibilities and protect their rights related to data.

Organisations involved in several regions of the world may participate in more than one SDI. Standards allow for interoperability between SDIs, when desired, and participation in a SDI strengthens the collaboration with other stakeholders in a given region of the world.

The **economic and operational driving forces** motivating the development of SDIs are:

- The need to easily discover datasets that already exist in various organisations, in order to avoid repeating data collection tasks and to uncover projects or studies having potentially useful information;
- The need to understand how the discovered data has been collected and processed, if it has usage restrictions, and to assess its fitness for the intended use;
- The need to easily and transparently access, view and use the selected data originating from a variety of organisations, independently of the diversity of technologies used to produce it and to store it;
- The need to facilitate interoperability between the different systems of the various organisations that produce, process and distribute spatial data, through the use of standards, procedures and policies;
- The need for a common framework that facilitates communication between various stakeholders and access to their data. This is similar to infrastructures such as electricity and transportation networks. That is to say, a true infrastructure involving the collaboration of stakeholders for the benefits of society.

These driving forces call for a solution, namely a SDI, that will provide cost savings, time savings and that will reduce error.

A **SDI can be defined as "the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of, and access to, spatial data**" (Global Spatial Data Infrastructure Association, 2009). It is a mechanism for making data available and for sharing and exchanging it to help achieve social, environmental and economic goals of the participant organisations. SDI stakeholders keep ownership and control of their data, which, in spite of being distributed, appears to be integrated.

The **key components of a SDI** include (CP-IDEA, 2013), (GeoConnections, 2012):

- Institutional arrangements and collaboration between participating organisations: the mechanisms enabling stakeholders to collaborate in the planning and implementation of the SDI;
- Data: including framework and thematic spatial data;
- Technologies: covering all aspects of the SDI, from distributed data storage to discovery, access, harmonization and dissemination of spatial data;
- Standards: allowing for diverse data sources, services, applications, and systems to operate with each other (i.e., to "inter-operate");

- Policies: covering the whole spatial data lifecycle and enabling users to exchange data effectively and efficiently.

These components will be addressed in details in other sections of the manual, within a spatial information management framework context.

Working together thanks to interoperability, the SDI components deliver the key capabilities of the infrastructure (CP-IDEA, 2013). They:

- Enable online access to a wide range of spatial data and services;
- Enable the integration of geographically distributed spatial data;
- Enable collaboration by multilateral information exchange and synchronization;
- Allow autonomous organisations to develop interdependent relationships in a distributed environment; and
- Facilitate the definition and sharing of spatial semantics.

The **concept of interoperability** is at the heart of a SDI. It can be defined as "the ability of different types of computers, networks, operating systems and applications to work together effectively, without prior communication, in order to exchange information in a useful and meaningful manner" (CP-IDEA, 2013). Interoperability encompasses many aspects: technical, semantic, geosemantic, organisational and legal. These will be discussed in details in section 4.

1.2 Brief History of the Arctic SDI

The SDI of particular interest in this manual is the Arctic SDI. The first idea of a spatial data cooperation between Arctic countries was the Geographic Information Technology project in the Barents region (GIT Barents), launched in 1998 (Palmér, 2009). This project, conducted by national mapping agencies (NMAs) of Finland, Norway, Russia and Sweden, aimed at producing a common geographic database covering the entire Barents Sea region and at making data available to users by establishing an Internet-based infrastructure aligned with the principles of the European Union's (EU) INSPIRE Directive (Arctic SDI National Contact Points, 2015). The idea of an Arctic SDI started to circulate in 2007 and it **received a formal support from the Arctic Council in 2009**, following a request from the NMAs of the 8 Arctic countries.

The Arctic SDI was officially launched in 2011 by representatives of the 8 NMAs of the Arctic countries (Arctic SDI National Contact Points, 2015). In 2014, it has been formalized by the signing of a Memorandum of Understanding (MoU) in the English, French and Russian languages by the 8 Arctic countries (Arctic SDI, 2014). The **Arctic SDI vision** is: "The Arctic SDI will facilitate access to geospatial information in support of social, economic, environmental, monitoring, decision-making and other needs in the Arctic." (Arctic SDI Working Group on Strategy, 2015). The **mission of the Arctic SDI** "is to promote cooperation and development of a Spatial Data Infrastructure that enables discovery, visualization, access, integration and sharing of Arctic spatial data, while pursuing best data management practices." (Arctic SDI Working Group on Strategy, 2015). The **objective of the Arctic SDI** is to provide governments, policy makers, scientists, private companies and citizens in the Arctic with access to geographically related Arctic data, digital maps and tools to facilitate monitoring and decision-making (Arctic SDI National Contact Points, 2015). It covers the Arctic regions of the participating countries, as defined by the countries themselves.

The **Arctic SDI organisation** is composed of a Board, an Executive Board, National Contact Points (NCPs), the Secretariat for the Chair of the Board and working groups (Arctic SDI Secretariat, 2015):

- Working Group on Geoportal
- Working Group on Cloud and Cascading Web Mapping Services (WMS)
- Technical Working Group
- Working Group on Strategy
- Working Group on Operational Policies
- Working Group on Communication

The chairmanship of the Arctic SDI Board rotates among member countries synchronized with the membership of the Arctic Council. Since 2011, work has been conducted at many levels by the Arctic SDI working groups to develop the Arctic SDI **Strategic Plan 2015-2020**, the **Implementation Plan**, the Arctic SDI **Roadmap** and the **Governance document**. Elements of the initial phase of the Arctic SDI, the basemap and the geoportal that also includes a map viewer, are available through the Arctic SDI Website, and **pilot activities** have also been conducted with the Conservation of Arctic Flora and Fauna (CAFF) working group of the Arctic Council to include their thematic remote sensing data on land cover change (Arctic SDI National Contact Points, 2015).

The Implementation Plan details the tasks that will be accomplished from 2015 to 2020 by each Arctic SDI working group to address the **6 objectives** presented in the Strategic Plan (Arctic SDI Working Group on Strategy, 2015):

- Objective 1: Users and Stakeholders 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

For more information:

- Please visit the Arctic SDI Website at: http://arctic-sdi.org/ for up-to-date documentation and access to the Arctic SDI.

1.3 Intended Audience of this Manual

This manual addresses the needs of **3 different audiences**: the high-level strategic decision makers, the Arctic data providers and distributors, and the end-users of Arctic data, as detailed in the following paragraphs:

- **High-level strategic decision makers** such as the Arctic Council with its working groups and permanent participants and the United Nations;
- **Arctic data providers and distributors** of reference and thematic spatial data, as well as the 8 NMAs participating in the Arctic SDI (and also contributing to their own national SDI);
- **End-users** of Arctic data: governments, policy makers, scientists, private enterprises and citizens in the Arctic.

1.4 Objectives of this Manual

There exist a number of SDI manuals available from various organisations, for example, the United Nations *SDI Manual for the Americas* (CP-IDEA, 2013) and the *SDI Cookbook* of the Global Spatial Data Infrastructure (GSDI) Association (Global Spatial Data Infrastructure Association, 2009). The SDI Manual for the Arctic references these existing guides, best practices and case studies, when relevant, and presents new contents adapted to the specific needs of the Arctic SDI stakeholders as presented in section 1.3.

The objectives of this manual are:

- To provide guidance on the planning, management, development and maintenance of the Arctic SDI to the various involved groups.
- To provide best data management practices.
- To identify policy and guideline requirements.
- To identify the value and benefits of using a SDI for efficient monitoring and decision making in the Arctic.

This manual addresses objectives 1 (User and Stakeholders Needs and Requirements) and 5 (Spatial Operational Policies) of the Arctic SDI Strategic and Implementation Plans (Arctic SDI Working Group on Strategy, 2015).

This manual is partly based on the content of the *SDI Manual for the Americas* (CP-IDEA, 2013) and other references (see section 10).

1.5 Manual Overview

This manual is structured in 10 chapters, including this introductory chapter. It also comprises appendices containing the case study of a pilot project conducted with the Conservation of the

Arctic Flora and Fauna working group of the Arctic Council, a sample list of operational SDIs and a Glossary of SDI terms.

Chapter 2 discusses methods for identifying users of the Arctic SDI and their needs, and presents the concepts of user-centered design.

Chapter 3 discusses SDI economics in general and in the specific context of the Arctic SDI and presents ways of evaluating the value of the Arctic SDI.

Chapter 4 addresses various considerations at each phase of the development and implementation of the Arctic SDI, for its core elements: institutional arrangements, data (creation, maintenance, and distribution), technologies, interoperability, standards, and policies.

The purpose of Chapter 5 is to discuss Open SDI considerations: open software, data, standards and policies.

Chapter 6 discusses how to engage Arctic communities and other international stakeholders in the Arctic SDI and also includes capacity building considerations.

The aim of Chapter 7 is to present the components of a communication strategy adapted for the Arctic SDI and its various stakeholders.

Chapter 8 discusses the importance of measuring and monitoring the benefits of a SDI initiative and presents methodologies for measuring and monitoring the impacts and benefits of the Arctic SDI.

Chapter 9 draws conclusion from the informational elements presented in this guide.

Chapter 10 contains the reference of documents cited in the manual.

Figure 1 presents the workflow corresponding to the chapter structure of the manual.

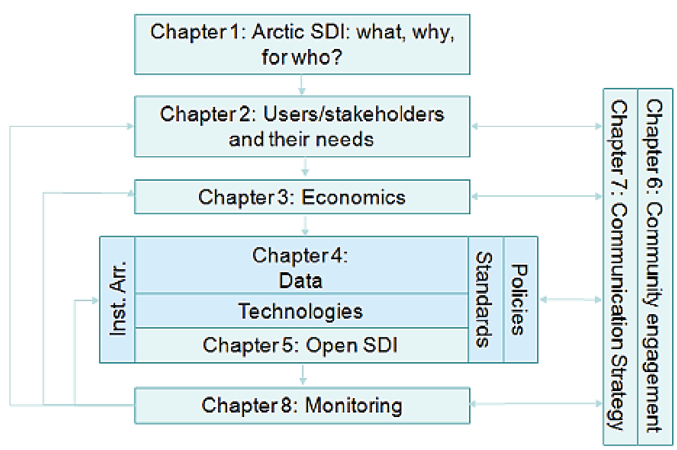


Figure 1. Workflow presenting the chapter structure of the manual.

1.6 Illustrated Case Study

An illustrated case study, presented in Figure 2, will be used throughout the document, in whole or in part, to illustrate the concepts discussed in the different sections.

Figure 2. International case study illustrating the challenges and benefits of an Arctic SDI.

Cell 1 of the illustration shows that, to ensure a sustainable exploitation of the ocean's resources, every person or group involved relies on data, and is also part of the data solution. Building the Arctic SDI requires a thorough understanding of the users, their needs and their position in the overall picture of relevant Arctic SDI stakeholders, which can be very diverse.

Cell 2 presents a few example questions the various stakeholders may ask themselves about the data they need to produce or the data they need to use with regards to their exploitation of the Arctic's resources. User needs assessments can help organisations involved in the Arctic SDI set priorities and make decisions about the elements required to address the implementation, usage and maintenance phases.

Cell 3 illustrates a sample of data production and data usage challenges that the Arctic SDI will help to address. Building an Arctic SDI requires the development of a set of best practices addressing the core elements (institutional arrangements, framework and thematic data, technologies and interoperability): requirements, standards and policies.

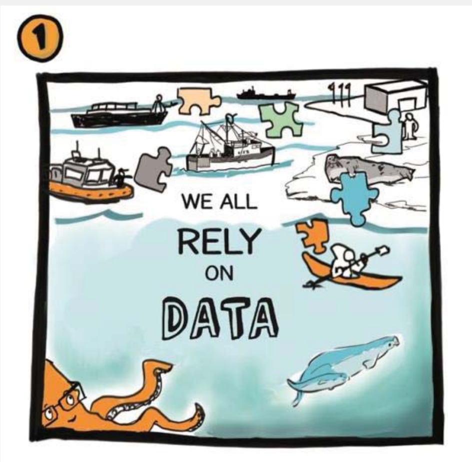
Cell 4 shows the Arctic SDI, represented as an octopus working behind the scenes (under water) with its 8 tentacles providing solutions to the data production (interoperability, use of standards, required policies, etc.) and data usage (data discovery and access, fitness for use, data harmonization, etc.) challenges presented in Cell 3.

The final cell, Cell 5, presents the resulting benefits of the Arctic SDI collaboration efforts as realized by the persons and groups involved in the exploitation of the Arctic's resources.

2. Arctic SDI Users and their Needs

Users and their needs are central parts of a SDI project. They drive development priorities to ensure the SDI serves the requirements. This chapter discusses methods for identifying users of the Arctic SDI along with their needs, and presents the concepts of user-centered design. User needs assessments usually occur after an organisation has developed a strategic plan and/or business plan. They are used as a preliminary guide to focus development of a system, an interface and/or the content to be provided. User-centered design occurs later, when a SDI decision-support system, application or interface is being developed (GeoConnections, 2007).

The task of identifying the users of the Arctic SDI, along with their needs, corresponds to objective 1 (Users and stakeholders needs and requirements) of the Arctic SDI Strategic Plan (Arctic SDI Working Group on Strategy, 2015).



Building an Arctic SDI requires a thorough understanding of the users, their needs and their position in the overall picture of relevant Arctic SDI stakeholders, which can be very diverse as illustrated in Figure 3.

Figure 3. The Arctic SDI stakeholders.

2.1 Identifying Users

Users, or stakeholders in a more general way, of a SDI can be grouped in **broad profiles**, or categories (GeoConnections, 2007), (CP-IDEA, 2013).

- *Enablers/facilitators*: They typically are government or inter-government agencies or programs that facilitate the use of spatial information by a large group of organisations and the public in general.
- *Suppliers*: They contribute spatial data and Web services to the SDI. They are at the core of the SDI, providing the building blocks necessary to develop spatial applications that will be accessed by end-users.
- *Developers*: They implement the technical infrastructure of the SDI and they create Web-based applications that allow users to interact with the SDI data and services.

- *Marketers*: They promote or sell the SDI, and spatial applications created within the SDI, to end users.
- *End users*: They use spatial data in decision-making or in business operations and rely on the SDI spatial applications to produce usable outputs.

In the Arctic SDI context, these categories are comprised of the following members:

- *Enablers/facilitators*:
  - The Arctic Council and its working groups and permanent participants;
  - The Arctic SDI Board;
  - The Arctic SDI Working Group on Strategy; and
  - The Arctic SDI Working Group on Operational Policies.
- *Suppliers*:
  - The Arctic Council working groups and permanent participants;
  - The NMAs of the 8 participating Arctic countries; and
  - Other data providers and distributors of Arctic Data.
- *Developers*:
  - The Arctic SDI Technical Working Group;
  - The Arctic SDI Working Group on Geoportal;
  - The Arctic SDI Working Group on Cloud and Cascading Web Mapping Services (WMS); and
  - Other developers of spatial applications within the Arctic SDI.
- *Marketers*:
  - The Arctic Council and its working groups and permanent participants; and
  - The Arctic SDI Working Group on Communications.
- *End users*:
  - The Arctic Council and its working groups and permanent participants; and
  - Governments, policy makers, scientists, private enterprises and citizens in the Arctic.

Potential end users of the Arctic SDI cover a broad spectrum of public and private sector organisations, as well as the Arctic communities and the general public. End users within organisations, the "professional users", will typically be looking for spatial information that complies with accepted standards, that they can quickly access and integrate with their own data or other data accessed via the SDI. Professional users usually have a greater need for authoritative spatial information. Citizens and the general public, the "non-professional users", will typically use the Arctic SDI to access spatial data for such purposes as locating a particular service or business, planning a trip or vacation, or facilitating a recreational activity (CP-IDEA, 2013).

In addition, based on their level of expertise towards spatial data and services (from non-experts to experts), stakeholders of the Arctic SDI will have varying needs that must be taken into consideration during the Arctic SDI planning and design phases.

2.2 Identifying Users' Needs

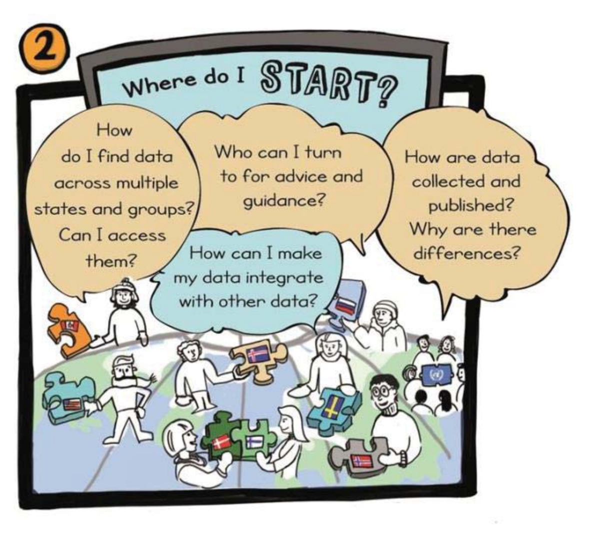


Figure 4. Arctic SDI stakeholders: what are their needs?

User needs assessments can help organisations involved in the Arctic SDI set priorities and make decisions about the elements, the pieces of the puzzle, required to address the implementation, usage and maintenance phases as illustrated in Figure 4.

A **user needs assessment** is a process of discovering and assessing the needs of users by taking into account their ideas, attitudes, wants and preferences on a particular issue. A user needs assessment can help organisations set priorities and make decisions about a program, application or system, or the allocation of resources (GeoConnections, 2007).

2.2.1 The Scope of an Arctic SDI User Needs Assessment

User needs assessments, in the context of the Arctic SDI, should cover the following aspects (Arctic SDI Working Group on Strategy, 2015), (CP-IDEA, 2013):

- The characteristics of users (user profiles) that may impact use.
- The key activities or tasks performed by users.
- What reference and thematic data are the most useful for different types of users and at what geographic extent, spatial scale and time scale.
- What levels of quality and usability of the data (including licensing and use restrictions) are required in order to ensure that the data offerings can be fully exploited.
- What data enhancements are required.

- How existing reference and thematic data are used and accessed, and from where they can be accessed.
- What distribution formats are preferable for different types of users.
- What Web services and tools are the most useful for different types of users.
- What types of data and service documentation (e.g., metadata, user manuals) are required by different types of users in order for them to evaluate the fitness for use of the data and services.
- What data products and services might be available from providers or stakeholders.
- The scope of general knowledge about information management policies, geoportals, SDIs and their benefits.
- What legislation, strategic and operational policies, and guidance (standards, technology, procedures, etc.) are required or should be applied to enable the data providers, data distributors and data users to participate in the Arctic SDI.
- The level of effort required by data providers and staff of the participating NMAs to incorporate their data into the Arctic SDI.
- What types of future requirements would be needed by users in order for them to better accomplish their work in the Arctic.

2.2.2 Conducting a User Needs Assessment

The user needs assessment process is typically carried out in **three phases** (GeoConnections, 2007):

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

The *planning phase* includes the following tasks: setting the objectives of the assessment, profiling users, examining existing material, determining location and timeline, selecting research methods, determining costs, and setting the budget.

The research methods used, either qualitative or quantitative, will depend on the type of information required, attitude information or behavioral information, as presented in table 2.

Table 1. Examples of quantitative and qualitative research methods suited for collecting attitude or behavior information (from (GeoConnections, 2007)).

	Qualitative	Quantitative
Attitude	Focus groups Interviews	Surveys
Behavior	Usability walkthroughs Ethnographic research Job shadowing	Usability test Benchmark test

The *assessment phase* includes the following tasks: development of the research instruments, and conducting the research.

The *interpretation and reporting phase* consists of analyzing the results and presenting them into a report that will eventually provide input into the user-centered design process. To be most useful, this report must clearly articulate the key issues that designers will need to consider. The user needs assessment report serves as the primary reference to develop a SDI project and indicates the users' view to the developers.

Detailed user requirements related to data can be expressed using the *ISO 19131 Geographic information - Data Product Specifications* standard (International Organization for Standardization, 2007). According to ISO: "A data product specification is a detailed description of a dataset or dataset series together with additional information that will enable it to be created, supplied to and used by another party. It is a precise technical description of the data product in terms of the requirements that it will or may fulfil". A data product specification may be created by producers to specify their product or by users to state their requirements. Procedures exist for the development of data specifications from user requirements, for example the INSPIRE *Methodology for the Development of Data Specifications* (INSPIRE, 2007), which describes how to arrive from user requirements to a data specification through a number of steps including use-case development, initial specification development and analysis of analogies and gaps for further specification refinement.

It is generally recommended to have the user needs assessment conducted by an experienced individual or third party organisation (GeoConnections, 2007).

It is also important to note that user needs assessment is an ongoing process. As their knowledge about the concepts and the data and services available through the infrastructure increases, users will typically expand their use of the SDI and have an expanded set of requirements. If the SDI users recognize that their changing needs are being understood and addressed, the use of the infrastructure and the user base will continue to grow (CP-IDEA, 2013).

2.2.3 Benefits of a User Needs Assessment

From a SDI point of view, user needs assessments increase the chances for success and sustainability of a project. They help to (GeoConnections, 2007):

- Define the users of, and the demand for, a SDI-related element (data, services, technologies, standards, policies);
- Ensure that the SDI will meet the needs of its intended users;
- Define, explore and solve users' problems;
- Ensure priorities and opportunities are based on user requirements; and
- Ensure accountability in the allocation of public resources.

Understanding and meeting user needs is important **in developing effective applications, tools and systems that will be widely used in decision support and planning**, as well as in creating coherent and accepted SDIs.

2.3 User-Centered Design

User-centered design involves soliciting the input of users at various stages in the design of a system, application, web site, or portal to ensure that it is easy to use and meets the needs of its intended users (GeoConnections, 2007). It involves measuring usage: ease of use, ease of learning, and satisfaction. It also involves iterative design, in which the system, application, web site, or portal is designed, tested and modified repeatedly throughout the product lifecycle.

The goal of user-centered design is to improve the usability of applications by integrating the user into the design and development processes. A user-centered design approach includes examining:

- 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.

2.3.1 The User-Centered Design Process

The *ISO 9241-210 Ergonomics of human-system interaction - Part 210: Human-centered design for interactive systems* standard (International Organization for Standardization, 2010) is the basis for many user-centered design methodologies. It proposes a general process for human-centered design activities throughout the development lifecycle of computer-based interactive systems.

The user-centered design process is composed of **four main activities** (GeoConnections, 2007):

- Specifying the context of use: the purpose of this stage is to identify the people or groups who will use the application/system (existing/expected users), what they will use it for, their key requirements, and under what conditions they will use it.
- Specifying requirements: involves the specification of both business and user requirements, including usability goals to help determine the acceptable level of performance.
- Producing design solutions: involves the creation of mock-ups or prototypes of the application/system to be developed, taking into account the technical and design requirements.
- Evaluating the designs: involves having the users test the application/system to see if they can easily navigate the interface and find the desired information.

Several research methodologies can be employed to complete a user-centered design process: surveys, focus groups, usability testing, accessibility testing, etc. Details on the methods used can be found in (GeoConnections, 2007).

It is generally recommended to have the user-centered design process conducted by an experienced individual or third party organisation (GeoConnections, 2007).

2.3.2 Benefits of User-Centered Design

The key benefits of using a user-centered design approach are:

- More effective time and cost management;
- Enhancement of user-productivity;
- Increased user satisfaction; and
- Better achievement of project/application objectives.

2.4 In Summary

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 1 Users and Stakeholders Needs and Requirements (Arctic SDI working Group on Strategy, 2015). http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf.*

Applicable standards:

- *ISO 19131:2007 Geographic information - Data Product Specifications (International Organization for Standardization, 2007).*
- *ISO 9241-210:2010 Ergonomics of human-system interaction - Part 210: Human-centered design for interactive systems (International Organization for Standardization, 2010).*

For more information and examples:

- *Understanding Users' Needs and User-Centered Design (GeoConnections, 2007). http://geoscan.ess.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&format=FLFULL&search=R=292113.*
- *Appendix 3 of the above document provides an example of user needs assessment and user-centered design approach applied in an environmental context.*

3. Arctic SDI Economics

The purpose of this chapter is to introduce SDI economic considerations in general, and also in the specific context of the Arctic SDI. It presents approaches to SDI financing and ways to evaluate the value of the Arctic SDI.

3.1 Arctic SDI Resources

Significant financial resources are necessary to cover the costs of planning and implementing a SDI. **Expenditure categories** may include (CP-IDEA, 2013):

- SDI organisation: resources may be needed for the use of new staff resources or upgrading of staff's skills, expenses associated with stakeholder engagement activities (e.g., travel, meeting), consulting fees for specialized experts who will assist with SDI planning and will conduct research and studies, etc.
- Framework data: resources are required to bring data contributed by different organisations into a common standard or to upgrade its quality.
- Standards: SDI organisations need resources to identify and set international requirements for interoperability, and to plan, coordinate and support the development, and possibly fund the implementation, of those standards.
- Policies: policy development work may be required at both the strategic and operational levels in order to facilitate the widespread use of the SDI as an operational spatial information environment.
- Technologies: technology-related costs may include the development and deployment of the SDI Geoportal, procurement of software, the development or enhancement of applications that leverage the data and services available through the SDI, etc.
- Supporting and monitoring SDI adoption and implementation: resources may be required for outreach, communication and training related to the adoption of the SDI by users and its implementation within their operational environment, and also to establish a measurement and monitoring program to help demonstrate the benefits and performance of the SDI initiative.

Funding mechanisms must be identified to address the entire life cycle of the SDI: the development phase, the implementation phase, and the maintenance phase (Economic Commission for Africa, Global Spatial Data infrastructure Association, and EIS-Africa). The choice of funding model(s) and method(s) will depend upon a number of factors, including (CP-IDEA, 2013):

- The product access that the SDI facilitates (i.e., spatial information as a public good, quasi-public good, or quasi-private good, see (Economic Commission for Africa, Global Spatial Data infrastructure Association, and EIS-Africa) for a discussion on these categories);
- The level of the SDI (i.e., international, national, regional or local);

- The government structure influencing the SDI implementation (e.g., within a single organisation or as a collaborative effort involving multiple organisations); and
- The implementation environment (e.g., open data policies, budget austerity, etc.).

Funding mechanisms for SDIs that facilitate access to spatial information considered **a public or quasi-public good** will be influenced by government policies. Examples include (CP-IDEA, 2013):

- Government funding: funds derived from general taxation, or in some cases, from financing provided by international financial or aid institutions (e.g., World Bank, Inter-American Development Bank, United Nations).
- Special taxation: taxes imposed on either goods or services for the specific purpose of financing a SDI implementation.
- Public sector funding: funding from quasi-government organisations (i.e., Crown corporations or statutory bodies) that are self-sufficient and do not rely exclusively on taxes for their funding.
- Partnerships: collaboration among the different sectors of society aimed at implementing a SDI, which usually involves the pooling of resources (financial and non-financial) to efficiently implement the SDI.

Funding mechanisms for SDIs that facilitate access to spatial information considered a **quasi-private good** (i.e. viewed as a commodity that can be traded for a profit or at least at a self-sustainable level) include (Economic Commission for Africa, Global Spatial Data infrastructure Association, and EIS-Africa), (CP-IDEA, 2013):

- Consortium: creation of a consortium to manage and generate funds for SDI implementation.
- User fees: different types of fees charged to the user for spatial information, the access to which is facilitated by the SDI.
- Private sector funding: the models that are built solely on direct private sector investments into the development of a SDI.

Sometimes, the funding of a SDI may require the creation of a pool of funds that are combinations of the funding models described above.

Currently, the Arctic SDI is financed using the government funding model. According to Clause 6 of the Arctic SDI MOU, signed by the 8 participating NMAs of the Arctic countries (Arctic SDI, 2014):

> a) Each participant intends to pay for the cost it incurs in the application of the MOU unless otherwise decided upon in writing under an Implementing Arrangement.
>
> b) The participants intend to ensure that all costs or estimated costs are detailed in the Implementing Arrangements.
>
> c) The participants understand that their activities are subject to the availability of their respective funds and resources.

The required financial means for each participating organisation depends on the organisation's chosen level of involvement in system development and other Arctic SDI efforts (Palmér, et al., 2011). Although currently financed by the national governments of the involved countries, it may be required, in the future, to identify alternative funding sources in order to ensure the long-term sustainability of the Arctic SDI.

3.2 The Value of the Arctic SDI

In general, organisations receiving public funds for an initiative must clearly achieve and demonstrate efficiency, effectiveness, and impact with their resources (CP-IDEA, 2013) and must prove that their expenditures will have a reasonable return. Justification of any expenditure comes down to weighing the costs against the benefits.

Three primary methodologies can be employed for determining the **costs and benefits of implementing a SDI**:

- Return on investment analysis: this approach is typically applied to private sector investments. The costs and benefits considered are strictly financial and can be expressed as cash flows over time. The point of view is restricted to that of the investing entity.
- Economic impact analysis: this approach is typically applied to public sector investments. As with return on investment analysis, the costs and benefits considered are strictly financial, although sometimes, ways are found to convert non-financial impacts into financial terms.
- Socio-economic impact analysis: this approach expands economic impact analysis to include non-quantifiable social impacts in addition to the financial impacts.

Several **considerations** must be kept in mind when conducting expenditure justifications, including the following (CP-IDEA, 2013):

- Incrementality: impacts and effects to be considered are those directly due to the SDI;
- Attribution: sharing of impacts and effects with affiliated programs, funding sources, organisations or stimulants;
- Time: difficulties in identifying and measuring impacts and attributing them to the originating activity due to uncertainties of SDI timeframe; and
- Uncertainty: importance of specifying the level of confidence in SDI benefits based on such techniques as sensitivity, scenario or Monte Carlo analyses.

It is strongly advised that organisations attempting to provide expenditure justification of a SDI for the first time seek experienced assistance.

The challenge related to this process of justification, is to sell the importance of spatial information and services available through the SDI. Impacts and benefits can be economic (dollars) or non-economic (social, political, environmental, knowledge). Examples of **impacts and benefits**, in the context of the Arctic SDI include:

- Stimuli of economic growth;
- Facilitator of good governance;
- Enabler of more efficient natural resources management;

- Improved surveillance of pollution;
- Improved disaster preparedness;
- Key component of environmental management;
- Improved regional development;
- Improved community health and safety;
- Improved international cooperation;
- Advancement of scientific knowledge;
- Better efficiency of decision-making;
- Better access to the same data for all users;
- Contribution to the development of society in all aspects (United Nations Committee of Experts on Global Geospatial Information Management, 2015).

3.3 In Summary

Linkages:

- *The Arctic SDI Memorandum of Understanding (Arctic SDI, 2014). http://arctic-sdi.org/wp-content/uploads/2014/07/Appendix1_Signed-ALL-Lang-MOU_5-29-14.pdf.*

For more information and examples:

- *Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013). http://geoscan.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&search=r=292897&format=FLFULL.*
- *SDI Africa: An Implementation Guide Preamble (Economic Commission for Africa, Global Spatial Data infrastructure Association, and EIS-Africa). http://gsdiassociation.org/images/publications/cookbooks/SDI_Africa_Guide_full_text.pdf.*

4. The Development of a SDI

This chapter addresses various considerations related to each phase of the development and implementation of the Arctic SDI, for its core elements: institutional arrangements, framework and thematic data (creation, maintenance, and distribution), technologies, interoperability, standards, and policies. It suggests applicable guidelines, standards, policies and provides examples from other SDIs.

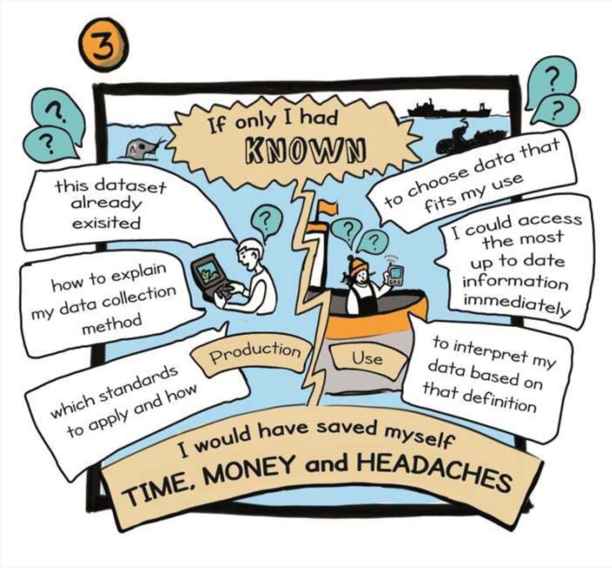


Figure 5. Arctic SDI stakeholders should establish and follow best practices.

Building an Arctic SDI requires the development of a set of best practices addressing the core elements (institutional arrangements, framework and thematic data, technologies and interoperability). These best practices include requirements, standards and policies, as illustrated in Figure 5.

The development of a SDI may be based on a **spatial information management framework**. Such framework is in use for example in the state of Victoria, Australia, where it aims to provide a consistent approach to the management of spatial information by data custodians (Victorian Spatial Council, 2013) (see section 4.1.4). A spatial information management framework establishes a core set of best practices: requirements, standards and policies, for managing spatial information. The underlying principles are that the information managed within the spatial information management framework will:

- Represent the definitive and authoritative source of the data it contains;
- Be managed by designated custodians;
- Be accessible and available to all members of the community, except where confidentiality and sensitivity restrictions apply; and
- Have the potential to be combined with other spatial information products for analysis and decision making purposes.

A spatial information management framework should address four main elements (Victorian Spatial Council, 2010):

- Institutional arrangements for developing spatial information: governance, custodianship.
- Requirements for creating and maintaining spatial data: framework and business data, data quality.
- Mechanisms for making spatial data accessible and available: metadata, awareness, access, pricing and licensing, and privacy.
- Strategic development of technology and applications.

These elements will be discussed in more details in the following sections.

4.1 Institutional Arrangements

Once the decision to proceed with a SDI initiative has been made, the required institutional arrangements must be put in place to enable the infrastructure to develop and mature. Some key questions that will need to be answered are (CP-IDEA, 2013):

- What type of model will be used for SDI development (i.e., mandatory versus voluntary) (see section 4.1.1)?
- Who are the key partners in the initiative and how will they be engaged (see section 4.1.2)?
- Who will lead the SDI development (see section 4.1.3)?
- What are the sources of authoritative spatial data (see section 4.1.4)?

Institutional arrangements are key elements for (Economic Commission for Africa, Global Spatial Data infrastructure Association, and EIS-Africa):

- Facilitating access to the data asset components owned by, or in custody within, government, non-government organisations, and private sector agencies;
- Ensuring the maintenance of these datasets, and their related metadata;
- Avoiding duplication of efforts and resources invested in data collection;
- Developing appropriate standards;
- Complying with the international standards;
- Identifying and developing core datasets.
- Establish reliable distribution services.

In the context of the Arctic SDI, the *Memorandum of Understanding* (Arctic SDI, 2014) and the Governance document (Arctic SDI Secretariat, 2015) describe the institutional arrangements agreed by the Arctic SDI partners.

4.1.1 SDI Development Model

A SDI development model can be mandatory or voluntary.

The **mandatory model** of SDI development is normally backed up by legislation, regulation or some other type of government decree or directive that requires spatial information providers to make their datasets discoverable and accessible via the infrastructure (CP-IDEA, 2013). This model exists in the European Union, where SDIs are being implemented in Member States as mandated by the INSPIRE Directive (European Parliament, 2007), and common implementing rules are being adopted as Commission Regulations/Decisions in a number of specific areas (e.g., metadata, data specifications, network services, data and service sharing, and monitoring and reporting).

The alternative to SDI implementation under some type of enforcement mechanism is the **voluntary model** where the use of the SDI is on a purely voluntary basis (CP-IDEA, 2013). The Arctic SDI development model is a voluntary model.

Whether the adoption and use of the SDI is mandatory or voluntary will have a significant impact on the institutional and other arrangements that are put in place for its development and implementation (CP-IDEA, 2013).

4.1.2 Building Partnerships

Collaborative efforts are essential for the success of any SDI initiative, and particularly so with the SDI voluntary model, which the Arctic SDI is based on. Cooperation and partnerships across different levels of the public sector and with the private sector are an important means at every stage of SDI development to collect, build, share, and maintain spatial data (CP-IDEA, 2013).

SDI partnerships should be based on mutually agreed principles. For example, the Canadian Geospatial Data Infrastructure recommends the following principles for data partnership:

- Data should be collected once, closest to the source and in the most efficient way possible.
- Data should be as seamless as possible, with coordination across jurisdictions and boundaries when possible.
- Data should be collected, processed and maintained according to international standards.
- Partners should contribute equitably to the costs of collecting and managing the data, and should be allowed to integrate the resulting information into their own databases and distribute it to their stakeholders.
- There should be an attempt to harmonize terms and conditions for use where practical.
- A group or agency within each government should be designated to promote and coordinate the development of a common spatial data infrastructure, both within its jurisdiction and between jurisdictions.
- Agreements between agencies will normally be negotiated on a case-by-case bilateral or multilateral basis, according to these principles of partnership.

These principles are also applicable to the Arctic SDI. In this context, NMAs of the 8 Arctic countries, Arctic Council Working Groups, and Arctic Council Permanent Participants are the first data partners in the Arctic SDI. Other organisations will certainly join the Arctic SDI in the future and principles for data partnerships will facilitate their integration within the infrastructure.

4.1.3 Governance

Governance can be defined as "the establishment of policies, and continuous monitoring of their proper implementation, by the members of the governing body of an organisation" (Business Dictionary, 2016). It includes the mechanisms required to balance the powers of the members (and the associated accountability), and their primary duty of enhancing the prosperity and viability of the organisation. Governance rests on 3 key elements: authority, decision-making and accountability.

A SDI initiative requires the establishment of a governance structure. A typical SDI governance structure includes the following components (CP-IDEA, 2013):

- Management Board;
- Policy Committee;
- Standards Committee;
- Framework Data Committee;
- Technology Committee; and
- Stakeholders and Special Interest Groups.

The Arctic SDI governance structure is described in details in the *Arctic SDI Governance Document* (Arctic SDI Secretariat, 2015). This document presents the organisation of the Arctic SDI and the agreed governance policies for the cooperation between the 8 participating NMAs.

Also of importance in a SDI context is the notion of data governance. Data governance formalizes the orchestration of people, processes, and technology to enable an organisation to leverage data as an asset (The Master Data Management (MDM) Institute, 2013). Data governance establishes a quality control framework for adding rigor, security and discipline to the process of managing, using, improving and protecting organisational information. Effective data governance can enhance the quality, availability and integrity of an organisation's data, thus improving the quality of analyses (GeoConnections, 2014).

4.1.4 Data, Stewardship and Custodianship

Identifying authoritative data sources and assigning data stewardship and custodianship is an important cornerstone for a successful SDI initiative (CP-IDEA, 2013).

Stewardship ensures that there is an organisation with formally appointed accountability for the management and maintenance of a spatial dataset so that it meets the needs of its users. Stewardship includes all aspects of managing spatial data including, updated data products and specifications, data architecture, quality, maintenance, metadata, pricing, licensing, access and release, bearing in mind any statutory responsibilities and government data management policies. (New Zealand Geospatial Office, 2011). Stewardship also ensures that appropriate data management policies and standards are developed and maintained.

The steward is accountable for maintaining the quality, integrity, availability and security of the data.

Responsibilities of data stewards can include (CP-IDEA, 2013):

- Data collection, maintenance and revision;
- Standards development;
- Quality control;
- Provision of access;
- Metadata; and
- Security and privacy.

Custodianship of spatial data is the act of ensuring appropriate care in the collection, storage, maintenance and supply of the data (New Zealand Geospatial Office, 2011).

The custodian is responsible for the continued physical existence, maintenance, availability and dissemination of the data.

The role of data custodian is part of the *ISO 19115-1:2014 Geographic information - Metadata -- Part 1: Fundamentals* (International Organization for Standardization, 2014).

The stewardship and custodianship model is applicable to the management of all datasets whether they contain framework or thematic data.

Responsibilities of data custodians can include (CP-IDEA, 2013):

- Collection of data under their custodianship to agreed specifications;
- Discrepancy tracking and resolution;
- Data quality assessment and reporting; and
- Data accessibility assurance (i.e. ensure that data is always accessible, up and running).

Identified data stewards and data custodians should manage the data according to the management principles established within the spatial information management framework.

4.1.5 Institutional Arrangements Summary

Linkages:

- *The Arctic SDI Governance Document (Arctic SDI Secretariat, 2015).* http://arctic-sdi.org/wp-content/uploads/2014/08/20151208Arctic-SDI-Governance_v1-1-update.pdf.
- *The Arctic SDI Memorandum of Understanding (Arctic SDI, 2014).* http://arctic-sdi.org/wp-content/uploads/2014/07/Appendix1_Signed-ALL-Lang-MOU_5-29-14.pdf.

For more information and examples:

- *Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013).* *http://geoscan.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&search=r=292897&format=FLFULL.*
- *SDI Africa: an implementation guide preamble (Economic Commission for Africa, Global Spatial Data infrastructure Association, and EIS-Africa).* *http://gsdiassociation.org/images/publications/cookbooks/SDI_Africa_Guide_full_text.pdf.*
- *Victoria's Spatial Information Management Framework and Directory of Resources (Victorian Spatial Council, 2010).* *http://victorianspatialcouncil.org/cms/library/attachments/SI%20Management%20Framework%20and%20Directory%20v1.1-May%202010.pdf.*

4.2 Data Creation, Maintenance and Distribution

In the data creation, maintenance, and distribution processes, producers, distributors and users of spatial data each have duties and responsibilities.

The concept of **responsible data producer** rests on the following obligations (GeoConnections, 2014): the duty to verify and control the internal quality of the dataset and the duty to inform users of the dataset. In cases where producers make their spatial datasets widely available, for example through a SDI, additional issues arise, as the producers have less knowledge and control of the potential uses of their products. Some of these potential uses may be sensitive to errors and misinterpretation, while others may not. The approach used in these circumstances is to treat uncertainty in the data as an inherent risk associated with spatial data use and to require that the producer warns potential users of this risk. At a minimum, producers of spatial data should include quality related metadata along with their spatial datasets and clearly warn users about the potential risks (Chandler & Levitt, 2011).

Data integrators and distributors also have duties to properly inform their clients and to provide advice, as their role is that of a link between the source of data and the users. Their responsibility is normally less than that of the producer, particularly if they act as simple retailers or distributors. However, there is no absolute rule and their responsibility will be evaluated with regards to the role they have in the transaction. For example, their responsibility will be greater if they produced an added-value to the dataset or if they compromised themselves on the type of possible usages of the dataset.

Users of spatial data products have legal obligations to ensure that data is properly used. The most important obligations are those of collaboration with the data producer, consistency when defining their needs, and consistency when using the dataset (i.e., in accordance with the conditions emitted by the dataset producer) (Le Tourneau, 2002). Collaboration must take place continuously when negotiating, defining the expectations, providing the required documentation and information, identifying the potential risks, designing and populating the dataset, and defining the means to deal with the identified risks of usage. See (Gervais, Bédard, Lévesque, Bernier, & Devillers, 2009) for examples.

4.2.1 Data Models

A data model encodes an abstraction of the real world. It defines data elements and their structures, and also the relationships between them. In other words, the geometry, attribute table and topology of the data are defining the data model. However, a data model is independent of a computer system and its associated file structures.

“The interoperability in an SDI means that users are able to integrate spatial data from disparate sources “without repetitive manual intervention”, i.e. the datasets they retrieve from the infrastructure follow a common structure and shared semantics.” (European Commission, Joint Research Centre, 2012). In the Arctic region and its multi-jurisdictions context, a common agreement on a collaborative data model is key to ensure interoperability across administrative borders.

“Digital technologies could facilitate the reuse of geographic information, but is hampered by incomplete documentation, lack of compatibility among spatial datasets, inconsistencies of data collection, and cultural, linguistic, financial and organisational barriers.” “These challenges are ultimately rooted in the diversity of how geographic data is defined as a partial abstraction of reality. Geographic data, like any data, is always an abstraction, always partial, and always just one of many possible views. As a consequence, rivers may be represented as polygons in one dataset and as lines in another, the line representing roads on both side of a national border may not meet, a watercourse may appear to flow uphill when combining a hydrological and an elevation dataset.” (European Commission, Joint Research Centre, 2012).

<u>Vector-based data product</u>

When designing a **vector-based data product**, the *ISO 19109:2015 Geographic information – Rules for application schema* standard can be used to properly define the model (called application schema) of the data product to be built/updated (International Organization for Standardization, 2015) (GeoConnections and Intelli3 Inc., 2015). This standard covers:

- The conceptual modeling of features and their properties from a universe of discourse;
- The definition of application schemas;
- The use of the conceptual schema language for application schemas;
- The transition from the concepts in the conceptual model to the data types in the application schema;
- The integration of standardized schemas from other ISO geographic information standards with the application schema.

The *ISO 19110:2005 Geographic information – Methodology for feature cataloguing* standard can be used to properly define the **data dictionary** (called **feature catalog**) of the data product to be built/updated (International Organization for Standardization, 2005). This standard describes:

- A methodology for cataloguing feature types;
- How the classification of feature types is organized into a feature catalogue and presented to the users of a set of geographic data.

Raster-based data product

When designing a **raster-based data product**, the *ISO 19123:2005 Geographic information – Schema for coverage geometry and functions* standard can be used to properly define the model (called **schema for coverage geometry**) of the data product to be built/updated (International Organization for Standardization, 2005). This standard describes:

- The conceptual schema for the spatial characteristics of coverages;
- The relationship between the domain of a coverage and an associated attribute range.

Data modeling also involves the development of **data product specifications**. The *ISO 19131:2007 Geographic information – Data product specifications* (International Organization for Standardization, 2007) (with *ISO 19131:2007/Amd 1:2011 Requirements relating to the inclusion of an application schema and feature catalogue and the treatment of coverages in an application schema* (International Organization for Standardization, 2011)) standard can be used to define the detailed specifications of the data product to be built/updated. This standard:

- Defines requirements for the specification of geographic data products, based upon the concepts of other ISO 19100 International Standards;
- References application schema, feature catalog or schema for coverage geometry.

4.2.2 Data Specification

"A data specification contains the data model and other relevant provisions concerning the data, such as rules for data capture, encoding, and delivery, as well as data quality requirements, metadata for evaluation and use, data consistency, etc. Data modelling and data specifications are linked, in the first place, to data collection and data product delivery.

Since an SDI is usually composed of many data themes where cross-theme interoperability may be required, a robust framework should be established that drives the development process of the data component in a coherent way. In the European Union, INSPIRE has adopted a conceptual framework that consists of two main sections:

- The Generic Conceptual Model (GCM) defines 25 aspects or elements relevant to achieving data interoperability in an SDI, and proposes methods and tools to address them. These include, for example, registries, coordinate reference systems, identifier management, metadata and maintenance, to name just a few.
- The description of the methodology for developing data specifications for interoperability includes a detailed discussion of the relevant actors, steps and the overall workflow from collecting user requirements to documenting and testing the specifications that emerge from this process." (European Commission, Joint Research Centre, 2012).

4.2.3 Metadata

Knowledge about geographic information is collected in terms of metadata. Metadata constitutes a description of captured or modeled data in databases or applications. The *ISO 19115-1:2014 Geographic information - Metadata - Part 1: Fundamentals* standard (International Organization for Standardization, 2014), defines the schema required for describing geographic information and services by means of metadata about:

- Identification
- Constraints
- Lineage
- Quality
- Maintenance
- Spatial representation
- Spatial reference system
- Content
- Portrayal
- Distribution
- Application schema

A **good practice** is to develop a **profile** of the ISO standard for example *the North American Profile of ISO 19115:2003 Geographic information – Metadata (NAP – Metadata)* (National Standards of Canada, 2003), developed jointly by Canada and the US. Another example is the *INSPIRE profile of ISO 19115* (*Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119*) developed by the Drafting Team Metadata and European Joint Research Centre (INSPIRE, 2013).

Metadata is useful during the whole data lifecycle:

- Creation of the dataset;
- For maintenance;
- For distribution; and
- For use;

The use of appropriate metadata (e.g., the core of ISO 19115 or as specified in a metadata profile) should be a prerequisite for the distribution of data through the Arctic SDI. For managing metadata, it is a good practice to use a dedicated metadata management tool (e.g., GeoNetwork (Open Source Geospatial Foundation, 2015)).

In a SDI context, there is a need to educate users about metadata (their goal, their structure and their use).

4.2.4 Framework Data

Framework data (also called “base mapping”, “fundamental,” “core” or “reference” data) is the set of continuous and fully integrated spatial data that provided context and reference information in the SDI (GeoConnections, 2009). Framework data is often used as the **foundation for the positioning of thematic data**. Framework data function as important “anchors” for the development of integrated data sets for data collection, reporting and analytical processes (CP-IDEA, 2013).

Framework data must adhere to the principle of data being collected once, closest to the source, and shared with many.

Framework data already available in the Arctic SDI (part of the basemap; Arctic SDI, 2015) include:

- Coastline
- Hydrography
- Road networks
- Topography
- Geographical names

According to preliminary user needs assessments (Arctic Council, 2015), bathymetry framework data is also needed.

As one of the SDI pillars, framework data has an important role to play in helping to ensure interoperability within the infrastructure (CP-IDEA, 2013). Key considerations include the following: the data layers that are selected; procedures, technology and guidelines that provide for data integration, sharing, and use; and institutional relationships and business practices that encourage data maintenance. The selection of framework data layers depends upon jurisdictional circumstances, but is typically handled by the principal national mapping organisation alone or in partnership with other key data producers, based on user needs assessments.

4.2.5 Thematic Data

Thematic data is data that describes the characteristics of spatial features or provides information on **specific topics or themes**, such as forest types, water contamination, permafrost, ice-coverage or disease patterns and trends. Examples of themes where thematic data could be made available through the Arctic SDI:

- Permafrost
- Land cover
- Treeline
- Biodiversity
- Tourism
- Urban environments

- Energy and Mining
- Shipping routes
- Forestry
- Geology
- Conservation areas
- Ice cover
- Weather
- Ecologically and Biologically Significant Areas (EBSAs)
- Local communities and local knowledge

To be successful, the Arctic SDI has to take particular requirements into account, including responding to priorities of Northerners and Indigenous communities, working in zero/low bandwidth regions and considering the realities of frontier economies.

4.2.6 Internal Data Quality

The need to manage and embed spatial data quality information within datasets appeared in the early 1980s (Larrivée, Bédard, Gervais, & Roy, 2011). The *ISO 19157:2013 - Geographic information - Data quality* standard (International Organization for Standardization, 2013) defines geospatial data quality as **how well the dataset represents a universe of discourse**. The literature clearly shows two trends in addressing geospatial data quality. The first trend restricts quality to the dataset's internal characteristics (i.e., intrinsic properties resulting from data production methods). This is identified as internal quality and it is generally approached from a data producer perspective. The other trend relates to the "fitness for use" definition, quality being defined as the level of fitness between data characteristics and users' needs. This is identified as external quality and it is usually approached from a data user point of view. The ISO 19157 standard also recognizes that a data producer and a data user may view data quality from different perspectives (International Organization for Standardization, 2013). We may also encounter the expression "fitness for purpose" for such a concept.

Internal quality is usually described using five to seven parameters: lineage (or source), positional accuracy (or spatial accuracy), attribute accuracy, semantic accuracy, temporal accuracy (or temporal information), logical consistency, completeness, and usability, depending on the source. From the end-user perspective, knowledge about internal data quality typically comes from the metadata transmitted with datasets by data producers. The following definitions of internal data quality parameters are from the ISO 19157 standard (International Organization for Standardization, 2013).

- *Completeness* is defined as the presence and absence of features, their attributes and relationships.

- *Logical consistency* is defined as the degree of adherence to logical rules of data structure, attribution and relationships (i.e., data structure can be conceptual, logical or physical). A reference to the logical rules is required.
- *Spatial accuracy* is defined as the accuracy of the position of features in relation to Earth.
- *Thematic accuracy* is defined as the accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships.
- *Temporal quality* is defined as the quality of the temporal attributes and temporal relationships of features.

The ISO 19157 standard distinguishes the following hierarchical levels of data quality: dataset series, dataset, feature type, feature instance, attribute type, and attribute instance.

Quality management processes may be used in the different phases of a product's life cycle. The ISO 9000 quality management framework (International Organization for Standardization, 2015) can be used, though there are other methods to manage quality related to the geospatial data production process. Software engineering methods based on formal models (e.g., Unified Modeling Language (UML), Rational Unified Process (RUP), Model Driven Architecture (MDA)) are recognized as rigorous approaches to develop quality systems. Furthermore, ISO 19158 aims to provide a quality assurance framework for the producer and customer in their supplier-consumer supply chain relationship, to increase user confidence in the data that is provided (International Organization for Standardization, 2012).

There are many **ways to communicate the quality information** of a geospatial dataset, which is essential to promote the reuse of the datasets by a large community of users. The first is with the use of metadata and data quality reports. Over the last 20 years, several research projects have focused on ways to better describe and communicate quality information. Many other solutions were proposed such as user manuals, warnings, and rating systems.

The Arctic SDI should not evaluate the internal quality of the data fed into the system as it is the responsibility of data custodians. However, the Arctic SDI could implement processes to help users determine the fitness of the available data for their personal use.

4.2.7 External Data Quality

External quality of a geospatial dataset corresponds to the concept of **fitness for use** (Chrisman, 1983). It is the degree of agreement between data characteristics (i.e., internal quality) and the explicit and/or implicit needs of a user for a given application in a given context. Contrary to the internal data quality, which has a unique set of values for each specific dataset, the external data quality value will vary from one application to the other. External quality is approached from a data user point of view and corresponds to the "usability" quality element of ISO 19157, which may be used to evaluate the fitness for use of a dataset. Usability is used to describe specific quality information about a dataset's adherence to a particular application or set of requirements. ISO 9000 can also be used. It defines quality as the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs (International Organization for Standardization, 2015).

Within a collaborative environment where users give their opinion about the quality of datasets, the process of defining the fitness for use of a dataset may be complicated by the number of involved users with very different needs and usually by the very small subset of the dataset being used and assessed. Since they all use different subsets of the same dataset for similar or different purposes, they will each have a different view of the external data quality. The increasing number of such users leads to a wide range of requirements, to different assessment processes, and consequently, to a variety of quality perceptions. This is the concept of *perceived quality*.

External quality and perceived quality can be communicated using user warnings, lists of recommended and non-recommended usages, rating systems, etc.

4.2.8 Interoperability

Interoperability is the ability of different types of computers, networks, operating systems and applications to **work together effectively**, without prior communication, in order to exchange information in a useful and meaningful manner. Interoperability makes the required underlying processes transparent to the users (CP-IDEA, 2013). Interoperability facilitates information sharing and allows users to find information, services and applications when needed, independent of physical location. Interoperability also means the possibility for spatial data sets to be combined and services to interact in such a way that the result is coherent and the added value of the datasets and services is enhanced (INSPIRE Directive Art.3(7)).

To achieve interoperability between systems and system components, a SDI must follow **international standards** of the OGC, ISO, W3C and domain-specific thesauri or ontologies. Interoperability can be addressed at various levels:

- *Technical interoperability:* deals with purely technical aspects of interoperability such as transmission protocols, and data exchange formats, standard interface specifications, data transport.
- *Semantic interoperability:* means that applications can interpret data consistently in the same manner in order to provide the intended representation of the data.
- *Geosemantic interoperability:* ability of systems using spatial data and services to cooperate (inter-operate) at the semantic and geometric levels (e.g., definitions of shapes, criteria to define boundaries and position).
- *Organisational interoperability:* "coordinated processes in which different organisations achieve a previously agreed and mutually beneficial goal" (Interoperability Solutions for European Public Administrations, 2010).
- *Legal interoperability*: the legal rights, terms, and conditions of data from two or more sources are compatible and the data may be combined by any user without compromising the legal rights of any of the data sources used.

In a vision of optimal collaboration between the Arctic Council and its groups, national mapping agencies of the Arctic countries and other data providers, the Arctic SDI should focus on technical interoperability first in order to allow for the discovery of, and access to, relevant datasets that exist elsewhere (e.g., other SDIs) (concept of "inward" interoperability, i.e. discover sources and access them through the Arctic SDI). Semantic, geosemantic and organisational interoperability should come after in order to allow for visualizing, assessing and combining the available datasets coming from a number of sources. Finally, even though many of the Arctic SDI sources of data will be open, access to some sources will be restricted and the notion of legal interoperability will need to be addressed to protect these sources.

4.2.9 Data Discovery, Visualization and Access

A SDI provides users with the functionality to discover the type of data they are seeking, to visualize the data and metadata online to confirm that it will meet their needs and to access the data directly (CP-IDEA, 2013).

Data discovery is a **critical aspect** for the wide adoption of the Arctic SDI. It must be very efficient and support many filtering options, such as thematic filtering, geographic filtering and temporal filtering, in order to help users to focus their data research. For example, (Wilson, Devillers, & Hoeber, 2011) have proposed a new method based on fuzzy-logic that helps users find the most appropriate datasets in a geospatial data clearinghouse, and have tested it for the Canadian GeoConnections Discovery Portal. Data discovery is supported by metadata that document the location of the dataset, its content and structure, and the appropriate use(s) of the dataset, and also by catalog services. The Arctic SDI discovery layer should facilitate the discovery and access of Arctic data available through all the other SDIs, geoportals and data services. The Arctic SDI has the potential to become an international Arctic data hub.

Once SDI users have discovered what they think are interesting datasets, data visualization processes can help them see the selected datasets before they proceed further with the access/acquisition processes. In a SDI context, data visualization is supported by Web mapping, portrayal and tiling services to produce maps of the selected datasets. Depending on the visualization services implemented and used, maps can be produced as pictures, series of graphical elements, or a packaged set of geographic features (CP-IDEA, 2013).

Data access involves the ordering, packaging and **delivery, offline or online**, of the specified data. Access processes should address all identified types of users, and respect the various constraints they may face (e.g., low to no bandwidth in the North, a need to install the data on their computers, etc.). As such, access processes should allow for packaging and physical delivery of data sets in either hardcopy or softcopy (this is critical as many people in the North do not have efficient access to the Internet), delivery via ftp or e-commerce order request for example, and support many formats (e.g., **Shapefile format**, as it is very much used among Northern communities). SDI users expect simple discovery and access to cheap (or free) data in simple standard formats that can be used in desktop applications or on mobile devices (CP-IDEA, 2013).

Access to data requires that **legal interoperability** be addressed in proper ways in order to protect personal, private and sensitive information. Clear data licenses should be put in place. A data license can be defined as the formal sharing or dissemination of data under a contractual instrument. The **data licensing** issue may be facilitated by adopting open-data policies as implemented in several nations, for example in Canada (Government of Canada, 2014).

With data licensing comes the **pricing** question. A SDI requires a pricing policy. This policy should encourage the use of spatial information by minimizing costs (access and delivery), while providing a sufficient revenue for custodians to help them maintain their spatial datasets. High prices of data are likely to limit its distribution. In the North, for example, there is a need for accessing high resolution imagery in the easiest way possible and at a minimal cost, as Northern local communities usually cannot afford high priced datasets. Here again, open-data policies may help to overcome the potential barriers as they encourage free access to data.

4.2.10 Data Auditing

To continuously ensure that the datasets continue to meet their specifications, data audits can be conducted by data custodians. The result of a data audit is a quality report containing information on:

- The audit mandate and related needs;
- The audited dataset description;
- General advices regarding the dataset;
- The recommended and not recommended uses of the dataset;
- The audit results: favorable or unfavorable;
- The warnings (and risks) regarding the use of the dataset;
- The guarantees (in line with the liability of the data producer);
- Licensing of the dataset.

4.2.11 Data Archiving and Preservation

The actual context showing an explosion of digital cartography, and the emerging variety and volume of spatial products bring an unprecedented complexity regarding the archiving and preservation of data assets. As new technologies and approaches to data collection and cartographic production are established, new challenges in preserving and archiving spatial digital data and maps are emerging (Lauriault, Pulsifer, & Fraser, 2011). Spatial data producers need to work collaboratively with archivists, librarians, and technology specialists to design and build cartographic artifacts that will stand the test of time. The use of cloud technology brings new capabilities but raises new questions (e.g., location of storage nodes and replication, security, legal constraints to store data within the administrative boundaries of a jurisdiction). There are plans to release an ISO standard for geographic information preservation of digital data and metadata in November 2017.

4.2.12 Risk Management

Risk is "the effect of uncertainty on objectives" (Canada, 2012), (International Organization for Standardization, 2009). The effect is any deviation from the expected situation (positive and/or negative). Risk is about the effect of uncertainty, and is therefore future-oriented. In the context of geospatial data, the risk considered is the risk of inappropriate usage of geospatial data. As spatial datasets are increasingly being used for purposes other than their producers' intended ones, the risk of potential incidents, faulty decisions or accidents also increases. Risk management is "**the act or practice of dealing with risk** (…)" (Kerzner, 2009). Risk management is the activity of directing and controlling what an organisation does to minimize unexpected impacts on its objectives. A key principle in risk management is that zero risk does not exist. Risk management implies balancing the efforts to prevent unexpected outcomes with potential negative impacts of such outcomes for stakeholders (including consumers).

The *ISO 31000:2009 - Risk management - Principles and guidelines* standard (International Organization for Standardization, 2009) describes a risk management framework that can be used to manage the risks of inappropriate use of spatial data. The general steps of the ISO 31000 risk management process are:

- Describing the organisational and risk management context
- Assessing risks
- Building risk responses
- Communicating risks
- Monitoring and reviewing risks

From a legal perspective, **using a risk management approach is necessary to better protect both the spatial data producer and user**.

4.2.13 Data Creation, Maintenance and Distribution Summary

Good practices:

- A good practice regarding data quality and risk management is to follow the Complete Cycle of Geospatial Data Quality for a Spatially-Enabled Society (GeoConnections and Intelli3 Inc., 2015) which suggests evaluating data quality using ISO 19157, managing risks of inappropriate data usage using ISO 31000, and communicating properly with all players, especially non-expert users using ISO 3864-2 (International Organization for Standardization, 2004).
- A good practice regarding data is to apply master data management principles (The Master Data Management Institute, 2015), for the SDI but also at the source (e.g., the national mapping agencies feeding data to the SDI).
- Another good practice is to evaluate the data being fed to the SDI using data maturity models (e.g., Data Management Maturity Model (CMMI Institute, 2016) or the Open Data Maturity Model (The Open Data Institute, 2016).

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 2 Reference Datasets* (Arctic SDI Working Group on Strategy, 2015). *http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf*.
- *The Arctic SDI Strategic Plan 2015-2020 – Objective 3 Thematic Datasets.*

Applicable standards:

- *ISO 9000 – Quality Management.*
- *ISO 19109:2015 Geographic information – Rules for application schema.*
- *ISO 19110:2005 Geographic information – Methodology for feature cataloguing.*
- *ISO 19115-1:2014 Geographic information - Metadata - Part 1: Fundamentals.*
- *North American Profile of ISO 19115:2003 Geographic information – Metadata.*
- *ISO 19123:2005 Geographic information –Schema for coverage geometry and functions.*
- *ISO 19131:2007 Geographic information – Data product specifications.*
- *ISO 19131:2007/Amd 1:2011 Requirements relating to the inclusion of an application schema and feature catalogue and the treatment of coverages.*
- *ISO 19157:2013 Geographic information - Data quality.*
- *ISO 31000:2009 Risk management – Principles and guidelines.*

For more information and examples:

- *Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013). http://geoscan.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&search=r=292897&format=FLFULL* .
- Arctic SDI Fact Sheet (Arctic SDI, 2015). http://arctic-sdi.org/wp-content/uploads/2016/09/fact-sheet-copy-Sept-2016.pdf
- A Conceptual Model for Developing Interoperability Specifications in Spatial Data Infrastructures (European Commission, Joint Research Centre, 2012). http://inspire.ec.europa.eu/file/1418/download?token=rzNYULUf
- *European Interoperability Framework (EIF) for European public services (Interoperability Solutions for European Public Administrations, 2010). http://ec.europa.eu/isa/documents/isa_annex_ii_eif_en.pdf*
- *Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119 (INSPIRE Drafting Team Metadata and European Commission Joint Research Centre, 2013). http://inspire.ec.europa.eu/documents/Metadata/MD_IR_and_ISO_20131029.pdf*
- *Geospatial data quality guide (GeoConnections and Intelli3 Inc., 2015). http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&se*

arch1=R=297536.

- *Geosemantic interoperability backgrounder (GeoConnections and Hickling Arthurs Low Corporation, 2015). http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=296963*.
- *The Master Data Management Institute. http://0046c64.netsolhost.com/mdm/aboutMDMinstitute.html*.
- *The Data Management Maturity Model. http://cmmiinstitute.com/data-management-maturity*.
- *The Open Data Maturity Model. https://theodi.org/guides/maturity-model*.

4.3 Technological Framework

4.3.1 Arctic SDI Architecture

A SDI is based on the premise that **distributed networked access** makes data more readily available (CP-IDEA, 2013). The Arctic SDI architecture is designed to facilitate such access and enable the implementation of systems to support service providers, data providers and application developers, using interoperable and reusable components.

A model that can be used to document the architecture of a SDI is **RM-ODP**, as described in the *ISO/IEC 10746-3:2009 Information technology - Open distributed processing - Reference model: Architecture (RM-ODP)* standard (International Organization for Standardization, 2009). The RM-ODP defines five viewpoints of a distributed system of systems: the enterprise viewpoint describing the business model, the information viewpoint describing the information content and system behavior, the computational viewpoint describing components, interfaces and constraints, the engineering viewpoint describing infrastructure and mechanisms for component distribution, and the technology viewpoint describing implementation and deployment environments using technologies, standards and products. The RM-ODP model covers the management (nodes, objects, clusters, etc.), coordination (event notification, transaction, recovery, etc.), repository (storage, etc.), and security (access control, authentication, etc.) functions of a complex system.

A SDI architecture can be viewed from different linked perspectives: conceptual, operational, technical and systems (CP-IDEA, 2013). The *conceptual* architecture is composed of data, services, applications and users that are described in sections 4.3.2, 4.3.3 and 2 respectively. The *operational* architecture contains descriptions of the operational elements, assigned tasks and activities, and information flows required to support users. The *technical* architecture provides the technical systems implementation guidelines upon which engineering specifications are based, common building blocks are established, and product lines are developed. The *systems* architecture shows how multiple systems and/or parts of systems link and interoperate.

SDI architectures typically contain the components identified in Table 2.1 (CP-IDEA, 2013).

Table 2.1. SDI Architectural Components and Their Functions.

Components	Functions
Objects	Spatial objects describe real-world entities that are employed in client applications. The SDI makes the interfaces to the objects available to clients and providers with seamless views of the information. A representative list of fundamental geospatial objects includes: ▪ Geographic Features ▪ Geographic Coverages ▪ Geographic Measurements/Observations ▪ Spatial Reference Systems ▪ Geographic Projects ▪ Geographic Events ▪ Geographic Transformations ▪ Map Styles and Symbologies
Open Standards and Specifications	The endorsement and adoption of international or national standards ensures the SDI is interoperable for operational transactions and information exchange with other SDIs around the world. SDI managers typically adopt or endorse international standards to achieve the following benefits: ▪ Reduce development costs ▪ Minimize redundancy ▪ Hide the complexity of components ▪ Permit GIS practitioners and developers to benefit from “plug and play” components
Registries	The service registry serves as the key link between supplier and consumer. Once a supplier has published metadata about its offering to the registry, a consumer can verify with the registry before connecting to the supplier. Furthermore, when changes to the supplier’s offering occur, the registry can redirect the consumer to the new location, or present alternative services from similar suppliers.
Metadata	Metadata answers the who, what, where, when, why and how of every facet of the data or service available through the SDI. Using metadata, SDI users are able to: ▪ Determine what geospatial data is available ▪ Evaluate the suitability of the data for their use ▪ Access the data ▪ Transfer and process the data ▪ Accomplish these things in the order appropriate for them
Security and Authentication	The need for security and authentication mechanisms increases with the need to share information in an open and interoperable fashion, particularly in those operations that create or update data. For access to services and data, a secure infrastructure will provide the following:

Components	Functions
	▪ *Protected access* – Interactions between components are private (prevents eavesdropping) and integrity is ensured (prevents tampering); ▪ *Verified access* – Communications are authenticated (to avoid impostors by confirming identity or role) and signed (to be non-deniable); and ▪ *Authorized access* – Access to services and data is controlled by the verified identity and/or role of the requesting user or client.

4.3.2 Data Discovery, Visualization and Access

Data are at the core of the infrastructure, with services and applications developed to contribute them from a producer point of view, and to access them from a user point of view. Datasets contributed to a SDI typically follow formal thesauri, ontologies or detailed specifications described in metadata and complementary documents, in order to facilitate their discovery, visualization and access by SDI users. *Discovery* is supported by catalog services. *Visualization* is supported by Web mapping, portrayal and tiling services that can produce a map as a picture, a series of graphical elements, or a packaged set of geographic features, answer basic queries about the map content, and tell other programs what maps it can produce and which of those can be queried further. Access is supported by offline services, direct to data store services, brokered services, and online data service in order to package and deliver the datasets.

4.3.3 Arctic SDI Services and Applications

The SDI Web services are based on open standards and they provide the **basis for interaction across the Internet** and allow data providers as well as users to contribute, access, and exchange spatial datasets. Web services in a spatial data context can be grouped in the following classes (Open Geospatial Consortium, 2011):

- Application services (e.g., discovery, map viewer, image, sensor Web)
- Registry services (e.g., data registry, service registry, device registry)
- Data services (e.g., feature access, coverage access, sensor collection)
- Portrayal services (e.g., map portrayal, coverage portrayal, mobile presentation)
- Processing services (e.g., geocoder, gazetteer, coordinate transformation)

In a Web services architecture, the service "service registry" serves as the key link between the supplier and the consumer of web service. The Web services from the participating organisations and SDIs as well as the common Arctic SDI services will serve as a platform or framework to build applications or to build dynamic Web pages for specific identified needs and use cases in the Arctic. SDI applications use data from Web services to provide users with the ability to produce and analyze spatial data or produce new information to make informed decisions. The Arctic SDI Geoportal is an example of application built using Arctic SDI Web services. (http://geoportal.arctic-sdi.org/). Other Arctic SDI applications will be developed in the future to address various use cases (e.g., create and publish metadata, search and find, evaluate the fitness for use of geo-resources, consume geo-resources, download geo-resources, pay, etc.). A good practice in developing SDI applications is to follow a user-centered design approach to ensure user satisfaction and a SDI that is usable and used.

4.3.4 Technological Framework Summary

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 4 Data and Technical Interoperability* (Arctic SDI Working Group on Strategy, 2015). *http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf*.
- *The Arctic SDI Framework Document (Arctic SDI National Contact Points, 2015). http://arctic-sdi.org/wp-content/uploads/2014/08/20150825-Arctic-SDI-Framework-Document_V2-0.pdf.*

Applicable standards:

- *ISO/IEC 10746-3:2009 Information technology - Open distributed processing - Reference model: Architecture (RM-ODP).*
- *OGC Standards http://www.opengeospatial.org/docs/is).*
- *W3C Standards* http://www.w3.org/standards/*).*

For more information and examples:

- *Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013). http://geoscan.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&search=r=292897&format=FLFULL.*

4.4 Standards

4.4.1 The Importance of Standards

Standards are one of the key pillars of SDIs. The specification and adoption of a compatible suite of standards is a **critical means of enabling interoperability**. The Arctic SDI should adopt an approved suite of standards and write guidelines on how (and to which level) they should be applied. Standards facilitate the open transfer of spatial data between platforms and they ensure consistent connectivity and user experience within an infrastructure framework.

Standards are used throughout the whole data lifecycle, from acquisition/creation to portrayal and distribution. They address:

- Data encoding
- Data storage
- Data description
- Data presentation
- Data visualization
- Data manipulation
- Data query
- Data access

Benefits of using standards include customer benefits, operational benefits, financial benefits, strategic benefits and social benefits. Specifically, in a SDI context, standards help to reduce development costs, help to minimize redundancy by promoting the development of small reusable components and hide the complexity of components as they take care of many technological considerations in a way that is completely transparent to the users. They also allow spatial data practitioners and developers to benefit from "plug and play" components, so the data can circulate easily from one stage to the other, from acquisition to dissemination to end-users through the SDI.

4.4.2 Applicable Standards and Profiles

Many types of standards exist and many organisations, at all levels and in all fields, develop and promote standards. The development of a SDI requires the use of generic as well as domain-specific standards. Domain-generic international standards related to SDIs are published by:

- The *International Organization for Standardization (ISO) Technical Committee 2011 Geographic information/Geomatics (ISO/TC 211)*. The ISO standards address conceptual modelling, geometry of spatial features, metadata, encodings, portrayal, Web map services, etc.
- The *Open Geospatial Consortium (OGC)*. The OGC standards address Web map services, Web feature services, Web coverage services, catalog services for the Web, etc.
- The *World Wide Web Consortium (W3C)*. The W3C standards address Web design and applications (HTML, CSS, etc.), Web architectures (HTTP, URI …), Semantic Web (OWL, SKOS, etc.), XML, GML, etc.

Depending on the subject matters of the SDI, domain-specific international standards can be used. Examples of relevant domains in the context of the Arctic SDI include:

- The International Hydrographic Organization (IHO) (e.g., S-11, S-57, …)
- ISO TC 204 (Intelligent transportation systems)
- The International Civil Aviation Organization (ICAO)
- ISO TC 215 Health Informatics

The Global Spatial Data Infrastructure Association has published, in its SDI Cookbook, a list of standard grouped in relevancy categories, from essential, to others (Global Spatial Data Infrastructure Association, 2009).

- Essential standards:
    - ISO 19115 Geographic Information - Metadata (or a profile)
    - OGC Web Map Service
    - OGC Web Map Tile Service
- Highly desirable standards:
    - OGC Web Feature Service
    - OGC Filter Encoding
    - OGC Geography Markup Language
    - OGC KML
    - OGC Catalogue Service
    - ISO 19157 Geographic Information – Data quality
    - ISO 31000 Risk Management
- Additionally useful standards (they represent good practice in the SDI development context):
    - ISO 19131 Geographic Information
    - OGC Web Coverage Service
    - OGC Styled Layer Descriptor Profile
    - OGC Web Processing Service
- Other standards that can be included depending on the context:
    - OGC Web Map Context
    - OGC Sensor Model Language
    - OGC Sensor Observation Service

Since several of the Arctic data sets are within the themes specified by different regional or national organisations, data providers may be obliged to fulfill requirements from different standards organisations. For example, the infrastructure needs to be flexible for services that comply to OGC and ISO standards (Table 2.2).

Table 3.2. Mapping of OGC to ISO service standards.

OGC	ISO
Discovery service OGC™ Catalogue Services Specification 2.0.2	ISO Metadata Application Profile for CSW 2.0 [CSW ISO AP]
View service OGC™ Web Map Service (WMS) 1.3.0 OGC™ WMS 1.1.1 OGC™ Web Mapping Tiling Service - WMTS 1.0.0 OGC™ Styled Layer Descriptor Profile [OGC SLD]	ISO 19128 Geographic information - Web map server interface
Download Service OGC™ Web Feature Service 2.0 OGC™ Filter Encoding 2.0	ISO 19142:2010 Geographic information - Web Feature Service, ISO 19142 ISO 19143:2010 Geographic information - Filter encoding, ISO 19143
Transformation OGC™ Simple Feature Access Specification Version 1.2	

4.4.3 Cultural and Linguistic Adaptability

In the Arctic SDI context, there is a requirement to support cultural and linguistic adaptability in metadata, conceptual schema, feature catalogues, interfaces (e.g., the Geoportal), and communication tools (e.g., website, policy and guidelines documents, etc.). Currently, the Arctic SDI only supports the English language. A number of other languages, including languages of Arctic native communities, need to be included in the future for a wider spread of the data and information server through the Arctic SDI. For example, the European Commission INSPIRE documents are available in more than 20 languages.

Another challenge in interoperability and data integration is **understanding what the data means** (definitions may vary between organisations; the language is also different). In order to overcome this challenge, there is a need for a machine-readable description of the data (ontology) and a need for machine-driven ontology matching and automatic warning in case of potential geosemantic problems.

ISO Profiles can be used for cultural and linguistic adaptability. The ISO 19106:2004 Geographic Information - Profiles standard (International Organization for Standardization, 2004) provides a mechanism for developing profiles of geographic information standards developed by ISO/TC 211. One example of profile that addresses cultural adaptability is the *North American Profile of ISO 19115:2003 Geographic information – Metadata*.

Additionally, the *ISO/IEC TR 24785:2009 Information technology - Taxonomy of cultural and linguistic adaptability user requirements* standard (International Organization for Standardization, 2009) defines a taxonomy describing the various elements of cultural and linguistic adaptability user requirements for use in a computer environment.

4.4.4 Maintenance of Standards

Once standards are developed and/or adopted, SDI stakeholders must ensure their viability in relation with evolving technologies, evolving user needs and compatibility with the underlying evolving IT standards. Policies must be developed within the Arctic SDI governance structure to address the inevitable standards evolution.

4.4.5 Standards Summary

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 4 Data and Technical Interoperability* (Arctic SDI Working Group on Strategy, 2015). *http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf*.

Standards:

- *ISO TC 211 Standards. http://www.isotc211.org/.*
- *OGC Standards. http://www.opengeospatial.org/docs/is.*
- *W3C Standards. http://www.w3.org/standards/.*
- *ISO/IEC TR 24785:2009 Information technology - Taxonomy of cultural and linguistic adaptability user requirements.*

For more information and examples:

- *Standards user's guide for geographic information (GeoConnections and IDON Technologies Inc., 2016). http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=297543.*
- *Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013). http://geoscan.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&search=r=292897&format=FLFULL.*

4.5 Policies

Successful spatial data infrastructure initiatives are closely linked to the overall policy environment in the jurisdiction in which they are implemented (CP-IDEA, 2013). In the context of the Arctic SDI, the policy environment is quite complex and involves the 8 Arctic countries, the Arctic Council, and other stakeholders, for example the United Nations.

Two types of policies are required for a SDI context: **strategic and operational policies**. Strategic policies create a formal structure within which the SDI initiative can develop. They encourage stakeholder commitment to participate in the development of and to use the infrastructure. Operational policies address topics related to the lifecycle of spatial datasets (i.e., their collection, management, dissemination, and use), their delivery, access and use through the SDI, and the operation of the SDI. They are practical tools to build, access and use the infrastructure.

4.5.1 Policy Environment

Identified Arctic Council specific context and needs related to the development of policies include the following elements (Arctic SDI National Contact Points, 2015):

- Support of cross-border activities (conservation of natural environment and economic development);
- Support of integrated planning;
- Clarify and explain Indigenous peoples land use practices and improve presentation, communication and better integration of these issues;
- Improved information management practices;
- Support the use of the Arctic SDI by international and national authorities, schools and universities, private enterprises, public and private international projects;
- Need for common authentication and authorization of Arctic SDI users;
- Need for the mapping agencies to harmonize their data models;
- Must be in line with UN-GGIM, INSPIRE, ELF, NSDI and CGDI activities;

4.5.2 Policy Development Process

In a SDI context, many policies and guidelines are needed. Their development should be prioritized by their impact, importance, scope, complexity and the results of user needs assessments (CP-IDEA, 2013). Stakeholders engagement is essential in the policy development process as they will also be the primary users of the policy framework they develop. The policy development process comprises four stages:

- Development:
    - Environmental scan

  - Needs analysis
  - Topics identification and prioritization
  - Stakeholder involvement
  - Policy creation
- Adoption:
  - Policy introduction
  - Policy review
  - Policy adoption
- Implementation:
  - Change management
  - Outreach and awareness building
- Monitoring:
  - Objective, Input, Process, Output, Outcome, Impact

4.5.3 Policy Topics in the Arctic SDI Context

It is good practice to **foresee legal, security and administrative constraints** as early as possible in the technological process of SDI development in order to avoid taking the wrong path and having to redo the work. Being international and multi-level, the Arctic SDI will face many challenges and policies should address these topics, including:

- Legal/administrative context:
  - Recommendations regarding the compliance with standards and procedures regarding data, services, applications and tools.
  - Open government policies
  - Confidential, secure and sensitive information
  - Privacy
  - Intellectual property
  - Licensing
  - Data sharing (at the international level, including legal interoperability)
  - Liability of providers, distributors and users
  - Archiving and presentation (including location of cloud storage for certain sensitive data)
  - External data quality/fitness for use
  - Semantics/languages

- Communications
- Technological context:
  - Open data/open-source software
  - Cloud computing
  - Volunteered geographic information (VGI)
  - Sensor data
  - High resolution imagery
  - Mobile and location-based services

4.5.4 Policy Summary

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 5 Spatial Operational Policies* (Arctic SDI Working Group on Strategy, 2015). *http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf*.

For more information and examples:

- *Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013). http://geoscan.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&search=r=292897&format=FLFULL*
- *The SDI Cookbook (Global Spatial Data Infrastructure Association, 2009). http://gsdiassociation.org/images/publications/cookbooks/SDI_Cookbook_from_Wiki_2009.pdf*.
- *User's guide on the classification of geospatial information policy instruments (GeoConnections and Hickling Arthurs Low Corporation, 2013). http://geoscan.ess.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&format=FLFULL&search=R=295671*.

4.6 In Summary

The development and implementation of the Arctic SDI and its core elements (institutional arrangements, framework and thematic data, technologies, interoperability, standards and policies) provide solutions to data production and data usage. Important datasets are produced and distributed by many stakeholders and most of it is or can be geographically referenced. A SDI offers guidelines, standards, policies and tools for data distributors to ensure that their geospatial data is easier for users to access, validate and combine with other data.

Other regional, national and international SDIs, like INSPIRE, can incorporate or link to unique Arctic datasets. The value of SDIs is to promote more effective data discovery, analysis, management, and distribution in an open environment, with no data duplication or versioning and with maintenance at the source. It facilitates value-added data integration and analysis as well as free and open access to interoperable data.

The Arctic SDI provides improved access to geospatial data and help to better predict, understand and react to changes in the Arctic. Responses to the impact of climate changes and human activities in the Arctic require accessible and reliable data to facilitate monitoring, management, emergency preparedness and decision making (Arctic SDI, 2015).

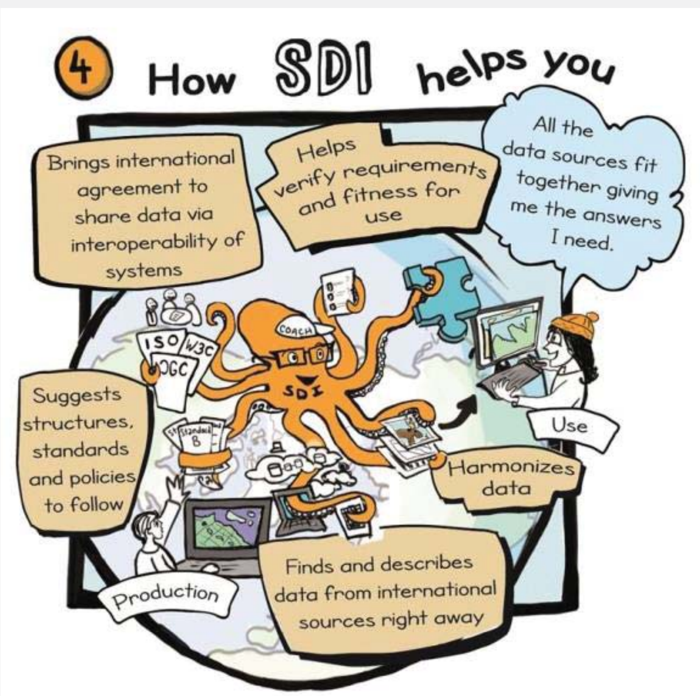


Figure 6. How the SDI helps the Arctic stakeholders.

The Arctic SDI provides solutions to the data production (interoperability, use of standards, required policies, etc.) and data usage (data discovery and access, fitness for use, data harmonization, etc.) challenges as illustrated in Figure 6.

5. The Open SDI

SDI initiatives to facilitate data sharing and integration are **in line with the broader open data movement**, in which common goals are (CP-IDEA, 2013) to remove restrictions on use and dissemination, to disseminate works at minimal or no cost, and to improving public use and access of data in the public interest. SDI initiatives are also **in line with open government initiatives**, which emphasize on facilitating public access to data held by government to develop new and useful products and applications that leverage the value of the original data. This chapter will discuss open data, open source software and open standards.

5.1 Open Data

Open data is a philosophy and practice that makes data easily and freely available, without restrictions from copyright, patents or other mechanisms of control, by way of portals, metadata and search tools in order to enable reuse of the data in new and unforeseen ways (CP-IDEA, 2013). The concept of 'open data' involves removing restrictions on use and dissemination, standardizing formats to foster interoperability and accessibility, disseminating data at minimal or no cost, and improving public use of, and access to the data, in the public interest. The Open Data Maturity Model (The Open Data Institute, 2016) aims to help organisations assess how effectively they publish and consume open data. A good practice in democratizing spatial data access, services and applications is to better protect both producers and users by properly informing users with a language and symbols they can easily understand.

With open data, the roles and responsibilities of producers, distributors and users of spatial data and services are evolving. Data quality being key to good decision making, following the *Guide to Geospatial Data Quality* (GeoConnections and Intelli3 Inc., 2015) is a good practice in an open data environment. Following the guide, producers and distributors of data must inform users, in a language they can understand, about the quality of a product or service, as well as about the risks and prohibited usages. They must also take actions to minimize the risks related to spatial data usage. In the guide, the Complete Cycle of Geospatial Data Quality for a Spatially-Enabled Society suggests evaluating data quality using ISO 19157 (International Organization for Standardization, 2013), managing risks of inappropriate data usage using ISO 31000 (International Organization for Standardization, 2009), and communicating properly with all players, especially non-expert users using ISO 3864-2 (International Organization for Standardization, 2004). This professional duty, for producers and distributors of spatial datasets, calls for going beyond traditional metadata and quality assurance procedures.

The **benefits of open data** include increased use, standardization that improve data interoperability and reuse, network externalities, which include efficiencies and common understanding, and novel applications for the open datasets. The United Nations have identified open data as a trend that will continue to develop in the near future (United Nations Committee of Experts on Global Geospatial Information Management, 2015).

5.2 Open Source Software

Open-source software is computer software with its source code made available with a license in which the copyright holder **provides the rights to study, change, and distribute the software to anyone and for any purpose** (Wikipedia, 2016). Although proprietary commercial software can be used for SDIs, open-source software offers some advantages including flexibility, freedom and easier code sharing, no acquisition cost in several cases, and it can also help a broader developer community to offer new services and applications, reaching a broader user community to benefit from the use of spatial data. These advantages have to be balanced with existing in-house expertise, risks of reinventing the wheel, inappropriate software reuse, development and maintenance costs. In a good strategy, it is frequent to see organisations integrate open-source software with commercial proprietary software.

Good practices regarding open-source software include relying on proven software that has been widely tested for the task by similar organisations and on developers having experience with SDI, and carefully assessing the development and maintenance costs, as well as the reusability of the available code (which is often developed in a very specific context) that is shared by the developers' community.

Examples of **proven open-source software** used in a SDI context include:

- GeoNetwork (metadata management)
- Oskari (web mapping platform)
- PostgreSQL and PostGIS (database management system with spatial component)

5.3 Open Standards

An open standard has the following characteristics: is created in an open, international, participatory industry process, it is freely distributed and openly accessible, it does not discriminate against persons or groups, and it ensures that the specification and license are technology neutral. Examples of SDI-related open standards:

- Open Geospatial Consortium (OGC) standards
- World Wide Web Consortium (W3C) standards

5.4 Open SDI Summary

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 5 Spatial Operational Policies (Arctic SDI working Group on Strategy, 2015).* http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf.

Applicable standards:

- *OGC Standards. http://www.opengeospatial.org/docs/is.*
- *W3C Standards http://www.w3.org/standards/.*
- *ISO 19157:2013 Geographic information - Data quality.*
- *ISO 31000:2009 Risk management – Principles and guidelines.*
- *ISO 3864-2:2004 Graphical symbols – Safety colours and safety signs - Part 2: Design principles for product safety labels.*

For more information and examples:

- *Future trends in geospatial information management: the five to ten year vision – Second Edition (United Nations Committee of Experts on Global Geospatial Information Management, 2015). http://ggim.un.org/docs/UN-GGIM-Future-trends_Second%20edition.pdf.*

- *The Open Data Maturity Model (The Open Data Institute, 2016). https://theodi.org/guides/maturity-model.*

- *The Geospatial Data Quality Guide (GeoConnections and Intelli3 Inc., 2015). http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=297536.*

6. Community Engagement

Community and stakeholder engagement through outreach and awareness, and capacity building programs **is essential** to successfully plan, develop, implement and monitor a SDI initiative (CP-IDEA, 2013). This chapter discusses ways to ensure the Arctic SDI is properly publicized and optimally used by its intended users. This chapter also presents a short case study of a data pilot project conducted by the Conservation of Arctic Flora and Fauna (CAFF) Working Group of the Arctic Council.

The community engagement strategy must be adapted to the various stakeholders and must take into account **their level of involvement, their level of knowledge, their language, etc**. In the Arctic SDI context, the “community” includes the following member groups:

- Arctic Council with its working groups and permanent participants;
- Other international stakeholders such as the United Nations;
- The Arctic SDI Board and the Arctic SDI working groups;
- The 8 NMAs participating in the Arctic SDI and other data providers and distributors;
- Other users of Arctic spatial information: governments, policy makers, scientists, private enterprises and citizens in the Arctic.
- Local governments

The community engagement strategy can take a number of forms: print publications, online publications, workshops, focus groups, webinars, open forums, meetings with key individuals, involving stakeholders and communities in working groups and committees, developing pilot projects, etc.

6.1 Outreach and Awareness Building

Outreach and awareness building among stakeholders aims to promote the need for, the benefits of, and the mechanisms of the Arctic SDI. The first step in an awareness campaign is to understand the knowledge, attitudes and practices of the various user groups (stakeholder study) in order to choose the most appropriate means. Examples of means to reach this goal:

- Pilot projects (**they are interesting because they are engaging**) that provide assistance and guidance for users to test an application, with their own data and use cases. When successful, they will be an important means of convincing organisations to use the infrastructure and become engaged in ensuring the SDI initiative is a success.
    - E.g., the CAFF pilot project described in Appendix 1.
- Project showcase in order to highlight successes.
- Documenting case studies, good practices and lessons learned help convey the underlying factors that led to success stories in SDI implementation.
- Using an opinion leader who occupies a position of influence in the area.

6.2 Capacity Building

Capacity building is an important element of the SDI implementation strategy (CP-IDEA, 2013). Such strategy should address the needs of each group of stakeholders:

- Data providers and distributors need to know how to make their data fit the requirements of the SDI, how their contribution will benefit them and others and what will be the impacts on their work.
- Systems developers need to know how to interface with the infrastructure
- Spatial data users need to understand and be comfortable with data discovery, visualization and access processes and any other spatial tools and applications that are provided by the SDI.

Examples of means to reach this goal include online learning tools (manuals, user guides, computer-based training), technical guidelines for data providers, distributors and users, seminars and webinars, workshops and courses (either through their own efforts or in cooperation with educational institutions), SDI capacity-building elements included in spatial information programs at colleges and universities.

It is good practice to try to reach the early critics of the SDI project at first and see them as an opportunity to build capacity and improve the system.

6.3 Community Engagement Summary

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 1 User and stakeholders needs and requirements* (Arctic SDI Working Group on Strategy, 2015). *http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf*.

For more information and examples:

- *The SDI Cookbook (GSDI Association, 2019). http://gsdiassociation.org/images/publications/cookbooks/SDI_Cookbook_from_Wiki_2009.pdf*.
- *Various case studies (CGDI Resource Center). http://www.nrcan.gc.ca/earth-sciences/geomatics/canadas-spatial-data-infrastructure/8904*.
- *NSDI Training Materials. https://www.fgdc.gov/training/training-materials*.

7. Communication Strategy

Communicating with, and addressing the needs of, the Arctic Council, Arctic Council Working Groups, other Arctic stakeholders and users of the Arctic SDI are key to the optimal implementation and success of the Arctic SDI. In order to optimally plan the communications to the various stakeholders groups, a communication strategy should be developed. A communication strategy may include the following components (Overseas Development Institute, 2005):

- The objectives of the strategy;
- Audiences, including languages, for the communications;
- The messages that will be communicated;
- Tools and activities that will be used/put in place;
- The resources required;
- The timescales of the communication project;
- The evaluation and amendment of the strategy.

Tools and activities include: publications (print and online), meetings, workshops, seminars, webinars, website development, calendar of events, communication packages, etc.

The Arctic SDI should provide a **communication package** that explains what it can offer, how one can benefit from it, and the usefulness of harmonization for data integration.

7.1 Audiences and Messages

Within the strategy, both **external and internal audiences** for the communications need to be identified. In the Arctic SDI context, these audiences include:

- Arctic Council with working groups and permanent participants (external);
- Other international stakeholders such as the United Nations (external);
- The Arctic SDI Board and Arctic SDI working groups (internal);
- The 8 national mapping agencies participating in the Arctic SDI and other data providers and distributors (United Nations, scientific organisations, provinces, First Nations, etc.) (external);
- Other users of Arctic spatial information: governments, policy makers, scientists, private enterprises, First Nations and citizens in the Arctic (external).

The strategy first needs to identify which audiences will be interested in which parts of the Arctic SDI activities. This is usually presented in a matrix and helps to establish the communication priorities. Second, for each pair "audience-activity", communication channels must be identified (e.g., e-bulletin, conference, workshop, leaflet, press release, event, public media, website, etc.). The channel must be adapted to the particular audience (i.e. their level of involvement, their level of knowledge, their language). It is good practice to make use of professional social networks and email marketing.

For internal audiences, there is a need to communicate:

- The fact that the Arctic SDI belongs to all its stakeholders and that their engagement in its development and evolution is essential;
- Expertise on SDI development (SDI knowledge sharing and transfer);
- Expertise on how to contract data producers so the resulting datasets comply with relevant ISO and OGC international standards and can be fully discovered, accessed and used through the SDI;
- Standard ways to write data licenses and disclaimers.

For external audiences, there is a need to communicate:

- To external data producers: the necessity of using international standards to facilitate interoperability and the reuse of their datasets by a larger community.
- To communicate the benefits realized by using standards.

7.2 Communication Strategy Summary

Linkages:

- *The Arctic SDI Strategic Plan 2015-2020 – Objective 6 Communications* (Arctic SDI Working Group on Strategy, 2015). *http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf*.

8. Measuring Impacts and Benefits

The Arctic SDI Benefits as illustrated in Figure 7.

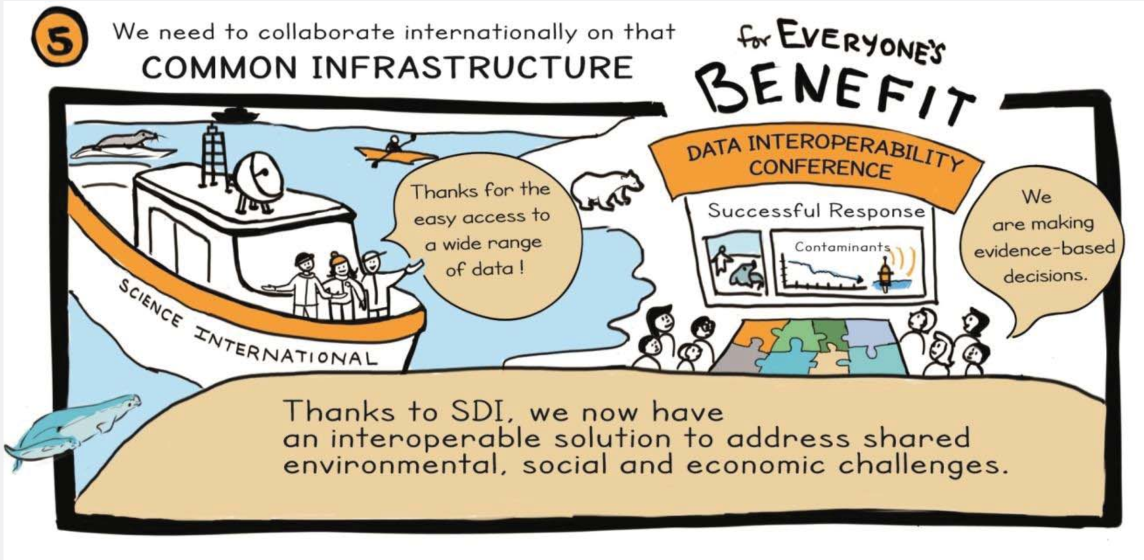


Figure 7. Arctic SDI: What are the benefits?

Managers of SDIs are required to **demonstrate the performance** of their projects as well as the impact they are having on society (CP-IDEA, 2013). Performance-based management systems can be used to demonstrate the benefits and performance of SDIs. It is however a challenge to develop cost-effective, functional frameworks to measure and monitor the performance of complex infrastructures such as SDIs because they possess multiple components and multiple stakeholders.

Measuring and monitoring allow for determining if a SDI is:

- Achieving its objectives;
- Performing in an efficient manner;
- Having positive effects on the society;
- Requiring improvements to achieve desired goals.

8.1 Performance-Based Management

The performance of an initiative is derived from the relationship among its objectives, inputs, processes, outputs, outcomes, and in some cases, the impact. Performance-based management is "a systematic approach to performance improvement through an ongoing process of establishing strategic performance objectives; measuring performance; collecting, analyzing, reviewing, and reporting performance data; and using that data to drive performance improvement."

(Performance-Based Management Special Interest Group, 2001). The key processes of performance-based management include:

- Defining the organisation's or project's mission, goals and objectives.
- Identifying key performance areas (i.e., areas critical to the assessment success).
- Developing an integrated performance measuring system.
- Applying performance information to decision-making and system improvement.
- Analyzing, reviewing and communicating performance.
- Developing data collection systems and methodologies.

Metrics must be developed for measuring performance. Metrics can include performance indicators (PIs) and key performance indicators (KPIs). Metrics must be chosen with care because the quality of the final results will depend on the quality of the selected metrics. It is good practice to make sure that the metrics developed are in sync with clearly identified goals of the project.

8.2 Methodologies

SDI assessment methodologies can be grouped in two categories, the SDI Readiness Assessment methodologies and the SDI Performance Assessment methodologies (CP-IDEA, 2013). SDI Readiness Assessment methodologies include the following techniques:

- Clearinghouse readiness
- Clearinghouse suitability
- SDI readiness model
- State of play

SDI Performance Assessment methodologies comprise the following techniques:

- GeoConnections framework
- GeoMaturity
- Balanced scorecard

Details about these methodologies and techniques can be found in the Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013).

8.3 Monitoring the Arctic SDI

According to the Arctic SDI strategic plan (Arctic SDI Working Group on Strategy, 2015), **several key performance indicators will be measured over the time period from 2015 to 2020** to gauge the effectiveness of the implementation of the Arctic SDI Strategic Plan 2015-

2020, as well as the effectiveness of the Arctic SDI itself. Key performance indicators will include qualitative or quantitative metrics on:

- User satisfaction of authoritative reference and thematic data and services;
- Relevance of Arctic SDI reference and thematic data to users;
- The use of the Arctic SDI Geoportal, web services and metadata;
- Known applications based on the Arctic SDI and their relevance;
- Arctic SDI Operational Policies influence on the development of Arctic Council information management policies.

8.4 Measuring Impacts and Benefits Summary

Linkages:

- *The Arctic SDI Implementation Plan 2015-2020 (Arctic SDI Working Group on Strategy, 2015). http://arctic-sdi.org/wp-content/uploads/2014/08/201511-Arctic-SDI-Implementation-Plan_FINAL.pdf.*

For more information and examples:

- *Spatial Data Infrastructure (SDI) Manual for the Americas (CP-IDEA, 2013). http://geoscan.nrcan.gc.ca/cgi-bin/starfinder/0?path=geoscan.fl&id=fastlink&pass=&search=r=292897&format=FLFULL.*
- *Performance-Based Management Special Interest Group. http://www.orau.gov/pbm/.*

9. Conclusions

The Arctic SDI was established to address the need for a better understanding of, and a better response to, the impacts of climate change and human activities in the Arctic. To do so, it requires accessible and reliable data to facilitate monitoring, management, emergency preparedness and decision making and partnerships have been/are being established. To ensure the success of the Arctic SDI, its stakeholders must fully engage in their roles and must be supported by appropriate arrangements, standards, guidelines and policies.

In 2014, the signing of a MOU in the English, French and Russian languages by the 8 Arctic countries led to demonstrable progress toward building the Arctic SDI (Arctic SDI, 2014). The Arctic SDI publishes authoritative data from numerous jurisdictions which are combined over the web using international information management standards.

Furthermore, Arctic SDI's information management best practices break down data silos in support of multi-disciplinary ecosystem-based analysis (Arctic Council, 2013).

As one support tool, this SDI manual aims to provide guidance on the planning, management, development and maintenance of the Arctic SDI to the various groups involved. This manual is a living or dynamic document, which is expected to be continually edited and updated to reflect the evolution of SDI components and the changing information requirements of the Arctic stakeholders.

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Appendix 1 – Case Study

Data Pilot Project with CAFF

What is CAFF?

The Conservation of Arctic Flora and Fauna (CAFF) group was formed in 1991 after Canada, Denmark, Finland, Iceland, Norway, Sweden, Russia and the United States adopted the Arctic Environmental Protection Strategy (AEPS), a multilateral agreement among Arctic states to protect the Arctic environment. In 1996, the Ottawa Declaration formally established the Arctic Council as a high level intergovernmental forum to provide a means for promoting cooperation, coordination and interaction among the Arctic States, with the involvement of the Arctic Indigenous communities and other Arctic inhabitants on common Arctic issues. The Arctic Council now oversees and coordinates the programs established under the AEPS including CAFF. CAFF is the biodiversity working group of the Arctic Council. CAFF is governed by a Chair and Management Board that consists of National Representatives assigned by each of the 8 Arctic Council Member States and Permanent Participants representing the six Indigenous Peoples' organisations of the circumpolar north. The CAFF International Secretariat assists the CAFF Chair, Management Board and Working Group to implement the CAFF work plan, and provides necessary support functions to the CAFF program.

CAFF Activities

CAFF serves as a vehicle to cooperate on species and habitat management and utilization, to share information on management techniques and regulatory regimes, and to facilitate more knowledgeable decision-making (Conservation of Arctic Flora and Fauna, 2016). It provides a mechanism to develop common responses on issues of importance for the Arctic ecosystem such as development and economic pressures, conservation opportunities and political commitments. CAFF's mandate is to address the conservation of Arctic biodiversity, and to communicate its findings to the governments and residents of the Arctic, helping to promote practices which ensure the sustainability of the Arctic's living resources (through various monitoring, assessment and expert group activities). CAFF's projects provide data for informed decision making to resolve challenges arising from trying to conserve the natural environment and permit regional growth. CAFF data is made available through the Arctic Biodiversity Data Service (ABDS), which allows for accessing, downloading and exploring data sets, web mapping services, graphics and more from circumpolar contributors.

The CAFF Arctic SDI Pilot Project

CAFF has expressed an interest in working with the Arctic SDI Board on two data sets:

- Migratory bird index
- Land cover change index

An engineering assessment has been conducted to verify how to publish selected CAFF vector and raster data so the datasets can be made available through the Arctic SDI. The results of the assessment showed that the publication of vector data was a straightforward process. However, the raster datasets posed standard and technology challenges (regarding temporal data) and these issues are now being addressed.

Test datasets are housed at, and Web Mapping Services (WMS) are served from, CAFF's ABDS. The WMS were successfully added to Arctic SDI Geoportal and dataset metadata were successfully harvested into the Arctic SDI Metadata Catalogue. CAFF serves as an example of effective data stewardship and custodianship. The provisions of access managed along with the metadata standards, quality control and data accessibility assurance.

A distributed Artic SDI effort supported all project components and included assistance from Canada, Denmark, Finland, Iceland, Norway, Sweden, with extensive support from the Arctic SDI Technical Working Group members.

Results and Benefits

The Arctic SDI has worked closely with the CAFF working group in developing a means of facilitating access to data including remotely sensed data developed via the Circumpolar Biodiversity Monitoring Programme (CBMP). The Arctic Biodiversity Data Service (ABDS) now streams CAFF data into the Arctic SDI GeoPortal. This pilot project helped assess the level of effort required, by working with, or, "learning from the data", based on the principles of open data, open software and open standards.

This cooperation has proved very productive and allowed for the exchange of both knowledge and skills between the Arctic SDI and an Arctic Council working group. This will serve as a model for the other Arctic Council working groups as well as other data producers, for the dissemination of their datasets through the Arctic SDI.

Appendix 2 – Sample SDIs

- *National Spatial Data Infrastructure (NSDI, USA). https://www.fgdc.gov/nsdi/nsdi.html.*
- *Canadian Geospatial Data Infrastructure (CGDI). http://www.nrcan.gc.ca/earth-sciences/geomatics/canadas-spatial-data-infrastructure/10783.*
- *National Spatial Data Infrastructure (NSDI, Russia) of Russia.*
- *Infrastructure of Spatial Information in the European Community (INSPIRE). http://inspire.ec.europa.eu/.*
- *Australian Spatial Data Infrastructure (ASDI). http://www.icsm.gov.au/asdi/.*
- *New Zealand National Spatial Data Infrastructure (SDI). http://www.linz.govt.nz/about-linz/our-location-strategy/geospatial-strategy-for-spatial-data-infrastructure.*
- *Chilean Spatial Data Infrastructure (IDE). http://www.ide.cl/.*
- *Swedish Spatial Data Infrastructure. http://www.geodata.se/.*
- *The Open Geoportal. http://data.opengeoportal.org/.*
- *Polar Data Catalogue https://www.polardata.ca/.*
- *Arctic Biodiversity Data Service http://www.abds.is/.*
- *Acadis Gateway https://www.aoncadis.org/home.html.*
- *Geoss Portal http://www.geoportal.org/web/guest/geo_home_stp.*
- *European Location Framework (ELF) http://locationframework.eu/.*
- *National Geophysical Data Center: Geoportal. https://www.google.ca/?gws_rd=ssl#q=geoportal&start=10.*
- *Géoboutique Québec. http://geoboutique.mern.gouv.qc.ca/edel/pages/menu/qui_sommes_nous.faces*
- *Ontario GeoPortal. http://www.ontariogeoportal.com/.*
- *DataBC. http://www.data.gov.bc.ca/dbc/geographic/index.page.*

Appendix 3

Arctic SDI Glossary of Terms

The SDI Manual for the Arctic was produced using the definitions from the Arctic SDI Glossary of Terms (Version 1.0). Please visit the Arctic SDI website for subsequent versions of the Glossary of Terms.

Acronym	Term	Definition	Source
	Application	The use of capabilities, including hardware, software and data, to manipulate and process data for user requirements. Applications are designed to perform a specific function directly for the user or, in some cases, for another application program. Related terms: Application Program, Application Software, End-User Software	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
API	Application Program Interface	The interface (calling conventions) by which an application program accesses operating systems and other services. An API provides a means of developing custom user interfaces.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Application Schema	Defines content and structure of both geographic data and other related data, and operations for manipulating and processing data by an application.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Applications Profile	The set of metadata properties, policies and guidelines defined for a particular metadata application or implementation.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Architectural Framework	Identifies key interfaces and services, and provides a context for identifying and resolving policy, management and strategic technical issues. Related terms: Conceptual Architecture, Reference Architecture	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Arctic	Designating the north polar region of the Earth, which comprises the Arctic Ocean and land areas in parts of Canada, Kingdom of Denmark, Finland, Iceland, Norway, Russia, Sweden and the United States of America. The Arctic SDI is to cover the Arctic regions of the involved participating countries, as defined by the countries themselves. It can be identified and defined in many different ways depending on the parameters used (tree line, climate, Arctic Circle, temperature, flora, fauna, jurisdiction). Related term: Polar, Circumpolar, Pan-Arctic	Oxford English Dictionary: http://www.oed.com/view/Entry/10461?redirectedFrom=Arctic#eid Arctic SDI Framework Document: http://arctic-sdi.org/wp-content/uploads/2014/08/20150825-Arctic-SDI-Framework-Document_V2-0.pdf Rapid Change in the Arctic, UNEP: http://www.unep.org/gc/gc27/Docs/se/What%20Future%20for%20the%20Arctic.pdf
	Arctic Community	Almost four million people live in the Arctic today, with the precise number depending on where the boundary is drawn. They include Indigenous Peoples and recent arrivals, hunters and herders living on the land, and city dwellers. Many distinct Indigenous groups are found only in the Arctic, where they continue traditional activities and adapt to the modern world at the same time. Humans have long been a part of the arctic system, shaping and being shaped by the local and regional environment. In the past	Arctic Council: http://www.arctic-council.org/index.php/en/our-work/arctic-peoples

		few centuries, the influx of new arrivals has increased pressure on the arctic environment through rising fish and wildlife harvests and industrial development. The Arctic includes part or all of the territories of eight nations: Canada, Kingdom of Denmark, Finland, Iceland, Norway, Russia, Sweden and the United States of America, as well as the homelands of dozens of Indigenous groups that encompass distinct sub-groups and communities. Related Terms: Northerners, Indigenous Peoples.	
Arctic SDI	Arctic Spatial Data Infrastructure	The Arctic Spatial Data Infrastructure (Arctic SDI) is a voluntary, multilateral cooperation between the Arctic countries to develop data, standards, applications, policies, and governance necessary to promote geospatial data sharing in an open, efficient and flexible way. The goal of the Arctic SDI is to provide politicians, governments, policy makers, scientists, private enterprises and Northerners with access to reliable and interoperable geospatial data, tools and services to facilitate monitoring and decision making in the Arctic.	Arctic SDI Framework Document: http://arctic-sdi.org/wp-content/uploads/2014/08/20150825-Arctic-SDI-Framework-Document_V2-0.pdf; Arctic SDI Fact Sheet 2015: http://arctic-sdi.org/wp-content/uploads/2015/09/Arctic-SDI-faktaark_tryksep15_2_low.pdf
	Arctic SDI Reference Model	A reference model in enterprise engineering parlance is an abstract framework consisting of an interlinked set of clearly defined concepts produced by an expert or body of experts in order to encourage clear communication. The purpose of the Reference Model is to aid strategic Arctic SDI discussions by grouping existing and potential SDI components. The Reference Model is the basis to implement the Vision through a consistent understanding of what needs to be done. All Arctic SDI projects link to the Reference Model. This reference model is also incorporated into the 2015-2020 Arctic SDI Strategic Plan.	Arctic SDI Framework Document: http://arctic-sdi.org/wp-content/uploads/2014/08/20150825-Arctic-SDI-Framework-Document_V2-0.pdf; Arctic SDI Strategic Plan 2015-2020: http://arctic-sdi.org/wp-content/uploads/2014/08/20151119-Arctic-SDI-Strategic-Plan-2015-2020_FINAL.pdf

	Arctic SDI Stakeholders	Include: the Arctic Council Working Groups, NGOs, research groups, universities, scientific communities, governments and governmental authorities, media and the public. Related Terms: Arctic SDI users	Arctic SDI Implementation Plan: http://arctic-sdi.org/wp-content/uploads/2014/08/201511-Arctic-SDI-Implementation-Plan_FINAL.pdf
	Arctic Stakeholders	Stakeholders are defined as actors who have interests in Arctic developments or who are affected by Arctic policies.	The Changing Arctic and the European Union: https://books.google.ca/books?id=j7C8CgAAQBAJ&pg=PA285&lpg=PA285&dq=Arctic+stakeholders+are+definition&source=bl&ots=8kVyHd6zwP&sig=5pcQNesXPh0tcFtT5Pjhu6gXI1s&hl=en&sa=X&ved=0ahUKEwifjOz4o-PJAhUi7YMKHUvJAHQQ6AEIKjAD#v=onepage&q=Arctic%20stakeholders%20are%20definition&f=false
	Attribute	Descriptive information about features or elements of a database. For a database feature like census tract, attributes might include many demographic facts including total population, average income, and age. In statistical parlance, an attribute is a `variable,` whereas the database feature represents an `observation` of the variable.	Open Geospatial Consortium: http://www.opengeospatial.org/taxonomy/term/13
	Attribution	Ascribing the production of the data to a specific data custodian.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Basemap	A basemap provides a user with context for a map. It depicts background reference information such as landforms, roads, landmarks, and political boundaries, onto which other thematic information is placed. A basemap is used for locational reference and often includes a geodetic control network as part of its structure. In the context of Arctic SDI it is applied to topographic maps, using authoritative data from the Arctic National Mapping Agencies, to be used in the construction of other types of maps by the addition of particular data.	USGS User Guide: http://nhd.usgs.gov/userGuide/Robohelpfiles/NHD_User_Guide/Interactive_Tutorials/Module_1/Basemaps_Overlays/Popups/What_is_a_Basemap_.htm Geography Dictionary: http://www.geography-dictionary.org/base_map Esri GIS Dictionary Support: http://support.esri.com/en/knowledgebase/Gisdictionary/browse
	Bathymetric Data	Data regarding the elevation of the earth's surface beneath a body of water, especially the ocean, typically determined by measurements of depth from the water surface.	USGS: http://www.usgs.gov/science/science.php?term=80&n=27
	Capacity Building	Development of individuals with various profiles and backgrounds—through training and education—to meet well-defined objectives, usually within the scope of a program or project. Related terms: Organisational Development, Institutional Strengthening, Improvement Management	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Case Studies	Analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

CSW	Catalog Service for the Web	Provide a registry service to support the ability to publish and search collections of descriptive information (metadata) for data, services, and related information objects. Metadata registered in catalogues represent resource characteristics that can be queried and presented for evaluation and further processing by both humans and software. Catalogue services are required to support the discovery and binding to registered information resources within an information community.	Natural Ressources Canada: http://www.nrcan.gc.ca/earth-sciences/geomatics/canadas-spatial-data-infrastructure/standards-policies/8910
	Catalogue	A single collection of metadata entries that are managed together.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Catalogue Service	A service that responds to requests for metadata in a catalogue and that complies with certain browsing or search criteria.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Circumpolar	The area traditionally covered by the terms “Arctic” and “Subarctic,” the northern lands of the world’s eight northernmost countries (the Arctic Eight): Canada, Finland, Denmark (including Greenland and the Faroe Islands), Iceland, Norway, Russia, Sweden, and the United States (Alaska). Related Terms: Pan-Arctic, Arctic, Polar	UArctic Education: http://education.uarctic.org/circumpolar-north/
	Clearinghouse	A distributed network of geospatial data producers, managers and users linked electronically. Incorporates the data discovery and distribution components of a spatial data infrastructure for a community.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Cloud Computing	A model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Conformance	Fulfillment of specified requirements.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Coordinate Reference System	A system that defines the coordinate space such that the coordinate values are unambiguous.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Copyright	A temporary monopoly granted over a work. Copyright protects a number of different rights over a work, chief of which is the right to create copies. The creator (or "author") of a work retains rights to that work but can transfer some or all of the rights to others. Re-creating a significant portion of a copyrighted work without permission is illegal.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Data	Distinct pieces of factual information, especially information organized for analysis or used to reason or make decisions. Data are usually formatted in a special way and presented in a variety of forms.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Data Collection	Data that has one or several common elements and that has been assembled by these common elements to form a data set. Related terms: Product Collection	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Data Model	An abstraction of the real world. The data model would normally define specific groups of entities, their attributes, and the relationships between these entities. A data model is independent of a computer system and its associated file structures.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Data Product Specification	A detailed description of a data set or data set series together with additional information that will enable it to be created, supplied to and used by another party.	ISO 19131:2007: https://www.iso.org/obp/ui/#iso:std:iso:19131:ed-1:v1:en
	Data Provider	Data providers share data that is accessible under specific conditions. Related terms: Data Custodian	How to Share Geospatial Data Primer: http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/downloade.web&search1=R=292415
	Data Quality	Indications of the degree to which data satisfies stated or implied needs. This includes information about lineage, completeness, currency, logical consistency and accuracy of the data.	Open Geospatial Consortium: http://www.opengeospatial.org/taxonomy/term/13
	Decision-maker(s)	An individual (or group of individuals) who uses a cognitive process to select a final option between several other scenarios. The final decision should result in an action.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Developer	An individual who creates Web-based applications that allow users to interact with a SDI.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
DEM	Digital Elevation Model	The representation of continuous elevation over a topographic surface by a regular gridded array of elevation values (z-values) referenced to a common vertical datum representing the "Bare Earth" conditions. Related terms: Digital Terrain Model (DTM), Digital Surface Model (DSM)	GIS Dictionary Support: http://support.esri.com/en/knowledgebase/Gisdictionary/browse ; LiDAR Data Services: http://www.lidardataservices.com/services/dtm-dem-and-dsm-generation
DSM	Digital Surface Model	Digital Surface Model (DSM) represents the highest elevations of the reflective surfaces of trees, buildings, and other features elevated above the "Bare Earth".	LiDAR Data Services: http://www.lidardataservices.com/services/dtm-dem-and-dsm-generation
DTM	Digital Terrain Model	Digital Terrain model (DTM) can be described as a three dimensional representation of a terrain surface consisting of X, Y, Z coordinates stored in digital form. It includes not only terrain elevation, but also natural features such as rivers, ridge lines, etc. Natural features are called break lines.	LiDAR Data Services: http://www.lidardataservices.com/services/dtm-dem-and-dsm-generation
ELF	European Location Framework	A versatile cloud-based and cascade-supporting architecture that provides up-to-date, authoritative, interoperable, cross-border, reference geo-information for use by the European public and private sectors.	European Location Framework: http://www.elfproject.eu/content/overview
XML	Extensible Markup Language	A markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. It is defined in the XML 1.0 Specification produced by the W3C, and several other related specifications.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Feature	An abstraction of real world phenomena.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Framework	Software design, a reusable software template, or skeleton, from which key enabling and supporting services can be selected, configured and integrated with application code. Related terms: Information Architecture	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Framework Data	Common base map data that provides spatial reference to physical features and other types of information that is linked to geography and provides a foundation for integrating other kinds of data. Related terms: Reference Data, Fundamental Data, Core Data	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Gazetteer	Directory of instances of a class or classes of features containing information regarding position.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
GIS	Geographic Information System	An information system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface. Both vector and raster GISs are available. Related terms: Geographic Information Service	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

GML	Geography Markup Language	The Geography Markup Language (GML) is an XML grammar for expressing geographical features. GML serves as a modeling language for geographic systems as well as an open interchange format for geographic transactions on the Internet. As with most XML based grammars, there are two parts to the grammar – the schema that describes the document and the instance document that contains the actual data. A GML document is described using a GML Schema. This allows users and developers to describe generic geographic data sets that contain points, lines and polygons.	Open Geospatial Consortium: http://www.opengeospatial.org/standards/gml
	Geolinked Data	Data that is referenced to an identified set of geographic features without including the spatial description of those features. It is normally attribute data in tabular form (such as population counts) that refers to a known jurisdiction (such as provinces), where the elements (the provinces) are referred to by their unique identifier (such as the province name).	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Geomatics	The science and technology of gathering, analyzing, interpreting, distributing and using geospatial data. Geomatics encompasses a broad range of disciplines, including surveying, global positioning systems, mapping, remote sensing and cartography.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Geomatics Sector	Includes federal, provincial/state and municipal departments, non-profit organisations, academic organisations (universities, colleges) as well as commercial organisations that supply and use data, services and resources of a geospatial nature. Related terms: Geomatics Industry, Geospatial Information Industry	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Geoportal	A type of Web portal used to find and access spatial information and associated geographic services (display, editing, analysis, etc.) via the Internet.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Georeferencing	The process of assigning a geographic location to a piece of information.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Geospatial Data	Data with implicit or explicit reference to a location relative to the Earth's surface. Related terms: Geodata, Geographic Data, Location-Based Data, Spatial Data, Geospatial Information, Geographic Information, Geographically referenced	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Geospatial Privacy	The right to control access to geospatial information about one's self.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Geospatial Standard	Standards specify the content and structure of data. When data content is standardized, information can be accessed, exchanged and used by people and computers more effectively. The harmonization of geospatial standards is fundamental to ensuring the efficient exchange of location-based information. Standards for geospatial interoperability provide consistent and interoperable patterns for creating, reproducing, updating and maintaining geographic information and services for decision-makers in the public and private sectors. Standards have been developed to address specific interoperability challenges. Geospatial standards are technical documents that detail interfaces or encodings. Software developers and data producers use these documents to build open interfaces and encodings into their products and services. The standards also provide an indicator of quality, including the structure for encoding metadata to help identify geospatial data. Related terms: Standards, Geospatial Data.	Natural Resource Canada: http://www.nrcan.gc.ca/earth-sciences/geomatics/canadas-spatial-data-infrastructure/8902
GeoWeb	Geospatial Web	A term that implies the merging of geographical (location-based) information with abstract information on the Internet, creating an environment where one could search by location instead of keyword only.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	GIT Barents	The GIT Barents was "launched in the 1990's by the participating national mapping agencies in Finland, Norway, Russia and Sweden. The purpose was to increase the ability to use spatial information within the Barents Region by producing a common geographic database covering the entire region and to make data available to users by establishing an Internet--based infrastructure aligned with the principles of the EU INSPIRE Directive (EU Infrastructure for Spatial Information). The GIT Barents Service facilitates cross--border cooperation, primarily in the fields of environmental planning, monitoring and protection, land use, physical planning, transports, natural resource management and development of cross--border tourism."	Arctic SDI Framework Document: http://arctic-sdi.org/wp-content/uploads/2014/08/20150825-Arctic-SDI-Framework-Document_V2-0.pdf GIT Barents Service: www.gitbarents.com Note: URL no longer in service (Last checked April 28, 2016).
HTTP	Hypertext Transfer Protocol	The Hypertext Transfer Protocol (HTTP) is an application-level protocol for distributed, collaborative, hypermedia information systems. It is a generic, stateless, protocol which can be used for many tasks beyond its use for hypertext, such as name servers and distributed object management systems, through extension of its request methods, error codes and headers. HTTP has been in use by the World-Wide Web global information initiative since 1990.	World Wide Web Consortium (W3C): https://www.w3.org/Protocols/rfc2616/rfc2616.html;The Internet Engineering Task Force (IETF®): https://tools.ietf.org/html/rfc2616
	Hydrographic data	Data from measuring the depth of the water and fixing the position of all the navigational hazards that lie on the seafloor, such as wrecks and rocks. This is done mainly with specialised ships and boats operating echo sounders and sonars, but also using survey aircraft fitted with lasers. Useful information can also be derived sometimes from satellite observations. Hydrography also involves measuring the tide and the currents.	International Hydrographic Organization: https://www.iho.int/srv1/index.php?option=com_content&view=article&id=613:what-is-hydrography&catid=42&Itemid=852&lang=en

	Identifier	Linguistically independent sequence of characters capable of uniquely and permanently identifying that with which it is associated.	International Organization for Standardization: https://www.iso.org/obp/ui/#iso:std:iso:19135:-1:ed-1:v1:en:term:4.1.5
	Imagery	Digital data of the Earth collected by a variety of types of sensors (e.g., optical, radar) mounted on satellite, airborne or ground-based platforms.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
IP	Intellectual Property	Information that is useful and transferable, and in which someone has rights that give control over the information. Types of IP include invention, copyright, trade secrets, plant breeders' rights, integrated circuit topography, industrial design and trademark.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Interoperability	The ability of different types of computers, networks, operating systems and applications to work together effectively, without prior communication, in order to exchange information in a useful and meaningful manner. There are three aspects of interoperability: semantic, structural and syntactical.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Key Performance Indicators	A measurable objective which provides a clear indication of service centre capability, quality, customer satisfaction, etc. In the Arctic SDI context, key performance indicators are used to gauge the effectiveness of the implementation of the Arctic SDI Strategic Plan 2015-2020, as well as the effectiveness of the Arctic SDI itself. These qualitative or quantitative metrics will be measured, assessed and tracked yearly over the 2015-2020 timeframe with regular reports to the Arctic SDI Board: • User satisfaction of authoritative reference and thematic data and services; • Relevance of Arctic SDI reference and thematic data to users; • The use of the Arctic SDI Geoportal, web services and metadata; • Known applications based on the Arctic SDI and their relevance; • Arctic SDI Operational Policies influence on the development of Arctic Council information management policies.	Guidelines for Core, Key Performance Indicators, Interim Report on Primary Service Channels: https://www.tbs-sct.gc.ca/si-as/kpi-icr/interim/interim-eng.rtf Arctic SDI Implementation Plan - 2015: http://arctic-sdi.org/wp-content/uploads/2014/08/201511-Arctic-SDI-Implementation-Plan_FINAL.pdf
	Layer	Basic unit of geographic information that may be requested as a map from a server.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Licence	A legal agreement granting someone permission to use a resource for certain purposes or under certain conditions that would otherwise be disallowed or unlawful. A licence does not constitute a change in ownership of the copyright. Includes data licenses and software licenses.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Licensing	Authorizing by the licensor the use of the licensed material by the licensee.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Life-cycle	Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.	International Organization for Standardization: https://www.iso.org/obp/ui/#iso:std:37456:en
	Lineage	Linear referencing can be used to model the relationships of objects that are associated with an network, but where the position of those associated objects i s not known (or required) to a very high level of absolute accuracy.	INSPIRE Glossary: http://inspire-regadmin.jrc.ec.europa.eu/dataspecification/themes/tn/Chapter10.pdf
	Linked Data	Creates links to data residing in other databases on the Web that are universally available.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
LBS	Location-Based Services	A wireless IP service that delivers and uses geographic information to serve a mobile user.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Marine data	Data regarding environments with marine water.	INSPIRE Glossary: http://inspire.ec.europa.eu/codelist/EnvironmentValue/marine

MMG	Mass Market Geomatics	The preparation and online publication of geospatial data and services by private sector organisations such as Google Earth, Microsoft Virtual Earth and MapQuest.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Metadata	Information about data. Metadata describes how, when and by whom a particular set of data was collected, and how the data was formatted. Metadata is essential for understanding information stored in data warehouses.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	INSPIRE-Metadata	Means information describing spatial data sets and spatial data services and making it possible to discover, inventory and use them [INSPIRE Directive]. NOTE: A more general definition provided by ISO 19115 is data about data.	INSPIRE Glossary: http://inspire.ec.europa.eu/glossary/Metadata
	NAP-Metadata	North American Profile of ISO 19115:2003 – Geographic information – Metadata.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Metadata Catalogue	A system prepared to store and distribute information about geospatial ressources and to organize specific information into a set of data. Metadata in catalogues represent resource characteristics that can be queried and presented for evaluation and further processing by both humans and software. Catalogue services are required to support the discovery and binding to registered information resources within an information community.	Open Geospatial Consortium: http://www.opengeospatial.org/standards/cat Antarctica - Contributions to Global Earth Sciences: https://books.google.ca/books?id=2u1V-IEycvMC&pg=PA399&dq=%22Metadata+catalogue%22+definition&hl=en&sa=X&ved=0ahUKEwiPm63kkOPJAhUG5CYKHVR6CF4Q6AEILjAA#v=onepage&q=%22Metadata%20catalogue%22%20definition&f=false
	Metadata Entry	A set of metadata that pertains specifically to a spatial data set.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Metadata Schema	A semantic and structural definition of the metadata used to describe recordkeeping entities. It describes the names of metadata elements, how they are structured and their meaning.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Network Services	Network services make it possible to discover, transform, view and download spatial data and to invoke spatial data services.	INSPIRE Glossary: http://inspire.ec.europa.eu/documents/Spatial_Data_Services/Spatial%20Data%20Services%20Working%20Group%20Recommendations%20v2.pdf

	Ontology	A formal representation of phenomena with an underlying vocabulary, including definitions and axioms, which makes the intended meaning explicit and describes phenomena and their interrelationships.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Open Data	A philosophy and practice that makes data easily and freely available—without restrictions from copyright, patents or other mechanisms of control—by way of portals, metadata and search tools in order to enable reuse of the data in new and unforeseen ways. Open data relies on 1) a permissive licensing model that encourages reuse, 2) data discoverability, and 3) data accessibility.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Open License	Enables third parties to reuse data with minimal or no legal or policy constraints, but copyright is maintained.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Open Standards	An open standard is one that 1) is created in an open, international, participatory industry process; 2) is freely distributed and openly accessible; 3) does not discriminate against persons or groups; and 4) ensures that the specification and license are technology neutral (its use must not be predicated on any proprietary technology or style of interface). Related terms: Open Specification	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Operational Policies	A broad range of practical instruments such as guidelines, directives, procedures and manuals that address topics related to the life cycle of spatial data (i.e., collection, management, dissemination, use) and that help facilitate access to and use of spatial information.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Oskari	Arctic SDI geoportal is built using Oskari. Oskari is an open source software framework for creating geoportals and other web applications. Use cases for Oskari include viewing, disseminating and analyzing geographical data, especially from distributed SDI data sources. With Oskari it is possible to easily configure and embed map clients on other webpages, so that the data can be viewed in actual context.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Preservation	Protecting a collection of historical records (i.e., records that have been selected for permanent or long-term preservation on grounds of their enduring cultural, historical or evidentiary value) from destruction, decay or degradation.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Producer	An individual or institution that generates geographic information from data.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Profile	A set of one or more base standards or subsets of base standards and, where applicable, the identification of chosen clauses, classes, options and parameters of those base standards, necessary for building a complete computer system, application or function.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Protocol	A set of semantic and syntactic rules that determine the behavior of entities that interact.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Reference Data	Geospatial data depicting background locational information, often acting as a base for displaying thematic data. Reference data are officially recognized data that can be certified and provided by an authoritative source. These are delivered to be consumed by applications in a number of ways by different types of web services. The following geospatial data layers have been listed as reference data layers in previous Arctic SDI documentation: administrative boundaries, elevation, bathymetric data, hydrography, transportation, settlements, vegetation, and geographical names. By listing the reference data layer above, it in no way infers all participant nations hold or will provide access to those listed data layers. NOTE: The data layers cited in the reference data definition above are taken from the Arctic SDI Constitution Meeting Project Plan (6 April 2011) and were confirmed during the first Arctic SDI Board Meeting (31 March 2012; www.Arctic-SDI.org). Related term: Reference Map	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf Arctic SDI Framework Document: http://arctic-sdi.org/wp-content/uploads/2014/08/20150825-Arctic-SDI-Framework-Document_V2-0.pdf UN-GGIM: EUROPE Preparatory Phase Working Group 1 – "Data Definition and Access Conditions" Report: Consolidated Version 11 April 2014: http://un-ggim-europe.org/sites/default/files/GGIM-Europe-Working%20Group%201%20-%20Report%20-%2020140411.pdf www.Arctic-SDI.org
	Register	Set of files containing identifiers assigned to items with descriptions of the associated items.	International Organization for Standardization: https://www.iso.org/obp/ui/#iso:std:iso:19135:-1:ed-1:v1:en

	Registry	A listing of the individual data sets, services or other things made available by an organisation to users of a SDI. There are two kinds of registries: • Type Registry: A listing of different types or classes of objects, such as services, components or events, that are recognized by the SDI services or applications. • Instance Registry: A listing of individual services, components, data sets or other things that comprise the SDI or are relevant to its users. Instance registries are used to identify, locate and describe individual instances. Related terms: Catalogue, Directory, Inventory	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Semantic Web	Enables queries across the Web, as if the entire Web were a single federated database. In addition, the concept of a Semantic Web refers to the understanding of a machine or computer to find links or similarities to the searched data in order to provide the most useful search results.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Semantics	In the spatial data context, semantics deal with representations of the geographical world as interpreted by human users or communities of practitioners. Defines the meaning of geospatial functions (e.g., the meaning of the input data, the capability of this function, the meaning of the output data).	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Sensitive Data	Geospatial data that may be considered restricted for purposes of dissemination and therefore requires some form of safeguarding.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
SOA	Service-Oriented Architecture	A set of principles and methodologies for designing and developing software in the form of interoperable services. SOA separates functions into distinct units or services, which developers make accessible over a network in order to allow users to combine and reuse them in the production of applications.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Spatial Data	Data with a direct or indirect reference to a specific location or geographic area.	INSPIRE Glossary: http://inspire.ec.europa.eu/glossary/SpatialData
SDI	Spatial Data Infrastructure	The relevant base collection of standards, policies, applications, and governance that facilitate the access, use, integration, and preservation of spatial data. It is provided for users and suppliers within all levels of government, the commercial sector, the non-profit sector, academia and citizens in general. Related terms: Geospatial Data Infrastructure	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
SDI Evaluation	Spatial Data Infrastructure Evaluation	SDI evaluations are used to assess if the SDIs realize the intended objectives and benefits by providing a snapshot of its current state. They are an integral part of SDI policies that assess the impact and efficiency of access, the intensity of use, and the extent to which spatial data are shared with stakeholder organisations and individuals. SDI evaluations are performed to: • Obtain more knowledge about SDI functioning • Determine if the SDI is on the intended	Assessing Spatial Data Infrastructures: http://www.ncgeo.nl/phocadownload/76Grus.pdf 2015 Assessment of the Canadian Geospatial Data Infrastructure: http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=297880

		track of development • Assist SDI development • Determine accountability Related terms: SDI Assessment, Success Metrics	
	Spatial Data Services (discovery, view, etc.)	The operations which may be performed, by invoking a computer application, on the spatial data contained in spatial data sets or on the related metadata.	INSPIRE Glossary: http://inspire.ec.europa.eu/glossary/SpatialDataServices
	Spatial Data Set	A specific packaging of spatial (geospatial) information provided by a data producer or software, also known as a feature collection, image or coverage.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Spatial Object	Abstract representation of a real-world phenomenon related to a specific location or geographical area. Spatial objects are digitally represented as point, line and polygon, linked to attributes. Spatial objects contain the information about location such as latitude and longitude, as well as topology.	INSPIRE Glossary: http://inspire.ec.europa.eu/glossary/SpatialObject DePaul University: http://gis.depaul.edu/shwang/teaching/arcview/module1.htm
	Spatial Schema	Conceptual schemas for describing and manipulating the spatial characteristics of geographic features.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Specification	A document written by a consortium, vendor or user that specifies a technological area with a well-defined scope, primarily for use by developers as a guide to implementation. A specification is not necessarily a formal standard.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Stakeholder	A stakeholder in a program is any person or institution that has a controlling influence, benefits in some way from the program, has an interest in its process or outcome, or has resources invested in the program.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Standard	Established by consensus and approved by a recognized body. A standard provides, for the common and repeated use of rules, guidelines or characteristics for activities or their results and is aimed at achieving the optimum degree of order in a given context. It is produced in the form of a published document and should be based on the consolidated results of science, technology and experience. It is also designed to promote optimum community benefits. Related terms: Standardization	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Syntax	In the spatial data context, syntax defines how the meaning of geospatial functions is expressed.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Temporal Schema	Conceptual schemas for describing the temporal characteristics of geographic information as they are abstracted from the real world.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
	Thematic Data	Geospatial data focused on a specific theme or subject area, organized as layers related to physical or human geographies, e.g. statistical, water contamination, historical flood areas, disease patterns and trends. Thematic geospatial data are often viewed over reference data to provide context. Dataset providers could be governmental or interest organisations, companies etc. These datasets and metadata could be delivered and harvested by applications in a number of ways by different types of web services.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf Arctic SDI Framework Document: http://arctic-sdi.org/wp-content/uploads/2014/08/20150825-Arctic-SDI-Framework-Document_V2-0.pdf www.Arctic-SDI.org
	Topology	Spatial relationships between adjacent or neighboring features; properties that define relative relationships between spatial elements, such as adjacency, connectivity and containment.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

	Traditional Knowledge	Traditional knowledge refers to the knowledge, innovations and practices of Indigenous and local communities around the world. Developed from experience gained over the centuries and adapted to the local culture and environment, traditional knowledge is transmitted orally from generation to generation. It tends to be collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language, and agricultural practices, including the development of plant species and animal breeds.	United Nations Inter-Agency Group (IASG): http://www.un.org/en/ga/president/68/pdf/wcip/IASG%20Thematic%20Paper_%20Traditional%20Knowledge%20-%20rev1.pdf
UCD	User-Centered Design	Involves the input of users at various stages in the design of an application or system to ensure that it is easy to use and meets the needs of its users. UCD examines how an application is used, how people go about doing their work, how they want or need to work, how they think about their tasks, and how often they do particular tasks.	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
VGI	Volunteered Geographic Information	A term coined by Michael F. Goodchild, who defines it as “the widespread engagement of large numbers of private citizens, often with little in the way of formal qualifications, in the creation of geographic information…” (Goodchild M. F., 2007).	Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
WCS	Web Coverage Service	"Supports the networked interchange of geospatial data as "coverages" containing values or properties of geographic locations. Unlike the Web Map Service, which returns static maps (server-rendered as pictures), the Web Coverage Service provides access to intact (unrendered) geospatial information."	Open Geospatial Consortium: http://www.opengeospatial.org/taxonomy/term/13

WFS	Web Feature Service	An Internet-based service that allows clients to conduct data manipulation on geographic features, allowing for querying, retrieval and transactional (i.e., add, update or delete) operations. The WFS conforms to the OpenGIS Web Feature Server Interface specification. This OpenGIS Specification supports INSERT, UPDATE, DELETE, QUERY and DISCOVERY of geographic features. WFS delivers GML representations of simple geospatial features in response to queries from HTTP clients. Clients access geographic feature data through WFS by submitting a request for just those features that are needed for an application.	Open Geospatial Consortium: http://www.opengeospatial.org/taxonomy/term/13 Spatial Data Infrastructure (SDI) Manual for the Americas: http://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf
WMS	Web Map Service	An Internet-based service that allows clients to display maps and/or images with a geographic component and whose raw spatial data files reside on one or more remote WMS servers. The WMS conforms to the OpenGIS Web Map Server Interface specification. This OpenGIS Specification standardizes the way in which Web clients request maps. Clients request maps from a WMS instance in terms of named layers and provide parameters such as the size of the returned map as well as the spatial reference system to be used in drawing the map.	Open Geospatial Consortium: http://www.opengeospatial.org/taxonomy/term/13 SDI Manual:
WMS-T	Web Map Service Time	The WMS-T standard allows the user of the service to set a time boundary in addition to a geographical boundary with their HTTP request. Related term: WMS	QGIS: http://planet.qgis.org/planet/user/4/

WMTS	Web Map Tile Service (WMTS)	Web Map Tile Service (WMTS) provides access to cartographic maps of geo-referenced data, not direct access to the data itself. The tile service standard specifies the way in which map tiles are requested by clients, and the ways that servers describe their holdings. WMTS trades the flexibility of custom map rendering for the scalability possible by serving of static data (base maps) where the bounding box and scales have been constrained to discrete tiles. The fixed set of tiles allows for the implementation of a WMTS service using a web server that simply returns existing files. The fixed set of tiles also enables the use of standard network mechanisms for scalability such as distributed cache systems.	Natural Resources Canada: http://www.nrcan.gc.ca/earth-sciences/geomatics/canadas-spatial-data-infrastructure/standards-policies/8940 Open Geospatial Consortium: http://www.opengeospatial.org/standards/wmts
	Web Map Viewer	Interface for client computers to query, request and display spatial information from remote spatial databases.	Spatial Database Systems: Design, Implementation and Project Management: https://books.google.ca/books?id=_xEaJYJwiKoC&pg=PA540&dq=%22a+Web+map+viewer%22+glossary&hl=en&sa=X&ved=0ahUKEwj46eGGxePJAhXI64MKHeziAI4Q6AEIJDAA#v=onepage&q=%22a%20Web%20map%20viewer%22%20glossary&f=false
	Web Services	Self-contained, self-describing, modular applications that can be published, located and invoked across the Web. Web services perform functions that can be anything from simple requests to complicated business processes. Once a Web service is deployed, other applications (and other Web services) can discover and invoke the deployed service.	Open Geospatial Consortium: http://www.opengeospatial.org/taxonomy/term/13