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CANADIAN GEOSPATIAL DATA INFRASTRUCTURE
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Case Studies: CGDI And Geo-Information

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1. Case Study: Parks Canada Monitoring and Reporting

This case study describes activities undertaken by Parks Canada over 30 years to respond to their need for geospatial data. The case study provides important lessons learned by illustrating how Parks Canada has adopted, used and shared geospatial information during these three decades. The case study also showcases three essential benefits of the Canadian Geospatial Data Infrastructure (CGDI):

1. Combining current, standards-based data from the CGDI and other sources makes for better decision-making.
2. Layering different data sets expands insights.
3. Sharing data reduces costs and improves decision making.

Parks Canada needs to monitor and report on the parks under its jurisdiction as well as provide materials and tools for managing, planning, and outreach. In this way, this case study is relevant to any large organization with complex, over-lapping requirements for geospatial information. This case study also refers to research into meeting specific information needs.

1.1 Audience and Clients

One might argue that Parks Canada has the most diverse audience and clients for geo-information anywhere in the world. The audience ranges, literally, from school children to the Prime Minister and Parliament. Indeed, one could say that Canada's wildlife also depends on the geo-information collected and used by Parks Canada. For example, the 42 species of mammals, including grizzly bears, found in Nahanni National Park, could also be considered clients inasmuch as they benefit from Parks Canada using geo-information to manage wildlife habitats. For instance, Parks Canada biologists can monitor bears, caribou, and other wildlife by fitting these animals with global positioning system (GPS)-equipped collars.

In effect, Parks Canada employees develop and use geo-information to help provide the basis upon which Canada's national parks are monitored, managed, planned, understood, funded and recognized internationally. Thus those responsible for these many aspects of the parks are among the diverse audience and clients for geospatial information. These audience and client bases have presented both a challenge and an opportunity for Parks Canada geomatics specialists and those managing their activities.

The challenge and opportunity come from having to provide suitable information for each distinct audience—from summer students collecting park entry fees, to wildlife biologists researching in the North, to elementary students seeking information on the web, to Ministers and Prime Ministers striving to ensure a legacy for future generations. Each of these audiences and many more, share and use Parks Canada geospatial information. In some cases, this information can be a simple map. In others, it may involve accessing a geographic information system (GIS) or image-analysis display, creating scenarios, conducting modeling exercises, or producing a map on a web page. These highly varied audience requirements have shaped the need for well-presented, accurate and easily understandable geospatial information.

1.2 Understanding the Scope of the Problem

The scope of Parks Canada's mandate is unique among federal agencies. The organization manages and monitors large, geographically dispersed, ecologically diverse and often environmentally sensitive areas of the country. Within these areas, Parks Canada also monitors and reports on a host of topics, including the following:

- Ecological integrity;
- Management actions;
- Environmental assessments;
- Public safety;
- Ecosystem management;
- Fire management;
- Campground supervision and maintenance; and
- Human-wildlife conflicts.

The Parks Canada Charter, which describes the organization's mandate and role, is a useful beginning point for discussing the agency's challenges[1]: "Our Mandate: On behalf of the people of Canada, we protect and present nationally significant examples of Canada's natural and cultural heritage, and foster public understanding, appreciation and enjoyment in ways that ensure the ecological and commemorative integrity of these places for present and future generations." Parks Canada assumes four roles, each of which can use geospatial information:

1. Guardians of the national parks;
2. Guides to visitors from around the world;
3. Partners building on the rich traditions of our Aboriginal people, the strength of our diverse cultures; and
4. Storytellers recounting the history of our land and our people.

[1] Source: http://www.pc.gc.ca/eng/agen/chart/chartr.aspx accessed March 1, 2012.

Parks Canada's employees manage approximately 253,000 sq. km. of park lands.[2] Park management and change monitoring have become even more complex with the dramatic growth in new parks established since 1986. These new parks cover 123,000 sq. km, and of this area, almost 95,000 sq. km. are in the North where climate change and adaptation are a concern. To complicate its tasks, Parks Canada is required to report on all 42 national parks under its jurisdiction once every five years. Consequently, the need for long-term scientific trend data in a geospatial framework is important. By any measure, Parks Canada must be efficient and effective in its data collection, information management, and reporting.

1.3 Details of the Activity

1.3.1 Some History

Parks Canada utilized digital geospatial information as early as the mid-1970s. At that time, the organization used airborne and space-based remote sensing data for research in Forillon National Park in the Gaspé region of Québec. These kinds of data were also used in planning Auyuittuq National Park on Baffin Island. By 1990, Parks Canada was gradually implementing GIS at its offices in Banff, Jasper and Revelstoke, as well as in several other locations across the country. In effect, Parks Canada began to use geo-information not at a specific moment but rather over time.

As the growth of the parks system demanded more and better information for management, and as monitoring requirements expanded, Parks Canada increasingly recognized the value of geo-information as a vehicle to improve operations. The Agency employed biophysical information from Environment Canada's Canada Land Data System and Agriculture Canada's CanSIS or Soil Information Systems. These systems provided the Agency with its first external geo-information data sources. Parks Canada subsequently bought systems and created data to meet the needs of local management. The use of geo-information has long been deeply embedded in the organization.

1.3.2 Current Status

In the past, Parks Canada used geo-information for specific projects. This tendency has changed. Today, the functional lead for geomatics rests with the Chief Information Officer.[3] As an agency with an operational mandate, Parks Canada now uses a wide range of geospatial technologies including GIS, GPS (to ensure accurately locating field observations, for example) and remote sensing. The important consideration is not what technology is used, but rather how the technology is used. The Parks Canada vision is clear and simple: "Geomatics is applied to the top priorities of each business unit as

[2] Source: http://atlas.nrcan.gc.ca/auth/english/learningresources/facts/parks.html accessed March 1, 2012.
[3] Anon. ***Geomatica*** 65 (1) 201, p 65.

efficiently as possible, and is funded in proportion to the benefit it provides to the Agency."[4]

Parks Canada uses geo-information that ranges from the common national topographic system (NTS) map sheets to digital elevation models, hydrology layers, road networks, park ecology inventories, trail maps, management areas and key species habitats, among others. Agency staff make maps and interpret images from space or air photos to show different types of plants, habitats and landscapes. Staff also use this information to predict how changes will affect the ecosystem, to see how land changes over time, and to assess the home range of key species. Across the Parks Canada network, the emphasis is on commercial off-the-shelf software that meets operational needs associated with the agency's mandate.

1.3.3 Technical Perspective

Data standards are essential to Parks Canada's use of geo-information. Standards save time and money and increase transparency. For example, the Agency performs geometric and atmospheric corrections to imagery. In doing so, Parks Canada follows procedures consistent with approaches developed by the Canada Centre for Remote Sensing (CCRS) that meet CGDI and international standards. These standards allow both the imagery and any information derived from it to be developed once and then integrated into a database or GIS. Data can then be used many times, overlaid with all manner of other data. No one has to re-process the original data or worry about whether it will integrate properly with other data.

This interoperability allows the same data to be used for multi-purposes such as monitoring, field-work planning, management, land-use planning, fire suppression, wildlife studies, reports to Parliament, public display, or one-off applications. In short, standards allow multiple audiences to use information for multiple purposes, from one place to another over time. This flexibility has saved Parks Canada ample time and money, making the organization more efficient and better able to meet its challenging mandate.

For example, standards have enabled Parks Canada to develop an ecosystem classification approach by integrating and overlaying remote sensing data and other information. Parks Canada uses this process to organize and help communicate knowledge of park ecosystems and in turn provide a useful and cost-effective tool for park management.

[4] Anon. ***Geomatica*** 65 (1) 201, p 66.

This approach is consistent with the core CGDI principle of "collect data once—closest to the source—share and use many times." All over the world, this principle has been attributed to Canada as a major contribution to the understanding and use of geospatial information. And the principle relies on standards.

Parks Canada also benefits from access to recent, high-quality information on land conditions. Today, scientists use imagery from a variety of sources to collect information for monitoring and reporting. This imagery can minimize field work by allowing scientists and resource managers to extrapolate knowledge to other areas of a park. As will be discussed below, reduced field work can produce economic benefits. The imagery also provides a standardized and common geospatial framework that facilitates monitoring and reporting over time.

1.4 The ParkSPACE project

Because of limited internal capacity and expertise in remote sensing, Parks Canada has partnered in several issues-driven and highly focused research projects to develop remote sensing monitoring tools specific to its needs. These projects provide interesting examples of how an operational agency can focus geomatics research to better meet its information needs.

In the most recently completed research project, ParkSPACE, Parks Canada worked with the Canada Centre for Remote Sensing. Largely funded by the Canadian Space Agency, this project focused on operational goals, capacity building and distribution of results internally over the intranet. Methods and protocols were developed to use satellite imagery and apply satellite-based methodologies to monitoring and quantifying changes in Canada's Arctic national parks. Of course, these same tools are applicable elsewhere in Canada's North and are also suitable to many of the southern national parks. Parks Canada will employ information from satellite monitoring to prepare State of the Park reports, generate and revise mandatory management plans for individual parks, and document the extent and impacts of climate variability and change in some northern parks.

Tools and approaches were also developed and tested in several national parks to measure ecological variables such as land-cover change, biomass estimation, permafrost and active layer depth, and vegetation productivity. The project delivered an important operational plan that outlines the human and financial resources required to deliver satellite-based monitoring protocols for five-year state of the park reporting. The project also identified how field units, service centres and the national office would need to coordinate to support this five-year reporting.

1.5 The Cost

Here we look at the project's costs from several perspectives: the cost of research, the costs of competing approaches to collecting data, and a generalized view of the cost of the people involved.

1.5.1 Research

Research and development is expensive, and the costs associated with failure are high: research therefore can be risky. In the ParkSPACE project, however, the work was highly focused and based on previous successes, thereby lessening the likelihood of failure. By deriving information from remote sensing and then integrating it within a GIS environment, Parks Canada gains a unique tool, one previously unavailable. The GIS provides a common platform for producing, analyzing and disseminating information over time, whether for planning, managing or conducting field work. This platform is important when one considers Parks Canada's on-going requirement for consistent monitoring in a cost-effective manner. To reproduce observations over time, Parks Canada needs data standards and sophisticated monitoring protocols that detail all aspects of each remote-sensing monitoring.

1.5.2 Competing approaches

Satellite imagery has proven so economical and effective for general monitoring that few would consider any other approach today. Good field work relies on imagery, and while imagery cannot replace this method, it has the potential to greatly reduce the cost of field work.

In the 1970s scientists and others working in remote parks relied extensively on field camps, helicopters and aircraft. Given the costs associated with this approach, one can easily build a business case for satellite imagery. For two hours' worth of helicopter time, a researcher can buy a satellite image that covers 3600 sq. km. Monitoring also benefits from the up-to-date and useful satellite data available at no cost from GeoBase[5], a key component of the CGDI. Such imagery augments other imagery that Parks Canada either buys commercially or obtains from the CGDI.

[5] Source: www.GeoBase.ca

1.5.3 Personnel

It has been estimated that Parks Canada spends a little more than one percent of its salary budget on geospatial technology and activities.[6] Many Parks Canada staff members use GIS for at least part of their work. A relatively small percentage of them have GIS training. Fewer still use image-analysis systems software, but many of the biggest parks may have their own GIS and map-production capabilities. Although Parks Canada employs relatively few GIS users today, this small group clearly contributes to the agency's cost-effectively meeting its mandate and serving the millions who use Canada's national parks.

1.6 The Need

Parks Canada needs geo-information to conduct all manner of its business, from planning to managing to monitoring. As these requirements have grown, the Agency has increasingly viewed the web as the best mechanism to obtain, share and provide geo-information. The geospatial activities in recent years at Parks Canada have therefore been driven by and, at the same time, at least partially dependent upon web-based access to information holdings such as GeoBase. Consequently, Parks Canada has focussed on obtaining and distributing data and ensuring that the data it produces are interoperable as well as accessible. In future, one can expect that more and more Parks Canada geo-information will be web-accessible.

1.7 The Benefits

Parks Canada has used web-based geo-information to cover the range of the organization's activities, from developing and expanding parks to showing international audiences the value of parks and heritage sites.

For remote parks recently created in the North, satellite imagery and geo-information contributed to planning and identifying appropriate boundaries. Indeed, one might argue that such parks would be impossible without geo-information—much of which was or can be accessed via the Internet. Data were not only used in creating new parks, they have proven useful in the expansion of parks, including Nahanni National Park.

Once a new northern park has been established, satellite imagery offers the only practical option for monitoring the area. The ParkSPACE project developed six new satellite-based ecological integrity monitoring protocols now used in state of the park reports. These comprehensive protocols are also available for others to monitor ecological change in the Arctic.

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[6] See Anon. Geomatica 65 (1) 201, p 65.

Remote sensing and ecological integrity monitoring, two cornerstones of national park reporting today, are especially important for northern monitoring and accurate assessments. For example, Parks Canada uses imagery to assess the severity of fire burns and to control burning when managing forests. Other uses of geospatial data include the following:

- Locating long-term ground-based monitoring plots;
- Developing wildlife habitat suitability maps;
- Planning visitor use (such as trails or snowmobiling routes);
- Assessing the impacts of Lesser Snow Geese populations; and
- Developing models of ecosystem change under different climate change scenarios.

Parks Canada also uses data for management related activities. These activities include developing management plans such as that prepared for Point Pelee National Park[7] and monitoring forest ecosystems, forest fires, wildlife habitats and wetlands. One such wetland is found in Wood Buffalo National Park, a World Heritage Site that contains two Ramsar wetlands of international significance,[8] making it a target for both domestic and international monitoring and concern.

Satellite imagery equips field workers to target areas that have changed unexpectedly. In effect, this imagery allows Parks Canada's staff to respond to environmental issues in keeping with the severity of the problems—much like triage in a hospital's emergency department.

Staff and management are not the only users of Parks Canada's geo-information. Others use it to book campground reservations,[9] some to print trail maps for school children.[10] International users include recipients of Canada's 2006 nomination of the Rideau Canal as a world heritage site. In helping to prepare this nomination, Parks Canada integrated hydrographic charts with other data layers such as the boundary of the Parks Canada's property, lock stations and buffer zones along the Rideau River and Rideau Canal. The 1377-page nomination contained 88 pages of maps.

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[7] Source: http://www.pc.gc.ca/pn-np/on/pelee/plan/plan1/plan4.aspx#a Accessed March 5, 2012.

[8] Source: http://www.pc.gc.ca/pn-np/nt/woodbuffalo/plan/plan2.aspx and http://www.pc.gc.ca/pn-np/nt/woodbuffalo/plan.aspx Accessed March 5, 2012.

[9] http://www.pccamping.ca/parkscanada/en/popup.cgi?action=1 The campground reservation system is not yet fully operational in terms of picking one's specific camp site, but the system will be on line to book sites by park in April, 2012.

[10] See: http://www.pc.gc.ca/pn-np/ab/elkisland/visit/visit9/d.aspx Accessed March 5, 2012

1.8 Analysis and Lessons Learned

Many of the project's lessons have come from Parks Canada's experience establishing and managing national parks, and through its use of geospatial information, technologies and the Internet. The lessons learned are described below:

- *Adhering to standards:* Standards are especially important in large organizations with varying needs and clientele who rely on geospatial information acquired over a long period across a large diverse area. Consistent, widely accepted standards for handling geospatial data are important to ensure that data and derived information can be properly compared and used over time. With its current focus on standards and data compatibility, Parks Canada is well placed to make more data discoverable on the web, if additional resources are made available to do so.
- *Learning from others:* Applying lessons learned from others about geospatial information can save time and effort and reduce the risk of failure.
- *Focusing on issues and needs:* Projects relevant and important to the agency's mandate and requirements demonstrate the value of geospatial information to the Agency.
- *Engaging the organization in the integration of the geo-technology:* People throughout an organization will more be more inclined to accept geo-technology when they use it frequently to simplify their jobs or gain some other benefit. This endorsement must come from senior decision-makers.
- *Collecting data once closest to the source:* Collecting data once closest to the source and using the data many times results in savings, better data, better information, and better decision-making.
- *Working at the leading edge, not the bleeding edge of technology:* Working at the leading edge of technology, not the bleeding edge, lowers the risk that new alternatives will replace adopted technologies. Consequently, it is often preferable to use proven operationally implemented technologies or widely accepted solutions, rather than to custom build technologies.
- *Engaging in highly-focused, low-risk research:* Engaging in highly focused, low-risk research helps ensure the usefulness of the research. The research must focus on a real problem, the solution to which will improve performance or save money. The costs must be well understood at the outset to ensure that any new solution will indeed be cost effective. To be worthwhile, the research must be low risk (or very high payoff). Low-risk research is usually based on research proven in some related application.

1.9 Conclusion

Parks Canada serves as a case study for how a complex organization can use and share geographic information. Today Parks Canada can transparently monitor the environment in ways only dreamed of a little more than two decades ago.

Canada's national parks are world-renown areas that encompass and protect a broad range of ecological diversity. Geospatial data helps park managers make better decisions about these parks and educate others about them as well. These are ultimately two of the major benefits of the agency's successfully harnessing geographic information.

1.10 Sources of Information

See the footnotes. Parks Canada's web site contains a wealth of map and related information.

Anon. (2011) "Federal Government Activities 2007-2011. *Geomatica* 65 (1) pp. 65-68

Fraser, R.H. et al (2009) Monitoring land cover change and ecological integrity in Canada's national parks *Remote Sensing of Environment* 113 (2009) 1397-1409

Parks Canada (undated) *Using Satellite Remote Sensing Technology to Monitor and Assess Ecosystem Integrity and Climate Change in Canada's National Parks April 2004-March 2008 Project Synthesis Report.*

Poitevin, J. and A. Savoie (2007) Parks Canada Agency submission for the Special Issue of *Geomatica*: Cartography in Canada 2004 to 2007.

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2. Case Study: The North American Environmental Atlas—Mapping North American Environmental Issues

2.1 Summary of Activity

This project created the North American Environmental Atlas, which permits users to view North American environmental maps and geo-referenced environmental data. Employing a consistent geographic base for presenting and analyzing information, the Atlas is a repository of maps and data available without cost as downloadable files. The Atlas's goal is to assist decision makers in North America to more easily research and analyze environmental issues and visualize options and solutions. In achieving this goal, the project not only demonstrates the value of standards and the benefit of the web for accessing and distributing data but also shows how multiple jurisdictions can share data.

2.2 The Audience and Clients

The Atlas's key client was the Commission for Environmental Co-operation (CEC). Representing Canada, the U.S. and Mexico, this intergovernmental organization helps its three members cooperate to address environmental issues of continental concern. The CEC's tri-national audience needs harmonized and accurate maps of North America. A map book was created by CEC and Natural Resources Canada (NRCan), United States Geological Survey (USGS) and Instituto Nacional de Estadística y Geografía (INEGI) of Mexico to demonstrate the value of the maps.[11]

With North American environmental harmonized data now accessible on the web, Atlas users have ranged from Cabinet Secretaries and Ministers of Environment to school children. However, the primary audience includes four types of users:

1. Users of other CEC reports and background papers who will be better served by being able to create enhanced maps

[11] The Map Book (Atlas e-book) is available at: http://www.cec.org/Page.asp?PageID=749&SiteNodeID=631&AA_SiteLanguageID=1

2. Researchers in environmentally related disciplines (such as ecology, earth sciences, biology and geography) who may be interested in using harmonized North American environmental data
3. Decision makers with a need to understand the continental scope of environmental topics
4. Members of the public who have an interest in better understanding North American environmental issues

2.3 Details of the Activity

2.3.1 Background

Work on the Atlas began with informal discussions involving representatives of the three national atlas organizations responsible for mapping in Canada, the U.S.A. and Mexico: Natural Resources Canada, U.S. Geological Survey and Instituto Nacional de Estadística Geografía e Informática of Mexico. In 2003–2004 the discussions formalized when mutual interests, user benefits and maturing technologies came together to make collaboration not only possible but also desirable.

When the informal discussions started, Canada was preparing to publish another North American map. Natural Resources Canada has published several versions of its Atlas of Canada North American paper map over the past 37 years. Typically, the map was produced by consulting third-party references for Mexican and United States data. However, the North American map published in June 2004 represented a bold new approach.

In 2003 the CEC, the Atlas of Canada, INEGI and USGS agreed to partner to compile a new harmonized set of framework data (also known as base layers) and a new paper map for North America. First, the map was compiled in partnership with the national atlas programs in Canada (NRCan), Mexico (INEGI) and the United States (USGS). Second, it was accompanied by digital frameworks (or base maps) that the three countries had harmonized. These frameworks are available on-line with accompanying metadata. Framework data layers or base map layers include bathymetry, elevation, shaded relief, glaciers and sea ice, rivers and lakes, watersheds, major roads, political boundaries, population density, populated places, and railroads.

Together the three agencies prepared the base layers and additional map layers for specific themes (e.g. land cover, watersheds, ecoregions) both in hard copy and in digital form, to serve as a platform for other data. The layers provide a consistent, harmonized geographic data collection, known as the North American Atlas Framework, for displaying and analyzing thematic data at the North American scale.

In October 2006, the national atlas agencies; the governments of Canada, the U.S.A. and Mexico; and the CEC Secretariat formalized their working relationship by creating the North American Atlas Coordination Group (NAACG). From 2007–2010 the CEC funded a project called "Mapping North American Environmental Issues" to enable users to view North American environmental information on maps. This project established the North American Environmental Atlas, an interactive mapping tool to research, analyze and manage environmental issues in Canada, the U.S.A. and Mexico.

The North American Environmental Atlas now contains more than 60 maps. Some of these maps and the data layers on them were developed in cooperation with other CEC projects, while the national atlas agencies contributed other layers. All completed data layers and associated metadata are shared with the public through the North American Environmental Atlas webpages at http://www.cec.org/naatlas/. Data for the maps come from a variety of sources including the following[12]:

From Canada

- Environment Canada
- Parks Canada
- Natural Resources Canada—Canadian Forest Service, Canada Centre for Remote Sensing, Mapping Information Branch

From the U.S.A.

- U.S. Forest Service
- USGS

From Mexico

- Comisión Nacional Forestal (CONAFOR)
- Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO)
- INEGI

[12] Detailed metadata is available for each layer and is downloadable from: http://www.cec.org/Page.asp?PageID=924&ContentID=2336

2.3.2 A Technical Perspective

A comprehensive outline of the technical issues and how they were resolved is given in a paper by Regan and Paul[13] from NRCan. The framework data production process started with the design of the models to produce the 1:10,000,000 North America Atlas Framework. The data model was developed by evaluating the source data sets in consultation with the three countries and the CEC. The goal was to select and harmonize from each country the features and attributes needed for studying the environment. This data model was documented in the form of a data dictionary, which described each of the layers of the frameworks and defined all the features in each layer and their attributes. The data dictionary was then used in the project as a guide for restructuring the files and tagging the attributes.

The next step involved editing the data and integrating the source data from the three countries. It was essential to ensure that features met appropriately at the borders. The final stage involved the quality control of the geometry and attributes of the data layers. Source data for the base layers (bathymetry, political boundaries, populated places, hydrography, sea ice, glaciers, roads and railroads) was supplied by the three countries. In some cases, the data had been generalized from a larger scale data set prior to delivery, and in other cases, the selection and generalization were done when the data were integrated. Details of the work are given in Regan and Paul (2005) and are much the same for all three jurisdictions.

The project's success was influenced by the fact that common, commercially available technologies and some open-source technologies were available in each organization. All work was done in-house by the three mapping agencies.

The resulting outputs consisted of the North American wall map and several other products that the CEC compiled and then published. As well, basic data layers were compiled, harmonized, documented, and delivered via download and through a web map service.[14] Another beneficial outcome of the project was that the three countries collaborated in preparing information and support products.

[13] Regan, A. and Paul, P. (2005). This section is taken from this paper, as well as from information provided by Anna Regan, Jay Donnelly and Karen Richardson.

[14] Web map service (WMS) is a standard protocol for serving geo-referenced map images over the internet.

2.4 Sharing Quality Control

Others who wish to share data can gain by understanding how the project handled quality control. Each country controlled the quality of the base layer geometry and attributes; in other words, each took responsibility for its own data. All four partners monitored the quality of the entire printed map, as well as their digital data. While the data are shared and meant to be viewed as one data set (hence, for example, the printed map showed all three countries in the same colour), each partner retained responsibility for, and ownership of, its own data.

Without this control, those whose data are being shared can feel less committed to the partnership. As a result, over time, errors can creep into data sets, and there can be confusion about whether data are current. Given that data owners and providers can easily share data over the web, it is not only possible but in some respects even easier to assign control of this data to the data's owners or administrators rather than to one central entity. Of course this approach to quality control works only if participants adhere to standards and sound data-sharing policies, such as those associated with the Canadian Geospatial Data Infrastructure (CGDI) and its GeoBase framework data.

The CGDI principles[15] much influenced how the Atlas data sets were developed and made available. The CGDI is based on open and shared specifications for operational transactions and information exchange. The CGDI is transparent; it allows users to access data and services seamlessly in a manner that removes the complexities of the underlying technology and information infrastructure. Another principle is that it is cooperative: the CGDI facilitates the cooperation and interoperability of participating organizations. In the end, in the words of Mr. Jay Donnelly of the USGS, "what was remarkable was that there were views of data streaming from Ottawa, Aquascalientes, and Virginia in a seamless map viewer that adhered to open standards for access and delivery, documented in three languages." The result is that the data is freely accessible by way of an open licence based on the CGDI Geogratis licensing model, which allows users to transparently view and download the data and use it without constraint[16].

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[15] CGDI Vision Mission and Roadmap - The Way Forward, GeoConnections, Natural Resources Canada, 2012 http://geoconnections.nrcan.gc.ca/18

[16] Metadata for accessible files (http://www.cec.org/Page.asp?PageID=1293&SiteNodeID=495) include Tems of Use which is covered by the Geogratis Licence Agreement (http://geogratis.cgdi.gc.ca/geogratis/en/licence.jsp).

2.5 The Cost

While it is difficult to compare costs from one jurisdiction to another, by any measure the cost of the entire project was surprisingly low. The annual cost for the USGS has ranged from $50,000 to $200,000 per year. In Canada, the first year (2004) required about two person years of effort. Since then, the project has required about 0.2 person years of effort annually. As well, the project leveraged existing infrastructure, including the U.S. National Spatial Data Infrastructure led by Federal Geographic Data Committee (FGDC), CGDI, and GeoBase, and the significant experience that has come from these national initiatives. From the CEC's perspective, the North American Environmental Atlas is now an on-going project, not a one-time effort. The CEC receives approximately $50,000 a year in funds to maintain the Atlas and update the data[17]. All three participating nations have agreed to continue the project.

2.6 The Need

The need was clear: The information in the Atlas is required to research, analyze and manage environmental issues in Canada, the U.S.A. and Mexico. The brochure for the Atlas describes both the scope and challenge of meeting this need: "At first glance, the maps in the North American Environmental Atlas look no different from maps found on walls across the continent. These maps are unique, however, in that they harmonize geographic information across North America's political boundaries to depict significant environmental issues at a continental scale."[18]

Environmental issues affect neighbors without regard to political boundaries. The Atlas serves as the cartographic foundation for visualizing and understanding how the nations of North America share economic and social interests in sustaining healthy ecosystems and citizens, clean water and air, and untainted food supplies. At the same time, North America is part of the global community, and the Atlas has contributed to a number of global initiatives including those of Unites Nations agencies and others.

[17] "The CEC receives financial support of the Government of Canada through the Federal Department of Environment, the Government of the United States of Mexico, through the *Secretaría de Medio Ambiente y Recursos Naturales*, and the Government of the United States of America through the Environmental Protection Agency." http://www.cec.org/Page.asp?PageID=1226&SiteNodeID=310&BL_ExpandID=154

[18] North American Environmental Atlas - Mapping North America's shared environment, CEC, Atlas brochure http://www.cec.org/storage/84/8000_CEC_NAAtlas_Brochure_en.pdf

2.7 The Benefits

Previously, only paper maps or by common Geographic Information System (GIS) file format were made available. Now, a full suite of on-line and downloadable files are offered, contributing to the ease and speed with which new maps and analyses can be produced. A single source of accurate data is faster to find, obtain, and use than three.

Consequently, the Atlas is benefiting many types of users. For example, Atlas information in briefings has allowed cabinet-level decision-makers to share a common understanding of environmental issues. At the same time, the Atlas is routinely used by a variety of government agencies in all three countries, as well as by the general population. The CEC employs Atlas framework products as the base for thematic maps and as integrated and reliable geospatial underpinnings to interpretative studies. The CEC also uses Atlas maps to identify priority areas to conserve biodiversity and predict the spread of invasive species. In addition, maps are used to track cross-border transfers of pollutants and monitor carbon dioxide emissions across major transportation routes.

Many others also benefit from the Atlas's free and up-to-date data:

- The education and academic community
- Geographic Information System software vendors who want reliable digital data
- The media looking for data to help describe environmental issues
- Environmental agencies, such as the International Joint Commission, involved in cross-border issues; this Commission has long been concerned with environmental impacts on shared watersheds in Canada and the U.S.A.

Another benefit of the Atlas project is that it brought together disparate data sources onto a common platform. Two examples illustrate this result.

First, the CEC published a map of interest to environmental groups that want to know how carbon dioxide emissions affect global warming. Entitled *North American Power Plant Air Emissions, 2005*, the map displays over 3,000 power-generating facilities using fossil fuel sources in 2005. These facilities are classified based on the primary fuel source they use to generate electricity: oil, natural gas, coal or other fuels. Each map layer illustrates the emissions of a specific pollutant (e.g., carbon dioxide) from the facilities. These map layers were developed for the CEC's 2011 publication, *North American Power Plant Air Emissions*. No complex tables could do what the maps do: display the location and nature of these power generating stations and their emissions.[19] Such information is especially useful in explaining the relative level of emissions from different areas and regions.

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[19] North American Power Plant Air Emissions, CEC, 2005
http://www.cec.org/Page.asp?PageID=924&ContentID=25146&AA_SiteLanguageID=1

The second example is the 2011 North American Forest map, which "shows the distribution of eighteen different primary ecological zones pertaining to forest systems within Canada, Mexico, and the United States. (The)… map was developed by the forestry agencies of the three countries: NRCan's Canadian Forest Service, U.S. Forest Service and the Comisión Nacional Forestal (CONAFOR). Their collaboration results in an update of the FAO ecological zones data from the year 2000, based on the CEC's terrestrial ecoregion data."[20]

At a global level, the Atlas contributes harmonized North American frameworks to the International Steering Committee for Global Mapping's Global Map program (1:1,000,000 scale), which aims to provide harmonized global coverage for environmental monitoring.

In addition to delivering specific map products, the North American Environmental Atlas project also demonstrated how users could apply emerging internet mapping standards to visualize data from different web mapping services. The data files were subdivided into four sets, one for each of Canada, the U.S.A. and Mexico and a fourth for foreign areas—i.e., those beyond the three countries. Each of the three countries use a web map service to publish all of the data sets. The goal was for each country to select and display its own data but store the others' data as a backup. This way, if one country's server were down, the Atlas could still function. This cooperation is again a notable feature of how both the NSDI in the U.S.A. and the CGDI in Canada work together.

2.8 Analysis and Lessons Learned

The North American Environmental Atlas project has produced a number of lessons learned and reinforced conclusions well known to the geospatial community. The lessons have been documented by a variety of groups and in a variety of activities including those involving the CGDI and NSDI. Several of these lessons are listed below:

- Without the parties' adherence to data standards, the project could not have been undertaken as easily, quickly, or cost effectively. And the data could not have been integrated as they were nor used in the many ways that they have been. In other words, adherence to standards permitted the parties to share data and collaborate, and these results contributed to the project's success and low costs. The cost efficiency comes from more easily and more quickly overlaying and using many different data sets for a much wider range of activities than originally intended.
- By adhering to international standards and data specifications, including descriptions of metadata, the partners avoided having to create their own

[20] North American Forests, CEC, 2011 http://www.cec.org/Page.asp?PageID=924&ContentID=25137&AA_SiteLanguageID=1

standards or adopt unique fixes to harmonize data. The partners also adopted a number of other technical standards and common approaches to data sharing. By so doing, the players brought their data together at low cost, with a common look and feel, and with relative ease. The various source materials listed in this case study provide further details on the technical standards.

- Standards are crucial to sharing data at the best of times, let alone when the parties represent different countries. But a common understanding of terminology is also important in these situations. Consequently, this project established a “data dictionary” to define various data terms and help the parties work together more easily.
- Partners are more likely to buy into their partnership’s decisions and schedules when members share leadership and collaborate closely. In this case, each nation assumed responsibility for individual projects or key components of shared projects, allowing all three countries to meet deadlines and goals.
- Behind almost every successful project lies a champion with both a focus and a mandate. The CEC was vital in this respect. It served as a facilitator and integrator. It gave the impetus to the development of the North American Environmental Atlas. And it was essential to the initial and ongoing success of the Atlas.
- The North American Environmental Atlas has shown that making high-quality data available through the Internet can inspire creative applications and lower the cost of such diverse pursuits as governing the country and educating children. These kinds of benefits are, of course, a central goal of the CGDI and the GeoConnections initiative in the Government of Canada.

2.9 Sources of Information

Gierman, D.M., et al (1975) “Remote Sensing and the Canada Geographic Information System for Impact Studies” (Invited Paper) North American Symposium on Land Use Mapping/Fall Meeting American Society for Photogrammetry p. 697–705. Also in 3rd Canadian Symposium on Remote Sensing, Edmonton, Alberta. September 1975.

The Map Book (Atlas e-book) is available at:
http://www.cec.org/Page.asp?PageID=749&SiteNodeID=631&AA_SiteLanguageID=1

Meta data is available for each layer and is downloadable from:
http://www.cec.org/Page.asp?PageID=924&ContentID=2336

North American Power Plant Air Emissions, 2005:
http://www.cec.org/Page.asp?PageID=924&ContentID=25146&AA_SiteLanguageID=1

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3. Case Study: CGDI Framework Data Imagery Layer Case Study and PCI Geomatics

3.1 Summary of Activity

On behalf of federal and provincial agencies, Natural Resources Canada (NRCan) awarded a contract to TELUS, Iunctus Geomatics[21] and PCI Geomatics to prepare a new high-resolution, satellite-generated imagery coverage of Canada. Part of NRCan's mandate is to provide quality geospatial information to Canadians, and the Government of Canada posted the final product on the GeoBase website.

3.2 The Audience and Clients

Natural Resources Canada (NRCan), several other federal agencies and the provinces and territories paid for the work. However, the final geospatial products have been made freely available to all Canadians through the CGDI on the GeoBase portal.

3.3 Details of the Activity

In 2006, NRCan awarded the contract to TELUS, Iunctus Geomatics and PCI Geomatics to prepare a high-resolution imagery coverage of Canada. Earth observation satellites (SPOT satellite) captured the imagery, which was collected by Iunctus Geomatics from 2005 to 2010 and geometrically corrected (to remove distortions) to create a new image coverage of Canada. Production took place both at the Iunctus Geomatics office in Alberta using software supplied by PCI Geomatics and at the PCI Geomatics office in Quebec. NRCan, Mapping Information Branch, performed quality control and posted the data to the GeoBase website. The final products are freely available for download under the heading of "GeoBase Orthoimage 2005-2010 Collection." (See Sources of Information below.)

[21] Now Blackbridge Geomatics.

Other key facts:

- The contract included acquiring and processing 11.5 million square kilometers of satellite data[22] covering all of Canada south of 80 degrees latitude.
- The five-year contract included delivery of production software by PCI Geomatics and the final geometrically corrected products and associated metadata[23].
- Ninety-eight percent of the more than 5000 images collected were unaffected by clouds.
- A digital elevation model and several sources of ground control were used by PCI Geomatics to correct image distortions.
- PCI Geomatics adhered to CGDI standards such as the metadata standard. This adherence gives the Government confidence in the final product provided and allows its discovery via the web to the public.
- Users were able to access data for this layer as they became available during the course of the project.
- The project was completed on time and on budget.

3.4 The Cost

The total contract was for approximately $2.5 million. PCI Geomatics received $750,000 of this total. In-kind contributions of NRCan were approximately $1.1 million.

3.5 The Need

The project objective was to generate an up-to-date coverage of Canada with higher resolution imagery for use by government departments and the public. The satellite imagery used to produce this coverage offered higher resolution and more up-to-date coverage than that provided by the previous layer (1999-2003[24]), based on other types of satellite imagery.

This project represented a natural step in NRCan's evolution. NRCan has long captured and disseminated geospatial information, including satellite imagery. A number of user-needs studies conducted for the Canada Centre for Remote Sensing (CCRS) and GeoConnections have confirmed the importance of such imagery data: providing free or highly subsidized imagery leads to more efficient natural resource management, improved environmental monitoring and better understanding of ecosystems.

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[22] 10m panchromatic and 20m multispectral resolution SPOT 4 and 5.

[23] Information about data. Metadata describes how, when and by whom a particular set of data was collected, and how the data was formatted.

[24] Landsat 7 Orthorectified Imagery over Canada (1999-2003), RADARSAT-1 Orthorectified Imagery (2001-2002, for northern regions above 82 degree latitude).

3.6 Benefits

3.6.1 Broad array of uses

More than 30,000 downloads have occurred between 2009 and 2012—75 percent of these in 2011. Data users include a number of federal and provincial/territorial agencies, the resource industry, environmental groups and teachers, among others. Uses have ranged from assessing development-related vegetation changes, to mapping land-use shifts, to planning national parks. The data have also been widely used in the classroom and for university research.

Recent studies[25] suggest that wider use of such imagery leads to better and faster decision making, which in turn advances the Government of Canada's social, economic and environmental priorities.

3.6.2 Excellent return on investment

The usual high expense of correcting data was reduced by automating production and limiting user and operator intervention. This reduction led to lower-cost data access and less costly data production for the Government. Typically, the cost of processing and geometrically correcting imagery limits the imagery's access and use. And yet, effective and timely decision and policy making in several areas often relies on up-to-date and higher resolution country-wide coverage of satellite imagery. For example, such imagery is often used in resource management, regional planning and state of the environment reporting.

The project has given industry and governments access to tens of millions of dollars' worth of imagery, all for a relatively modest $2.5 million investment. According to data supplier Blackridge Geomatics (formerly Iunctus)[26], users would typically pay $1200 for each image created under this project. Given that imagery from this layer has been downloaded more than 30,000 times, if each user were to have purchased just one image at the standard rate (and many users acquired more than one image), Canadians and their governments would have downloaded at least $36 million worth of imagery. These numbers confirm the Government's position that low or no-cost recent geospatial data will be much more widely used than pricier data. Moreover, the total savings associated with this project could be as high as $75 million to $125 million[27].

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[25] See Miller, H. et al (2011). "The Users, Uses, and Value of Landsat and Other Moderate-Resolution Satellite Imagery in the United States - Executive Report" USGS Open-File Report 2011–103.

[26] Information obtained February 23, 2012, from Blackbridge Geomatics (formerly Iunctus) Order Desk.

[27] This projection is based on studies on satellite imagery in the 1990s by the Canada Centre for Remote Sensing (CCRS) and Kodak Remote Sensing. These studies suggested that for every dollar spent on imagery, $5 to $8 were spent in industry and government on analysis, and every dollar spent on analysis produces derived benefits of a further $5 to $10. Given that over 35 percent of downloads go to industry and government, and therefore, even discounting benefits by 75 percent, the benefits associated with this data set could range from $75 million to more than $125 million over several years.

3.7 Analysis and Lessons Learned

The importance of standards cannot be overstated. Standards allow confidence in the data. This confidence, in turn, leads to several benefits. Firstly, it expands the utility of the Canadian Geomatics Data Infrastructure since data can be more easily shared and integrated with other data such as that pertaining to road networks, wildlife habitats, watersheds and municipal boundaries. This sharing and integration enables users to generate unique views of the world. Secondly, it leads to broader use of the data and expands the opportunity to create new applications, products and services. In effect, standards unlock the data's power.

3.8 Sources of Information

PCI Geomatics has a white paper titled "National Imagery Project: Developing an Automated Workflow to Produce Timely and Accurate Orthorectified SPOT Imagery Over the Canadian Landmass" at:

http://www.pcigeomatics.com/applications/pdfs/case_study_NIP.pdf. The complete dataset is freely available for download at: http://www.geobase.ca/geobase/en/data/imagery/index.html

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4. Case Study: Strata360 Corporate Development

4.1 Summary of Activity

This case study examines how consulting firm Strata360 Ltd. used its experience with an earlier GeoConnections project, the Cree GeoPortal[28], to apply geospatial data-management tools and web applications in other Aboriginal projects.

The Cree GeoPortal[29] project delivers geospatial information to Cree communities in Quebec. The communities use this information to research, plan and make decisions about managing resources and developing tourism. The Cree GeoPortal incorporates Cree traditional knowledge datasets in combination with information and base maps (vector and satellite images) from other distributed data sources including the Canadian Geospatial Data Infrastructure (CGDI). Capitalizing on its experience with the Cree GeoPortal, Strata360 has now undertaken related geomatics projects with other Aboriginal communities in three areas: Nunavik, northern Quebec and Nunavut Baffin Region. Discussions have been held for work elsewhere in the North in Labrador, North West Territories and Yukon.

4.2 The Audience and Clients

Strata360's long experience in working with Aboriginal communities has encouraged the company to focus on Aboriginal groups, including First Nations and Inuit across Canada. Strata360 has also worked internationally, including in South Africa; the company expects more international development work will follow. New business initiatives have been moving from mapping and GIS services to development of geospatial applications for decision support and land management.

[28] http://geoconnections.nrcan.gc.ca/18
[29] www.CreeGeoPortal.ca

4.3 Details of the Activity

In serving clients in Nunavik, northern Quebec and Nunavut Baffin Region, Strata360 employed technologies from several sources. The company used GIS desktop, server and Internet map server technologies, along with mass-market application programming interface and an open source database application. The data that Strata360 employed in the new projects have been similar to those used in the Cree GeoPortal project:

- Framework data from government sources (federal, provincial and territorial sources including GeoBase and CGDI)
- Thematic data from government and/or industry
- Other data from traditional knowledge and internal databases

In all of its work, Strata360 pays great attention to CGDI standards, an essential part of the company's success. These standards include those for data storage, for data sharing services, and for data encoding.

This case study profiles three activities that Strata360 was involved in after the company completed work on the Cree GeoPortal:

1. Strata360 has performed follow-up work on behalf of other Cree organizations. For example, the Cree Regional Authority (CRA) forestry department requested an application for monitoring projects and investments on forestry impacted traplines. This request involved expanding the Cree GeoPortal.
2. Working with the Inuit and under contract with Makivik Corporation, Strata360 developed a land registry and geospatial database for the Nunavik Landholding Corporation Association (NLHCA) in Nunavik, northern Quebec. Community members use this registry, which includes an automated invoicing system, to manage land leases. Strata360 was also involved in a second activity for an International Polar Year project. This project developed a system to issue research permits, and it will be followed up with a full land permitting system for Nunavik offshore areas.
3. In Nunavut, Strata360 developed a land registry and traditional knowledge database for the Qikiqtani Inuit Association (QIA). The company also developed the Nunavut Government Fur Tracking System. While not strictly a geospatial application, this work came from experience gained in the original Cree GeoPortal development.

4.4 The Cost

The development of the original Cree GeoPortal cost approximately $680,000 from 2006 to 2010, of which some 40 percent was provided by GeoConnections. GeoConnections provided resources which were used by Strata360 to develop four applications for four different Cree organizations. With this experience, Strata360 can now implement similar applications for between $50,000 and $100,000, depending on complexity and specific functional requirements. Development usually takes about a year from user needs assessment to beta testing and implementation of the final version.

4.5 The Need

The main objective of the original portal was to provide Cree users with a wide range of geographic information on the lands and resources of Eeyou Istchee; the Cree use, management and protection of these resources; the threats to these resources from non-Cree activities; and Cree and non-Cree infrastructure. Subsequent projects also focused on real needs within the Aboriginal communities. These projects were intended to help the Cree do the following:

- monitor forestry-project impact on trap lines
- access land-lease information
- monitor lease renewals and invoicing
- make decisions related to mining
- identify protected areas

4.6 Benefits

The blending of traditional knowledge and modern data technologies has been important to use of geospatial data. In the newer projects, access to data for management and monitoring has led to wider-than-anticipated use among a larger-than-anticipated community. Further details are provided on the Strata360 web site.

While it is too early to assess the full benefits of the new projects, these benefits will likely prove similar to those offered by the Cree GeoPortal Project. Data that were once scattered and often inaccessible are now available and in a consistent format. This availability and consistency saves time and money in data retrieval as well as in decision making. As noted above, the work on land holdings has improved cash flow. And Strata360 has been able to leverage its experience in previous projects to deliver new projects at less cost. As well, since it completed the Cree GeoPortal project, Strata360 has added three employees in geospatial applications development.

4.7 Analysis and Lessons Learned

- Standards are important. The work described in this case study and all the work derived from it by Strata360 conforms to CGDI standards and specifications. The work also supports applications based on visualizing map data such as land registries, permit systems and environmental and change monitoring, among others. Following the standards used in the CGDI enabled and facilitated interoperability to allow easier access and integration of geospatial information to support decision making..
- Data-sharing polices are especially important in the Aboriginal context as most Aboriginal data is confidential and sensitive. Data-sharing must be done under strict access and password protected (providing limited and selective access to confidential and sensitive datasets).
- While it is necessary to develop confidentiality and data-sharing agreements, sometimes data-sharing policy development can get too complicated and slow the process.
- As users gain experience and develop applications and solutions, they can apply these outputs in future similar situations. For example, users may be able to simply plug in already developed applications or solutions to develop new projects faster and more cost effectively than would otherwise be possible.
- There are challenges associated with internet connectivity and speed in the North. These challenges impact how one must design systems and software for remote communities.
- At the beginning, most Aboriginal communities and organizations were unaware of the potential benefits of a geoportal as a decision-support tool, but that awareness is growing as a result of the demonstrated successes.

4.8 Sources of Information

Stewart, M.A. "GeoConnections Geospatial Return on Investment Case Study: Cree GeoPortal." *Canadian Geospatial Data Infrastructure Information Product 17*. http://geogratis.cgdi.gc.ca/eodata/download/part6/ess_pubs/288/288866/cgdi_ip_17.pdf

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5. Case Study: Mapping the Evolution of “Food Deserts” in a Canadian City

5.1 Summary of Activity

This project illustrates how researchers can bring together geospatial information from different sources and time periods to explore spatial relationships and draw conclusions about important societal issues. In this case, researchers used geospatial information to answer three questions important to urban planning, education, and health:

1. Are disadvantaged residents[30] of certain areas of cities systematically unable to access healthy food at nearby supermarkets?
2. Have such geographic inequalities in access to supermarkets increased or decreased over time?
3. Are people of certain socio-economic standing systematically prevented from buying healthy food at supermarkets?

5.2 The Audience and Clients

In addition to the academic world of geographers and sociologists among others, the audience for this work includes local planning officials, public health officials and those who provide community services to the disadvantaged in London, Ontario. Over time the audience has grown considerably, as explained further under the Benefits section of this case study.

5.3 Details of the Activity

This work explored the historical and geographical evolution of supermarket access in a mid-sized Canadian city (London, Ontario) from 1961 to 2005. The study used a basic geographic information system (GIS) and a combination of data sources including business directories, street maps, census information and bus routes. The bus routes helped determine how easily residents without automobiles could access supermarkets. While the study drew on business directories for some historical information, much of the

[30] Disadvantage residents can be characterized as single-parent families, persons with low incomes, the elderly or disabled.

basic location information (such as road location and addresses) was available on-line from city, provincial and federal sources, including GeoBase. Various gazetteers[31] also provided information on business types and their street addresses. The open standards and access promoted by the Canadian Geospatial Data Infrastructure (CGDI) and provincial authorities are critical to applying geospatial data in this kind of low-cost societal study.

For this application, location accuracy over time was required to the level of a street address and within a particular census area. The researchers used the same road base maps and definitions (of disadvantaged persons, for example) for each year to legitimately compare information from different dates. In addition, locations of stores and census areas were tied to the road base maps in the same way over time. This information was brought together to assess whether there were inequalities in access to supermarkets, whether these inequalities had increased or decreased over time, and whether there were systematic inequalities. The open data policies and low or no-cost access to geospatial data promoted by the CGDI and agencies in the U.S.A. have led to the same type of study in other Canadian and American cities.

In London, local policy makers and community services have considered how best to re-introduce healthy food into areas known as "food deserts"—parts of cities with relatively poor access to healthy and affordable food. This reintroduction is expected to lower the need for community services and therefore save money. In other cities, similar studies have been or are being done to assess the food-desert problem. In Montreal, for example, food deserts do not exist. Their absence is attributed in part to high population density, allowing stores providing fruit and vegetables to exist in the central city while serving customers who shop on foot or by public transit. In many other cities, food deserts have been identified, and various approaches have been considered to address the issue.

5.4 The Cost

The work was done by Dr. Jason Gilliland and Kristan Larsen of the University of Western Ontario, for under $20,000. The team used university GIS software and hardware and existing geospatial data including open and no-cost data provided on the web by governments. With broad access to data, the researchers were able to conduct a wide range of studies comparing various socio-economic variables from one place to another and from one time to another.

[31] A Gazetteer is an online "dictionary" of geospatial words or terms, with or without applicable feature geometries.

5.5 The Need

While more and more large-format supermarkets are erected on suburban lands, smaller grocery stores in older central-city neighbourhoods seem to be rapidly disappearing. A growing body of research suggests that the suburbanization of food retailers in North America and the United Kingdom in recent decades has contributed to the emergence of urban food deserts. Home to disadvantaged populations, these areas offer relatively poor access to healthy and affordable food. This poor access has serious implications for public health, student performance, and several other socio-economic indicators.

Access to supermarkets is important since a healthy diet can reduce the risk of many chronic diseases. The majority of these health problems can be linked to diets low in fruits and vegetables and high in sugary or fatty foods. Most Canadians shop for food at local supermarkets, which offer the widest variety of products at the most competitive prices. While supermarkets also carry unhealthy foods (e.g., chips, soft drinks, and processed foods), these items are more readily available at convenience stores found in inner city neighbourhoods, which are less likely to offer healthy foods.

What happens to residents when the only supermarket in a neighbourhood closes? For disadvantaged populations without vehicles, residing in a food desert may harm their health and quality of life. The fact that healthy food costs 1.6 times as much in the food desert as in suburban supermarkets further indicates the disparity and pressures felt by disadvantaged residents in the central city.

5.6 Benefits

This work has quickly become a widely read academic geographic study. Over 17,000 copies of the paper have been downloaded. Its visibility has been further enhanced by widespread media attention and the National Institute of Environmental Health Sciences, which, inspired by the article, developed a teaching module on food deserts. Yet, without easy access to geospatial data, including basic maps of roads and addresses, the study would not have been possible.

This work has underlined the variability of access to healthy food. This access is believed to broadly and significantly impact the provision of community health and support services. But the lack of healthy food sources may also limit urban redevelopment, medical and hospital services, and education. Studying the relationship between the accessibility of healthy food and redevelopment is especially important as an aging population increases the demand for specialized housing in inner cities. Such studies can be expected to detail millions of dollars of benefits solely from tax increases associated with redevelopment, without even considering the parallel health benefits. These studies would also benefit from the amount and variety of geospatial information now on the web.

5.7 Analysis and Lessons Learned

This study has shown that with access to a broad range of good quality web-based geospatial information, researchers can now study highly important policy issues more inexpensively and quickly.

5.8 Sources of Information

Larsen, K. and J. Gilliland, (2008) "Mapping the evolution of 'food deserts' in a Canadian city: Supermarket accessibility in London, Ontario, 1961–2005" *International Journal of Health Geographics* 2008, 7:16 : http://www.ij-healthgeographics.com/content/7/1/16

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