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by

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A THESIS

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ABSTRACT

Aboriginal rights are a key issue affecting resource development in Canada on Aboriginal lands. However, searching for land related information can be very time consuming and incomplete, particularly in remote Aboriginal areas. There is a need for an on-line system providing integrated information about land and its resources, such as natural resources, topography, existing infrastructures, statutory requirements and the regulations that might apply to various developments on the land.

The goal of this research is to explore the role of new and emerging technologies, specifically GIS and Internet technologies, for resource management, and thereby develop a web GIS prototype to assist the resource development and management process involving Aboriginal communities.

The research started by reviewing the use of web GIS by Aboriginal communities, governmental agencies and the private sector for aboriginal resource management. It then reviewed the current trends of web GIS technologies. This included a comparison of two commercial software ESRI ArcIMS and Intergraph Geomedia Webmap. ESRI ArcIMS was chosen to develop the prototype because of its easy maintenance and customization. In this research, the Yukon Territory, comprising 14 First Nations, was selected as the study area. Data for the Yukon First Nations was collected, edited, processed. A database was then designed and populated, and a web GIS prototype was developed.

In the prototype implementation, an interactive users' interface was designed and developed. ArcIMS was customized to set up and enhance the website functions. Hyperlinks on the spatial layer were created, a mechanism for restricting access to the website was examined, and various advanced queries using ArcXML were developed and tested. Furthermore, a methodology, using combined vector and raster analysis, was developed to deal efficiently with multi-layer overlay analysis.

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LIST OF SYMBOLS, ABBREVIATIONS, NOMENCLATURE

API	Application Programming Interface
ASP	Active Server Pages
CGI	Common Gateway Interface
CSS	Cascading Style Sheet
DBMS	Database Management Systems
DHTML	Dynamic HyperText Markup Language
DOM	Document Object Model
GDO	Geographic Data Objects
GIS	Geographic Information Systems
GPS	Global Positioning System
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
IMS	Internet Map Server
JDBC	Java Database Connectivity
JSP	Java Server Pages
JVM	Java Virtual Machine
RPC	Remote Procedure Call
SQL	Structured Query Language
TEK	Traditional Ecological Knowledge
URL	Unified Resource Locator
XML	Extensible Markup Language

CHAPTER 1: INTRODUCTION

Various land management initiatives to reform the land management systems in Indian reserves have been introduced by the federal government since 1973, when Aboriginal rights were first recognized legally in Canada (Rakai, 2003). Aboriginal rights have become a key issue for those involved with resource development on Aboriginal lands in Canada.

Every development of Aboriginal land is a unique process, each with its own requirements and following a different approval procedure. The first question asked before any land development should be whether it makes sense to develop the land in question. Determining whether the land selected can be used for the purpose intended, and whether there is appropriate road access are just a few preliminary issues to be considered in the context of the suitability of the development.

Currently, data and information regarding Aboriginal land and Aboriginal communities are scattered among different governmental, non-governmental organizations (NGO), and the Aboriginal communities network. The difficulty in obtaining complete information on land use sometimes may result in conflicts between Aboriginal communities and non-Aboriginal individuals, agencies and organizations. For example, land developers usually start with field trips and look for information at various organizations and agencies. With some important information being missing, for example, the developer may not realize the land in question involves Aboriginal communities. In such cases, after land development starts, the conflicts that arise between Aboriginal communities and commercial developers are difficult to resolve. It is therefore necessary to have complete information regarding land ownership, in particular Aboriginal lands, from the beginning.

Today, the internet has become an important information resource. There is a need for a web GIS system to allow timely information on land use of Aboriginal communities (such as land ownership, natural resources, existing infrastructures, topography etc. and

the regulations and statutes applicable to land development) to be accessed, viewed, integrated, analyzed and shared as needed by all users.

The purpose of this research is to explore the role of new and emerging technologies, such as GIS and the internet for resource mapping and management; and to develop a web GIS prototype to assist the land resource development and management process involving Aboriginal communities.

1.1 PROBLEM STATEMENT

As mentioned, currently, data and information on Aboriginal Peoples' land use activities are scattered between different agencies and organizations. The extensive information on land use available through the Aboriginal and Government websites are in the form of HTML files, which are unstructured (not compatible with normalized databases) and very time-consuming for end-users wishing to extract information about specific types of land use. It is important to note that land use activities that are of interest have both spatial and non-spatial attributes. Problems arise when users want to gather information from text, or from static maps (such as sketch maps and images) that are stored at different websites scattered across Canada. There is no centrally maintained website that provides integrated information¹ retrieval services. The first problem is that the spatial data for First Nation communities are not always complete and well maintained. In most cases, metadata is not available. The second problem is that different static maps are sometimes not geo-referenced to a common coordinate system, and it is difficult to compare the locations and conduct spatial measurements and analysis. The third problem is that these static maps cannot be changed to suit the users' needs. For example, a user cannot change the scale of a map, select an area of interest, or perform any spatial analysis. The fourth problem is that the descriptive information (text, pictures and videos) that is available is not linked with the spatial location (e.g. map of campsite, hunting area, traditional territories). In most cases, just by looking at the maps, the user doesn't have the full

¹ Integrated information here means both spatial and non-spatial land use information, which includes information on topography, natural resources, land ownership, land use, transportation, demography, etc.

understanding of the land use activities on the land. For the reasons mentioned above, it is currently difficult for a user to obtain integrated information regarding specific areas of Aboriginal land use.

Integrated land use information is crucial for land management. For example, a land use manager or planner wanting to know where the most suitable place that oil and gas could be exploited, would be interested in geological, topographic and infrastructure information. As many land developments involve First Nations land, the developer, planner or land use manager may also be interested in information on the Aboriginal communities involved, and on any regulations that apply to reduce the impact on Aboriginal People's traditional activities. Furthermore, information regarding the procedure and costs to obtain the proper development license and for the consultation of Aboriginal communities are also very important, and are best obtained at the beginning, to assist decision-making.

In order to provide information and tools that can assist the decision-making process mentioned above, issues regarding data collection, data integration, spatial database design, and development of suitable query and analysis tools need to be addressed.

In addition, information security is always an important issue when disseminating information through the internet. Land use information, especially on First Nations land, is passed down through generations, relating to every living aspect of the First Nations people. Some information is culturally sensitive and not suitable for public access. A website disseminating such information needs to have measures restricting access to its database.

In summary, the following problems need to be addressed in this research:

- How to develop a web-based information system prototype that provides integrated information accessing?
- How to incorporate legal information (usually as untabulated data) into the spatial database (usually in a highly structured format)?

- How to develop the suitable query and spatial analysis tools (such as overlay and buffer, etc.) for the prototype system?
- How to design security mechanisms to restrict public access to sensitive information?

1.2 RESEARCH OBJECTIVES

The objectives of this research project are to:

- Evaluate current commercial Internet Map Server software packages to select suitable software for establishing the server.
- Design the architecture of a prototype Web GIS system. The working process of the map server will be explored in order to customize the specific application.
- Populate a web-based spatial database. Various data formats, both structured and unstructured, will be integrated by designing and incorporating hyperlinks into the database.
- Develop a prototype website using the selected commercial Internet Map Server (IMS) software.
- Enhance the prototype system by customizing the website functionalities with interactive analytical tools (more advanced spatial analysis and queries) to suit land management needs.
- Address the data security issues by developing mechanisms to provide restricted website access.

1.3 METHODOLOGY

As a tool to integrate, manage, and visualize spatial data, Geographic Information Systems (GIS) have been accepted as a useful solution for resource mapping (Bernhardsen, 1999). Web GIS, emerging with internet technology development, is proving to be an efficient way to disseminate spatial information of land use. This

research will also adopt the current available Web GIS techniques for the development of the prototype.

Most web GIS implementations have commercial software installed as Internet Map Server (IMS), such as ESRI ArcIMS and Intergraph Geomedia Webmap. By using existing commercial software, the web site setup is straightforward, and very basic functions, such as browsing, searching and accessing of spatial data can be provided. For the application in this research, textual information that includes both tabulated and untabulated information (e.g. legal information) needs to be incorporated into the website. Furthermore, some interactive queries and spatial analysis tools (such as buffer and overlay) also need to be developed.

This research is comprised of three phases: analysis and problem definition, prototype system design and implementation, prototype system enhancements and advanced query implementation. Figure 1.1 below illustrates the research methods that were used to meet the objectives in each phase:

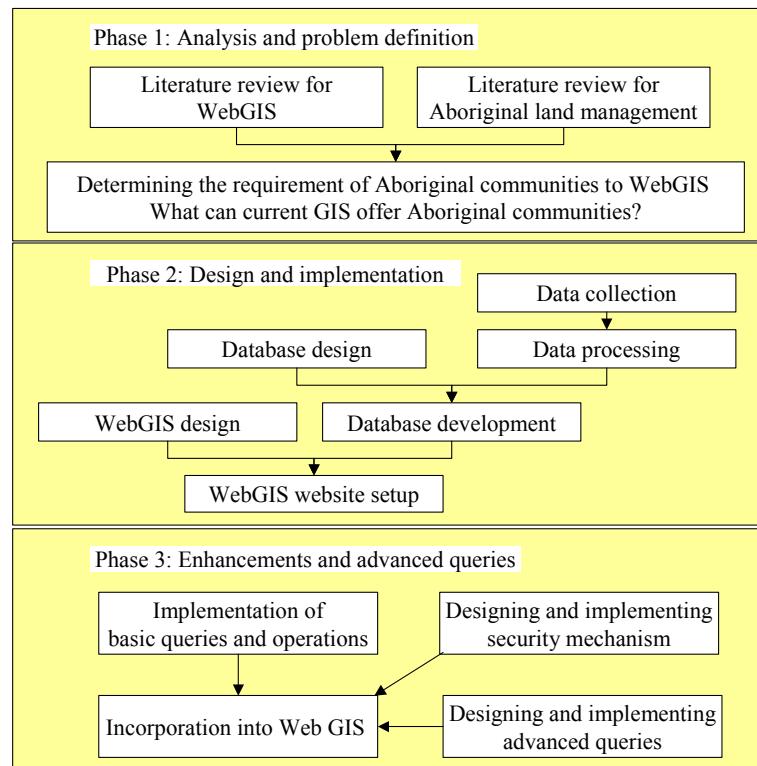


Figure 1.1: The Research Method

Phase 1

This phase begins with a literature review of issues affecting Aboriginal rights in the land resource development process in Canada. The literature review then focuses on Web GIS technologies and its application in the resource mapping and land use planning area. Based on the literature review, the need for a Web GIS system is determined.

The backbone of most Web GIS is the Internet Map Server (IMS). Two popular commercial Internet Map Server (IMS) software packages, ESRI's ArcIMS and Intergraph's Geomedia WebMap, are therefore compared and evaluated to select a suitable IMS for this research. The system architecture and the way in which they work are studied in depth, to provide the foundation for the development and implementation of the prototype system.

The Yukon Territory is selected as the study area in this research. The Yukon is one of the three northern territories in Canada. As shown in figure 1.2 below, to the east is the Northwest Territories, to the west is the state of Alaska, to the south is British Columbia and to the north is the Arctic Ocean. There are 14 First Nations in the Yukon Territory and about 24 percent of the population is First Nation peoples.



Figure 1.2: Location of the Yukon Territory

Phase 2

Data collection starts with various government organization websites (such as the Geomatics Department, Yukon Government). Then other national databases (such as Georeferencing, Geoconnections) are searched for the base mapping datasets. Other data will be obtained from local websites, books, videos related to Aboriginal territories, natural resources, land use activities and legislation.

After data collection, spatial and attribute data, and other legal information are edited and processed; a spatial database is then designed and populated. A literature review on the system architecture of various Web GIS applications is conducted, and then prototype system architecture is designed. Various software for the web server and map server are installed before a prototype system is developed.

Phase 3

The Internet Map Server software is customized for the application by programming in ArcXML. Enhancements include examining and implementing advanced combined spatial and attribute queries. This research also examines web-based spatial analysis tools (such as buffer, overlays) and its implementation for the prototype system. The need for restricted user rights in data access is also addressed.

1.4 RESEARCH SIGNIFICANCE

This research aims to provide an accessible Web GIS prototype consisting of spatial and legal information related to Aboriginal land development and management. An integrated on-line information system will assist land managers and land developers to efficiently obtain information, conduct analysis and reduce the length of the decision-making process. It will also benefit remote self-governing Aboriginal communities across Canada, allowing them to analyze land management-related information in a timely

fashion, by conducting on-line GIS queries, analysis and ‘what-if’ scenario models concerning land management issues.

While this research is primarily intended for aboriginal peoples, it will also be useful for non-aboriginal peoples who are interested in using Web GIS for managing their resources. The investigation and comparison of popular commercial Internet Map Server (IMS) software packages will assist GIS managers to select suitable software for their Web GIS system. In this research, various methods are introduced for customization in ArcIMS, which may be useful for Web GIS developers. The methodology for developing spatial querying and spatial analysis tools provides insights into approaches for web-based decision-support GIS development.

1.5 THESIS STRUCTURE

Figure 1.3 provides an overview of this thesis, which is organized into six chapters.

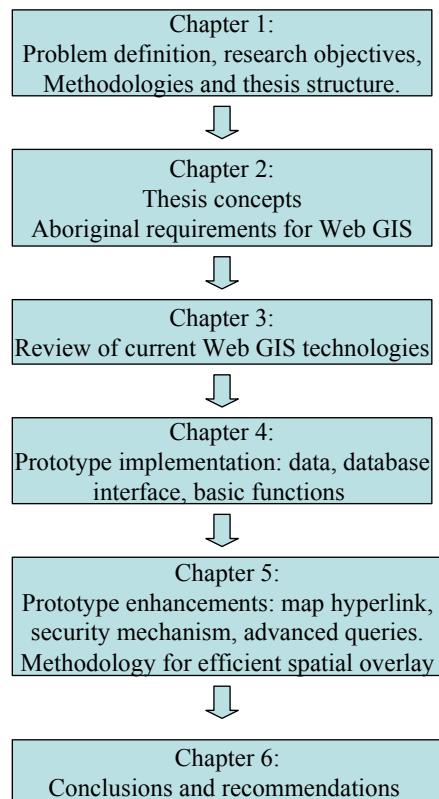


Figure 1.3: Thesis Overview

Chapter 1 introduces the research problem, objectives, and methodologies; and concludes with overview of the thesis structure.

Chapter 2 provides an overview of Aboriginal rights, and sets the context for why Web GIS is important for Aboriginal land development and management.

Chapter 3 provides a review of current web-GIS technologies. The functionalities and architectures of Internet Map Servers (IMS) are compared.

Chapter 4 describes the design and development of the web GIS prototype, which is comprised of data acquisition, data preparation, system architecture design, database design and population, website setup and user interface design. The basic system functions are illustrated.

Chapter 5 discusses the enhancement of the prototype system, which includes creating map hyperlinks and developing mechanism for restricting information access. Advanced queries, especially the combined spatial-attribute queries, are further developed after using ArcXML programming. Because of the limitation of ArcXML programming, a methodology for efficient spatial overlay analysis is then developed.

Chapter 6 contains findings and conclusions formed from this research as well as recommendations for further research and development.

CHAPTER 2: GIS APPLICATIONS FOR ABORIGINAL LAND MANAGEMENT

In this chapter, important thesis concepts, such as Geographical Information System (GIS) and Aboriginal rights are introduced. The implications of Aboriginal rights in resource development are discussed. The use of GIS in the decision-making process in land management is examined by reviewing some successful applications.

2.1 THESIS CONCEPTS

2.1.1 Geographical Information Systems (GIS)

The term Geographical Information Systems (GIS) is used generally for any computer system that has the capability to manipulate and display spatial data. A GIS includes not only hardware and software components, but also specialized devices used to input spatial data and create map products, together with communication systems (Bernhardsen, 1999).

The definition of GIS, as “an integrated system of storing, managing, displaying, and analyzing geospatial data.” (Burrough & McDonnell, 1998) has been adopted for the purpose of this research. As a spatial database, an important functionality of GIS is to integrate and analyze spatial and textual data. As a spatial information manipulation tool, GIS allows for the integration of many ‘layers’, thus, input data may be gathered from a variety of sources: maps, aerial photos, satellite images, etc. As an analytical tool, GIS can be used to perform spatial queries, develop dynamic models, analyze trends over time, simulate scenarios, and develop predictive models.

The development of internet technology has allowed some GIS data and functions to be accessed remotely by end users. By using web GIS, data and operations can reside anywhere, hosted by institutions, organizations and companies around the world. This means that users need not purchase a GIS software license to run a simple operation (e.g. geo-coding, proximity) on their own computer. End users can use data and operations on

the web to perform real-time data processing remotely. The analysis is completed on the remote computer where the main GIS functionality is located and the result is sent back to the client through the internet.

2.1.2 Aboriginal Rights

Aboriginal rights are *sui generis*² rights that originate in traditional rights exercised by Aboriginal peoples in Canada prior to European contact (Canada, 1996). Aboriginal rights may be described as a broad spectrum of rights, the cornerstone being the relationship of Aboriginal rights to land. At one end of the spectrum of Aboriginal rights are practices, customs and traditions unrelated to land claims, for example, the right to speak an Aboriginal language. In the middle of the spectrum are treaties and Aboriginal “site-specific” rights dependent on use of the land, such as fishing, hunting and trapping (whether it be for ceremonial, commercial or sustenance purposes). At the other end of the spectrum is Aboriginal title (Campbell and Sindlinger, 2001).

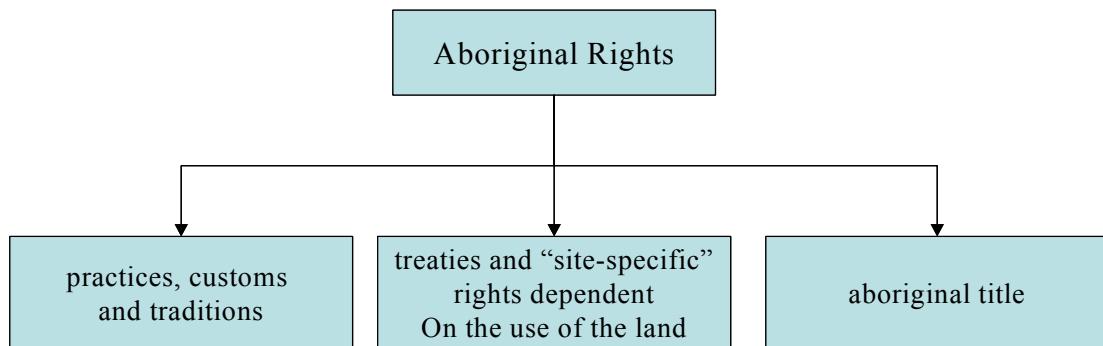


Figure 2.1: Spectrum of Aboriginal Rights (Campbell and Sindlinger, 2001)

Aboriginal peoples holding Aboriginal title have an indefeasible interest in land. Aboriginal title is a *sui generic* right in land, between fee simple right and a usufructuary right (Issac, 2004). Aboriginal title arises from pre-sovereignty occupation of lands and not from Crown grant (Calder, 1973). Therefore it is incompatible with the Torrens system of priority, which is based on date of registration of rights to land and not based

² Being the only example of its kind; unique

on when such rights are acquired. Aboriginal title is a collective right, inalienable except to the Crown (Issac, 2004). Aboriginal title is held communally, and not by any one member of an Aboriginal community.

Although Aboriginal title has its legal source in pre-sovereignty occupation of the land, there is an inherent limit on the possible uses that can be made of the land. For example, Aboriginal people may not use lands to which Aboriginal title is asserted, for activities that impact negatively on such land. If a group claims a special bond with the land because of its ceremonial or cultural significance, it may not use the land in such a way as to destroy that ceremonial or cultural relationship (Campbell and Sindlinger, 2001). In addition, Aboriginal title may be infringed on by either provincial or federal governments if the infringement satisfies a compelling legislative objective, for example the protection of the environment or endangered species. If there is to be an infringement on Aboriginal title the government must recognize its fiduciary relationship with Aboriginal people, and ensure that there is as little infringement as possible, that fair compensation is made available, and that the Aboriginal group has been consulted.

2.2 IMPLICATIONS OF ABORIGINAL RIGHTS IN RESOURCE DEVELOPMENT

As mentioned earlier, one of the guiding principles for any land development in Northern Canada is that it must fully respect and be consistent with Aboriginal rights as defined in the Canadian Constitution, in common law, in treaties, and in land claim and self-government agreements. The federal and provincial Crown, and all third parties whose activities potentially interfere with or infringe Aboriginal rights must consult affected Aboriginal peoples.

To determine who must be consulted and what regulations may apply, a two step process involving the identification of affected Aboriginal people and assessment of their governance structure is required (Sharvit et al., 1999). Both may be difficult to identify depending on the nature and scope of a project or development. For example, at one

extreme, a project proponent in northern British Columbia may identify and be required to consult with one Aboriginal group. At another extreme, a project in southwest British Columbia in the Greater Vancouver area may involve consultation with a dozen or more groups of Aboriginal peoples. Where a project covers a large area or long distance, such as pipeline construction, numerous Aboriginal peoples may need to be consulted. Special attention must be paid to “shared lands” where joint title or joint rights may exist.

The accurate identification of affected Aboriginal peoples requires an assessment of internal governance structures of each Aboriginal community. Determining who or which internal body is the governing authority of an Aboriginal people can be complex. Legislation, custom and culture, the status of hereditary chiefs and tribal councils, and ongoing treaty negotiations are considered when determining who is the legal representative and who has the right to enter into agreements on behalf of an Aboriginal people (Canada, 1996).

For any land/resource development, identifying the applicable land management regime plays an important role in assessing the governance structure from the legal perspective. Every piece of First Nation land being contemplated for development is unique and it is advisable not to make hasty assumptions about the land’s legal status or applicable laws. Below are some possible situations that may be encountered which could impact the land’s development (Fiscal Realities, 1999):

- a) Reserve land subject to the Indian Act;
- b) Reserve land subject to First Nation Land Management Act and First Nation Land Code;
- c) Settlement land subject to the Final Land Settlement Agreement;
- d) Settlement land subject to a Treaty or Comprehensive Land Claim Agreement;
- e) Crown land over which Aboriginal title has been asserted and which is subject to an interim measure under the treaty process;
- f) Land held in fee simple that is subject to Self-Government Legislation.

There is no one legal regime that applies identically to all First Nation land in Canada. In British Columbia, for example, there is reserve land that is subject to the *Indian Act* (1985), some of which may also be subject to the *First Nation Land Management Act* (1999). One might also encounter fee simple land that is the subject of self-government legislation (e.g. Sechelt). In addition, if development traverses both reserve and non-reserve land, there maybe Aboriginal rights or title asserted to the non-reserve land and such land may also be subject to interim agreements under the British Columbia Treaty Process.

British Columbia can be contrasted to the Yukon where First Nations have entered into the *Yukon Umbrella Final Agreement ("UFA")*(1993) and reserve land that is subject to the Indian Act does not generally exist. Instead, with the UFA, individual Final Agreements for each First Nation are now either in place or being negotiated.

The *UFA* provides for the retention of Aboriginal title of more than 16,000 square miles of the Yukon Territory by Yukon First Nations. These Yukon First Nation lands are known as "Settlement Lands". There are three possible types of Settlement Land where Aboriginal title is retained (See Appendix A: Yukon Land Status). Each has its own, unique characteristics (Government of Canada, 2004):

- *Category A* (10,000 square miles): On Category A lands Yukon First Nations retain both surface and sub-surface rights. This means that Yukon First Nations own the mines and minerals under Category A lands. Yukon First Nations also have exclusive rights to fish and harvest wildlife on Category A lands.
- *Category B* (6,000 square miles): On Category B lands Yukon First Nations have surface rights only. This means that the Crown retains the rights to mines and minerals and that the general public has the right to fish and harvest wildlife on Category B lands, subject to the Fish and Wildlife Chapter provisions of First Nation Final Agreements.
- *Protected Area:* the Umbrella Final Agreement also provides for the creation of special management areas or Heritage sites. These sites are intended to protect

unique natural features or places of special significance outside of specific Yukon First Nation land selections.

2.3 GIS APPLICATIONS FOR ABORIGINAL LAND MANAGEMENT

As mentioned earlier, Aboriginal land rights are protected by the constitution in Canada. However, there are still many factors that make Aboriginal land management a complicated problem. For example, First Nations in Canada are isolated and scattered, especially in the northern and rural areas. Accessing land related information is difficult and time-consuming. Land boundaries kept changing due to various land initiatives going on. Sometimes, arguments over the land title and land boundary happen due to lack of centrally maintained land information system.

Aboriginal title has very strong spatial aspects. A normal relational database cannot present its rich spatial aspects. GIS is a useful tool to integrate and visualize the spatial information and is very useful in presenting Aboriginal title and assisting Aboriginal land development and management. The following section will highlight some applications of GIS for the development and management of Aboriginal land.

Maguire & Dangermond (1991) outlined three perspectives of GIS (mapping, database populating and spatial analysis), which can support Aboriginal land management:

- Using the GIS mapping function, the external boundaries of Aboriginal title can be delineated.
- Using the spatial database function, the GIS can be used to store and manage both spatial and textual information pertaining to Aboriginal title. Many land claim applications lodged with the federal court highlight the need for appropriate database facilities.
- The GIS spatial analysis functions can be used to analyze land tenure information and determine “gaps” and “overlaps” of Aboriginal title claims.

With increasing emphasis placed on the protection of Aboriginal rights, valuable local knowledge of Aboriginal peoples is taken into consideration to achieve sustainable resource management. The application of GIS in some of the First Nations highlights the ways in which traditional knowledge systems may be documented.

Traditional Ecological Knowledge (TEK) may be described as knowledge of “local environments accumulated through generations of contact with the land and communicated through stories, conversation, oral history, and song”(quoted in Rakai & Nichols, 1998). The application of GIS as a “computer based tool allows TEK to be documented and integrated with a variety of other types of information that can then be analyzed and visually displayed for litigation purposes or for land claims negotiation purposes” (Rakai & Nichols, 1998). The use of GIS allows the overlay of a variety of datasets to determine cultural areas and lands that are associated with claims and litigation. Traditional knowledge, as presented in the GIS, has been used to support a number of land claims throughout Canada (Duerden & Kuhn, 1996).

The rationale for applying GIS in the Aboriginal communities “is to build on the local knowledge and articulate traditional concepts and present them in a format that facilitates transactions with external agencies” (Mohamed & Ventura, 2000). This is where GIS offers the opportunity to provide a mapping product and a tool for the management and dissemination of information pertaining to Aboriginal title.

The project “Mapping Customary Land in East Kalimantan, Indonesia: a Tool for Forest Management” conducted by the Indonesian Forest Department has demonstrated an integrated method for mapping customary land use systems. This system has been officially recognized as the basis for resolving land use conflicts. Following are the specific objectives of this study (Sirait et al, 1994):

- Map the customary lands of a village in East Kalimantan (Long Uli) using oral history, traditional knowledge, sketch maps, and a global positioning system (GPS);

- Use GIS to overlay this information with official land use maps in order to clarify land-boundary conflicts;
- Identify management alternatives.

It should be noted that despite the widespread adoption of GIS technology, its potential is far from being realized, with limited ability to play an active role in a decision support process. A review of the literature indicated there is little difficulty in integrating TEK into GIS from a technical perspective. Rather, many obstacles to establishing such a system come from social and political perspectives.

- The first obstacle to integrating TEK with Western knowledge system is the skepticism of the scientific community about the credibility or reliability of Aboriginal information elicited through interviews. “Objective” data is valued highly by people on policy or regulatory committees, who tend to dismiss Aboriginal knowledge as subjective, anecdotal, and unscientific (Johannes, 1993).
- A second obstacle is the difficulty that social scientists and mapmakers have in accurately capturing the complex relationships of traditional land management systems on maps. The process of understanding the spatial organization imposed by traditional peoples on landscapes, as well as mapping customary lands, suffers all the usual methodological difficulties of studying human subjects (Moore & Golledge, 1976).
- The most overwhelming barrier to integrating TEK into the western land management system is the political obstacle i.e. the political will of parties involved in recognizing different forms of land rights. The local complexity of land rights renders boundaries of land and resources more ambiguous than mapmakers and state land planners assume. At the same time, property rights and claims continue to be a complex bundle of overlapping and hierarchical rights distributed among many persons and related to other social relationships within and outside particular communities (Wavey, 1993). This contradicts the clear

boundaries assumed by provincial land titling programs. Whether the government is willing to accept different perspectives regarding land rights and resource management is a key issue. McDonald and Fleming (1991) described the development of a community-based management system for commercial harvesting of eiderdown in the Belcher Islands, which illustrates how indigenous knowledge is integral to the management process. It is important to note that upon starting this research and development initiative, there was little consensus on how to achieve sustainable, community-based development of living common-property resources in northern Canada (McDonald & Fleming, 1991). In any case, Respect, trust and community empowerment must be central to any collaborative processes that link western science and traditional knowledge.

2.4 CHAPTER SUMMARY

In summary, currently many First Nations in Canada are using GIS as a tool to assist with the administration of information significant to land claims and natural resource management. Land information maintained in GIS is being used as the basis for many agreements and negotiations to be implemented at a local or regional level. However, limitations to the development of GIS are due in part to the recent acquisition of GIS technologies by many of the First Nations, the lack of trained GIS personnel who are aware of the intrinsic nature of land and the Aboriginal people, the limited access and quality of spatial information and finally the failure of First Nations to develop objectives for the appropriate application and development of GIS.

An effective way to help solve the technical and personnel problems is to provide integrated web-based GIS that can centrally maintain the data that can be accessed by many users. This could reduce the cost of repeated data collection and database construction. The availability of basic and popular GIS functions on the website would assist First Nation communities who cannot afford buying complete GIS software for their data analysis. The Web GIS system provides a user-friendly interface that also reduces the cost of personnel training. But debate continues regarding public access to

Aboriginal land data as certain geographical information, such as ceremony site and burial grounds, are culturally sensitive information, which require protection.

CHAPTER 3: WEB-BASED GIS

As mentioned in Chapter 2, GIS is valuable for documenting, interpreting and displaying the spatial extent of Aboriginal title and land use information of Aboriginal communities. However, access to and the efficient use of GIS is limited. The internet is changing the way in which spatial data can be accessed and disseminated. It has had a great impact on many fields and GIS is no exception. Web GIS became a cheap and easy way of disseminating geospatial data and processing tools without time and location restrictions to users. This is an opportunity for remote and isolated First Nation communities to use GIS tools for their land resource management.

This chapter will review the existing Web GIS from the technology perspective. The commonly used system architectures, client viewers, interface programs, and map servers are examined. Then two popular commercial Web GIS software packages: ESRI ArcIMS 9.0 and Geomedia WebMap 5.2 will be introduced and compared.

3.1 WEB-BASED GIS APPLICATIONS

Various web-based projects have been implemented in US and Canada's federal agencies to allow users to access various types of data and map services by using Web GIS. Many public data services provide interactive capabilities to retrieve spatial data and information from the internet to local machines. For example, the Florida Geographic Data Library (FGDL, 2005) provides a repository of spatial data of Florida to clients using the data service concept. In contrast, some map services are constrained to online use and no data or information can be retrieved by local client machines. For example, the web site "Surf Your Watershed" developed by the U.S. Environmental Protection Agency provides map services to clients (U.S. Environmental Protection Agency, 2004). An example of an interactive Web GIS site providing map services is the Florida Seminole County Watershed Atlas web site (Florida Seminole County, 2004).

In addition, there are broad ranges of applications addressing different Web GIS issues. For example, a mapping application project, OMIMA, developed by Fisheries and Oceans Canada (DFO) has demonstrated the feasibility of combining raster and vector data and disseminating the results efficiently over the Internet (Michalak and Wojnarowska, 2002). Interactive maps of Nunavut's capital city, Iqualuit, and its environment, have been successfully developed for viewing and distribution on the internet by a team in Geomatics Canada (Siekierska et al, 2000). To promote better democratic decision-making, the Kentucky Water Information Network (KY-WIN) allows citizens to share their non-formal local knowledge with formal information held by government agency staff, in web accessible database (Harvey, 2002).

3.2 OVERVIEW OF WEB-BASED GIS TECHNOLOGY

Initial developments of web-based GIS concentrated on map visualization, eg. MapViewer (Xerox, 2004). The developments were quickly followed by querying capabilities such as MapServer (University of Minnesota, 2004) and USCB Tiger mapping service (U.S.Census Bereau, 2004). Generally, the main components of any Web GIS are the client, the server, and the network. On the server side resides the GIS database and applications to process the user's request. On the client side is a user interface within a web browser. Whenever a user submits a request, the server processes the request with the GIS application program and returns the result to the user. With web-based GIS, the technology has evolved from web map publishing to web GIS mapping.

3.2.1 Static Web Map Publishing

At the basic level, publishing geospatial data on the internet does not require any GIS. All it needs is a web server (also called HTTP³ server) and a set of maps. The maps should be supplied in a format which most web browser (such as well-known Internet Explorer,

³ HTTP: hypertext transfer protocol

Netscape Navigator) understand like JPEG⁴ or GIF. Standard web browser communicates with the web server by the HyperText Transfer Protocol (HTTP), and the server can then send the maps on request to the browser (see Figure 3.1). The HTTP is the standard for transferring World Wide Web documents. The simplest HTTP message is "GET url", to which the server replies by sending the named document.

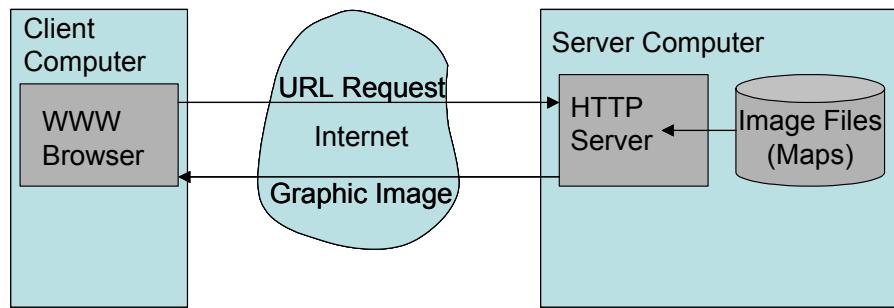


Figure 3.1: Static Map Publishing (Plewe, 1997)

The next level of geospatial data publishing is to use clickable images. HyperText Markup Language (HTML) allows creating image maps which link certain parts of an image (a circle, rectangle or polygon) to another URL. With a click on an image a request with the related URL will be sent to the web server.

3.2.2 Interactive Web GIS Mapping

Static map publishing mentioned above is simply an electronic copy of a paper map. The user can only look at the map images on the web page and cannot interact with the map in any other way. This is because the HTTP server cannot handle user requests other than serving ready-made files. To increase user interactivity, web mapping emerged. It uses data and a database to create the maps needed by users dynamically rather than providing static maps for viewing and downloading.

⁴ JPEG, GIF: Joint Photographic Experts Group (JPEG) and Graphics Interchange Format (GIF) are the standard computer file formats for storing graphic images in a compressed form for general use.

In a dynamic configuration (see Figure 3.2), the HTTP server is connected to a Map Server with GIS software installed, which is able to generate maps on request. This request is processed by the GIS server. The result will be sent to the browser. A server with GIS functions is called an Internet Map Server.

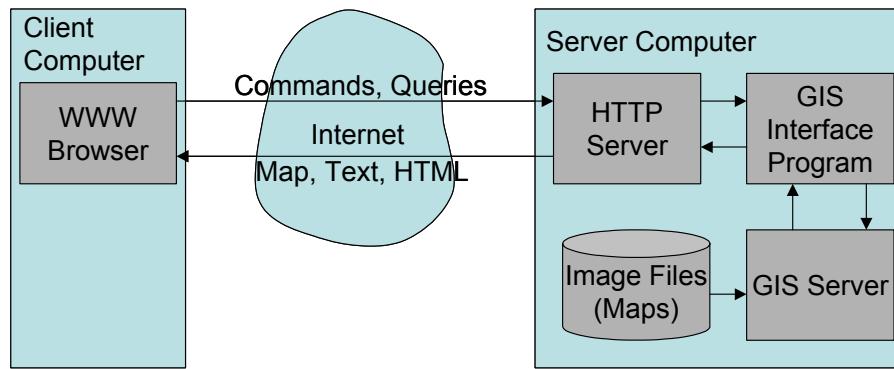


Figure 3.2: Dynamic Map Display (Plewe, 1997)

In the following section, the author will examine the various technologies and computer software available for building the client viewer, web server, interface program and GIS server.

3.2.2.1 HTTP server

HTTP server is a computer that provides a service to other client computers. Simply speaking, it delivers Web pages. Every HTTP server has an IP address and possibly a domain name (URL). Any computer can be turned into a Web server by installing server software and connecting the machine to the internet. There are many Web server software applications, including public domain software from NCSA and Apache, and commercial packages from Microsoft, Netscape and others.

3.2.2.2 Interface program

Because there are many ways to link the HTTP server with the GIS server through interface programs, specific applications may adopt various settings based on the different interface programs available.

a. Common Gateway Interface (CGI)

Literature shows there is a common architecture that dominates the early-stage Web mapping applications, as shown in the figure below.

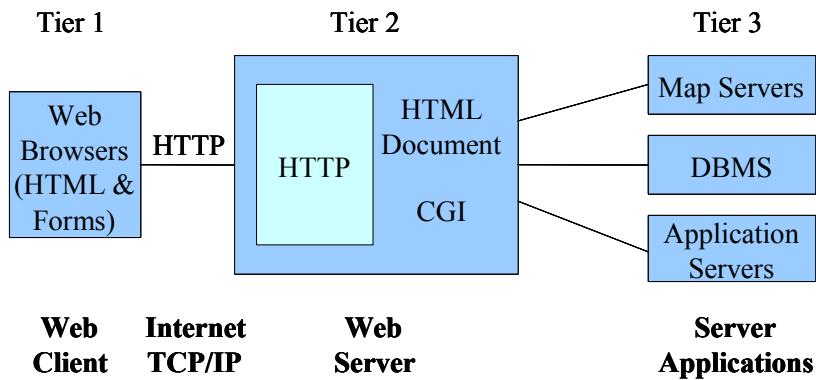


Figure 3.3: Architecture of CGI-based Internet GIS (Tang & Sun, 1997)

Here, the web browser sends a request to the HTTP server including information about the map extent, the requested map layers and so on. The HTTP server receives the HTTP message, however, it can not respond because the HTTP server does not understand any requests other than retrieving the HTML files with the identified URL. Therefore, the HTTP server passes the user requests to the Map server that extends the functions of HTTP to respond to the user requests. The HTTP server uses a Common Gateway Interface (CGI) to pass the requests, the parameters and the variables to the server applications. The server-side applications do the actual processing. In the case of web mapping, these programs include map servers and Database Management System (DBMS). Any client-server based GIS programs that work on the server can become a map server. The role of the map server is to fulfil the user requests and return the results

to the Web Server via the CGI protocol. The Web server then returns the results to the Web client. The web server becomes middleware, connecting the Web client and server applications.

An important characteristic of this architecture is that all the user requests are processed by server-side applications. All output at the client-side are merely mirrors of map images created by the server. Some of the examples of this type of application include: Visa ATM locator (<http://www.visa.com>), MapQuest (<http://www.mapquest.com>), MapBlast (<http://www.mapblast.com>) and many others. It is worth noting that the earliest Web GIS appeared in 1995 with the first noticeable contributions as GRASSLink (Huse, 1995). It has also adopted the same architecture.

The following sections will examine in more depth the relationship of CGI with HTML viewer and HTTP server.

i) HTML forms and CGI

In web mapping, in order for the user to interact with the map server, the HTML viewer needs to have two basic functions:

- To provide a mechanism for users to enter text, such as an address, and/or select different options, such as selecting different display layers.
- To submit the users' input and selections to the server. For example, the user may enter an address and then submit the request to the server to return with a map showing the location of the address. After seeing the return map, the user may decide to zoom in (by submitting another request) to see a more detailed map in a larger scale.

These two functions can be made available in HTML forms, eg. Forms are generally used in HTML 3.2 or later version to gather information from users for a CGI-based server application. A form in HTML starts with a <FORM> tag and ends with </FORM> tag. The <FORM> tag has two mandatory attributes: METHODS and ACTION. METHOD

specifies the invocation methods for the data to be transmitted to the CGI server application. The GET method encodes the data input in the Uniform Resource Identifier (URI), while the POST method transmits the user input in the HTTP message body. Simply speaking, the GET retrieves data while POST involves the request. The ACTION attributes specify the URI where the data is processed. The URI is the name of a server and location of the CGI or scripts. For example,

```
<FORM METHOD = “POST” ACTION=HTTP://notebook/cgi-bin/geocode>
```

This ACTION attribute tells the Web server that the incoming request is for a CGI program that is located in the cgi-bin directory, so the web Server will invoke the geocode program via the CGI protocol.

ii) HTTP Server and CGI

It can be seen that CGI is an important middleware to link the HTML viewer and HTTP server with the external server application such as map server. It is a language-independent standard interface used to process the user's request that involves computation or invokes other applications on the server. It works on any type of web server and allows a server to start an external process. Basically CGI is a message-handling protocol or interpreter that receives the user inputs and parses them into parameters of variables to be used in map server or other GIS programs. The figure below shows this process:

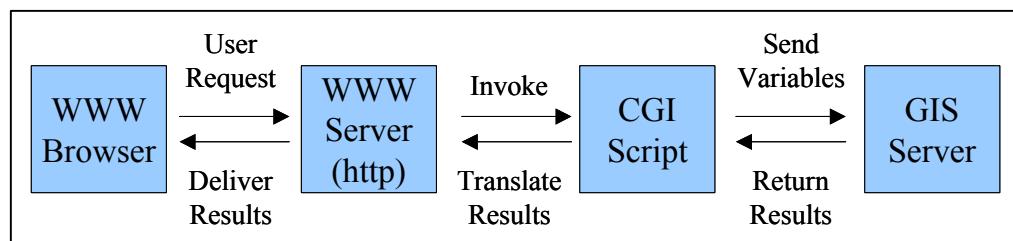


Figure 3.4: Workflow of CGI-based Internet GIS (Peng and Tsou, 2003)

A CGI program can be written in any language, such as C or Perl. It can access external resources such as files and databases. The CGI program can also connect with other applications using any of the communication middleware such as Remote Procedure Call (RPC) and object-messages. CGI programs add more functions and interactivity to the web page.

iii) CGI Summary

In summary, the use of HTML forms and CGI to process user requests makes Web mapping possible. Users can request their own maps by specifying the layers and scales, and can also take advantage of the analysis function of the existing GIS program. However, a simple HTML viewer with forms is still limited in terms of user interactivity, especially when dealing with spatial objects. To create more interactive Web mapping and increase client-side processing and functionalities, we need alternative viewers that can facilitate the user to interact with the spatial objects directly. Therefore, dynamic HTML and client-side application such as plug-ins or help programs, Java applets, and ActiveX controls were developed to handle the spatial objects. In addition, CGI extensions are used instead of CGI as the middleware. These CGI extensions include Netscape's NSAPI, Microsoft's ISAPI and ASP, Javasoft's servlets, Allaire's ColdFusion and many others (Peng and Tsou, 2003). These CGI extensions generally perform better than the CGI scripts. CGI extensions overcome some of the major drawbacks of the CGI, such as low performance (a new process has to be created for every request), and statelessness. Rather than create a separate process and close the process of each request received, as the CGI does, the server-side CGI extensions stay in the memory and are always ready to service other requests. Furthermore, unlike CGI programs that run in different processes, the CGI extensions run server-side scripts in the same address as the Web server. Therefore, all the resources that are made available by the HTTP server program are also made available to CGI extensions. Most current commercial Web GIS programs are based on this model, that is, a dynamic view coupled with CGI extensions. ArcIMS, Geomedia WebMap, MapXtreme, and MapGuide all belong to this category.

The following section will discuss the commonly used CGI extensions Servlets and ASP.

b. *Servlets*

Servlets are modules of Java code that run in the Web server to extend the capabilities of the HTTP server. Since servlets are written in the highly portable Java language and follow a standard framework, they can be used independently of server types and operating systems. Currently, Servlet is more commonly adopted in the Internet Map Server (IMS) than Common Gateway Interface (CGI).

Servlets make use of the Java standard extension classes in the packages “javax.servlet (the basic Servlet framework) and javax.servlet.http (extensions of the Servlet framework for Servlets that answer HTTP requests)”. Servlets have access to the entire family of Java APIs⁵, including the Java Database Connectivity (JDBC) API⁶ to access enterprise databases. Servlets can also access a library of HTTP- specific calls and receive all the benefits of the mature Java language, including portability, performance, reusability and crash protection (Peng, 1999).

HTTP servlets are similar to CGI scripts and usually have the following major functions (Orfali et al., 1999):

- processing and/or storing data submitted by an HTML form;
- providing dynamic contents (e.g., returning the results of a database query to the client) ;
- managing state information on top of the stateless HTTP (e.g. managing many concurrent requests for the same map services);

⁵ The Java Application Programming Interface (API) is prewritten code, organized into packages of similar topics. For instance, the Applet and AWT packages include classes for creating fonts, menus, and buttons. The full Java API is included in the Java 2 Standard Edition download.

⁶ Java Database Connectivity (JDBC) API is a standard SQL database access interface.

- initiating a connection to a database and maintaining its connection across requests;
- providing an interface between Web users and application database.

Because of these features, servlets become good alternatives to the CGI programs. A servlet can be run by a servlet engine or servlet container just like an applet⁷ runs in a Web browser's Java Virtual Machine (JVM), which increase the server security.

c. Active Server Page (ASP)

An Active Server Page (ASP) is another server-side feature or Web server extension to receive and process the user requests on the Microsoft Internet Information Server (IIS). It is used to replace the CGI scripts on the Web server. An ASP is essentially an HTML page that includes one or more scripts (small embedded programs). These scripts are processed in a Microsoft Web server before the pages are sent to the user. The user accesses the ASP Web page on the Web browser. User requests are then sent to the ASP scripts on the server. When the server receives the ASP scripts, it then accesses data from a database, builds or customizes a HTML page then sends it back to the user. Therefore, the server-side ASP simply creates a regular HTML page or ASP file by processing the user request and/or extracting the data from the database on the server. ASP scripts can be written in either VBScripts or Jscript.

3.2.2.3 Interactive client viewers

Another decisive question for using GIS on the internet is the data-publishing format (vector or raster), which is used to transfer data to client. For data transmission to the client, map is converted into suitable raster or vector format.

⁷ An applet is a small Internet-based program written in Java, which can be downloaded by any computer. The applet is also able to run in HTML. The applet is usually embedded in an HTML page on a Web site and can be executed from within a browser. Java applets can run in a web browser using a Java virtual machine (JVM).

- The raster data model divides the entire study area into a regular grid of cells in specific sequence. When raster data is transferred, a standard Web browser without extension can be used, since Web browser displays GIF and JPEG.
- The vector data model uses discrete line segments or points to identify locations. Vector data needs to be handled by a standard Web browser with extended functionalities.

In general, the user gets more functionality with vector data, e.g. single objects can be selected directly or highlighted. An advantage in using vector data is the possibility of local processing. It is not necessary to contact the server per executed browser action, as some of the data can be stored in the local computer.

In order to make client viewers interact with maps and spatial objects, especially support vector data publishing, client viewers need to extend the capabilities of the standard web browser. Different interactive client viewers with various functions have been developed using different programs and technologies, from very simple HTML interfaces with forms to more advanced client-side applications such as plug-ins, ActiveX controls, and Java applets. The following three types of programming techniques normally used for building the interactive client viewers are introduced: GIS plug-ins, Java applets, and ActiveX controls.

a. *GIS plug-in viewers*

Plug-in viewers are small programs that run on the browser to extend the capabilities of Web browsers. Plug-in viewers can support both vector and raster data and images. The role of a plug-in viewer is also to allow the user to interact with geospatial data and map images so that the user can view maps, select features and make queries directly on the map. While plug-in viewers are small applications installed in the web browser, GIS helper programs can be large GIS applications (such as ArcView, MapInfo and Geomedia) that are located at the user's local machine. When the web browser detects a

GIS data type in an HTML page, it can automatically launch the respective GIS helper program.

Figure 3.5 illustrates the working process of a GIS plug-in viewer. When the web browser encounters a spatial data type (most GIS data types are unknown to web browsers), it will look for a plug-in that is associated with that data type and then load it. If a GIS plug-in or helper program is not available in the client computer, it has to be downloaded from the Web server over the network. Once the GIS plug-ins or helper program is installed, it then communicates directly with the GIS data stream from the server.

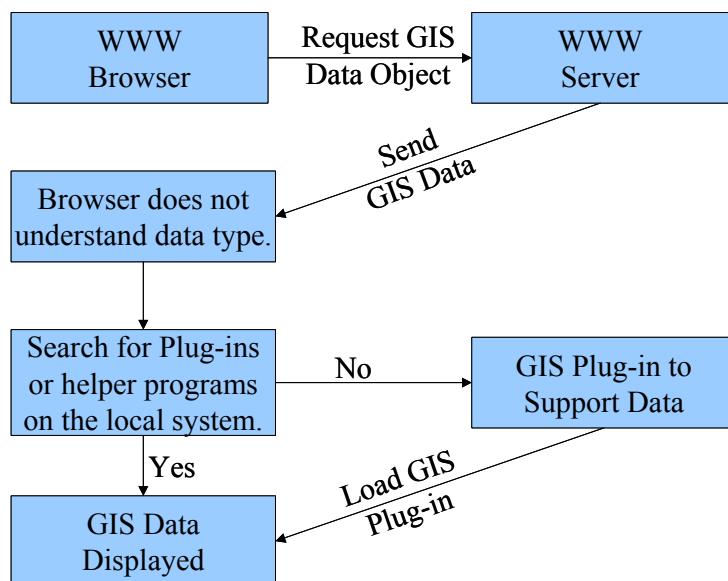


Figure 3.5: Work process of GIS plug-ins (Peng and Tsou, 2003)

b. Java applets viewers

Java applets are executable java codes that are downloadable from the server and executed on the client. Java Applets initially reside on the Web server. They are referenced inside an HTML document and executed by a Web browser at the client side. Figure 3.6 below illustrates the process of loading a Java applet viewer.

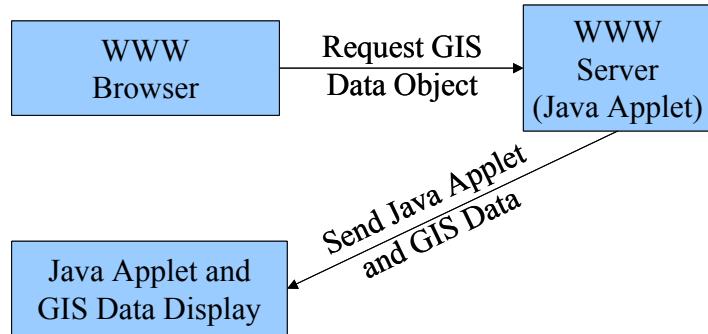


Figure 3.6: Work process of Java applets

Java viewers use a Java applet for displaying spatial information and handling requests. The Java viewer usually incorporates map-rendering and data processing functions in Java applet so that the user can render maps, make queries, and do other processing inside the viewer without going back to the map server.

Java viewers can support both vector data and raster images. With raster images, the Java applet is simply a fancy display of map images similar to the HTML viewer. The user interacts with images, but all logical processing such as map rendering and query processing is conducted at the server. With vector data, it is streamed to the Java viewer from the data server, and temporarily cached on the client machine, so that the user can interact with it. If the user requests data that is not in the cache, the request is sent to the server to either retrieve more data or process data residing on the server.

In addition to Java applets that work with a web browser, a whole java-based viewer created by Java Beans⁸, can also work as an independent viewer or a mobile client agent.

Many GIS vendors are developing Java-based viewers, such as ESRI's ArcIMS Java viewer.

⁸ Java Beans are a specification developed by JavaSoft that defines how Java objects interact. An object that conforms to this specification is called a JavaBean, and is similar to an ActiveX control. It can be used by any application that understands the JavaBeans format. The principal difference between ActiveX controls and JavaBeans are that ActiveX controls can be developed in any programming language but executed only on a Windows platform, whereas JavaBeans can be developed only in Java, but can run on any platform.

c. *ActiveX viewer*

ActiveX viewers use ActiveX controls to program the viewer. ActiveX was developed by Microsoft to “activate the internet”. It builds on the Object Linking and Embedding (OLE) technology standard to provide a common framework for extending the capability of Microsoft’s Internet explorer (Chappell, 1996).

An ActiveX control is a modular piece of software that performs tasks and communicates information to other programs and modules over the internet via OLE. ActiveX controls are general components that can be plugged into any application. There are many types of ActiveX controls, each with different capabilities and functionalities, and can be used just like the plug-ins and Java applets within Web pages.

While Java applets are in the form of byte codes and have to run inside a Java Virtual Machine (JVM), ActiveX is native binary code and operates directly inside the computer’s native operating system. ActiveX controls can take full advantage of the local computer’s computing power and have direct access to all local platform functionality such as local files, local memory, and other system resources that are unavailable to a Java applet. Therefore, compared with a Java applet, ActiveX components have better performance (Shan and Earle, 1998).

However, this performance advantage also carries a price – portability and security concerns:

- i) ActiveX controls are compiled to the native executable format, requiring different versions of ActiveX controls for all platforms. ActiveX controls are therefore platform dependent. This is in contrast with the Java applets, which are platform independent.
- ii) As ActiveX controls are able to access local files and other local resources, they present potential danger for users’ local computers. Someone could write a vicious ActiveX code that could erase all local files.

Intergraph's Geomedia Webmap adopted ActiveX controls for the client viewer development.

3.2.2.4 GIS server

Currently, there are over 30 different GIS server packages or solutions available from different GIS vendors. Thousands of Web GIS servers operate in the world. However, different types of mapping tasks require different types of Web GIS servers. A GIS professional or GIS manager might be overwhelmed with different choices of Web GIS software programs. Choosing the right Web GIS software for specific GIS application is truly a major challenge.

From a manager's perspective, major considerations will be the price of Web GIS server packages, the training of technical staff, and the maintenance of Web servers. From a GIS professional's perspective, the focus of Web GIS servers will be the functions provided by the server, the system requirements, the implementation procedures, and GIS database connectivity (Peng & Tsou, 2003).

The following general questions usually are asked at the very beginning:

- Which internet GIS program approach to use?
- Is it server-side or client-side?
- Which server platform can carry out needs and tasks?
- Which client viewer is suitable: an HTML or Java viewer?
- How stable is the system's performance?

The following discussion will focus on comparing two of the most popular WebGIS commercial software packages: ESRI ArcIMS 9.0 and INTERGRAPH GeoMedia WebMap 5.2.

a. *ESRI ArcIMS 9.0*

ESRI, a world leader in GIS, was first to apply Web GIS capabilities as an extension to the GIS desktop. ArcIMS (Internet Map Server) has since been designed specifically to easily create and publish maps, data and metadata on the Web.

ArcIMS is a multi-tier architecture consisting of the presentation, business logic and data storage tiers, in addition to a set of applications for management. Figure 3.7 below shows the architecture and components of ArcIMS (ESRI, 2004):

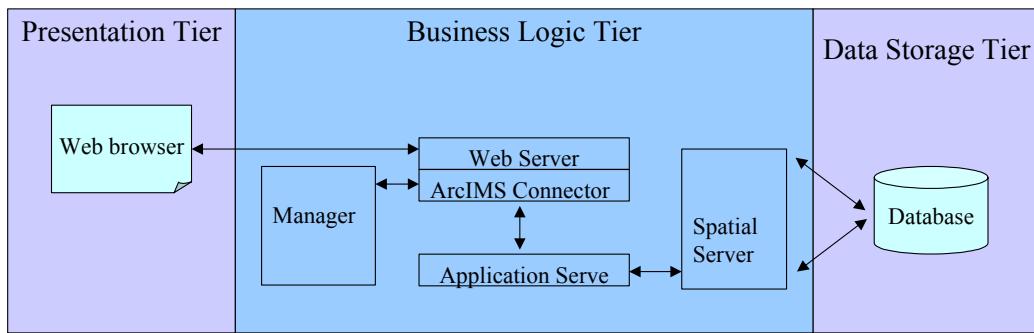


Figure 3.7: ArcIMS Architecture (ESRI, 2004)

i) *Presentation tier*: This consists of client side components, namely the ArcIMS Viewers that are used to send requests to the web server and to view the maps and data.

ArcIMS provides four types of client viewers: Java Custom, Java Standard, HTML Standard and HTML Custom. The Java viewers, which can support Image, ArcMap Image, and Feature Services, contain more client-side processing capabilities. The HTML viewer only supports Image and ArcMap Image services but custom implementations can take advantage of ActiveX, ColdFusion, Java Connectors and .NET Link, etc.

ii) *Business logic tier*: This consists of the server side components, including the Web server, ArcIMS Application Connectors, ArcIMS Application Server and ArcIMS Spatial Server.

- *ArcIMS application connectors*

When the Web Server receives a request, it is handed off to one of the ArcIMS Application Connectors, which translates the client request into ArcXML. They include: ArcIMS Servlet, ColdFusion, ActiveX, ArcIMS Java and .NET Link connectors.

- *ArcIMS application server*

Written in Java, this component tracks client requests for information and distributes them to the appropriate ArcIMS spatial server.

- *ArcIMS spatial server*

It processes requests for maps and attribute information. The seven server types which comprise the Spatial Server (Image, Feature, Query, Geocode, Extract, Metadata and ArcMap servers) are accessed by four ArcIMS service types: Image, ArcMap Image, Feature and Metadata services.

- *ArcIMS manager*

It provides access to components in the business logic tier for authoring maps, administering ArcIMS services and designing Web site. It combines IMS Author, Designer and Administrator into one user interface.

iii) Data storage tier: This consists of all data sources available for use with ArcIMS.

Besides the components mentioned above, the Web server, Java Virtual Machine (JVM) and servlet engine are supporting components necessary to successfully run ArcIMS. These components are not included and must be supported for use with ArcIMS.

b. *INTERGRAPH GeoMedia WebMap Professional 5.2*

Geomedia Webmap 5.2 Professional was introduced by INTERGRAPH in 2004, and still follows the typical three-tier architecture as shown in Figure 3.8 below:

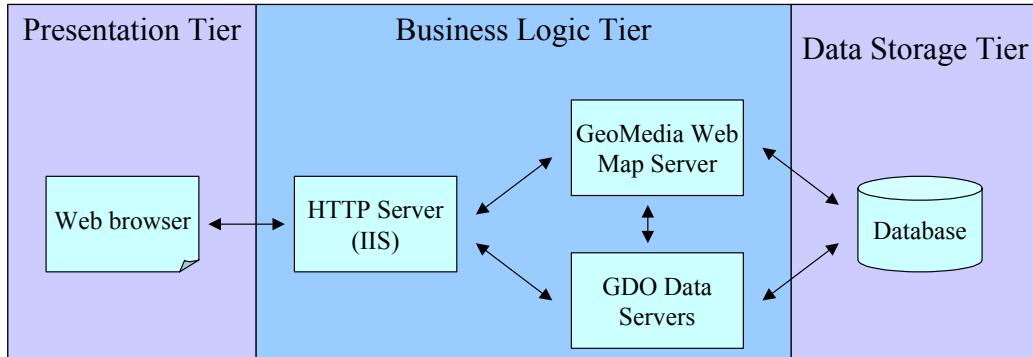


Figure 3.8: GeoMedia WebMap Architecture (Francica, 2004)

i) Presentation tier:

The presentation tier is a Web browser with a client viewer, an ActiveX control component for Internet Explorer, and a plug-in component for Netscape. Here the user interacts with the Geomedia Webmap. This client side viewer provides both vector and raster viewing. It has built-in client-side functionality for users to perform GIS analysis at the client side. If JPEG images are published, dynamic HTML may be used to give more client-functionality.

ii) Business logic tier:

The business logic tier which processes user requests and connects database is comprises of 3 components, viz,

- a HTTP server, specifically Microsoft's IIS The role of IIS is to communicate with the Web browser, including receiving user requests from the browser and sending output to the browser client. It also acts as a middleware to transport user requests to the Geomedia WebMap Sever and GDO server.
- a Geomedia WebMap server The Geomedia WebMap Sever is a map server that processes user requests and produces maps.
- a Geographic Data Objects (GDO) server. The GDO data servers are created to communicate with different data sources with different data formats (Francica, 2004). A specific GDO data server is developed for

every data format so that Geomedia WebMap can support and retrieve any data format without pretranslation.

iii) Data storage tier:

The database tier stores data with their original data formats and projections in their sources, and can be at one or more locations. The data can be retrieved and combined using the GDO data servers.

c. Comparative Summary

Table 3.1 below summarizes the differences between ESRI ArcIMS9.0 and Intergraph Geomedia Webmap Professional 5.2.

	Advantages	Disadvantages
ArcIMS 9.0	<ul style="list-style-type: none"> • Can provide service with or without a required plug-in download • Provides Java and HTML viewer, but customers can also build their own using ASP, ActiveX controls ,ColdFusion, and Java • Easily integrated with other ESRI GIS software 	<ul style="list-style-type: none"> • Must first create an Image or Feature Service • Requires middle-ware XML translation
Geomedia WebMap 5.2	<ul style="list-style-type: none"> • Compatibility and interoperability with other file formats from various databases without conversion. • Provides raster and vector viewing, It also provide rendering and manipulation in the browser. 	<ul style="list-style-type: none"> • Need ActiveX control component for Internet Explorer and plug-in For Netscape Navigator. • Customization of applications can add time and cost to an initially expensive project.

Table 3.1: Comparative Summary of ESRI ArcIMS 9.0 and INTERGRAPH Geomedia Webmap 5.2

An advantage of ArcIMS is that it can provide service with or without a required plug-in download. Java viewer needs Java2 plug-in, but the HTML viewer doesn't need any plug-in. The HTML viewer is the most likely choice for Web sites designed for large audiences and generalized functionality. But in Geomedia Webmap, plug-ins are required by the client viewers in order to see the maps.

A second advantage is that ArcIMS, as a member of the ESRI family, can be easily integrated with other ESRI GIS software, such as ArcGIS, MapObject-Java.

The advantage of the Geomedia Webmap is that it has high compatibility and interoperability with other data formats from various databases without conversion. Unlike ArcIMS, which requires data to be pre-processed, to generate an image or feature service in advance. Further more, it requires using ArcXML as the translator for all the data communications; Geomedia Webmap, data has been taken as it is from multiple locations in various formats.

Geomedia Webmap provides both raster and vector viewing. It can provide rendering and manipulation in the browser. But it is difficult to customize the client viewer in the initial phases as not many documents are available. So for specific applications, this may involve more time and costs. In comparison, ArcIMS provides many methods and documentation, such as ASP, ActiveX controls, ColdFusion, and Java, for the developer to build his/ her own viewer.

3.3 CHAPTER SUMMARY

In this chapter, the evolution process of web GIS techniques was reviewed. The major techniques involved in the development of web server, interface program, web GIS server and client viewer were introduced and compared. This review provides the foundation for the prototype system design and implementation, which will be addressed in detail in Chapter 4.

CHAPTER 4: PROTOTYPE SYSTEM IMPLEMENTATION

In this chapter, a prototype for a web GIS system for Aboriginal land management is developed. The system design and implementation are discussed in detail, and technical and cultural considerations are addressed.

4.1 GIS DESIGN PROCEDURES

The methodologies of designing a GIS tool for application involve the “construction of spatial and non-spatial databases, development of information processing capabilities, installation of the appropriate computer hardware and software, and implementing the organizational, procedural, and staffing changes needed to operate and use the system successfully” (Huxhold and Levinsohn, 1995).

The design of GIS incorporates the following components (Huxhold and Levinsohn, 1995), which is illustrated in Figure 4.1 below. Generally speaking, the first stage in designing a GIS system is to determine user and data requirements and to establish system objectives. The second stage is the development of a prototype, which includes design of the user interface and functionalities. The third stage is the evaluation and further refinement of the functionalities and operation of the prototype and final implementation of the GIS tool or application. At this stage, changes in staffing and training needs are incorporated. Furthermore, legal issues such as the liability, intellectual property and security of information need to be considered.

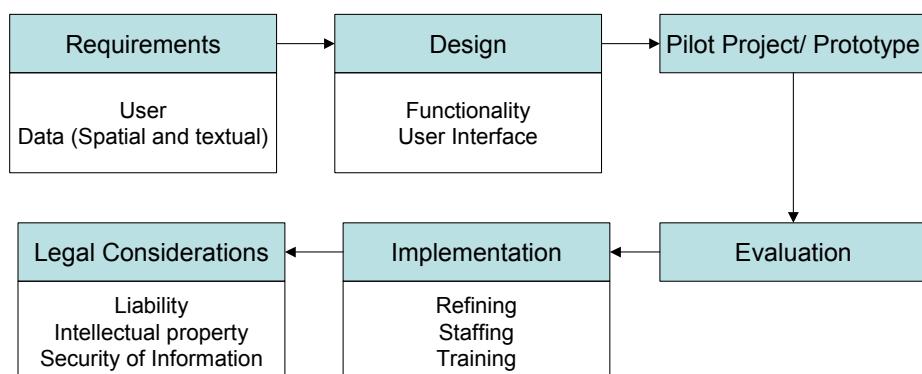


Figure 4.1: GIS System Design Procedure (Huxhold and Levinsohn, 1995)

To achieve a successful web GIS implementation it is necessary to consider the implementation as a process rather than a step. The implementation should also respect the available technology and the application requirements.

4.2 SYSTEM REQUIREMENTS ANALYSIS

Determining user requirements is one of the basic and fundamental components of GIS design as each project is unique and each user has a distinct view of the system and the spatial information produced by it.

The potential users of this web-based GIS system include remote First Nation communities, land managers, land developers and various academic and governmental agencies. The purpose of this Web GIS prototype is to provide the basic spatial information, land tenure information of First Nation land, together with other planning and policy information. The required functions will be browsing, retrieving spatial information, conducting queries, performing location-related analysis as well as generating the “what if” scenarios to assist decision-making process.

In order to meet user requirements, the fundamental part requiring special attention is the data source. Currently, the data source (both spatial and textual data) for First Nations is in either analogue or digital format. Several issues are associated with the collection of spatial data and the conversion of analogue to digital formats. Understanding the sources of data and the limitations imposed will assist in better application of data and ultimately better graphical representation and decision-making capabilities. Many users are unaware of the limitations of digital spatial data due to poor metadata documentation resulting in unreasonable or inappropriate decisions. Data collection, and in particular, the data source used in this project will be described in detail later.

4.3 PROTOTYPE DESIGN AND IMPLEMENTATION

Prototype implementation involves designing a system based on user requirements, and testing the feasibility of the project. In this project, Yukon Territory in Canada was chosen as the study area, mainly because of the availability of data.

In general, the steps for a prototype system implementation include: data collection, data pre-processing, database design and populating, system architecture design, user interface design and functionality development.

4.3.1 Data Collection

4.3.1.1 Spatial data collection

Numerous governmental websites in Canada provide spatial data for public use. For this research, digital spatial data was collected from different sources: Yukon Government Geomatics Department Website (www.geomaticsyukon.ca), GeoConnections (www.geoconnections.org), Geogratis (geogratis.cgdi.gc.ca), etc.

The data used in this research are base mapping and First Nation related data:

- a. Base mapping includes administrative boundary, cities and towns, roads, rivers and lakes.
- b. First Nation related data includes:
 - i) *Traditional territories* data which shows the traditional boundaries of Aboriginal communities.
 - ii) *Land settlement data* which provides ownership information for land parcels within the First Nation territories. E.g. “Crown land” means that the land belongs to the crown. Under the Yukon Umbrella Final Agreement (UFA), “Category A” means that First Nation owns both surface and mineral rights, while “Category B” means that First Nation owns only the surface right.
 - iii) *Protected area*

- iv) *Game management or wildlife management area*, is the area set for the protection, propagation, management, preservation and controlled harvest of wildlife. This data provides information about the animals usually hunted by the First Nations.
- v) *Data related to mining claims*, which shows the area where the different mining claim occurred. From a legal perspective, “mining” or “placer mining” includes every mode and method of working whereby earth, soil, gravel, or cement may be removed, washed, shifted, or refined or otherwise dealt with, for the purpose of obtaining gold or other precious minerals or stones. Mineral exploration and production have been the most significant economic activities in the Yukon. Different legal requirements exist for different mining types, such as Placer mining, quartz mining etc. Different lease may also apply with the mining site. Usually the mining site boundary needs to be surveyed and recorded. So the mining claim information together with various geographic data will be very valuable for the people who are interested in placer mining activities in Yukon.

Figure 4.2 shows the summary of the various datasets used in this research:

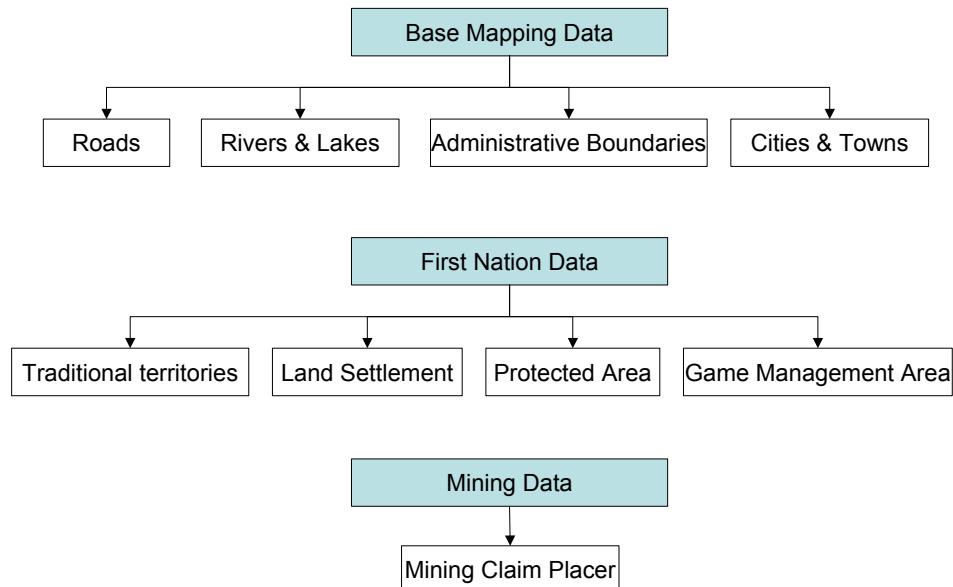
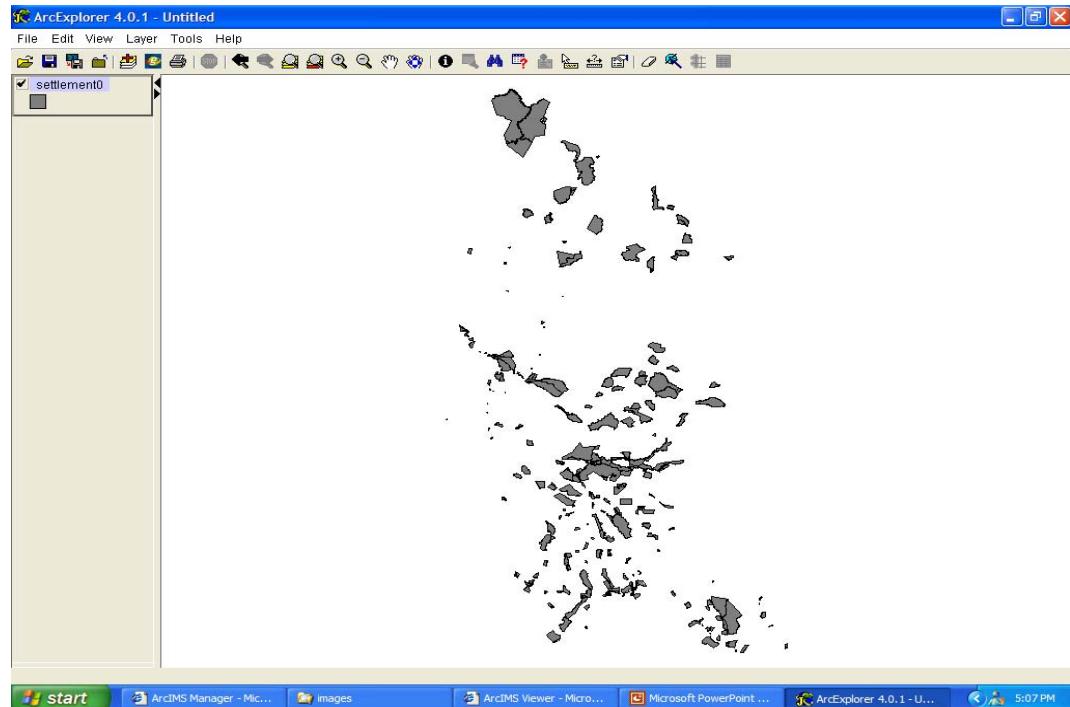
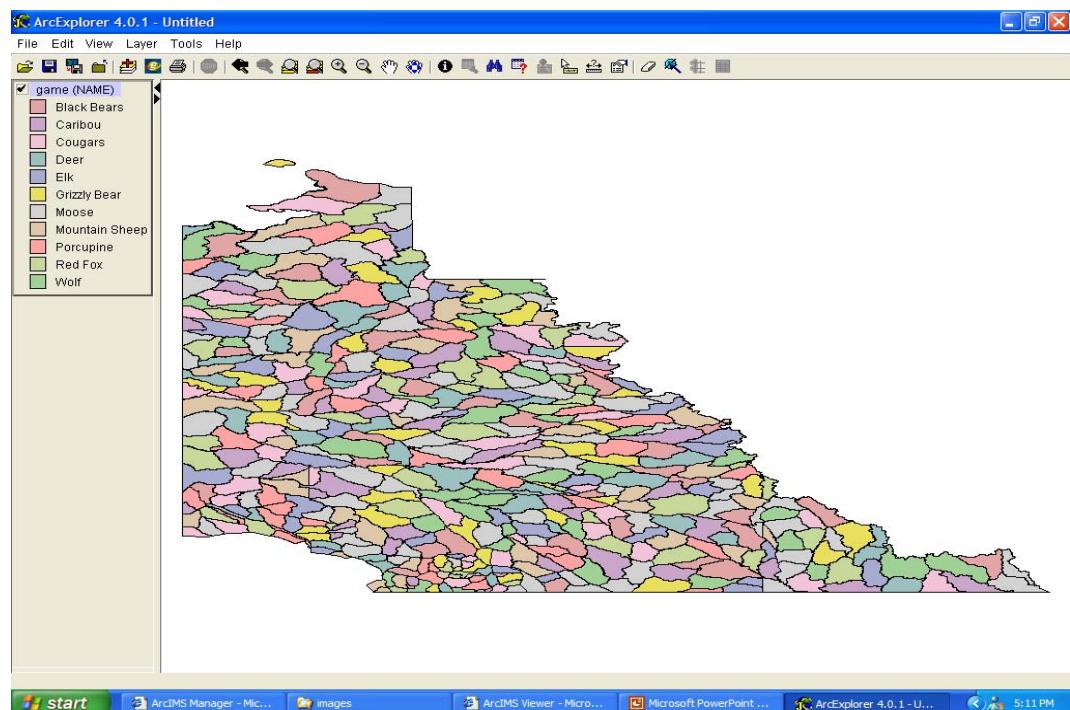


Figure 4.2: Spatial Datasets used in Research for Yukon Territory

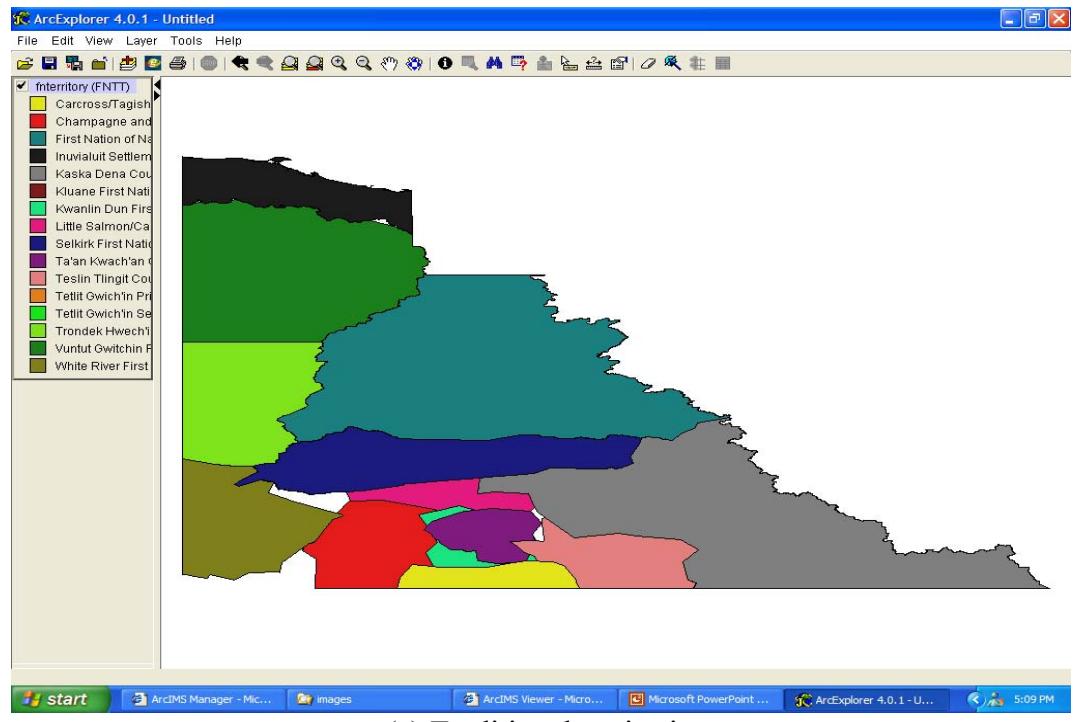
Figure 4.3 shows snapshots of various spatial data acquired before data processing:



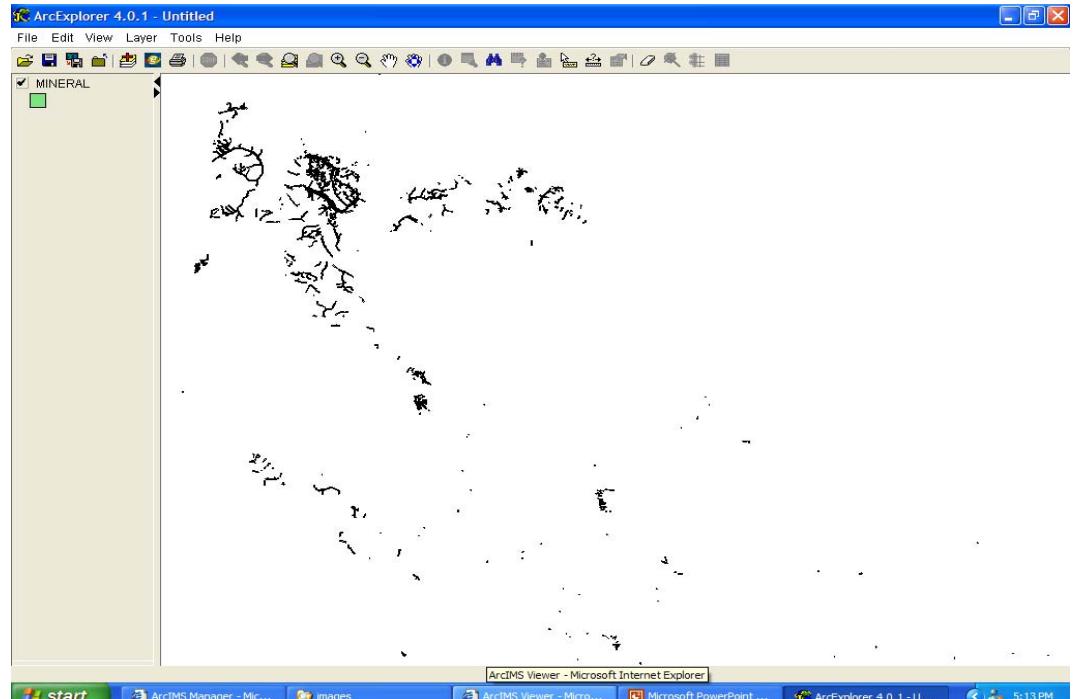
(a) Land Settlement Data



(b) Game management Area



(c) Traditional territories



(d) Mining claim placer

Figure 4.3: Snapshots of Spatial Data

4.3.1.2 Regulation and legal information

Another important dataset is the land use procedure and regulations information. In this prototype design, placer mining is taken as an example. Related information was collected from various sources, including the Yukon Placer Mining Act, and the Yukon government website. Table 4.1 below provides general information about the various approval processes regarding placer mining in Yukon.

Class	Type of Approval	Fees (YPMLUR Schedule 2)	Approval Time	Approval Expiry
I	follow Operating Conditions	no fee required	-	one year
II	Notification and Mining Land Use Approval	\$100	25 days	one year
III	Operating Plan and Mining Land Use Approval	under five years \$250 over five years \$500	25 days	up to ten years
IV	Operating Plan Type B Water License ~	under five years \$250 over five years \$500	up to and exceeding ten months	up to ten years

Table 4.1: General Approval Information for Different Types of Placer Mining

Detailed steps for claiming placer mining process is shown in Table 4.2.

No.	Description
1	Go to the Mining Recorder's Office (MRO) in Whitehorse, Watson Lake, Dawson City or Mayo to find out if the area is available for staking and how to stake a claim. To obtain geographical information for researching your project, go to Exploration and Geological Services. For a review of compliance guidelines, visit Mining Inspection.
2	Stake your claim.
3	Fill in and submit your application with the appropriate fees to your district MRO.
4	If your claim application is approved, define your operating class as a I, II, III or IV and follow appropriate steps for each.
5	If your project does not exceed the class I criteria, simply follow the operating conditions. You do not need to obtain approval.
6	For class II, a notification application must be completed and submitted to Mining Lands. The notification is reviewed by the Chief of Mining Land Use and you will be contacted if any further information is needed.
7	Submit the appropriate operating plan to the Chief of Mining Land Use. Class III requires you to apply for Mining Land Use approval at your district MRO. A separate application is needed for class IV. An environmental assessment is done under the CEAA before your class III or IV project can be approved.
8	Apply for any other approvals you may need to operate your claim, remembering that if you have a class IV operation, you must apply for Type B Water License through the Yukon Territory Water Board.
9	Once you receive all the necessary approvals, you can begin your operation.
10	Inspection of your site will occur approximately three times a year by Mining Inspection which will ensure compliance with the operating plan and water license (if issued). Refer to the Inspection section of this guide for a detailed overview of inspection procedures.
11	Although reclamation efforts should be ongoing, once your project is completed a final inspection will be carried out by Mining Inspection.
12	At the end of your project (upon request and if all conditions of the License and MLU approval are met) a Certificate of Completion is issued on class III and IV approvals by the Chief of Mining Land Use.

Table 4.2: Steps for claiming placer mining process (INAC, 2002)

All placer mining application information above has been included in the prototype website. This is an example where legal information can be incorporated to enrich the spatial database. Integrating such kind of information is useful for the land developer in order to minimize time to get the information to support the application process, and also for Aboriginal land managers and the general public as a whole.

4.3.2 Spatial Data Processing

As collected spatial datasets were obtained from various sources, they varied in format, map projections, and coordinate systems. E.g. with data format, some data was in the form of interchangeable files (.e00), others in coverages, and in Shapefiles. It is important to note that a Shapefile is the currently accepted format in ESRI software products, therefore all datasets have been converted into Shapefile format.

The lack of metadata has made data processing a challenge. E.g. the map projection of some of the layers was unavailable, resulting in non-fit of the boundaries of the layers, after overlaying all data. Different projections were tested, and distinct points along the boundaries were used to check whether such projections were correct. An assumption made was that the correct projection would result in identical layer boundaries. After identifying the correct projection, all data were re-projected onto one common system. The Parameters for Yukon Albers Projection, which were used as the common projection, are shown in Figure 4.4:

Projection: Albers Equal Area Conic
Datum: NAD83, Spheroid: GRS80
Central Meridian: 132°30'00" W (-132.5 in decimal degrees)
Projection Origin: 59°00'00" N
1st Standard Parallel: 61°40'00" N (61.6666667 in decimal degrees)
2nd Standard Parallel: 68°00'00" N
False Easting: 500,000 m
False Northing: 500,000 m

Figure 4.4: Parameters for Yukon Albers Projection

4.3.3 Spatial Database Design

After data collection and processing, a spatial database was designed then populated. Spatial database is the foundation for any web-based mapping service. In the following section, some basic concepts about spatial databases are introduced and the implementation of spatial database for the prototype system then discussed.

4.3.3.1 Spatial database basics

The spatial database is a relational database that stores spatial data. At its most basic level, the spatial database is a container for storing spatial and attribute data and the relationships that exist among them. In a spatial database, vector data (e.g. point, line, and polygon features), tabular data, and raster data formats can work together as an integrated system using rules, relationships, and topological associations. In other words, the spatial database allows one to create a complex data model for representing the real world.

There are two types of spatial databases: personal and multiuser.

- a. *Personal spatial database* (shown in Figure 4.5) has the .mdb file extension (a format used by Microsoft Access) and can be read by multiple users at the same time, but edited by only one user at a time.

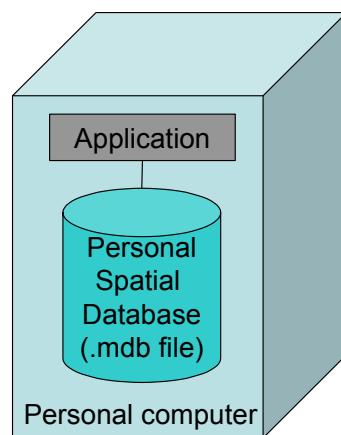


Figure 4.5: Personal Spatial database

b. *Multiuser spatial databases* are suitable for large workgroups and enterprise GIS implementations, and can be read and edited by multiple users at the same time. As shown in Figure 4.6 below, multiuser spatial databases require ArcSDE™ and a DBMS (database management system) such as IBM DB2, Informix, Oracle, or SQL Server. ArcSDE provides the interface that allows one to store and manage spatial data in a DBMS.

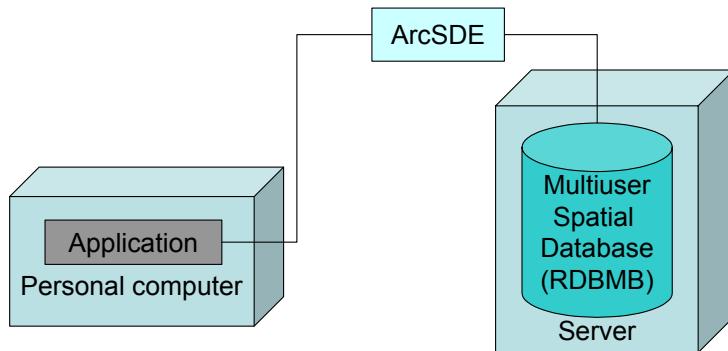


Figure 4.6: Multiuser Spatial databases

In this prototype project, due to limited resources regarding hardware and software, personal database was selected for its simplicity in data management. However, it can be extended to multiuser spatial database.

4.3.3.2 Spatial database implementation

The challenge in spatial database design is to link many different types of data. Some were structured data that can be normalized and stored as records in the database, while others were unstructured (such as regulation and legal information) that cannot be represented as fields in the database. To solve this problem, a mixed storage method was used. This involved extracting some information from the data and incorporating it into the database as records to become structured data. Other information has rich semantic aspects, but is not easily incorporated as table fields. Thus, they are kept intact and referred to through hyperlinks. These hyperlinks are easily incorporated into the database system as extra fields. This is very important to ensure that pictures and hypermedia data

can be integrated into the system. Chapter 5 will cover the creation of hyperlinks within the spatial database.

In this prototype, attribute tables were redesigned as shown in Figure 4.7 below:

Roads	Road_ID	Geometry	Name	Type
Places	Place_ID	Geometry	Name	Population
First Nation Territories	Territory_ID	Geometry	Name	Hyperlinks
Games	Game_ID	Geometry	Name	
Settlements	Settlement_ID	Geometry	Name	Category
Mining	Mining_ID	Geometry	Claim_Type	
Mining license renewal	Mining_ID	Renewal_Number	Start_date	End_date

Figure 4.7: Sample of Attribute Tables of Web-GIS Prototype System

In summary, the following fields were added and populated from different sources:

- “Hyperlinks” in the Aboriginal Traditional Territories table, to create a link to unstructured information.
- “Category” in the Settlements table, to provide the type of land ownership. Refer Figure 4.3a.
- “Claim type” in the Mining table and “Start_date” and “End_date” in the Mining license renewal table. “Start_date” and “End_date” are added as extra fields to include temporal aspects of the mining placer claims.

It should be noted that the “Geometry” field in the tables shown above includes shape, coordinates in addition to length (for line features) and perimeter and area (for polygon features).

The original tables were edited and cleaned by removing empty and redundant fields to ensure a complete, integrated and efficient database.

4.3.4 Prototype System Architecture Design

As discussed in Chapter 3, the necessary components for the web GIS construction include client side (typically a Web browser with extension); and server side, which consists of a Web Server, interface program, Web GIS software and Database. The functions and technologies that apply to build these components were also discussed in chapter 3.

The advantages and disadvantages of the server side application solutions and client side application solutions will now be examined before introducing the architecture used in the prototype.

4.3.4.1 Thin Client Architecture (server side applications)

In a thin-client system, the clients only have user interfaces to communicate with the server and display the results. All processing is done on the server, as shown in Figure 4.8.

The server computers usually have more power than the client, and manage the centralized resources. As mentioned in chapter 3, on the Web server side, there are some possibilities to link the GIS to the Web Server through interface program, such as Common Gateway Interface (CGI), Active Server Pages (ASP), Java Server Pages (JSP) and Java-Servlet (Helali, 2001).

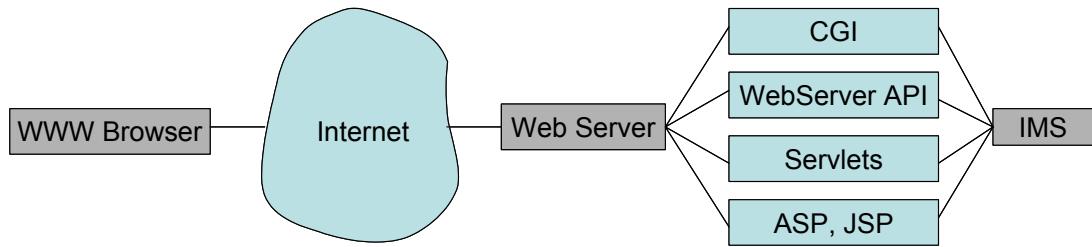


Figure 4.8: Server Side Applications

In the thin-client architecture system, the user on the client side does not need any knowledge about the linkage of the server side, but the system administrator or application developers should be familiar with these techniques.

The *advantages* of this model, which is derived from Data Base centralization, are:

- Central control
- Easy for data maintenance and updating
- Generally cheaper

Conversely, the *disadvantages* of this model are:

- Slow response time: each request is sent to the server for processing, and return of the result. Therefore, longer response time is expected.
- Less interactive: limited applications and browser abilities are available to the client
- Vector data do not appear at the client side: browsers without additional plug-in cannot read vector files.

4.3.4.2 Thick client architecture (client side applications)

As mentioned in the chapter 3, a Web browser can handle HTML documents, and embedded raster images in the standard formats. To deal with other data formats like vector data, video clips or music files, a browser's functionality has to be extended. To

overcome this problem the client side has progressed from simple document displaying to more interactive applications. The technologies provided for building interactive viewer include HTML forms and CGI, Java applets and plug-ins, ActiveX controls (Figure 4.9) (Byong-Lyol et al, 1998).

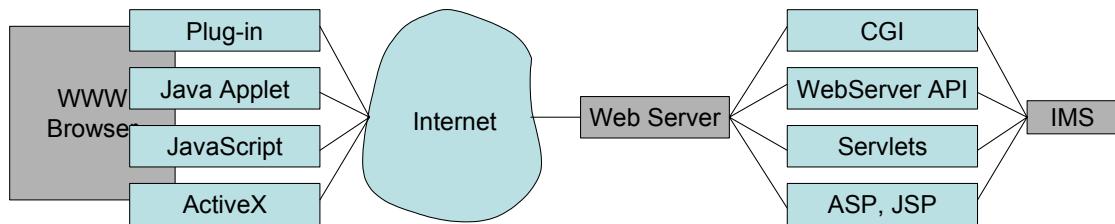


Figure 4.9: Client Side Applications

Major advantages of this model are:

- Document/graphics standards are not required
- Vector data can be used
- Image quality not restricted to GIF and JPEG
- Modern interface is possible; it is not restricted to single-click operations

The disadvantages to Client Side GIS

- Users need to obtain additional software to install in the client viewer.
- New users need to be familiar with IT technology to understand what is needed to extend the capability of the browser in order to display some of the information.

4.3.4.3 Hybrid system architecture design

From the comparison, both thin and thick-client systems have both advantages and drawbacks. In this project, ArcIMS software is used as the map server, so the system architecture is fixed by the ArcIMS to some extent, as shown in the prototype system architecture (Figure 4.10). However, the developer still has the flexibility to decide how to divide the function modules at client and server side as ArcIMS provides different types of client viewer: Java Standard, HTML Standard, Java Custom, HTML Custom. The HTML viewer is a relatively thin client, and the Java viewer is a relatively thick

client. For customized types of viewers, ArcIMS can provide this using JavaScript, Java Beans, ActiveX control, Coldfusion. The type of interface program used to connect the web server and the Internet Map Server (IMS), and developers preference, will determine the choice of appropriate programming language selected.

For our specific application, a customized HTML viewer was chosen for the following reasons. Neither client-side nor server-side application is suitable for this prototype. It is because this prototype requires some functionalities at the client side to increase the interactivity, and as this website is for general public, it is more convenient to provide the client viewer to the user without downloading or installing anything, such as Java applets and plug-ins.

In the prototype system design, it uses the hybrid system architecture by taking both the advantages of the server side application and client side application.

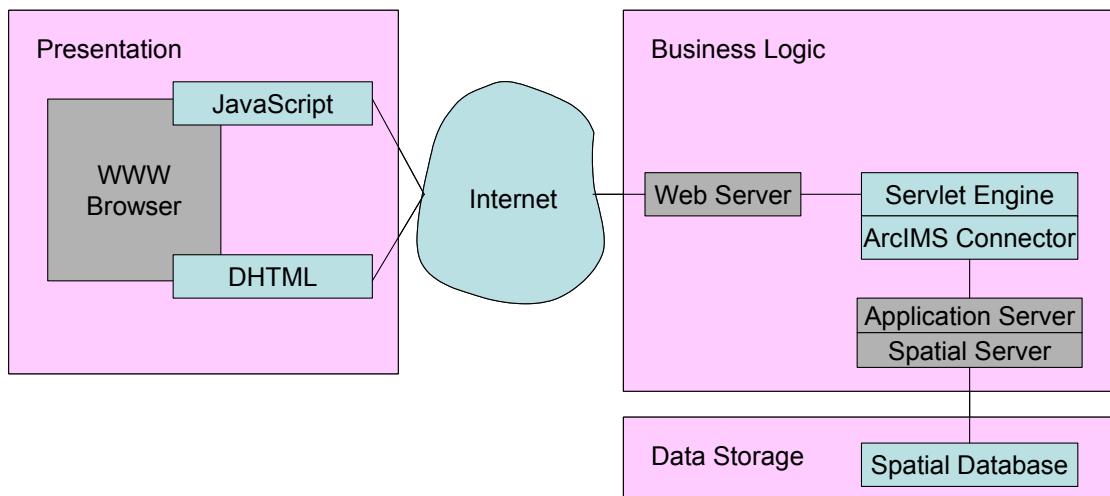


Figure 4.10: Prototype System Architecture

As shown in Figure 4.10 above, this prototype system used a three-tier architecture consisting of presentation, business logic and data storage tiers. The business logic follows the architecture of ArcIMS. The function of each component was discussed in Chapter 3. In the prototype implementation, Apache 2.0.42 is installed as the Web Server, while Tomcat 4.0.5 is installed as the Servlet Engine. ArcIMS connector is used in this

project as the interface program. At client side, the HTML viewer is developed through customization using Dynamic HTML and JavaScript.

The normal HTML viewer is static or non-interactive for Web mapping. After a page and map is loaded in the browser, they become static. The only thing a user can do in a static web page is:

- If there is a link, click on it
- If there is a form, fill it out and click on the submit button

In both cases the response is slow, as the page appears after a complete round trip from the client to the server and back. This is where DHTML comes in.

DHTML makes plain HTML dynamic by using Client-side Scripting, Document Object Model (DOM) and Cascading Style Sheet (CSS). The difference between HTML and DHTML is that DHTML page can change even after the page has been loaded into a browser. An area of map can change color when the mouse moves over it or a new popup window appears. The DHTML viewer has three advantages over the static HTML viewer:

- The web page and the map can respond to user actions instead of sending every request to the server for processing. It greatly reduces the volume of data to transfer.
- The response is immediate (without making a around trip to the server) and it greatly reduces the response time.
- No special plug-ins are needed to install in that browser, which saves the trouble for the user to look for correct software to install.

DHTML makes static HTML page dynamic by using the following:

- *Client-side Scripting*: Client-side scripting uses JavaScript and VBScript to change HTML. VBScript works only in Microsoft Internet Explorer, while JavaScript works in all browsers.
- *Document Object Model*: The DOM is the hierarchy of elements that are present in the browser. This includes browser properties such as the browser's version number, window properties (such as location of the window) and HTML elements (such as tables), e.g., you can point to a specific check box in a specific form on the webpage and check it. Thus by exposing the elements and their properties in the scripts, the browser enables the user to manipulate them. The DOM also specifies the events that are triggered as a result of a user action. For example, the DOM defines an event “OnMouseOver” for a link. This enables you to write a script for something to happen when the user passes the mouse over the link.
- *Cascading Style Sheet (CSS)*: CSS allows users to control the rendering of a web document without compromising its structure. It allows users to set style values in a way that can be easily manipulated by a scripting language. It uses common desktop publishing terminologies, which allows designers to make use of its features. It addresses many of the problems of old-style HTML. With CSS, style information can be centralized, resulting in increased power and flexibility. With cascading style sheets, designers are able to use tags to reference a style rather than describe it each time. When a style needs to be changed, only the referenced declarations need to be changed, not all of the instances where it is used. By changing the CSS properties of a page element (such as color, position or size), it is possible to change almost anything in a webpage.

JavaScript and Dynamic HTML programming increase the cartographic functionalities of the website. So it is between the server side application and client side application, but it avoids using plug-ins (such as Java plug-ins) at the client side. The detailed interface implementation will be explained in detail in Section 4.4.1.

4.3.5 Website Setup

The basic template of the website is first set up through ArcIMS, then user interface and functionalities are developed through customization.

Basically, creating an ArcIMS Web site is a three-step process (ESRI, 2004):

- a. Use ArcIMS Author to create a map to be displayed on a Web site. In Author, the different geographic layers and symbology are added and organized according to the developers' choice. When completed, the map is outputted as a text file with an AXL extension. In the ArcIMS documentation, this file is referred to as the map configuration file and is the foundation of any kind of map service.
- b. Once the map configuration file is created, it is registered for publishing on the internet, using ArcIMS Administrator. This step is called starting an ArcIMS Service. The map configuration file generated using Author is the input to an ArcIMS Service. When a map server receives a request for an ArcIMS Service, the ArcIMS Service follows the instructions in the map configuration file and sends the data to the client.
- c. Once the ArcIMS Service is created and started in Administrator, the next step is to design a site for public display. ArcIMS Designer has a wizard interface that guides you through the process of creating HTML pages and supporting files.

4.3.6 User Interface Development

The HTML viewer is best for ArcIMS Web sites that incorporate only one Image Service. If the Web site does not have a Feature Service, the HTML viewer is probably the most efficient and user-friendly choice, as no plug-in is needed at the client side.

As earlier discussed, the customized HTML viewer is developed through DHTML and JavaScript, and contains a set of HTML and JavaScript files. The HTML (.htm) and JavaScript (.js) files form the foundation of the HTML viewer. Figure 4.11 shows all the

files that have been created for the interface; and Figure 4.12 shows the corresponding frame layout in the viewer.

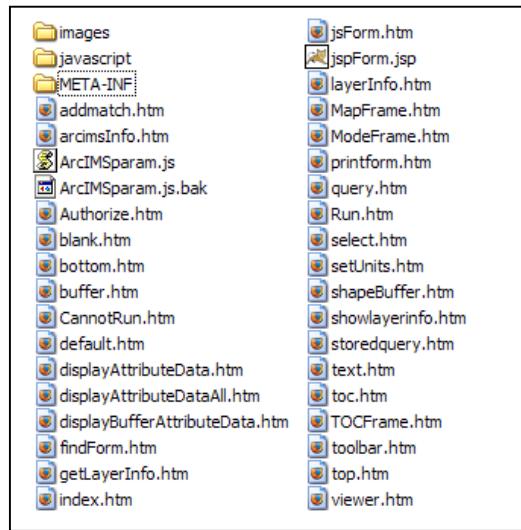


Figure 4.11: Files included for the Website

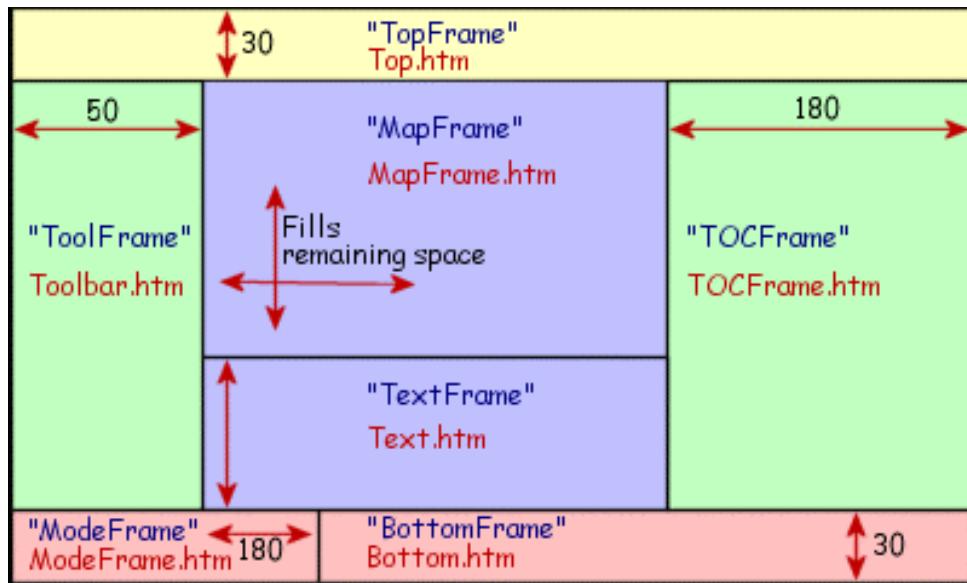


Figure 4.12: User Interface Layout

The entry page into the site is default.htm. The images folder contains all the images used for the Web page, including the button icons and frame backgrounds.

Most HTM files shown in Figure 4.12 are used to define the contents of each frame within an HTML viewer. These files are customizable; e.g., the toolbar.htm file may be reorganized to produce a different look.

Figure 4.13 below shows the user interface of the system. It includes the following area in the map: title, tool bar, layers information, legends, overview and detail maps, and query results.

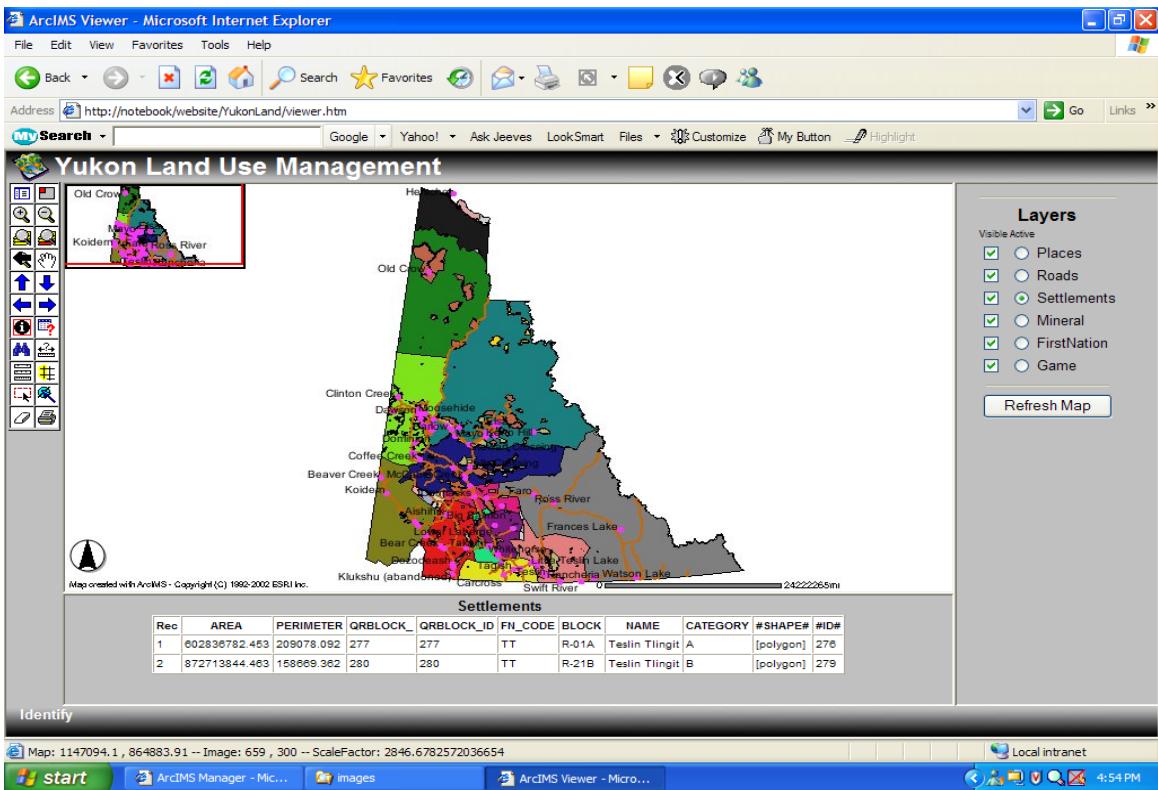


Figure 4.13: User Interface

4.3.7 Basic Functions

The basic functions are as follows:

- Map manipulation tools: pan, zoom.
- Map selection tools: rectangle, circle, polygon, unselection etc.
- Map searching tools.

- Measuring tools: distance and perimeter.
- Simple query tools: identification, query builder.

Below are some of the query examples implemented by using the functions mentioned above.

Query 1: Find the places where the population is less than 5000 in Yukon?

Query Builder is shown in Figure 4.14 while the results are shown in Figure 4.15.

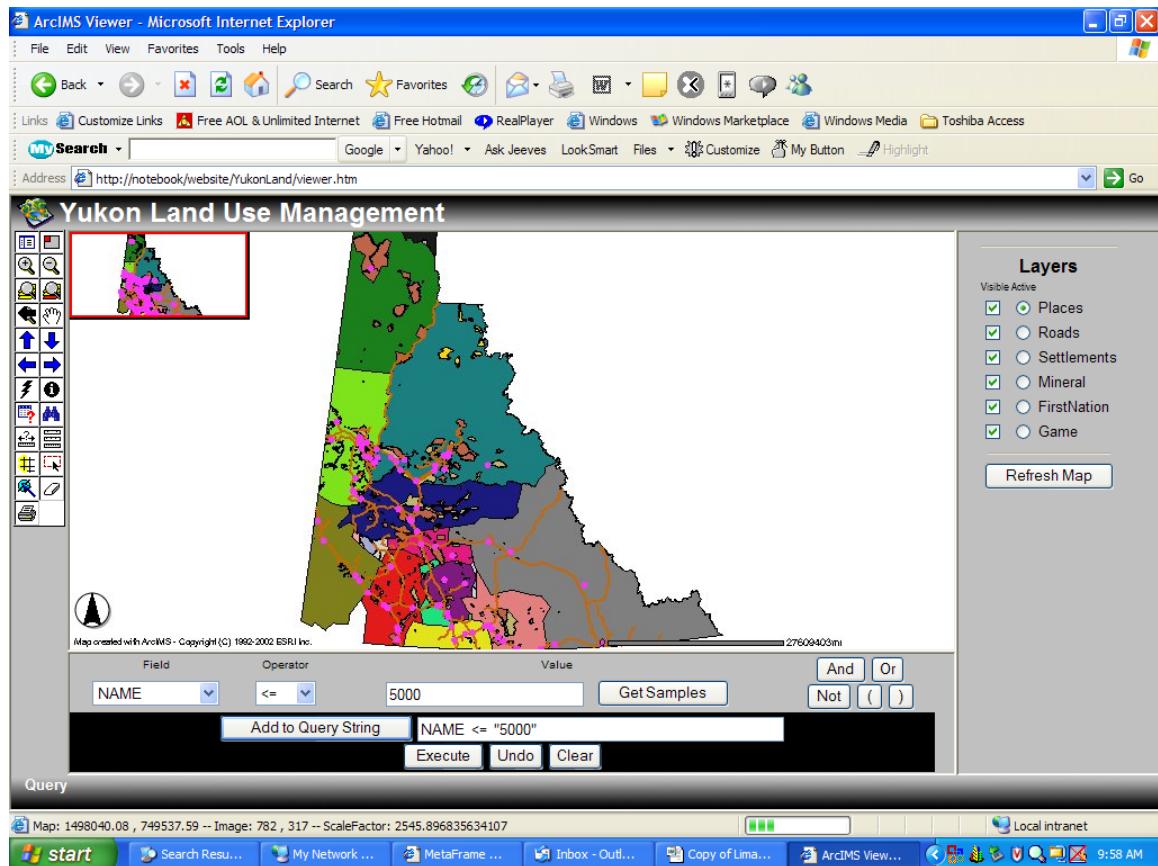


Figure 4.14: Query Builder for Query 1

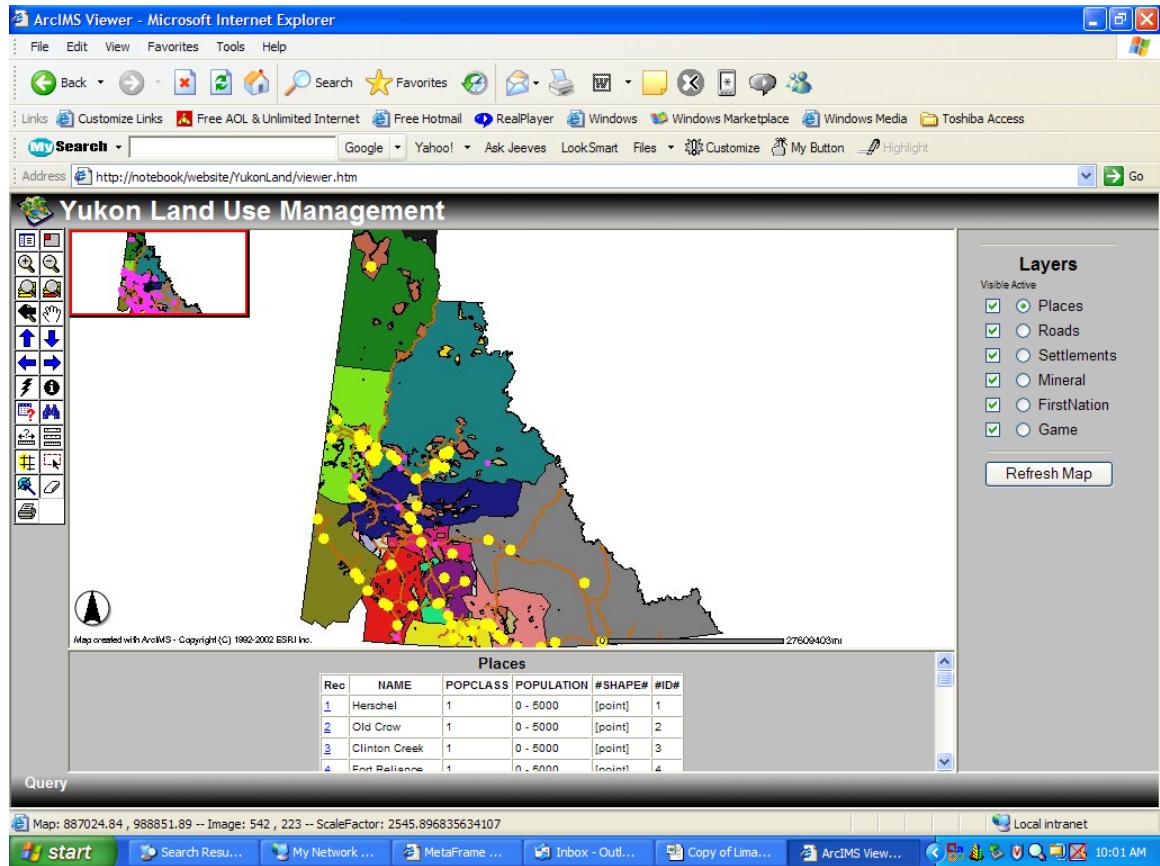


Figure 4.15: Results for Query 1

Query 2: Find the areas where deer can be hunted?

Query Builder is shown in Figure 4.16 while the results are shown in Figure 4.17.

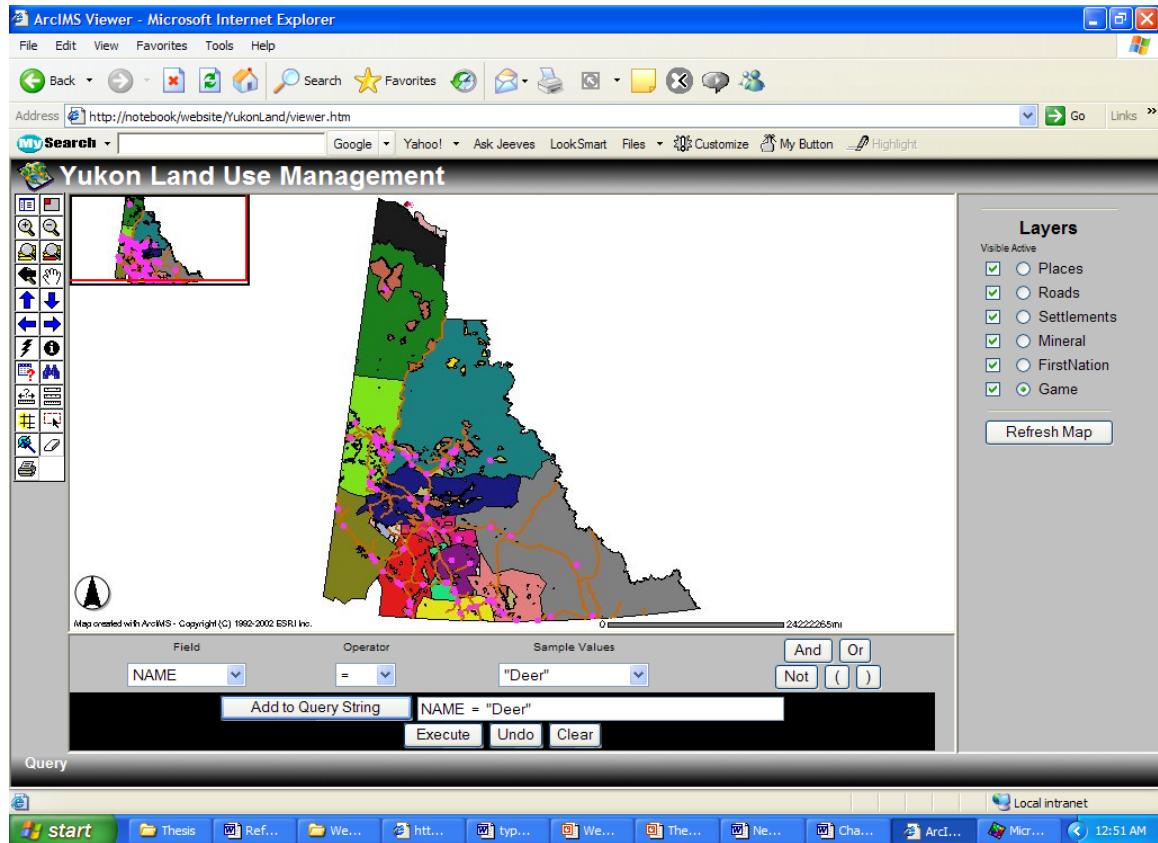


Figure 4.16: Query Builder for Query 2

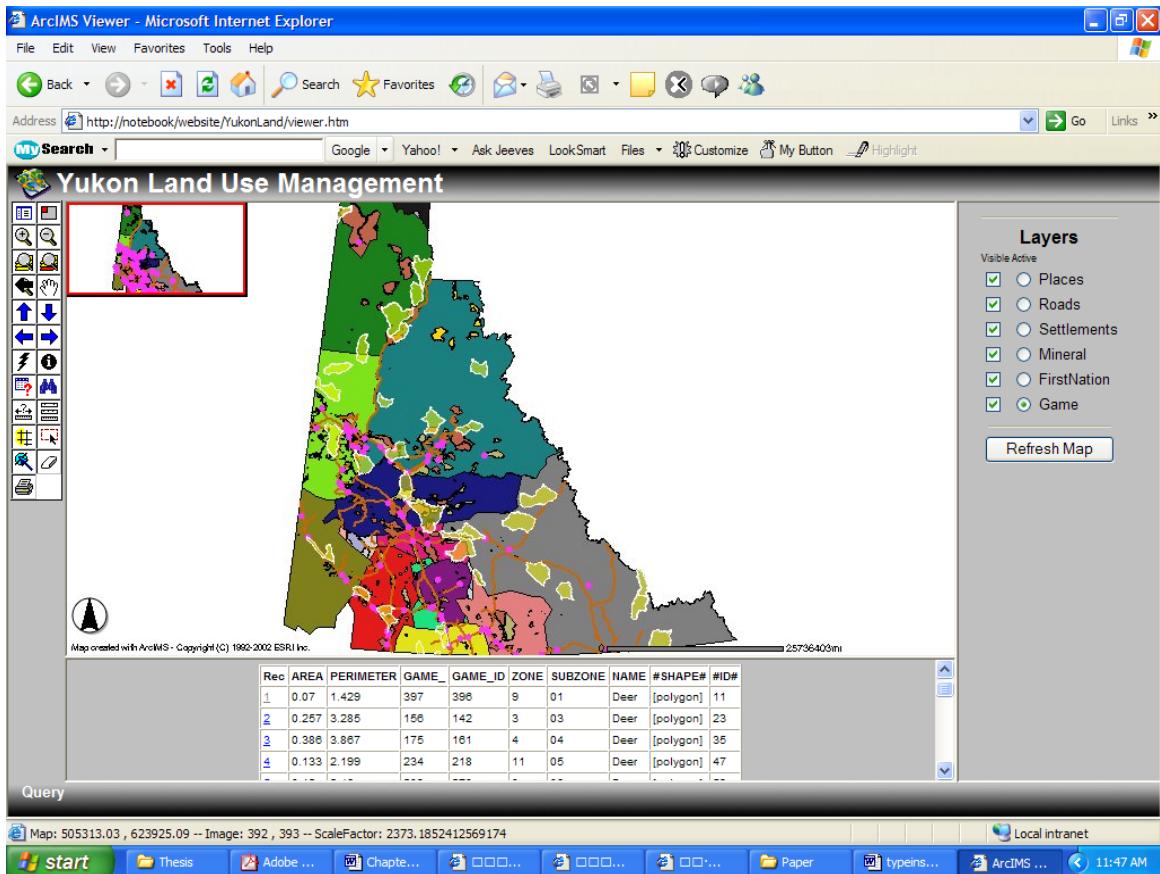


Figure 4.17: Results for Query 2

Query 3: Identify the type of land settlement in selected area?

Window Selection and Identification is shown in Figure 4.18, and the query results are shown in Figure 4.19.

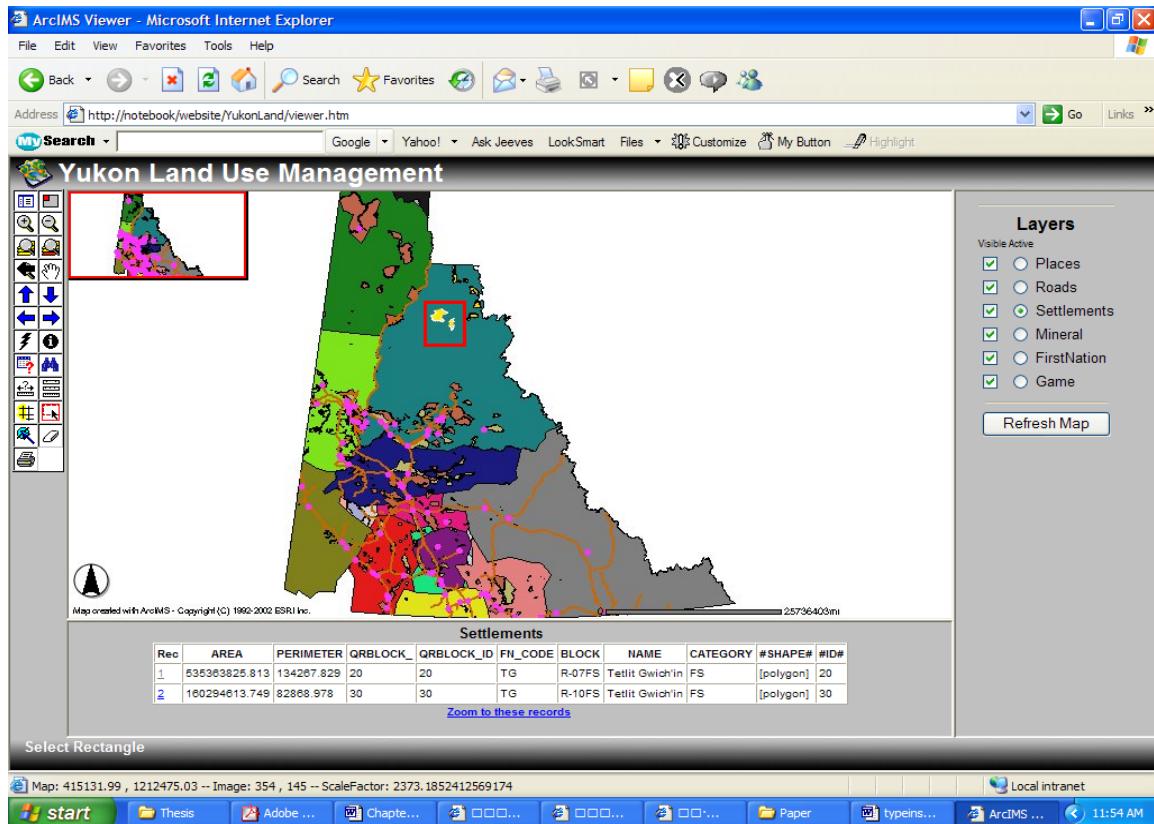


Figure 4.18: Window Selection and Identification for Query 3

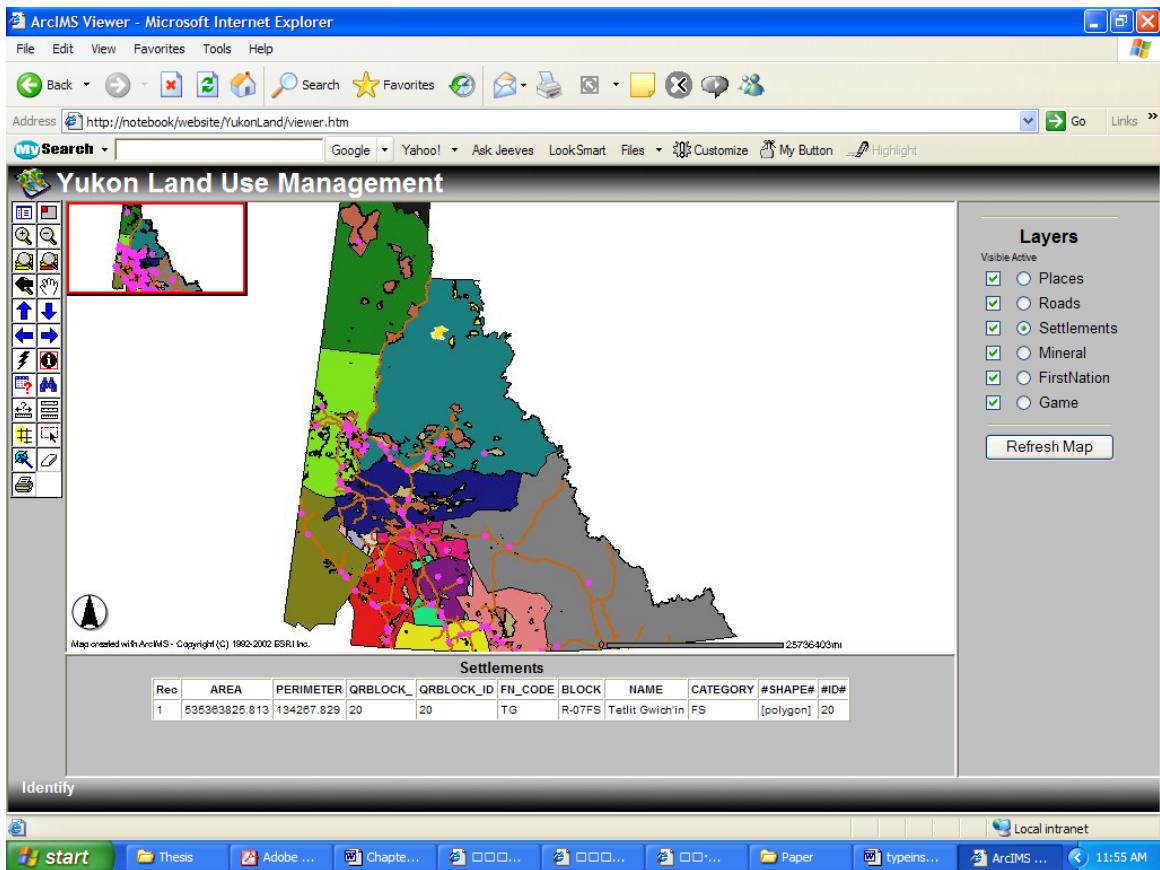


Figure 4.19: Results for Query 3

Query 4: Find the mining claim placer that will expire in December 2010?

Query Builder is shown in Figure 4.20 while the results are shown in Figure 4.21. Zooming in on one of the mining areas that is going to expire is shown in Figure 4.22.

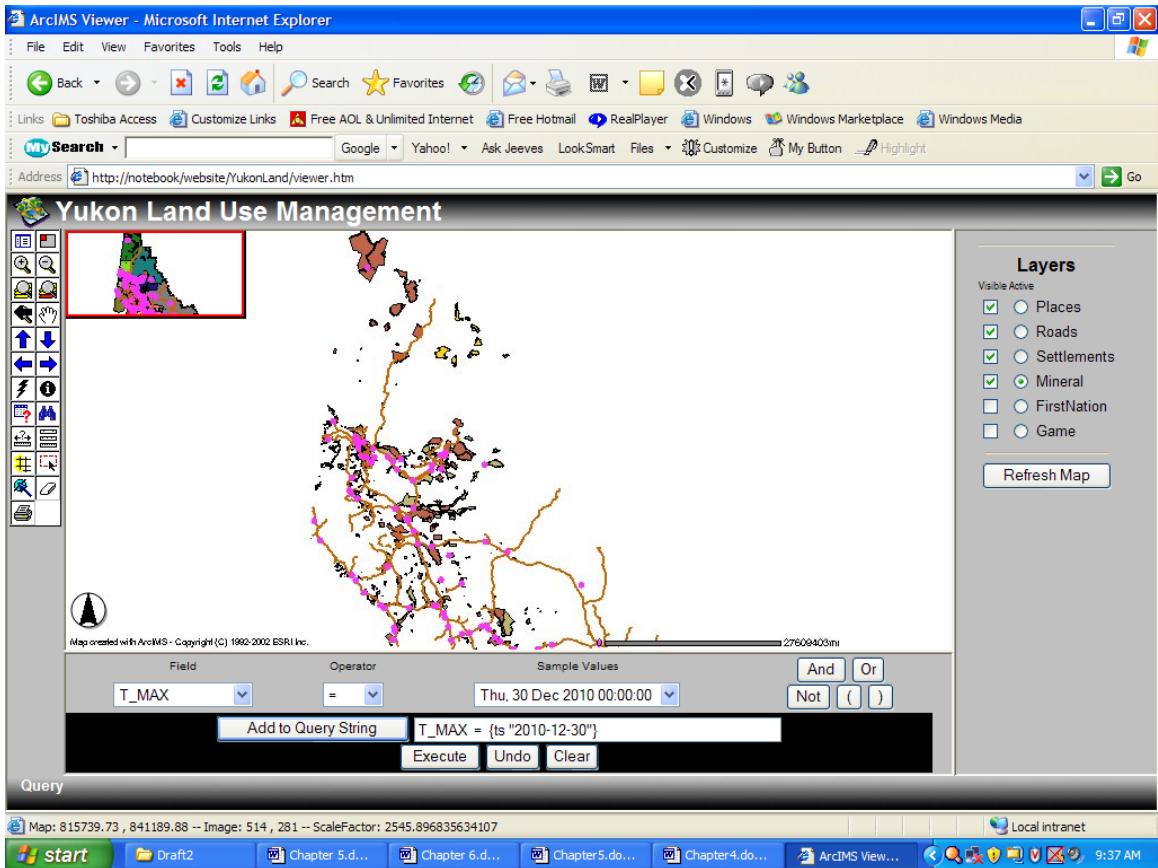


Figure 4.20: Query Builder for Query 4

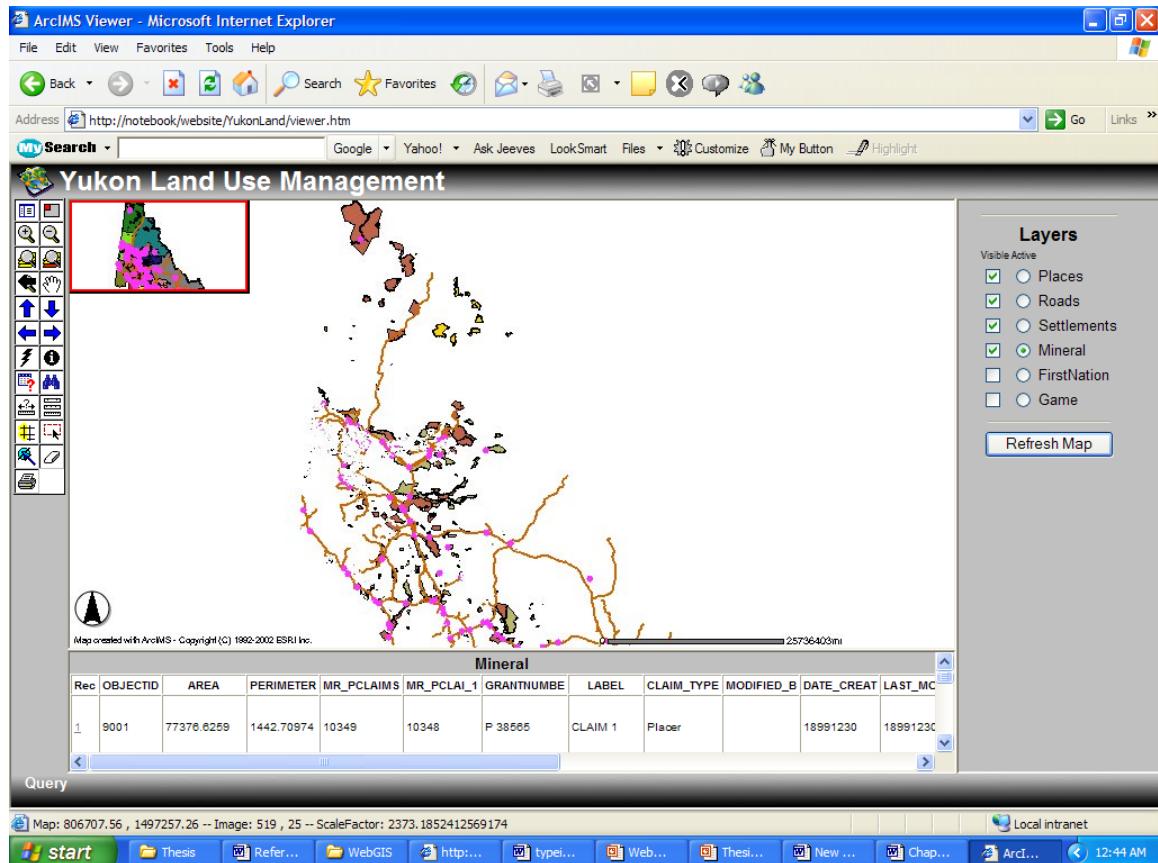


Figure 4.21: Results for Query 4

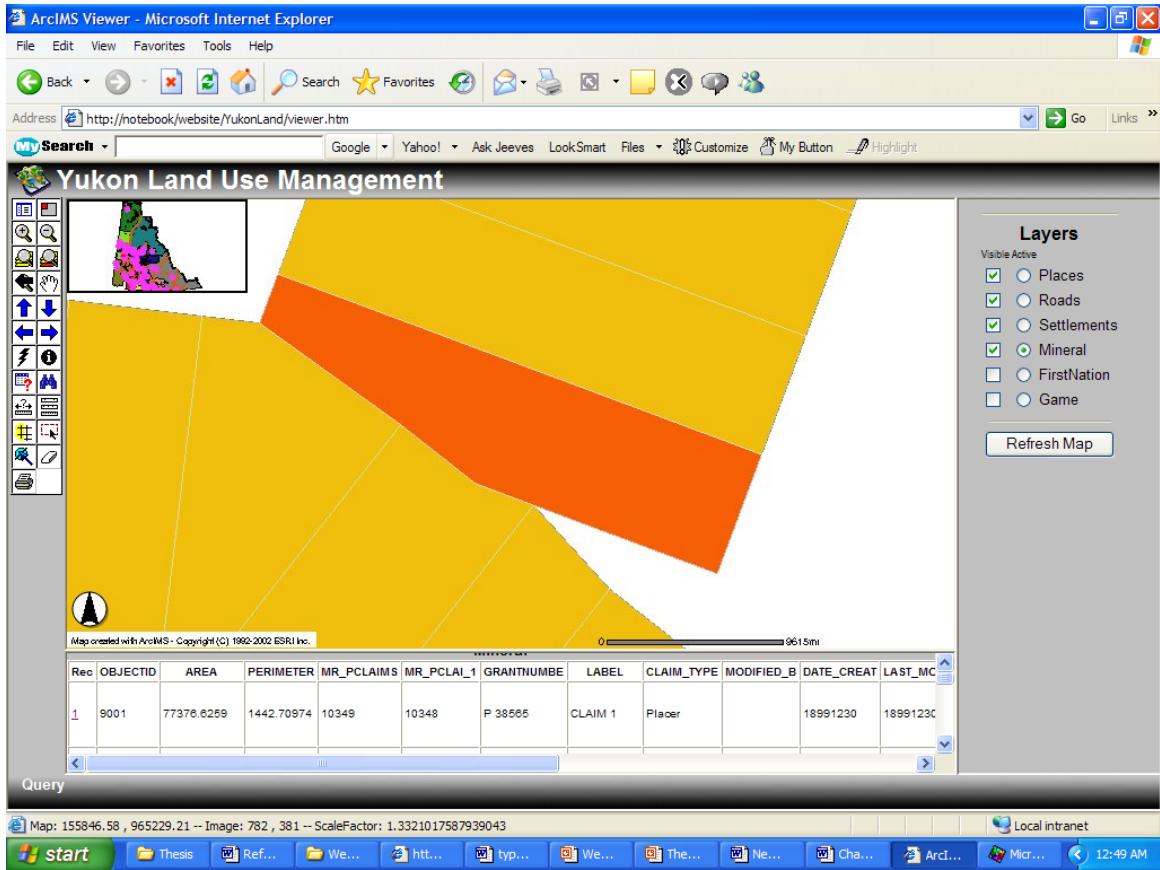


Figure 4.22: Subset of the results for Query 4, zooming in on one of the mining areas

In the above queries, results have been verified by visual inspection of the shapefiles and attribute tables. The average responding time is 2-3 seconds, which depends on the volume of data. In conclusion, query results are accurate and response time is reasonable for the user.

4.4 CHAPTER SUMMARY

In this chapter, the actual implementation process of the prototype system was presented. The procedures include: data collection, data processing, spatial database design and populating, system architecture design, website setup and user interface development. The examples of basic functions were illustrated. In the next chapter, system

enhancements based on the user needs will be discussed. An important function of web information system is to provide the user with sufficient query abilities. Advanced query implementation will also be addressed in the next chapter.

CHAPTER 5: SYSTEM ENHANCEMENT AND ADVANCED QUERY IMPLEMENTATION

In chapter 4, the actual implementation process of the prototype system was presented. The prototype system provides an interactive user interface, and some basic map manipulation and querying tools. To satisfy the users' specific needs, such as incorporating unstructured information into the database, and restricting website login, some system enhancement is necessary.

In this chapter, two system enhancements: map hyperlink implementation, and design of map security mechanism design will be discussed in detail. An important aspect of a web GIS system is to provide the user with sufficient query abilities. In many cases, it needs to combine both spatial and attribute queries. As shown in chapter 4, the basic existing query abilities concentrate only on attribute queries, which cannot fully satisfy query needs. In this case, advanced query needs to be implemented. This chapter will also address various issues involved in the advanced query implementation.

5.1 PROTOTYPE SYSTEM ENHANCEMENT

5.1.1 Map Hyperlinks

Land management and land use activities are largely a combination of technical, legal and institutional practices. Therefore, as a specific knowledge information system, the land information system also needs to reflect the legal and institutional aspects. Some may contain meaningful information, such as the list of steps for the mining placer application, which are not easily represented as fields in the table.

To solve the structured and unstructured data-storage problem, as mentioned in the database design, unstructured data is kept through map hyperlinks that are incorporated as fields in the database system. In this case, the spatial feature on the map should have more flexibility to link to other types of information other than the attribute table. For

example, it is useful to link each First Nation Territories with their band council webpage, so users can get the contact information making hyperlink an important feature in this case.

For a hyperlink to work, the ArcIMS website needs to be customized. As shown earlier, HTML and Javascript files make up the website interface. Most simple customization takes place in “ArcIMSParam.js” file. This JavaScript parameter file stores preferences selected in “Designer” as well as in many other variables that affect the Web site's look and functionality. In this case, we need to revise the “jsp” (use of this file) and set the variable “userHyperlink” to “true”. The database that needs the hyperlink link must contain a field with valid URLs. For example, in this project, linking each First Nation Territory to its First Nation Council webpage is important, to obtain the contact details of a specific First Nation. So as shown below, a field called Hyperlink was created in the First Nation Territories database (Refer to Figure 4.14) to link the features in the spatial layer to the band council website:

First Nation Territories	Territory_ID	Geometry	Name	<u>Hyperlink</u>
--------------------------	--------------	----------	------	------------------

After this, the arrays of layers and field name on which the hyperlink is performed need to be created. To create a list of layers, the array variable “hyperLinkLayers” is assigned an index. Assign a string (layer name) for each layer in this array, with the top-most layer set at index 0. To create the list of hyperlinks fields, set the array variable “hyperlinkFields”. The field name should be specified as the field name in the attribute table with the valid URLs, as shown in Figure 5.1 below.

```

var hyperLinkLayers = new Array(); // layers to have hyperlink
var hyperLinkFields = new Array(); // field in those layers to be used for hyperlink
var hyperLinkPrefix = new Array(); // prefix (if any) to place before field value to make
//hyperlink url
var hyperLinkSuffix = new Array(); // suffix (if any) to place before field value to make
//hyperlink url
hyperLinkLayers[0] = "FNTerritories ";
hyperLinkFields[0] = "Hyperlink";
hyperLinkLayers[1] = "Mineral";
hyperLinkFields[1] = "URL";

```

Figure 5.1: Example of Setting Hyperlinks

The user then selects the hyperlink tool from the left tool box, and clicks on a specific First Nation community on the map, the link to its band council's website is shown. Refer to Figure 5.2.

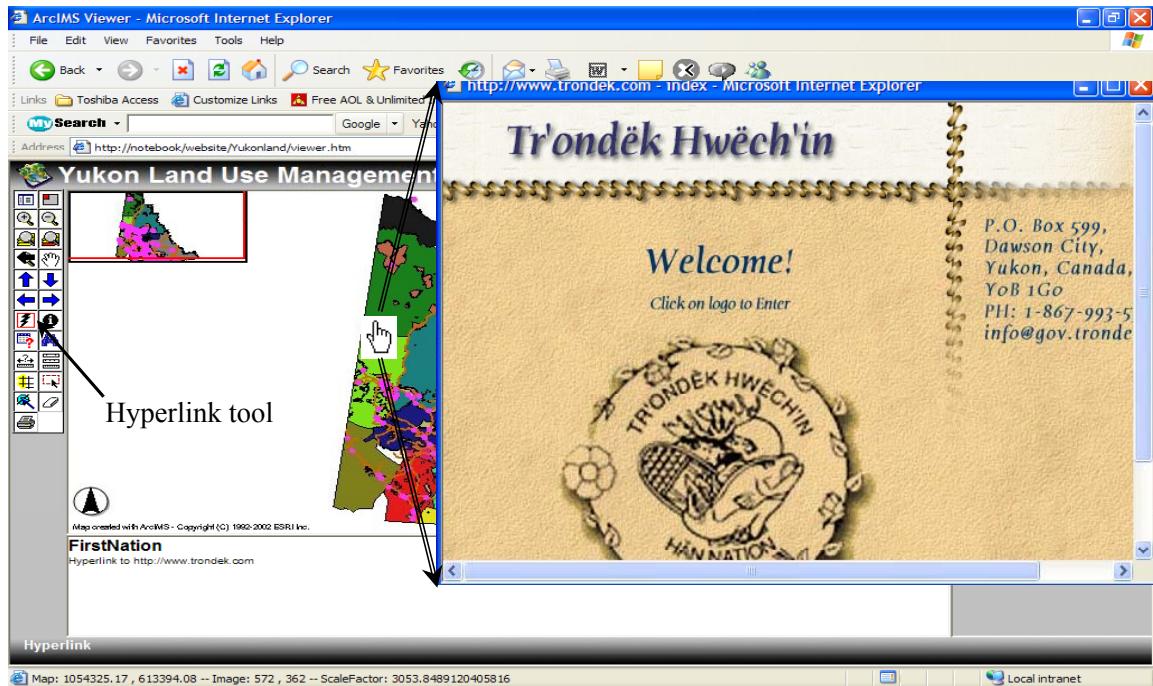


Figure 5.2: Hyperlinks to the First Nation Band Council Website

It should be noted that more than one layer could be set active with the hyperlink. For example, the legal information mentioned earlier can also be incorporated into the layer “placer mining” in the same way.

5.1.2 Security Login

Security issues have come to the forefront with the dissemination of information over the World Wide Web. As information on Aboriginal land is culturally sensitive, security of information is important. Restricting user access to the web information provides the security needed. Consequently, a security mechanism was designed to limit user access to the web service.

To limit user access, the most direct way is to set the user name and password for the website. A table of pairs of user id and password is therefore created in the MSAccess database. During login, a servlet is invoked to connect to the database and search for the matching pair. If the table contains the correct combination of the given user-id and password, the login is successful, and the servlet delivers the viewer page to the user. Otherwise, an error message will be shown on the user screen and the user will be redirected back to the log in page. The login process is depicted in Figure 5.3.

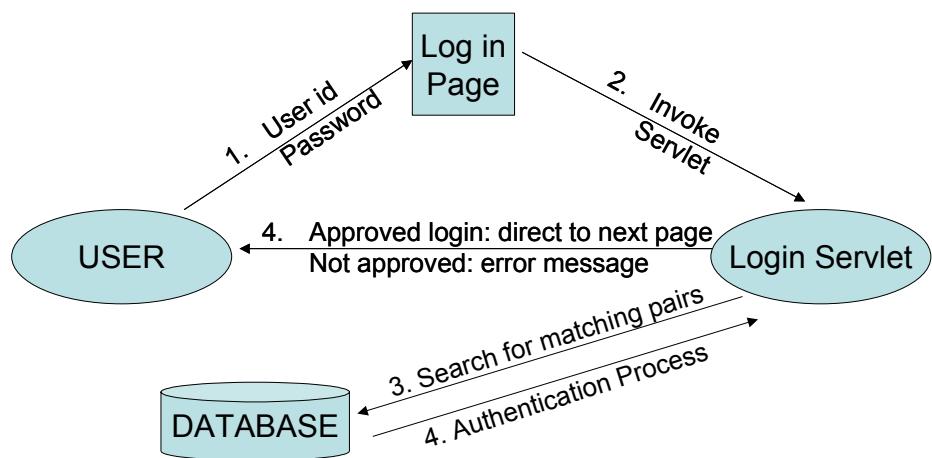


Figure 5.3: The login process

A problem with this method is that authorized users can see information of other authorized users if they shared the same map service. A desired security feature should therefore begin with a login dialog followed by every service that ArcIMS provides on the condition that each viewer sees his or her own data only. Consequently, users can view the map service without intruding on other user's private information.

The ArcIMS Servlet Connector has no source code available, therefore no modification can be made to the connector that performs the authentication feature. The source codes available were limited to: HTML and JavaScript files produced by the ArcIMS designer, authentication, and authorization page. Therefore, it is difficult to implement different viewers based on different user rights just by changing the existing code.

5.2 ADVANCED QUERY IMPLEMENTATION

By using the existing tools (e.g., query builder) provided at the client viewer, simple queries, as presented in Chapter 4, could be easily carried out. However, more complex spatial and attribute queries are difficult, as multi-step analysis (i.e. a series of queries) is not supported by existing tools. In other words, a new query based on a previous query result cannot be done. To achieve multi-step querying, the query and its procedure have to be customized.

As outlined in chapter 4, the website is comprised of HTML files and Javascript files. The javascript folder contains the JavaScript Library, which is a series of JavaScript files used to create ArcXML requests and process ArcXML responses from the ArcIMS spatial server. Most HTM files are used to define the contents of each frame within an HTML viewer. These files can be customized, e.g. the toolbar.htm file may be reorganized to produce a different look. An important HTML file to note is jsForm.htm. This HTML form sends the ArcXML request to the ArcIMS spatial server and accepts the response.

Within ArcIMS, query requests and results are processed through ArcXML programming. Communication of ArcXML will be explained in detail in the following section. ArcXML can be used to re-write and customize the code sending the request thus improving the limited query abilities.

5.2.1 ArcXML Programming

ArcIMS connector has been used in the prototype as an interface program, therefore all requests sent and received by the client have been changed into ArcXML format, a specification of XML language used in the ArcIMS system. The following section will discuss the implementation of complex queries through ArcXML programming, commencing with examining query process using ArcXML in ArcIMS.

ArcXML is the protocol for communicating within the ArcIMS Spatial Server. As mentioned earlier, an ArcIMS Spatial Server is the backbone of the ArcIMS system and provides the functional capabilities for accessing and bundling maps and data into an appropriate format before sending data to clients.

To understand ArcXML, it is necessary to know how the configuration files, ArcIMS services, requests, and responses relate to each other and how they interact with the ArcIMS Spatial Server. Figure 5.4 shows this inter-relationship.

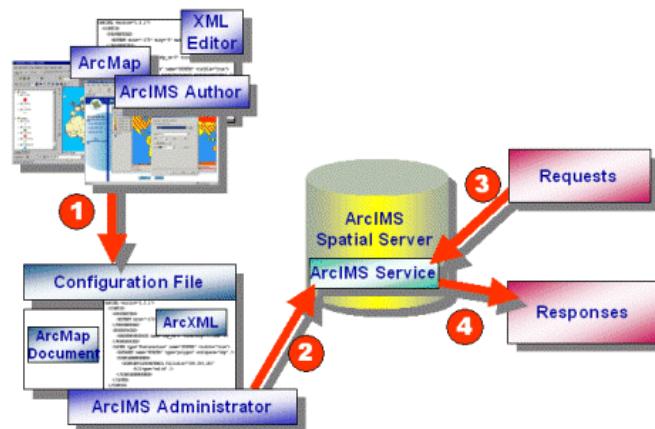


Figure 5.4: Inter-relationship between ArcIMS Spatial Servers and ArcIMS services through ArcXML programming (ESRI, 2004)

- a. *Step 1*- a configuration file that is used to define maps is generated. The user creates a map configuration file for the Image and Feature Services for the vector data using ArcIMS Author or a text or XML editor. When this file is saved in ArcIMS Author, the result is a map configuration file, written in ArcXML, containing layer information of the map contents (The file has an *.axl extension).
- b. *Step 2*- this sets up the map service. An ArcIMS service is a process that runs on the ArcIMS Spatial Server. A service can be thought of as a portal to the Spatial Server. The spatial Server's functionality is accessible only through services running on the server. In this step, the map configuration file “*.axl” is the input to an ArcIMS service. It provides drawing instructions for each layer in a service, i.e. the default state of the service.
- c. *Step 3*- requests from internet users can be sent once an ArcIMS service is running on the ArcIMS Spatial Server. When a client sends a request, that request is sent in the form of ArcXML using the REQUEST element. The requests are:

- GET_IMAGE
- GET_FEATURES
- GET_GEOCODE
- GET_EXTRACT
- GET_SERVICE_INFO
- GET_RASTER_INFO
- GET_LAYOUT
- GET_METADATA
- PUBLISH_METADATA

The XML element that distinguishes a request from other types of ArcXML files is REQUEST. A request can also over-ride some of the information in a service by:

- asking for a new map at a different scale
- turning layers on or off
- requesting a subset of the attribute data

- changing the projection or
- adding acetate layers (ESRI, 2004).

With the Image Server, a request can also be used to change the rendering of a layer or add new data in dynamic layers.

d. *Step 4-* the ArcIMS Spatial Server processes a request and then sends it back to the user in the form of ArcXML. The XML element that distinguishes a response from other types of ArcXML files is RESPONSE.

In summary, ArcXML is the protocol used for sending requests and receiving responses through the ArcIMS spatial server. It is a specialized XML that follows ESRI's protocol.

Figure 5.5 illustrates an example of the request for an image and the response in ArcXML.

```

<ARCXML version="1.1">
  <REQUEST>
    <GET_IMAGE>
      <PROPERTIES>
        <ENVELOPE minx="-180" miny="-90" maxx="180" maxy="90" />
      </PROPERTIES>
    </GET_IMAGE>
  </REQUEST>
</ARCXML>



---


<ARCXML version="1.1">
  <RESPONSE>
    <IMAGE>
      <ENVELOPE minx="-180" miny="-90" maxx="180" maxy="90" />
      <OUTPUT url="http://tr/output/TR9.jpg"/>
    </IMAGE>
  </RESPONSE>
</ARCXML>

```

Figure 5.5: Example of an ArcXML request and response

Typically, a request is made to the server through ArcXML and created on the client side using embedded JavaScript functions. Using dynamic HTML with custom JavaScript functions, the client can generate ArcXML code directly, and then send the code to the server for processing using the servlet connector.

5.2.2 Advanced Queries Developed by ArcXML

Many advanced queries such as combining spatial and attribute queries can be developed using ArcXML. The following example illustrates the capability of ArcXML programming of sending more complicated spatial analysis requests.

This is an advanced query that needs further process based on the result of buffer: “Select Game Area, within the buffer distance of 20 miles of the major roads”. Figure 5.6 shows the original ArcXML code, which is then rewritten in the form of JavaScript and sent as the request.

```

<ARCXML version="1.1">
<REQUEST>
<GET_IMAGE>
<PROPERTIES>
<ENVELOPE minx="-141" miny="60" maxx="-124" maxy="70" />
<IMAGESIZE width="500" height="350" />
</PROPERTIES>
<LAYER type="featureclass" name="theBufferTarget" visible="true"
id="buffertarget">
<DATASET fromlayer="5" />
<SPATIALQUERY>
<BUFFER distance="20" bufferunits="miles">
<TARGETLAYER id="2" />
</BUFFER>
<SPATIALFILTER relation="area_intersection">
<ENVELOPE minx="-141" miny="60" maxx="-124" maxy="70" />
</SPATIALFILTER>
</SPATIALQUERY>
<SIMPLERENDERER>
<SIMPLEPOLYGONSYMBOL fillcolor="255,255,0" filltype="solid" filltransparency="1"
/>
</SIMPLERENDERER>
</LAYER>
<LAYER type="featureclass" name="theBuffer" visible="true" id="buffer">
<DATASET fromlayer="5" />
<SPATIALQUERY>
<BUFFER distance="20" bufferunits="miles"/>
<SPATIALFILTER relation="area_intersection">
<ENVELOPE minx="-141" miny="60" maxx="-124" maxy="70" />
</SPATIALFILTER>
</SPATIALQUERY>
<SIMPLERENDERER>
<SIMPLEPOLYGONSYMBOL fillcolor="100,100,100" filltype="solid"
filltransparency="0.5" />
</SIMPLERENDERER>
</LAYER>
</GET_IMAGE>
</REQUEST>
</ARCXML>
```

Figure 5.6: ArcXML Code for the Query

The result of the query is shown in Figure 5.7.

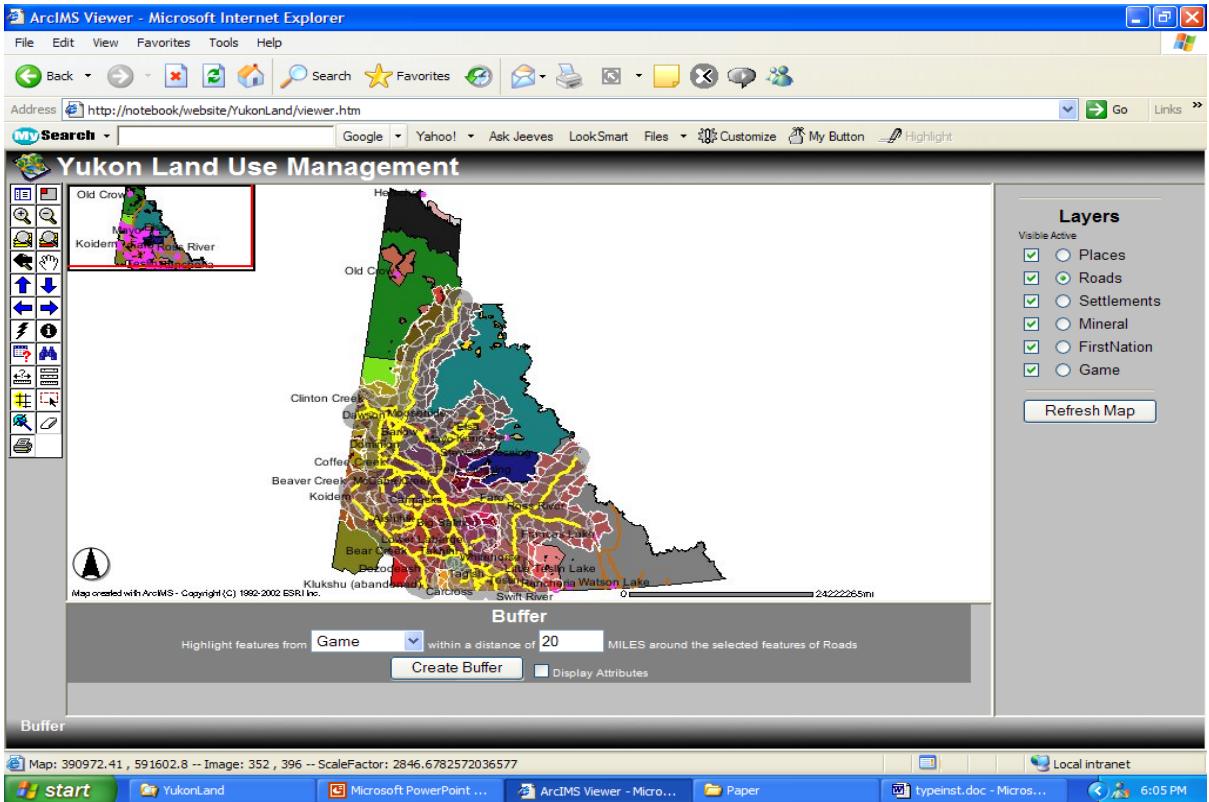


Figure 5.7: Query Result

5.2.3 Analysis of ArcXML Programming

These examples illustrate two advantages of ArcXML. First, it has clear and hierarchical syntax, which is easy for beginners to develop. Another advantage of the ArcXML syntax is the provision of the “spatial filter”, which is used to specify the users’ spatial queries. In this case, it is possible to use the buffer result to intersect with other layers.

The disadvantages of ArcXML however are that the spatial queries (especially intersection and overlay) are not efficient, partly because the intersection operation provided by ArcXML involves only two layers, and cannot perform queries which are requiring multi-layers overlay. In addition, restricted by the ArcXML syntax, inside one

spatial query, the times of using the “spatial filter” are limited. It is impossible to embed spatial filter several times inside the spatial query.

The use of ArcXML programming to implement spatial queries does not solve all the problems. From the land management perspective, it is important that the system can perform multi-criteria location selection, which requires the multi-layer overlay.

This can be achieved by implementing complex overlay and intersection using other programming languages, then integrating this into the ArcIMS website. In view of the compatibility between Esri products, MapObjects-Java can be used to implement the task. MapObjects-Java has a rich collection of client and server components for Java developers. It can be used to build custom applications that incorporate GIS and mapping capabilities or to extend the capabilities of existing applications. Firstly, however, a methodology for multi-layer overlay and intersection will need to be designed.

5.3 METHODOLOGY FOR MULTI-LAYER OVERLAY IMPLEMENTATION

Before implementing the multi-layer overlay, a strategy for an efficient overlay process will need to be developed. In general, an overlay is classified into either vector or raster overlay, each with its own advantages and disadvantages. This section will commence with a general review of the vector and raster overlay followed by discussion of a new methodology.

5.3.1 Vector/Raster Data Analysis

Traditional approaches to the representation and processing of spatial data in geographic information systems (GIS) assume that data is organized into semantically uniform layers or themes. For example, data on a territory may comprise layers such as elevation, rivers, roads, cities, and other economic districts. With data representation, vector and grid-based layers are distinguished.

- a. *Vector layers* consist of discrete geographic objects in the form of points, lines, or areas that are specified by their coordinates (Lee, 2005; Tuman, 2005; Burrough, 1986; Star and Estes, 1990). Each object has its own unique identification, which is the primary key to its attributes, usually stored in a table.
- b. *Raster layers* are grid-based data that consist of values of an attribute specified in nodes of a regular rectangular grid. This format is frequently used when conveying information about continuous spatial phenomena, such as surface elevation models and earth gravity. Grid-based data can also be used to represent derived information about spatial and spatio-temporal properties of discrete geographical objects, e.g., density of roads or communication lines, parameters of seismic flow (density of earthquakes, seismic activity, fractal dimension), and statistical parameters of accidents (Lee, 2005; Tuman, 2005; Burrough, 1986; Star and Estes, 1990).

5.3.1.1 Overlay, Spatial Join, and Intersection

A basic way to create or identify spatial relationships is through the process of spatial overlay, accomplished by joining and viewing separate data sets that share all or part of the same area.

In the literature, the terms “overlay”, “spatial join” and “intersection” are used interchangeably. However, they are different, and the distinction between them needs to be clarified before proceeding. “Spatial joins” join tables based on location, while not allowing features to split. Conversely, “overlay” is a spatial join of tables based on location, while allowing splitting of features during the join process. To understand this concept, refer to Figure 5.8, which has been developed by the author, to show the results of identifying the roads inside a specific parcel. Overlay results are shown in Figure 5.8(c). Note that only portions of lines 2, 4, 6, 7 and 8 are inside the specific parcel. As overlay allows splitting of the features, these lines are split and only the portions within the parcel are identified.

Spatial join results can vary depending on the algorithm, as shown in Figure 6.1(d) to (e). Some algorithms may identify all the lines that are inside or passing through the parcel, see Figure 5.8 (d), while others may consider only the lines that are completely inside the parcel, see Figure 5.8 (e). It is worth mentioning that there are many other implementations of the spatial join, but no feature splitting is allowed. This research will focus on the “overlay”, rather than on “spatial join”, being a more accurate method as it allows splitting of the objects, resulting in sub-object accuracy.

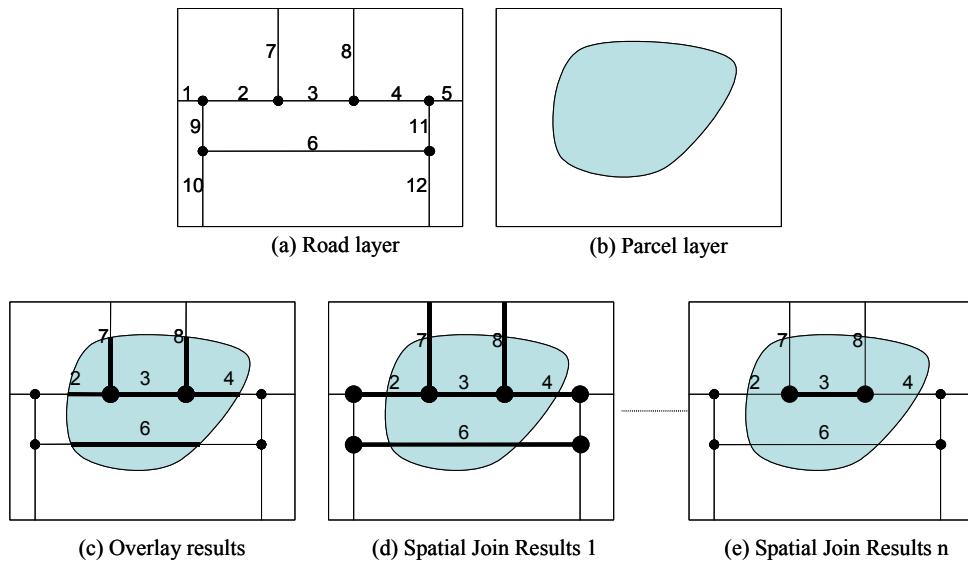


Figure 5.8: Distinction between “Overlay” and “Spatial Join”

It is also important to define “Intersection” as it is used in the developed methodology. Intersection is the area that both feature classes have in common. Figure 5.9 (c) below, which has been developed by the author, shows the intersection results of the layers in Figures 5.9 (a) and (b). It is worth mentioning here that an overlay, rather than spatial join, is important to perform the true intersections, as features have to be split.

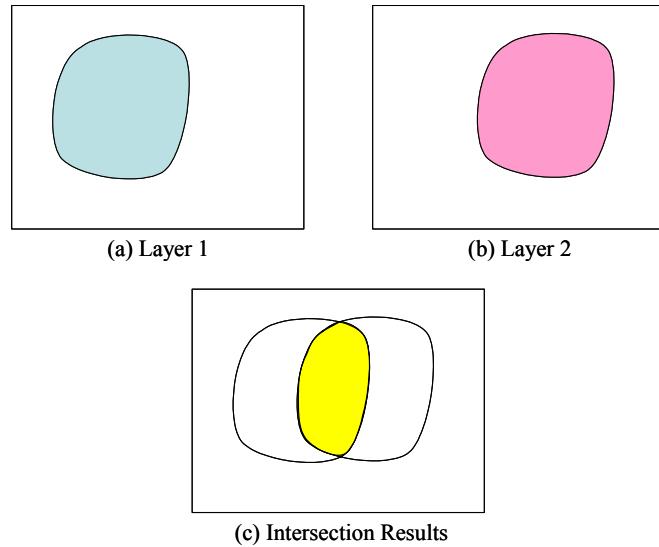


Figure 5.9: Intersection

After distinguishing between these major GIS operations, the next two sections discuss overlay of vector and raster layers.

5.3.1.2 Vector Overlay

Overlaying vector layers requires many computations and high complexity (Lee, 2005; Tuman, 2005; Burrough, 1986; Star and Estes, 1990). For example, overlaying two polygon layers which contain n and m polygons (see Figure 5.10 below, which was developed by the author) requires many polygon overlays, possibly $n*m$ polygon overlay.

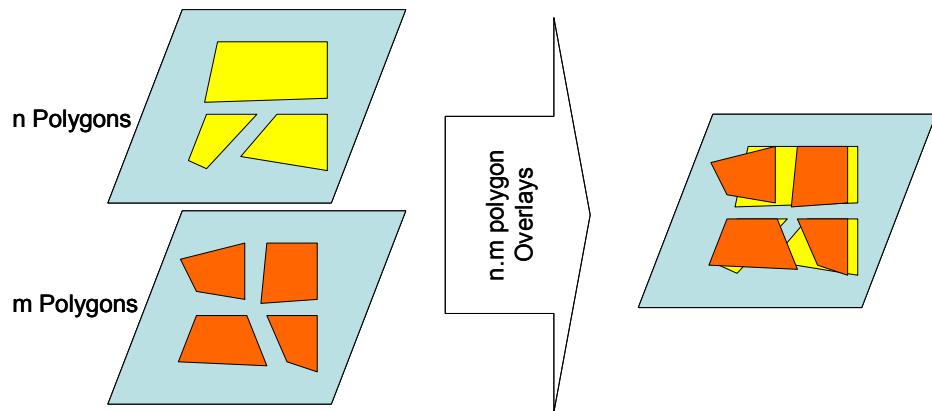


Figure 5.10: Overlaying two polygon layers

Moreover, overlaying two polygons requires examining all the edges of the polygons. Figure 5.11, which was developed by the author, shows an overlay of two polygons having i and j vertices (i and j edges). It is possible to find intersections at most edges. Therefore, many edges have to be examined for possible intersection. This is the case with overlaying only two layers. With increasing layers, it becomes inefficient and time consuming. Inspite of this, vector overlay is an accurate method to perform the queries as it allows for splitting of objects. To overcome computation complexity problem, many applications tend to use raster instead of vector overlays.

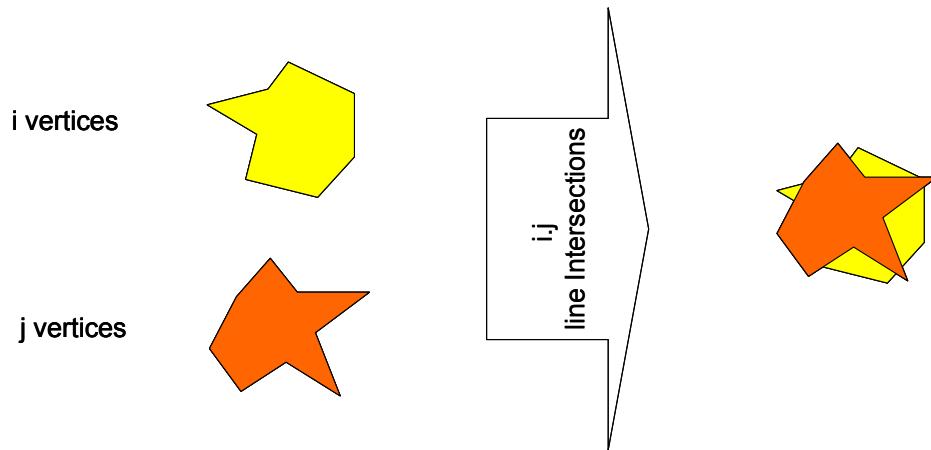


Figure 5.11: Overlaying two polygons

5.3.1.3 Raster Overlay

Raster overlay requires having a raster map. Usually, collected map data exists in the form of vectors (as acquired by surveying of points and digitization of photos), which can be transferred from vector to raster format by first converting to a regular grid, then storing feature attributes in raster values. These values can be identified through Look-Up Tables (LUT). As shown in Figure 5.12 (developed by the author), a raster GIS map consists of:

- Raster images
- Look-Up Table (LUT)

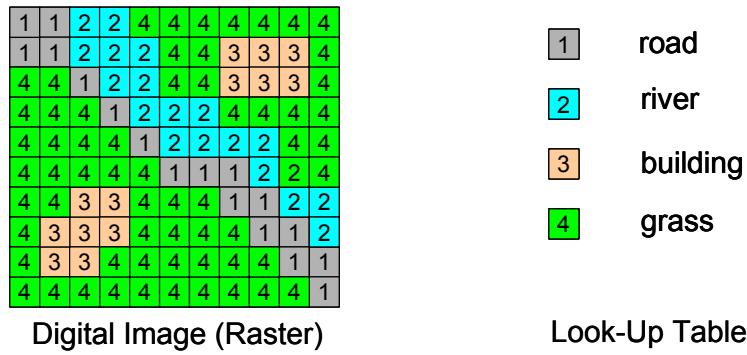


Figure 5.12: Raster GIS Map

The raster map should not be confused with a satellite or aerial images. This is because values of an image represent reflectance information (usually called gray/color values), which are not the same as the attribute information that exists in the raster map. To obtain a raster map, an appropriate grid size needs to be selected. A large pixel size will result in loss of information. For example, a road of 10 m width does not appear in a raster map with 20m resolution. On the other hand, a small grid size is preferred for preserving accurate information, however, this requires large storage space.

Raster overlay is performed by comparing corresponding pixel values in each layer. In this case, pixels in layers have to represent the same areas. Figure 5.13, which is developed by the author, shows potential problems that exist in raster overlay, since pixels do not correspond to the same areas. Figures 5.13(a), 5.13(b) and 5.13(c) represent two raster layers of different pixel size, different orientation and different origins, respectively. In each case, raster overlay becomes difficult. This can be resolved in two ways:

- Firstly, use of vector overlay can be considered. Here, pixels can be considered as square polygons that can be split into smaller polygons, resulting in an overlay that is no longer a raster.
- Secondly, to resample the raster maps so pixels represent the same areas in all the layers. However, resampling a raster GIS map is different from that of digital

images since the former has specific meanings in pixel values while the latter has only grey/color values.

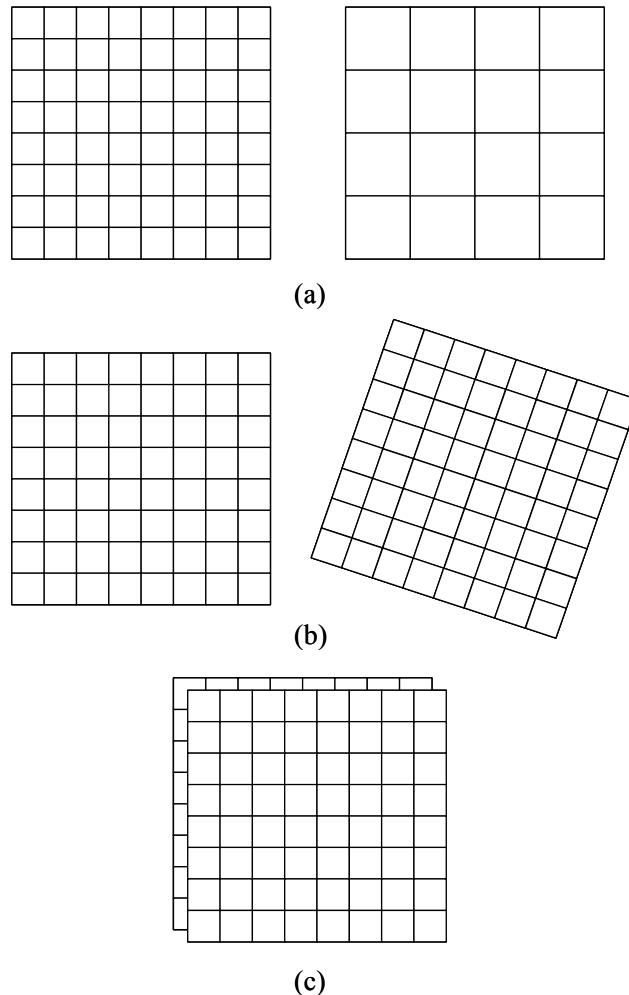


Figure 5.13: Problems of Raster Overlay

It is worth noting that if raster GIS maps are obtained in a way that pixels represent same areas in all the layers, overlaying becomes very easy through boolean operators. Boolean operators include “and”, “or”, “xor”, “not”. Figure 5.14 shows the basic Boolean operators. These operations will be considered in the developed methodology for advanced multi-layer queries.

$0 \text{ AND } 1 = 0$	$0 \text{ OR } 1 = 1$	$0 \text{ XOR } 1 = 1$	
$1 \text{ AND } 0 = 0$	$1 \text{ OR } 0 = 1$	$1 \text{ XOR } 0 = 1$	$\text{NOT } 1 = 0$
$1 \text{ AND } 1 = 1$	$1 \text{ OR } 1 = 1$	$1 \text{ XOR } 1 = 0$	$\text{NOT } 0 = 1$
$0 \text{ AND } 0 = 0$	$0 \text{ OR } 0 = 0$	$0 \text{ XOR } 0 = 0$	

Figure 5.14: Basic Boolean Operators

5.3.1.4 Comparison of Vector and Raster Overlay

Table 5.1 summarizes the advantages and disadvantages of vector and raster overlays.

	Advantages	Disadvantages
Vector Overlay	<ul style="list-style-type: none"> Vectors require less storage space Most accurate overlay method 	<ul style="list-style-type: none"> Requires many computations
Raster Overlay	<ul style="list-style-type: none"> Easy to perform 	<ul style="list-style-type: none"> Requires large storage space Resampling raster maps is not easy

Table 5.1: Comparison of vector and raster overlay

The advantages of reduced storage space, and accuracy of vector overlay, in addition to the ease of raster overlay will be used to develop a methodology for advanced multi-layer queries. In addition, the extensive computation of vector overlay and the large storage requirement for raster maps will be avoided. A methodology will be developed that embraces the advantages and reduces the disadvantages of both vector and raster overlays. The next section discusses the developed methodology.

5.3.2 Methodology for Multi-layer Overlay

Users vary in their requirements for data accuracy. For example, a developer may require parcel-level accuracy queries in one situation, and community-level accuracy analysis in another. So the accuracy requirements can be an input by the user. Furthermore, queries can be limited to specific areas, e.g., a developer may look for a specific area within a

city rather than a whole territory. Limiting the extent of interest can greatly reduce the computation time. Figure 5.15 shows the overview of the developed methodology.

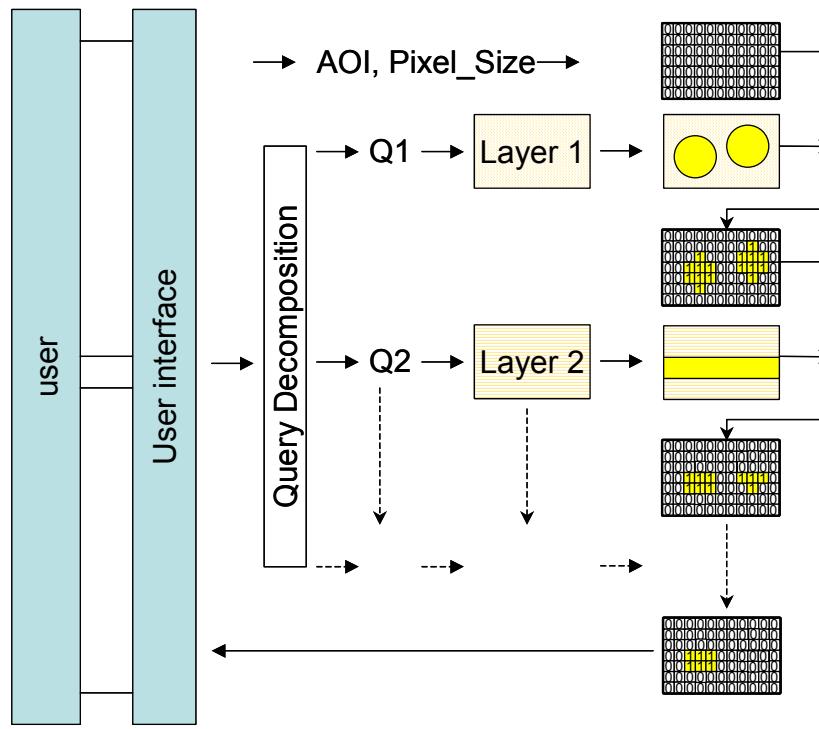


Figure 5.15: Advanced Multi-layer Overlay Queries

In this process, the user has to specify the Area of Interest (AOI) and accuracy represented by Pixel Size (Pixel_Size). Based on the Area Of Interest and the required accuracy, a grid can be generated. The Grid limit can be chosen as the bounding box of the area of interest. This grid will hold the query results through the overlay operation.

A complex query can be decomposed into simpler queries, each concerned with a specific layer. For example, a query for finding areas that within 100km of major cities and 50 km from major roads can be considered as two simple queries dealing with cities and roads layers. After decomposing the complex query, simpler queries can be performed. Instead of vector overlaying these results, overlay is performed based on the grid. As shown in the figure, query results are overlaid with the grid, one at a time.

This developed methodology is expected to significantly reduce the computation time resulting from the use of the Area of Interest and user input of the required accuracy. Furthermore, overlaying the results with the same AOI makes the Boolean operations faster and efficient.

During implementation, all grid values will be firstly initialized to “0”. For the first simple query, the grid points which fall within the query result will be updated to “1”. After performing each of the remaining simple queries, the grid will be updated through Boolean operation with the previous result. For example, a query that is decomposed into “(Q1 AND Q2) OR Q3” can be implemented as shown in Figure 5.16.

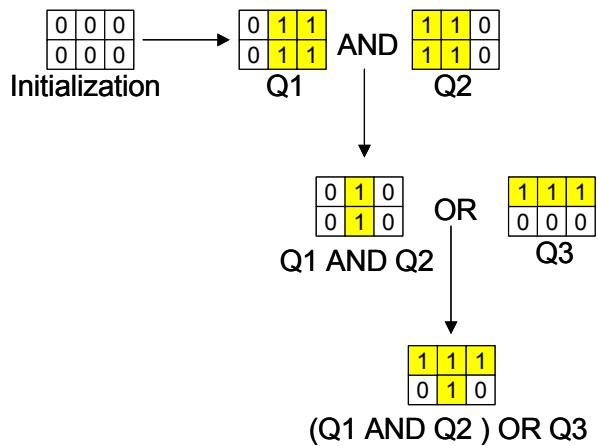


Figure 5.16: Implementation of “(Q1 AND Q2) OR Q3” query

This methodology was implemented and tested on a desktop GIS. However, because of time restrictions for completing this research and the non-availability of a MapObject-Java license, the methodology remains to be fully implemented and tested on the web GIS prototype.

5.4 CHAPTER SUMMARY

In this chapter, system enhancements including advanced query implementation were discussed. Map hyperlinks enrich the information provided by the original web GIS prototype, and simultaneously, increase the efficiency of the information searching

process. Security access to the website restricts user rights to full access, and is important where culturally sensitive information is available. Advanced queries, especially the spatial attribute combined queries, were developed after examining the ArcXML programming. The advantages and disadvantages of ArcXML programming were then compared. A methodology for handling multi-layer overlay queries for land management was presented. This involved decomposing complex queries into simpler ones, while maintaining Boolean operations between them. An integrated raster/vector approach was then used resulting in an efficient and timely query process, but it has yet to be fully implemented and tested in the web GIS prototype.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF RESEARCH

This research aimed to provide an accessible Web GIS prototype consisting of spatial and legal information related to Aboriginal land development and management. This integrated on-line information system will assist developers to efficiently obtain information, conduct analysis and reduce the length of the decision-making process. It will also benefit remote self-governing Aboriginal communities across Canada; allowing them to analyze land management-related information in a timely fashion, by conducting on-line GIS queries, analysis and ‘what-if’ scenarios concerning land management issues.

Currently, many First Nations in Canada are using GIS as a tool to assist with the administration of information significant to land claims and natural resource management. Land information maintained in GIS is being used as the basis for many agreements and negotiations to be implemented at a local or regional level.

An effective way to help solve the technical and personnel problems in First Nation communities, as addressed in Chapter 2, is to provide integrated web-based GIS that can centrally maintain the data which can be accessed by many users. This could reduce the cost of repeated data collection and database construction. The availability of basic and popular GIS functions on the website would assist First Nation communities who cannot afford buying complete GIS software for their data analysis. The Web GIS system provides a user-friendly interface that also reduces the cost of personnel training. But debate continues regarding public access to Aboriginal land data as certain geographical information, such as ceremony site and burial grounds, are culturally sensitive information, which require protection.

The evolution process of the web GIS techniques was reviewed in Chapter 3. The major techniques involved in the development of web server, interface program, web GIS server and client viewer were introduced and compared. This review provides the foundation for the prototype system design. The actual implementation process of the prototype system

was presented in Chapter 4. The procedures include: data collection, data processing, spatial database design and populating, system architecture design, website setup and user interface development.

Data for the Yukon First Nations was collected, edited, and processed. A database was designed and populated. Several Internet Map Servers were compared and ArcIMS from ESRI was selected. The ArcIMS web site was then customized and enhanced with special features in Chapter 5: interactive user interface, hyperlinks related to the spatial features, and restricted website access. Map hyperlinks enrich the information provided by the original prototype, and simultaneously, increase the efficiency of the information searching process. Security access to the website restricts user rights to full access, and is important where culturally sensitive information is available.

Advanced queries, especially the combined spatial attribute queries, were developed after examining the ArcXML programming. However, ArcXML has limitation in implementing spatial overlay and intersection. This leads us to the development of complex overlay tools. A methodology for handling multi-layer overlay queries was presented. This involved decomposing complex queries into simpler ones, while maintaining Boolean operations between them. A raster and vector integrated approach was then used resulting in an efficient and timely query process.

6.2 CONCLUSIONS

The research has led to the following conclusions:

There is a need for a web based information system which provides timely information on Aboriginal land tenure and land use activities to be accessed, viewed, and analyzed by Aboriginal land managers and other potential users.

Web GIS is a suitable and efficient tool for disseminating integrated spatial and non-spatial information related to Aboriginal land management. Web GIS requires a suitable

Internet Map Server, such as ArcIMS. For ArcIMS, map data has to be properly processed into the same coordinate system and same projection; and the database has to be designed and populated prior to being published on the website.

HTML viewer as used in the prototype, being suitable and user friendly, as it does not require additional plug-ins at the client side.

Security login can be enforced using the login servlet to implement ArcIMS authentication with an MS Access database, which contains the pairs of user name and password.

Spatial queries such as buffering and intersections can be created through ArcXML by embedding them into java functions on the client side. Spatio-temporal queries can be incorporated into the website after including temporal aspects in designing of the database. Similarly, multi-media and Hyperlinks can be incorporated into the website through proper database design and customization in ArcIMS.

ArcXML programming uses simple and clear syntax, and is therefore good for novel web developers to customize queries for ArcIMS website. It however cannot perform all the required spatial analysis functions. Complex overlay queries can be efficiently decomposed into simpler queries and Boolean operations. They may be implemented using the vector/raster integrated methodology developed in this research.

6.3 RESEARCH CONTRIBUTIONS

This research developed an accessible Web GIS prototype consisting of spatial and legal information related to Aboriginal land development and management. This integrated on-line information system can benefit remote self-governing Aboriginal communities in the Yukon, allowing them to analyze land management-related information in a timely fashion, by conducting on-line GIS queries, analysis and ‘what-if’ scenario models concerning land management issues. This information system can also assist land

managers and land developers to efficiently obtain information, conduct analysis and reduce the length of the decision-making process.

While this research is primarily intended for aboriginal land managers, it will also be useful for non-aboriginal users who are interested in using Web GIS for managing their resources. The investigation of web GIS techniques and the comparison of popular commercial Internet Map Server (IMS) software packages can assist GIS managers to select suitable software for their Web GIS system. In this research, various methods were introduced for customization in ArcIMS, which may be useful for Web GIS developers. The methodology for developing spatial querying and spatial analysis tools provides insights into approaches for decision-support GIS development.

6.4 LIMITATIONS

This research for a Web-based GIS was originally primarily intended for aboriginal communities in Canada. Due to time restrictions, Aboriginal issues have not been addressed in depth. Therefore, web-GIS techniques were the main focus in this research. Interviews with First Nations communities in Yukon were not conducted due to the lack of time available in which to obtain the necessary band council consents for this research. As a result, traditional ecological knowledge has not been documented or incorporated into the prototype. The spatial database has been populated based on the public data and information collected for the Yukon Territory.

In the security implementation, MS Access database is used to test the security login-mechanism since the prototype is a centrally maintained and small-scale application. For large applications with distributed environment, Oracle is recommended to be used for developing the database.

The multi-layer overlay can be implemented by using the integrated vector/raster methodology developed in this research. This methodology has been tested in the desktop

environment, but has yet to be fully implemented in this web GIS prototype due to time restrictions and the non-availability of MapObject-Java license.

6.5 RECOMMENDATIONS FOR FUTURE WORK

Future work will require more enhancements and adding more interactive tools into the web GIS prototype. The methodology for multi-layer overlay needs to be tested and implemented in the web GIS environment. It is important to note that disseminating land information for Aboriginal communities is a challenge as it may contain cultural sensitive information. More research on social, cultural and political issues related to this web GIS prototype is needed. To satisfy multiple users with different needs, future work will need to focus on giving users different views based on their user rights. Currently, one viewer is corresponding to one map service. Further research also needs to investigate how to generate different client views without creating different map services in ArcIMS. More importantly, to make the information system more useful, more legal and planning information, such as mining, and wildlife management information, needs to be collected, processed, and integrated. Multi-media information can also be incorporated. To evaluate the system, feedback needs to be obtained from various Aboriginal communities and other potential users.

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APPENDIX A: YUKON LAND STATUS MAP

