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**GIS Concepts and Capabilities Needed to Support  
Kluane National Park Reserve Management Planning:  
The Aisek River Valley Pilot Study**

by

Philip James Wilson

Thesis submitted to the  
School of Graduate Studies and Research  
in partial fulfilment of the requirements for the  
degree of Master of Arts in Geography.

University of Ottawa



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*"I'm a great believer that you need to befriend technology and make it increase your humanity rather than the other way round.."*

Peter Gabriel, 1993.

## Abstract

Parks Canada uses park management planning to put into practice the dual mandate of protecting environmentally significant areas and providing for recreational activities within those areas. A park management plan lays out the objectives and strategies to indicate how each national park will protect and represent its natural and cultural heritages. A geographic information system (GIS) can support park management planning by providing the concepts of a data base management system and the capabilities of transforming spatial data into information through data integration, analysis-synthesis, and communication.

Park management planning of a section of the Alsek River valley of Kluane National Park Reserve in the Yukon Territory requires the use of specific GIS concepts and capabilities. A three-phase GIS framework focusing on the *pre-conditions to GIS application*, the *GIS application*, and the *GIS application evaluation* is used to define the necessary concepts. The capabilities include acting as an inventory, analysis-synthesis or management tool to contribute to mapping, monitoring, and modelling the valley's resources and visitor activities.

## Résumé

Parc Canada utilise un plan de gestion des parcs afin de mettre en pratique son double mandat de protéger les régions vulnérables aux impacts environnementaux, en plus de permettre la pratique d'activités récréatives à l'intérieur ces régions. Les objectifs et stratégies identifiés par le Service canadien des parcs, dans son plan de gestion, ont pour but d'indiquer à chaque parc la façon dont il doit protéger et représenter son héritage naturel et culturel. Un système d'information géographique (SIG) vient en aide à l'implantation du plan de gestion en offrant des concepts que l'on retrouve dans un système de gestion de base de données, de même que les outils nécessaires à la transformation des données géoréférencées en information au travers des opérations d'intégration, d'analyse-synthèse et de communication des données.

Le plan de gestion pour une section de la vallée de la rivière Alsek, située dans la réserve du parc national Kluane, requiert l'utilisation de concepts et outils spécifiques aux SIG. Un cadre de travail propre au SIG, qui inclut trois phases dont *les pré-conditions à l'application d'un SIG*, *l'application d'un SIG* ainsi que *l'évaluation de l'application du SIG*, est utilisé afin de définir les concepts nécessaires au projet de recherche. Le système proposé joue à la fois le rôle d'outil d'inventaire, d'analyse-synthèse et de gestion. Le système a donc pour but principal de permettre la cartographie, la surveillance et la modélisation des ressources naturelles de la vallée de l'Alsek, de même que les activités de ses visiteurs.

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## **List of Acronyms**

<b>CHRS</b>	<b>Canadian Heritage Rivers System</b>
<b>CNPPA</b>	<b>Commission on National Parks and Protected Areas</b>
<b>CPS</b>	<b>Canadian Parks Service</b>
<b>CYI</b>	<b>Council of Yukon Indians</b>
<b>DBMS</b>	<b>Data Base Management System</b>
<b>DSS</b>	<b>Decision Support System</b>
<b>EARP</b>	<b>Environmental Assessment and Review Process</b>
<b>EIA</b>	<b>Environmental Impact Assessment</b>
<b>ESA</b>	<b>Environmentally Significant Area</b>
<b>GDS</b>	<b>Geographic Data System</b>
<b>GIS</b>	<b>Geographic Information System</b>
<b>GKS</b>	<b>Geographic Knowledge System</b>
<b>IUCN</b>	<b>International Union for Conservation of Nature and Natural Resources</b>
<b>KNPR</b>	<b>Kluane National Park Reserve</b>
<b>NTS</b>	<b>National Topographic Series</b>
<b>UTM</b>	<b>Universal Transverse Mercator</b>
<b>WCED</b>	<b>World Commission on Environment and Development</b>
<b>WCS</b>	<b>World Conservation Strategy</b>

## Chapter 1

### Introduction

#### 1.1 Introduction

There continues to be concern over the accelerating rate of extinction of plant and animal species as well as destruction of ecosystems (eg. Durrell, 1986; Hummel, 1989; Mungall and McLaren, 1991; Soulé, 1986; WCED, 1987; Willison *et al.*, 1992). This concern is being translated into research and action to define the ways of conserving and improving the state of natural and built environments. One document which focuses on the conservation of natural environments is the *World Conservation Strategy* (WCS), launched in 1980 by the International Union for Conservation of Nature and Natural Resources (IUCN) in cooperation with other international agencies. The WCS has three main objectives (IUCN, 1980, 1):

- To maintain essential ecological processes and life-support systems.
- To preserve genetic diversity.
- To ensure the sustainable utilization of species and ecosystems.

The WCS outlines the need to understand and conserve endangered *spaces* as well as endangered *species*. It also describes the need for sound resource management based on effective legislation, organization, training, and information, and provides a conservation framework of objectives and strategies for management of environmentally significant areas (ESAs) by national governments. The management of ESAs requires an integrated approach focusing on the interactions between specific perspectives (eg. physical, biological, cultural), time periods (eg. past, present, future), and spatial scales (eg. local, regional, global).

Although there has been no comprehensive Canadian response to the WCS in terms of defining a national conservation strategy, the Canadian position on ESAs does emphasize the preservation and protection of ecosystem, plant, and animal species and habitat as well as unique

geological, biological, and cultural features (Nelson, 1987). One federal organization which represents a part of this position is Parks Canada, formerly known as the Canadian Parks Service (CPS).

Parks Canada has the dual mandate of protecting representative areas of environmental significance in a system of national parks and providing for recreational activities within those areas. This requires that a balance be found between the resource conservation and visitor use aspects through a combination of sound research and effective management. An important process used to achieve this balance is park management planning which lays out the objectives and strategies to indicate how national parks will protect and represent their natural and cultural heritages.

Sound research underlies the park management planning process so as to acquire knowledge about a particular problem. The more knowledge and better understanding there is about a problem, the better chance there is of making the correct decision as to why and how to solve it. It is appropriate to make the connection between research and management, in the context of Parks Canada, whereby *better data bases → better information bases → better knowledge bases → better park management planning → better park management planning outcomes* becomes the practice (Wellar and Harris, 1992).

Unfortunately, the connection between research and management in the context of park management planning has not yet been fully realized. The first *State of the Parks* report of 1990 concluded that both internal and external threats are negatively affecting the environmental quality of existing national parks (Environment Canada, 1991). As a particular example, Kluane National Park Reserve (KNPR) in the Yukon Territory is affected by development pressures that threaten its wilderness values, several species which move across park boundaries (eg. bears, moose, wolves), as well as the water quality in the Alsek River. To mitigate these threats, the following

six opportunities are recommended (Environment Canada, Parks, 1991, 183):

- Undertake public awareness programs to discuss poaching impacts;
- Amended *National Parks Act* has increased fines for poaching to reduce problem;
- Participate in regional land use planning within the Greater Kluane area;
- Participate in cooperative management of transboundary species with Yukon Government and First Nations;
- Intensive bear management program using grizzly-proof food containers, area closures protects bears and visitors; and
- Improve natural resource data base.

## 1.2 Purpose Statement

The purpose of this thesis is to design, implement, and apply a geographic information system (GIS) data base for a section of the Alsek River valley of KNPR. The end product of the thesis is an operational GIS data base specifically for this area. This requires designing the GIS data base, producing a set of GIS map layers, and testing the GIS data base design in the context of a pilot study.

Welch (1988) concluded that a GIS could contribute to the research and management processes of Parks Canada including park management planning. Having accepted this conclusion and building on the purpose statement, the central research question of this thesis is:

*What GIS concepts and capabilities are needed to support Kluane National Park Reserve management planning?*

Both conceptual and practical perspectives must be considered to answer the central research question. From a conceptual perspective, it is necessary to answer the following questions:

- What are the fundamental concepts and capabilities of a GIS?
- What is the structure and function of Parks Canada in terms of an organizational philosophy?

- How and why can the GIS concepts and capabilities contribute to the structure and function of Parks Canada?

And, from a practical perspective, it is necessary to answer the following questions:

- What problems are likely to arise with respect to the research and management components of KNPR?
- What are the specific geographic considerations that need to be accounted for in the design of the KNPR management planning GIS data base?
- What relevant data need to be specified, collected, verified, and stored in the KNPR management planning GIS data base?
- What procedures, methods, techniques, and operations need to be developed to facilitate the use and management of the KNPR management planning GIS data base?

### 1.3 Context

Research is undertaken to add to knowledge about a particular subject and add to the ways and means of continuing to add to knowledge through new or different research methods, techniques or operations (Ackoff, 1953). This thesis focuses on a component of the latter, that is, adding to the *means* of adding to knowledge. It examines the park management planning methods and techniques of Parks Canada which contribute to adding to the data, information, and knowledge bases.

A geographic information system (GIS) is a tool which enables users to input, store, manage, retrieve, analyze, synthesize, and display geographically-referenced data which model objects from the real world as points, lines, and polygons (Burrough, 1986). GIS technology provides powerful spatial query, and analysis and synthesis tools which can help manage data

from a geographic perspective. Specific GIS concepts and capabilities can be used to transform geographic data into information (Wellar, 1993b). Sound management of national parks is reliant on the efficient management of geographic data and information.

The primary objective of a GIS in this context is to contribute to the park management planning process. If the GIS does not succeed in this goal then it is not a worthwhile investment. The GIS should facilitate user interaction with geographic data and information and with geographic problem-solving (ie. human-problem interaction), rather than with software, hardware or peripherals (ie. human-computer interaction) (Mark and Gould, 1991). This means that the software, hardware, and peripherals should ultimately be transparent interfaces which allow users easier access to the geographic data and information.

Welch (1988) completed an initial user needs assessment to determine how Parks Canada should go about using GIS technology to assist in national park management. A principal application of the natural resources data is park management planning which determines the development and operation of each national park and constitutes a framework within which subsequent management, detailed planning, and implementation will take place (CPS, 1990b). An essential component in the process of acquiring data related to national park resources is the biophysical land inventory. Because a large amount of data exist within this inventory for each national park, it has become increasingly necessary to seek more efficient and effective ways to store, manage, and retrieve these data.

It is vital to design and implement a GIS data base for each national park that takes into account the structure of the biophysical land inventory as well as each national park's geographic considerations. This is because the GIS should be "of the organization, not just in it" (Wellar, 1993a, 209) and therefore should take on the structure and function of the organization itself. A contextual GIS framework should be designed based on a statement of each national park's

purpose as outlined in the park management plan (Gauthier, 1989).

There are several reasons why is it worthwhile to focus attention on the *design* of the GIS data base. First, as in all research, the methodological aspect is of central importance since the quality of results depends upon the quality of thought that went into the design. Also, reliable, valid, and relevant knowledge on a subject stems from methodologically-designed research and allows the process to be cumulative. In this thesis, the primary objective is to design the GIS data base which, if designed successfully, can be used to aid in acquiring information and knowledge about park resources.

It is important to focus on the design because the thesis is of an exploratory nature. The emphasis of *exploratory* research is on the methodological design and not the results, whereas *confirmatory* research focuses more on the results since the initial development of the methodology has been done. For the GIS to be successful, Croswell (1991, 52) states that there is a maxim which needs to be respected: "GIS development efforts must use a structured systems approach with a sensitivity to the unique characteristics of GIS as compared to more traditional information systems". The purpose of the design is to facilitate the evolution of the GIS from an *inventory* tool to an *analysis-synthesis* tool, and eventually, to a *management* tool (Crain and MacDonald, 1984; Wellar, 1993b).

#### 1.4 Study Area

In order to guide the development of a system of national parks, Parks Canada uses a plan which divides Canada into 39 distinct *national park natural regions* based mainly on physiography and vegetation (CPS, 1990a). There are currently 22 natural regions represented by 36 national parks. The ultimate goal is to represent each natural region in the national parks system. The national marine parks system plan defines 29 marine regions, but have only one designation and four marine additions to existing terrestrial parks (Duffus and Dearden, 1993).

Kluane National Park Reserve (KNPR) is located in the southwest corner of the Yukon Territory and represents natural region number 6: *Northern Coast Mountains*. KNPR is dominated by glaciers and high mountains, including the highest mountain in Canada (Mount Logan at 5,959 m), and is an area in excess of 22,000 km<sup>2</sup>. Fringing the mountains and glaciers is a narrow greenbelt area whose vegetation ranges from coniferous and deciduous forests to alpine tundra. The greenbelt covers about 18 percent of the park and provides habitat for wildlife (CPS, 1990b).

Large river valleys dominate the regional morphology of the greenbelt area including the Slims, Kaskawulsh, Donjek, Dezadeash, and Aisek. In particular, this thesis focuses on a section of the Aisek River valley. The Aisek River begins at the confluence of the Kaskawulsh and Dezadeash Rivers and ends in the Gulf of Alaska having flowed through both British Columbia and Alaska. The Aisek River is presently a part of the Canadian Heritage Rivers System because of its highly significant natural themes and the valley is designated Zone 1 (*Special Preservation*) under the Parks Canada zoning system (CPS, 1990b).

At present, the entire Aisek River valley is wilderness with no recreational infrastructure (eg. buildings, campgrounds, boat docks). A motorboat tour down the Aisek River to the Lowell Glacier has been proposed by Parks Canada (CPS, 1990b). This tour would allow a large number of tourists to access and view one of the park's glaciers, which at present is a difficult and expensive activity. Also, rafting trips down the Aisek River to Dry Bay in the Gulf of Alaska are becoming more frequent. This is leading to an increase in campers and hikers in the valley.

A thorough environmental review of this proposed development is required. Wielgus *et al.* (1992, 2) have designed a six-year grizzly bear research program for KNPR to "provide CPS with the ability to manage the wilderness' use to prevent significant impact on the park's grizzly population". This thesis attempts to contribute to the grizzly bear research program by applying and evaluating specified GIS concepts and capabilities. The GIS is used in the context of a pilot

study to test the relationship between topographic features and the distribution of grizzly bears in the Alsek River valley. Also, the pilot study is used to evaluate the GIS data base design and to recommend modifications so that successful design and implementation of a park-wide GIS data base to support KNPR management planning will be likely.

## 1.5 Structure

In order to complete the research objectives, the topics which appear in this chapter are elaborated on in the body of the thesis. In this chapter the focus is on presenting a general overview by outlining the research purpose, context, study area, and structure.

Chapter 2 puts the thesis in context by reviewing definitions of GIS and national park management, describing the national scale structure and function of Parks Canada, and elaborating on the relationship between GIS and park management planning.

Chapter 3 defines a framework for the regional scale case of GIS use to support KNPR management planning. The 1990 *KNPR Management Plan* is summarized so as to provide a background for defining the needed GIS concepts and capabilities.

Chapter 4 applies the KNPR management planning GIS framework to a local scale study of the Alsek River valley. A pilot study exploring the relationship between topographic features and grizzly bear distribution is used to test the initial GIS data base design.

Chapter 5 synthesizes the findings by presenting the conclusions, a brief discussion, and recommendations for future work.

## Chapter 2

### Parks Canada and GIS: A Conceptual Review

#### 2.1 Introduction

The objective of this chapter is to introduce the two main components of the thesis. The basis of the chapter is a comprehensive literature review to gain insight into the relationship that exists between a geographic information system (GIS) and Parks Canada.

The chapter begins with definitions of the two main components. The definition of GIS examines the view that it is a special member of the information system family because of its unique ability to link spatial and attribute data (Wellar, 1993b). National park management is defined by using a framework designed by Dearden (1991). This framework puts national park management in the larger context of decision making and inherently includes the spatial dimension. Following from these definitions is an outline of the organizational structure and function of Parks Canada. Particular attention focuses on the park management planning process to understand how the issue of balancing resource conservation and visitor use is handled.

The main focus of the chapter identifies and elaborates on the relationship between GIS and Parks Canada, and seeks to justify the proposition that GIS *can* be used to support park management planning. To be effective, the GIS must respect organizational considerations and be defined by the specific methods and techniques which lie behind the park management planning process.

#### 2.2 Geographic Information System (GIS)

It is important to state that definitions of GIS are numerous, and in some instances, quite different from one another (Cowen, 1988). Wellar (1993b, 7) states that "there is no single, simple, one-time, all-purpose definition of the GIS field in general or a GIS in particular". Nonetheless, it is possible to identify the principal concepts and capabilities which contribute to

a definition of GIS (Wellar and Wilson, 1993). Like research itself, defining terms is a cumulative and continuous process.

Dueker (1979) makes the point that GIS is simply one member of the information system (IS) family. Other members include management (MIS), land (LIS), planning (PIS), financial (FIS), and transport (TIS). However, there are unique characteristics of GIS which distinguish it from the other IS members (Crowell, 1991). Dueker (1979, 106) states that GIS is:

a special case of information systems where the database consists of observations on spatially distributed features, activities, or events, which are definable in space as points, lines or areas. A geographic information system manipulates data about these points, lines and areas to retrieve data for ad hoc queries and analyses.

Many of the concepts supporting IS and GIS emerged in the 1960s and 1970s, although the corresponding technology has only become available in the last five to ten years (Masser and Onsrud, 1993).

Moving the notion of the geographic significance of GIS one step further, Burrough (1986), Mark and Gould (1991), and Tomlinson (1988) agree that GIS should be a transparent interface which brings together maps, data, and models. Tomlinson (1988, 249) states that "the classic steps of observation, measurement, description, explanation, forecast and decision can be grouped into the more familiar categories of data gathering, data handling, data analysis models (mental and formal) and decision making".

Mark and Gould's (1991, 1427) philosophical position deals with moving GIS from a human-computer interaction to a human-problem or human-phenomenon interaction. They state that "the prime objective should be to enhance user interaction with geographic information and with geographic problem-solving, rather than with software and hardware".

Burrough (1986, 7) states that a GIS should *itself* be considered to be a geographic model:

GISs should be thought of as being very much more than means of coding,

storing, and retrieving data about aspects of the earth's surface. In a very real sense the data in a GIS, whether they are coded on the surface of a piece of paper or as invisible marks on the surface of a magnetic tape, should be thought of as representing a model of the real world. Because these data can be accessed, transformed, and manipulated interactively in a GIS, they can serve as a test bed for studying environmental processes or for analysing results of trends, or for anticipating the possible results of planning decisions.

Smith *et al.* (1987) and Goodchild (1985) focus attention on the data base as a fundamentally important component of a GIS (Figure 2.1). The design of the spatial data base ultimately determines the effectiveness of the system as a whole. That is, if the data base is not designed according to the needs of the users then the system will be ineffective. Smith *et al.* (1987, 13) state that "a GIS may be viewed as a data base system in which most of the data are spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the data base". Goodchild's (1985, 36) definition is similar: "a GIS is best defined as a system which uses a spatial database to provide answers to queries of a geographical nature... The generic GIS thus can be viewed as a number of specialized spatial routines laid over a standard relational database management system".

The use of the term *transform* by Burrough (1986) is relevant in defining the capabilities of a GIS. Once an effective spatial data base has been designed and built, GIS capabilities allow for the transformation of geographic data into information (Wellar, 1993b). The transformation capabilities can contribute to the *reality* → *data* → *information* → *knowledge* flow which is relevant to both researchers and managers (Wellar and Harris, 1992). Some of the main kinds of GIS capabilities are shown in a hierarchical overview in Figure 2.2 and "will, in most geographical information systems, be provided in such a way that a user can work interactively in order to perform the analyses and syntheses required" (Burrough, 1986, 81). Burrough (1992) provides a thorough review of these GIS capabilities within a nine class system.

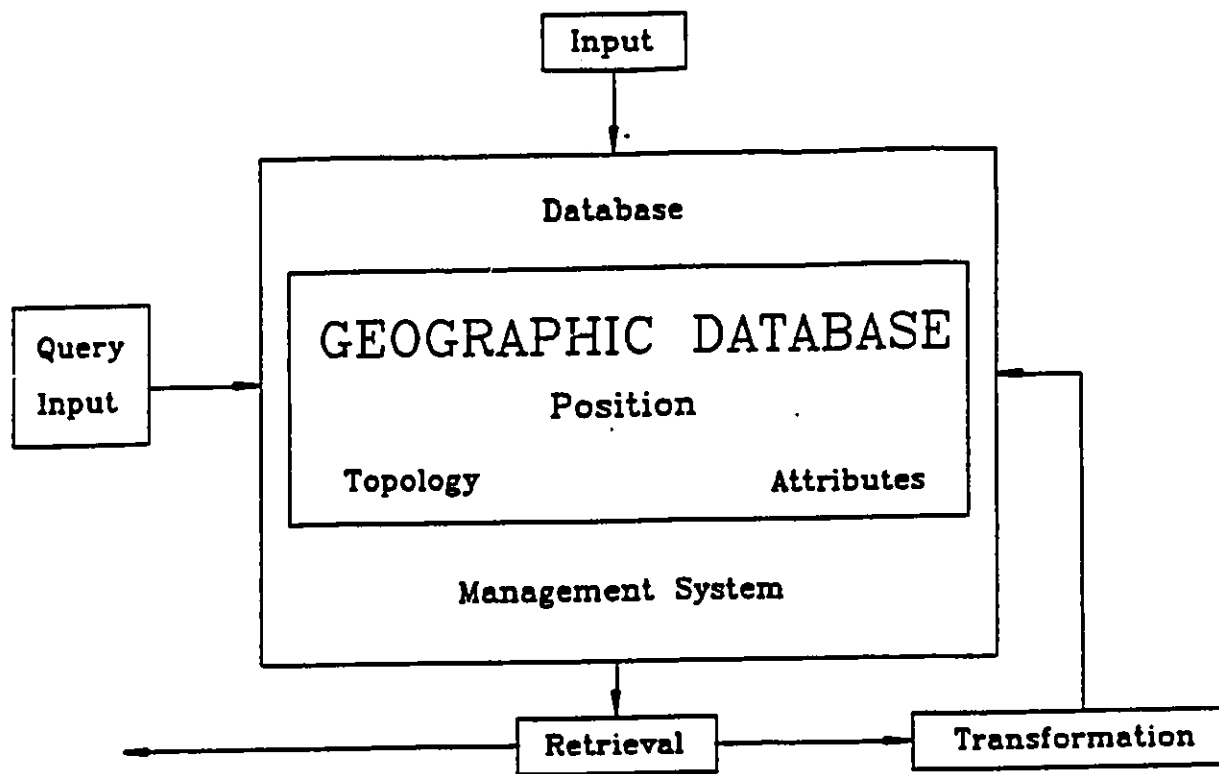


Figure 2.1 The components of a geographic data base (Burrough, 1986, 8).

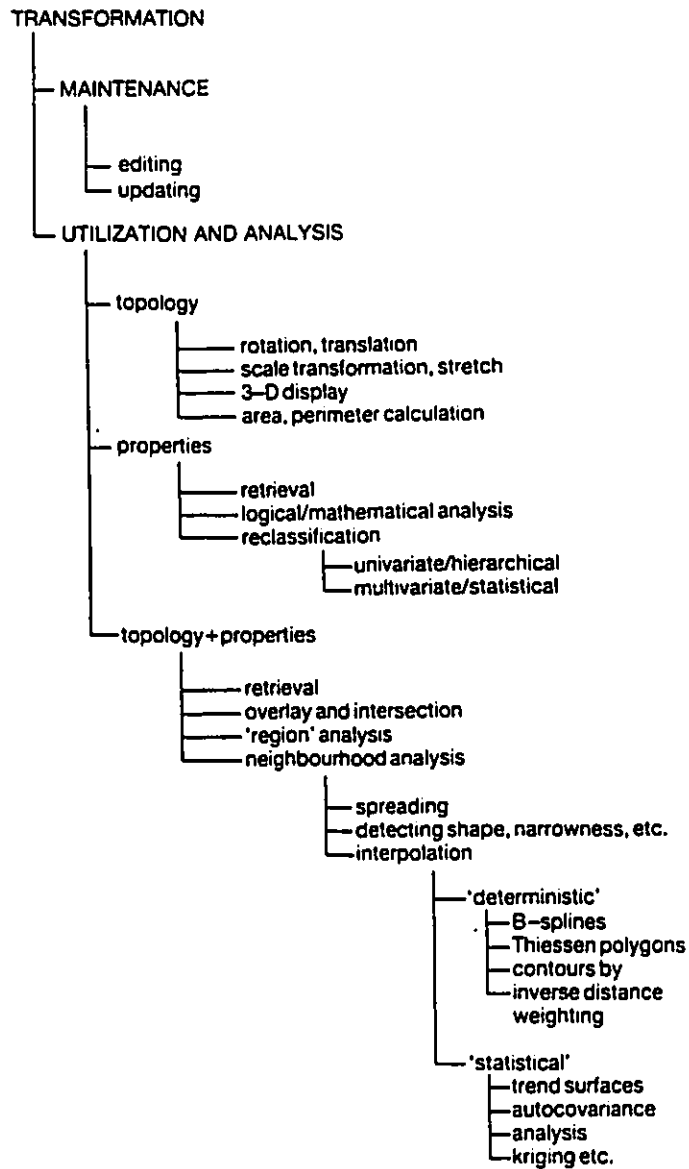


Figure 2.2 Overview of the hierarchy of data transformation operations in a GIS (Burrough, 1986, 81).

The data stored in a GIS can be divided into two components: the *spatial* or *graphical* data and the *attribute* or *feature* data. There are two general types of data structures, also called data models, relating to the spatial data: *raster* and *vector* (Figure 2.3) (Aronoff, 1989; Burrough, 1986; Wang, 1992). The raster data structure consists of an array of grid cells each of which can have a different attribute. The location of geographic objects is defined by the row and column position of the cell they occupy. The vector data structure represents objects as points, lines, and polygons. The position of each object is defined by its placement in a coordinate reference system. Aronoff (1989, 165) states that "in the raster approach, the homogeneous units are cells... In the vector approach, the homogeneous units are points, lines, and polygons". Each of the two data structures has its own set of advantages and disadvantages (Table 2.1).

The attribute data represent the objects. These data are stored in a data base management system (DBMS) as individual records. For example, a polygon map may have a forest stand feature. In the data base, its attributes might include species composition, average tree height, and the date the stand was last logged. The relationships between all the spatial and attribute data need to be explicitly defined. It is this ability to link the spatial and attribute data which distinguishes a GIS from an IS (Figure 2.4) (Dangermond, 1990).

A **geographic information system (GIS)** is a tool that enables users to input, store, manage, retrieve, analyze, synthesize, and display geographically-referenced data which model objects from the real world as points, lines, and polygons. *Spatial* data are stored in assorted data structures (ie. raster and vector) and linked to *attribute* data stored in a data base management system (DBMS). Together, the spatial and attribute data facilitate the testing of specific spatial relationships between objects in the data base and the transformation of geographic data into information (Figure 2.5).

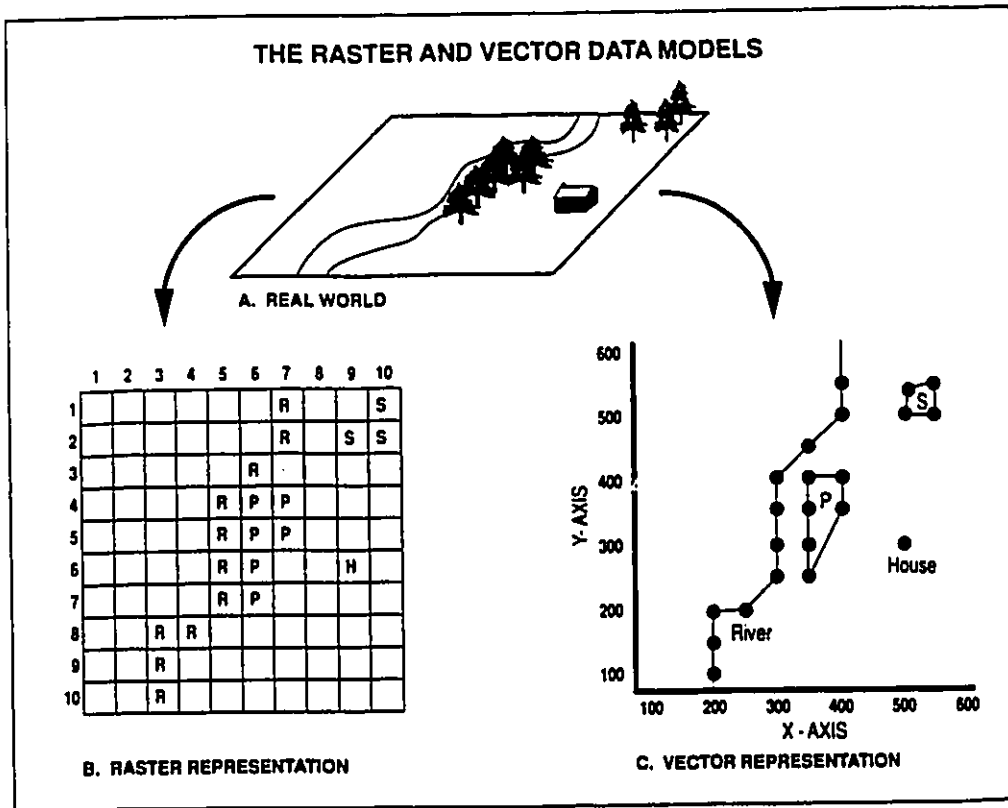


Figure 2.3 Comparison of the raster and vector data models (Aronoff, 1989, 164).

Raster Data Structure		Vector Data Structure	
<b>Advantages</b>			
1	Simple data structure.	1	More compact data structure than the raster model.
2	Overlay operations are easily and efficiently represented in a raster format.	2	Efficient encoding of topology, and, as a result, more efficient implementation of operations that require topological information, such as network analysis.
3	High spatial variability is efficiently represented.	3	Better suited to supporting graphics that closely approximate hand-drawn maps.
4	More or less required for efficient manipulation and enhancement of digital images.		
<b>Disadvantages</b>			
1	Data structure is less compact.	1	More complex data structure than a simple raster.
2	Topological relationships are more difficult to represent.	2	Overlay operations are more difficult to implement.
3	Output of graphics is less aesthetically pleasing because boundaries tend to have a blocky appearance rather than the smooth lines of hand-drawn maps. This can be overcome by using a very large number of cells, but may result in unacceptably large files.	3	Representation of high spatial variability is inefficient.
		4	Manipulation and enhancement of digital images cannot be effectively done in the vector domain.

Table 2.1 Comparison of raster and vector data structures (Adapted with modifications: Aronoff, 1989, 166).

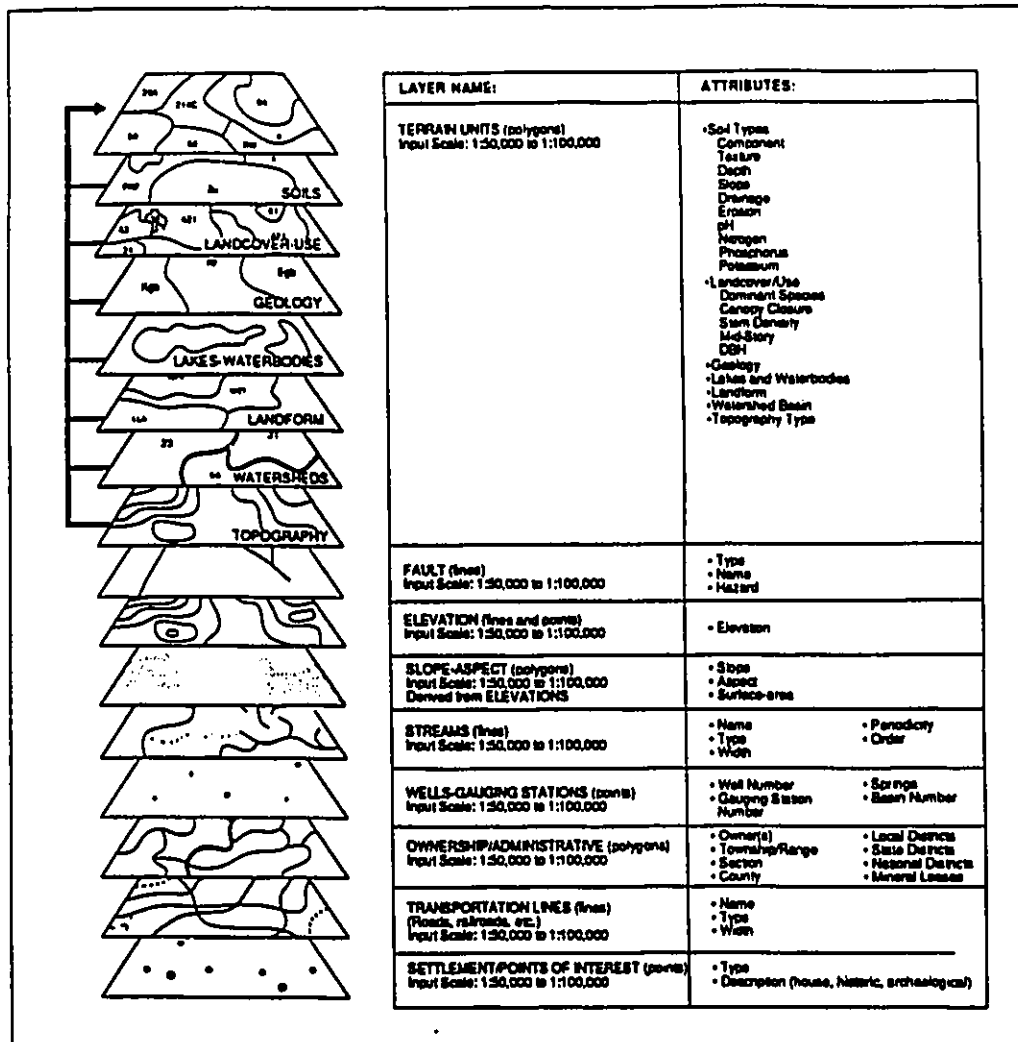


Figure 2.4 GIS data layers used in natural resource applications (Aronoff, 1989, 192).

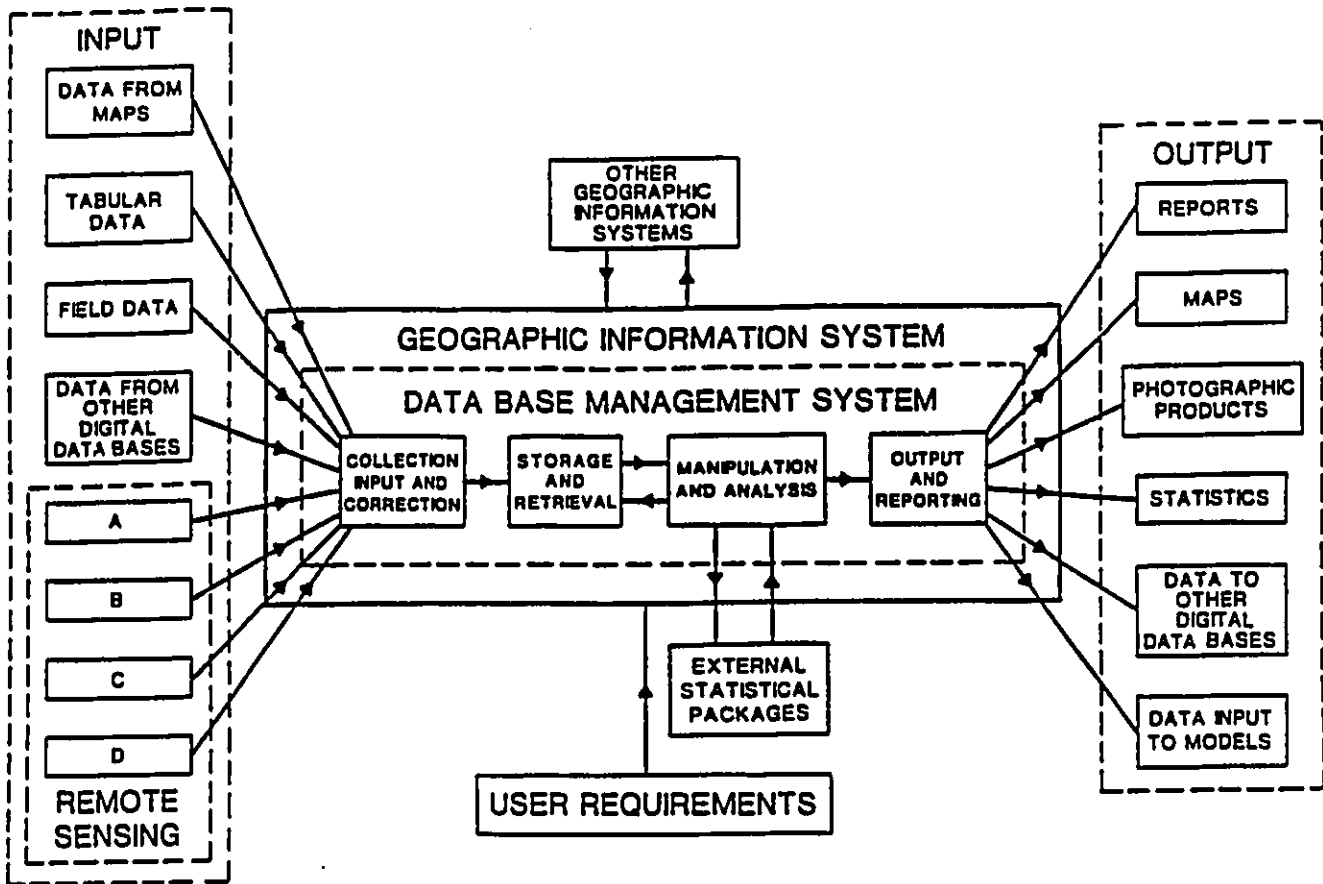


Figure 2.5 The main components of a GIS (Linden, 1990, 192).

### 2.3 National Park Management

Dearden (1991) developed a conceptual framework of how national park management fits into the bigger picture of decision making (Figure 2.6). In the framework, decision making at each level must reflect the context of the higher levels. Therefore, in order to be functional national park management must reflect the societal, scientific, resource management, protected areas, protected areas management, and national parks contexts. Dearden (1991, 131) states that "protected areas must be seen within the context of resource allocation as a whole, with attention given to the rationale for such allocations, how the allocations are determined, and the current status of protected areas in Canada". This statement concentrates on the methods (ie. why?) and techniques (ie. how?) of management set in the contemporary context.

Different social systems and different ways of life provide input into the way nature and resources are defined. Spoehr (1956, 94) states that "the interpretation of specific resources cannot be understood except as a facet of human culture" and that natural resources are controlled not only by technology (that converts them into useable goods), but also by the "nature of social structure". Natural resources are defined by human perceptions, attitudes, values, wants, skills, legal, financial, and institutional arrangements, as well as by political customs (Mitchell, 1989). Zimmermann (1951) states that what is a natural resource for one culture may be of no use to another culture, and that resources are subjective, relative, and functional.

Resource management represents the actual decisions involving laws, policies, plans, programmes or projects with respect to how resources are allocated and under what conditions they may be exploited (Mitchell, 1989; Nelson, 1987). It emphasizes the control or direction of resource development based on an understanding of the fundamental characteristics of the resources and the processes through which they are, could be, and should be allocated and developed (Mitchell, 1989).

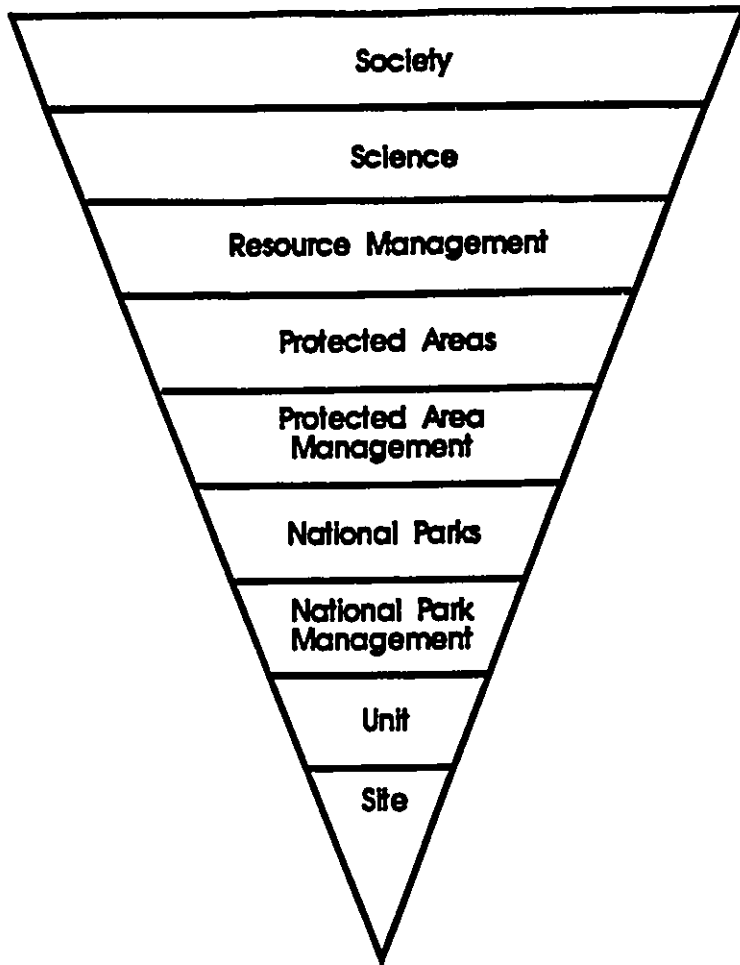


Figure 2.6 National park management set in the larger context of decision making (Adapted with modifications: Dearden, 1991, 131).

An important underlying component of resource management is the use of science and environmental monitoring: "research is increasingly recognized as a handmaiden of sound management" (Nelson, 1987, 300). Science focuses on adding to knowledge and adding to the ways and means of adding to knowledge (Ackoff, 1953). Reliable, valid, and relevant knowledge stems from methodologically-designed research and allows the process of acquiring knowledge to be cumulative (Wellar and Harris, 1992). Management based on sound methodologies and principles of acquiring knowledge of relevant processes increase the chances of management success (Janzen, 1986; Mitchell, 1989; Polunin and Eidsvik, 1979).

Ecological conservation is recognized as being the principal factor in the planning and management of national parks (Lemons, 1987; Nelson, 1978; Polunin and Eidsvik, 1979). Polunin and Eidsvik (1979, 26) illustrate how the principles of conservation and the practices of national park management are interconnected and interdependent. They state that "dynamic ecosystems require dynamic management, and... management in the future will be required increasingly to attain specific conservation objectives". To attain specific conservation objectives, basic ecological processes must to be studied. Soulé (1986, 370) states that "managers must be as conversant with genetics, ecology, and biogeography as the biologists are with the social and economic rules that must influence management policies".

An important component related to ecology and national park management is ecosystem or ecological integrity (Nelson, 1991; Serafin *et al.*, 1989; Woodley and Theberge, 1992). Ecological integrity currently exists as a general model which needs an operational definition to be useful in the context of national park management (Nelson, 1991). Serafin *et al.* (1989, 13-14) initiated the work into developing an operational definition of ecological integrity specifically for Parks Canada:

As a model, ecological integrity intermingles scientific theories with moral and ethical judgements. The scientific elements appear rooted in concepts of minimum

viable population size, island biogeography, biological diversity and ecosystem structure and function. When applied to National parks, such concepts appear to promise opportunities for more informed and improved management. However, such concepts must be applied in ways which recognize that we really do not know how ecosystems work and our models of nature are laced with moral and ethical judgements.

Environmental monitoring is a way of observing and measuring ecosystem integrity through the use of indicators (Berger, 1992; Goldsmith, 1991; Woodley and Theberge, 1992). "Monitoring is undertaken to ascertain whether the prevailing conditions (physiological, behavioural, ecological or environmental) match the previously defined standards or norms, expressed perhaps as acceptable minima or maxima, or that they lie within certain defined limits" (Hellawell, 1991, 2). Ongoing monitoring studies provide information and knowledge necessary to prepare and complete *State of the Parks* and *State of the Environment* reports (Berger, 1992; Keddy, 1991; Nelson, 1991).

The International Union for Conservation of Nature and Natural Resources (IUCN) system of national parks and protected areas is summarized in Table 2.2. This table reveals the subtle variations between different types of protected areas. The national parks category (Category II) is just one of the spatial categories for conservation management within the IUCN system. The IUCN Commission on National Parks and Protected Areas (CNPPA) has been promoting a parks and protected areas network which is part of a larger development and conservation system (Nelson, 1987).

**National park management** is concerned with the structure and function of natural areas representative of the diversity of ecosystems of a nation which visitors are allowed to enter for inspirational, educative, cultural, and recreative uses. It is the decision making process emphasizing the control or direction of resource planning and development, and is necessarily set in the contexts of society (ie. the public's perceptions, attitudes, and values), science (ie. ecology and environmental monitoring), and resource and protected areas management (ie. laws,

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**Category I - Scientific Reserve/Strict Nature Reserve**

Areas with some outstanding ecosystem features and/or species of flora and fauna of national scientific importance, representative of particular natural areas, fragile life forms or ecosystems, important biological or geological diversity, or areas of particular importance to the conservation of genetic resources. Concern is for continuance of natural processes and strict control of human interference.

**Category II - National Park**

A relatively large area where one or several ecosystems are not materially altered by human use, the highest competent government authority has taken steps to prevent or control such alteration and visitors are allowed to enter, under specific conditions for inspirational, educative, cultural, and recreative uses.

**Category III - Natural Monument/Natural Landmark**

Area normally contains one or more specific natural features of outstanding national significance which because of uniqueness or rarity should be protected. Ideally little or no sign of human activity.

**Category IV - Nature Conservation Reserve/Managed Nature Reserve/Wildlife Sanctuary**

A variety of areas fall in this category. Although each has as its primary purpose the protection of nature, the production of harvestable renewable resources may be a secondary role in management. Habitat manipulation may be required to provide optimum conditions for species, communities, or features of special interest.

**Category V - Protected Landscape or Seascape**

A broad category embracing a wide variety of semi-natural and cultural landscapes within various nations. In general two types of areas, those where landscapes possess special aesthetic qualities resulting from human-land interaction and those that are primarily natural areas managed intensively for recreational and tourist uses.

**Category VI - Resource Reserve (Interim Conservation Unit)**

Normally extensive, relatively isolated, and lightly inhabited areas under considerable pressure for colonization and greater exploration. Often not well understood in natural, land-use, or cultural terms. Maintenance of existing conditions to allow for studies of potential uses and their effects as a basis for decisions.

**Category VII - Natural Biotic Area/Anthropological Reserve**

Natural areas where the influence of technology of modern man has not significantly interfered with or been absorbed by the traditional ways of life of inhabitants. Management is oriented to maintenance of habitat for traditional societies.

**Category VIII - Multiple Use Management Area/Managed Resource Area**

Large areas suitable for production of wood products, water, pasture, wildlife, marine products, and outdoor recreation. May contain nationally unique or exceptional natural features. Planning and management on a sustained-yield basis with protection through zoning or other means for special features or processes.

**Category IX - Biosphere Reserve**

Intended to conserve representative natural areas throughout the world through creation of global and national networks of reserves. Can include representative natural biomes, or communities, species of unique interest, examples of harmonious landscapes resulting from traditional uses, and modified or degraded landscapes capable of restoration to more natural conditions. Biosphere reserves provide bench-marks for monitoring environmental change and areas for science, education, and training.

**Category X - World Heritage Site**

To protect natural - and also cultural - features considered to be of world-heritage quality; examples include outstanding illustrations of the major stages of earth's evolutionary history, habitats where populations of rare or endangered species of plants and animals still survive, and also outstanding archaeological or architectural sites. Stress on maintenance of heritage values for world-wide public enlightenment, and to provide for research and environmental monitoring.

**Category XI - Wetlands of International Importance (Ramsar)**

Marshes, swamps, and other wetlands of value for flood control, nutrient production, wildlife habitat, and related purposes. Management procedures designed to prevent destruction and deterioration through national agreement to an international convention known as Ramsar after the site in Iran where the convention was initially agreed to by a number of founding countries.

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**Table 2.2 Categories for conservation management (Nelson, 1987, 294).**

policies, plans, programmes, and projects) (see Figure 2.6).

## 2.4 Parks Canada

### 2.4.1 Structure

Parks Canada is one of the oldest park services in the world. Its origin is linked to the construction of the transcontinental railway when, in 1885, Banff National Park was created around two natural hot springs (McNamee, 1993). The first transcontinental railway brought people to the Rocky Mountains where legislators decided to preserve and administer as a public enterprise the natural hot springs (Lothian, 1987). Since then, Parks Canada has evolved from a preservation and protection mode for a *collection* of national parks to a resource management mode, and to its present integrated resource management mode based on an *ecosystem approach* (Figure 2.7) (Dearden, 1991; Foresta, 1985; McNamee, 1993). There are currently 36 national parks covering an area of 218,902.9 square kilometres (Table 2.3).

The national parks are representative of 22 of Canada's 39 natural regions which have been defined based on physiographic, ecological, geographic, and geologic characteristics (Figure 2.8) (Foresta, 1985). The natural regions are the result of the development and implementation of a systematic approach to planning the national parks. The goal of the system is to establish a national park representing each of the natural regions. To date, this goal has not been achieved (CPS, 1990a).

Further, a concern is beginning to develop regarding the decrease in environmental quality of the existing national parks (McNamee, 1993; Rollins, 1993). The first national *State of the Parks* report of 1990 confirmed that national parks are affected by internal and external threats including water pollution, poaching, and logging on land near national park boundaries (Environment Canada, Parks, 1991). A recent realization was that most of the threats originate from outside park boundaries so that there is the need for an integrative or ecosystem approach

Scientific and Management Complexity

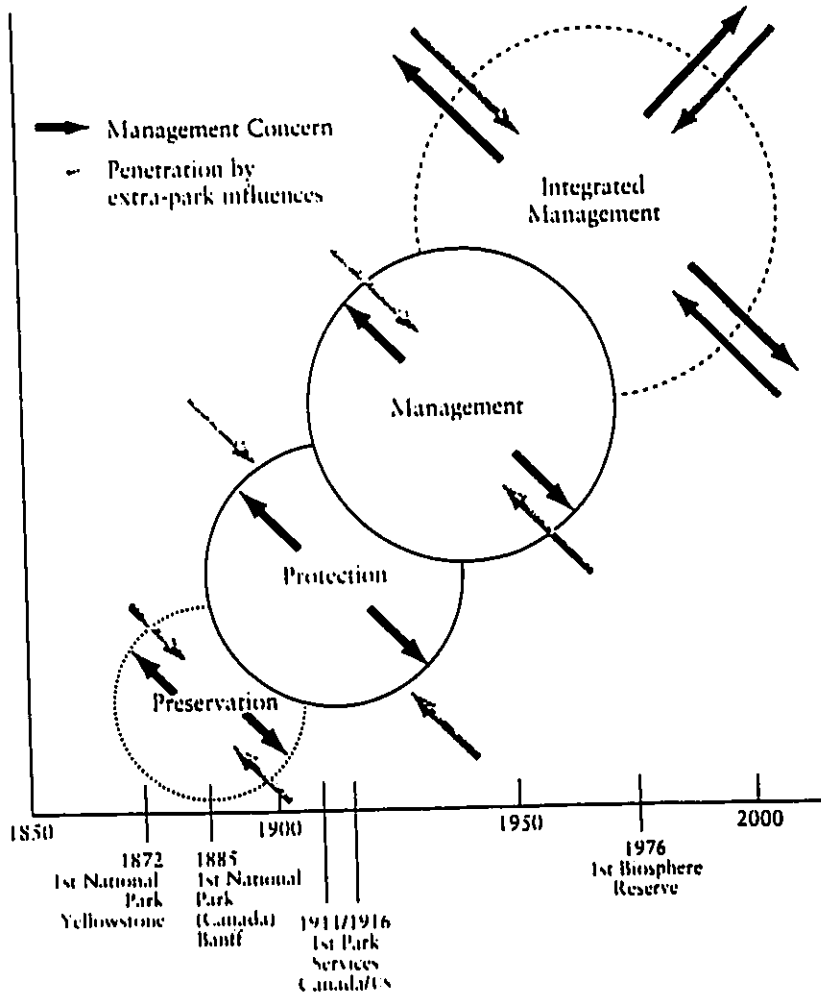


Figure 2.7 Protected areas - evolving relationships from isolation to integration (Dearden, 1991, 143).

National Park or National Park Reserve (R)	Year Established	Area (km <sup>2</sup> )
Banff, Alberta	1885	6641.0
Glacier, British Columbia	1886	1349.3
Yoho, British Columbia	1886	1313.1
Waterton Lakes, Alberta	1895	505.0
Jasper, Alberta	1907	10878.0
Elk Island, Alberta	1913	194.0
Mount Revelstoke, British Columbia	1914	259.7
St. Lawrence Islands, Ontario	1914	8.7
Point Pelee, Ontario	1918	15.0
Kootenay, British Columbia	1920	1406.4
Wood Buffalo, Alberta-N.W.T.	1922	44802.0
Prince Albert, Saskatchewan	1927	3874.3
Riding Mountain, Manitoba	1929	2973.1
Georgian Bay Islands, Ontario	1929	25.6
Cape Breton Highlands, Nova Scotia	1936	948.0
Prince Edward Island, P.E.I.	1937	21.5
Fundy, New Brunswick	1948	205.9
Terra Nova, Newfoundland	1957	399.9
Kejimikujik, Nova Scotia	1974	403.7
Kouchibouguac, New Brunswick	1979	239.2
Pacific Rim, British Columbia (R)	-	285.8
Forillon, Quebec	1974	240.4
La Mauricie, Quebec	1977	536.1
Pukaskwa, Ontario	-	1877.8
Kluane, Yukon (R)	1976	22013.3
Nahanni, N.W.T. (R)	1976	4765.2
Auyuittuq, N.W.T. (R)	1976	21469.4
Gros Morne, Newfoundland	-	1805.0
Grasslands, Saskatchewan	-	906.4
Mingan Archipelago, Quebec (R)	1984	150.7
Ivvavik (Northern Yukon), Yukon	1984	10168.4
Ellesmere Island, N.W.T. (R)	1988	37775.0
Bruce Peninsula, Ontario	-	154.0
Gwaii Haanas (South Moresby), British Columbia (R)	-	1495.0
Aulavik, N.W.T.	-	12200.0
Vuntut, Yukon	-	4345.0
North Baffin, N.W.T.	-	22252.0

**Notes:**  
**Year Established** refers to year park was formally created by Order-In-Council, proclamation or enactment.  
**(R)** refers to National Park Reserve: A reserve is an area set aside for the purpose of a national park, to which the National Parks Act applies, but the lands, fish, and wildlife are subject to the future settlement of native land claims.  
Total number of parks is 36, total area equals 218902.9 km<sup>2</sup> (as of October, 1993).

Table 2.3 Canada's National Parks and Reserves (updated from Eidsvik and Henwood, 1990).

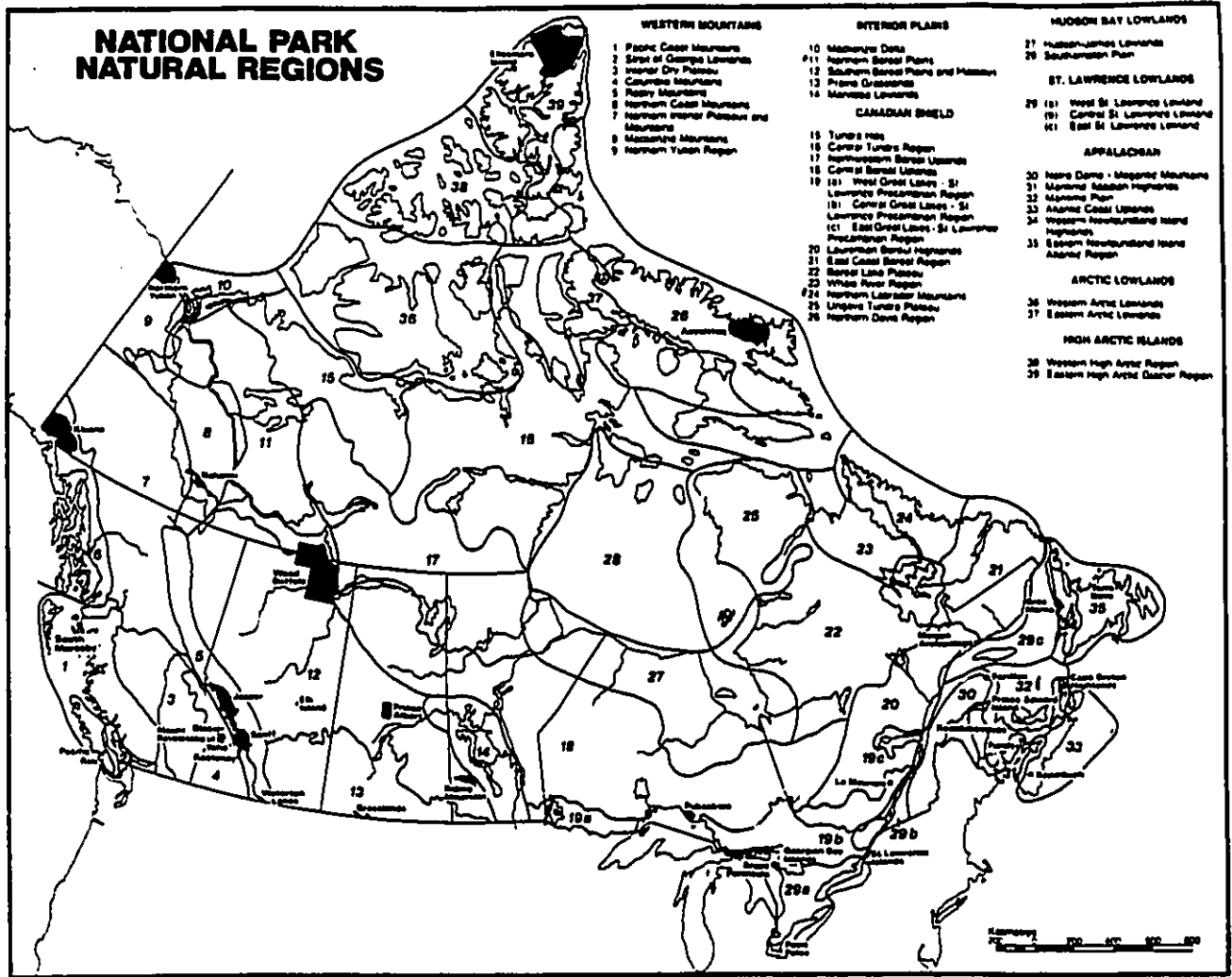


Figure 2.8 National park natural regions (CPS, 1990a, 5).

recognizing the interconnectedness of ecosystems at all spatial scales (Dearden, 1991).

The creation of a new national park normally follows a five-step sequence (CPS, 1990a). Step 1 *identifies* areas which are highly representative of the natural region's biophysical features and processes, and where human impact is minimal. Step 2 *selects* a potential park from the natural region's representative natural areas. Step 3 *assesses* the feasibility of establishing the potential park. Step 4 *negotiates* a new park agreement and possible boundaries for the new national park are drawn. The last step formally *establishes* a new national park in legislation. This means that it must be "approved by a legislature, must be followed by the government and by the citizenry, and is enforced by an independent court system" (Eagles, 1993a, 57). The House of Commons and the Senate are responsible for the passage of legislation regarding the creation of national parks as outlined in the *National Parks Act*.

Rollins (1993) devotes a section of his work on the management of national parks to the administration and bureaucracy of Parks Canada under the following headings: Jurisdiction, Submission to Central Agencies, Financial Management, Decentralized Organization, Toward Greater Accountability, and Multi-disciplinary Management Support and Reviews. The following points are made:

- "With national parks, authority for park management emanates from the National Park Act" (Rollins, 1993, 91).
- "Regulations have been developed for the following kinds of management activities: camping, domestic animals, fire protection, fishing; garbage, aircraft landings, highway traffic, timber and fire management, wildlife, licensing commercial activities, and so on" (Rollins, 1993, 91).
- "The chief organizing principle of the Canadian Parks Service is decentralization" (Rollins, 1993, 92).
- "Among the best examples of (the) multi-disciplinary work is the process of planning park management and natural resources management. Park management plans take national direction and following public consultation, apply it to individual parks. They thereby give the occasion every few years to consider the role and purpose of individual parks, to review park objectives, and to reassess park

heritage values in the light of biophysical and socioeconomic situations" (Rollins, 1993, 93).

#### 2.4.2 Function

Parks Canada has the objective (CPS, 1990a, 1):

To protect for all time representative natural areas of Canadian significance in a system of national parks, and to encourage public understanding, appreciation and enjoyment of this natural heritage so as to leave it unimpaired for future generations.

Once an area has been designated as a national park, the issue of balancing resource conservation and visitor use arises (Eagles, 1993b). The park management planning process can then be applied. Major direction for this process is set out in the *Park Purpose and Objectives Statement*. For example, the *Park Purpose Statement* for Kluane National Park Reserve is (CPS, 1990b, 9):

To protect for all time, and to present to the public, a natural area of Canadian significance representative of the Northern Coast Mountains Natural Region.

In 1988, the Canadian Parliament amended the *National Parks Act* to include the statement: "Maintenance of ecological integrity through the protection of natural resources shall be the first priority when considering park zoning and visitor use in a management plan" (Bill C-30, 1988). Also, a new provision of the Act is the legal requirement that park management plans be reviewed every five years (Nelson, 1991; Serafin *et al.*, 1989). These amendments are significant because they establish that the priority for national parks is conservation over recreation (McNamee, 1993).

The park management plan provides the necessary direction by which the resources and activities in a particular park, site or other heritage area are managed, ensuring fulfilment of the *Park Purpose Statement*. Each plan is a local expression and provides for the specific application of Parks Canada policies (CPS, 1991). The original *Planning Process for National Parks* document introduced the *park management plan* as being defined as (Parks Canada, 1978, i):

The guide by which Parks Canada manages the resources and uses of a National Park. It contains the management objectives and the means and strategies for achieving them. The management plan is not an end in itself; rather it constitutes a framework within which subsequent management, implementation and detailed planning will take place.

Since then, a revised *National Parks Management Planning Process Manual* has been developed which integrates the following principles into the process (Parks Canada, 1986, 5-6):

- integrated senior program management and planning responsibilities;
- a Park Management Plan characterized by: flexibility, park-wide coverage, general level of detail, and comprehensive treatment of information, issues, concepts and interrelationships;
- multi-disciplinary team approach;
- public participation;
- broad environmental impact assessment;
- ministerial approval of the Park Management Plan with long term application; and
- continuity in plan preparation, implementation, evaluation and plan review.

As mentioned in Section 2.3 and demonstrated by Dearden (1991) in Figure 2.6, national parks are defined initially based on the societal context. Nelson (1987, 297) states that "many concepts, values, perceptions and belief systems are involved in the ideologies or philosophies associated with national parks and protected areas". The development of policies, plans, and other initiatives of Parks Canada provides the opportunity for public participation at national, regional, and local levels. Parks Canada, along with the provincial or territorial and local governments, has the responsibility to inform the Canadian public about the management of national parks. In cooperation with many agencies, groups, and citizens, Parks Canada works towards integrating public consultation into the park management planning process (CPS, 1991; Eidsvik and Henwood, 1990; Nelson, 1993; Parks Canada, 1978).

Park management plans identify critical park, canal, and site values for protection, as well

as areas for potential appropriate facility development. Services and facilities are provided in appropriate zones as approved in park management plans or encouraged by adjacent communities (CPS, 1991). The process is described in Parks Canada (1986), is shown in Figure 2.9, and is summarized in Table 2.4.

The original park management plan guide recognized the need to integrate the environmental assessment and review process (EARP) into the park management planning process: "Park Management Plans, Resource Management Plans, Interpretive Plans, etc., should be subjected to an environmental assessment and review process, as defined in the EARP Guide" (Parks Canada, 1978, 34). Subsequently, the Parks Canada *Proposed Policy* states that the EARP must be implemented: "all proposed actions on public lands under the administration of CPS will be subject to assessment and review. All programs, procedures, plans, developments and activities will be assessed to identify individual and cumulative impacts" (CPS, 1991, 18). Theberge (1993) focuses on the importance of environmental impact assessment (EIA) as a conservation tool in the development of a national (or regional) conservation strategy. Parks Canada could contribute to the development of a national conservation strategy through a hybrid approach to EIA using a variety of EIA methods, procedures, techniques, and practices to complement the use of EARP. Nelson (1991, 265) makes the further claim that monitoring should be linked to park management plans and EIAs:

The basic role of processes, diversity, productivity, and other characteristics of resources in measuring and making judgements about sustainability can be set forth more explicitly and actually used as key elements in guiding the preparation of park-management plans as well in planning for sustainability in the larger regions in which the parks are located. In this context, regular collection and monitoring of data on key processes, diversity, productivity, and connectivity need to be made as part of State of the Park reports and used as a basis for judgements about sustainability and how well we are doing in that regard. Such information is also needed for use in project and policy impact assessments or other means of measuring and making judgements about land proposals and their compatibility with ecosystems in national parks and surrounding areas.

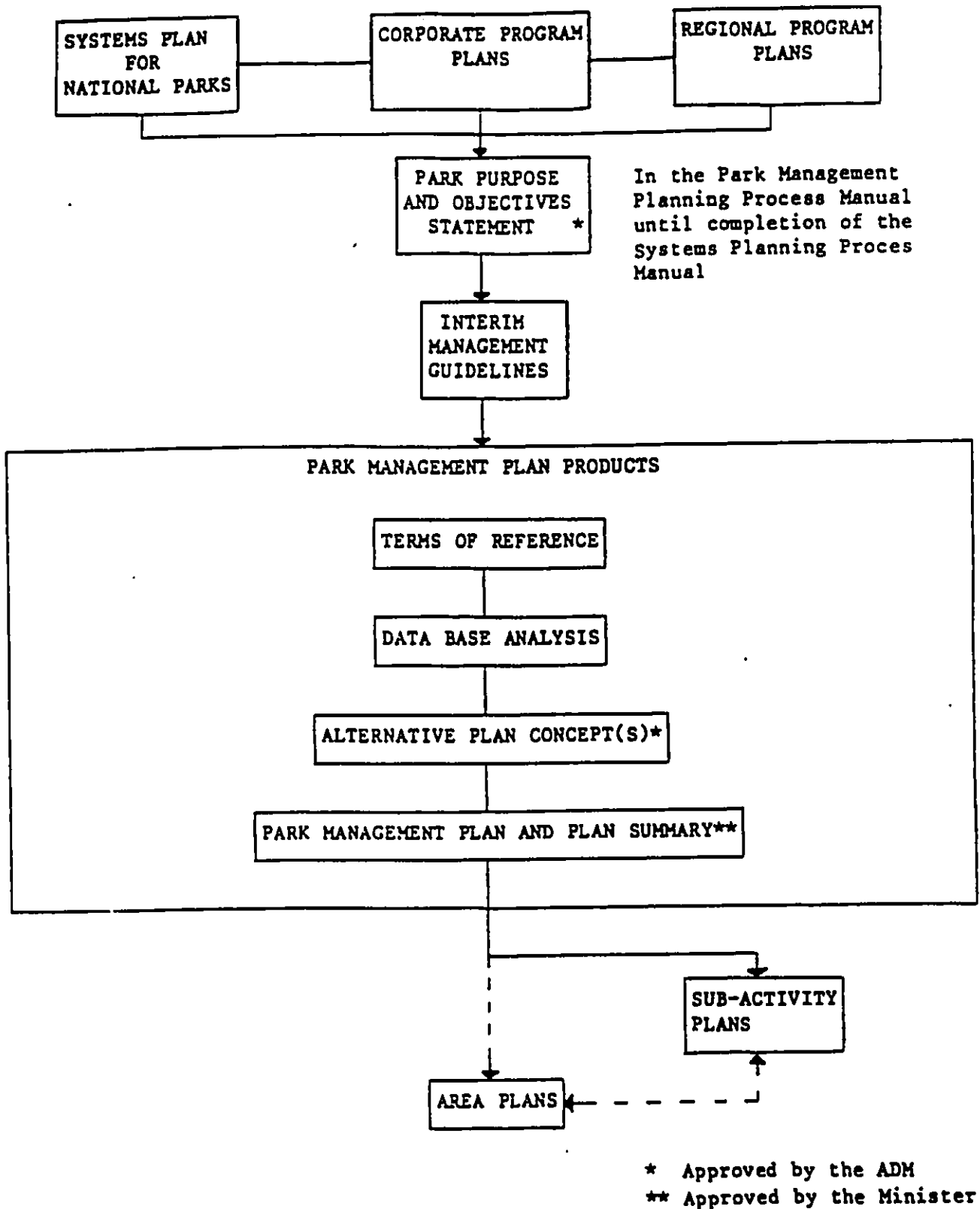


Figure 2.9 Park management planning process (Parks Canada, 1986, 8).

Procedure	Purpose	Content	Responsibility
Statement of Purpose and Objectives for the NP	To define the specific role of the park within the NP System, and the park management objectives consistent with the stated purpose of the park.	Statement of the Park Purpose: defines the role of the park in terms of relative emphasis placed on preservation, presentation and visitor use, and its role in the region. Statement of Management Objectives: provides direction for resource preservation, management practices, visitor use, interpretation and for the integration of the park into the region.	Park System Planning (in collaboration with Regional and Park staff), Regional Director, Superintendent.
Terms of Reference for Planning Program	To ensure that the park management planning activity will result in decisions and actions that satisfy the Purpose and Objectives Statement.	Defines the responsibilities of the planning team to carry out the planning program and represent the formal commitment of management to the provision of the required resources.	Regional Director, Superintendent.
Data Base and Analysis	To provide the information required for methodical and rational planning and management.	Information on natural and cultural resources, resource sensitivities, socio-economic characteristics, recreation capabilities, interpretive potentials, land use relationships, policies and park operations, and the results of public consultation.	Planning Team.
Synthesis and Alternative Plan Concepts	To identify strategies to meet the objectives set for the park and the planning program, in rational ways relative to the data base.	Plan concepts will be developed for protection of park resources, visitor use, and the type and character of public and private facilities necessary to support and administer activities. They must meet the objectives and reflect the constraints and opportunities identified for the park.	Project Manager in collaboration with the Planning Team.
Park Management Plan	To constitute a framework within which subsequent management, implementation and detailed planning will take over.	A statement of management objectives and the means and strategies for achieving them, stated in a broad but comprehensive manner. The level of detail is confined to the definition of the type, character, locale of developments, and the provision of guidelines for resource management, interpretation and visitor use.	Project Manager of the Planning Team.

Table 2.4 Summary of planning process for national parks: park management planning process (see Figure 2.9) (Parks Canada, 1978).

Procedures	Purpose	Content	Responsibility
Area Plan Concepts	Optional product of the overall process. To evaluate the more complex issues and strategies identified in certain areas of the park, ie. reapplying the five step management planning process for a smaller geographical area.	Concepts that result from a stepwise progression exactly like the park management planning process. Objectives on the use/preservation spectrum would be refined for the area in question.	Superintendent, Regional Director, Project Manager, and the Regional Planning Division.
Development, Site, Facility Plans	To specify the requirements with respect to capacity, site, detailed location, scale, standards, and accurate costing of facilities and developments.	Area Development Plan, Corridor Development Plans, Pre-design briefs, Site Development Plans, Engineering and Architecture Plans, Specifications, Cost Estimates.	Regional Manager of Engineering and Architecture.
Sub-Activity Plans	To provide for another level of achievement of the overall park goals and objectives set out in the Park Management Plan.	Procedures, program requirements and practices necessary to meet sub-activity goals and requirements ( within, for example, Natural Resource Management Plans, Interpretation Plans and Visitor Service Plans).	Regional Sub-Activity Chiefs, Park staff.
Evaluation and Monitoring	To monitor the Park Management Plan and the subsequent implementation activities related to it, including area concept planning and sub-activity planning to ensure that they are in line with stated objectives.	A formal review of the Park Management Plan would take place every 5 years.	Superintendent (annual monitoring), committee reporting to the Regional Director (5 year monitoring)
NP Programs and Operations	To contribute to a more effective management approach to NP programs and operations which precede, continue during and follow the planning process.		Superintendent.

Table 2.4 (continued) Summary of the planning process for national parks: implementation (Parks Canada, 1978).

Zoning is one of the most important tools in the park management planning process (Eidsvik and Henwood, 1990). The national parks zoning system is a resource-based technique by which land and water areas of a national park are classified according to their need for protection and their capability to accommodate visitors. A zoning plan is an integral part of each park management plan and assists in managing the conflict between conservation and visitor use. Each area of a national park is classified into one of the following zones: Zone 1 - *Special Preservation*; Zone 2 - *Wilderness*; Zone 3 - *Natural Environment*; Zone 4 - *Outdoor Recreation*; and Zone 5 - *Park Services* (Table 2.5) (Parks Canada, 1986).

## 2.5 Parks Canada and GIS

### 2.5.1 From Inventory to Park Management Planning

A biophysical land inventory is used by Parks Canada to provide descriptive data on the current cadastral, physical, biological, and cultural states of each park and allows for the study of interrelationships among the principal features (Table 2.6). This data base of park resources classifies the elements and is the foundation for proper park use and protection through effective research, planning, and management (East *et al.*, 1979). It is important to recognize that this inventory is a part of the park management planning process (ie. *data base analysis* phase of Figure 2.9) and not an end in itself (Jakimchuk, 1982).

The park management planning process involves moving from the data collection and inventory phases to ultimately making decisions: "diversifying data and planning inputs is most likely to succeed if a *building block* approach is used, allowing discrete initiatives to proceed incrementally but designing them to fit together eventually within an integrated environmental management framework" (Lang, 1979, 293). The generic process concerning the connection between information and knowledge bases for decision making is described by Wellar and Harris (1992, 87): "there is an urgent need to seek solutions to the stubborn, age-old problem of Making

Zone Class	Zone Purpose	Boundary Criteria	Management Framework	
			Resources	Public Opportunity
I Special Preservation	Specific areas or features which deserve special preservation because they contain or support unique, rare or endangered features or the best examples of natural features	The natural extent and buffer requirements of designated features	Strict resource preservation	<ul style="list-style-type: none"> <li>Usually no internal access. Only strictly controlled and non-motorized access</li> <li>Visitor appreciation and park research programs consistent with resource preservation</li> </ul>
II Wilderness	Extensive areas which are good representations of each of the natural history themes of the park and which will be maintained in a wilderness state.	The natural extent and buffer requirements of natural history themes and environments in areas of 2000 ha and greater.	Preservation of natural resources	<ul style="list-style-type: none"> <li>Internal access by non-motorized means</li> <li>Dispersed activities providing experiences consistent with resource preservation</li> <li>Primary camping areas</li> <li>Primitive roofed accommodation including emergency shelters</li> </ul>
III Natural Environment	Areas that are maintained as natural environments and which can sustain, with a minimum of low-density outdoor activities with a minimum of related facilities	The extent of natural environments providing outdoor opportunities, and required buffer areas	Oriented to preservation of natural environment setting	<ul style="list-style-type: none"> <li>Internal access by non-motorized and limited motorized means, including in the north, authorized air charter access to riversides</li> <li>Usually dispersed activities, with more concentrated activities associated with limited motorized access</li> <li>Rustic, small scale permanent fixed roof accommodation for visitor use and operational use.</li> <li>Camping facilities are to be to the semi-primitive level</li> </ul>
IV Recreation	Limited areas that can accommodate a broad range of education, outdoor recreation opportunities and related facilities in ways that respect the natural landscape and that are safe and convenient	The extent of outdoor opportunities and facilities and their area of immediate impact	Oriented to minimizing impact of activities and facilities on the natural landscape.	<ul style="list-style-type: none"> <li>Outdoor opportunities in natural landscapes or supported by facility development and landscape alteration</li> <li>Camping facilities will be to the basic serviced category.</li> <li>Small and decentralized accommodation facilities</li> </ul>
V Park Services	Towns and Visitor Centres in certain existing national parks which contain a concentration of visitor services and support facilities as well as park administration functions	The extent of services and facilities and their immediate area of impact	Oriented to emphasizing the national park setting and values in the location, design, and operation of visitor support services and park administration functions	<ul style="list-style-type: none"> <li>Internal access by non-motorized and motorized means</li> <li>Centralized visitor support services and park administration activities</li> <li>Facility-based opportunities</li> <li>Major camping areas adjacent to, or within, a Town or Visitor Centre to the basic serviced category. Town of Visitor Centre.</li> </ul>

Table 2.5 National park zoning system summary (Parks Canada, 1986, 84).

<b>Component</b>	<b>Features</b>	<b>Scope</b>
Cadastral/Geodetic	(a) Coordinate system (b) Legal boundaries (c) Land ownership (d) Purchase date (e) Land value	Fundamental survey data concerning the park's location, necessary for base map production.
Physical (Abiotic) Environment	(a) Climate (b) Water (c) Topography (d) Bedrock geology (e) Surficial materials (f) Soils	Data regarding the natural environment, concerning the characteristics, the processes involved and the basic interrelationships.
Biological Environment	(a) Vegetation (b) Wildlife species (c) Special interest items	Data regarding the living environment, concerning the structure, function and evolution of species and communities.
Cultural Resource Information	(a) Archaeology/History (b) Paleontology (c) Transportation Routes (d) Resource Exploitation	Data regarding the human environment, concerning the experiences, developments and actions of individuals and communities.

Table 2.6 Structure of biophysical land inventory used by Parks Canada (Gauthier, 1989, 321-323).

**Connections** - effectively and efficiently - whereby better data bases → better information bases → better knowledge bases → better decision making → better decision outcomes is the rule rather than the exception".

Wellar (1990) and Wellar and Harris (1992) also present a decision support system framework for the data to decision flow process (Figure 2.10). The key elements are summarized as:

- Dimension A illustrates the process of building and moving from data base development to knowledge development.
- Dimension B shows the relationship between current reality, the desired future, and associated players, dynamics, and forces.
- The broken arrows between Dimensions A and B represent both the connectivity, and uncertainty and incompleteness of the decision making process.

Related flow diagrams using similar logic have been designed by others, including Watson and McGaw (1980) (Figure 2.11), Milton and Milton (1983) (Figure 2.12), Davis *et al.* (1990) (Figure 2.13), and Wiken (1979) (Figure 2.14). This data to decision flow process can be translated for use by Parks Canada, whereby *better inventories → better information bases → better knowledge bases → better park management planning → better park management planning outcomes.*

### 2.5.2 GIS Use to Support Park Management Planning

Welch (1988) initiated the research into the use of GIS by Parks Canada and produced the report: *Geographic Information System Needs Analysis and Product Selection for End-Users in Canada's National Parks*. The main conclusion reports that each national park office, or end-user, is required to design and implement its own GIS data base which is compatible with the GIS software product *SPANS* (SPatial ANalysis System).

The justification for the use of GIS by Parks Canada stems from two issues. The first issue

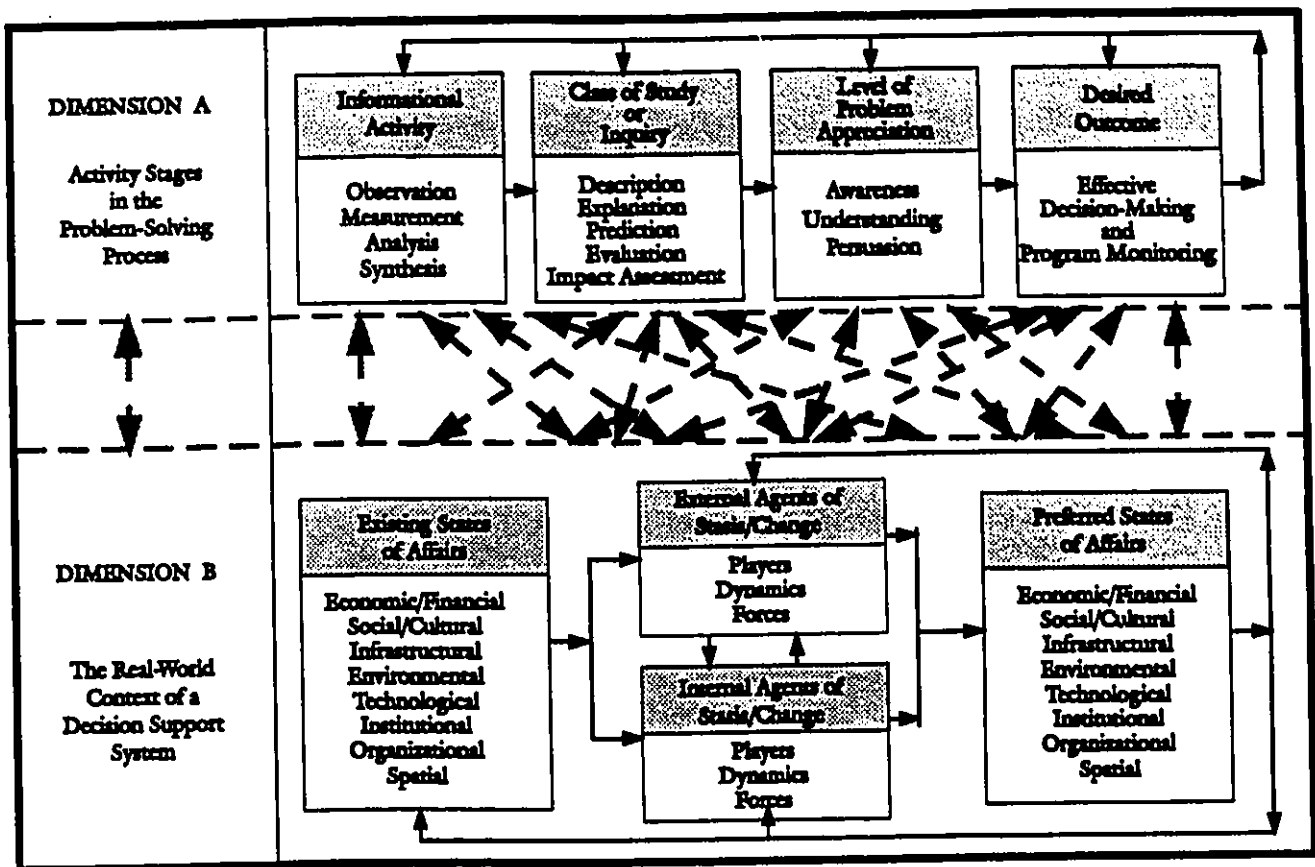


Figure 2.10 Rudiments of a decision support system (DSS): substance, process, context (Wellar, 1990, 864).

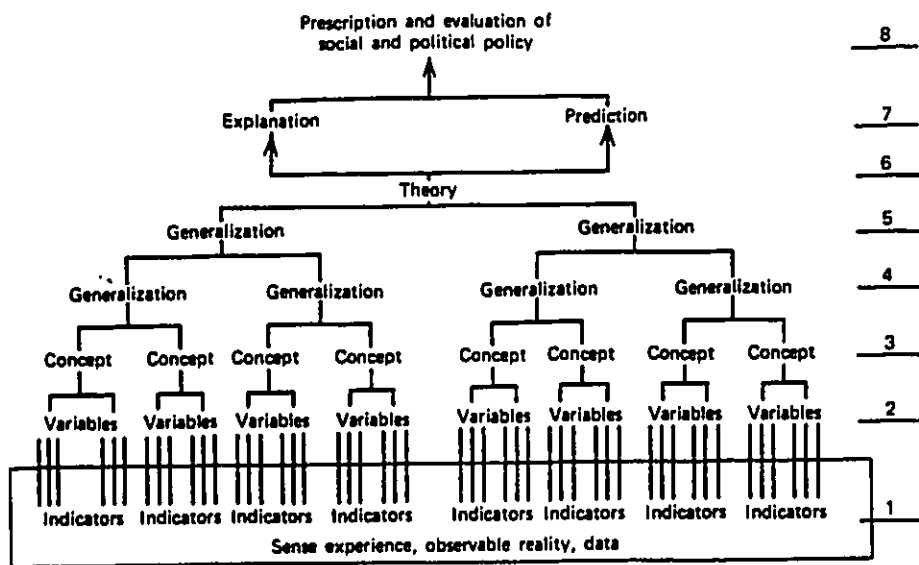


Figure 2.11 The program of research for the policy and social sciences (Watson and McGaw, 1980, 31).

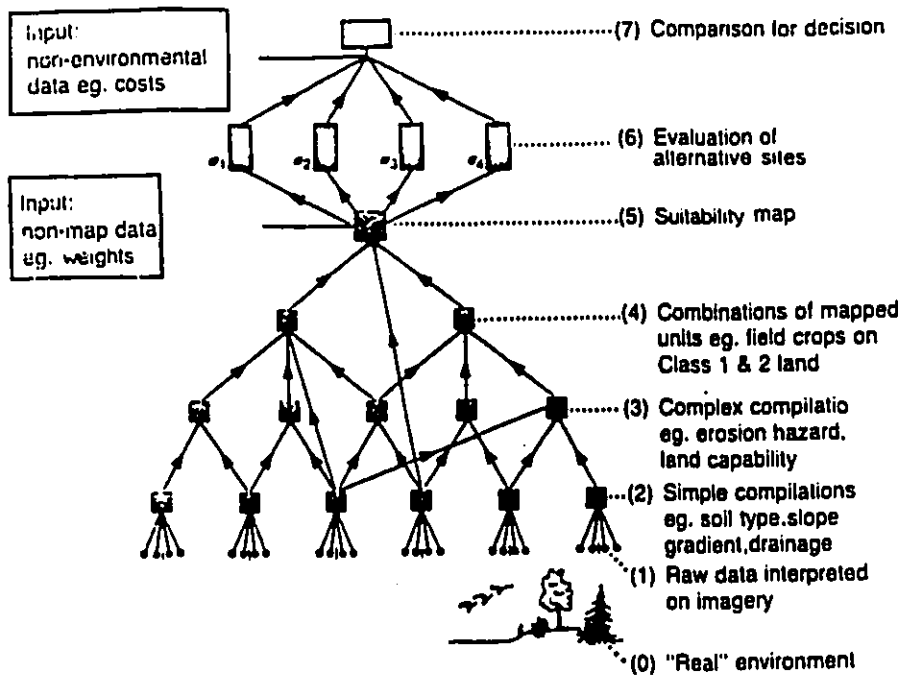


Figure 2.12 Levels of derivation of environmental data from real environment to decision (Milton and Milton, 1983, 17).

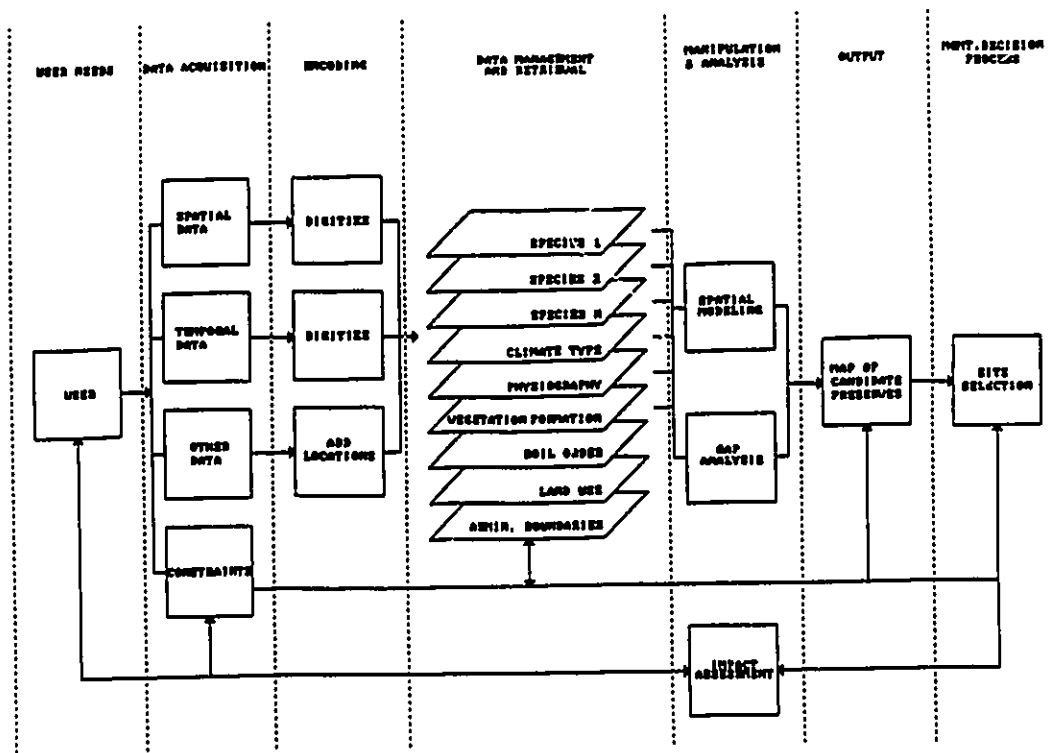


Figure 2.13 An example of an information system flow in a biodiversity data base (Davis *et al.*, 1990, 65).

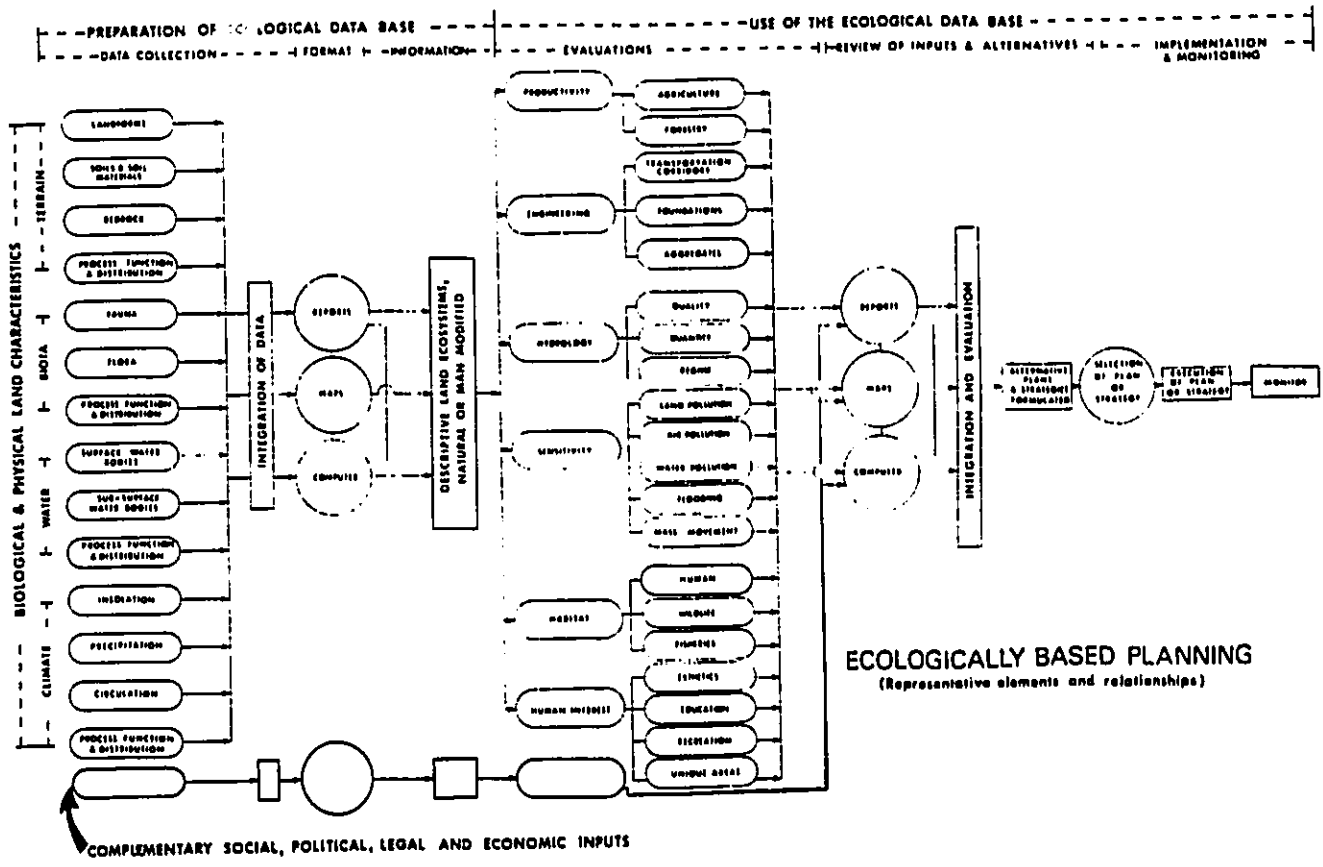


Figure 2.14 Ecologically based planning, representative elements, and relationships (Wiken, 1979, 41).

focuses on the existing state of affairs as related to the limited use of park inventory data: "In practise many urgent environmental impact screenings and evaluations, and resource monitoring and management plan proposals, etc, fall back on personal knowledge and manual browsing of inventory documents" (Welch, 1988, 4). Relative to the complexity of the park decision making process, Welch's (1988) finding suggests an inefficient and ineffective approach to park management planning.

The second issue stems from the condition that sound management of national parks is reliant on efficient management of geographic data and information: "National Parks should manage its primary asset, its natural resources, with the aid of a computer geographic information system, GIS, distributed at each park, not just at other agencies. On-site, self-serve GISs will provide prompt and thorough information. They will be essential if natural resource managers are to provide timely and professional input to park operations, studies and plans" (Welch, 1988, 6).

In the initial report, Welch (1988, 9) outlined that the main GIS functions needed to support park management planning are to:

- Better understand a park's natural features and ecosystems,
- Locate significant features,
- Assess impacts, sensitivity or carrying capacity,
- Select and plan sites for visitor facilities and resource management actions such as animal release programmes,
- Monitor natural and induced changes, and
- Aid operations such as prescribed forest burning.

Further, Arbour (1984, 225) states that park management planning requires a series of informational activities, which include:

- Describing the resources in map form depicting area, points, and linear features,
- Illustrating data on specific resources and detailed site descriptions, and

- Outlining general process oriented data which applies to the various ecosystems of the park.

Arbour (1984, 225) also states that "in all cases, information on a temporal basis is needed where monitoring has been identified as necessary".

Subsequent to the initial report by Welch (1988), work on designing, implementing, and applying a GIS data base for each national park is ongoing. The works of Gauthier (1989), Poitevin *et al.* (1992), and Colville and Bridgland (1992) serve as examples of the GIS data base development processes. Gauthier's (1989, 318) work pays special attention to the development of a contextual GIS framework for Grasslands National Park and states that: "each park, due to different combinations of features of national importance, provides more unique values at local, regional, and national scales". He also states that "the structuring of the database will allow the managers to access and integrate information within the GIS to meet their needs at different levels of management" (Gauthier, 1989, 323).

Poitevin *et al.* (1992) define the implementation strategy for Elk Island National Park based on the acquisition and digitizing of the park's resource data. The main conclusion of the paper is a warning about the amount of time needed to develop the digital data base: "It is important to realize that the benefits and increased productivity to be obtained from using the system are not achieved immediately because of the long data compilation phase and training needs" (Poitevin *et al.*, 1992, 480).

Colville and Bridgland (1992) use the GIS data base to contribute to studying the distribution of species which have significance on a regional scale in relation to the existing Zone 1 (*Special Preservation*) boundaries of Cape Breton Highlands National Park. They concluded that one-third of all the species studied are not protected by the current Zone 1 areas and that a number of areas which are richest in significant features fall outside the Zone 1 boundaries.

Davis *et al.* (1990) designed a framework connecting specific geographic scales to

variables about the distribution of wildlife, ecological factors that characterize the habitats, and human activities that affect the habitats (Table 2.7). This framework can be applied to park management planning for assessing the status of the natural and cultural resources. These variables, and the data associated with them, are inherently spatial attributes and can be stored in a GIS data base.

Crain and MacDonald (1984) make the connection between the capabilities of GIS and land inventory, analysis, and management. They see the process as an evolution defined by three phases that are necessary for a successful or useful GIS (Table 2.8) and state that "systems die, or are murdered, mainly for their inability to evolve in this pattern" (Crain and MacDonald, 1984, 41). The basic features of each phase can be described as follows:

- *Phase I - Inventory:* The principal activities include data collection, input, editing, and output which ensure the development (ie. designing and implementing) of an accurate, high integrity data base. The most important capability is presentation mapping which allows visualizing the data in the form of a map. This system could be considered to be a geographic *data* system (GDS).
- *Phase II - Analysis-Synthesis:* The principal activities move from data gathering and storing to data retrieval and transformation for such purposes as exploring relationships to help confirm hypotheses or to provide data for research and modelling. A modification of the Crain and MacDonald (1984) framework is necessary to add the *synthesizing* capability of a GIS (Wellar, 1993b). An analogy about a jigsaw puzzle demonstrates the similarities and differences between analysis and synthesis: *analysis* identifies the details of each puzzle piece and the relationships between puzzle pieces; *synthesis* actually puts the puzzle pieces together to allow the complete picture to be seen. The term *synthesis* is rarely used in connection with the capabilities of a GIS (Wellar *et al.*, 1994), but it is required for data integration and the transformation of data into

<b>Spatial Scale, Areal Extent (km<sup>2</sup>), Suggested Map Scale</b>	<b>Taxon Distribution</b>	<b>Habitat Factors</b>	<b>Cultural Features</b>
Biogeographic 10 <sup>4</sup> -10 <sup>6</sup> 1:2,500,000 - 1:10,000,000	Species Range (Historical & Modern)	Climate Type Physiography Vegetation Formation Soil Order	Dominant Land Use Administrative Boundaries
Regional 10 <sup>2</sup> -10 <sup>4</sup> 1:100,000 - 1:2,500,000	Species and Subspecies Range (Historical & Modern) Population Occurrences (Notably rare, endangered & indicator species)	Climate Provinces Landform Vegetation Series Surface Geology Soil Order Community Interactions	Land Use Prime Farmlands Land Capability Energy/Mineral Resources Transportation Corridors Air/Water Quality Land Ownership Nature Reserves
Local 10 <sup>2</sup> -10 <sup>2</sup> 1:10,000 - 1:100,000	Narrowly Endemic Species Population Occurrences Observation Data	Microclimate Topography Vegetation Association Surface Geology Soil Series Hydrography Community Interactions	Land Use Zoning Primary/Secondary Roads Air/Water Quality

Table 2.7 Taxonomic, ecological, and cultural variables and their corresponding spatial scales (Davis et al., 1990, 57).

<b>Phase</b>	<b>System Capabilities</b>	<b>Primary Activity</b>	<b>User/Supplier Relationship</b>
I Inventory	Data input; editing; simple retrieval; and routine reporting.	Data input.	Clear division between client and supplier; and little interaction.
II Analysis-Synthesis	All above plus: complex retrievals; ad hoc queries; statistical processing; derived reporting (eg. graphics); and derived data sets.	Data retrieval and transformation.	Supplier involved in determining output needs; and interactive retrievals and direct data access by user.
III Management	All above plus: modelling, simulation; decision support tools (eg. forecasting); and integration of local data sets.	Data exploration and modelling.	User and supplier indistinguishable; fully interactive; and distributed responsibility.

**Table 2.8** Phases and features of GIS evolution (Adapted with modifications: Crain and MacDonald, 1984, 42 to include Wellar, 1993b).

information (Abler, 1993; Backus *et al.*, 1990; Burrough, 1986; Peuquet, 1988; Stafford *et al.*, 1994; Wellar, 1993b). This system could be considered to be a geographic *information* system (GIS).

- *Phase III - Management:* The principal activities include assisting in the decision making process by adding the ingredients of forecasting and planning: "a land management GIS might provide answers to 'what if?' questions related to alternate land use policies or various strategies for optimization of land use under conflicting demand. It is with these modelling and planning tools, superimposed on a broad base of hard raw data, that a GIS reaches maturity as a resource management system" (Crain and MacDonald, 1984, 43). This system could be considered to be a geographic *knowledge* system (GKS).

The message of the literature is taken to be that effective park management planning is founded on timely access to and accurate processing of large amounts of geographic data that lead to informed decisions. By using the data base integration, analysis and synthesis, and communication capabilities of a GIS, park managers can gain a better understanding of the relationships between the physical, biological, and cultural considerations of a national park.

## 2.6 Summary

- A geographic information system (GIS) is a tool which enables users to input, store, manage, retrieve, analyze, synthesize, and display geographically-referenced data which model objects from the real world as points, lines, and polygons. *Spatial* data are stored in assorted data structures and linked to *attribute* data stored in a data base management system. Together, the spatial and attribute data facilitate the testing of specific spatial relationships between objects in the data base and the transformation of geographic data into information (see Figures 2.1 to 2.5).

- National park management focuses on the structure and function of natural areas representative of the diversity of ecosystems which visitors are allowed to enter for inspirational, educative, cultural, and recreative uses. It is the decision making process emphasizing the control or direction of resource development, and is set in the contexts of society, science, and resource and protected areas management (see Figure 2.6).
- There are currently 36 national parks covering an area of 218,902.9 square kilometres (see Table 2.3). They represent 22 of Canada's 39 natural regions and are defined by physiographic, ecological, geographic, and geologic characteristics (see Figure 2.8). The 39 natural regions are a result of the development and implementation of a systematic approach to planning the national parks. The goal of the system is to establish a national park representing each of the natural regions.
- Park management plans are essential in the process of operationalizing the mandate of Parks Canada. They contain the management objectives for each national park as well as the means and strategies for achieving them (see Figure 2.9 and Table 2.4). Current approaches to park management planning limit the use of geographic data and information, with the result being that national parks are affected by internal and external threats.
- The connection between Parks Canada and GIS lies in the methods and techniques of park management planning. A GIS has the potential to support the park management planning process based on the concepts and capabilities of data base integration, analysis and synthesis, and communication.
- An evolutionary approach to the design, implementation, and application of GIS is

required. This approach is divided into three phases: inventory, analysis-synthesis, and management (see Table 2.8). Care in designing and building the GIS data base for each national park allows the GIS to support park management planning.

## Chapter 3

### Kluane National Park Reserve Management Planning: A GIS Framework

#### 3.1 Introduction

The objective of this chapter is to develop a methodology for defining the GIS concepts and capabilities needed to support Kluane National Park Reserve (KNPR) management planning (Figure 3.1). This chapter is the link between the review of the conceptual literature (Chapter 2) and the practical application (Chapter 4) and focuses on the GIS data base design process set in the context of KNPR.

From a park management planning perspective, the context for designing the GIS data base is derived from the Dearden (1991) framework (see Figure 2.6). For this thesis, the application of the Dearden (1991) framework means replacing "Unit" with "KNPR" and "Site" with "Aisek River valley". All other components of the framework remain the same and are conceptually defined in Chapter 2 (*Parks Canada and GIS: A Conceptual Review*). KNPR represents the northern coast mountains and consists of icefields and high mountains as well as a small greenbelt area. These characteristics make for a specific set of geographic considerations which must be taken into account in the park management planning process.

The GIS data base design process is detailed on the basis of the findings and recommendations of relevant literature. This process is considered important because it lays out a logical and systematic approach consisting of several major steps which ultimately leads to an operational system: "the structured system approach does not take more time but simply ensures that all necessary ground is covered in a logical way" (Croswell, 1991, 52). This design process consists of specifying the hardware, software, users, procedures, and data which will most effectively and efficiently meet the needs of the organizational structure and function. For this particular case, the needs are set in the context of the park management planning process of

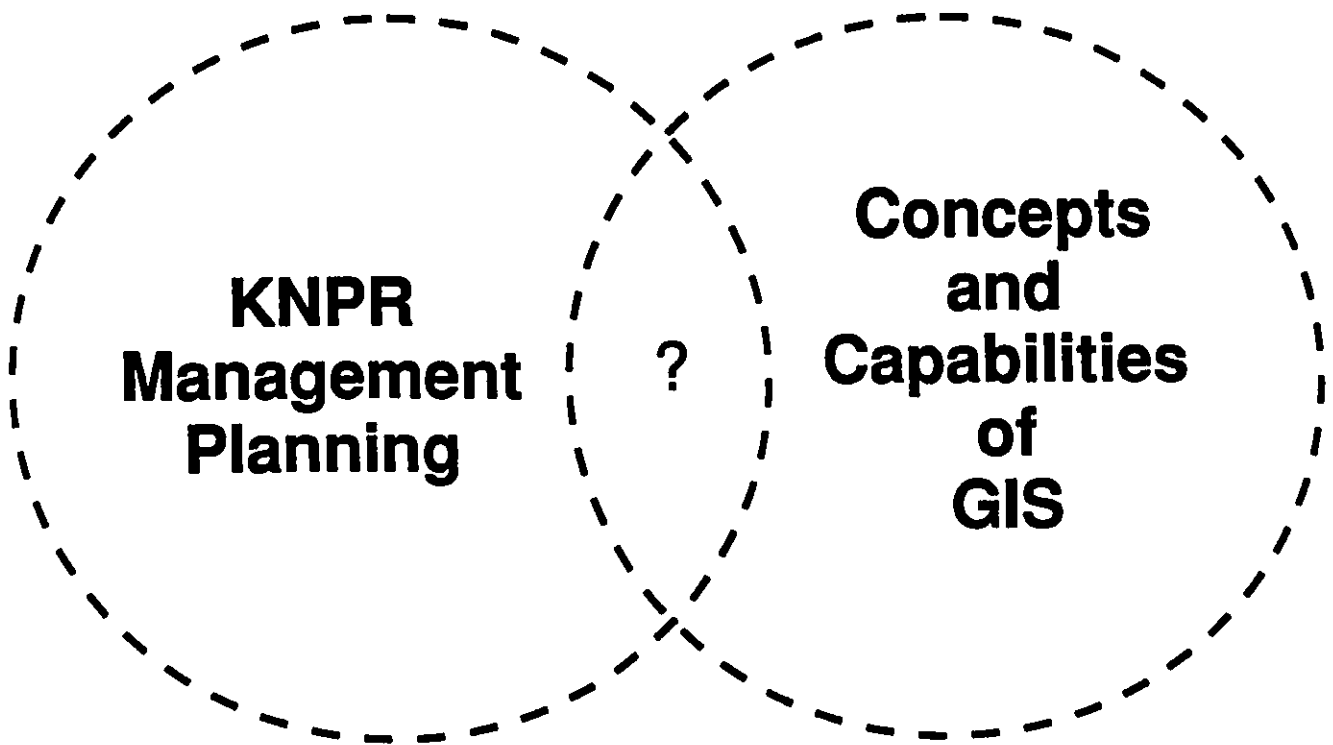


Figure 3.1 A set approach exploring the connection between KNPR management planning and the concepts and capabilities of GIS (Adapted with modifications: Wellar, Cameron, and Sawada, 1994, 69).

KNPR which provides direction for resource preservation, visitor use, administration, and regional cooperation.

### 3.2 Kluane National Park Reserve

KNPR is located in the southwest corner of the Yukon Territory and was established in 1972 to represent national park natural region number 6: *Northern Coast Mountains*. The area of KNPR is 22,015 square kilometres and can be divided into two broad zones: the icefields and the greenbelt. Two-thirds of the park is occupied by the St. Elias Mountains, characterized by Canada's highest peaks and the largest nonpolar icefields in the world. These icefields are remote, inaccessible, and dominated by glaciers including the Kaskawulsh, Lowell, and Donjek as well as high mountains including Mount Logan (5959 m), Mount St. Elias (5488 m), and Mount Lucania (5139 m) (Environment Canada, Parks, 1987).

Fringing the mountains and glaciers is a narrow greenbelt area. This area contains most of the park's wildlife habitat and areas of greatest visitor access and use. Large river valleys including the Slims, Kaskawulsh, Donjek, Dezadeash, and Aisek dominate the greenbelt area. The wildlife species of the greenbelt include grizzly and black bears, Dall's sheep, moose, wolverine, coyote, lynx, red fox, wolf, and mountain goats (CPS, 1990b).

KNPR retains only *reserve* status at present due to the possibility of adjustments to the park boundary as a result of the settlement of Native land claims. People of Native origin are allowed to perform traditional hunting, fishing, and trapping activities in the park. The Native peoples of the Yukon, represented by the Council of Yukon Indians (CYI), are presently negotiating a comprehensive land claims settlement. In particular, agreements were negotiated with the Champagne and Aishihik First Nations and Kluane Tribal Council regarding the final establishment of KNPR. The Kluane National Park Agreement includes: revision of the present reserve boundaries due to the Native land selection; advice by the Champagne and Aishihik on

park planning and management; the exercise of traditional activities within the park; and employment and economic activities (CPS, 1990b; Seale, 1994).

The area of KNPR has been designated by a variety of international and national institutional arrangements which focus on protecting the environment (CPS, 1990b; Environment Canada, Parks, 1991; 1987):

- KNPR along with Wrangell-St. Elias National Park in Alaska were jointly nominated as a United Nations World Heritage Site in 1979. This endorsement recognizes the importance of protecting examples of the world's cultural and natural heritages.
- The International Biological Programme (IBP) identified four special sites of KNPR that are representative of natural ecosystems: Sheep Mountain/Mount Wallace; Mount Archibald/Mount Decoeli; the Lowell Glacier; and the Kaskawulsh Glacier.
- A 90 kilometre stretch of the Alsek River has been nominated to the Canadian Heritage Rivers System (CHRS). This helps maintain the unique natural, historical, and cultural features for which the river is recognized.

The existing recreational facilities of KNPR are adjacent to the Alaska and Haines Highways and include a visitor reception and administration centre in the town of Haines Junction; an operations centre approximately four kilometres west of Haines Junction along the Alaska Highway; the Kathleen Lake campground and day use area; the Sheep Mountain information centre; and various trails and hiking routes (Figure 3.2).

Visitation numbers from 1987 showed that 88,500 travel parties representing 194,000 visitors travelled to the Yukon. Of these, 180,000 individuals passed KNPR along the Alaska Highway. Only 44 percent of the visitors stopped along the Alaska Highway corridor bordering the park, usually for less than a day. Further, direct visitor use of the park is low. Registered back country overnight use is less than 1,000 people per year. The present reality of KNPR tourism

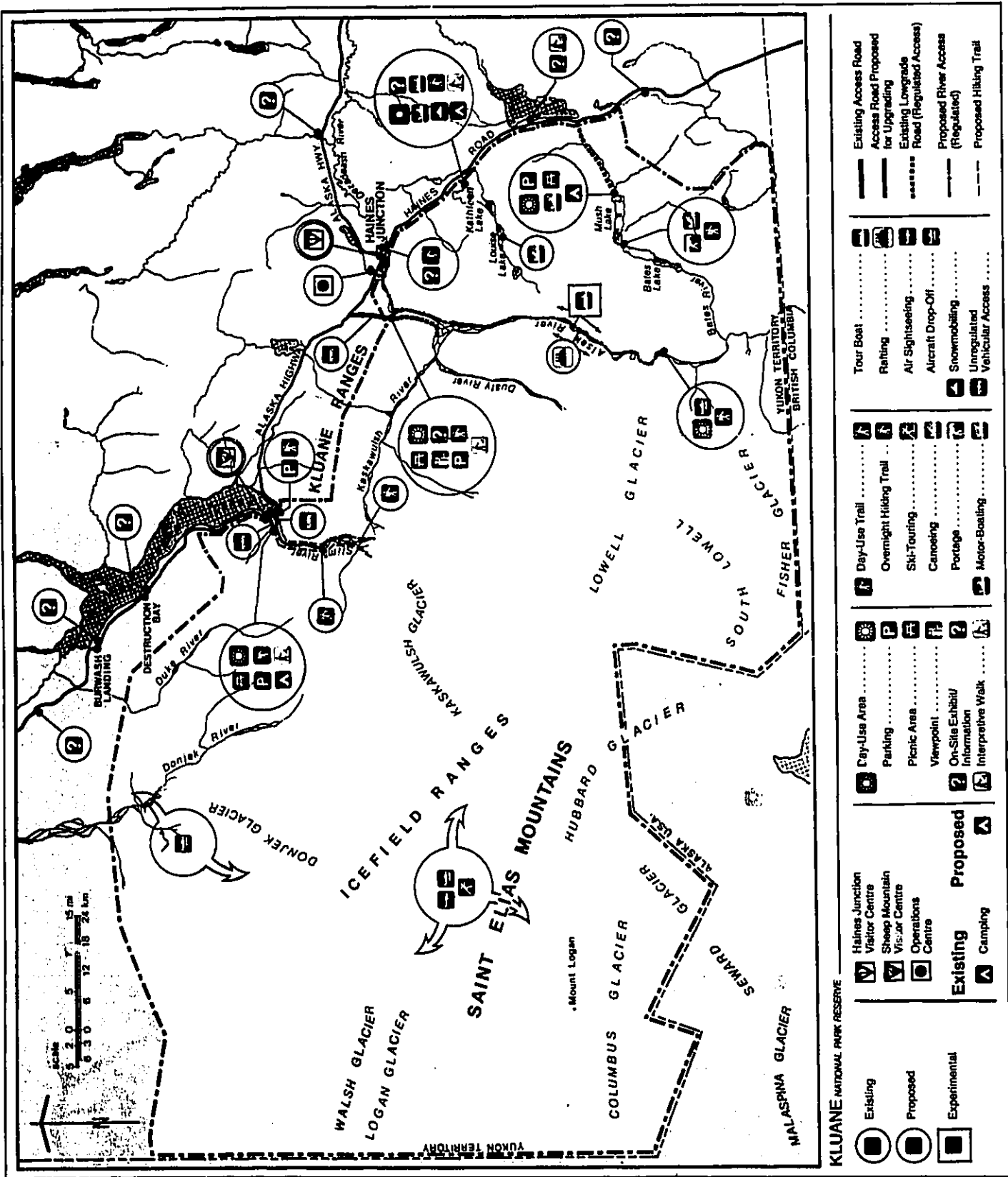


Figure 3.2 Kluane National Park Reserve, Yukon Territory (CPS, 1990b, 29).

is that the great majority of visitors confine themselves to the Alaska Highway corridor en route to or from Alaska (CPS, 1990b).

### 3.2.1 Park Management Planning

An initial understanding of the KNPR management planning objectives as well as the means and strategies for achieving them is important if the GIS is to be fully effective and efficient. These objectives, means, and strategies are found in sufficient detail in the park management plan. In 1990, KNPR published an updated and revised park management plan consisting of the following main sections: Introduction, Background, Plan Decisions, and Implementation Strategy Summary (CPS, 1990b). A summary of the *KNPR Management Plan* allows understanding the specific geographic characteristics of the park.

There are two distinct branches to KNPR management planning. The first is *resource conservation* which ensures the conservation of the park's natural and cultural resources. The second is *visitor activities, services, and facilities* which ensures the provision of visitor services and facilities that are compatible with the international, national, and local management obligations of the park (CPS, 1990b).

The present situation regarding visitor activities, services, and facilities can be related to seven geographic settings (Table 3.1). These include the Alaska Highway corridor (bus and car sightseeing); the Mush and Bates Lakes area (boating and hiking); the Kathleen Lake valley (camping and boating); the Aisek Pass (hiking and mountain biking); the Aisek River valley (rafting, boating, and hiking); the Slims River valley (hiking); and the Icefields Range (hiking and mountaineering) (CPS, 1990b). These visitor activities represent decisions made by the park managers based on identifying potential impacts to the areas. In keeping with Parks Canada's mandate, only low impact visitor activities are permissible (depicted in Table 3.1 by check-marks).

The resource conservation branch has structured its program around seven management

Visitor Activities	Visitor Activities' Settings						
	Hwy Corridor	Mush-Bates Lk	Kathleen Lake	Alek Pass	Alek River	Slims River	Icefields + other
Bus Tours	✓						
Auto-Sightseeing	✓						
Day Visits	✓			✓	✓	✓	✓
Outfitted Tours		✓	✓		✓	✓	✓
Overnight Camping	✓						
Boating-Fishing	✓	✓	✓		✓		
Winter Recreation	✓	✓	✓	✓			
Backpacking		✓	✓	✓		✓	✓
Expedition Outfitting							✓
Mountaineering							✓

Table 3.1 Visitor activities and settings as outlined in the KNPR Management Plan (adapted with modification: CPS, 1990, 26).

objectives. These include the following (CPS, 1990b, 22-24):

- A natural resource management process, which provides for the integration of resource management and the Environmental Assessment and Review Process (EARP) with park management planning and other programs;
- Aquatic resource management, which emphasizes the protection of the ecological integrity of representative and unique aquatic ecosystems;
- Bear management, which attempts to minimize bear-people interactions;
- Sheep Mountain area management, which controls access to allow visitors to see the Dall's sheep while minimizing disturbance to the site or the animals;
- The Man and the Biosphere (MAB) program, which is an international program for the conservation of species diversity and the promotion of ecological research, monitoring, training, and education;
- Public safety and enforcement, which involves search and rescue plans, training of personnel, public education, maintenance of supplies and equipment, and carrying out operations; and
- Law enforcement, which is responsible for the provisions of the *National Parks Act* and *National Parks Regulations* pertaining to resource conservation and public order.

The *KNPR Management Plan* outlines the following park management objectives based on preservation of the wilderness character of the park (CPS, 1990b, 19):

- To protect the natural and cultural resources of Kluane;
- To allow natural processes to continue without interference except to offset man's influence, or to protect unique resources or man-made facilities;
- To expand interpretation and information services to ensure that visitors of all ages and capabilities have opportunities to learn about the four main park themes: the Icefields, Man in the St. Elias Mountains, Life on the Edge of the Icefields, and

#### Origins of the Landscape;

- To develop services and programs which will create opportunities for park visitors to gain better access to the interior of the park but which will also ensure that the wilderness character of the park is maintained;
- To improve services and facilities in the highway corridor bordering the park so as to provide convenient and appropriately designed opportunities for park visitors to enjoy the Front Ranges of Kluane;
- To encourage the development, by private interests, of commercial visitor accommodation and related services outside the park along the Haines/Alaska highway corridors;
- To ensure that the management and operation of Kluane National Park Reserve is integrated with the region's activities and concerns in a fashion compatible with the park's other management objectives; and
- To allow for the involvement of the public with Kluane National Park Reserve through activities such as volunteer programs and co-operating associations.

As made explicit in five of these eight objectives, the primary goal of the current park management plan is to increase opportunities for visitors to experience the park but still meet the park's ultimate objective of maintaining its wilderness character. This presents the managers of KNPR with the challenge of balancing the familiar Parks Canada mandate of conservation (through the resource conservation branch) versus visitor use (through the visitor activities, services, and facilities branch). In response to this challenge, Parks Canada has adopted the concept of "sustainable wilderness management" (CPS, 1990b, 19) and accepted the following criteria that Parks Canada "should use to evaluate park management/development proposals or actions and ensure sustainable development" (CPS, 1990b, 19):

- **Compatible:** Park use and management actions will be compatible (sympathetic and complementary) with the wilderness nature of the park and the sensitivity of its resources.
- **Controllable:** Parks Canada will ensure that control is maintained with respect to the means, timing, and frequency of a particular park use or management action.
- **Reversible:** Parks Canada will monitor the effects of park use and management, adjust actions in response if required, or completely remove a use or facility if

necessary.

Wielgus *et al.* (1992, 4) explain the need for sound research as the basis for sustainable wilderness management:

The successful implementation of this management protocol can only be achieved through the acquisition and assessment of scientifically credible resource data obtained from research programs, long-term monitoring, and follow-up studies together with the political and economic will to impose remedial action where necessary.

The "assessment of scientifically credible resource data" entails assessment of the resources of the park, and any potential development impacts on the resources. As a basis for the park management planning process, Parks Canada must initiate environmental impact assessments (EIAs) through the use of the environmental assessment and review process (EARP) as well as other assessment methods and techniques.

Within the context of the current *KNPR Management Plan*, the EARP "has not identified any major significant or irreversible environmental impacts" (CPS, 1990b, 38) with regard to development proposals. Further on in the Plan, however, the following statement is made: "Some of the proposals do contain aspects that are likely to generate some environmental impacts or contribute towards a cumulative effect" (CPS, 1990b, 38).

One proposal which has been identified as a potential cause of significant impacts was the proposed development of a public access system on the east side of the Slims River to the terminus of the Kaskawulsh Glacier. This proposal has subsequently been rejected due to environmental and financial constraints (CPS, 1990b).

On the one hand, then, there is a clear need to know about park resources and potential development impacts. On the other hand, however, it is clear that there is a general lack of resource data and information. Therefore, it is logical to suggest, prior to any further development proposals being implemented, that there should be development of a sound resource data base

for use in EIAs. The ultimate use of the resource data base and subsequent EIA results and conclusions is in the development and implementation of a zoning plan which is a key decision support tool in the overall park management planning process (see Table 2.6). At present, the majority of KNPR is zoned for special preservation (Zone 1) and wilderness (Zone 2) management which reflects the park's primary objective (CPS, 1990b). Future developments could see a rezoning of certain areas of the park, primarily to encourage low impact visitor access (CPS, 1990b).

### **3.3 Kluane National Park Reserve Management Planning GIS Framework**

A framework approach to the design, implementation, and application of a GIS data base for KNPR management planning allows the eventual users to understand its true concepts and capabilities by placing it in a more general context (Gauthier, 1989). The KNPR management planning GIS framework outlines the key design phases and defines the specific GIS concepts and capabilities.

#### **3.3.1 GIS Data Base Design**

Designing and implementing a GIS data base is best accomplished by a systems analysis and design approach (Berkun and Juhasz, 1982; Crowell, 1991; Marble, 1988). When a structured, systematic approach is used, the designer must progress from step to step in a careful, methodological fashion, meeting a number of well defined criteria for each step (Davis, 1983). Each step of the system life cycle is critical to success or failure of the entire system.

Fernandez and Rusinkiewicz (1993, 526) outline the following goals of the GIS data base design process: "to assure that all data needed to satisfy users' requirements are stored in the database; to eliminate redundant data; to provide a way to understand the organization of the data; and to support the specified processing requirements and performance objectives". The data base design is a process of more fully understanding the relationships between detailed

descriptions of data and products (Sugarbaker *et al.*, 1984). This means understanding the structure of the data base, the definition of its contents, and the validity of the data which are to be placed in it (Marble, 1988).

The data base design process can determine gaps in the data base which need to be filled based on competent field work to acquire new data or update existing data (Parker *et al.*, 1991). It is also important that the users participate in the design and implementation of the data base so that they "buy into the system, obtain a sense of ownership in it, and are more likely to benefit from what GIS has to offer them" (Ahlstrand, 1991, 399).

These design matters are valuable to data base and information system users in general, but how does adding the geographic dimension make the design process unique? The answer to this lies in the development of a *seamless* GIS data base which does not adhere to the outmoded concept of individual map sheets (Marble, 1988). Although the spatial data may have originated from the digitizing of map sheets, edge matching can take place to neatly and correctly join the elements (ie. points, lines or polygons) from adjacent map sheets (Campbell *et al.*, 1989; Smith *et al.*, 1987; Stoms *et al.*, 1990).

Croswell (1991, 44) critically assessed the GIS design and implementation phases by asking "why do systems fail or fall short of expectations?" in an attempt to increase the opportunities for success. The work went further than just describing current obstacles by formulating a series of maxims for GIS managers to follow during the design and implementation phases. The main obstacles identified include:

- Lack of data and software standards/data integration: A range of problems from low-level connection and networking concerns, to fundamental approaches to the design of GIS data bases, and the coding of geographic data;
- Lack of organizational coordination: Problems with communication among

participants and conflict with and lack of understanding by the organization's main data processing department;

- Lack of planning/management support: Similar to the second obstacle, but also includes inadequate high-level support or mandate and lack of implementation plan; and
- Lack of training/understanding of the technology: Insensitivity to cultural issues, poor system documentation, and lack of trained staff.

The Croswell (1991) paper ends with both organization-specific and societal/industry maxims for GIS design and implementation success. The organization-specific maxims are relevant to KNPR GIS design and implementation strategies. These maxims include the following: perform an initial evaluation of organizational risk; get commitment from management; assign a GIS manager early in the project; adopt a structured approach to system development; involve users in system design; formulate a goal-oriented plan and schedule; develop a project organization that encourages cooperation and consensus; allocate sufficient staff time; keep users, managers, and constituents informed; and provide education and training at all implementation stages (Croswell, 1991, 51-53). Croswell (1991, 55) concludes with these words: "with an understanding of the unique characteristics of geographic information systems, we are in a position to apply sound management principles to make these systems work". This statement is very relevant to KNPR use of GIS with a forward-looking approach to scientific information management that connects research and environmental management components.

As a result of the expanding scope of environmental research, including national park management (see Section 2.3), developers of data bases must address an assortment of issues: "the wide variety of data, both spatial and non-spatial, being considered for inclusion; the size and complexity of databases being created; their design, development and utilization; the different

spatial and temporal scales of data collection; increasingly sophisticated analytical requirements; new systems to provide information about and access to databases; and the integration of data from various sources and disciplines" (Stafford *et al.*, 1994, 4). These data management issues continue to evolve away from and beyond the traditional and simplistic scope of organizational tasks and services (Stafford *et al.*, 1994).

It follows from the above statements that a structured, systems approach is necessary for the GIS data base design process specifically in the context of KNPR management planning. Although some initial research has been done with respect to Parks Canada's use of GIS in general (eg. Welch, 1988), no work has been done regarding the case of KNPR management planning. Therefore, emphasis should explicitly be on the actual design of the KNPR management planning GIS data base.

With reference to the design of an operational plan: (ie. in this case, the design of a GIS data base), Ackoff (1953, 335) states that "up to this point, our concern with the practical design has not required us to descend to the depths of really vulgar detail. At this point, however, there is no retreat. The researcher must eventually face the dismal task of planning the actual conduct of the research".

Designing a GIS data base for KNPR management planning revolves around the use of a three-phase GIS framework which serves to focus attention on the data management issues (Table 3.2). This section examines Phase 1 of the GIS framework. Phase 2 is completed in the next chapter (*The Alesk River Valley Pilot Study: A GIS Application*) while Phase 3 is completed in Chapter 5 (*Conclusions, Discussion, and Recommendations*). All three phases are completed within the context of a pilot study.

Croswell (1991, 52) states that "in many cases, the inclusion of a prototype project to test the database design and GIS applications should be incorporated into the process". This is

Phase		Scope	Concepts
1	Pre-Conditions to GIS Application	It is essential to design in detail what system, in terms of efficient input, storage, management, analysis, synthesis, and display of geographic information, will be most suitable for the given application.	User needs assessment; system analysis and design; data base design; training; documentation; input, verification, storage of data; hardware/software configuration; pilot study, pretest, trial run.
2	GIS Application	This is the use phase. The GIS provides a tool to test, manage, and maintain the spatial relationships of the various components making up the study (ie. mapping, monitoring, and modelling capabilities), and the related sample locations.	Problem definition; practical research design; building GIS data base; data validity, reliability, and accuracy; data analysis and synthesis, and spatial modelling.
3	GIS Application Evaluation	This phase seeks to determine how adequately the GIS worked and what variables or criteria account for its (lack of) success. Basically, it should answer the question, <i>is the GIS meeting its intended objectives (ie. pay-offs)?</i>	Definition of scientific and educational criteria according to capacity, value, efficiency, and effectiveness; quality control; benchmarking.

Table 3.2 A GIS framework: Phases of GIS evolution for maximum utility (Burrough, 1986; Chambers, 1986; Kishor *et al.*, 1990; McRae, 1989; Mitchell, 1989; Smith *et al.*, 1987; Ventura, 1989).

appropriate because more often than not modifications are needed to the GIS data base structure and function after its initial use (Chambers, 1989). The next chapter of this thesis (ie. Chapter 4: *Alesk River Valley Pilot Study: A GIS Application*) deals with an application of the KNPR management planning GIS framework set in the context of a pilot study.

### 3.3.2 GIS Concepts and Capabilities

#### GIS Concepts

The concepts of GIS can be defined by specific structures, that is, what the GIS is and what it consists of. The *Pre-Condition to GIS Application* phase of Table 3.2 can be seen to be the process of automating the biophysical land inventory. For KNPR management planning, the following GIS configuration is proposed:

- Specific organizational conditions which provide the overall context for the GIS data base design as outlined in Section 3.2.
- Hardware: PC-DOS and OS/2-based computer system including high resolution colour monitor, external storage unit (ie. tape back-up device), digitizing table, and plotter.
- Software: Licensed copies of *SPANS* (raster-based GIS), *dBase IV* (data base management system), *Lotus 123* (spreadsheet), and *WordPerfect 6.1* (word processor).
- Map scale and spatial resolution: Digitizing of greenbelt area based on 1:50,000 scale and interior icefield range based on 1:250,000 scale with 100-metre spatial resolution.
- Spatial variables: Topography, hydrology, vegetation, soil, roads and trails, park boundaries, and indicator species (see Table 2.7).

The concept of spatial data integration is also a necessary component of the KNPR

management planning GIS framework. Spatial data integration has been defined generically as "the process of combining multiple spatial data types and providing for their storage, retrieval, analysis, and display" (Knapp, 1980, 48). Wellar (1993b) emphasizes that synthesis is also required to attain spatial data integration (see Section 2.5.2). Stoms *et al.* (1990, 433) differentiate between horizontal integration: "integration of data from disparate sources into a common geographic coordinate system, sharing data among agencies and institutions at a particular geographic scale" and vertical integration: "aggregation of data across scales from detailed local studies up to national and international resource inventories". With respect to KNPR management planning, this means using the GIS to aid in participating in regional land use planning and in cooperative management groups (Environment Canada, Parks, 1991).

### GIS Capabilities

The capabilities of GIS can be defined by specific functions, that is, what the GIS does in terms of specific procedures, methods, techniques, operations, and specifications (Table 3.3). These activities constitute a set of proposals for actually applying the GIS data base to KNPR management planning. The procedures and specifications can be seen to be bookends so as to keep the methods, techniques, and operations in place and organized. Without a logical and systematic approach, the books would lie scattered about leading to a ineffective and inefficient design.

There are three basic levels to the functioning of GIS with respect to KNPR management planning as derived particularly from Crain and MacDonald (1984), but also others (eg. Berkun and Juhasz, 1982; Curtis and Rowland, 1988; Davis *et al.*, 1990; Knapp, 1980; Ventura, 1990; Wellar, 1993b). They include the use of GIS as an inventory, analysis-synthesis or management tool (see Section 2.5.2 and Table 2.8). The process is considered to be evolutionary, therefore moving cumulatively from an inventory system towards a management system.

Task	Generic Definition	KNPR Management Planning GIS Framework
Procedures	The reasoning, functioning, and directing behind the entire design process.	<b>Administering</b> system responsibilities (ie. who does what and why?); <b>Training</b> users with respect to GIS concepts and capabilities.
Methods	Behaviour and instruments used in selecting and constructing techniques (ie. why?).	<b>Mapping, monitoring, and modelling</b> relevant greenbelt resources and visitor activities; <b>Merging and integrating</b> local resource data (eg. NTS map sheets).
Techniques	Behaviour and instruments used in performing operations (ie. how?).	<b>Observing, measuring, analyzing, and synthesizing</b> relevant greenbelt GIS data layers; <b>Sampling, classifying, generalizing, and displaying</b> park resources and visitor activities.
Operations	Research tasks, research directives, and research instruments used to actually complete the research as specified (ie. what?).	<b>Digitizing, storing, verifying, editing, and managing</b> (ie. geocoding) KNPR biophysical land inventory data; <b>Map projecting and transforming</b> (ie. UTM and latitude-longitude coordinates systems).
Specifications	Set of detailed processes which can be translated into operations.	<b>Documenting</b> all items and codes for each GIS data layer (ie. creating a digital map library).

Table 3.3 KNPR management planning GIS framework related to methodological design tasks (Ackoff, 1953; Burrough, 1986; Chamber, 1989; Forrester and Vanderwall, 1987; Wellar, 1993a).

The system capabilities of a GIS as an inventory tool include data input, editing, simple retrieval, and routine reporting. With respect to KNPR management planning, this can be translated into the following:

- **Mapping:** Inputting, editing, updating, and displaying digital maps of the park in terms of topography, vegetation, soil type, hydrology, icefields, indicator species, roads and trails, and park boundaries. Such a system should answer the following kinds of questions: Where are various species located? Where are visitor activities taking place?

As an analysis-synthesis tool, the system capabilities include complex retrievals, ad hoc queries, statistical processing, derived reporting (eg. graphics), and derived data sets, in addition to the inventory capabilities. With respect to KNPR management planning, this can be translated into the following:

- **Monitoring:** Analyzing and synthesizing critical species habitat in relation to visitor activities as a component of the Environmental Assessment and Review Process (EARP). Such a system should answer the following kinds of questions: What is the actual or potential range of a given species or community type? What areas have greatest species richness?

As a management tool, the system capabilities include modelling and simulation, decision support tools (eg. forecasting), and integration of local data sets, in addition to the analysis-synthesis capabilities. With respect to KNPR management planning, this can be translated into the following:

- **Modelling:** Integrating geographic layers to determine potential zones of the park in accordance with the Parks Canada zoning strategy. Such a system should answer the following types of questions: Which important sites are at greatest risk

of development? Which species or community types are adequately protected? For which geographic areas are new data and information most needed?

### 3.4 Summary

- KNPR is located in the southwest corner of the Yukon Territory and represents the *Northern Coast Mountains* within Canada's system of national parks. The park consists of two broad zones: the icefields, dominated by glaciers and high mountains (eg. Mount Logan at 5959 m.) and the greenbelt, containing wildlife habitat and areas of greatest visitor access and use (eg. the Aisek River valley).
- Management planning of KNPR consists of conserving its wilderness character while allowing a certain level of visitor activities, services, and facilities (see Table 3.1). This requires the acquisition and assessment of scientifically credible resource data as a contributor to the Environmental Assessment and Review Process (EARP), the application of sustainable wilderness management, and the development of a zoning plan.
- The design and development of a KNPR management planning GIS framework can contribute to the overall management planning process by focusing on the specific geographic considerations of the park as well as acting as a spatial data integrator (see Table 3.2). The GIS can function as an inventory, analysis-synthesis or management tool to contribute to mapping, monitoring, and modelling the park's resources and visitor activities.
- Attention at this point must be on the pre-condition phase of the GIS framework regarding KNPR management planning through the application of a systems analysis and design process. This means defining the specific GIS concepts and capabilities; developing a seamless GIS data base; defining the actual procedures,

methods, techniques, operations, and specifications regarding the use of the GIS data base (see Table 3.3); as well as conducting a pilot study to test the initial GIS data base structure and function.

## Chapter 4

### Alsek River Valley Pilot Study: A GIS Application

#### 4.1 Introduction

The objective of this chapter is to apply the Kluane National Park Reserve (KNPR) management planning GIS framework to a particular management planning case within the park's greenbelt area. This means that the GIS concepts and capabilities needed to support management planning of this area are specified and tested by means of the pilot study.

It is important to initially define the concepts and capabilities of GIS needed to support KNPR management planning within the context of a *pilot study*. A pilot study is defined as a design-evaluation methodology directed towards determining alternative operational procedures for the overall research (Ackoff, 1953). This preliminary check allows evaluating the validity and reliability of the research methods, techniques, and operations while finding out what happens if a certain approach is chosen. Pilot studies can provide insights into the research problem and process, and thereby permit changes in the study design before becoming committed to a particular approach, schedule or budget (Isaac and Michael, 1981; Walizer and Wienir, 1978).

The pilot study area is a section of the Alsek River valley which is under investigation due to a proposed recreational development. The Alsek River provides an access route to the Lowell Glacier with the use of a tour boat (for day trips) and rafts (for multiple day trips). Confining access to the river itself *could* avoid bear-human conflicts as well as protect the valley from significant impacts caused by hikers and campers (CPS, 1990b).

The general hypothesis within the context of this pilot study states that:

*Topographic features affect the distribution of a self-regulating population of grizzly bears in the Alsek River valley of KNPR.*

Results and conclusions from testing the above hypothesis can contribute to management planning of the Alsek River valley. That is, the processes of mapping, monitoring, and modelling

park resources can contribute to making informed decisions. More importantly though, the pilot study results can contribute to the overall success of the pre-condition phase of the GIS framework by determining what went right and what went wrong. Following an evaluation of the GIS concepts and capabilities defined for the pilot study, successful design and implementation of a park-wide GIS data base for use in KNPR management planning will be likely.

#### 4.2 Alsek River Valley

The pilot study area is a corridor section in the greenbelt of KNPR. This area is defined as the Alsek River valley from immediately north of its source, which is at the confluence of the Kaskawuish and Dezadeash Rivers, to the terminus of the Lowell Glacier; the study area is approximately 2,300 square kilometres (Figure 4.1). The Alsek River is presently a part of the Canadian Heritage Rivers System (CHRS) because of the following highly significant natural themes: geomorphological features and processes; vegetation representation; wildlife representation and rare species; and landscapes (CHRS, 1982). The objective of the CHRS is to give recognition to selected rivers in Canada. The valley is also Zone 1 (*Special Preservation*) under the Parks Canada zoning system (CPS, 1990b).

This area is in the boreal-montane coniferous forest biome. Summer temperatures based on daily means are moderate, 10.4°, 12.2°, and 10.4° Celsius for June, July, and August. Mean daily temperatures during the winter are -19.9°, -21.6°, and -15.8° Celsius for December, January, and February (Pearson, 1975).

The area is dry, averaging about 250 millimetres of total precipitation during the year (Pearson, 1975). The Kluane Ranges, in the greenbelt area, form the outer front of the St. Elias Mountains, with peaks between 2,100 and 2,400 metres above sea level. All rivers and streams draining the area run into the Alsek River and then out to the Gulf of Alaska (CHRS, 1982).

The Alsek River was blocked off by advances of the Lowell Glacier creating a large ice-

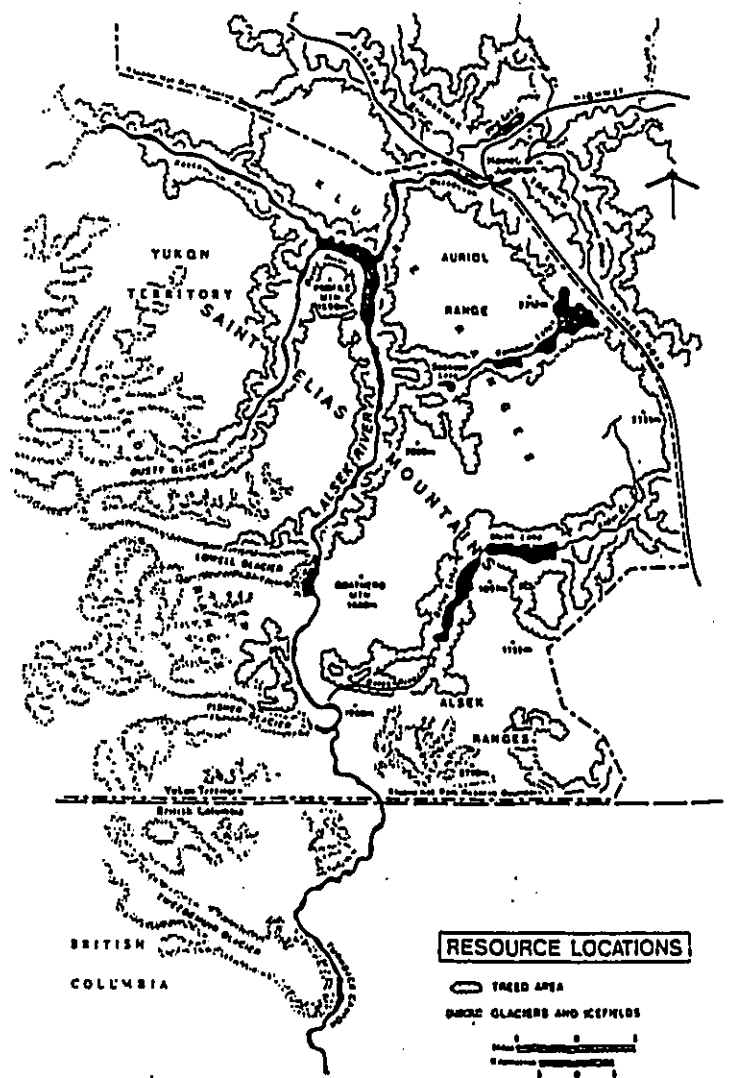
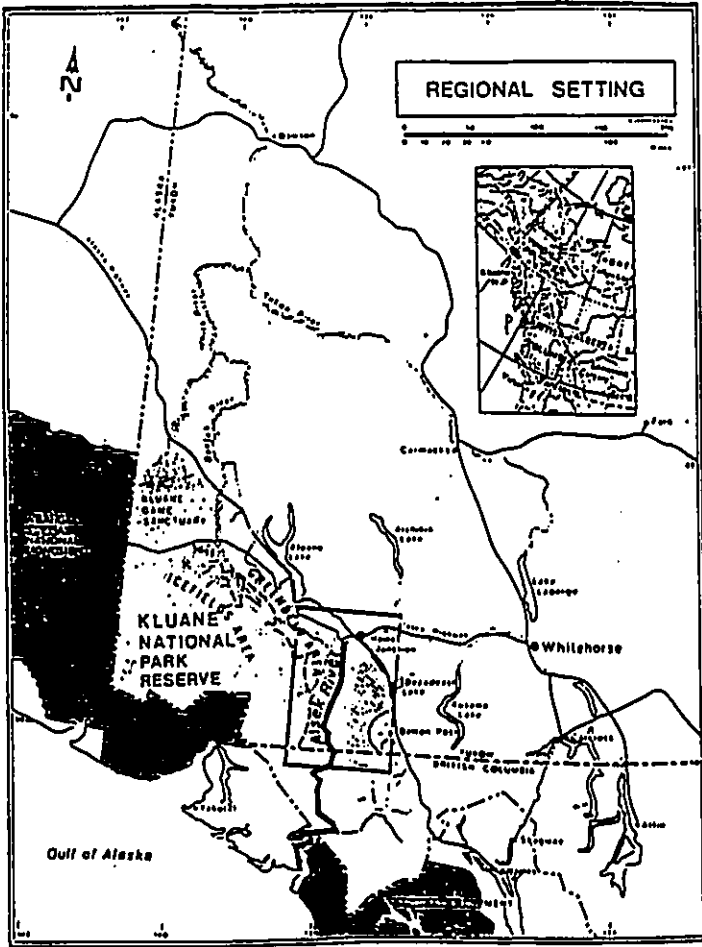


Figure 4.1 Alesk River valley, KNPR (CHRS, 1982, 10).

dammed lake. The resulting lake named Neoglacial Lake Alsek was, at its maximum, about 200 metres deep at the glacier dam and over 100 kilometres long. Staircase flights of beaches, wave-cut benches, layers of driftwood, and thin lacustrine sediments provide evidence of the former lake. Also, giant dunes and flood terraces on the floor of the Alsek River valley indicate that the lake emptied catastrophically when the Lowell Glacier dam burst about 125 years ago (Clague and Rampton, 1982).

Concerning vegetation, the valley can be classified into three zones: Montane (up to an altitude of 1100 m), Subalpine (1100-1400 m), and Alpine (above 1400 m) (CHRS, 1982). The Montane Zone is characterized by vegetation found on the lower slopes of the mountains and includes white spruce, balsam poplar, trembling aspen, and grey leaf willow. The Subalpine Zone is dominated by high and low brush including willow and heath-type shrubs. The Alpine Zone is underlain by permafrost and includes areas above the treeline. Dominant species include fescue, netleaf willow, and white dryas while crowberry and white mountain avens are found locally (CHRS, 1982).

The major mammals of the area include grizzly and black bear, moose, mountain goat, wolf, wolverine, and fox. Important small mammals include voles, shrews, arctic ground squirrels, chipmunks, and mice. A high diversity of birds in the area include merganser, harlequin duck, scoter, mallard, teal, snow goose, trumpeter swan, sand-hill crane, Brewer's sparrow, willow ptarmigan, whimbrel, golden plover, Smith's longspur, golden eagle, bald eagle, peregrine falcon, and a variety of hawks and owls. Because of the silt-laden and cold water, the variety of fish species in the Alsek River is low. Species that occupy the river include lake trout, Kokanee salmon, Dolly varden, round whitefish, Arctic grayling, northern pike, and slimy sculpin (CHRS, 1982).

In terms of visitor activities, services, and facilities, the Alsek River valley is wilderness

with no recreational infrastructure (eg. campgrounds, buildings, boat docks) apart from an existing low grade road for hiking and mountain biking from the Alaska Highway through the Alsek Pass to Ferguson Creek. So, at present, the valley is not easily accessible except to a small number of back country hikers and campers who provide their own means of transport and living.

#### 4.2.1 Park Management Planning

The Alsek River valley presents the park managers with some unique management planning concerns. These concerns and their geographic characteristics include the following (CHRS, 1982):

- *Grizzly bears:* Spatial and temporal distribution of grizzly bears in the valley, and the potential interaction between people and bears.
- *Visitor impact and development:* Overuse of the valley causing degradation of vegetation and displacement of wildlife.
- *Visitor risks, hazards, and safety:* The remote location of the valley and the increasing demand for wilderness experiences.
- *Land claims:* Possibility of the valley being involved in Native land claims negotiations as well as the possibility of Native tourism, hunting or trapping.
- *Pollution from mining in tributary rivers and creeks:* Mining operations in rivers and creeks outside the park boundary which flow into the Alsek River.
- *Forest fire:* The potential development or spread of fire in the valley, and the ecosystem and human consequences.
- *Horse grazing:* Prohibiting open horse grazing as a result of Yukon Territory law.
- *Flooding:* Long-term potential of the Lowell Glacier moving forward and blocking the Alsek River.

Some of these concerns can be seen to be more pressing than others so that it is the

responsibility of the managers to decide which are most important. For example, the potential of another ice-dammed lake developing is quite unlikely in the short-term, however, if the number of hikers and campers in the valley is to increase, a risk and hazard assessment methodology should be designed.

Although the Asek River valley is Zone 1 (*Special Preservation*), a part of the Canadian Heritage Rivers System (CHRS), a section of the larger Asek/Kaskawulsh Grizzly Bear Protection Area, and one of the large, undeveloped river valleys of KNPR, there is nevertheless pressure to develop the area for wilderness recreation and visitor use. For example, the *KNPR Management Plan* outlines a proposed boat tour which would begin in Haines Junction and travel down river to the terminus of the Lowell Glacier (Figure 4.2). This tour would allow a large number of tourists to access and view the Lowell Glacier which at present is a difficult and expensive activity. Also, rafting trips down the Asek River to Dry Bay in the Gulf of Alaska are becoming more frequent. This is leading to an increase in campers and hikers in the valley.

Other proposed minor developments of the Asek River valley include the upgrading of a general vehicle access road off the Alaska Highway; a day-use interpretation exhibit and observation area at the end of the access road; a commercial shuttle operation to take visitors from the day-use area to a lookout near the junction of the Kaskawulsh and Dezadeash Rivers; an aircraft landing strip at the terminus of the Lowell Glacier to pick up rafters and campers; and hiking trails and campsites at various points along the river (Figure 4.2).

The reason for confining access primarily to the river itself stems from the strategy of avoiding conflicts between bears and humans. Wielgus *et al.* (1992) have designed a six-year grizzly bear research program which is currently in progress and due for completion in 1998. An important reason for studying grizzly bears in and around KNPR is because "the vitality of the bear population has become a measure of the wilderness' 'health' and an indicator of the park's

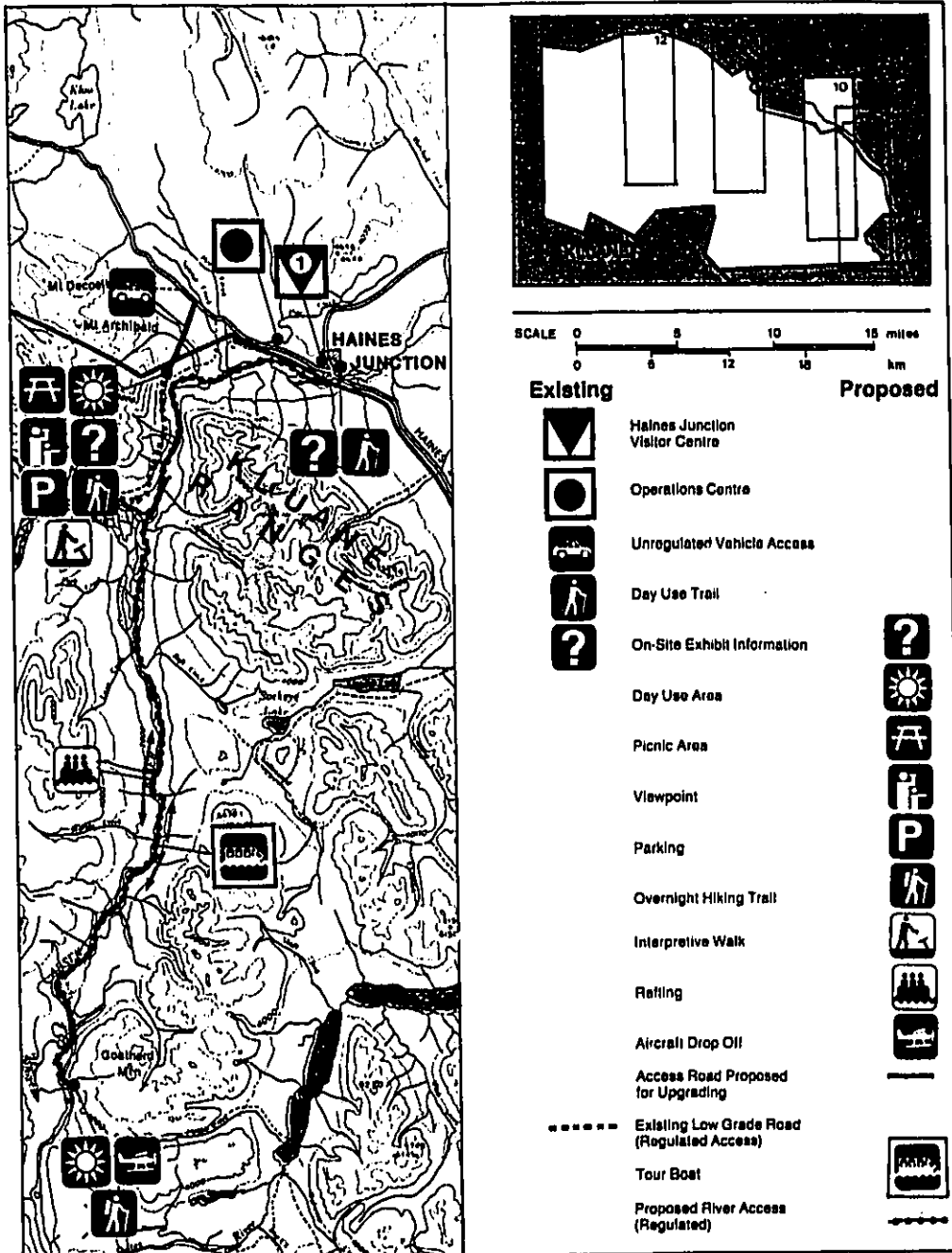


Figure 4.2 Existing and proposed recreational developments in the Alsek River valley, KNPR (CPS, 1990b, 32).

success in bear management" (Wielgus *et al.*, 1992, 5).

Leonard *et al.* (1990) observed an increase in bear-human conflicts and bear control actions in the Slims River valley of KNPR from 1981 to 1987, during which time the valley was managed as a wilderness hiking area. These problems arose due to a failure to address grizzly bears in park management planning and reactive rather than adaptive management responses to bear problems. No human injuries were reported from the Slims River valley, however five female grizzly bears were killed by management actions from 1985 to 1987 due to bear-human conflicts and subsequent bear habituation (Leonard *et al.*, 1990).

It is evident that future management planning cannot rely on past methods of dealing with grizzly bear and human interactions, so it is initially important to answer questions about where and when grizzly bears are located in the greenbelt area of KNPR. Wielgus *et al.* (1992, 6) state that "it is clear that bears and humans must be, as much as possible, separated in time and/or space to meet the objectives of the Park and Bear Management Plans".

A thorough environmental review of the Aisek River valley development is required which elaborates on the results from the grizzly bear research program. Component parts of the review have been carried out but, to this point in time, not integrated into a comprehensive report.

The pilot study area in the context of this thesis is considered representative of the entire park management planning area of KNPR for the following reasons:

- It contains a number of the park's geomorphic features and processes, including fluvial, glaciological, and lacustrine, that have created ecological niches which support a variety of wildlife species.
- In particular, it is prime habitat of grizzly bears (Pearson, 1975) which are currently being studied in and around the park (Wielgus *et al.*, 1992).
- It is accessible by road and trail off the Alaska Highway for both front and back

country wilderness experiences, and is the area of a proposed boat tour as well as rafting trips (see Figure 4.2).

- It contains areas which are both in the park as well as outside the park (ie. transboundary concerns).
- It is an area which is mapped on three 1:50,000 NTS map sheets (Figure 4.3) which permits digitizing and joining of these sheets that will eventually become part of the complete KNPR management planning GIS data base.

#### 4.3 Alsek River Valley Pilot Study

##### 4.3.1 Background

A fundamental concept concerning the conservation of an ecosystem is wildlife habitat. It is a principal factor affecting the well-being and perpetuation of all species. The present situation concerning wildlife habitat can be summed up by stating that various economic activities, from mining and forestry to tourism, have created and continue to create pressures on wildlife habitat. As a result, habitat of many forms of wildlife is shrinking. It is reasonable to expect that the pressures of those activities on wildlife habitat will continue to increase (Herrero, 1979; Litteljohn, 1989; Wildlife Habitat Canada, 1986).

Wildlife habitat is defined as the place where a plant or animal lives or where it can normally be found. It is more encompassing than the concept of home range and includes the climate, topography, vegetation, geology, soil, and drainage of the area used by a particular species. For wildlife, the basics of habitat are food, water, and cover which make the habitat well-suited to meet the life-cycle needs of the respective species. Data on actual range and wildlife habitat factors can be analyzed and synthesized to uncover underlying ecological relationships (Burnett *et al.*, 1989; Canadian Wildlife Service, 1981; Robinson and Bolen, 1989).

One case regarding the shrinking of wildlife habitat is the grizzly bear (*Ursus arctos*) in

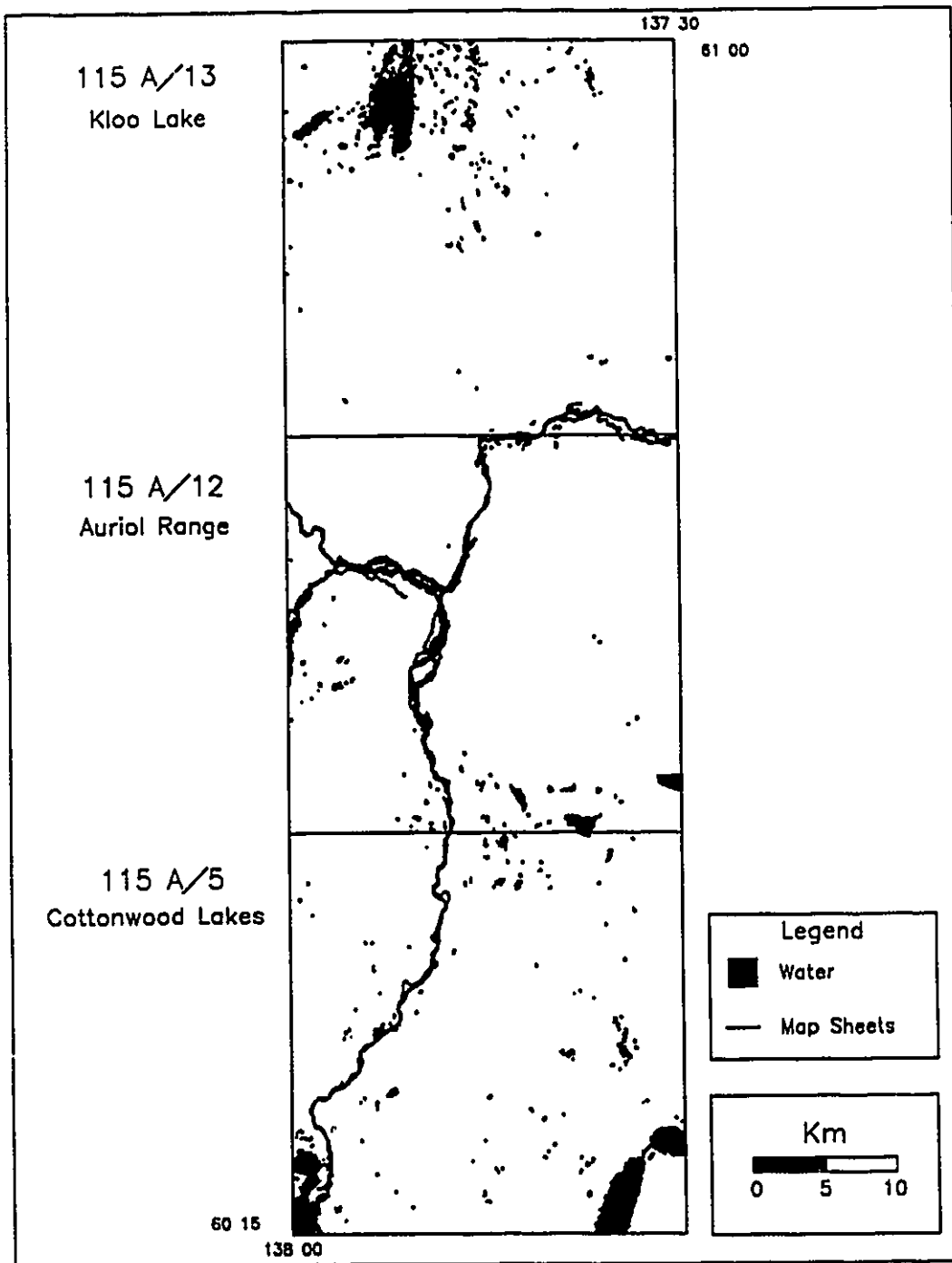


Figure 4.3 Alsek River valley pilot study area showing the three 1:50,000 NTS sheet extents.

North America. The rapid increase in resource exploitation and human settlement in North America that resulted in dislocation of the species from much of its original range continues to accelerate. Although the species cannot be referred to as being rare or endangered, there is no doubt that populations and habitats continue to be threatened (Miller *et al.*, 1982; Mundy and Flook, 1973; Pearson, 1975).

KNPR is seen as one of the last strongholds of the grizzly bear in North America. Self-regulating (ie. non-harvestable) populations of grizzly bears can be found throughout the greenbelt area of the park but are particularly abundant in the Slims River valley, the Asek and Dezadeash River valleys, and the Sockeye Lake-Kluk River area (Environment Canada, Parks, 1987). A necessary input to proper management planning of KNPR is information and knowledge about grizzly bear habitat in the Asek River valley. As Mundy and Flook (1973, 23) state: "distribution and numbers of grizzlies in relation to habitat, season and human distribution should be studied extensively in all the parks... With this information it may be possible to manage parks so as to maintain grizzly populations, while providing an acceptable degree of public safety".

There are a variety of factors which combine to define the habitat of the grizzly bear. For example, grizzly bears often use topographic zones such as elevation, slope, and aspect differently in combination with vegetation cover types on a seasonal basis (Wielgus *et al.*, 1992). Topographic zones alone can be used as an index to vegetation coverage and be useful in examining habitat preferences (Marcum and Loftsgaarden, 1980). Grizzly bears can then be associated spatially to a particular home range. In reality, the home range is made up of several seasonal ranges. In mountainous terrain such as the Asek River valley, the seasonal ranges are distributed by altitude whereby the lateral expansion of the range is blocked by topographic barriers during the early spring. These physical barriers are no longer a part of the distribution factor once the snow has melted but by autumn the bears concentrate along the valley floors to

eat berries and dig roots (Pearson, 1975).

Although the size and shape of home ranges are of little significance themselves, for calculating density of animals and animal management, home ranges have considerable importance. The home range of an animal is affected by habitat type as well as population density (Kupchella and Hyland, 1989).

#### 4.3.2 GIS Data Base Implementation

The process of selecting the pilot study variables for digitizing is derived from a definition of wildlife habitat and put in the context of the Asek River valley pilot study. These variables are found in the *Habitat Factors versus Local Scale* cell of Table 2.7 and include microclimate, topography, vegetation association, surface geology, soil series, hydrology, and community interactions (ie. grizzly bear location data). Data concerning most of these variables exist within KNPR's biophysical land inventory and were digitized for use in the GIS. The data on these variables serve two purposes. First, some of the data were used to test the hypothesis in the context of the pilot study. And second, the data will be used in future park management planning studies regarding the Asek River valley and will be joined with adjacent map sheets to create a complete KNPR management planning GIS data base.

A variety of methods, techniques, and operations were used to build the GIS data base for the Asek River valley. This included the use of the following personal computer-based software: *Arc/Info*, produced by Environmental Systems Research Institute Inc. (ESRI); *Atlas Draw* and *Atlas GIS*, produced by Strategic Mapping Inc.; *Idrisi*, produced by Dr. Ronald Eastman at the Department of Geography, Clark University, USA; *SPANS*, produced by Tydac; *dBase IV*, produced by the Ashton-Tate Corporation; and *Excel*, produced by the Microsoft Corporation. Various modules of each of these software packages were used but the final digital map layers were made compatible with *SPANS* for use by the KNPR managers as recommended by Welch

(1988). Most of the work on this pilot study was completed using *Idrisi*, however.

The pilot study area is mapped on three complete 1:50,000 scale NTS sheets (see Figure 4.3). These maps are graphical representations of the data sets that comprise them. Map sheets for each variable were digitized and stored in individual files (Table 4.1). Following the process of verification and editing (ie. error checking), the three files for each variable were joined to produce a *seamless* GIS map layer.

An important base map layer constructed for the area was a digital elevation model (DEM). A DEM is generally defined as "any digital representation of the continuous variation of relief over space" (Burrough, 1986, 39). DEMs have many uses including the planning of roads, analyzing of cross-country visibility, computing slope maps, aspect maps, and slope profiles, and providing data for simulation models of landscape processes.

The process of building the DEM for the Alsek River valley was based on digitizing the index contours from the 1:50,000 NTS map sheets (Figure 4.4) and then interpolating through the use of a triangulated irregular network (TIN). A TIN is a vector topological structure that uses a sheet of continuous, connected triangular facets to represent elevation (Burrough, 1986). Once the TIN was derived from the contour lines, the process of gridding the network was completed to make the DEM compatible with a raster-based GIS (Figure 4.5a). The grid cells were chosen to have a resolution of 100-metres to remain consistent with the resolution of the grizzly bear observation data.

The polygon-based maps were digitized with unique numbers being assigned to each polygon. These unique numbers can then be referenced to the attribute data about that particular area or site for verification, editing or queries. For example, the soil map polygons reference data on five different attributes including material type, major soil type, minor soil type, individual modifiers, and slope of the terrain. The data concerning these attributes are stored in the data

File Name	Feature	Feature Type	# of Features	Checked? (✓)
T115A13	Topography	Line	133	✓
T115A12	Topography	Line	204	✓
T115A5	Topography	Line	161	✓
V115A5	Vegetation	Polygon	258	✓
S115A12	Soil	Polygon		
S115A5	Soil	Polygon	148	✓
H115A13	Rivers/Lakes	Polygon	274	✓
H115A12	Rivers/Lakes	Polygon	97	✓
H115A5	Rivers/Lakes	Polygon	150	✓
R115A13	Streams	Line	183	✓
R115A12	Streams	Line	331	✓
R115A5	Streams	Line	223	✓
I115A13	Snow/Ice	Polygon	20	✓
I115A12	Snow/Ice	Polygon		
I115A5	Snow/Ice	Polygon	35	✓
A115A13	Roads/Trails	Line	3	✓
A115A12	Roads/Trails	Line	8	✓
A115A5	Roads/Trails	Line	5	✓
B115A13	Park boundary	Line	2	✓

Table 4.1 Inventory of map layers required for the Alsek River valley management planning GIS data base (note: the last column (*Checked?*) refers to verifying the accuracy of the digitized map layers).

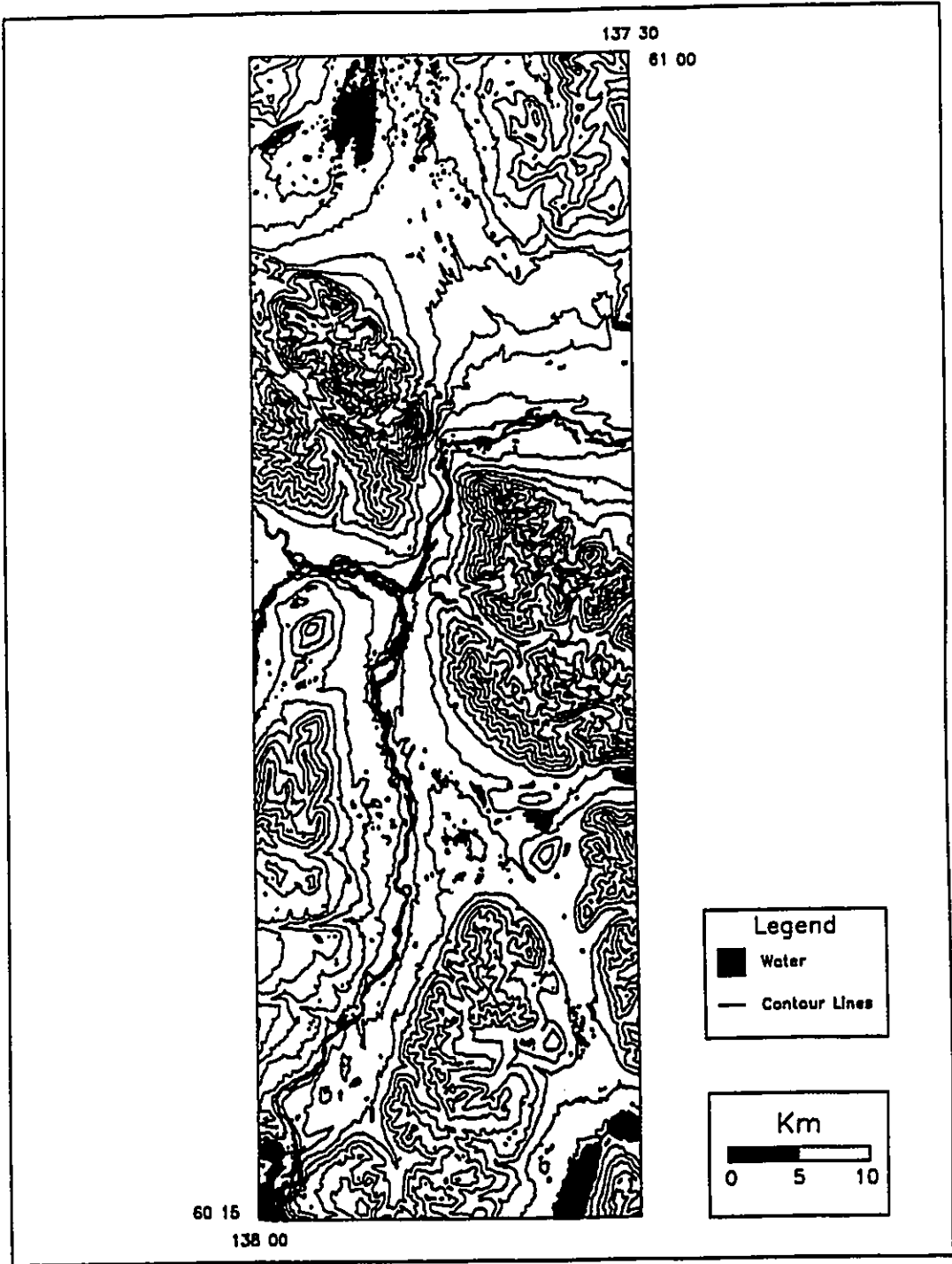
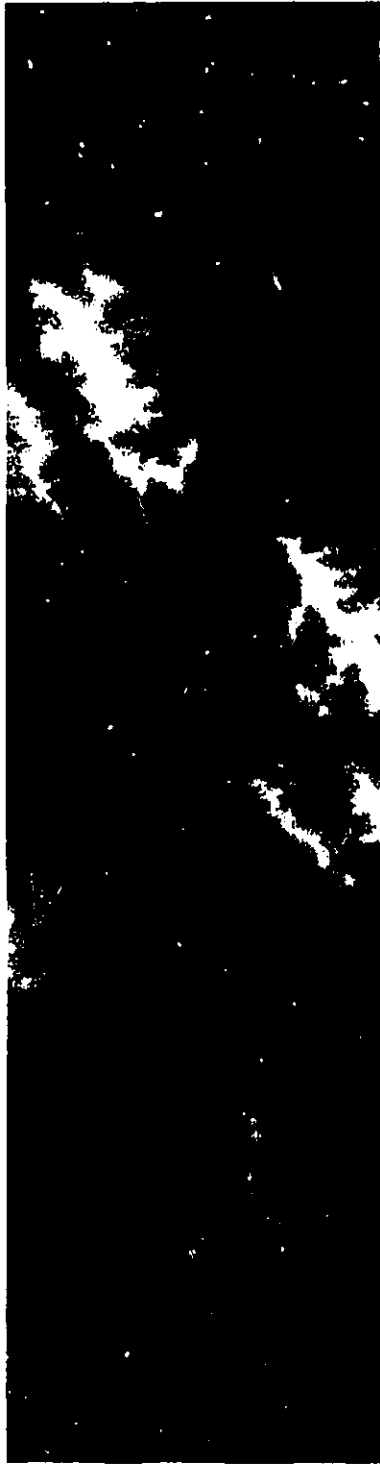


Figure 4.4 Index contour lines used to build the Alsek River valley digital elevation model.

(a)  
Elevation



(b)  
Hill-slope



(c)  
Aspect



Figure 4.5 Digital topographic features of the Aisek River valley.

base portion of the GIS.

Two individual map sheets concerning soil type and permanent snow and ice features were not digitized. In the case of the soil type map, sheet number 115 A/12 is currently missing from the KNPR operations centre and unavailable for use. The permanent snow and ice features, which are usually outlined on the NTS map sheets, are not shown on sheet number 115 A/12 and so were not digitized.

It is important to realize that all forms of spatial data tend to involve both error and generalization. The manually-prepared source maps include errors due to observation and measurement procedures. For example, the identification and drawing of a contour line may have been mistakenly given a value of 200 when it should have been 2000. A second error is associated with the process of digitizing the source maps. The digitizing process is intended to replicate the data included on the manually-prepared source maps. However, this process is complex so that errors may exist in the digitized spatial or attribute data. For example, a contour line attribute may have been incorrectly entered into the computer as 200 instead of 2000. Since the GIS is only as good as its data base, it is important to have methods and techniques in place to evaluate the integrity of the data (Forrester and Vanderwall, 1987; Knapp, 1980).

#### 4.3.3 Methodology

The general hypothesis being tested within the context of this pilot study can be further defined by three research hypotheses:

*(1) Elevation, (2) hill-slope, and (3) hill-slope orientation (ie. aspect) do not affect the distribution of a self-regulating population of grizzly bears in the Alsek River valley of KNPR.*

The practical research design to test these three research hypotheses deals with translating the ideal framework into a realizable working procedure and consists of four phases: the sampling design, statistical design, observational design, and operational design (Ackoff,

1953). The methodological design for this pilot study is primarily intended to demonstrate a potential application of the GIS data base. With such a small number of grizzly bear observations, it is not possible or intended to make confirmatory conclusions on specific grizzly bear habitat.

### Sampling Design

The sampling design deals with the method of selecting the variables to be observed (Ackoff, 1953). The variables for this pilot study have been digitized and currently exist within the KNPR management planning GIS data base (see Section 4.3.2). Grizzly bear location data were collected by park managers between 1989 and 1992 and a sample of five grizzly bears was used to test the research hypotheses (Table 4.2). Because grizzly bears are associated spatially to a particular home range, statistical analysis can only be performed on individuals and not on the five bears as a group. The study area is protected from hunting so the population of grizzly bears is assumed to be self-regulatory.

The location data of the sampled grizzly bears include the unique collar number, the UTM coordinates to within 100-metre accuracy referenced from the 1:50,000 NTS map sheets, the date of observation, and a brief description of the location as well as the bear's activity (eg. bear observed swimming across Alesk River). The brief description was valuable so as to verify the bear location after being digitized.

### Statistical Design

The statistical design deals with how many sample subjects are to be observed, and how the subjects are to be analyzed (Ackoff, 1953). Following the building of the GIS data base, a descriptive statistical analysis was undertaken to see which topographic features are important in the habitat of the grizzly bear.

The raster-based GIS *Idrisi* was used as a tool to contribute to testing the research hypotheses. Testing the hypotheses was facilitated by using the GIS since it allows cross-

<b>Collar Number</b>	<b>Sex</b>	<b>Date Collar Activated</b>	<b>Number of Observations</b>
KNP-1	Male	June 19/89	9
KNP-6	Female	July 2/91	8
KNP-10	Male	July 16/91	9
KNP-11	Female	August 15/91	9
KNP-12	Female	September 20/89	14

Table 4.2 Alesk River valley grizzly bear characteristics.

tabulating multiple map layers (Table 4.3). For example, location data of a particular grizzly bear were compared with the three topographic features to determine the form, extent, and precision of the relationships. Following this process for each grizzly bear, the acceptance or rejection of the research hypotheses was possible.

With such a limited number of observations for each sampled bear it was not proper to use the appropriate chi-square goodness of fit test (Neu *et al.*, 1974). Therefore, no statistical hypotheses were tested. Further work on making the sample more robust is ongoing as part of the six-year study designed by Wielgus *et al.* (1992).

### Observational Design

The observational design deals with the conditions under which the observations are to be made (Ackoff, 1953). Observing the sampled grizzly bears is based on radio-collaring and then monitoring. Collared grizzly bears were located by aerial telemetry through the summer months (ie. from den emergence to den entry). Telemetry allows for locating a collared grizzly bear and recording its movements (Pearson, 1975; Roney *et al.*, 1989). The monitoring process included recording the spatial location of the collared grizzly bears using the UTM coordinate system to within 100-metre accuracy with the use of a helicopter or fixed-wing aircraft. This process was completed by park managers for the five sampled grizzly bears (Table 4.2).

The use of a GIS contributed to this phase since it acts as a central reference system and enables the data to be updated. Hill-slope and hill-slope orientation maps were derived from the DEM so as to be used in the cross-tabulation process. The hill-slope map was classified in degrees with a range of values between 0° along the valley floor and 59° near the summit of Mount Archibald (Figure 4.5b). The hill-slope orientation map was also classified in degrees, but these ranged between -1° and 360°. This is defined by the compass direction so that both 0° and 360° represent north while -1° is included for flat terrain (Figure 4.5c). It was then possible to

Collar Number	Observation Data					
	ID	Elevation (m)	Slope (°)	Aspect (°)	Distance (m)	Month
KNP-1	1	600	0	-1	671	8
	2	600	0	-1	200	8
	3	600	0	-1	800	8
	4	1254	28	101	4016	9
	5	600	3	270	200	9
	6	600	0	-1	224	9
	7	600	0	-1	566	7
	8	600	0	-1	800	8
	9	1200	10	136	5349	7
KNP-6	13	600	0	-1	671	7
	14	663	7	272	990	7
	15	1400	15	235	7571	7
	16	600	0	-1	0	7
	17	600	0	-1	0	8
	19	1200	13	190	3734	9
	20	989	5	343	10081	10
	22	1720	31	160	8884	10
KNP-10	27	600	0	-1	283	7
	29	600	0	-1	100	7
	30	600	0	-1	510	7
	31	600	0	-1	200	8
	32	600	0	-1	400	8
	33	600	0	-1	200	8
	34	800	3	180	10500	9
	35	829	12	150	10500	9
	36	800	5	180	10400	9
KNP-11	40	600	0	-1	200	8
	41	600	0	-1	922	8
	42	713	8	310	2000	8
	43	1328	23	124	4401	9
	44	1200	3	90	5385	9
	45	1145	17	113	4020	9
	46	1029	14	26	6476	10
	47	660	5	90	1237	10
	48	1196	11	77	4243	10
KNP-12	49	1219	8	0	17311	4
	50	1066	1	270	25922	4
	52	1066	6	284	12692	5
	55	2025	31	143	11602	5
	56	703	2	198	3801	6
	57	1035	4	356	16059	6
	58	1066	10	87	4827	7
	59	1314	11	18	13248	7
	61	886	2	188	3114	7
	62	1343	14	356	15628	9
	63	1371	0	-1	14822	9
	64	1219	0	-1	17207	9
	66	1383	19	237	7200	10
	68	1482	20	233	7103	10

Table 4.3 Alsek River valley grizzly bear observation data derived from GIS data base (Note: Aspect values of -1 means flat terrain; "Distance" refers to distance from Alsek River; numeric month values follow convention: 1=January, 12=December).

calculate the proportions of each topographic category in relation to the entire study area (Table 4.4). An additional map was generated using buffers around the Aisek River to determine the bears' proximity to the transportation route of the proposed boat tour.

#### Operational Design

The operational design deals with the techniques by which the procedures specified in the sampling, statistical, and observational phases can *actually* be carried out (Ackoff, 1953). This thesis focuses on a pilot study intended to test the initial GIS data base design. The pilot study allowed for the application of the design process within a small, representative study area. The GIS data base was small and manageable while still allowing insights to be made about the actual GIS concepts and capabilities needed to support KNPR management planning.

#### 4.3.4 Results

The results of the pilot study focus on testing the three research hypotheses. The following chapter (Chapter 5: *Conclusions, Discussion, and Recommendations*) discusses the effectiveness of the GIS concepts and capabilities to complete the pilot study. Each individual grizzly bear was tested against the three topographic features using five functions (Table 4.5, Column 2). From this, it was possible to accept or reject the hypotheses of whether or not grizzly bears use each topographic category in proportion to its occurrence in the study area (see Table 4.4). Then, it was possible to determine which topographic categories the grizzly bears prefer (Marcum and Loftsgaarden, 1980). It is necessary to re-emphasize that with such a small sample size the amount of significance put on the results is quite meagre.

With reference to the quality of the data used in the pilot study two aspects are important. These two aspects include the quality of the *spatial* data and the quality of the *attribute* data. The spatial and attribute data were verified for the DEM and the grizzly bear point locations. It was determined prior to beginning the pilot study that the entire spatial data base should have a pixel

Elevation (m)	Area %	Slope (°)	Area %	Aspect (°)	Area %
520-720	17	0-6	48	0-45	10
721-820	24	7-12	17	46-90	11
921-1120	19	13-18	12	91-135	11
1121-1320	10	19-24	9	136-180	9
1321-1520	10	25-30	7	181-225	9
1521-1720	10	31+	7	226-270	12
1721-1920	6			271-315	10
1921+	4			316-360	7
				-1	21

Table 4.4 Proportions of each topographic category in relation to the entire study area.

Collar Number	Summary Data			
	Function	Elevation (m)	Slope (°)	Distance (m)
KNP-1	Range Minimum	600	0	200
	Range Maximum	1254	28	5349
	Median	600	0	671
	Mean	739	5	1425
	SD	277	9	1892
KNP-6	Range Minimum	600	0	0
	Range Maximum	1720	31	10081
	Median	826	6	2362
	Mean	972	9	3991
	SD	432	11	4239
KNP-10	Range Minimum	600	0	100
	Range Maximum	829	12	10500
	Median	600	0	400
	Mean	670	2	3677
	SD	105	4	5094
KNP-11	Range Minimum	600	0	200
	Range Maximum	1328	23	6476
	Median	1029	8	4020
	Mean	941	9	3209
	SD	295	8	2185
KNP-12	Range Minimum	686	0	3114
	Range Maximum	2025	31	25922
	Median	1219	7	12970
	Mean	1213	9	12181
	SD	334	9	6404

Table 4.5 Alesk River valley grizzly bear summary data.

resolution of 100 metres since that is the smallest observable unit when relocating a grizzly bear using radio telemetry.

The DEM and derived hill-slope and hill-slope orientation maps were verified against the original 1:50,000 NTS map sheets through a visual inspection. By overlaying the digital contours on the DEM and cross-referencing to the original map sheets, it was possible to quickly determine and correct any spatial or attribute errors. The DEM is considered to be of high accuracy.

The grizzly bear point locations were verified against the 1:50,000 NTS map sheets using the brief descriptor of the bear's location and activity which is included as an attribute to the bear data. For example, if the bear's brief descriptor states that the *bear was observed swimming across the Asek River*, then the location was verified to confirm that the point is indeed in the river. These brief descriptors proved to be valuable in verifying the grizzly bear point location accuracy. The grizzly bear point location data are considered to be of high accuracy.

The first research hypothesis states that *elevation* does not affect the distribution of a self-regulating population of grizzly bears in the Asek River valley of KNPR. The minimum elevation in the study area is 520 metres while the maximum is 2438 metres (Figure 4.5a and 4.6a). From the five sampled bears, observations were found between 600 metres (KNP-1, -6, -10, and -11) and 2025 metres (KNP-12). Although it is possible to state that grizzly bears can be found at almost all elevations (except above 2025 metres, probably due to snow and ice coverage), three (KNP-1, -6, and -10) of the five bears are found disproportionately around the valley floor. Therefore, the first research hypothesis is accepted.

The second research hypothesis states that *hill-slope* does not affect the distribution of a self-regulating population of grizzly bears in the Asek River valley of KNPR. The minimum hill-slope in the study area is 0° while the maximum is 59° (Figure 4.5b and Figure 4.6b). From the five sampled bears, observations were found between 0° (all five bears) and 31° (KNP-6 and -12).

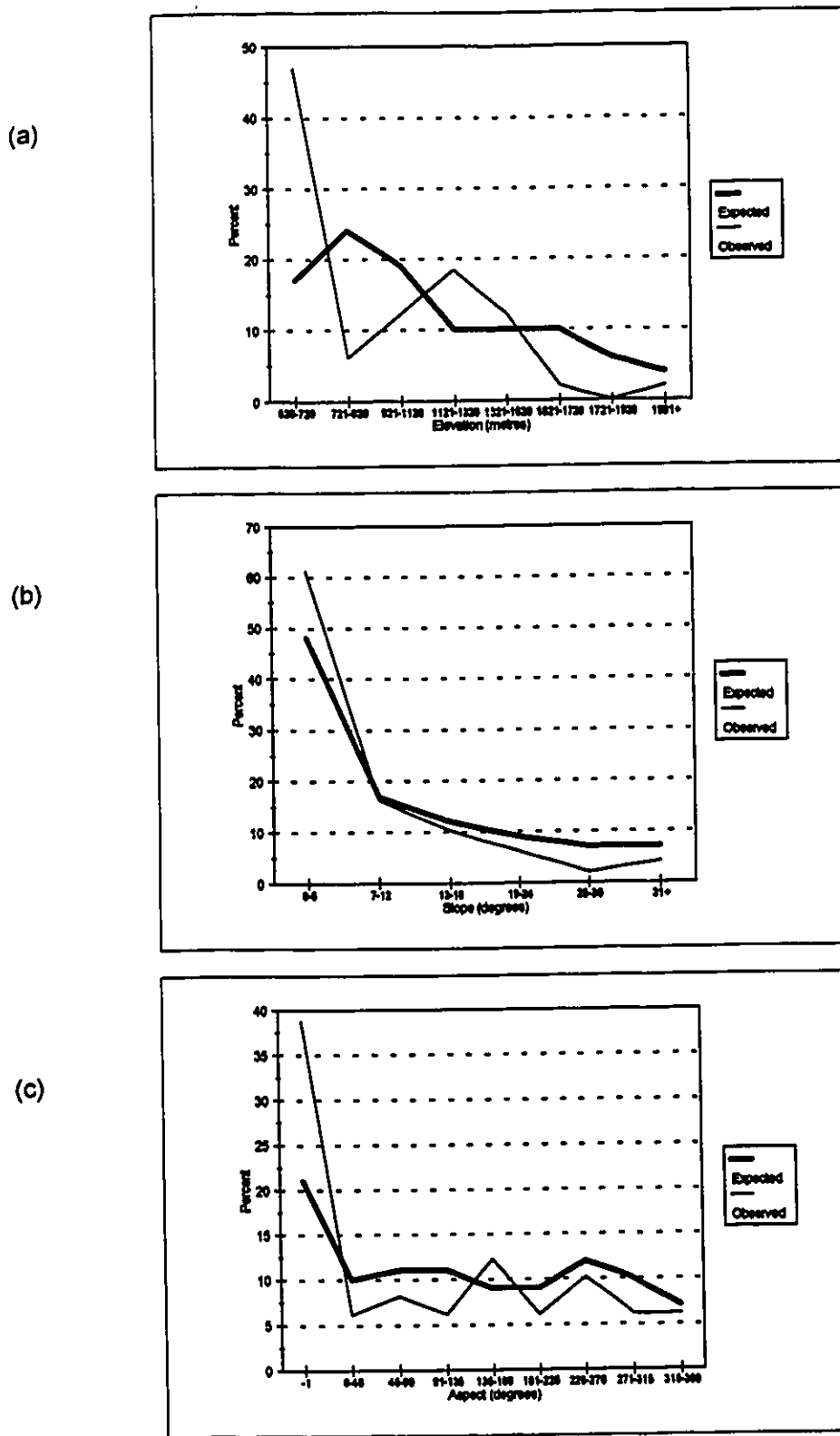


Figure 4.6 Alsek River valley elevation (a), slope (b), and aspect (c) proportions (expected) in relation to grizzly bear observations as a group (observed).

A large proportion of the study area has hill-slopes of less than 6° (48%) while less than 10 percent of the study area has hill-slopes above 31°. These trends are also reflected in the preferences of each sampled grizzly bear. The sampled grizzly bears use slope in proportion to their amount in the study area. Therefore, the second hypothesis is rejected.

The third research hypothesis states that *hill-slope orientation* (ie. aspect) does not affect the distribution of a self-regulating population of grizzly bears in the Alsek River valley of KNPR (Figure 4.5c and 4.6c). This hypothesis is more difficult to test. As was found with the hill-slope hypothesis, three (KNP-1, 6, and 10) of the five bears prefer flat areas (ie. with no hill-slope orientation). However, this is proportionate to the amount of the *no aspect* category within the study area (21%). The other two grizzly bears (KNP-11 and 12) are not affected by any particular hill-slope orientation but use each category in proportion to its amount. It is not possible to state that the sampled grizzly bears use the hill-slope orientation categories out of proportion to its amount in the study area. Therefore, the third hypothesis is rejected.

In mountainous areas, such as the Alsek River valley, there is a wide range of topography including a flat valley floor as well as steep mountain ridges. It is possible to ascertain from inspection of the sampled grizzly bear distribution map (Figure 4.7) that the bears can be found almost throughout the study area. However, as was made explicit in testing the three research hypotheses, the bears can be found disproportionately around the flat valley floor close to the Alsek River.

#### 4.4 Summary

- The pilot study area represents a corridor section of the greenbelt of KNPR. This area is defined as the Alsek River valley from immediately north of its source, which is at the confluence of the Kaskawulsh and Dezadeash Rivers, to the terminus of the Lowell Glacier. The study area is approximately 2,300 square

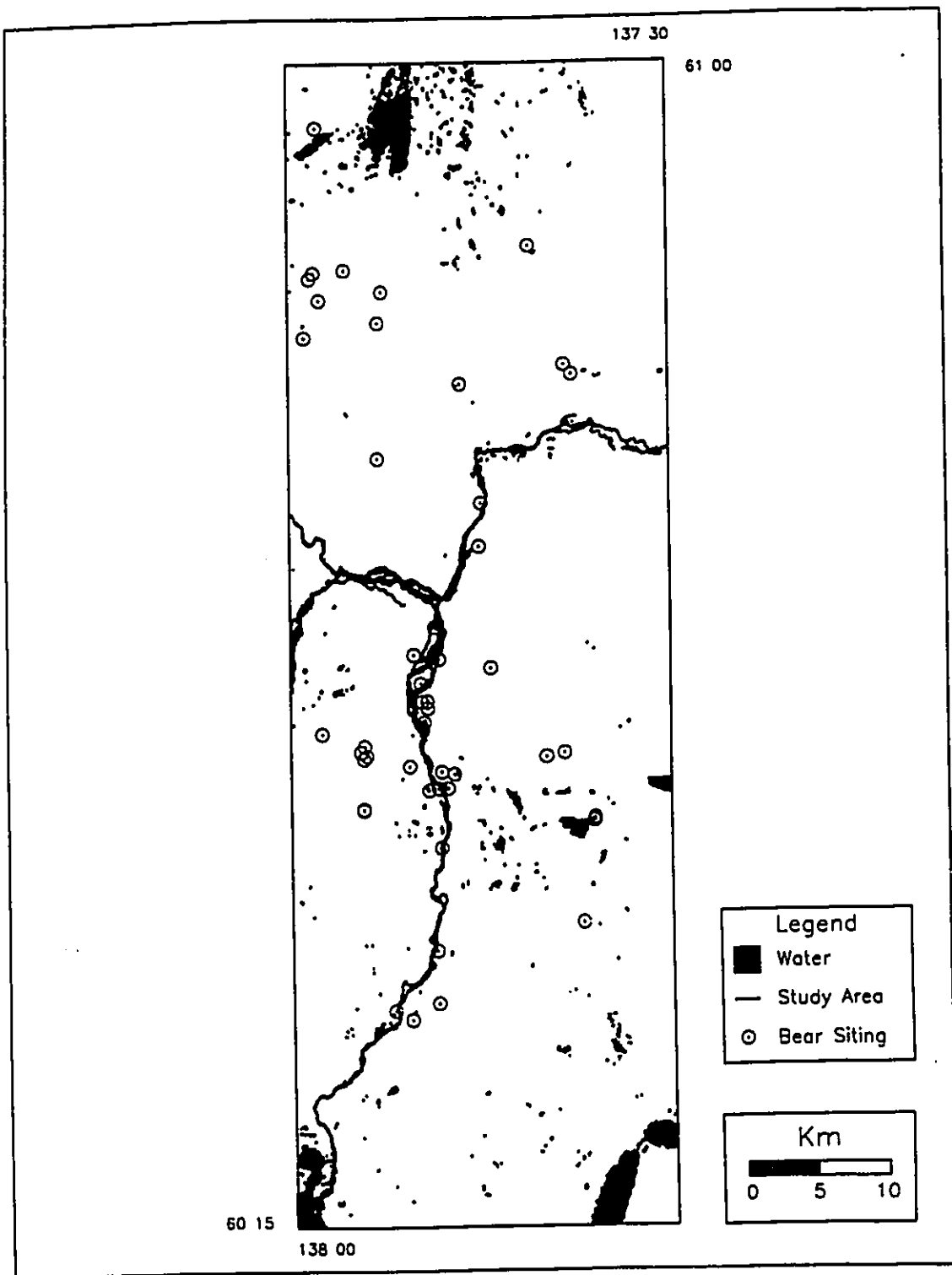


Figure 4.7 Locations of the five sampled grizzly bears in the Aisek River valley.

kilometres (see Figure 4.1).

- The Asek River valley presents park managers with some unique management planning concerns (see for example Figure 4.2). These concerns are evident because of the specific geographic characteristics of the area and include: grizzly bears; forest fire; visitor risks, hazards, and safety; flooding; pollution from mining in tributary rivers and creeks; visitor impact and development; horse grazing; and land claims.
- Wielgus *et al.* (1992, 2) have designed a six-year grizzly bear research program to "provide CPS with the ability to manage the wilderness' use to prevent significant impact on the park's grizzly population". This research program is currently in progress and due for completion in 1998.
- The three research hypotheses tested in the pilot study relate specifically to grizzly bear distribution and topographic features and state that:  
*(1) Elevation, (2) hill-slope, and (3) hill-slope orientation (ie. aspect) do not affect the distribution of a self-regulating population of grizzly bears in the Asek River valley of KNPR.*
- A variety of methods and techniques were used to build the GIS data base for the Asek River valley (see Table 4.1). The variables which were digitized include the topography, vegetation association, soil series, hydrology, community interactions (ie. grizzly bear location data), as well as roads and trails and park boundary. The topographic data were used to test the hypotheses in the context of the pilot study. All the map layers could be used in future park management planning regarding Asek River valley studies and joined with adjacent map sheets to create a complete KNPR management planning GIS data base (see Figure 4.3).

## Chapter 5

### Conclusions, Discussion, and Recommendations

#### 5.1 Introduction

The objective of this chapter is to synthesize the findings of the thesis by presenting the fundamental conclusions, a brief discussion, and recommendations for further work. References are made to specific sections, figures, and tables from preceding chapters so as to allow for an elaboration of the synthesis.

#### 5.2 Conclusions

The fundamental conclusions focus on answering the central research question and evaluating the adequacy of the Kluane National Park Reserve (KNPR) management planning GIS data base design. These two conclusions are connected and contribute to the effective use of GIS to support KNPR management planning.

The central research question being explored is:

*What GIS concepts and capabilities are needed to support Kluane National Park Reserve management planning?*

The GIS *concepts* are based on the premise that the demands of KNPR management planning determine what geographic data and information should be contained in the GIS data base (see Section 2.5.1). This premise connects the GIS data base design, implementation, and application aspects by requiring a definition of the entire park management planning process. If the GIS data base is designed and implemented effectively then it will facilitate user interaction with geographic data and information and contribute to the park management planning process. Whereas the park management planning process runs from input to output (ie. data → information → knowledge → park management planning → park management planning outcomes), the process of design and implementation begins with the products that users expect from the GIS data base and then works backwards to the requirements of source data.

The connection between the GIS data base design, implementation, and application aspects is operationalized in a three-phase GIS framework (see Table 3.2). The *Pre-Conditions to GIS Application* phase determines the hardware, software, data, users, and procedures. For KNPR management planning, the following GIS configuration and capability is proposed:

- Specific organizational conditions which provide the overall context for the GIS data base design as outlined in Section 3.2.
- Hardware: PC-DOS and OS/2-based computer system including high resolution colour monitor, external storage unit (ie. tape back-up device), digitizing table, and plotter.
- Software: Licensed copies of *SPANS* (raster-based GIS), *dBase IV* (data base management system), *Lotus 123* (spreadsheet), and *WordPerfect 6.1* (word processor).
- Map scale and spatial resolution: Digitizing greenbelt area maps based on 1:50,000 scale and interior icefield range maps based on 1:250,000 scale with 100-metre spatial resolution.
- Spatial variables: Topography, hydrology, vegetation, soil, roads and trails, park boundaries, and indicator species (see Table 2.7) used by researchers and park managers on the resource conservation branch.

The GIS *capabilities* include acting as an inventory, analysis-synthesis or management tool to contribute to mapping, monitoring, and modelling the park's resources and visitor activities (see Section 3.3.2). Various procedures, methods, techniques, operations, and specifications are defined with respect to KNPR management planning (see Table 3.3).

The initial KNPR management planning GIS framework was evaluated based on a pilot study. Specific map layers were digitized for the Alsek River valley (see Table 4.1) and a general

hypothesis was tested with regard to the relationship between topographic features and grizzly bear distribution (see Section 4.3). Within the current *KNPR Management Plan*, grizzly bear research and management is considered a priority and must be taken into account during the GIS data base design (see Sections 3.2.1 and 4.2.1). The following conclusions can be drawn:

- Specific GIS capabilities used to complete the pilot study are as follows: digitizing (maps), editing (map files), joining (map files), interpolating (between contours), gridding (TIN), computing hill-slope and hill-slope orientation maps (from the DEM), querying (map layers), cross-tabulating (map layers), calculating (map layers' area), buffering (around Alsek River), classifying (map layers), displaying (map layers), and reporting (results). These specific GIS capabilities are derived from the GIS acting as a *mapping* tool.
- The GIS capabilities listed above were executed using a variety of personal computer-based software and included: *Arc/Info*, *Atlas Draw* and *Atlas GIS*, *Idrisi*, *SPANS*, *dBase IV*, and *Excel*.
- It is evident that the general hypothesis of the pilot study would not have been able to be tested as effectively or efficiently without the use of the specified GIS concepts and capabilities.

### 5.3 Discussion of Research Findings

The pilot study in this thesis was more than just an application of a design and a technology, in addition, a real data base was created that can be used to generate useful products. In particular, the map layers created for the Alsek River valley can be joined with adjacent map sheets to create a complete KNPR management planning GIS data base. Ultimately, the GIS is only as good as its data base (see Section 4.3.2).

A fundamental prerequisite to use of a GIS is the proper representation of reality in the

form of the spatial data base. This data base can then be transformed using specific GIS concepts and capabilities to build an information or knowledge base to support park management planning (see Section 2.5.1). There are specific criteria which must be fulfilled to create a proper representation of reality in the GIS data base. They include: consistency, reliability, validity, and accuracy in the data.

One problem which needs to be solved so as to improve the GIS data base structure deals with inconsistencies *between* map layers. For example, there is a class for water (ie. lakes, rivers, and streams) on the vegetation, soil, and NTS map sheets. However, the location and extent of these features are not consistent between the three layers. This can lead to marked differences in area covered by each feature and problems overlaying map layers. A potential solution to this problem is to acquire a remotely sensed image and classify it according to fundamental landcover classes (eg. water, ice, and rock).

Another problem is the poor quality of the vegetation map sheets. These maps are polygon-based with many polygons not attributed or not closed. Also, there are serious discrepancies between sheets making it difficult to correctly join maps once they have been digitized. Since this is an important map layer, it may have to be re-mapped altogether, perhaps with the aid of a remotely sensed image.

There will be times when the statistical capabilities of a GIS are simply inadequate to test a particular hypothesis. More generally, there will be times when one GIS software package is inadequate for a particular park management planning problem. Therefore, a hybrid approach using a variety of software packages defined under the KNPR management planning GIS framework is required.

Much of this thesis is about communication through the use of data, information, and knowledge of a geographic nature. Specific concepts and capabilities of a GIS can be used to

efficiently and effectively communicate results so that researchers and managers can work cooperatively. An example of this type of integrated national park management is the grizzly bear study designed by Wielgus *et al.* (1992) with the GIS providing a centralized data base and capabilities of transforming geographic data into information (see Sections 4.2.1 and 4.3.1).

#### 5.4 Recommendations for Future Work

Results from the pilot study suggest that the Alsek River valley is a fragile environment which is home to a number of grizzly bears (see Section 4.3.4). These results could be confirmed following the completion of the six-year grizzly bear research program and contribute to a thorough environmental screening of the valley. At this point in time, it appears appropriate that all proposed developments in the valley be put on hold until needed data, information, and knowledge have been acquired for the park management planning process. Rezoning of areas in the valley to encourage low impact visitor access based on a rational, informed park management planning process might then be justified.

The current KNPR management planning GIS data base acts only as a mapping tool. The focus of this thesis was to initiate the design, implementation, and application of the GIS data base so as to eventually evolve into a management tool, also known as a decision support system (DSS). Eventually, the KNPR management planning GIS should contribute to not only mapping but, also, to monitoring, modelling, and managing the park's resources and visitor activities. Development of the GIS data base away from the concept of the descriptive biophysical land inventory structure used by Parks Canada may accelerate the evolution.

KNPR should benefit from a survey of other national park's applications. Seminars should contribute to success of GIS use in Parks Canada as a whole, as well as providing a forum for individuals to communicate and document their respective results. A follow-up report evaluating what has happened since Welch (1988) initiated the needs assessment should provide direction

and training to the individual national parks. Also, the GIS should allow an integration of data from various national parks on particular resource themes. The ultimate objective is to create a nation-wide Parks Canada GIS data base to permit *State of the Parks* reports to be completed, and thereby contribute to the ultimate organizational objective of making better decisions and realizing better outcomes as they affect Canadian national parks.

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