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**A SENSITIVITY MAPPING SCHEME
BASED ON ECOLOGICAL LAND SURVEYS:
CASE STUDY WOOD BUFFALO NATIONAL PARK**

by

© Robert B. Sayer B.A.

A thesis submitted to the Faculty of Graduate,
Studies and Research in partial fulfilment of
the requirements for the degree of Master of

Arts

in Geography

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Carleton University

Ottawa, Ontario

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ABSTRACT

This paper introduces to Parks Canada, a sensitivity scheme for determining sensitivity levels and producing sensitivity maps for identified potential disturbances induced by particular activities. The aim is to produce reconnaissance level information which is usable by planners in the early phases of project design and by park resource managers. In addition, the scheme provides data for a park's resource inventory and description documents.

The sensitivity measurement techniques employed are based on methodologies found in the literature. The data source is primarily the ecological inventories of National Parks stored in the Canada Geographic Information System (CGIS). The output is in the form of tables of sensitivity values and sensitivity maps.

The sensitivity scheme is illustrated using Wood Buffalo National Park as a case study. Although the measurement techniques are aimed at the Wood Buffalo National Park resource inventory data, they could be modified to suit other park inventories.

PREFACE

This paper has been financed by and written for Parks Canada in addition to being a Carleton University, Geography Department graduate thesis. However, it must be noted that this paper reflects the views of the author and not necessarily those of Parks Canada.

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GLOSSARY

Activity

- An activity is considered as any utilization of the natural environment by man. This includes activities ranging from large numbers of people walking through a field or forest to construction of pipelines, communities and hydro projects, as well as many other engineering projects and usages.

Disturbances

- A disturbance is a negative impact and is the disruption of the natural environment causing degradation. Disturbances may be caused by the direct action of man, or occur subsequent to such action as a result of an altered equilibrium in natural processes (Edlund and Vincent, 1978). The disturbance may be immediate or manifest itself at some future date. It may be localized or have an effect at a considerable distance from the originating action.

Those disturbances resulting directly from the activity are primary impacts; those disturbances not directly caused by the activity are secondary impacts. For instance, the clearing of vegetation from a slope will increase erosion, which is a

primary impact. The soil removed from the slope enters a stream and is deposited downstream where it covers over and destroys a spawning ground; the latter action is classified as a secondary impact.

Ecological Land Classification (ELC) - Ecological Land

Classification is a land survey methodology in which an integrated multidisciplinary team maps and describes distinctive land units. The aim is to identify distinguishable environmental components and describe environmental processes occurring within a unit to enable the classification of land units by their ecological unity (Duffy 1978, Wiken 1977).

Environmental Assessment - An environmental assessment is a process to identify or predict the impacts that a particular project (activity) will create. The process should consider both the beneficial and adverse effects to the economic, social and natural environment of the area (Jain, 1977).

An assessment determines the processes at work in an environment and how the processes will affect the environment in the

future and then superimposes the activity on the environment to predict the changes that will occur. In addition, the assessment suggests mitigating measures to alleviate the predicted negative changes.

Infrastructure - The infrastructure is the foundation or framework upon which an activity operates. For example, the infrastructure for the activity "Campgrounds" includes the roads, campsites, sanitary facilities and any other support facility required by a camper.

Sensitivity - Sensitivity can be considered from a social, economic or natural environmental point of view.

Armour and Lang (1980) identify the sensitivity of land by social, economic and natural environmental concerns. Armour and Lang (1980) separate sensitive lands into: those requiring protection from human activity so as to reduce their hazards to man (social); those to be preserved for continued use of their resources (economic); and those that should be protected for the benefit of nature (natural environment).

Another approach is to consider man's effects on natural systems without social or economic regard. Barnett et al (1977) defines the sensitivity of a land unit as the summary evaluation of the resistance of the natural environment to man's impact. The higher the sensitivity, the smaller the trigger necessary to create visible change, usually considered to be deleterious.

Barnett notes that it is a "visible change" that is triggered; however, not all changes need to be visible to be significant. Edlund and Vincent (1978) state that sensitivity is considered to be the susceptibility of an area to disturbance, where disturbance is a man-initiated change to surface characteristics.

Armour and Lang offer a classification for separating sensitive land from non-sensitive land, but there is no indication of the degree of sensitivity. Barnett's as well as Edlund's and Vincent's definitions allow the determination of a degree of sensitivity and will be the basis for interpretation of sensitivity in this paper.

The sensitivity of a unit of land is the susceptibility of the unit to an identified disturbance induced by a particular activity. The higher the degree of sensitivity the greater the increase in the rate of disturbance (e.g. erosion) or the greater the potential for the disturbance to occur (e.g. slope failure).

CHAPTER I

INTRODUCTION

1.1 PRACTICAL AND THEORETICAL SETTING

Since the early sixties conservationists have been informing the public of the environmental consequences of increasing growth. There have been measurable changes in the quality of air, water and land that are generally perceived by the public to be losses in environmental quality. There has been a groundswell of concern over dwindling supplies of natural materials and energy resources (Erickson, 1979) thus creating demands for increased resource management. In addition, concern over preservation of the natural environment has led to increased efforts in environmental protection.

If natural areas are to be allowed to continue to be subject to their natural processes and still be utilized by man, then man must minimize his disturbance* of an area. This is a problem that affects Parks Canada which must protect the

*Defined in Glossary

environment of the National Parks and also provide access and facilities for the public. If this double goal is to be accomplished it is important to be aware of potential disturbances or impacts such as erosion, increased stream sedimentation, slope failure or the destruction of habitats that can be caused by man's modification of the environment.

Once potential impacts have been identified, it is possible to establish the kinds and limits of development that might be carried out, and yet keep impacts within acceptable levels. In addition, the identification of potential impacts of proposed projects helps in the identification of possible solutions (mitigating measures) which in turn may reduce the construction and environmental costs of the project.

One approach to the identification of potential impacts is to determine the sensitivity* of an area to particular activities.* Some ecosystems are less sensitive than others and can tolerate man's disruption to a greater degree. It is necessary that planners be aware of and understand the ecological relationships that exist within an ecosystem, so that changes made to any component of the ecosystem will avoid serious disturbance to ecosystem linkages (Parks Canada, 1978).

*Defined in Glossary

Effective park use planning considers a project's impact on the environment and the design of appropriate mitigating measures as well as the usual cost/benefits analysis. In addition it is essential to have ecological information available as early as possible in the planning process. If information concerning ecological relationships and prediction of potential impacts of a project can be presented during the conceptual phase of project planning, then it is argued that environmental concerns can be effectively addressed.

It is the purpose of an environmental assessment* to provide such data and suggest mitigating measures as early as possible to decision-makers, planners and designers (Canter 1977, Cheremisinoff 1977, Jain 1977 and Holling 1978). However, one problem is that most screening and other impact studies are done after designs are submitted (Canter 1977, Morrison 1980) because assessment is based on the design of the particular project. If mitigating measures are identified by an impact study following the design phase, as is the usual case, then there is additional time and expense of redesigning part or all of the project. It is suggested that if, during the conceptual phase,

*Defined in Glossary

planners are made aware of potential impacts which the project may cause then mitigating measures can be incorporated into the design. This would increase the chances of a successful screening and reduce overall costs.

It is recognized that similar projects on similar sites have a high probability of creating similar impacts (Erickson, 1979). Therefore, if the proposed activity is known and an environmental data base exists, then potential impact predictions can be made prior to a detailed design of the project.

1.2 THESIS OBJECTIVE

* Ecological Land Classification* surveys (described in section 1.3.2) provide Parks Canada with the data base, while park plans identify the proposed activities. What is needed is a scheme to bring these two sources of information together and produce sensitivity ratings of disturbance for the ecological units within a park.

This paper introduces a reconnaissance level sensitivity scheme, aimed at determining the potential level of environmental disturbances caused by particular human activities. The scheme would provide managers with additional data for a park's

*Defined in Glossary

Basic Resource Inventory and provide information for the Resource Description and Analysis of a park. In addition, this process is intended to be used in the conceptual phase of project planning for design purposes and for initial site and/or corridor selection. The information, although beneficial to planners and resource managers, does not replace the need for a detailed environmental screening of a project.

The end product of introducing this reconnaissance type of assessment is a sensitivity severity-risk map. That is, each ecological unit on the map will have associated with it a level of sensitivity to a particular disturbance resulting from an identified activity, as well as the risk of such a disturbance occurring. For example, a unit may have a severe sensitivity rating but it may only affect 30% of the unit. Therefore, the risk of encountering the severe sensitivity limits within that unit is 30%.

As a demonstration of how this scheme operates, the ecological data base of Wood Buffalo National Park is used to identify potential disturbances caused by five activities: roads, campgrounds, hydro electric projects and forestry operations. The disturbances this paper will focus on are erosion, slope failure and the loss of vegetation.

1.3 BASIC ELEMENTS OF THE SENSITIVITY SCHEME

Information that is required to determine the degree of sensitivity of an area and the types of impacts that may occur is obtained from the study of three elements: 1) the type and level of intensity of activity that is planned; 2) a data base of the ecology and terrain of the area involved (ecological land survey); and 3) a method of analysing the data to predict impacts (environmental impact assessment). The remainder of this section will set the background for the paper by discussing activities, ecological land surveys and environmental impact assessments, and how they relate to each other and Parks Canada operations.

1.3.1 ACTIVITIES

A proposal for development of an activity for an area requires consideration of the potential disturbances such an activity may create. This is because most activities require an infrastructure* and it is the construction and maintenance of the infrastructure that often produces the greatest disturbances. For instance, a road's infrastructure can alter drainage patterns, increase erosion, block wildlife movement and destroy vegetation communities.

*Defined in Glossary

The impacts of the various stages of construction and maintenance must be identified and considered in the planning and design of facilities. It is important that mitigating measures be considered where environmental disturbances are identified as being possibly beyond acceptable levels.

A recognized method of identifying potential impacts or disturbances produced by a particular activity is to conduct a survey of land resources and to initiate an environmental assessment. The environmental assessment requires the data of the land survey and the plans of the activity in order to predict impacts.

1.3.2 ECOLOGICAL LAND CLASSIFICATION

Ecological Land Classification (ELC) is a land survey methodology that refers to an integrated approach to mapping and describing distinctive land units as opposed to individual thematic surveys (soils, geology, vegetation, wildlife, etc.).

ELC surveys in Canada have evolved in stages from single theme surveys, through Bio-physical Land Classification to its present form. A user requiring environmental information under the single theme approach was forced to collect data from unrelated surveys that had probably been conducted at different

times, at different scales and for different purposes. From the series of surveys a user had to synthesize the data to provide an understanding of the various components of the environment.

Researchers around the world recognized the advantages of conducting surveys that encompassed environmental components into a single survey.

Development of the Canadian process of integrated surveys was based largely on work from Australia in the late 50's and 60's. In 1969 the National Committee on Forest Land, Subcommittee on Bio-physical Land Classification provided guidelines for a Canadian Bio-physical Land Classification scheme (Lacate, 1969). The aim of the guidelines was to permit rapid differentiation and classification of ecologically significant segments of the land surface, on a small scale (reconnaissance-level) (Lacate, 1969). A hierarchical bio-physical land classification (Table 1.1) based on units having common characteristics of soils, landforms, surficial materials, vegetation, climate and water bodies was proposed. In 1976 the Canadian Committee on Ecological Land Classification (CCELC) was formed with the objective of revising the guidelines and proposing a more ecological approach to land classification (Parks Canada, 1980a). The CCELC proposed new terminology to be employed across

TABLE 1.1

LEVELS OF INTEGRATION AND MAPPING SCALES

BPLC AND ELC

<u>Bio-physical Land Classification</u>		<u>Ecological Land Classification</u>	
<u>Levels of Integration and Mapping Scale</u>	<u>Definition</u>	<u>Level of Integration and Mapping Scale</u>	<u>Definition</u>
Land Region 1:1,000,000 - 1:250,000	An area of land characterized by a distinctive regional climate, as expressed by vegetation.	Ecoregion 1:3,000,000 - 1:1,000,000	An area of the earth's surface characterized by distinctive ecological response to climate as expressed by vegetation, soils, water, fauna, etc.
Land District 1:250,000 - 1:125,000	An area of land characterized by a distinctive pattern of relief, geology, geomorphology.	Ecodistrict 1:500,000 - 1:125,000	A part of ecoregion characterized by a distinctive pattern of relief, geology, vegetation, soils, water and fauna.
Land System 1:125,000 - 1:50,000	An area of land through which there is a recurring pattern of landforms, soils, vegetation chronosequences and water bodies.	Ecosection 1:250,000 - 1:50,000	A part of an ecodistrict throughout which there is a recurring pattern of landforms, soil vegetation, water bodies and fauna.
Land Type 1:20,000 - 1:10,000	An area having a fairly homogenous combination of soil (e.g. soil series) & chronosequence of vegetation.	Ecosite 1:50,000 - 1:10,000	A part of an ecosection having a relatively uniform parent material, soil and hydrology, and a chronosequence of vegetation.
Land Phase 1:10,000 and greater	An area of land having fairly homogenous combination of soil and vegetation. Subdivision of land type based on vegetation succession as expressed by the existing vegetation at the time of the survey.	Ecoelement 1:10,000 - 1:2,500	A part of an ecosite displaying uniform soil topographical, vegetative and hydrological characteristics.

Source: Parks Canada (1980a)

Canada, including the terminology of the hierarchical classification (Table 1.1). The term bio-physical was dropped partly due to possible association with the science of biophysics and partly because of the more ecological approach intended to be taken. ELC is to provide more of a description of ecological relationships within a unit rather than just a listing of environmental variables present, as in the physical land classification inventories (Morrison and Wiken, 1982).

The aim of ELC is to identify distinctive combinations of distinguishable environmental components (e.g., climate, flora, fauna) and processes (e.g., erosion and deposition) in order to determine their relationships and thus enable the classification of land units by their ecological unity (Duffy 1978, Wiken 1977).

The ELC methodology classifies and maps ecologically similar units of land based on five main components: terrain, hydrology, climate, flora and fauna. However, variations in the landscape can be considerable over very short distances and are not easily mapped, due to the scale of the minimum mapping unit. The result is that the ecological units are not necessarily homogeneous. What is mapped as a unit, is an area that exhibits a particular assemblage of components.

Data collection and land unit delineation is usually undertaken by a multidisciplinary team of researchers. The team members consult existing data, maps, and photos and satellite imagery in order to select the areas to be studied, delineate land units, and establish the ecological relationships. Reliance is placed on airphoto interpretation and the use of ground truth for verification (Duffy 1978, Lacate 1979).

A limited number of environmental variables are considered in ELC's otherwise the task would be enormous in complexity, time and cost. Certain key variables often control the character of the ecological unit. It is the processes associated with these variables that need to be known in order to predict the reaction of ecological units to activities (Mackintosh, 1978),

Advantages of ELC over single theme surveys are: reduction of survey costs, the shorter time span required and the reduction in the volume of noncorrelated material (East, 1978). ELC reduces cost by having the whole survey administered by one organization, by eliminating the duplicate costs of logistic support incurred by successive field surveys and reducing the manpower required for post-field integration (Duffy 1978, East 1978, Environment

Canada, 1980). In addition, ELC data for all variables are collected at the same scale.

The data produced by the ecological land survey is referred to as baseline information. The information is usually in three forms: quantified environmental variables; mapped outlines of ecological units; and a description of the ecological relationships within each ecological unit. The information is presented on maps, in written reports and stored in computer files in a way that permits easy comparison of variables within or between units.

The survey is primarily used to measure stable environmental phenomena (e.g. soils, surficial geology) which reflect on-going processes; therefore, the survey maintains its utility for future applications. In addition, dynamic phenomena (vegetation and wildlife) are also considered as a source of data for current applications and as a reference for long-term monitoring (Environment Canada, 1980).

ELC information can be applied to resource planning, management and environmental impact assessment (CCELC 1976). From baseline information it is possible to identify ecologically sensitive areas such as: a rare species habitat or plant community areas; problem areas in major engineering

projects such as unstable slopes, fault zones, permafrost and frost susceptible materials and high water tables. The baseline information of an ELC survey also provides quantitative data and descriptions of ecological associations often required in an environmental assessment.

1.3.3 ENVIRONMENTAL ASSESSMENT

The Canadian decision to formalize a Federal Environmental Assessment and Review Process was made by Cabinet in 1973 and revised in 1977. The Minister of the Environment established a process to ensure that an environmental assessment is carried out for all federally funded projects, or projects on federal lands, which may have environmental impacts. The results of an assessment are to be incorporated into the planning, decision-making and implementation phases of a project before irrevocable steps are taken (Environment Canada, 1980).

An environmental assessment is used to predict the potential impacts that a project is expected to have on the environment, whether they be adverse or beneficial (Jain, 1977, Bisset, 1980). In addition to the identification of impacts, the magnitude (scale) and the significance (severity) of the impacts must be determined (Canter, 1977). Finally, environmental assessments must suggest mitigating

measures to alleviate adverse impacts. This provides the information for the decision-makers to determine if a proposed project should proceed and if so, to choose between any proffered alternative mitigation measures for a project. The assessment enables planners to design project improvements and it provides managers with information on environmental variables that may require monitoring during the lifespan of the project.

In order to identify the relevant environmental variables that will influence impacts the assessment team must understand the design of the proposed action as well as the type and amount of construction materials, manpower and resources utilized by the project (Jain 1977, Canter 1977).

There are different methods used in predicting impacts. The versatility and usefulness of a particular methodology for prediction purposes depends on the type of project to which it is applied. Critiques of methodologies are extensive in the literature (Canter 1977, Holling 1978, Jain 1977, Warner 1974 and Smith 1981).

1.3.4 PARKS CANADA'S ENVIRONMENTAL STANCE

The National Parks Branch of Parks Canada has undertaken the process of producing resource inventories of the parks within the National Parks

System in the form of Ecological Land Classification inventories and conducting environmental assessments. This was partly in response to substantial pressure exerted in the late 60's for a stronger "preservationist" and "protectionist" stance in park management (East, 1978).

Information from the surveys is important in the fulfilment of the park system policy that states, "Natural resources within national parks will be given the highest degree of protection to ensure the perpetuation of a natural environment essentially unaltered by human activity" Parks Canada Policy statement, (Parks Canada 1980b, Section 3.1). To fulfill this obligation a national resource inventory itemizing the resources is required.

"Natural resources within national parks will be protected and managed with minimal interference to natural processes to ensure the perpetuation of naturally evolving land and water environments and their associated species" (Parks Canada 1980b, Section 3.1). To fulfill this obligation requires that all activities within national parks be assessed as to their potential interference to natural processes. "The process used for environmental assessment and review within national parks will be consistent with Federal Environmental Assessment and Review Process (EARP)" (Parks Canada 1980b, Section 3.3.2).

Guidelines for conducting National Park resource surveys are set out in Ecological Inventories in National Parks Concept and Methodology (Parks Canada, 1980a). The Parks Canada guidelines follow the ELC methodology but the hierarchical terms of the Biophysical Land Classification system are still maintained. Existing guidelines concerning environmental assessments within National Parks are found in Parks Canada Management Guidelines 2.4.2 and Smith (1981).

1.4 WOOD BUFFALO NATIONAL PARK

As has been stated Wood Buffalo National Park is used to aid in explaining the scheme. Wood Buffalo National Park is Canada's largest park, straddling the Alberta-Northwest Territories boundary and covering over 44,000 square kilometers (Fig. 1.1).

The climate of the Park is harsh, in keeping with its northern location. As a result the average February temperature is -21.0 degrees Celsius and the average August temperature is 14.6 degrees Celsius (Airphoto Analysis Associates, AAA, 1979). There is a brief frost free period from June to August or September and a growing season of 142 days. Precipitation is frequent but light, characterized by rainstorms in the spring, thunderstorms in the summer and relatively clear winters. The average summer rainfall ranges from 12 to 17 cm., occurring

Fig. 1.1 Location of Wood Buffalo National Park

Source: AAA 1979

primarily in July, and due to moisture removal by dry air masses and the low precipitation, there is an estimated moisture deficit of 15 cm. by fall. Winter snowfall is 30 to 50 cm. and the average period of snow cover is 185 days (AAA, 1979).

Geologically, the Park's oldest rocks are Precambrian Shield outcrops along the northeast and eastern boundary of the Park (Fig. 1.2). This area is heavily faulted with the orientation of the Slave River being controlled by a major north south trending fault and minor east west faults. Precambrian rock forms the basement bedrock under the rest of the Park.

During the Devonian and Cretaceous Periods there were several marine transgressions. As a result the geologic structure shows many unconformities as well as marine and deltaic deposits, some of which still remain in the upland areas. Due to the varied depositional environments, sediments from these periods formed sandstone, shale, carbonates, evaporites, dolomites and anhydrite, which has been subsequently altered to gypsum (AAA, 1979).

In the Tertiary Period the final regression of the seas left gently undulating plains, underlain by horizontal beds (mostly shale and sandstone). Subsequent subaerial erosion and dry conditions resulted in mesa formations from river erosion. By

Fig.12

Physiography of Wood Buffalo National Park

Source: AAA 1979

the end of the Tertiary Period all Cretaceous sediments had been removed except in the Birch and Caribou Mountains (Fig. 1.2).

During the Quaternary Period glaciers covered the Park with ice from the Laurentide Ice Sheet to the northeast. Glacial erosion deepened the Tertiary river valleys, particularly those paralleling the direction of the ice flow. In addition the ice oversteepened the mountains' northeast slopes. Deglaciation left till covering much of the Park. The retreating ice impounded meltwater and proglacial lakes were formed. The lakes were the sites of glacial outwash and inflowing river sediment deposition. With the final draining of the lakes the high sand content of the deposits were subjected to wind erosion resulting in dune formations (AAA, 1979).

Topographically the Park varies from flat to undulating (AAA, 1979). The Park (Fig. 1.2) is dominated by the lowlands of the Peace River (from west to east through the centre of the Park) and the Athabasca and Slave Rivers (on the eastern border of the Park). On the south and western borders of the Park are the Birch and Caribou Mountains which are portions of the Alberta Plateau to the west. The mountains rise 420 metres above the surrounding Park landforms. However, only the frontal slopes of the

mountains are within the Park. These frontal slopes contain numerous incised streams.

The Peace River Valley is up to 22 kilometres wide and incised up to 60 metres with heavily terraced slopes. The Athabasca and Slave River valleys are similar but more restricted. The Peace and Athabasca Rivers converge in a large depressional area to form the Peace-Athabasca Delta (the world's largest inland delta) located almost entirely within the Park on the western shores of Lake Athabasca.

The lowlands between the Birch Mountains (to the south) and the Peace River are dominated by organic terrain, with dunes and beach ridges providing the relief, up to 20 metres. A large area of muskeg is in the northwest centre of the Park in the Buffalo Lake area, where local relief is up to 8 metres (AAA, 1979).

Northeast of Highway #5 (Fig. 1.2) is an extensive, poorly drained till plain covered with shallow lakes, calcareous marls, forested muskeg and few streams. The tills of this plain provide up to 15 metres of local relief.

The most complex area of the Park is east of the Caribou Mountains. This area is made up of hummocky sand deposits, flat sand plains, large dune formations and fluted tills surrounded by organic deposits, water eroded sand hills over 30 metres high

and numerous water bodies scattered over well developed karst landforms. The relief in the area can exceed 100 metres with the local drainage being deranged and intermittent.

The karst landforms of the Park are said (AAA, 1979) to include some of the world's finest examples of collapsed and pond sink holes, in which depths can exceed 60 metres.

A northwest trending limestone escarpment in the northeast of the Park has saline springs at the base producing salt flats to the east of it (Fig. 1.2).

The Park lies within the Boreal Forest Region (AAA, 1979). The common tree species are white and black spruce, jack pine and less common larch and balsam fir. Common deciduous species include trembling aspen, balsam poplar and white birch.

The Park's successional climax community is a pure white spruce stand over feather moss ground cover (AAA, 1979).

There are large tracts of forest throughout the Park separated by extensive areas of muskeg (wet, shrub or treed). The muskeg's development is due partly to the poor development of a drainage system and partly because of underlying sporadic permafrost. Concentrations of grass and sedge marshes are found in the delta area and prairie grass lands are found east of the Slave River.

The number of plant species within the Park is limited by harsh growing conditions, and because of the recent deglaciation of the area and its distance from potential sources of new plants (AAA, 1979).

A more detailed description of the Park is found in the Integrated Resource Survey, Wood Buffalo National Park (AAA, 1979) from which this section was condensed.

A master plan is presently being produced for the Park and has resulted in raising concerns over some activities that will exist or are proposed for the Park. The Natural Resources Division of Parks Canada has identified roads, campgrounds, hydro transmission corridors, hydro reservoir flooding and forestry operations as activities requiring investigation.

1.5 CANADA GEOGRAPHIC INFORMATION SYSTEM

There is a tremendous task involved in the wise management of resources, particularly in a country as large as Canada. In response to this need, a joint federal/provincial project, the Canada Land Inventory (CLI) was established in 1963. The aim of the project was to produce a data base that would provide information needed to develop policies and to solve problems concerning land resource management (Environment Canada, 1974).

CLI data is handled by the Canadian Geographic Information System (CGIS), which is a computer system developed to process the mass of CLI data through reduction, manipulation and analysis with the output being in map or tabular form (Environment Canada, 1974).

The information stored in CGIS includes maps and descriptions of variables. All CGIS map units (polygons) are stored in digital form in computer files and identified so that complex descriptions of the polygon which are entered in the system can be retrieved and coupled to the polygon. The description can be of any theme and include any number of variables.

The ecological inventories of Parks Canada meet the input requirements of CGIS and therefore can be stored in CGIS. However, not all park inventories are stored in CGIS. The mountain parks of Banff, Jasper, Glacier, Yoho, Kootenay and Revelstoke are stored in the Canadian Soil Information System (CanSIS) of Agriculture Canada. CGIS is preferred by Parks Canada over CanSIS because of its greater graphic and analytical capabilities, although CanSIS has superior line and colour quality.

The ELC survey of Wood Buffalo National Park required that the Park be divided into ecological units (polygons) and described in the form of

variables (Fig. 1.3). The variables are factors of water, geology, soils, geomorphology and vegetation. Since the inventory meets the input requirements of CGIS, the Wood Buffalo National Park resource inventory data is stored in CGIS.

Retrieval of CGIS information is in the form of a request system which produces reports, tabulations and maps. The request system answers a user's specific enquiry through the use of manipulation commands. A sequence of commands (Fig. 1.4) triggers a function or series of functions which manipulate and analyse the data file (Environment Canada, 1974).

The Interactive Graphics Subsystem (IGSS) is a simple user-oriented retrieval subsystem of CGIS. The output is displayed at a computer terminal in the form of maps and tables. The terminal display can be produced in hard copy by using a terminal hard copy device (Chartrand, 1980). The subsystem is designed to assist the user, who does not necessarily have a computer background, in the manipulation of the data base through user commands.

A map of the requested information is displayed on the terminal screen virtually instantaneously and the user may perform further alterations to the map in order to satisfy a particular request. Through IGSS the user can access CGIS's capability to analyse

Fig. 1.3 :

EXAMPLE OF VARIABLES IN THE
COMPUTERIZED INVENTORY OF
WOOD BUFFALO NATIONAL PARK

Variable	Identifier	"Value" Appended to Ecological Unit	Description of Value
BVEG1	-	Biophysical Vegetation 1	
	10	- Aspen-Balsam Poplar Dominated Mixed Forest	
	11	- White Spruce Dominated Mixed Forest	
	12	- White Spruce on Feather Moss	
	13	- Disturbed Areas After Severe Fire	
	14	- Pine Dominated Mixed Forest	
SLMO1	-	Soil Material 1	
	G1	- Glacial Till - sand, loamy sand, sandy loam	
	04	- Glacial Outwash - coarse and gravel	
	E6	- Eolian and Lacustrine Sand - fine sand or alluvial	
	A8	- Lacustrine or Alluvial - silt, silt loam, loam	
	OH	- Organic - humic	

Refer to Appendix I

Fig. 1.4

SAMPLE COMMANDS TO ACCESS WOOD BUFFALO
NATIONAL PARK FILES

The following is a description of the information supplied
by the users (U), and responses given by the system (S):

U: LOGON

S: ENTER USERID
U: enter your assigned userid

S: ENTER ACCOUNT NUMBER
U: enter your assigned account number

S: READY
U: GRAPHICS

S: WELCOME TO THE "CANADA GEOGRAPHIC INFORMATION
SYSTEM"
BIENVENUE AU "SYSTEME D'INFORMATION GEOGRAPHIQUE
DU CANADA"

--- ENGLISH (E) OR FRENCH (F)...ANGLAIS(A) OU
FRANCAISE (F)?: E

--- ENTER GRAPHICS DATABASE NAME: WOOD BUFF

--- ENTER THE TERMINAL TYPE (4010/4012/
4014/4027): 4014

--- ARE YOU USING A TEKTRONIX HARD COPY UNIT?
(YES) (Y) OR NO (N): Y

INTERACTIVE GRAPHICS SUBSYSTEM (I.G.S.S.)
VERSION 5.8

S: ENTER COMMAND:
U: LIS

The LIS command instructs the system to display
on the terminal a list of variables available for
database: WOOD BUFF.
See Appendix I for the list of variables.

Source: Chartrand, 1980

and compare maps on a particular theme or themes. The comparison of themes or variables within a theme is based on an overlay method of examination. For example, the system could find all areas of the variable Black spruce and all areas of the variable 2% slope and map those areas where they overlap.

The overlay technique is the major method of analysis, however, in order to expand the capabilities of CGIS and allow alternate analysis of data an #ASSESS command exists. This command accesses the computer language PL/1 which allows a programmer to direct the manipulation or analytical process. The full use of the PL/1 language is available, so there is no restriction to the logic used to code a program (Environment Canada, 1974).

CGIS does not have the user commands for the automatic assessment of a unit's sensitivity, but it does have the capability to manipulate the Park's baseline data (through #ASSESS) to determine the sensitivity of an ecological unit.

CGIS is an essential tool in the sensitivity scheme. Inventoried data is stored in CGIS, the system can be programmed, to manipulate data to determine sensitivity and it can produce the required sensitivity maps.

1.6 STRUCTURE OF THE SENSITIVITY SCHEME

This section discusses the components and general structure of the sensitivity scheme.

1.6.1 ACTIVITIES AND DISTURBANCES

The sensitivity study will be based on three types of potential disturbances created by five particular activities (Table 1.2).

The potential disturbances to be considered are: erosion, slope failure and damage or loss of plant communities (ecological sensitivity). Erosion is considered because of the loss of top soil and soil nutrients needed for plant growth and regeneration. Slope stability is considered because of the potential for damage to facilities constructed on slopes. Ecological sensitivity, in terms of the Park, is considered on the basis of the difficulty of regenerating a disturbed plant community to its former condition and not on community fragility or stability (a more detailed explanation follows in Chapter II).

There are activities that already exist in the Park or are proposed for the Park that can induce one or more of the identified disturbances. Five activities will be considered: roads, campgrounds, forestry, hydro reservoir flooding and hydro transmission corridors. The activities (as defined

TABLE 1.2

ACTIVITIES AND DISTURBANCES

<u>ACTIVITY</u>	<u>POTENTIAL DISTURBANCE</u>
ROADS	<ul style="list-style-type: none">- Increased Erosion- Disruption of Significant Plant Communities- Induced Slope Failure
CAMPGROUND	<ul style="list-style-type: none">- Increased Erosion- Disruption of Significant Plant Communities
FLOODING	<ul style="list-style-type: none">- Disruption of Significant Plant Communities
TRANSMISSION CORRIDORS	<ul style="list-style-type: none">- Increased Erosion- Disruption of Significant Plant Communities
FORESTRY	<ul style="list-style-type: none">- Increased Erosion- Disruption of Significant Plant Communities

in the Glossary) will be limited to the infrastructure construction, maintenance or operation and not the activities of people using the facilities (greater detail follows in Chapter II).

1.6.2 SOURCE OF DATA

The data source for the scheme is the ELC survey of Wood Buffalo National Park conducted by Airphoto Analysis Associates and completed in 1979. The survey was conducted at the land system level (East 1978, AAA 1979); however, some of the identified land systems are further divided, into subsystems. Each subsystem (or a land system where subsystems are not identified) is composed of almost identical ecological units which carry the same classification.

It is important to note that the level of the survey limits the information detail, thus affecting the accuracy of any predictions. However, the scheme's principles may be applied to a more detailed inventory with greater accuracy.

The ecological baseline information is described in a written report entitled Integrated Resource Survey Wood Buffalo National Park (IRS) (AAA, 1979) and stored in the computerized Canadian Geographic Information System (CGIS) of Environment Canada. It is intended that the proposed scheme would allow an operator to query CGIS and receive an answer in map

or tabular form, without frequent reference to the Integrated Resource Survey.

1.6.3 VARIABLES AND METHODS

Baseline data is necessary in order to determine the potential sensitivity to disturbance of an ecological unit created by a particular activity. Variables dealing with climate, geomorphology, geology, soils and vegetation must be measured in order to predict the degree of sensitivity.

The ELC survey of Wood Buffalo National Park provides data on all but the climatic component. In addition the data for some variables are not stored on data files, or are insufficient to allow for determination of sensitivity; therefore, additional variables (identified in Chapter III) must be added to the existing computer inventory where required.

The sophistication of the degree of sensitivity determined is limited by the actual methods available for measuring sensitivity and the detail or scale of data in the inventory.

The selection of the appropriate methodologies for determining sensitivity was based on the compatibility of the methods' demand for data with the data in the computer inventory, and on methods which required little modification. A detailed description of the methodologies, their modification and the data required follows in Chapter II.

As the result of a literature search for suitable methods: stability is determined by a check list method (Cooke and Doornkamp, 1974), erosion potential is determined by using the Universal Soil Loss Equation (Mitchell and Dubenzer, 1980), and ecological sensitivity is determined by an ecological sensitivity index (Suffling, 1980).

By modifying the measurement techniques where necessary, by adding the necessary data to the existing inventory, and by writing programs in PL/1 to manipulate the methodologies through CGIS, it is possible to map sensitivity ratings of the ecological units within Wood Buffalo National Park for the five identified activities.

1.6.4 SENSITIVITY - SEVERITY AND RISK MEASUREMENT

Sensitivity of each ecological unit to a particular activity is considered in terms of severity and risk.

Sensitivity severity is a rating of the potential of an ecological unit to slope failure, increased erosion and/or damage to hard-to-replace plant communities as the result of a given activity. That is to say, the greater the sensitivity severity is for:

- 1) slope stability, the more likely it is for a failure to occur;

- 2) erosion, the higher the probability for an increase in the erosion rate and;
- 3) ecological sensitivity, the harder it is to restore a damaged plant community to its former condition.

Risk is defined as the area of the ecological unit subjected to the sensitivity severity rating. As noted earlier, ecological units are not homogeneous. In Wood Buffalo National Park units can contain up to three soil types and seven vegetation communities (IRS, 1979). The percentage area of the ecological unit that each soil type or vegetational community occupies is recorded within the inventory. However, the methodologies selected for measuring sensitivity are primarily based on only one soil type or one plant community within each ecological unit. Therefore, the measure of risk is the chance of encountering the soil type or plant community upon which the sensitivity severity rating is based for that particular ecological unit.

The risk rating can be based on the dominant (by area) soil type and plant community or it can be based on the soil type and plant community that has the highest sensitivity rating. For example, soil₁ of any ecological unit is the dominant soil by area, therefore, a sensitivity rating derived from soil₁ would produce a sensitivity rating

covering the greatest area of the unit. However, if soil₂, which covers less area, is used it may actually have a higher sensitivity rating than soil₁.

Depending on which is used two different severity-risk ratings may be produced for the same ecological unit, although soil₁ may be both dominant by area and have the highest sensitivity rating. Both severity-risk ratings are of interest to planners and resource managers, but for the purpose of this paper the rating resulting from using the dominant soil or vegetation will be used, as this is the most extensive condition within an ecological unit. This was chosen because the scheme is to be used in the conceptual phase of design to aid in selecting sites, thus a unit with a high sensitivity rating will probably be eliminated. If the sensitivity of a unit is based on an area that only covers 10% of the ecological unit, yet has a high sensitivity rating, then 90% of the unit could still be utilized if the rest of the unit has a low sensitivity rating, and therefore the unit should not be eliminated from consideration.

1.6.5 OUTPUT

Output for the sensitivity scheme is in the form of tables and maps.

The tables which are produced show the actual calculated value of sensitivity determined for a disturbance created by an activity, and the risk rating. For instance, the table concerning the potential increase in erosion along a right-of-way created by constructing a road, shows the value determined from the Universal Soil Loss Equation for each unit (Table 1.3) and the risk rating which is the percentage of the unit occupied by the dominant soil type.

The maps created through CGIS (Fig. 1.5) for the scheme are coloured to indicate the severity risk rating of each unit to a disturbance by an activity. There are three colours, red, green and blue representing a high, medium and low severity rating. In addition, there is a fourth colour, orange, which represents units dominated by organic terrain which were not considered for sensitivity ratings.

The three colours of red, green and blue are divided into two shades of each. The darker shade of each colour represents units which have a risk rating of 50% or more and the lighter shades represent units with a rating less than 50%.

The colour and shade of each unit is determined from the tabulated results for that particular disturbance and activity. The range of values for high, medium and low are user-determined from

TABLE 1.3.

SAMPLE OF EROSION VALUES CALCULATED
FOR ROADS

ECOLOGICAL	USLE Xd	
UNIT	CALCULATED VALUE	RISK RATING
100	-4.0441	70
101	-0.9405	50
102	-13.1800	70
117	-6.1316	60
119	-13.1391	60
155	-10.5113	40

Fig. 1.5 Sample Sensitivity Map

COLOURED PICTURES
Images en couleur

1 of

y Map

WOOD BUFFALO - SENSITIVITY MAP
LOSS OF PLANT COMMUNITIES BY CAMPGROUND, ROAD, TRANSMISSION CORRIDOR
SCALE 1 : 1,000,000

LEGEND
HIGH- GREATER THAN 50 %		MEDIUM- GREATER THAN 50 %
HIGH- LESS THAN 50 %		MEDIUM- LESS THAN 50 %
ORGANIC SOILS		LOW- GREATER THAN 50 %
		LOW- LESS THAN 50 %

evidence of potential disturbance gleaned from pertinent discussions in the written report of the inventory or from any construction or procedural standards that may exist.

If the data of the tabulations and maps are stored in computer files within CGIS, then a user may access a particular activity and disturbance through the Interactive Graphic Subsystem. If the data has not been stored in files then a program must be run through CGIS to produce the tables or maps.

Chapter II will follow through the sensitivity scheme as it is applied to Wood Buffalo National Park.

CHAPTER II

ESTABLISHMENT OF DESIGN STANDARDS AND METHODOLOGIES

2.1 PROCEDURE FOR DETERMINING SENSITIVITY

This chapter outlines the procedures and the methods used in determining sensitivity ratings for the ecological units in Wood Buffalo National Park. In order to produce a sensitivity rating in either map or tabular form seven steps are followed. These basic steps are:

- 1) identify the activities and study area and set design standards for the infrastructure;
- 2) identify the potential disturbances to be investigated;
- 3) determine the data available in the computerized inventory data bank;
- 4) search literature for methods to predict the severity of the potential disturbances identified;
- 5) determine if the computerized data is sufficient for the method; if it is not, modify the methodology and/or add new data where possible;
- 6) determine the final methodological set up and the variables to be used;

- 7) write a PL/1 program to produce the desired tables and maps and input the program into CGIS.

2.2 ACTIVITIES AND THEIR DESIGN STANDARDS

The first step is to identify the activities to be considered and set the design standards for the infrastructure. In most cases the activities are identified in the conception of the project which established the need for a sensitivity study. In the case of this study the five activities roads, campgrounds, flooding, transmission corridors and forestry, were identified by the Natural Resources Division of Parks Canada as being of concern to them. The Division also identified the area of the Park in which the study was to be conducted (Fig. 2.1).

Once the activities and the area of development are known, the next phase is to establish the conditions under which the activities will operate. This is necessary in order to determine the amount of disruption which may result from the activities. Detailed design standards cannot be set because the plans for the activity are still in the conceptual phase. More general standards must be obtained from existing design guidelines. Guidelines for activities are available from federal and provincial departments and from professional associations.

Fig.2] Study Area of Wood Buffalo National Park

Source: AAA 1979

Where there are no guidelines to follow, then design standards must be established based on available information. The standards set for the five activities of this study and the guideline sources, are given below, along with a discussion of the activities in the Park.

2.2.1 ROADS

There are two roads in the Park at the present time (Fig. 2.2), however, there is a proposal to construct a road through the Park to connect with southern Alberta; to date a corridor has not been chosen.

A road can affect slope stability through the need for cut and fill operations on slopes and by the additional weight of overburden caused by the road bed. Erosion can increase due to the clearing of vegetation for the right of way and the digging of ditches, thus exposing more soil to potential erosion. The right of way clearing may also affect ecological sensitivity by the removal of plant communities.

By identifying areas susceptible to disturbance, route corridors can be identified which avoid sensitive areas as much as possible.

The design standards for roads are taken from Parks Canada Road Classification System and Geometric

Fig. 22

Wood Buffalo National Park - Activities

Source: AAA 1979

Design Standards (draft 1980c), Environmental Design for Northern Road Developments (Curran and Etter, 1976) and the Environmental Code of Good Practice for Highways and Railways (Storgaard, Canada 1979).

In accordance with Parks Canada Road Classification System the proposed road to the south would be classified as a rural arterial road. By definition, a rural arterial road joins major development areas (in this instance Fort Smith and the south) and connects with local and collector roads existing in the Park. A rural arterial road is designed to carry medium to heavy traffic at speeds of 65-100 km/hr (Parks Canada, 1980c).

Four basic design concerns are identified for roads; rights of way, organic terrain, slopes and grass cover. Clearing of right of ways, removes all trees, shrubs and brush. The width of the right of way clearing should be kept to a minimum. None of the design guidelines give any further indication of the minimum or maximum width of right of way, nor do they reference sources that do.

The second design concern is that areas of organic terrain should be avoided because of the low bearing capacity of peat soils, poor drainage and the possible presence of permafrost (Curran and Etter, 1976). In fact, none of the activities are to be located on areas of organic terrain (except possibly

the reservoir) and so ecological units of organic terrain are eliminated from consideration.

The third design standard concerns slope gradients. Any slopes with a greater than 6 percent gradient require road cuts and infilling (Curran and Etter, 1976). In addition, drainage ditches and embankments should not have a slope greater than 62 per cent for most soils and 100 per cent for clays (Storgaard, 1979). For this study ditches and embankments will be considered to have a slope of 62 per cent since there are few areas of clay soils in the Park.

The fourth design concern is that all cleared areas of the right of ways, excluding the road surface, should be grassed over (Storgaard, 1979). The Park's rights of way will have an estimated vegetal cover of 60 per cent. The vegetal cover is estimated because there is no indication in the guidelines of the per cent grass cover for the right of way. The estimation of 60 per cent for this study is based on the researcher's observation of the vegetal cover of Wood Buffalo National Park rights of way.

2.2.2 CAMPGROUNDS

Opening a road to the south would make the Park more accessible and so increase tourist activity in

the Park. This leads to the second activity to be considered, provision of campgrounds. Presently only one campground exists in the Park. Increased tourist use may require the construction of new campgrounds; new sites have yet to be identified. As with roads, construction of campgrounds could affect erosion and ecological sensitivity through the removal of vegetation.

The parameters for campground conditions are taken from Parks Canada Campground Manual (1977). The manual defines the types of campgrounds and the services available for each type (Table 2.1). The most developed level of campsite allowed in Wood Buffalo National Park is a semi-serviced campground, the type with which the Natural Resources Division is concerned. This study will refer to a semi-serviced level 2 campground: tent and trailer camping with no utility hook-ups but with centralized sanitary, water and sewage disposal facilities provided.

The density of campsites ranges from 8 to 18 sites per hectare. The suggested area of the campsite surface and parking area is 200 m² per campsite. The campground roads are 5.5 m wide, including shoulders and drainage and the surfaces are not paved. The length of road is estimated at 200 to 400 m per hectare.

TABLE 2.1 Definition of Campgrounds

Campground Types

Campgrounds are classified according to type with one or more levels of service.

1) Serviced

Level 1

Trailer camping with water, sewer and electrical hook-ups at each campsite. Centralized sanitary facilities are provided.

Level 2

Trailer camping with water and electrical hook-ups at each campsite. Centralised sanitary and sewage disposal facilities are provided.

Level 3

Trailer camping with no utility hook-ups. Potable water and centralized sanitary facilities are provided.

2) Semi-Serviced

Level 1

Tent and trailer camping with electrical hook-ups at each campsite. Centralized sanitary, water and sewage disposal facilities are provided.

Level 2

Tent and trailer camping with no utility hook-ups. Centralized sanitary, water and sewage disposal facilities are provided.

Level 3

Tent camping with potable water and pit/vault toilets.

3) Primitive

Level 1

Wilderness hike-in camping with basic campsite amenities. Potable water and pit/vault toilets are provided.

Level 2

Wilderness hike-in camping with no basic campsite amenities. Potable water and pit/vault toilets are provided.

4) Group

Level 1

Group tent camping with centralized parking, eating and sanitary facilities provided.

Level 2

Group tent camping with centralized parking, potable water and pit/vault toilets.

Source: Campground Manual, Parks Canada, 1977

The result of the space requirements for campsites, roads and support facilities is that 30 to 60 percent of the campground area must be cleared, depending on campsite density. This study will take the extreme case and state that 60 percent of an area will be cleared for campgrounds.

There is only minor grading of slopes for campsites and road excavations are necessarily shallow, requiring little change to existing slope gradients. According to the campground manual campsites are not to be located on slopes greater than 15 per cent.

2.2.3 HYDRO RESERVOIR FLOODING

A project proposed for outside the Park but which will have a direct impact on Park land is a hydro project on the Slave River near Fort Smith. The project would result in the flooding of park land (Fig. 2.2) and thus, may effect ecological sensitivity by drowning plant communities not found in the rest of the Park or found only in small areas.

A sensitivity rating of the affected communities will indicate the potential severity of plant community loss to the Park.

There are no guidelines available for the flooding of park lands as a result of hydro or other projects, therefore, the standards for this activity have been established specifically for this study.

It is the total loss of land and plant communities from the Park that is of significance, thus the ecological units to be flooded must be identified.

The potential reservoir (Fig. 2.2) has been mapped by Shawinigan Stanley Ltd. while producing a feasibility study of the project. The Park units which will be affected may be identified by overlaying the map of the reservoir and a map of the ecological units of Wood Buffalo National Park (available from Canada Land Data Systems Division). The reservoir will flood less than 2 percent of the park land, but will cause the total loss of plant communities in this area.

2.2.4 HYDRO TRANSMISSION CORRIDORS

Transmission lines must be constructed to deliver the power from the hydro project to southern Alberta.

Potential corridors may exist through the Park. These corridors must be studied to identify the disturbance a right of way may create. The potential disturbances are erosion and ecological sensitivity caused by the clearing of vegetation for a right of way.

Design guidelines for transmission corridors deal primarily with the width of corridors, construction methods for crossing rivers and roads,

methods of clearing rights of way, aesthetics of the right of way and the restoration of access routes after construction.

There is little information dealing with the types and quantity of vegetation to be removed in the clearing of the rights of way in guidelines (e.g., Newfoundland and Labrador Hydro, 1980); nor do the guidelines deal with the type of vegetation allowed to occupy the corridor after construction or consider the disturbance to the ground surface during construction. Assumptions are declared below for this study.

It is assumed that all trees and tall bushes will be removed from the right of way. The right of way will be maintained to keep down the growth of saplings and large bushes and shrubs. Those areas lacking trees and tall bushes will continue to support the original vegetation communities.

The only excavation along the right of way will be for the foundation of tower legs. The slope of the land will not be modified by construction of the corridor.

2.2.5 FORESTRY

Forestry, which is carried out along the Peace River (Fig. 2.2) is an activity that is being

considered by Parks Canada for termination. The removal of vegetation (ground cover as well as trees) by forestry operations may effect erosion and ecological sensitivity. Erosion of soils can reduce the regeneration of cut-over areas. An example of ecological sensitivity is that the majority of the Park's pure white spruce stands are within the timber tract and logging of these stands will substantially reduce the presence of white spruce within the Park. The fewer white spruce stands that remain, the smaller the seed source for regeneration and therefore, the more difficult the restoration of cleared sites to white spruce forest.

Sensitivity mapping should indicate which areas should be restricted from cutting.

The guidelines for this activity are found in the Wood Buffalo National Park Timber Agreements (Parks Canada, 1968). These agreements are the contracts allowing the cutting of merchantable timber within the Park.

The agreements identify the area under licence (less than 5 per cent of the park) (Fig. 2.2) and the timber to be cut - poplar and spruce. The cutting is to take mature, overmature, dead and damaged trees while preventing damage to young trees as much as possible. However, these agreements do not state how much timber is to be left standing, or the amount of

ground cover to be left. Actual practice is used as the basis for standards, determined specifically for this study from estimates of tree, shrub and ground cover remaining after cutting. Photographs (Fig. 2.3, 2.4, 2.5) taken of areas cut the previous year are used to determine the remaining vegetation cover estimates. The amount of vegetation remaining is visually estimated from the photographs as being less than 10 percent tree cover, less than 25 percent bush and weeds and less than 20 percent grass cover.

Skidding lanes and landing sites are scraped to bare soil but there is little alteration of the natural slope. This is an important factor in determining erosion rates.

2.3 DISTURBANCES

The second step (page 45) is to identify the disturbances upon which the sensitivity ratings are based. For the purpose of this study the disturbances to be considered are those noted in Chapter I: erosion, slope failure and ecological sensitivity.

The disturbances to be investigated relate specifically to the needs of this study and are based on the writer's estimation of which disturbances an activity may create. The same disturbances will not be considered for all five activities (Table 2.2).

Fig. 2.3

Forestry Cut-Over Area

Fig. 2.4

Forestry Cut-Over Area

Fig. 2.5

Forestry Cut-Over Area

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Images en couleur

TABLE 2.2 Summary of
Activities, Disturbances and Causes of Concern

<u>Activity</u>	<u>Disturbance</u>	<u>Cause of Potential Disturbances</u>
Roads	Erosion	- removing original vegetal cover along right-of-way and increasing slope angle through the construction of ditches and embankments.
	Ecological Sensitivity	- potential destruction of a significant plant community by right-of-way clearing.
	Slope Failure	- mass wasting induced by cutting into slopes, over loading slopes or altering slope drainage.
Campgrounds	Erosion	- removing much of the vegetal cover exposes more soil to rainfall and increased erosion.
	Ecological Sensitivity	- partial clearing of vegetation may alter the ecological balance of a significant plant community.
Flooding	Ecological Sensitivity	- the reservoir will drown plant communities under it and may alter others along its edge.
Transmission Corridors	Erosion	- removing original vegetation cover may expose more soil to rainfall and erosion.
	Ecological Sensitivity	- potential destruction of significant plant community by right-of-way clearing.
Forestry	Erosion	- removal of forest canopy and scraping bare of skidding lanes and landing sites expose soil to erosion.
	Ecological Sensitivity	- potential destruction of significant plant community by cutting operations.

The third step (page 45) towards predicting a sensitivity rating is to obtain a full listing of the variables in the Park inventory from CGIS (Appendix I) through the Canada Lands Data Systems (CLDS) offices of Environment Canada (Appendix II): information is provided on the range of data available in the inventory, how to obtain the data, data output format and medium and the cost of using the services.

With information collected on the proposed activities, design standards set for the infrastructure of the activity, disturbances to be investigated and the data available in the computer files, the next step is to determine the techniques to measure the sensitivity of the ecological units to disturbance.

Steps 4, 5 and 6 (page 45) involve the acquisition and modification of the methods to rate the sensitivity of units. The following is a discussion of this process for each of the three disturbances.

2.3.1 EROSION

To find a means of measuring the increase in the amount of erosion an activity will cause to the existing environment, a search of geomorphic and soil erosion literature was undertaken. The most widely

accepted method of predicting rates of erosion is the Universal Soil Loss Equation (USLE) which is used to predict the average rill and interill soil loss on a hillslope (Mitchell and Dubenzer, 1980, Arnoldus, 1980). The USLE has primarily been used as an agricultural tool, but has been modified by Wischmeier in 1974 (Mitchell and Dubenzer, 1980) to allow application to non-agricultural uses.

The Universal Soil Loss Equation is:

$$A = (0.224) RKLSCP$$

where:

A = the soil loss in $\text{Kg.m}^{-2}.\text{yr}^{-1}$

0.224 = constant,

R = the rainfall erosivity factor,

K = the soil erodibility factor,

L = slope length factor

S = slope gradient factor

C = the cropping management factor, and

P = the erosion control practice factor.

(Mitchell and Dubenzer, 1980).

However, the USLE cannot be used as it stands for this study, because some of the factors either cannot be determined from the available data, or are not necessary.

For the purpose of this study the rainfall erosivity factor (R) will be considered constant as the climate is fairly uniform over the Park, thus

allowing the R factor to be ignored. Furthermore the R factor requires detailed climatological data which does not exist for the Park and thus must be eliminated from the equation. The erosion control practice factor (P) can be omitted from the equation because this factor concerns agricultural practice and there are no agricultural activities within the Park. By removing factors R and P, a quantitative value for erosion is no longer possible, thus the constant 0.224 used in the derivation of a quantitative value is of no further significance and may also be dropped. Without a quantitative value of soil loss (A) a new index, X will replace A as an indicator of soil erosion.

The resulting equation is

$$X = KLSC.$$

Although the modified equation will not give a quantitative value for soil loss it is used in this study for predicting the erosion rate under present natural conditions within an ecological unit and then to predict the erosion rate after the introduction of the activity. The difference in the two rates of erosion is used to indicate the sensitivity of the unit to erosion. This allows comparison of the differences in rates of erosion between ecological units.

The K factor is a quantitative description of the inherent erodibility of a particular soil and reflects the fact that different soils erode at different rates when other factors affecting erosion are the same (Mitchell and Dubenzer, 1980). The values of K for various soils may be obtained from the Wischmeier Nomograph, U.S. Soil Conservation Service tables or U.S. Agricultural Research Service (ARS) tables (Table 2.3): the K factor table of ARS at 2 per cent organic matter content is used for this study.

The K factor value for each ecological unit in the study area is determined for the soil material of the dominant soil in each unit (coded as SLM01, Appendix 1). For instance, ecological unit 628 of the inventory has, as the dominant soil material, Very Fine Aeolian Sands, consisting of very fine sand and sandy loam textures (Appendix I). The average of these two textures of the ARS table (Table 2.3) is 0.30. Therefore, the K value for unit 628 is 0.30.

Organic terrain is given a K value of zero and is not considered for erosion.

Factors L and S, slope length and gradient are often evaluated as a single topographic factor. For this study a chart (Fig. 2.6) from Mitchell and Dubenzer (1980) is used to determine the LS factor. Formulas have been devised to determine the LS factor

TABLE 2.3 K FACTOR TABLE

Texture class	Organic matter content		
	0.5 per cent	2 per cent	4 per cent
	K*	K	K
Sand	0.05	0.03	0.02
Find sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13-0.29	

* The values shown are estimated averages of broad ranges of specific soil values. When a texture is near the borderline of two texture classes, use the average of the two K values. For specific soils, use Soil Conservation Service K-value tables which provide much greater accuracy. From ARS, 175.

Source: Mitchell and Dubenzer, 1980.

Fig. 2.6 LS FACTOR CHART

Source: Mitchell and Dubenzer, 1980

(Mitchell and Dubenzer, 1980) but are unnecessarily complex for this study.

Since the purpose is to compare the rates of erosion between the various ecological units and not the exact quantity of soil loss, the L factor is held constant at 5 m (an arbitrary figure). This is done primarily due to the lack of a variable for slope length in the inventory, so a nominal value is used to operate the equation. The slope for each unit is recorded in the inventory under the variable slope (coded as SLOP1, Appendix I). There are 11 classes of slope angles and a value is determined for each slope angle classification in the legend. For example, unit 628 has a slope (SLOP1) classification of 58 (58 per cent slope). Therefore, from Figure 2.6 the LS factor is determined to be 8.8 for unit 628.

The final factor, the cropping management factor, C, represents the effect of vegetation on the amount of erosion. Most work has been involved in agricultural crops but a table has been produced for undisturbed land (Mitchell and Dubenzer, 1980). Table 2.4 indicates C values by classes of percentage vegetation cover and the type of vegetal canopy.

In order to determine the C value for each ecological unit the dominant vegetation (coded VPCM1) within the unit is required. There are twenty-two

TABLE 2.4 C FACTOR VALUES
FOR UNDISTURBED LAND

Vegetal canopy		Mulch or vegetation at ground surface Percentage cover(a)					
Type and Height	Percentage Cover(b)	0	20	40	60	80	95-100
None		45	24	15	9.1	4.3	1.1
Tall weeds or short brush, 0.5 m effective height	25	36	30	13	8.3	4.1	1.1
	75	17	12	9	6.8	3.8	1.1
Brush or bushes, 2 m effective height	25	40	22	14	8.7	4.2	1.1
	75	28	17	12	7.8	4.0	1.1
Trees, 4 m effective height	25	42	23	14	8.9	4.1	1.1
	75	36	20	13	8.4	4.1	1.1
Factor to obtain C values with grass or compacted duff ground cover(c)		1.0	0.83	0.67	0.46	0.30	0.27

- (a) C values in Table are for ground cover of weeds or undecayed residue.
- (b) For canopy cover between 25-75 per cent, straight line interpolation is appropriate.
- (c) To obtain C values for ground cover of grass or compacted duff, multiply the C value from the table by the factor.

Source: Mitchell and Dubenzer, 1980

recognized plant communities in the inventory: however, the data files lack information on per cent cover of trees, brush or ground cover. This information is obtained from the written report of the inventory, the Integrated Resource Survey Wood Buffalo National Park (IRS) (AAA, 1979). From the information in the written description of each of the plant communities an estimation is made of the per cent tree, brush and ground cover. With this estimation a C value is determined for each plant community from Table 2.4. For example, unit 628 has a VPCM1 classification of 21, which is a black spruce dominated mixed forest, that was estimated as having a 60 per cent tree cover, and 60 per cent ground and shrub cover, giving a C value of 3.96.

Using the modified equation for unit 628, X_n (soil erosion under natural conditions) is:

$$\begin{aligned} X_n &= KLSC \\ &= 0.30 \times 8.8 \times 3.96 \\ X_n &= 10.54 \end{aligned}$$

The erosion for unit 628 under natural conditions is thus determined to be 10.54. As stated earlier this figure does not indicate the amount of erosion occurring, but is used as an index to compare rates of erosion.

The same procedure is carried out for unit 628 for each activity, but the parameters are changed.

For example, in determining the erosion potential for roads, the K factor remains constant but slope is changed to 62 per cent (for ditches and embankments) and the plant community becomes a grass community providing 60 per cent cover.

The new value X_a (soil erosion index for the activity) is:

$$X_a = 0.30 \times 10.5 \times 4.19$$

$$X_a = 13.20$$

The change in the erosion index (X_d) resulting from the road activity in unit 628 is

$$X_d = X_n - X_a \text{ or}$$

$$\begin{aligned} X_d &= \text{KLSC (natural conditions)} - \\ &\quad \text{KLSC (activity conditions)} \\ &= -2.77 \end{aligned}$$

Therefore, there is an estimated increase in the erosion index of 2.77 associated with the placement of a road through ecological unit 628. Although the X_d value is negative, it represents a positive increase in the erosion rate. Since X_a is larger than X_n the rate of erosion has increased, however, X_a is subtracted from X_n , thus producing a negative value.

In order to write a program to determine the change in the rates of erosion the programmer requires the values of K, L, S and C from the variables dominant soil (SLM01), slope (SLOP1) and

dominant vegetation (VPCM1) under natural conditions and under the design standards set for each activity (Table 2.5). In Table 2.5 the values Under Natural Conditions and under the activities are the K, L, S and C factor values for the various classifications of the soil, slope, and plant community variables in the inventory. The X_d equation and the appropriate values (depending on the soil, slope and plant community classification) are applied to each ecological unit.

The calculated erosion index for each ecological unit in the study area is presented in tabular form. In order to map the sensitivity of units to erosion it is necessary to rank the erosion index values into classes of high, medium and low sensitivity. The range of values reflecting sensitivity (Table 2.6) are determined by comparing the calculated erosion index values of the units, with references to some of the ecological units' potential for erosion as stated in the written report of the inventory. For instance, units that the written report states as having a severe potential for erosion have a range of erosion index values calculated for roads as being between -10.00 and -18.89, thus any calculated values falling within this range will have a high sensitivity rating. However, problems developed with this approach; a more detailed discussion follows in Chapter III.

TABLE 2.5 Erosion Variables

USLE Factors	Variable from Inventory (Appendix I)	Classifications of Variables (Appendix I)	Values Under Natural Conditions	Values for Roads	Values for Campgrounds	Values for Corridors	Values for Forestry
K	SLMO1	G1	0.12	0.12	0.12	0.12	0.12
		G2	0.43	0.43	0.43	0.43	0.43
		G3	0.23	0.23	0.23	0.23	0.23
		O4	0.02	0.02	0.02	0.02	0.02
		E5	0.03	0.03	0.03	0.03	0.03
		E6	0.14	0.14	0.14	0.14	0.14
		A8	0.43	0.43	0.43	0.43	0.43
		A9	0.24	0.24	0.24	0.24	0.24
		OH	0.00	0.00	0.00	0.00	0.00
		OF	0.00	0.00	0.00	0.00	0.00
		OM	0.00	0.00	0.00	0.00	0.00
		GO	0.03	0.03	0.03	0.03	0.03
LS	SLOP1	01	0.05	10.50	0.05	0.05	0.05
		02	0.14	10.50	0.14	0.14	0.14
		03	0.14	10.50	0.14	0.14	0.14
		05	0.22	10.50	0.22	0.22	0.22
		07	0.32	10.50	0.32	0.32	0.32
		11	0.63	10.50	0.63	0.63	0.63
		15	1.10	10.50	1.10	1.10	1.10
		21	1.60	10.50	1.60	1.60	1.60
		58	8.80	10.50	8.80	8.80	8.80
		98	0.55	10.50	0.55	0.55	0.55
		99	0.22	10.50	0.22	0.22	0.22
C	VPCM1	05	1.29	1.29	8.04	1.29	1.29
		07	15.00	4.19	20.00	4.00	15.00
		09	0.30	0.30	9.30	0.30	0.30
		10	1.23	4.19	9.30	4.00	1.23
		11	3.96	4.19	9.30	4.00	20.00
		12	1.23	4.19	9.30	4.00	20.00
		13	9.00	4.19	12.00	4.00	9.00
		14	1.23	4.19	9.30	4.00	20.00
		15	0.30	4.19	9.30	4.00	20.00
		16	16.18	4.19	17.02	4.00	20.00
		17	0.00	0.00	0.00	0.00	0.00
		18	0.00	0.00	0.00	0.00	0.00
		19	0.00	0.00	0.00	0.00	0.00
		20	0.30	4.19	9.30	4.00	20.00
		21	3.96	4.19	9.30	4.00	20.00
		22	1.23	4.19	9.30	4.00	20.00
		98	19.00	4.19	22.00	4.00	19.00
		99	1.29	1.29	1.29	1.29	1.29

TABLE 2.6 , Ranges of Erosion Sensitivity Rating

Activity	Sensitivity Rating	Range
ROADS	HIGH	<-10.00
	MEDIUM	-10.00 to -0.10
	LOW	>-0.10
CAMPGROUNDS	HIGH	<-10.00
	MEDIUM	-10.00 to -0.10
	LOW	>-0.10
TRANSMISSION CORRIDORS	HIGH	<-10.00
	MEDIUM	-10.00 to -0.10
	LOW	>-0.10
FORESTRY	HIGH	<-10.00
	MEDIUM	-10.00 to -0.10
	LOW	>-0.10

A further component for determining the sensitivity rating, is a measurement of risk. The value of risk is based on the per cent of the unit covered by the dominant soil obtained from the soil per cent variable (coded SLOPl) and reflects the per cent areas of the ecological unit affected by the sensitivity rating.

2.3.2 ECOLOGICAL SENSITIVITY INDEX

Ecological and environmental journals were searched for a method of rating the sensitivity of plant communities. Suffling (1980) provides an ecological sensitivity index that utilizes data available in the inventory data files.

The concepts of plant community productivity, diversity and stability as a means of measuring sensitivity to disturbance cannot be included because the data requirements are not available from the inventory.

The sensitivity of ecosystems is defined in terms of their relative ages. The older an ecosystem (plant community), the longer it will take to redevelop to the same stage after destruction and is therefore more difficult to replace (Suffling, 1980). The more difficult it is to restore a plant community the more sensitive the plant community is to disturbances. In addition, a landscape with a

constant rate of disturbance (regardless of successional age), will produce a landscape in which there is a negative exponential relationship between plant community age and the areal extent of the community (Suffling, 1980). The smaller the area occupied by a particular plant community type the more significant its loss (in terms of the other plant communities in the study area) and the more difficult it is to regenerate itself due to a smaller seed source, therefore, the more sensitive the plant community.

It is not known if the older plant communities occupy less area within Wood Buffalo than the younger communities, but for the purpose of this study it is assumed that Suffling's relationship exists. The major source of disturbance in the Park is fire started by lightning, which has an equal potential of striking anywhere in the Park, thus disturbance risk would be uniformly disturbed.

Suffling (1980) divides the landscape into grid cells and measures the sensitivity of each plant community within the cell, then adds the sensitivity values together to determine the sensitivity rating for the whole cell. This study does not divide the Park into grid cells but equates individual ecological units to cells.

According to Suffling (1980) the sensitivity of a unit is

$$S_x = (P_x \cdot \ln \text{area}_t) \quad t = 1 \\ = \text{max.}$$

where S_x = sensitivity of unit x to disturbance

P_x = proportion of unit x occupied by plant community of age t

$\ln$ = natural logarithm

Area_t = proportion of the Park of plant community age t

t = years (Suffling, 1980).

The inventory data meets the data requirements for the sensitivity equation. The vegetation variable ($V_n\text{PCM}$) indicates the type of plant communities within the unit. The vegetation percentage variable ($V_n\text{PCT}$) represents the percentage of the unit covered by $V_n\text{PCM}$. In addition the percentage of the Park covered by the plant community can also be determined from the inventory.

The equation, using the variables from the inventory is stated as

$$S_x = [(V_n\text{PCT} \times 0.1) \times \ln (\text{proportion of Park in } V_{\text{PCM}_n})] \frac{V_1\text{PCM}}{V_7\text{PCM}}.$$

Where n identifies communities 1 - 7, the per cent value $V_n\text{PCT}$ is presented in the

inventory on a scale of 0 to 9 and must be converted to a decimal expression of per cent (Suffling, 1980).

This equation determines the sensitivity of a unit using all the plant communities within the unit and will be used as it stands only to rate the sensitivity of the units to be flooded by the hydro project. For the hydro project, it is the loss of all the plant communities within a unit that is of concern and so the sensitivity of all plant communities must be determined.

A modification of the equation must be made for measuring the sensitivity of the remaining activities because the sensitivity of a unit is to be based on its dominant soil or plant community.

The equation is modified to

$$S_x = (VlPCT \times 0.1) \times \ln (\text{proportion of Park covered by VlPCM})$$

The equation is used to calculate the sensitivity of units to the activities of campgrounds, roads and power corridors. All three activities have design standards requiring removal of vegetation and therefore will create similar disturbances, thus only one sensitivity map is required for all three activities.

A final alteration is made for forestry. The concern with forestry operations is the logging of

white spruce, black spruce and poplar within the timber berth. For this purpose three maps are produced to show sensitivity, one map for each plant community type.

The sensitivity ratings are calculated only for those units within the timber berth and considers only one of the plant communities for each map.

For example, the equation for the black spruce sensitivity value states

$$S_x = [(V_n^{PCT} \times 0.1) \times \ln$$

(proportion of Park covered by
 V_{PCM_n})]

$V_n^{PCM} = 20$
$V_n^{PCM} = 21$
$V_n^{PCM} = 22$

where V_n^{PCM} 20, 21 and 22 are the black spruce communities (Appendix I). The V_n^{PCM} values for white spruce and poplar communities are inserted for the calculations of the other two maps.

Unlike erosion, neither the written report (IRS), nor Suffling (1980) provide any indication as to the ranges of calculated values that would represent high, medium and low sensitivity. The ranges chosen for the various activities (Table 2,7) are based on the writer's subjective observation of the areal extent, concentration and succession stage inferred from the inventory. A further discussion of the sensitivity ranges follows in Chapter III.

TABLE 2.7 Ranges of Ecological Sensitivity Rating

Activity	Plant Community	Sensitivity Rating	Range
Roads, Campgrounds and Transmission Corridors	Dominant Plant Community V1PCM	High	0.000 to 1.000
		Medium	1.001 to 2.000
		Low	2.001 to 3.000
Flooding	All Plant Communities Per Unit V1PCM-V7PCM	High	0.000 to 1.000
		Medium	1.001 to 2.000
		Low	2.001 to 3.000
Forestry	Poplar Forest	High	0.000 to 1.000
		Medium	1.001 to 2.000
		Low	2.001 to 3.000
	Black Spruce Forest	High	0.000 to 1.000
		Medium	1.001 to 2.000
		Low	2.001 to 3.000
	White Spruce Forest	High	0.000 to 1.000
		Medium	1.001 to 2.000
		Low	2.001 to 3.000

The final component of the sensitivity rating, risk, is based on the vegetation percent variable (VlPCT). This value indicates the dominance within the ecological unit of the plant community used in the sensitivity rating.

2.3.3 SLOPE FAILURE

Soil engineering and geomorphic literature was searched for a methodology capable of rating slope stability on a regional basis. There are equations to determine slope stability accurately; the most widely cited work is that of Terzaghi and Peck, 1967 (Cooke and Doornkamp, 1974). However, these equations require very detailed data and are applicable only to the point on the slope at which the measurements are made. Such precision cannot be achieved at the present level of survey.

Cooke and Doornkamp (1974) present a check list for sites liable to large scale instability (Fig. 2.7) which may be applied to the ecological unit level. Much of the information necessary for the check list is found in the written inventory describing the ecological units.

The check list is intended to identify potential areas of instability but cannot be used to predict how the alteration of slopes by man will affect slope instability. It can be assumed though, that the

greater the slope instability the more likely the alteration of the slope by man will trigger slope failure. For the purpose of this study the greater the slope instability rating the higher the unit's sensitivity rating of disturbance caused by roads.

The Cooke and Doornkamp check list was intended to be used in airphoto interpretation and field investigation. The check list is modified in order to make use of the inventory and requires that many of the categories be excluded, either because the data is not available (e.g., liquidity index) or the categories do not apply to the Park (e.g., the Man-Made Feature categories). A list of those categories that have been retained and those that have been eliminated is given in Table 2.8. Although almost two thirds of the check list is eliminated the categories remaining are sufficient to give an indication of slope stability.

A drawback of this checklist method is that there are no absolute values for the categories and the assignment of values is subjective.

For this project the retained categories are classified on a scale of 1 to 4 with 1 signifying small and 4 very large feature or high value. Cooke and Doornkamp (1974) use an 'x' in each box and simply state that the more x's that line up on the right, the less stable the slope. By giving each box

TABLE 2.8 List of Categories Excluded and Retained

Categories Excluded	Categories Retained	Variable from Computer or Written Inventory (IRS)
<u>Relief</u>	<u>Relief</u>	
- Height difference between different Valleys	- Valley depth	ELEV1
	- Slope steepness	SLPP1
	- Cliffs	IRS
<u>Drainage</u>	<u>Drainage</u>	
- River gradient	- Drainage density	IRS
- Concentrated seepage flow	- Slope undercutting	IRS
- Pore-Water Pressure	- Standing water	IRS
	- Recent incision	EROS1, EROS2
<u>Bedrock</u>	<u>Bedrock</u>	
- Jointing density	- Amount of dip (or steepness of joint and/or fault planes)	IRS
- Direction of major joints (faults or bedding planes) with respect to steepest slope	<u>Soils (including drift materials)</u>	
- Strong beds over weak beds	- Site	IRS
- Degree of weathering	- Coherent over incoherent beds	IRS
- Compressive strength	- Depth	IRS
- Coherence (particularly of lower beds)	<u>Legacies from the Past</u>	
<u>Soils (including drift materials)</u>	- fossil solifluction lobes and sheets	EROS1, EROS2
- Angle of rest	- Previous landsliding	IRS
- Shear strength		
- Liquidity index		
<u>Earthquake zone</u>		
- Tremors felt		
<u>Legacies from the Past</u>		
- Deep weathering		
<u>Man-Made Features</u>		
- Excavations-depth		
- Excavations-position		
- Reservoir		
- Drainage diversion across hillside		
- Lowering of reservoir level		
- Loading of upper valley side		

22
OF / DE

a value (1 - 4) the values of all categories retained (Table 2.8) may be totaled to give an overall value for each ecological unit. The overall value is used to determine the unit's sensitivity. The higher the overall value the less stable the slope and so the higher the sensitivity rating.

Although a program could be written to calculate the value of each category and then the values for each unit, it was decided to calculate manually the overall values. This was done because of the large number of categories that were rated from the written description of the units (Table 2.8). It was found to be more efficient to rate the remaining categories by hand from a computer listing of variables than it was to write a program to calculate the values.

The written inventory (IRS) discusses the occurrence of mass wasting and creep for some of units, providing a basis for determining sensitivity ranges. It was found that units in which active slumping occurs, have overall checklist values greater than 30 and are rated high (Table 2.9). Units that the report notes as having steep slopes, creep and/or some evidence of mass wasting obtained overall values between 20 and 30. Any unit with an overall value between 20 and 30 is rated as medium sensitivity. Units with overall values less than 20 receive a low sensitivity rating.

Table 2.9 RANGES OF SLOPE SENSITIVITY RATING

Activity	Sensitivity Rating	Range
Roads	High	Greater than 30
	Medium	20 - 30
	Low	Less than 20

The risk is based on the percent coverage of the dominant soil (code SLOP1) within each unit. This is chosen as the measure of risk because of the influence of soil on slope stability and the lack of any other useful variable that represents per cent coverage of a unit.

All units where organic terrain is dominant receive a sensitivity rating of zero since these areas are to be eliminated from the study.

2.4 PROGRAMMING AND INPUT

The final step (page 45) in the production of a sensitivity map requires a program that will select the required variables from the data files, convert the variables to appropriate values as outlined above, execute the calculation of the equations and produce a table of the results. The results are the values used to determine the sensitivity ranges that were mentioned previously. Once the sensitivity rating is determined for all units to be mapped, Canada Land Data Systems Division (CLDS) personnel will create the required map.

The most qualified personnel for writing programs are those of CLDS. However, anyone familiar with both PL/I program language and with the arrangement of the files and who had access to CGIS data files, can create the programs.

It is critical that the programmer understand the information received from the researcher and what the end product is to show. This will avoid incorrect manipulation of equations or incorrect map production, either of which will increase the time and cost of receiving the final sensitivity map. It is the responsibility of the researcher to provide the programmer with the necessary data, which includes all equations to be utilized, a complete list of required variables and to explain in detail the end product.

2.5 SUMMARY

This chapter has outlined the process involved in determining sensitivity ratings in order to produce sensitivity maps, using Wood Buffalo National Park as a case study. The chapter has indicated the need to identify the activities and disturbances upon which the sensitivity ratings are based. It is clear that the technique of measuring sensitivity must be based on the disturbance to be measured and the available data. The primary data source is preferably the computerized inventory files, followed by the written report of the survey.

In Chapter III an analysis of various aspects of the process requiring further consideration will be made along with an outline of map production and a discussion of the maps generated for this project.

CHAPTER III

ANALYSIS AND DISCUSSION

This chapter will consider some aspects of the sensitivity scheme, identify and discuss significant problems, and some advantages and disadvantages encountered. Discussion will deal primarily with how the ranges for high, medium and low sensitivity were determined from the calculations for the disturbances. The discussion will also include the production of a sensitivity map and an analysis of the sensitivity maps created for this project and their role in identifying highlights such as potential corridors, high risk areas and the significance of plant community loss due to reservoir flooding.

3.1 ACTIVITIES AND DISTURBANCES

There was no difficulty in identifying the activities associated with potential development in the Park and thus of concern for this project. Difficulty lay in determination of the design standards for the activities' infrastructures.

Questions arose concerning which aspects of the infrastructure needed to be identified (e.g., slopes, vegetation cover, etc.). The aspects considered were limited primarily by the requirements of the techniques used to measure the potential disturbances.

As noted in Chapter II, the specific information for identifying design standards for the infrastructure of the various activities was obtained from several guidelines. It was found that those which provided numerical information were most applicable for the measurement techniques used. For example, the Parks Canada Campground Manual (1977) identified area of a campsite, density of campsites per hectare and size of the campground roads; from this information it was a simple matter to determine the exact area that must be cleared for a campground, an essential element in determining C factor values (Chapter 2.3.1) used in predicting erosion rates.

Where the guidelines gave only descriptive information, it was necessary to interpret the information available in the guidelines or acquire an additional source of information in order to set the design standards. In either case design standards are less precise than if numerical data were available.

Other sources of information include data of the region concerned, engineering design specifications or the conceptual design plans of the project. For example, Environment Canada's Environmental Code of Good Practice for Highways and Railways (Storgaard, 1979) identifies the need to protect the cleared area of the right of way, preferably with vegetation, in order to reduce erosion, but it does not indicate what percent vegetation cover is required to provide such protection. Information from the Park was used in order to determine visually (Chapter 2.2.5), the percent vegetation the Park naturally supports.

Engineering standards do provide numerical data, but generally they are too site specific for this level of survey and application at smaller scales is difficult. The project planners are a source of information although they may not be prepared or able to give exact figures for design standards.

Where guidelines exist concerning an activity, there is generally sufficient information (either directly stated or coupled with another source of information) upon which to base design standards. A major problem exists where there are no design standards or standards of operation. This was encountered with the forestry activity of this project. There are no guidelines within Parks Canada concerning how much vegetation is to be left in a cut

over area. It was necessary to set standards for this project based on the existing practices in the Park. The question is whether existing conditions are satisfactory: unfortunately this cannot be answered objectively.

The identification of disturbances was based on my own knowledge of disturbances which various activities may create. There are several other potential disturbances that were not considered (e.g., soil compaction, loss of animal habitats, inhibiting plant regeneration) because the purpose of the project was to outline a scheme for determining sensitivity and the selected disturbances were used only as examples. However, if a complete list of potential disturbances created by various activities in the Park was compiled, then future sensitivity studies could be conducted without overlooking any potential disturbance.

3.2 MEASURING DISTURBANCES AND RATING THE RESULTS

Although the data from the computer files or from the Integrated Resources Survey of Wood Buffalo National Park (IRS) (AAA, 1979) was sufficient to allow application of the techniques selected, modification of the techniques to suit the data was required. Herein lies the first problem. Did the

modification of the techniques eliminate their usefulness or validity?

The modification to the slope stability analysis (i.e. the removal of categories) did not appear to affect the production of the results that matched statements in the IRS concerning slope stability of several ecological units. That is, units that the IRS noted as being stable, exhibiting some unstable features or as being unstable, received corresponding calculated values (Chapter 2.3.3). It is believed that there was sufficient information to identify units as having high, medium or low susceptibility or sensitivity to slope failure. The prime modification of the erosion equation was the elimination of the rainfall intensity factor; however, there was sufficient data to utilize the remainder of the USLE equation and provide a method for comparing an index of rates of erosion between units (Ch. 2.3.1). The vegetation sensitivity technique (Suffling, 1980) was not modified significantly. It was altered to measure the sensitivity of only one or two plant communities in an ecological unit rather than all plant communities in a unit. However, Suffling's (1980) equation is not dependent upon the number of communities per unit to produce a sensitivity value for the unit. The number of plant communities considered for each unit was altered in some cases

(Ch. 2.3.2), in order to determine a sensitivity value for particular plant communities. The relative sensitivity of an individual plant community within a unit never changes, it is the cumulative sensitivity value of the unit that changes when the number of communities considered is altered.

Therefore, it is suggested that for this particular project, the calculated indicators of the disturbances are appropriate.

The major problem was not in obtaining values for the ecological units but how to relate the measurements of the various activities involved with each disturbance and secondly, how to separate the values into ranges of high, medium and low. Both are discussed below.

3.2.1 THE RELATION OF ACTIVITIES TO THE DISTURBANCES

The erosion index produced a wide range of values, over three or four orders of magnitude, for each activity (Fig. 3.1). The activities can be arranged in a general descending order of sensitivity from roads to forestry to campgrounds to transmission corridors based on the calculated erosion index. However, the values for the various activities overlap to form a continuum. Thus in defining high, medium and low categories, should the range of each activity be considered separately or as part of the

RATES OF EROSION - Calculated from a Modified USLE

Fig. 3)

whole, that is, should the same ranges for high, medium and low sensitivity apply to all four activities? To answer this, it must be decided if it would be acceptable for a road to cause greater erosion in its low sensitivity category than a transmission corridor in its high sensitivity category.

As noted in Chapter 1.3.4, it is Parks Canada policy to minimize the disturbance caused by all activities and there is no indication that it is acceptable for one activity to cause a greater disturbance than another activity. Therefore, this project uses a unified scale in its assessment of all activities affecting erosion (Fig. 3.1).

Similarly, vegetation sensitivity ratings for the various activities are considered on the same scale. In this case the values are similar (Fig. 3.2) for each activity and so the question of creating different ranges for each activity does not arise.

3.2.2 LOW, MEDIUM AND HIGH SENSITIVITY RANGES

The second problem was how to differentiate the ranges for high, medium and low sensitivity. By definition, a highly sensitive ecological unit is one in which, as the result of a particular activity, the disturbance will occur or that the increase in the

ECOLOGICAL SENSITIVITY VALUES

Fig. 3.2

rate of the disturbance will be very significant. Medium sensitivity is related to a unit in which it is possible for the disturbance to occur. A low sensitivity is related to units in which the potential of the disturbance occurring or the rate increasing, is minimal.

This was directly applicable to slope stability but not for the other disturbances. As stated earlier (Ch. 2.3.3) the IRS described slope stabilities and from this the potential instability of slopes could be gauged. This was not possible for erosion and ecological sensitivity, for, although values were derived for sensitivity and the sensitivity of units can be compared, the absolute magnitude of the disturbance is not known. For example, it is not known how significant the change of -10.23 (Ch. 2.3.2) (Fig. 3.1) in the erosion rate induced by road activity for ecological unit 455 is, it could in fact be a minor or major change in the rate of erosion.

Fortunately, there is some evidence in the IRS and in the calculated sensitivity values themselves, to help identify relative ranges of high, medium and low sensitivity.

The IRS was used to aid in determining sensitivity ranges for erosion. The IRS predicts the potential increase in erosion of several ecological

units, if they are disturbed, as being minimal, moderate, moderately severe and severe. It was expected that the calculated erosion index values for the ecological units would correspond to the predicted potential increases identified in the IRS; however, they did not always correspond. An example is ecological unit 455, which has a relatively moderate X_d , increase in erosion, value of -2.13 for campgrounds, a relatively high X_d value of -10.23 for roads, while the IRS predicts a low potential for increased erosion. The major reason for the differences is that the IRS based the erosion potential predictions on K factor tables produced by Wishchmeier, Johnson and Gross (1971) similar to Table 2.3 Chapter II but they did not consider slope, vegetation cover or the type of activity disrupting the unit. The approach taken by this project gives a more accurate estimation of erosion potential due to the increased number of factors considered.

However, the IRS states that several ecological units were noted, as the result of field observations, as having low rates of erosion under natural conditions. These units, identified by the IRS, had calculated natural erosion values (X_n) (Ch. 2.3.1) between 0.00 and 0.10. This was used as the basis for determining the low sensitivity range.

It must be noted that the change in the erosion index (X_d) for the activities is the difference between the natural erosion rate (X_n) and the erosion rate induced by an activity (X_a). Since the erosion rate X_a is greater than X_n the difference, X_d , is a negative value. Nevertheless the intervals on the X_n and X_d scales (Fig. 3.1) are to be taken as being identical. Thus it was decided that any X_d value between 0.00 and -0.10 is considered as a low potential increase in erosion and any ecological unit with such an X_d value receives a low sensitivity rating.

The low sensitivity range covered three orders of magnitude, so it was determined that the moderate range would cover the next two orders of magnitude from -0.10 to -10.00, and the high sensitivity range would cover one order of magnitude from -10.00 to -100.00 (Fig. 3.1). An additional reason for choosing -10.00 as the break between medium and high sensitivity is that virtually all the ecological units which the IRS predicted as having severe potential for erosion if disturbed have values between -10.00 and -100.00 for roads. Although the IRS erosion predictions are not the basis for selecting sensitivity ranges, they can be used as indicators.

It is difficult to determine at this point the validity of the ranges; study of actual erosion rates within the Park would be required.

Several land systems and subsystems have X_d values of zero (Fig. 3.1), indicating that their erosion rates are not affected by forestry operations or transmission corridors. This is because neither activity alters the slope of the land or the soil type and for these particular units the dominant vegetation is not removed (e.g. grasslands have no trees to be cleared for a right of way or to be cut by forestry operations).

The absolute value of the increase in the index of erosion (X_d) is used because it is the absolute value of increase and not the percent increase that is important. A unit with a very low level of sensitivity could have an increase in the rate of erosion of 10 to 20 times and still have a low level of sensitivity, while a more sensitive unit could have the erosion rate increased by fifty percent and produce a significant increase in the amount of soil eroded.

Determining the ranges for plant community sensitivity (ecological sensitivity) was equally difficult. The calculated values from the computer-generated tables ranged from -1.286 to 0.441. The positive values represent plant

communities that cover ten percent or more of the Park (the total coverage of each community was manually calculated from the data files). This happens because the natural logarithm of a plant community covering greater than ten percent of the Park is positive, while the natural logarithm of a community covering less than ten percent is negative. To avoid confusion with positive and negative numbers, 2.000 was added to each value creating a new range from 0.714 to 2.441 (Fig. 3.2).

Any plant community covering ten percent or more of the Park has a considerable areal extent (over 4,400 square kilometres) and so is considered to have a low sensitivity rating. Thus any ecological unit with a value greater than 2.000 has a low sensitivity rating because it is dominated by one or two plant communities that cover large tracts of land elsewhere in the Park.

The next break in the range occurs at 1.000. Any plant community covering less than two percent of the Park received values less than 1.000. This included the Park's climax plant community of white spruce and the later successional stages of the pine forest communities. By Suffern's (1980) definition these communities should be the most sensitive. These communities are the oldest and therefore, take the longest to regenerate after disturbance, and by

occupying the smallest area have a limited seed source for regeneration. Thus, the range of values for high sensitivity is 0.000 to 1.000, medium is from 1.001 to 2.000 and low includes any value greater than 2.000.

It may be noted that because there are no aspen-balsam poplar dominated mixed forests (V_n PCM 10) within the timber berth there are no values for aspen-balsam poplar, under Forestry (Fig. 3.2), and therefore only two forestry maps can be produced instead of three as stated in Chapter 2.3.2.

Some plant communities that cover less than two percent of the Park are not in the later stages of succession. They cover little area because of restricted growing conditions or because they are not accurately mapped. Plant communities restricted by growing conditions are ericaceous shrubland/thickets (VPCMn 98, Appendix I) limited to levees and terraces along the Peace, Athabasca and Slave Rivers and aspen-balsam poplar in prairie (V_n PCM 9) limited to river flood plains and deltaic areas. Plant communities in which the areal extent is not well recorded or mapped in the inventory are areas 0 - 10 years after a severe fire (V_n PCM 13). The data files indicate that 453 square kilometres have been burnt in the past ten years, however the figure is low and therefore, this community is under

represented in the files and thus receives a relatively inaccurate, high, sensitivity rating.

Even though some of the plant communities with high sensitivity ratings are not at the climax stages of succession they occupy a small portion of the Park and disruption of their habitat would reduce their survivability. For this reason these communities are still considered to be highly sensitive.

It was found that in some cases a plant community which usually rates a high sensitivity has a value in the medium range. This is the result of altering the use of Suffling's (1980) equation. Part of Suffling's (1980) equation is based on the proportion of the ecological unit that the plant community occupies (Ch. 2.3.2) and the smaller the proportion of the unit covered by a community the less sensitive the community's rating. This is most significant when only one plant community within an ecological unit is being considered and it is not a dominant community.

The most notable example occurs in determining the ecological sensitivity of white spruce for the forestry activity. In this determination of ecological sensitivity, white spruce was the only plant community considered regardless of the proportion of the unit covered (Ch. 2.3.2). White spruce on feather moss (V_n PCM 12, Appendix I)

generally receives a high sensitivity rating, but in some cases, such as unit 32, white spruce has a value in the moderate range of sensitivity. This is because white spruce covers twenty percent of the area and the insertion of 20 percent into the equation produces a modified sensitivity value of 1.620 (Fig. 3.2), within the medium sensitivity range.

On the other hand when all plant communities within a unit are used in the calculations (Ch. 2.3.2) the combination of two plant communities in the same ecological unit, with sensitivity values at the high end of the medium range, may produce a high sensitivity rating for the unit. An example is the determination of the flooding sensitivity for unit 319. The dominant plant communities are black spruce on feather moss (V_n PCM 22, Appendix I) covering 60 percent of the unit and aspen-balsam poplar dominated mixed forest (V_n PCM 10) covering 40 percent. Each of the plant communities has a total percentage cover of the Park of less than 3 percent, close to that of plant communities that generally receive high sensitivity ratings. The sensitivity value of each community type is in the medium range but the ecological sensitivity of the unit requires the combination of the two to produce a modified value of 0.714, which is a high sensitivity value.

These two examples indicate that units that received a high sensitivity rating were ecological units dominated (30 percent or greater) by a plant community that covers less than two percent of the Park or it is dominated by two plant communities, each of which occupies less than three percent of the Park. Other combinations may exist to produce a high sensitivity rating but these were the only two encountered.

3.3 WOOD BUFFALO NATIONAL PARK COMPUTER DATA BASE

The data from the Wood Buffalo National Park survey has been stored on hardcopy maps, in computer data files and in a written report (the IRS): the map data was not used in this project. The computer data files and the IRS provided all the data required to execute the measurement techniques. Of the two sources of data used, the computer data files were the most useful.

The data files are preferred because numerical values can be placed on the variables (e.g., Table 2.5) stored in the files; data files are easily manipulated from the programmer's point of view at either the level of the ecological unit or land system. Furthermore, both the numerical values and manipulation of the files aid in programming the equations derived from the measurement techniques.

Problems do exist with the data files, such as the lack of certain information that is found only in the IRS and the lack of editing. A specific example of information in the IRS that is not in the data files is the percentage canopy, shrub and ground cover, of the plant communities. Most of the descriptions of the plant communities include the percent canopy cover but not the percent shrub or ground cover, although the amount of cover is indicated through descriptive terms. This information could be stored in the computer data files and would have aided in determining rates of erosion.

A second problem was the lack of editing of the files. As an example, for each plant community (VnPCM) recorded for a unit there is a corresponding record of the percentage of the unit that community occupies (VnPCT). If there are three plant communities recorded in a unit there should be three separate percentage coverages recorded. However, 20 percent of the land systems or subsystems have discrepancies between the number of plant communities recorded in the data files and the percent coverages recorded. It is difficult to say if this has a significant effect on the determination of each plant community's total percent coverage of the Park, as used in determining ecological sensitivity.

Another editing error was noted in the slope angle (SLOP 1) records. Several of the land system or subsystem units were blank, indicating a 0 percent slope (Appendix 1), while the IRS indicates that the units do have a slope. This affected the slope instability determination by requiring additional time in order to interpret slope angles for the units from the IRS rather than obtaining the angles directly from the data files.

The IRS was useful, as mentioned, because it contains data lacking in the data files and it also provides the researcher with a clearer impression of a unit than does a listing from a computer file. The drawback of the IRS is the amount of time required to search through it for information (the report is over 600 pages) and the need to interpret some data in order for it to be applied in an equation. An example is the need for a value of the percentage ground cover of a plant community, required for the C factor, used in predicting erosion rates. The IRS used ground cover descriptions such as sparse, common, abundant and continuous which required a conversion to percent cover; however, the estimation reduces the precision of the C factor.

3.4 CGIS COMPUTER GRAPHICS

As stated earlier computer programs are written by CLDS personnel to execute the calculation of

sensitivity values for the various activities and disturbances. From the tables produced by the calculations ranges of high, medium and low sensitivity are determined, as illustrated earlier in this chapter. The final step in the sensitivity scheme is to map the sensitivity severity rating of each ecological unit (see Fig. 3.3). The colour of each unit is dependent upon its rating. In virtually all cases, all the ecological units within a land system or subsystem receive the same rating.

The input required by the computer system to produce a map includes a list of the land systems, subsystems or individual ecological units to be mapped and the corresponding colour of each, in addition to all titles and the legend setup.

There are two systems available to produce the colour maps. The first is to have CLDS personnel input the listing into the computer system and have a map created on a drum plotter using ball point pens. The second technique is to use IGSS (accessible to any user) to create a colour map on the terminal screen and photograph the screen using a 35 mm camera to produce a slide. The map can be reproduced from the slide as a print or by using a colour photocopier. In addition, a small plotter has been connected to the colour screen and can create small colour plots.

The major advantage of the drum plotter is that the scale of the map can be controlled and can be made to overlay NTS maps. The scale of the map on the terminal screen cannot be altered through the production process. The map on the screen is made as large as the screen will accept. The only method of controlling the scale is to photographically enlarge or reduce the print of the map, however, this will introduce distortions to the edge of the map.

Another disadvantage of the terminal screen is that small or intricate units may be eliminated due to the coarse resolution used by the colouring process. However, the colour of the terminal screen is more consistent than that produced by the drum plotter: Ball point line weight is not always constant or the pens may skip, especially at high speed printing. The quality of line is improved by reducing the plotting speed as is done for higher quality maps.

CLDS personnel are extremely helpful in explaining the CGIS structure and products and their advice is invaluable. However, if the project does not have a high priority it may take several weeks or months to have the computer programs created. The time required to write programs depends on the number of programs requested and their complexity. The other time limiting factor is the plotting of the

maps. Each of the maps for this project required 45 minutes of plotting time. One or two weeks is required to complete the maps due to the length of time required to plot the nine maps for this project and the need to plot other maps with higher priority during this period.

3.5 SENSITIVITY MAPS

There were nine sensitivity maps generated on the CGIS drum plotter. Five maps are at a scale of 1:1,000,000 and four maps are at a scale of 1:500,000. The maps clearly indicate areas of high, medium and low sensitivity and the vast areas of organic terrain which restricts the location of activities. The maps generated may be overlayed on NTS maps or maps of the Park's ecological units if further study of the maps is required.

The clarity of the maps and the information they contain indicates the success of the scheme in producing sensitivity maps.

For best use the maps must be interpreted with the aim to locate activities in low sensitivity (blue) units as much as possible and to avoid high sensitivity (red) units: the darker shades of red, green and blue represent units in which the sensitivity rating affects more than 50 percent of the unit. Blue units have few restrictions to use,

while green units would require mitigating measures to reduce the impact of disturbance and red units would require extensive mitigating measures that may be prohibitively expensive if applicable at all.

Slope Failure Induced by Road
Construction (Fig. 3.3), Increased Erosion Rates
Induced by Road (Fig. 3.4) and Loss of Plant
Communities by Campground, Road, Transmission
Corridor (Fig. 3.5) provide information for the
selection of potential road corridors to the south.

The slope failure map (Fig. 3.3) identifies large tracts of stable land. Fortunately, many of the stable ecological units are connected to provide a selection of potential corridors. Based on the slope failure map, there are three primary routes that stand out (see Fig. 3.6). The first, follows the eastern boundary of the Park along the Slave River, crosses the Peace River into the Peace-Athabasca Delta and continues south out of the Park along the Athabasca River. Another corridor exists in the north, passing south through the centre of the Park to the Peace River. Here the corridor splits, one route lies to the south-west along the Peace River (referred to as the west-central corridor), the other route, referred to as the east-central

Fig. 3.3

COLOURED PICTURES
Images en couleur

1 of

WOOD BUFFALO - SENSITIVITY MAP

SLOPE FAILURE INDUCED BY ROAD CONSTRUCTION

SCALE 1 : 1,000,000

LEGEND

	HIGH- GREATER THAN 50 %		MEDIUM- GREATER THAN 50 %		LOW- GREATER THAN 50 %
	HIGH- LESS THAN 50 %		MEDIUM- LESS THAN 50 %		LOW- LESS THAN 50 %
					ORGANIC SOILS

COLOURED PICTURES
Images en couleur

12.08.2

Fig. 3.4

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WOOD BUFFALO - SENSITIVITY MAP

INCREASED EROSION RATES INDUCED BY ROADS

SCALE 1 : 1,000,000

LEGEND

[Patterned Box] HIGH-GREATER THAN 50 %

[Patterned Box] HIGH-LESS THAN 50 %

[Patterned Box] ORGANIC SOILS

[Patterned Box] MEDIUM-GREATER THAN 50 %

[Patterned Box] MEDIUM-LESS THAN 50 %

[Patterned Box] LOW-GREATER THAN 50 %

[Patterned Box] LOW-LESS THAN 50 %

Fig. 3.5

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WOOD BUFFALO - SENSITIVITY MAP

LOSS OF PLANT COMMUNITIES BY CAMPGROUND, ROAD, TRANSMISSION CORRIDOR

SCALE 1 : 1,000,000

LEGEND
HIGH- GREATER THAN 50 %		MEDIUM- GREATER THAN 50 %
HIGH- LESS THAN 50 %		MEDIUM- LESS THAN 50 %
		ORGANIC SOILS

Fig. 3.6

Potential Road Corridors

corridor, lies to the east, north of the Peace River, then crosses the Peace to join the eastern boundary corridor through the Delta. Although a road, the Loop Road, already exists and occupies portions of the corridors identified, it will be ignored in the analysis of the maps.

The eastern boundary corridor would require the crossing of organic terrain in the north, as well as the crossing of the Peace River. The east-central corridor would require short crossings of organic terrain and medium sensitivity land in addition to the river crossing. The west-central corridor does not necessitate a major river crossing, nor require the crossing of organic terrain or of medium sensitivity units.

The highly sensitive units to slope failure (Fig. 3.3) are primarily the incised valleys of the frontal slopes of the Birch and Caribou Mountains, where active slumping occurs. The medium sensitivity units are also primarily located on the frontal slopes. However, additional medium sensitivity units are located where sand dunes have steep slopes and along terraces of the Athabasca River.

It must be noted that the brown areas of Figure 3.3 are the water bodies within the Park and all areas outside the Park. On the other 1:1,000,000 scale maps the orange represents water bodies and

areas outside the Park, while brown represents units of organic terrain.

The road erosion map (Fig. 3.4) illustrates that all the ecological units have either a high or medium sensitivity to erosion induced by roads. The high sensitivity units tend to be located along the Park's drainage system. It must be noted that the white units are probably the result of not identifying that particular land system on the list of land systems required to generate a map (Ch. 3.4). This points out the need for care to be employed in all phases of the scheme.

Based on the road erosion sensitivity map, the preferred corridors are through medium sensitivity units, avoiding high sensitivity units and organic terrain. The same corridor options are available for the erosion map as the slope stability map, although none of the corridors avoid the crossing of highly sensitive land and some corridors are more restricted in width.

Apart from the disadvantages of crossing rivers and organic terrain and in contrast with the slope failure map, the route that crosses the least amount of highly sensitive land is the east-central corridor. The next best route is the west-central corridor through the medium sensitivity units that are along the northern edge of the incised Peace River valley. The least favourable corridor is the

eastern boundary corridor which crosses the greatest amount of highly sensitive land.

The ecological sensitivity map (Fig. 3.5) indicates that the only units which are highly sensitive are within the Peace River valley. Large tracts of medium sensitivity are found primarily along the mountain frontal slopes, the salt flats in the northeast and the Delta. Any route that is chosen for a corridor will have to cross large areas of medium sensitivity or a short distance across high sensitivity units.

In choosing the final corridor, the advantages and disadvantages of crossing a small area of high sensitivity or a large area of medium sensitivity must be weighed.

Based on the ecological sensitivity map (Fig. 3.5), the eastern boundary corridor requires that almost two thirds of the corridor cross medium sensitivity units. The east-central corridor requires less than a third of the route to cross medium sensitivity units, but there is also a short crossing of highly sensitive lands. The third route, the west-central corridor would encounter low sensitivity for eighty percent of its length, but there would be short crossings of medium sensitivity units and somewhat longer crossings of highly sensitive units.

The Potential Road Corridor map (Fig. 3.6) indicates the three corridors, selecting the least sensitive routes for each corridor by overlaying the three sensitivity maps. The corridor with the least distance over high sensitivity lands is the east-central corridor but this route crosses the greatest extent of medium sensitivity lands. The west-central corridor is second in the extent of high sensitivity units crossed, but the units are highly sensitive for both ecology and erosion. This corridor also covers the greatest extent of low sensitivity lands. The eastern boundary corridor crosses considerable stretches of high and medium sensitivity; however, the units are only highly sensitive to erosion. This route covers the least extent of low sensitivity land. Each corridor has its advantages and disadvantages, a planner would have to weigh these in conjunction with other factors concerning route selection in order to choose the preferred corridor.

3.5.2 CAMPGROUNDS

Campground site selection is based on two sensitivity maps, the Loss of Plant Communities by Campground, Road, Transmission Corridor (Fig. 3.5) and Increased Erosion Rate Induced by Campgrounds (Fig. 3.7). The ecologically highly sensitive units are the same as those noted for roads, since they are

Fig. 3.7

WOOD BUFFALO - SENSITIVITY MAP

INCREASED EROSION RATE INDUCED BY CAMPGROUNDS

SCALE 1 : 1,000,000

LEGEND

HIGH-GREATER THAN 50 %	MEDIUM-GREATER THAN 50 %	LOW-GREATER THAN 50 %
HIGH-LESS THAN 50 %	MEDIUM-LESS THAN 50 %	LOW-LESS THAN 50 %
ORGANIC SOILS		

based on the same data. The units that are highly sensitive to erosion are the incised valleys of the frontal slopes and those that tend to have steep slopes. The medium sensitivity units dominate, being located on the frontal slopes, along drainage systems and in the Delta area.

The Potential Campground Location map (Fig. 3.8) is compiled by overlaying the two campground sensitivity maps and selecting units where low sensitivity ratings overlap. The preferred units for campground location, based on the ecological and erosion sensitivity maps, are scattered throughout the study area on several different land systems or subsystems. The Potential Campground Location map provides the planner with additional information to aid in site selection.

3.5.3 TRANSMISSION CORRIDORS

The maps, Loss of Plant Communities by Campground, Road, Transmission Corridor (Fig. 3.5) and Increased Erosion Rate Induced by Transmission Corridor (Fig. 3.9) indicate the same potential corridors exist for transmission lines as for roads. However, the transmission corridors are less restricted than the road corridors due to lower erosion rates.

Fig. 3.8

Potential Campground Locations

Fig. 3.9

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WOOD BUFFALO - SENSITIVITY MAP INCREASED EROSION RATE INDUCED BY TRANSMISSION CORRIDORS SCALE 1 : 1,000,000

- LEGEND
- HIGH- GREATER THAN 50 %
 - MEDIUM- GREATER THAN 50 %
 - LOW- GREATER THAN 50 %
 - HIGH- LESS THAN 50 %
 - MEDIUM- LESS THAN 50 %
 - LOW- LESS THAN 50 %
 - ORGANIC SOILS

The eastern boundary corridor would not cross any highly sensitive units. Its disadvantage is that it crosses a great deal of medium sensitivity land and some units have a medium rating for both ecology and erosion. The east-central corridor crosses a very short stretch of high sensitivity and some medium sensitivity (less than the eastern boundary route, but much more than the west-central corridor). A result of the reduced erosion hazard along the west-central corridor is that the corridor can be altered slightly from the road corridor and avoid some ecologically high and medium sensitivity units. However, this corridor would still utilize the greatest amount of high and low sensitivity land.

• The Potential Transmission Corridor map (Fig. 3.10) illustrates the potential corridors. Once again the map does not indicate a perfect corridor, a planner must weigh the advantages and disadvantages of each corridor.

3.5.4 RESERVOIR FLOODING

Only one map, Loss of Significant Plant Communities Due to Reservoir Flooding (Fig. 3.11), was generated for consideration of hydro reservoir flooding. This map differs from the previous maps in that only the units affected by the flooding are mapped (see Fig. 1.3 for location of reservoir).

Fig. 3.10

Potential Transmission Corridors

Fig. 11

1 of 1

WOOD BUFFALO - SENSITIVITY MAP

LOSS OF SIGNIFICANT PLANT COMMUNITIES DUE TO RESERVOIR FLOODING

SCALE 1 : 500,000

LEGEND

HIGH

MEDIUM

LOW

ORGANIC SOILS

Another difference is that only one shade of red, green and blue is used. This is because the ecological sensitivity calculation is applied to all the plant communities within a unit thus covering 100 percent of the unit and not a portion of the unit as in the other ecological sensitivity calculations:

The actual flood zone would be smaller than the area mapped because only portions of the units would be flooded while the whole unit is mapped under the CGIS system. The map indicates that flooding will affect roughly equal portions of high, medium and low sensitivity units. As there is the potential for units highly sensitive to plant community loss to be flooded, it is suggested that additional study and serious consideration be given to the significance of the loss of the plant communities to the Park, before a decision to flood these units is made.

3.5.5 FORESTRY

The final three maps are used to consider the effects of forestry operations. The maps are Increased Erosion Rate Induced by Forestry Operations (Fig. 3.12), Removal of Black Spruce Communities by Forestry Operations (Fig. 3.13) and Removal of White Spruce Communities by Forestry Operations (Fig. 3.14). The forestry maps are similar to the flooding maps, in that only the ecological units

Fig. 3.12

1 of 1

WOOD BUFFALO - SENSITIVITY MAP

INCREASED EROSION RATE INDUCED BY FORESTRY OPERATIONS

SCALE 1 : 500,000

LEGEND

HIGH-GREATER THAN 50%	MEDIUM-GREATER THAN 50%
HIGH-LESS THAN 50%	MEDIUM-LESS THAN 50%
LOW-GREATER THAN 50%	ORGANIC SOILS
LOW-LESS THAN 50%	ECL UNIT IN TIMBER BERTH,
LACK MERCHANT SPECIES

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Fig. 3.13

11 of 1

WOOD BUFFALO - SENSITIVITY MAP

REMOVAL OF BLACK SPRUCE COMMUNITIES BY FORESTRY OPERATIONS

SCALE 1 : 500,000

LEGEND

- HIGH- GREATER THAN 50%
- HIGH- LESS THAN 50%
- LOW- GREATER THAN 50%
- LOW- LESS THAN 50%
- MEDIUM- GREATER THAN 50%
- MEDIUM- LESS THAN 50%
- ORGANIC SOILS
- ABSCENCE BLACK SPRUCE WITHIN ECOLOGICAL UNITS

Fig. 3.14

| 1 of |

WOOD BUFFALO - SENSITIVITY MAP REMOVAL OF WHITE SPRUCE COMMUNITIES BY FORESTRY OPERATIONS SCALE 1 : 500,000

- LEGEND
- HIGH-GREATER THAN 50%
 - HIGH-LESS THAN 50%
 - LOW-GREATER THAN 50%
 - LOW-LESS THAN 50%
 - MEDIUM-GREATER THAN 50%
 - MEDIUM-LESS THAN 50%
 - ORGANIC SOILS
 - ABSCENCE WHITE SPRUCE WITHIN ECOLOGICAL UNITS

within the timber berth are mapped (see Fig. 1.3 for location).

The erosion map (Fig. 3.12) indicates that most of the timber berth has a medium sensitivity to erosion, thus mitigating measures to reduce or prevent erosion must be considered. The Black Spruce map (Fig. 1.13) indicates that the removal of black spruce from the timber berth will not have a significant effect on the survivability of black spruce within the Park. The White Spruce map (Fig. 3.14) shows there are three areas of high sensitivity within the timber berth that should be excluded from cutting. Fortunately significant stands of highly sensitive white spruce and pine are just outside the timber berth along its southern edge (see Fig. 3.5). Twenty percent of the area of medium rated units are occupied by white spruce; it is suggested that a decision must be made as to the significance of these white spruce stands and as to whether or not they should be preserved.

3.6 SUMMARY

Several important points brought out in this chapter are summarized here.

There is a considerable lack of applicable design standard information available, thus the design standards used in this study were often

estimated. What is needed is information presented in a similar manner to the Campground Manual. The methods employed are valid for the purpose of the study, but they are by no means the ultimate. In addition, other sensitivity methods exist which are not immediately appropriate to the organization adopted in this study. Further research is required to develop a means of measuring sensitivity. Another problem is the definition of levels of sensitivity significance. For this study sensitivity levels were based on information contained in the IRS; what is needed are field observation based guidelines to calibrate levels of significance.

The data on computer files can be manipulated to produce sensitivity values. Difficulties arise when data required by the methodologies are in the IRS but not stored on computer files. In addition, editing errors within the files can cause some difficulty in determining sensitivity values.

There are several means of producing sensitivity maps through CGIS. The maps produced, successfully depicted sensitivity levels of ecological units as well as identifying disturbances and their causes.

The sensitivity maps produced can be overlayed to aid in site selection but the interpretation of the sensitivity maps requires that the analyst understand something of the methodologies used to measure sensitivity.

Although a computer listing provides more detailed sensitivity values for a unit, a sensitivity map is essential in illustrating the spatial distribution of the units. A graphic display of sensitivity is required in order to determine the shape, location and proximity of units at the various sensitivity levels. Potential corridors, for instance, cannot be identified without a map depicting the units' sensitivity.

CHAPTER IV

CONCLUSION

This project has demonstrated that it is possible to produce sensitivity maps for specific activities and disturbances, by applying data available from Parks Canada ecological inventories and the CGIS mapping system to the seven basic steps outlined in Chapter II. The sensitivity scheme outlined in this paper was successfully applied to Wood Buffalo National Park. Since the Park's ecological inventory is similar to other parks within the National Park System, it is reasonable to suggest that the sensitivity scheme is applicable to other parks.

The information generated by this scheme, the sensitivity values and sensitivity maps, can be a useful tool in determining the presence, extent and location of park activities and as a resource management tool. Although the maps indicate sensitivity levels for units within a park, the map user must be familiar with the measurement techniques employed in order to make valid interpretations of the map information.

To apply the same measurement techniques employed in this project to other parks in the Parks Canada National Park system may require modification to allow for variations in inventories. The inventories of the various parks are not identical in format because the studies were conducted by different groups and the survey methodology within Parks Canada has been evolving. Nevertheless there should be enough similarity (the same types of data are collected for each inventory) to allow the transfer of measurement techniques to other park inventories.

The sensitivity scheme outlined could be expanded to include other disturbances and activities. This would require further studies by Parks Canada to identify measurement techniques and design standards. In addition, the approach need not be limited to sensitivity mapping; any problem that can be best shown graphically and requires more manipulation of inventory data than overlay mapping may be handled effectively in a similar manner.

Although the paper shows that the methodologies employed can be applied to an ecological land survey and CGIS to produce sensitivity maps, it also illustrates the limits of available information concerning sensitivity. A major outcome of this paper is the indication of a significant lack of

applicable design standards, guidelines concerning levels of sensitivity significance and primarily the lack of acceptable methods of measuring sensitivity. All these are areas requiring considerable investigation. Work is being conducted in many areas (e.g. determining soil erosion) that are not directly related to sensitivity but could be applied once they are judged as acceptable methods of measurement. Advances in methodology are required before sensitivity mapping can become a significant source of information.

One of the aims of the project was to produce a sensitivity scheme that would be quick and easy to execute in order to fit into the design process and every day resource management. For this particular project the process in its present form took too long to be of practical value to resource managers on a demand basis and may be too long to be of use to planners, but there are several ways of reducing the time frame. Many of the time saving steps would require Parks Canada to expand the scheme and apply it to all parks to be worthwhile.

It is possible to reproduce the maps for this project by contacting CLDS where the data is stored. The data is not stored on computer files but the programs and reports generated for this project are kept on record and can be easily inputted into CGIS,

although several days would be required if further modifications were necessary.

The process could be greatly speeded if Parks Canada established or identified activities, disturbances, design standards and measurement techniques that could be applied to all park inventories. If this information were standardized and available, it would reduce a user's time required to locate the necessary information, or the information could be programmed and stored on CGIS for instant recall through the Interactive Graphic Subsystem (IGSS). Such an approach would require considerable use to justify the cost of storing the data in computer files; on the other hand the information (sensitivity values) and sensitivity maps would be produced in days rather than months.

Although it was demonstrated that the sensitivity scheme will produce sensitivity maps, several problems were encountered (as noted in Chapter III) but none that could not be overcome.

Further study is required to determine more accurate levels of sensitivity significance and for larger scale surveys. For instance, from this project it is not known what the absolute magnitude of erosion is for the ecological units. However, it must be noted that accurate comparisons of erosion rates and their significance can be made between

ecological units within Wood Buffalo National Park but not between parks.

The sensitivity maps generated through this project serve their purpose in aiding in site and or corridor selection. The maps do not indicate the perfect location for an activity but the graphic display of information and the planner's knowledge of the measurement techniques allows for the selection of preferable sites; these would require more detailed study before specific proposals are made. In the case of potential road corridors there are advantages and disadvantages to each route; the planner must weigh the environmental cost of crossing short stretches of high sensitivity areas or much larger stretches of medium sensitivity areas before selecting the preferred corridor.

As a decision-making tool there is not sufficient information provided by the sensitivity maps generated through this project upon which to base a decision concerning the location of an activity. However, the more disturbances that are considered for an activity the greater the weight this scheme carries and the more important the sensitivity aspect of the land upon which an activity may be located becomes. Therefore, the expansion of activities and disturbances considered by the sensitivity scheme will increase the scheme's importance as a decision-making tool.

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APPENDIX I LEGEND TO WOOD BUFFALO NATIONAL PARK COMPUTERIZED ECOLOGICAL INVENTORY

Variables available for data base: WOODBUFF

Variable description/type

- SHRL - SHORELINE
- PARK - PARK POLYGON
- MAPNO - MAP NUMBER
- DISTR - DISTRICT AND SYSTEM CODE
- SYSTM - IS USED ONLY WHEN PLOTTING WITH SUB-SYSTEM REQ
- SUBSY - SUBSYSTEM
- RGSYS - REGION DISTRICT SYSTEM AND SUBSYSTEM
- PERST - PERMAFROST
- DEPTH - PERMAFROST DEPTH
- PERD1 - FIRST GEOLOGIC PERIOD
- PERD2 - SECOND GEOLOGIC PERIOD
- PETRI - FIRST PETROGRAPHY
- PETR2 - SECOND PETROGRAPHY
- FORMG - GEOLOGIC FORMATION
- KARST - KARST
- OCROP - OUTCROPPING
- UFAT - UNIQUE FEATURE
- FEAT1 - UNIQUE FEATURE 01
- FEAT2 - UNIQUE FEATURE 02
- ELEV1 - ELEVATION 01
- ELEV2 - ELEVATION 02
- WILD1 - WILDLIFE CODE
- BVEC1 - BIOPHYSICAL VEGETATION 01
- BVEC2 - BIOPHYSICAL VEGETATION 02
- BVEC3 - BIOPHYSICAL VEGETATION 03
- BVEC4 - BIOPHYSICAL VEGETATION 04
- BVEC5 - BIOPHYSICAL VEGETATION 05
- BVEC6 - BIOPHYSICAL VEGETATION 06
- BVEC7 - BIOPHYSICAL VEGETATION 07
- BVEC8 - BIOPHYSICAL VEGETATION 08
- BVEC9 - BIOPHYSICAL VEGETATION 09
- SLM01 - SOIL 01 - MATERIAL
- SLR01 - SOIL 01 - REACTION
- SLD01 - SOIL 01 - DRAINAGE
- SLS01 - SOIL 01 - SPECIAL CONDITIONS
- SLP01 - SOIL 01 - PERCENTAGE
- SLM02 - SOIL 02 - MATERIAL
- SLR02 - SOIL 02 - REACTION
- SLD02 - SOIL 02 - DRAINAGE
- SLS02 - SOIL 02 - SPECIAL CONDITIONS
- SLP02 - SOIL 02 - PERCENTAGE
- SLM03 - SOIL 03 - MATERIAL
- SLR03 - SOIL 03 - REACTION
- SLD03 - SOIL 03 - DRAINAGE
- SLS03 - SOIL 03 - SPECIAL CONDITIONS
- SLP03 - SOIL 03 - PERCENTAGE
- MATR1 - GEOLOGY MATERIAL 1
- EROS1 - GEOLOGY EROSION 1
- PCNT1 - GEOLOGY PERCENTAGE 1
- STR11 - GEOLOGY STRATIFIC 1
- BED11 - GEOLOGY BEDROCK 1
- EROS1 - GEOLOGY EROSION 1
- SLOP1 - GEOLOGY SLOPE 1

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Variables available for data base: WOODSUFF

Variable description/type
 ASPC1 - GEOLOGY ASPECT 1
 MATR2 - GEOLOGY MATERIAL 2
 EROS2 - GEOLOGY EROSION 2
 PCNT2 - GEOLOGY PERCENTAGE 2
 STRT2 - GEOLOGY STRATIFIC 2
 BEDR2 - GEOLOGY BEDROCK 2
 ERUB2 - GEOLOGY EROSIONB 2
 SLOP2 - GEOLOGY SLOPE 2
 ASPC2 - GEOLOGY ASPECT 2
 MATR3 - GEOLOGY MATERIAL 3
 EROS3 - GEOLOGY EROSION 3
 PCNT3 - GEOLOGY PERCENTAGE 3
 STRT3 - GEOLOGY STRATIFIC 3
 BEDR3 - GEOLOGY BEDROCK 3
 VEGCT - VEGETATION COUNTEN
 MOICT - VEGETATION MOISTURE
 V1PCM - VEGETATION 1 PLANT COMMUNITY
 V1STR - VEGETATION 1 STRUCTURE
 V1SPP - VEGETATION 1 SPECIES GROUP
 V1SP1 - VEGETATION 1 SPECIES 1
 V1SP2 - VEGETATION 1 SPECIES 2
 V1SP3 - VEGETATION 1 SPECIES 3
 V1SP4 - VEGETATION 1 SPECIES 4
 V1HTC - VEGETATION 1 HEIGHT
 V1PCT - VEGETATION 1 PERCENTAGE
 V1MOI - VEGETATION 1 MOISTURE
 V2PCM - VEGETATION 2 PLANT COMMUNITY
 V2STR - VEGETATION 2 STRUCTURE
 V2SPP - VEGETATION 2 SPECIES GROUP
 V2SP1 - VEGETATION 2 SPECIES 1
 V2SP2 - VEGETATION 2 SPECIES 2
 V2SP3 - VEGETATION 2 SPECIES 3
 V2SP4 - VEGETATION 2 SPECIES 4
 V2HTC - VEGETATION 2 HEIGHT
 V2PCT - VEGETATION 2 PERCENTAGE
 V2MOI - VEGETATION 2 MOISTURE
 V3PCM - VEGETATION 3 PLANT COMMUNITY
 V3STR - VEGETATION 3 STRUCTURE
 V3SPP - VEGETATION 3 SPECIES GROUP
 V3SP1 - VEGETATION 3 SPECIES 1
 V3SP2 - VEGETATION 3 SPECIES 2
 V3SP3 - VEGETATION 3 SPECIES 3
 V3SP4 - VEGETATION 3 SPECIES 4
 V3HTC - VEGETATION 3 HEIGHT
 V3PCT - VEGETATION 3 PERCENTAGE
 V3MOI - VEGETATION 3 MOISTURE
 V4PCM - VEGETATION 4 PLANT COMMUNITY
 V4STR - VEGETATION 4 STRUCTURE
 V4SPP - VEGETATION 4 SPECIES GROUP
 V4SP1 - VEGETATION 4 SPECIES 1
 V4SP2 - VEGETATION 4 SPECIES 2
 V4SP3 - VEGETATION 4 SPECIES 3
 V4SP4 - VEGETATION 4 SPECIES 4

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Variables available for data base: WOODSUFF

Variable description/type
V4HTC - VEGETATION 4 HEIGHT
V4PCT - VEGETATION 4 PERCENTAGE
V4MOI - VEGETATION 4 MOISTURE
V5PCM - VEGETATION 5 PLANT COMMUNITY
V5STR - VEGETATION 5 STRUCTURE
V5SPP - VEGETATION 5 SPECIES GROUP
V5SP1 - VEGETATION 5 SPECIES 1
V5SP2 - VEGETATION 5 SPECIES 2
V5SP3 - VEGETATION 5 SPECIES 3
V5SP4 - VEGETATION 5 SPECIES 4
V6HTC - VEGETATION 6 HEIGHT
V6PCT - VEGETATION 6 PERCENTAGE
V6MOI - VEGETATION 6 MOISTURE
V6PCM - VEGETATION 6 PLANT COMMUNITY
V6STR - VEGETATION 6 STRUCTURE
V6SPP - VEGETATION 6 SPECIES GROUP
V6SP1 - VEGETATION 6 SPECIES 1
V6SP2 - VEGETATION 6 SPECIES 2
V6SP3 - VEGETATION 6 SPECIES 3
V6SP4 - VEGETATION 6 SPECIES 4
V7HTC - VEGETATION 7 HEIGHT
V7PCT - VEGETATION 7 PERCENTAGE
V7MOI - VEGETATION 7 MOISTURE
V7PCM - VEGETATION 7 PLANT COMMUNITY
V7STR - VEGETATION 7 STRUCTURE
V7SPP - VEGETATION 7 SPECIES GROUP
V7SP1 - VEGETATION 7 SPECIES 1
V7SP2 - VEGETATION 7 SPECIES 2
V7SP3 - VEGETATION 7 SPECIES 3
V7SP4 - VEGETATION 7 SPECIES 4
SPARE

Max. number of values per variable 30
Scale of input data base is 1 : 250,000

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SHRLN - SHORELINE

GENERAL - This coverage represents boundaries between land and water
- Land
- Water
- Unclassified, or water area
- Unclassified areas

PARK# - PARK POLYGON NUMBER LENGTH = -

GENERAL - Polygon numbers are assigned to each individual polygon.

MAPNO - MAP NUMBER LENGTH = 3

74M - Fitzgerald
85B - Buffalo Lake
85A - Little Buffalo River
74L - Fort Chipewyan
84O - Whitesand River
84P - Peace Point
84I - Lake Claire

DISTR - LAND DISTRICT VALUES LENGTH = 1

A - Peace/Slave/Athabasca Lowlands
B - Slave Plain
C - Cratceous Uplands
D - Buffalo Lk. Lowlands Robertson Lk. Uplands

SYSTM - SYSTEM LENGTH = 2

GENERAL - A 2 digit number identifying the system location

SUBSY - SUBSYSTEM LENGTH = 1

GENERAL - An alphabetic digit identifying the system subdivision

RGSYS - REGION DISTRICT SYSTEM AND SUBSYSTEM LENGTH = 4

GENERAL - Identifies the district, system, and subsystem

VEGCT - VEGETATION COUNTER LENGTH = 1

GENERAL - Identifies the number of vegetation classes possible
may be coded from 0-7

MOICT - MOISTURE REGIME COUNTER LENGTH = 1

GENERAL - Identifies the number of moisture regime available
May be coded from 0-3

VPCN - PLANT COMMUNITY VALUE LENGTH = 2

GENERAL - SAME CODES AND DESCRIPTIONS FOR V2PCM - V7PCM

99 - Meadows: seasonally submerged (1&2)
seasonal shortgrass (3)
wet meadows (4)
semi-open prairie (5)
salt flats Saline Meadows (6)
98 - Ericaceous Shrubland/thicket
7 - Willow-alder thicket
9 - Aspen-balsam poplar in prairie
10 - Aspen-balsam poplar dominated mixed forest
11 - White spruce dominated mixed forests
12 - White spruce on feather moss
13 - Disturbed areas after severe fire

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- 14 - Pine dominated mixed forests
- 15 - Pine on feather moss
- 16 - Pine heath
- 17 - Wet muskeg
- 18 - Shrub muskeg
- 20 - Black spruce on sphagnum
- 21 - Black spruce dominated mixed forest
- 22 - Black spruce on feather moss
- 5 - Semi-open prairie
- 0 - Unclassified

VISTR - STRUCTURE VALUE

LENGTH = 3

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2STR - V7STR

- F - Forest
- W - Woodland
- ST - Shrubland/Thicket
- M - Graminoid and/or Sedge Prairie
- N - Fen
- P - Peatbog (treed)
- PG - Wet graminoid muskeg
- PCC - Wet graminoid-herb muskeg
- PST - Shrub muskeg
- D - Disturbed Areas (Fire)
- MST - Combination of M and ST

VISP1 - PLANT SPECIES 1 VALUE

LENGTH = 2

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2SP1 - V7SP1

- WS - White Spruce
- BS - Black Spruce
- PN - Pine
- WW - Willow
- AL - Alder
- PO - Poplar
- ER - Ericaceous Species
- GR - Graminoids
- GC - Herb/Graminoids
- BC - Black spruce

VISP2 - PLANT SPECIES 2 VALUE

LENGTH = 2

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2SP2 - V7SP2

- WS - White Spruce
- BS - Black Spruce
- PN - Pine
- WW - Willow
- AL - Alder
- PO - Poplar
- ER - Ericaceous Species
- GR - Graminoids
- GC - Herb/Graminoids

VISP3 - PLANT SPECIES 3 VALUE

LENGTH = 2

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2SP3 - V7SP3

- WS - White Spruce
- BS - Black Spruce
- PN - Pine
- WW - Willow

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AL - Alder
PO - Poplar
ER - Ericaceous Species
GR - Graminoids
GC - Herb/Graminoids

VISP4 - PLANT SPECIES 4 VALUE

LENGTH = 2

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2SP4 - V7SP4

WS - White Spruce
BS - Black Spruce
PN - Pine
WW - Willow
AL - Alder
PO - Poplar
ER - Ericaceous Species
GR - Graminoids
GC - Herb/Graminoids

VIMTC - HEIGHT CLASS VALUES

LENGTH = 2

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2HTC - V7HTC

0 - Less than 1 metre
1 - 1 TO 5 METRES
13 - 1 to 15 metres
2 - 6 TO 10 METRES
23 - 6 to 15 metres
24 - 6 to 20 metres
3 - 11 TO 15 METRES
34 - 11 to 20 metres
35 - 11 to 25 metres
45 - 16 to 26 metres
44 - 1 TO 20 METRES

VIPCT - PERCENT COVER VALUES

LENGTH = 1

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2PCT - V7PCT

9 - 90-100%
8 - 80-89%
7 - 70-79%
6 - 60-69%
5 - 50-59%
4 - 40-49%
3 - 30-39%
2 - 20-29%
1 - 10-19%
0 - 0-9%

VIMOI - MOISTURE REGIME

LENGTH = 1

GENERAL- SAME CODES AND DESCRIPTIONS FOR V2MOI - V7MOI

1 ???
2 ???
3 ???
0 - Unclassified

UFAT - UNIQUE FEATURE

LENGTH = 1

U - Unique feature
- Unclassed

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FEAT1 - UNIQUE FEATURE 1

LENGTH = 2

GENERAL- Same codes and descriptions for FEAT2

- 01 - Peace Pnts historic site/gypsum deposits
- 02 - Peace River/bar deposits
- 03 - Lake One bison caving area
- 04 - Tar Sands
- 05 - Dunes
- 06 - Fossils
- 07 - Peace Athabasca delta
- 08 - Athabasca River
- 09 - Lake Claire
- 10 - Salt flat
- 11 - Angus Tower/Dollines
- 12 - Caves
- 13 - Submarine spring
- 14 - Sulphur Springs
- 15 - Caribou Mountains
- 16 - Caribou Mountains
- 17 - McIvor Creek
- 18 - Birch Mountains
- 19 - Oriented Blake
- Unclassed

ELEV1 - ELEVATION 1

LENGTH = 4

GENERAL- The first 2 numbers identify lower elevation * 10,
the 2 last the maximum elevation * 10.
For example, 2127 would represent 210m - 270m.
The same codes and descriptions for ELEV2

WILDL - WILDLIFE CODE

LENGTH = 5

GENERAL- Codes from 0001-0069 will, at a later date, represent
wildlife habitats

FORMG - FORMATIONS

LENGTH = 3

- F01 - Ireton and Waterways formations west/Shale pnt. formations/
Fort Vermillion formations/Nyarling formations/Key River
formations
- F02 - Waterways formations
- F03 - Methy formations
- F04 - Keg River formations/Chinchaga formations/Fitzgerald
formations/Precambrian granite
- F05 - Vermillion formations/Slave pnt. formations
- F06 - Precambrian granite/Elk pnt. group
- F07 - Precambrian granite
- F08 - Waterways, Slave pnt., Nyarling formations
- F09 - Chinchaga, Key River formations
- F10 - Nyarling, Keg River formations
- F11 - Precambrian granite, Fitzgerald formations
- F12 - Slave pnt. formations
- F13 - Slave pnt., Nyarling formations, Middle devonian carbonate
- F14 - Keg River, Chinchaga, Middle devonian carbonate
- F15 - Slave pnt., Nyarling, Keg River formations, Hay-River
formations, Middle devonian carbonate, Upper devonian shale
- F16 - Hay River, Slave pnt., Keg River formations, Devonian
shales and carbonate
- F17 - Hay River, Slave pnt., Nyarling and Vermillion formations,

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Devonian shales and carbonate, Cretaceous sandstones,
F18 - Nyrting formations, Middle devonian gypsum
F19 - Hay River formations, Middle devonian gypsum
F20 - Fort Vermillion formations
21 - Shaftsbury formations, Caribou Mountains, Waterways
formations, Birch Mountains
F22 - Loon River, Shaftsbury formations
F23 - Grand Rapide formations
F24 - Shaftsbury formations, Dunvegan formations
F25 - Loon River formation, Caribou Mountains, Waterways
formation, Birch Mountains
F26 - Shaftsbury formations
F27 - Ireton formations
F28 - Hay River formations
1 - Unclassed

PERST - PERMAFROST LENGTH = 1
GENERAL- PERMAFROST PERCENTAGE
1 - 10%
2 - 20%
3 - 30%
4 - 40%
5 - 50%
6 - 60%
7 - 70%
8 - 80%
9 - 90%
0 - 100%

DEPTH - PERMAFROST DEPTH LENGTH = 1
GENERAL- Depth of the permafrost in metres ex 030 is 30 metres

PERD1 - GEOLOGIC PERIOD 1 LENGTH = 2
GENERAL- Same codes and descriptions for PERD2
CL - Lower cretaceous
CM - Mid cretaceous
CU - Upper cretaceous
DL - Lower devonian
DM - Mid devonian
DU - Upper devonian
PR - Precambrian
RE - Recent
- Unclassed
U - UNCLASSED

PETR1 - PETROGRAPHY 1 LENGTH = 2
GENERAL- Same codes and descriptions for PETR2
SH - Shale
CA - Carbonate
GY - Gypsum
GR - Granite
LI - Limestone
AL - Alluvial
SN - Sandstone
- Unclassed

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KARST - KARST LENGTH = 1
K - Presence of Karst
- Unclassed

OCROP - OUTCROP LENGTH = 1
O - Presence of outcropping
- Unclassed

MATR1 - MATERIALS 1 LENGTH = 3
GENERAL- Same codes and descriptions for MATR2 and MATR3

AZ - Alluvial - Lacustrine
ALP - Alluvial - Lacustrine Plain
AT - Alluvial - Terrace
AP - Alluvial - Flood Plain
AF - Alluvial - Fan
AD - Alluvial - Delta
AO - Alluvial - Outwash
AL - Alluvial - Levee
AOP - Alluvial - Outwash Plain
APF - Alluvial - Flood Plain, Fan
CS - Colluvial - Frontal Slope
CV - Colluvial - Valley, Side Slope
EP - Eolian - Plain
ED - Eolian - Dune
ED1 - Eolian - Dune, Scif
ED2 - Eolian - Dune, Blow Out
ED3 - Eolian - Dune, Transverse
ED4 - Eolian - Dune, Elongated, Barchan
ED5 - Eolian - Dune, Complex
ED6 - Eolian - Dune, Barchan
ED7 - Eolian - Dune, Sandhill
GA - Glacial - Ablation Till
GP - Glacial - Till Plain
GF - Glacial - Fluted Till
GLP - Glacial - Lacustrine Plain
GLK - Glacial - Lacustrine, Beach Ridges
GLT - Glacial - Lateral Moraine
GPT - Glacial - Lateral Moraine Till Plain
GL - Glacial - Lacustrine
LP - Lacustrine - Plain
LS - Lacustrine - Salt Flat
LSP - Lacustrine - Salt Plain
LR - Lacustrine - Beach Ridges
O - Organic
M - Marl
R - Bare Rock
G - Glacial

BEDR1 - BEDROCK 1 LENGTH = 1
GENERAL- Same codes and descriptions for BEDR2 and BEDR3

G - Granite
H - Shale
L - Limestone
P - Limestone
S - Sandstone
- - Shale and Sandstone

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EROSI - EROSION I

LENGTH = 2

GENERAL- Same codes and descriptions for EROB1, EROS2, EROB2, EROS3

A - Eolian
F - Fluvial
G - Gullying
K - Karst
M - Mass movement
S - Solifluction
W - Sheet wash
KA - Combination of karst and eolian
MG - Combination of mass movement and gullying
FG - Combination of fluvial and gullying
MF - Combination of mass movement and fluvial
A - Eolian

STRT1 - STRATIGRAPHIC POSITION I LENGTH = 1

GENERAL- Same codes and descriptions for STRT2 and STRT3

I - Material over material
B - Material over bedrock
U - Material with material

SLOP1 - SLOPE I

LENGTH = 2

GENERAL- Same codes and descriptions for SLOP2 and SLOP3

00 - 0%
05 - 5%
21 - 21%
98 - 10%
99 - 5%
00 - 100%
01 - 1%
02 - 2.5%
03 - 2.5%
07 - 7%
11 - 11%
15 - 15%
58 - 58%

ASPC1 - SLOPE ASPECT I

LENGTH = 2

GENERAL- Same codes and descriptions for ASPC2 and ASPC3

E - East
S - South
N - North
W - West
SE - South East
NE - North East
NW - North West
EW - East West

PCNT1 - 2 COVERAGE

LENGTH = 2

GENERAL- Same codes and descriptions for PCNT2 and PCNT3

01 - 1%
05 - 5%
10 - 10%
35 - 35%
00 - 100%

- 150 -

SLM01 - SOIL MATERIAL I

LENGTH = 1

GENERAL- Same codes and descriptions for SLM02 and SLM03

- G1 - Glacial Till - sand, loamy sand, sandy loam
- G2 - Glacial Till - loam, silt loam, silt
- G3 - Glacial Till - clay, clay loam
- G4 - Glacial Outwash - coarse sand and gravel
- E5 - Eolian and Lacustrine Sand - coarse, medium sand or Alluvial
- E6 - Eolian and Lacustrine Sand - fine sand or Alluvial
- E7 - Eolian and Lacustrine Sand - very fine sand, sand, loam or Alluvial
- A8 - Lacustrine or Alluvial - silt, silt loam, loam
- A9 - Lacustrine or Alluvial - clay, silty clay
- OH - Organic - Humic
- OF - Organic - Fibric
- OM - Organic - Mesic
- G4 - Glacial outwash

SLR01 - SOIL REACTION I

LENGTH = 1

GENERAL- Same codes and descriptions for SLR02 and SLR03

- U - Acidic pH 5
- I - Neutral pH 5.5
- 2 - Alkaline pH 7.4

SLD01 - SOIL DRAINAGE

LENGTH = 1

GENERAL- Same codes and descriptions for SLD02 and SLD03

- 1 - Rapid
- 2 - Well
- 3 - Moderately well
- 4 - Imperfect
- 5 - Moderately poor
- 6 - Poor

SLS01 - SPECIAL CONDITIONS I

LENGTH = 1

GENERAL- Same codes and descriptions for SLS02 and SLS03

- F - Fibric
- M - Mesic
- H - Humic
- E - Evaporites
- D - Disturbed Soils
- S - Saline Soils

SLP01 - SOIL PERCENTAGE

LENGTH = 1

GENERAL- SAME CODES AND DESCRIPTIONS FOR SLP02 AND SLP03

- 9 - 90-100%
- 8 - 80-89%
- 7 - 70-79%
- 6 - 60-69%
- 5 - 50-59%
- 4 - 40-49%
- 3 - 30-39%
- 2 - 20-29%
- 1 - 10-19%
- 0 - 0-9%

- 151 -

2BVEGI - BIOPHYSICAL VEGETATION I LENGTH = 2

GENERAL- Same codes and descriptions as VIPCH for BVC01-BVC02

99 - Meadows: Seasonally submerged (142)
Seasonal shortgrass (3)
Wet meadows (4)
Semi-open prairie (5)
Salt flats saline meadows (6)

98 - Ericaceous shrubland/thicket
7 - Willow-alder thicket
9 - Aspen-balsam poplar in prairie
10 - Aspen-balsam poplar dominated mixed forest
11 - White spruce dominated mixed forest
12 - White spruce on feather moss
13 - Disturbed areas after severe fire
14 - Pine dominated mixed forest
15 - Pine on feather moss
16 - Pine heath
17 - Wet muskeg
18 - Shrub muskeg
20 - Black spruce on sphagnum
21 - Black spruce dominated mixed forest
5 - Semi-open prairie
0 - unclassified

APPENDIX II
CLDS OFFICES

Canada Land Data System
Lands Directorate
Environment Canada
Ottawa, Canada K1A 0E7
Phone: (819) 997-2510

Lands Directorate
Atlantic Region
Environment Canada
P.O. Box 365
Halifax, Nova Scotia B3A 2Y3
Phone: (902) 426-4196

Lands Directorate
Quebec Region
Environment Canada
P.O. Box 10100
Ste-Foy, Quebec G1V 4C7
Phone: (418) 694-4613

Lands Directorate
Ontario Region
Environment Canada
Box 5050
Burlington, Ontario L7R 4A6
Phone: (416) 637-4551

Lands Directorate
Pacific and Yukon Region
Environment Canada
1001 West Pender Street
Vancouver, British Columbia
V6E 2M7
Phone: (604) 666-3161

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1 2 4 0 9 1 8 4

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