CEAMF STUDY: VOLUME 2

CUMULATIVE EFFECTS INDICATORS, THRESHOLDS, AND CASE STUDIES

FINAL

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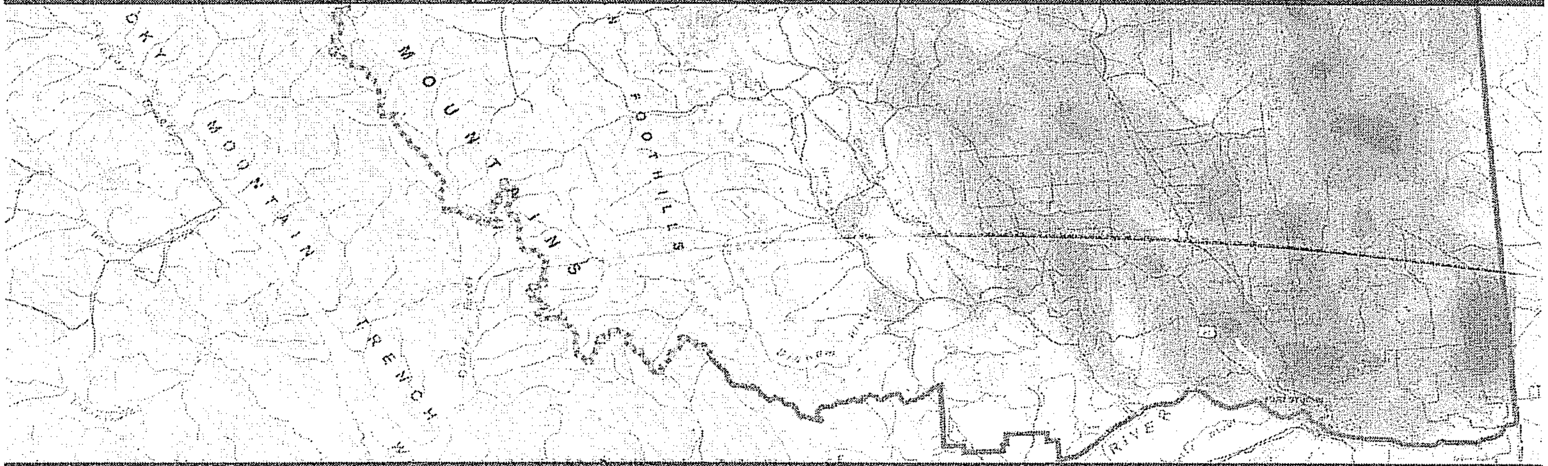

PREPARED FOR: THE BC OIL AND GAS COMMISSION - THE MUSKWA-KECHIKA ADVISORY BOARD

Cumulative Effects Assessment and Management
for
Northeast British Columbia

Volume 2
Cumulative Effects Indicators, Thresholds, and Case Studies

Prepared for:

British Columbia Oil and Gas Commission
Muskwa-Kechika Advisory Board

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EXECUTIVE SUMMARY

Cumulative effects are changes to the environment caused by the collective past, present, and future human actions; most result from the combined effects of simple, routine activities. There are four general types of cumulative effects: alteration, loss, and fragmentation of habitat; disturbance; barriers to movement; and direct and indirect mortality.

Management of cumulative effects is largely focused on defining where and how human activities can be continued without irreversible net harm to the environment. Thresholds (objective, science-based standards) based on ecological indicators can be used to evaluate the acceptability of both cumulative and project-specific effects. When properly derived and implemented, thresholds allow development activities to proceed without detailed review until the defined criterion is reached; at this point, additional review or regulation is initiated. To date, the best examples of thresholds are established air and water quality guidelines. For cumulative effects management, the most practical thresholds incorporate land-use and habitat indicators; these are being developed, but have not yet been widely applied on provincially-regulated lands.

To assess and manage cumulative effects in northeast British Columbia, we recommend the use of the following four complementary indicators:

- Land-use Indicators: Access Density, Stream Crossing Index
- Habitat Indicators: Core Area, Patch and Corridor Size

This report tested the applicability of various land-use and habitat indicators in the Blueberry and Sukunka study areas. Access density and core area size were both significantly related to moose and elk population indices in the Case Study areas; their predictive power was equivalent to that of more detailed and costly habitat indicators.

While road and trail density has been shown to be a practical cumulative effects indicator, results of the current Blueberry and Sukunka Case Studies suggest that previously published relationships between access density and large wildlife species may not apply directly to northeast British Columbia. This region has relatively low road and population densities, compared with other locations studied. As well, the intensity of road use is fairly low. In other areas, predators appear to select areas close to low-use roads, trails, and seismic lines while prey species appear to avoid them (presumably due to increased predation risk). This suggests that large predators may not be avoiding the physical feature the road represents, but rather the positive correlation between road density and number of encounters with humans.

A tiered threshold approach has been recommended since it provides a clear and integrated framework for derivation and implementation of ecological thresholds. With this approach, science-based and politically defined targets can be integrated with defined management actions so that operating rules are clear for all parties. As well, tiered thresholds provide the flexibility necessary for different land management regimes and ecological settings, and for a full spectrum of development proposals.

An implementation scheme for tiered thresholds is provided, using candidate access density and core area thresholds as examples. This implementation scheme is based on the existing resource management and review process and considers both project risk (i.e., simple, normal, complex) and land management regime (i.e., Land and Resource Management Plan Resource Management Zones) as a surrogate for acceptable change. Potential project-specific and cooperative management actions are related to these thresholds.

This information provides a foundation for threshold development and implementation but it is impractical to assume that this can immediately be applied to the entire region. The 'adaptive management' approach suggests that proposed management actions should be rigorously tested before they are widely applied.

The land use footprint in much of northeast British Columbia currently exceeds one or more candidate thresholds. Formal evaluations are recommended to allow government, industry, and other regional groups to understand the implications of threshold implementation and to ensure that derived thresholds provide an appropriate balance between environmental protection and economic development in the region. A variety of integrated management models, including the ALCES model tested in the Blueberry Case Study, are available for such evaluations.

Implementation will require agreement on definitions of acceptable change, threshold values, a standard public database, a standard process to calculate indicator values using this database, and project-specific and cooperative management actions to be implemented. The existing public database will need to be enhanced and made more readily accessible.

A pilot study is recommended to test the candidate thresholds and implementation process and ensure that they provide an appropriate balance between environmental protection and socio-economic interests, i.e., they reflect 'acceptable change' as defined by regional stakeholders. Stakeholders who will be affected by threshold implementation should be involved in designing and evaluating the pilot. This will allow the ecological, economic, and social implications of threshold implementation in northeast British Columbia to be explicitly considered.

Two areas are proposed for consideration: the Jedney Enhanced Resource Development Resource Management Zone in the Fort St. John Forest District, and the Etsho Enhanced Resource Development Resource Management Zone in the Fort Nelson Forest District. These are areas of ongoing interest from the petroleum and forest sectors that support boreal- and northern-ecotype woodland caribou. As demonstrated in the Case Studies, this species is extremely sensitive to cumulative effects of habitat fragmentation and disturbance. Both areas have existing data that can be used to enhance our understanding of animal response to combined natural and human disturbance and to test management actions that will effectively and practically address cumulative effects.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

Access corridor – a linear feature created by humans (road, trail, pipeline, powerline, railway line, cutline) that may be used by pedestrians, vehicles, hunters, anglers, or animal predators.

ALCES – 'A Landscape Cumulative Effects Simulator' computer model used to forecast changes in landscape patterns and wildlife habitat. This simulator integrates four submodels (habitat availability, population, land use, and natural disturbance) and considers all land use activities likely to occur in the region. It includes both aquatic and terrestrial indicators and is able to incorporate random events such as fire.

Barrier – a barrier is present when it is not possible for animals to move across a corridor, and the habitat on either side of the corridor becomes isolated (e.g., a busy highway is a barrier for small ground-dwelling insects)

Biodiversity – the diversity of plants, animals, and other living organisms in all their forms and levels of organization (BCF and BCE 1995a). The basic goal of biodiversity conservation is to maintain naturally occurring ecosystems, communities, and native species (CEQ 1993).

Biogeoclimatic zone – a geographic area having similar patterns of energy flow, vegetation and soils as a result of a broadly homogeneous macro-climate (BCF and BCE 1995a).

Cautionary threshold – a threshold established to indicate that additional or more intensive monitoring is required to provide sufficient local data to confirm scientific predictions of both target and critical thresholds.

CEAM – Cumulative Effects Assessment and Management framework consisting of an overall strategy for identifying, scoping, assessing, and managing cumulative effects in northeast British Columbia.

Core area – an area with minimal human impacts. Core areas are relatively undisturbed, 'unroaded' areas; they are often source areas for plant and animal populations or metapopulations.

Corridor – a reasonably uniform, linear feature that differs from its surrounding landscape. Corridors can occur naturally (e.g., river valley; windrow, aeolian ridge) or as the result of human disturbance (e.g., roads, cutlines).

Critical threshold – a science-based target reflecting the continuous maximum amount of stress that a sensitive ecosystem or species can support without sustaining long-term harm. This may incorporate economic and social values to determine the acceptable magnitude of change, risk of long-term damage, or level of protection required.

Cumulative effects – changes to the environment caused by collective past, present, and future human actions; most result from the combined effects of simple, routine activities and projects.

DC – Disturbance Coefficient; an index assigned to each feature or activity type that rates the degree to which the disturbance zone of influence remains effectively useable by the species. Ratings are on a scale of 0 to 1 and are used to calculate habitat effectiveness.

Density-dependent – factors that affect population growth and parameters in relation to as animal abundance. These depress population growth as animal abundance increases, and increase growth as animal abundance decreases. Examples include food availability and quality. Predation may be density-dependent or –independent.

Density-independent – factors that affect population growth and parameters regardless of animal abundance. Examples include natural environmental disturbances such as fire, floods, or severe weather. Predation may be density-dependent or –independent.

Disturbance – a natural or human action that affects physical, chemical, or biological conditions.

Disturbance feature – a corridor or patch created by natural random events (e.g., burn or flood) or human action (e.g., cutblock, facility, community, road).

Disturbance trajectory – the calculated or predicted rate of natural or human disturbance.

Drainage - a subset of a watershed, generally less than 1,000 km^2 in size.

Early seral – forest that are younger than 40 years old (BCF and MELP 1999b).

Ecological resilience – the ability of a system or species to absorb natural and human disturbance without altering its fundamental structure (Weaver et al. 1996).

Ecological sink – an area with degraded habitat that has lower survival (or higher mortality) rates, causing local population declines. Although individual animals may continue to use this area, it creates a net loss to the population that may not be detectable for several generations.

Edge area - the area bordering patches and corridors where abiotic conditions (e.g., moisture, light, temperature, wind regimes) and biotic conditions (e.g., predation, mortality, competition, vegetation diversity and structure, species diversity and abundance) may be altered. Examples include the intersection between a cutblock and forest or a trail and native grassland.

Filter or porous barrier – a type of corridor across which some movement occurs but the rate of movement is less than through intact habitat (e.g., a busy highway is a porous barrier for large mobile wildlife like deer [*Odocoileus* spp.]).

Fragmentation – the process of losing habitat continuity through temporary or permanent conversion of lands for human use (e.g., clearcutting forest, tilling native prairie for agriculture). Three general effects result from habitat fragmentation: (1) original habitat is lost, (2) remaining habitat patches decrease in size, and, (3) patches become increasingly isolated from one another.

Habitat – the environment in which an organism or biological population lives or grows.

Habitat alteration – habitat alteration occurs with disturbance of original habitat. *Temporary habitat alteration* occurs when pre-disturbance conditions are allowed to re-establish (e.g., forest regrowth after harvest). *Permanent terrestrial habitat alteration* occurs when different vegetation becomes established on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production; introducing non-native species). *Permanent aquatic habitat alteration* occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by upstream activities.

Habitat availability – the amount of usable habitat accessible to a particular species.

Habitat capability – the ability of a habitat unit to provide the life requisites of a species under optimum natural (seral) conditions, regardless of the current condition of the habitat, or the numbers of that species that are currently using the habitat (RIC 1999).

Habitat effectiveness – habitat quality, as perceived by a particular species. For instance, when a species uses the area around a man-made facility less than nearby areas of identical habitat, there has been a decrease in habitat effectiveness for that species.

Habitat loss – loss of habitat can occur in either terrestrial or aquatic ecosystems. *Terrestrial habitat loss* occurs when human activities disturb the soil or remove vegetation and regrowth is not allowed to occur (e.g., construction of a city, highway or industrial facility). *Aquatic habitat loss* occurs when water is removed, chemistry is substantially altered, or the structure of the waterbody is substantially altered.

Habitat suitability – the ability of a habitat unit, in its current condition, to provide the life requisites of a species. This rating is irrespective of the numbers of that species that are currently using the habitat (RIC 1999).

Habitat unit – a defined terrestrial or aquatic unit with consistent abiotic and biotic conditions.

Hazard level – the risk of an adverse cumulative hydrological effect defined by the British Columbia Interior Watershed Assessment Procedure (IWAP; BCF and BCE 1995b, BCF 1999).

Human activity – all forms of human actions including land conversion and disturbance, damming, water withdrawal, pedestrian, vehicle and aircraft movements, harassment, harvest, and contaminant input.

Index or metric – a numerical value used to represent or monitor the condition of an abiotic or biotic resource.

Indicator – a surrogate measure used to represent or monitor the condition of an abiotic or biotic resource. May be a representative species, an outcome, or an input.

Interior area – also referred to as core area in this report. Interior areas are those beyond the influence of edge effects.

IWAP – Interior Watershed Assessment Procedure; a method developed by the provincial government to help forest managers understand the type and extent of current water-related problems in a watershed, and to recognize the implications of proposed activity in that watershed (BCF 1999).

Juvenile – an individual age 1 or older that has not reached maturity.

Landscape – an area of tens to hundreds of square kilometres that includes one dominant background ecosystem. Northeast British Columbia consists of a number of landscape types including the forest landscape, the agricultural landscape, and the alpine/subalpine landscape.

Local population - A breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Lowest observed effect level – concept from the field of ecotoxicology that represents the lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms compared to the controls. Also called lowest observed adverse effect level (LOAEL). This concept is also applicable to behavioural, physiological, and population response.

LU – Landscape Unit; an area of land and water used for long-term planning of resource management activities according to the *Forest Practices Code of British Columbia Act*. It may be used for designed strategies and patterns for landscape level biodiversity and for managing other forest resources (BCF and MELP 1999b).

LRMP – Land Resource Management Plan; a plan approved by the provincial government that establishes direction for land use and specifies broad resource management objectives and strategies.

Matrix – the dominant background ecosystem or land-use type within a habitat mosaic. Within the matrix, patches and corridors are reasonably uniform areas and linear features that differ from their surroundings.

Mature growth/mature seral – forests greater than a specified age (generally >80 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Metapopulation - a population of populations. This represents an abstraction of the population concept to a higher level. Metapopulations generally consist of a group of interacting but spatially discrete or isolated populations, subpopulations, or stocks. These subunits are linked by drainage networks but movement between subunits is infrequent and typically takes place across unsuitable habitat or over great distances (Hanski and Gilpin 1991; Dunham and Rieman 1999). An example of a fish metapopulation is a group of isolated headwaters populations found in the same watershed.

MSRM - British Columbia Ministry of Sustainable Resource Management

Natural disturbance type – an area characterized by a natural disturbance regime. The provincial government has established five natural disturbance types for managing biological diversity according to the *Forest Practices Code of British Columbia Act* (BCF and BCE 1995a; BCF and MELP 1999b).

OGC – British Columbia Oil and Gas Commission.

Old growth/old seral – forests greater than a specified age (generally >100 years) based on biogeoclimatic zone and dominant species (BCF and MELP 1999b).

Patch – a reasonably uniform area that differs from its surrounding landscape. Patches can occur naturally (e.g., sloughs, burns) or as the result of human disturbance (e.g., farmyards, wellsites, clearcuts).

Population – a group of interacting individuals of the same species in a defined area distinguished by a distinct gene pool or distinct physical characteristics.

Population limiting factors – processes that quantifiably affect the population rate-of-increase. Responsible for inducing year-to-year changes in animal abundance (Messier 1991).

Population regulating factors – density-dependent processes that ultimately keep populations within normal density ranges. These are a subset of limiting factors and predictably depress population growth as animal abundance increases (Messier 1991).

Reach – a defined watercourse channel section, tens to thousands of meters in length, with relatively consistent channel morphology, hydrology, and water chemistry.

Regional - an area more than hundreds of square kilometres that incorporates several landscapes.

Riparian - the banks and slopes next to streams, lakes and wetlands that are affected by elevated soil moisture levels for at least part of the year. These riparian areas protect water quality, stabilize banks, provide a continuous source of woody debris, nutrients, and food organisms, and regulate stream temperature (BCF and BCE 1995c; BCF and MELP 1999b).

Riparian clearings - cleared areas within 15 m of a waterbody, including linear corridors, communities and residences, industrial and commercial facilities, cutblocks, and agricultural fields.

Riparian roads - roads and trails within 100 m of a waterbody.

RMZ – Resource Management Zone; defined subdivisions of an approved LRMP that have unique sets of resource values, objectives to maintain or enhance those values, and a number of strategies to be implemented to achieve those objectives. These provide geographically-focused, strategic direction (Fort St. John LRMP 1997).

Seral stage – the stages of natural ecological succession of a plant community, for example from young through mature to old stage (BCF and BCE 1995a).

Stream crossing - a road, trail, pipeline, powerline, railway line, or cutline crossing of a watercourse.

Subpopulation - a breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

Subwatershed - a subset of a watershed, generally less than 1,000 km^2 in size.

Target threshold – a politically-defined goal reflecting the optimum amount of stress on the system. This threshold is more protective than the critical threshold to provide a margin of safety. A target threshold can be characterized as the level that is politically and practically achievable and provides adequate long-term protection to the environment or resource of interest.

Threshold – a point at which a resource changes to an unacceptable condition, with acceptability defined either from an ecological or social perspective.

Viable population – a self-sustaining population with a high probability of survival despite the foreseeable effects of demographic, environmental, and genetic stochasticity and of natural catastrophes (BCF and BCE 1995a).

Waterbody – a specific aquatic basins or channel (lake, pond, wetland, river, or stream).

Watercourse – a specific flowing channel (river or stream).

Watershed – a large drainage area, generally 1,000 to 10,000 km^2 in size, which flows directly into a large river such as the Peace River.

WHA – Wildlife Habitat Area contain critical habitat elements for one or more species of Identified Wildlife. These areas are mapped and approved by the Chief Forester and WLAP according to the *Forest Practices Code of British Columbia Act.*

WLAP – British Columbia Ministry of Water, Land and Air Protection.

ZOI – Zone of Influence; the distance to which a species is affected by an activity or disturbance.

SECTION 1: INTRODUCTION

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY

1. INTRODUCTION

To address the environmental effects associated with oil and gas development, the British Columbia Oil and Gas Commission (OGC) established an environmental fund for research projects. In 2001, cumulative effects was one of three research envelopes for which funding was provided.

1.1 CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK

Salmo Consulting Inc. (Salmo), Diversified Environmental Services (Diversified), AXYS Environmental Consulting Ltd. (Axys), and GAIA Consultants Inc. (Gaia) received funding to conduct three separate but integrated cumulative effects studies. Together, these studies provide an overall strategy for identifying, scoping, assessing, and managing cumulative effects in northeast British Columbia (hereafter referred to as Cumulative Effects Assessment and Management, or CEAM). The CEAM framework will ensure that cumulative effects are consistently addressed and managed as part of the OGC's ongoing project approval process.

The three components of the CEAM strategy are:

1. **CEAM Framework**: Development of an overall approach, specific to northeast British Columbia, for conducting project-specific and regional cumulative effects assessments. The framework will recommend:
    - approaches for scoping cumulative effects assessments (e.g., important regional issues, selection of indicators for ecosystem and socio-economic effects, setting spatial and temporal boundaries, identification of projects and human actions appropriate to consider in a CEA),
    - analytical approaches and tools (including management determination of impact significance),
    - mitigation approaches, and
    - follow-up and monitoring needs.

    As part of the CEAM framework, a spatial overview of existing cumulative effects in the Muskwa-Kechika Study Area (Figure 1) will be developed to identify potential areas of concern.

2. **Cumulative Effects Case Studies**: Detailed assessment of cumulative effects in two representative areas in northeastern British Columbia to demonstrate the application of the CEAM Framework with specific regional data. Project outputs will include:
    - a literature review on appropriate ecological indicators and thresholds for fish and wildlife management,

- a spatial database of existing biophysical and land use features for each representative area,
- a review of development and renewable resource trends for each representative area,
- the application of various methods and indicators to assess cumulative effects,
- identification of candidate thresholds for northeast British Columbia,
- recommendations on the use of these thresholds for cumulative effects assessment and management, and
- identification of implementation and data needs.

Information from the Case Studies will be used to modify and refine the CEAM Framework.

3. **Decision Support**: Decision support systems are valuable tools when evaluating competing land-use demands. They provide a systematic and consistent method for decision-making, as well as an audit trail. In the case of the OGC, the decision support system must allow rapid assessment of applications for a wide range of activities. This component will include:

    - developing and testing an application screening process for decision-making on cumulative effects management for petroleum exploration, development, and production proposals;
    - recommendations for establishing, managing, and updating regional databases; and,
    - recommended approaches for staff training.

    The decision support system will reflect the CEAM Framework and incorporate Case Study findings.

All three components will build from the results of existing and past initiatives such as Land and Resource Management Plans (LRMP), Forest Renewal BC policy, plans and studies, Ministry of Water, Land and Air Protection (WLAP) and Ministry of Sustainable Resource Management (MSRM) inventory and research, Muskwa-Kechika Trust Fund research, and ongoing research funded by the OGC.

1.2 CUMULATIVE EFFECTS CASE STUDIES

The Cumulative Effects Indicators, Thresholds, and Case Studies (Case Studies) component focuses on the Blueberry and Sukunka study areas in plateau and foothills habitat northwest and southwest of Fort St. John respectively (Figure 1). These areas were selected with the input of government, industry, and public stakeholders.

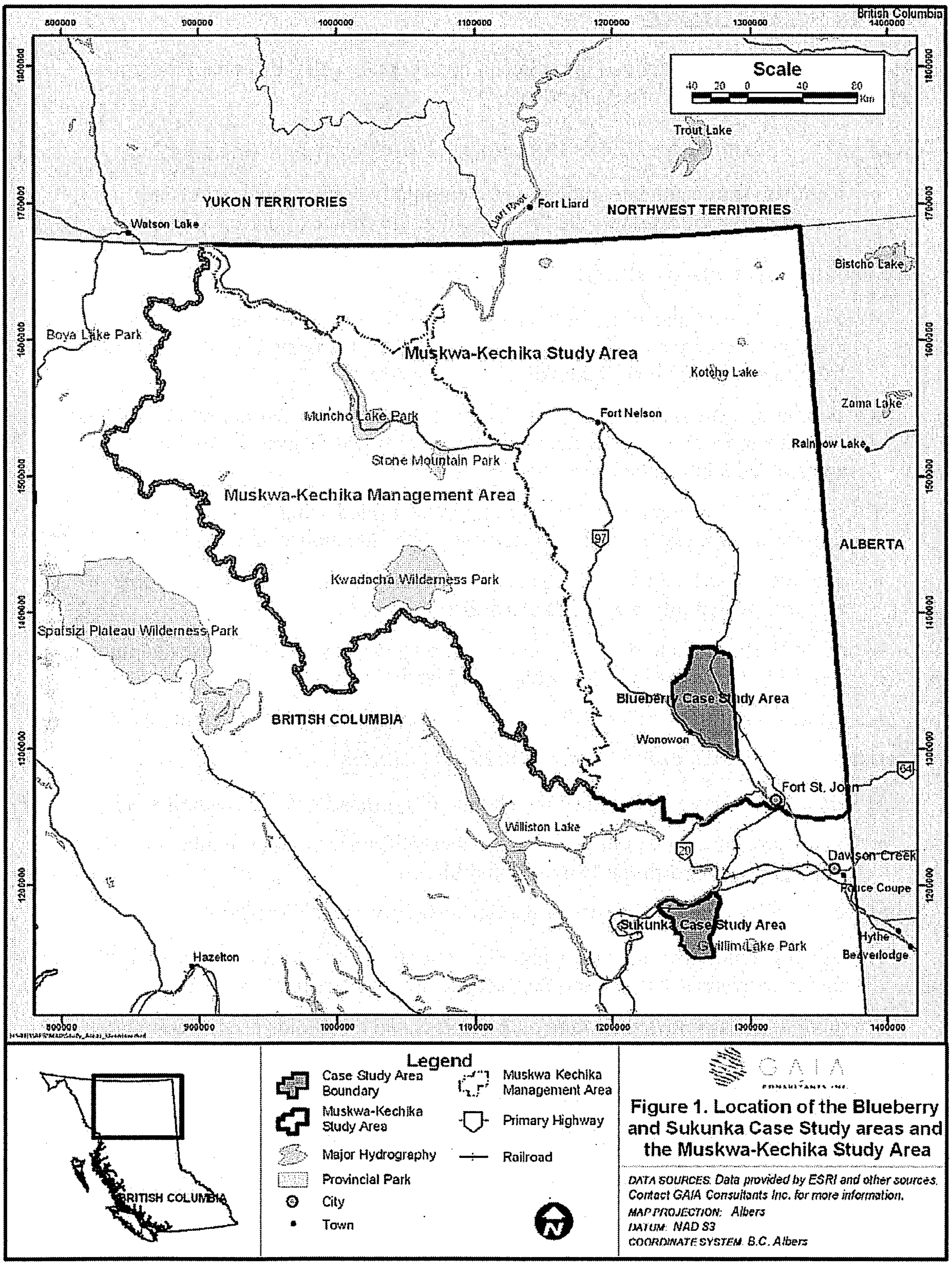


Figure 1. Location of the Blueberry and Sukunka Case Study areas and the Muskwa-Kechika Study Area

DATA SOURCES: Data provided by ESRI and other sources. Contact GAIA Consultants Inc. for more information.
MAP PROJECTION: Albers
DATUM: NAD 83
COORDINATE SYSTEM: B.C. Albers

1.3 REPORT OUTLINE

As follows, this report is divided into three main sections, with the detailed literature review and Case Studies in the appendices.

Section 2. Cumulative Effects Indicators for Northeast British Columbia

- identifies four candidate indicators for cumulative effects evaluation and management and explains the theory behind the choice of these indicators.

Section 3. Cumulative Effects Case Studies

- evaluates the applicability of the recommended cumulative effects indicators for OGC project-screening in northeast British Columbia using detailed regional data from the Blueberry and Sukunka Case Study Areas,
- summarizes the spatially explicit Geographic Information System (GIS) models that document existing development and biophysical features in the Case Study areas (details in Appendices 2 and 3),
- summarizes the cumulative effects analyses (applied using the CEAM framework) for the Case Study areas (details in Appendices 2 and 3),
- projects future land use and human activity patterns and possible renewable resource availability, abundance, and distribution,
- relates historical and projected renewable resource trends to land use and human activity patterns, and identifies apparent thresholds, and
- evaluates utility of existing data for use in cumulative effects assessments.

Section 4. Thresholds in Northeast British Columbia

- identifies proposed ecological thresholds for northeast British Columbia, and
- identifies a process to implement these thresholds and enhance cumulative effects management in northeast British Columbia.

Appendix 1. Cumulative Effects: Sources, Indicators, and Thresholds

- reviews cumulative effect concepts (i.e., alteration, loss, and fragmentation of habitat; barriers to movement; disturbance; direct mortality), and
- summarizes scientific literature on indicators and thresholds used in cumulative effects assessment.

Appendix 2. Blueberry Cumulative Effects Case Study

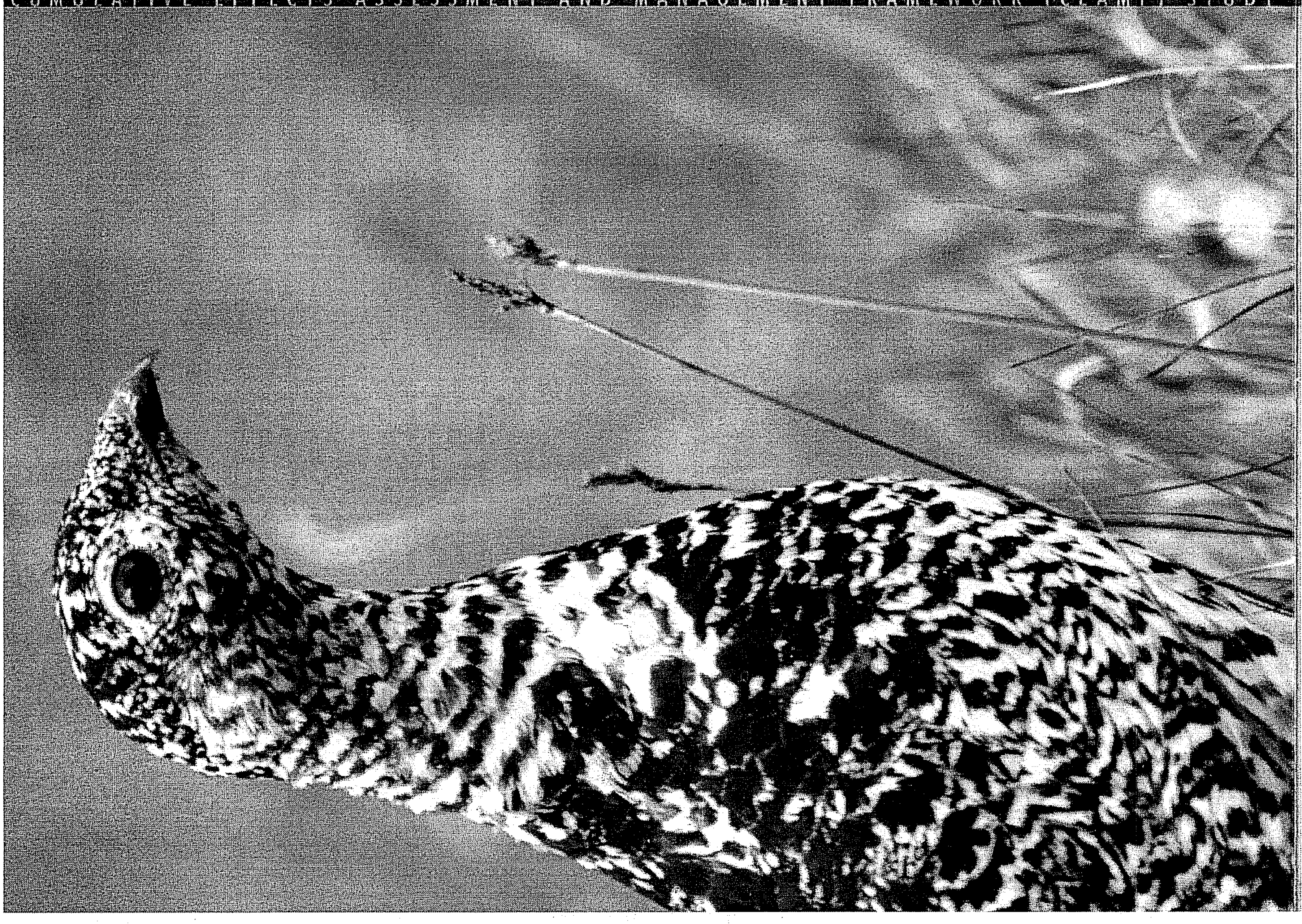
- provides a stand-alone Case Study report for the Blueberry area.

Appendix 3. Sukunka Cumulative Effects Case Study

- provides a stand-alone Case Study report for the Sukunka area.

SECTION 2: CUMULATIVE EFFECTS INDICATORS

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY



2. CUMULATIVE EFFECTS INDICATORS FOR NORTHEAST BRITISH COLUMBIA

2.1 DEFINITION OF CUMULATIVE EFFECTS

Cumulative effects are environmental changes caused by combined past, present, and future human actions. Over the last twenty years, cumulative environmental effects have received increasing interest; it is now recognized that the combined effects of unrelated individual activities can be different in nature or extent from the sum of the effects of each individual activity (Contant and Wiggins 1991; FEARO 1994; Riffell et al. 1996).

In northeast British Columbia, cumulative effects result from direct loss and alteration of habitat due to petroleum exploration and production, forest harvest, agriculture and cattle grazing, recreational use; municipal, urban, and residential development, and other industrial activities. Indirect disturbance and wildlife harvest also occurs due to use of roads and trails by recreational and subsistence users (e.g., hunters, anglers). Cumulative effects can be classified into four types:

1. Habitat alteration, loss, and fragmentation,
2. Barriers to movement,
3. Direct and indirect mortality, and
4. Disturbance.

In some cases, the combined effect on a species or population of interest may be greater than would be expected by adding the individual effects. For example, livestock are attracted to wellsites, and cause trampling and increased spread of non-native and invasive species. This expands the total area of habitat loss and alteration beyond that attributable to petroleum production or grazing alone.

2.2 EVALUATING CUMULATIVE EFFECTS

Cumulative effects evaluation differs from conventional project-specific environmental assessment by considering larger geographic study areas, longer time frames, and all projects or activities that have been, or will be, carried out. Specific guidance for evaluation of cumulative effects in Canada is provided in FEARO (1994), CEAA (1996), Davies (1996), Hegmann et al. (1999), and AENV et al. (2000).

There are two main types of cumulative effects evaluations:

- **Resource management** studies consider the effects of all possible past, present, and reasonably foreseeable future disturbance sources (industrial, municipal, agricultural, domestic, recreational) over large geographic areas and long time frames (10-100 years). These regional studies normally gather available information, project future trends, and make management recommendations (e.g., Banff-Bow Valley Study 1996). To be most successful, regional assessments should include input from all interested stakeholders, and should be completed before human activities begin.

- **Project-specific** evaluations examine a proposed project in the context of other existing and likely disturbance sources; they are clearly the responsibility of the proponent. Potential combined effects are related to available environmental criteria to assess the significance of potential cumulative effects. Unfortunately, most proposed petroleum activities are located in areas currently lacking explicit cumulative effects criteria.

2.3 RECOMMENDED CUMULATIVE EFFECTS INDICATORS

In other areas, resource managers have concluded that a complementary suite of habitat and land-use indicators is the most practical and effective choice for cumulative effects assessment and management (Axys 2001b; BCC 2001). Land-use thresholds have been applied in the northwest United States for management of species at risk such as the grizzly bear (*Ursus arctos*) and spotted owl (*Strix occidentalis*; e.g., Lamberson et al. 1992; Mattson 1993; Bart 1995). In Canada, similar thresholds have been applied within national parks; research is underway to establish disturbance-based thresholds for grizzly bear and boreal-ecotype woodland caribou (*Rangifer tarandus*) in Alberta (Dugas and Stenhouse 2000; BCC 2001).

Indicators adopted for northeast British Columbia will be most effective when they are:

- based on management objectives identified in the Dawson Creek, Fort St. John, and Fort Nelson Land and Resource Management Plans (LRMPs),
- readily calculated, understood, and monitored,
- science-based, ideally using regional data,
- protective of fish and wildlife species of management and public concern,
- compatible with existing development review and assessment processes, and
- applicable to a wide range of ecological settings and development activities.

Table 1 identifies the suite of cumulative effects indicators recommended for northeast British Columbia based on the literature review included in Appendix 1.

Table 1. Recommended cumulative effects indicators.

Habitat Indicators	Land Use Indicators
Core Area	**Access Density** (km of corridors per unit area)
Patch and Corridor Size	**Stream Crossing Index** (number of crossings per km of stream)

The reasons for choosing these indicators will be explored in the following sub-sections. These indicators are tested against detailed regional data in the Case Studies (Section 3); Section 4 (Conclusions) presents candidate thresholds for these indicators.

2.3.1 Core Area, Habitat Indicator

Remaining **core area** is a widely used habitat index that quantifies the availability and location of areas with minimal human impacts. Core areas are relatively undisturbed, 'wilderness' areas and are often source areas for plant and animal populations or metapopulations.

Continuity of core areas is lost through natural disturbance or conversion of lands for human use (e.g., clearcutting forest, tilling native prairie for agriculture). This process is called **habitat fragmentation** (Collinge 1996; Jalkotzy et al. 1997). Three general effects result from habitat fragmentation (Figure 2):

- original habitat is lost,
- remaining habitat patches decrease in size, and
- patches become increasingly isolated from one another.

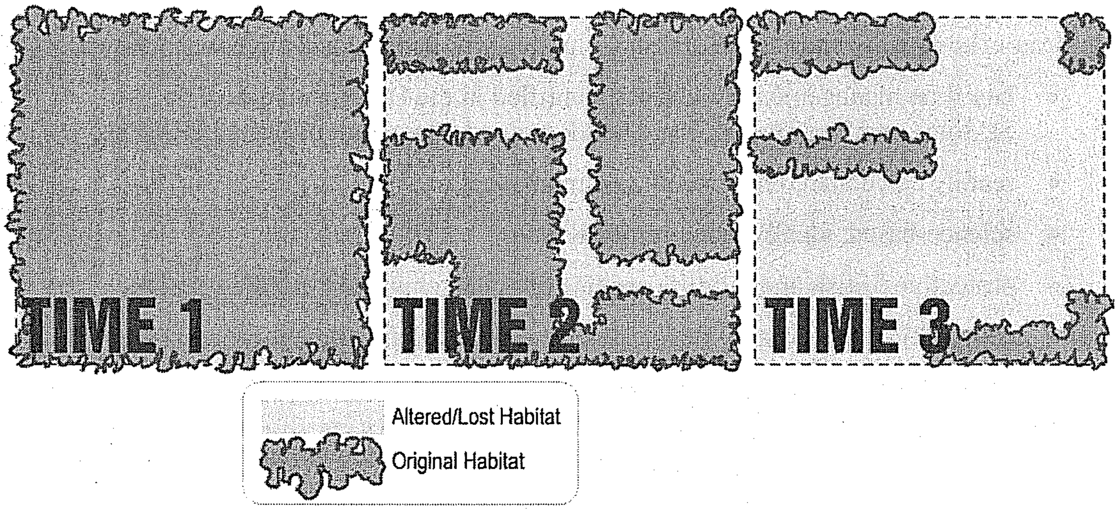


Figure 2. Representation of the habitat fragmentation process (adapted from Collinge 1996).

Core habitat is altered through **'edge' effects** at its boundaries when a new disturbance or corridor is introduced. Edge effects include altered microclimate, changes in habitat type and quality, altered predation patterns, and altered competition between species. Edges are particularly noticeable in forested landscapes, because of their dominant vertical structure. As fragmentation proceeds, edges between the patches and surrounding habitat increase in length and extent.

As depicted in Figure 3, edge effects are more pronounced in small or narrow patches. In very fragmented landscapes, all remaining habitat may be so close to an edge that no functional core habitat remains. As fragmentation proceeds, plants and animals that require core habitat are more likely to be affected than those with more flexible habitat needs.

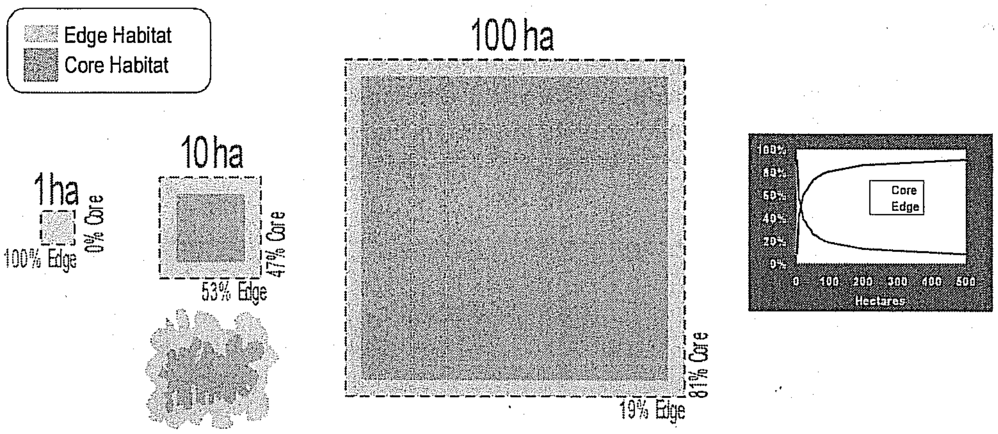


Figure 3. Relationship between patch size and edge area assuming 50 m edge width (adapted from Collinge 1996).

Core areas can be critical for population persistence in fragmented landscapes; conservation of these areas can be required to protect certain species (e.g., grizzly bear). Table 2 presents some examples of established core habitat guidelines.

Table 2. Examples of established core area guidelines.

	Guideline or Threshold	Comments
Core Area	>60% of available habitat as core area (Gibeau 2000).	Grizzly bear management threshold for Banff National Park.
	58 - 68% of available land as core areas (NCGBRT 2001).	Recommendation for grizzly bear recovery in the North Cascades of British Columbia.
	>60% of Forest Planning Area as roadless core wildlife habitat (Horejsi 1996).	Grizzly bear management recommendation for Yukon Territory.
	>40% of landscape in suitable habitat for habitat specialists such as interior forest songbirds (Wilcove *et al.* 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; With and Crist 1995).	Theoretical threshold based on modelling.
	Boreal-ecotype caribou populations declined when core area <50%; trend line identified threshold at <60% core area (Francis et al. 2002).	Threshold based on review of Alberta population data; used 250 m buffer from all linear features.
	>10 to 30% of landscape in suitable habitat for birds and mammals (Andren 1994).	Threshold based on review of Alberta population data, used 250 m buffer from all linear features.

2.3.2 Patch and Corridor Size, Habitat Indicator

Patches and corridors are reasonably uniform areas and linear features that differ from their surroundings. There are two main landscape types in northeast British Columbia. In the **forest landscape** (Figure 4), there are treed patches of variable size, age, structure, and species composition. Unforested openings associated with waterbodies, bedrock, and low-growing vegetative cover are also present. Within this matrix, there are human-disturbed patches such as wellsites and cut blocks, as well as disturbance corridors like roads, trails, and powerline and pipeline rights-of-way. The landscape outside forested areas (the **agricultural landscape**, Figure 5) is a human-dominated matrix with remnant areas of native trees, shrubs, and grasses in patches and along corridors (e.g., windrows or along road ditches).

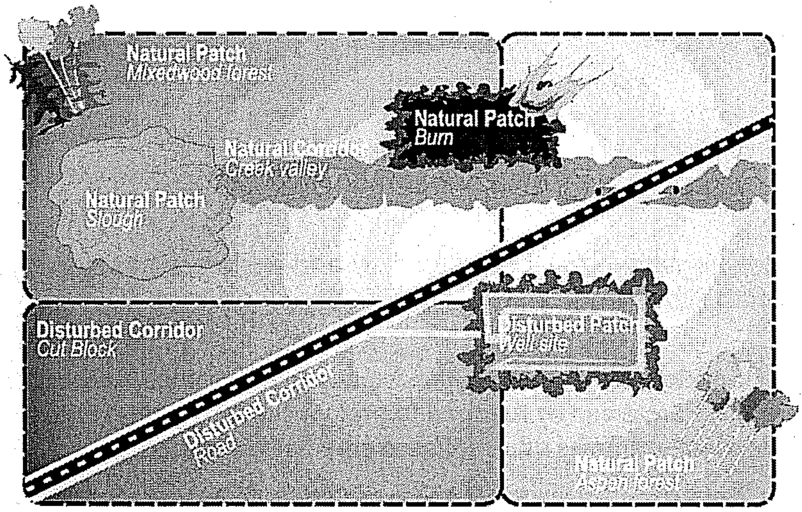


Figure 4. Patches and corridors within a forest landscape.

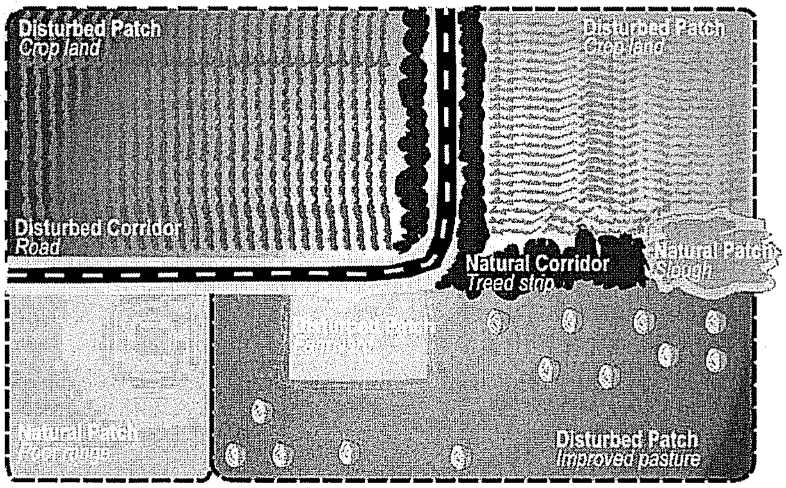


Figure 5. Patches and corridors within an agricultural landscape.

Cumulative effects occur where areas immediately adjacent to human-disturbed patches and corridors are used differently from nearby areas of identical habitat by individuals or species. This change in **'habitat effectiveness'** can accumulate over time and lead to reduced biodiversity and species abundance. In general, impacts are inversely related to the level and predictability of human disturbance. Unpredictable high-intensity activities (e.g., motorized snow machines, powerboats, gun shots) cause greater response than low intensity continuous activities (e.g., generator motor noise). Response of hunted animal populations is normally greatest. Animals may habituate to repeated or predictable disturbance that is perceived to be nonthreatening, lessening the loss of habitat effectiveness. However, as noted in Appendix 1, specific responses vary, and are complicated by many factors.

The shape of patches and corridors determines the amount of core habitat vulnerable to edge effects. Long, thin rectangles, like roads and cutlines, create more edge per unit area than other man-made features (Figure 6). As a result, they can have dramatic impacts on habitat effectiveness.

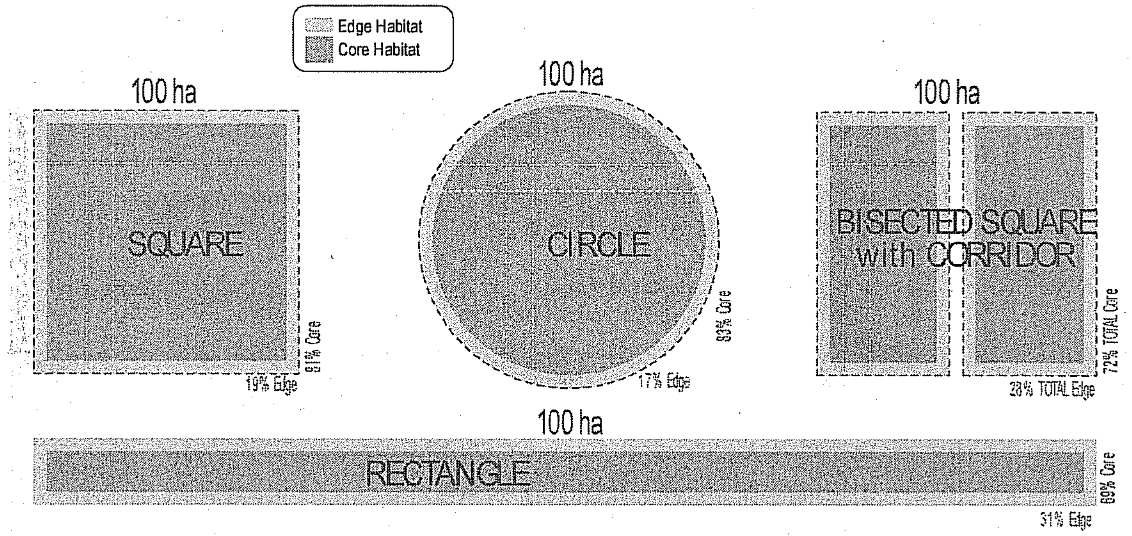


Figure 6. Relationship between patch geometry and edge area assuming 50 m edge width (adapted from Collinge 1996).

Corridors (and patches) can contribute to cumulative effects when animals are reluctant or unable to cross them. In general, the likelihood and magnitude of barrier effects increases as corridor width increases, the corridor becomes more dissimilar from surrounding habitat, and vehicular and human use of the corridor increases. A **barrier** is present when no movement occurs across a corridor and the habitat on either side of the corridor becomes isolated (e.g., an improperly constructed road culvert). If some movement occurs but the rate of movement is less than through intact habitat, then the corridor is considered a **filter** or **porous barrier**. The busy Alaska Highway would be considered a filter for large mobile wildlife such as deer but might represent a barrier for small ground-dwelling insect species.

Patch and corridor criteria can help define suitable habitat in fragmented landscapes. In the habitat fragmentation process, there appear to be 'critical thresholds' where rapid changes in patch size and isolation occur; criteria should reflect these critical thresholds. Table 3 presents some examples of established patch and corridor size guidelines.

Table 3. Examples of established patch and corridor size guidelines.

Indicator	Guideline or Threshold	Comments
Patch Size	>4.5 ha patch area for small and tolerant species (BCEAG 1999).	Based on literature review and local studies.
	Core area >10 ha in size, ideally >1,000 ha (NCGBRT 2001).	Recommendation for grizzly bear recovery in the North Cascades of British Columbia.
	Grizzly bear WHA security areas 1-500 ha; WHA foraging areas 5-250 ha (BCF and MELP 1999a).	Recommended British Columbia threshold; calculation method provided.
	Minimum patch size for 7 interior bird species ranged from 23 ha to 650 ha (Askins et al. 1987).	Based on studies in eastern mixedwood forest.
	>40 ha of suitable habitat in patch for persistence of black-throated green warbler (*Dendroica virens*; Hannon 1992).	Based on studies in central parkland of Alberta.
	>100-200 ha of suitable habitat in a patch for marten (*Martes americana*; Buskirk and Ruggiero 1994).	Based on literature review.
	200 ha undisturbed area for bull trout (*Salvelinus confluentus*; BCF and MELP 1999a).	Recommended British Columbia core area.
	Minimum core security area of 450 to 1,000 ha (Gibeau et al. 1996).	Grizzly bear core area used in western Canadian analyses based on 24 to 48 hour feeding bout of an adult female grizzly bear.
	>1,000 ha patch area for carnivores and sensitive species (BCEAG 1999).	Based on literature review and local studies.
Corridor Width	>200 m corridor width for moose (*Alces alces*; Nietfeld et al. 1985).	Based on literature review.
	>350 m corridor width for all species (BCEAG 1999).	Based on literature review; can be adjusted using prescribed formula to reflect security provided by vegetation and topography (BCEAG 1999).
	>600 m width for interior forest habitat conditions to be present (BCF and BCE 1995a).	Recommended British Columbia guideline.

2.3.3 Access Density, Land-Use Indicator

Road density is the best known and most widely applied land-use and access density indicator. This index represents the total length of roads, utility corridors (pipelines, powerlines, railway lines) or other human linear features present in a defined land area or watershed, and is usually expressed as km/km^2. It is a useful summary index because it integrates the many ecological effects of roads and vehicles (Forman and Hersperger 1996).

Roads are a very specific type of corridor. As long, narrow linear features, they create a very high edge per unit area (Figure 6). Thus, they can have dramatic impacts on the effectiveness of adjacent habitat. As well, the habitat occupied by the roads is temporarily or permanently lost. If the road is eventually reclaimed and allowed to revegetate, the habitat loss is temporary; permanent habitat loss may occur with public roads like highways.

Roads are of increasing concern for terrestrial and aquatic communities because research indicates that some animals under-use areas adjacent to active roads. Figure 7 depicts road-habitat effectiveness models developed for a hunted elk (*Cervus elaphus*) population; habitat effectiveness is inversely related to road density.

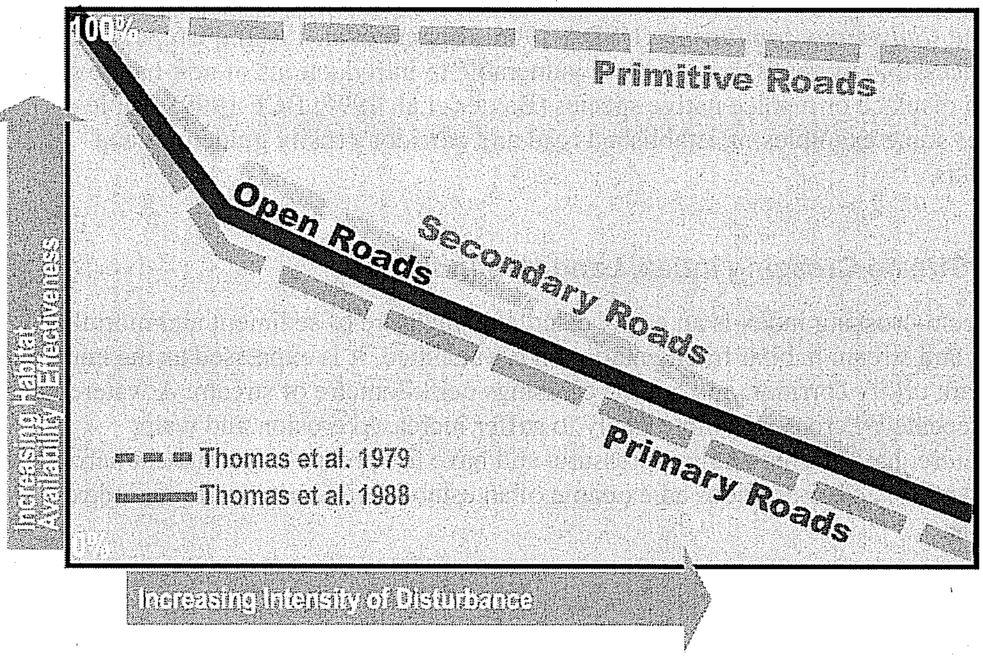


Figure 7. Impact of roads on predicted habitat effectiveness for elk (adapted from Thomas et al. 1979, 1988).

Figure 7 also illustrates the effect of disturbance intensity on habitat effectiveness. ‘Open roads’ is a summary class that includes all road types and is assumed to represent the average effect. Infrequently used access features like ‘Primitive Roads’ (truck trails) affect elk habitat use considerably less than more regularly used Primary and Secondary

Roads. This suggests that activity levels, rather than the roads themselves, are affecting the use of this habitat by local wildlife. The impact of cutlines and utility corridors (pipeline and powerline rights-of-way) may be lower since these features receive less human use, especially in lightly populated regions like northeast British Columbia. However, all types of linear corridors may increase predation rates by providing travel routes for wolves (*Canis lupus*), thereby increasing their search range and efficiency (Bergerud et al. 1984; Stuart-Smith et al. 1997; James and Stuart-Smith 2000). There is currently substantial debate on other effects (e.g., habitat fragmentation) associated with cutlines and utility corridors.

Access corridors can contribute to cumulative effects by increasing direct and indirect mortality rates. Primary and secondary roads can substantially increase vehicle collisions and direct mortality rates. All types of linear corridors can provide access for hunters and anglers, leading to increased harvest effort and success. These indirect mortality effects are difficult to manage (Mychasiw and Hoefs 1988; Trombulak and Frissell 2000). In addition, there is a tendency for roads and trails to be extended beyond their original destination, ultimately creating a permanent access network.

Increased road and trail density is related to increased sediment transport and peak flows in streams, and has been correlated with declines in trout and salmon species, including bull trout (*Salvelinus confluentus*; USDA 1996; Rieman et al. 1997). Fish populations in areas accessible by roads may be more vulnerable to introductions of non-native species that can displace or replace native species (Baxter et al. 1999; BCF 1999). Table 4 provides some examples of established road and corridor density guidelines and thresholds.

2.3.4 Stream Crossing Index, Land-Use Indicator

The stream-crossing index is an easily calculated measure of sediment and mortality sources and stream habitat fragmentation in a watershed. It is expressed as the number of road, trail, utility corridor, and cutline crossings per kilometre of stream. A watercourse that is repeatedly crossed is more likely to suffer increased erosion and water temperature, have higher angling pressure, and have temporary or permanent barriers to fish passage. Table 5 provides an example of an established stream crossing index guideline.

Table 4. Examples of established access density guidelines and thresholds.

Indicator	Guideline or Threshold	Comments
Road and Trail Density	▪ Road density <0.6 km/km^2 to protect high quality grizzly bear habitat (BCF and MELP 1999a).	▪ Recommended British Columbia threshold.
	▪ Density of calving barren-ground caribou highest at road density of 0 km/km^2 and declined by 86% at road densities >0.6 km/km^2; male and yearling density highest at 0.3-0.6 km/km^2 (Nellemann and Cameron 1998).	▪ Based on studies in Alaska petroleum development areas.
	▪ Road densities <0.6 km/km^2 in winter range used by northern-ecotype caribou range (Salmo unpub. data).	▪ Based on studies in west central Alberta.
	▪ Watersheds with >1 km/km^2 road density had degraded bull trout habitat (Craig 2001).	▪ Based on studies in Yakima River basin.
	▪ Grizzly bears selected areas with mean road densities of 0.6-0.68 km/km^2; areas with road densities >6 km/km^2 did not support grizzly bears (Mace et al. 1996; McLellan and Hovey 2001).	▪ Based on studies in northern Montana and southeast British Columbia.
	▪ Road densities >0.6 km/km^2 affect habitat usage by wolves and elk (Lyon 1983, 1984; Thiel 1985; Mech 1989; Edge and Marcum 1991; Rowland et al. 2000).	▪ Effects can be mitigated by the presence of visual barriers and adjacent unroaded areas.
	▪ Road density <1.5 km/km^2 to protect bull trout (BCF and MELP 1999a).	▪ Recommended British Columbia threshold; additional site-specific work required beyond this point.
	▪ Bull trout populations seven times more likely to be strong in subwatersheds with road densities <1.55 km/km^2 (Rieman et al. 1997).	▪ Based on study in interior watersheds in Pacific Northwest United States.
	▪ Total weighted road density should be 0 km/km^2 in grizzly bear core areas (USFS 1993).	▪ Management goal for Idaho National Forest; total weighted road density considers hiding cover, level of use, and closure status to provide a common standard.
Corridor Density	▪ Boreal-ecotype woodland caribou populations declined when total corridors >1.8 km/km^2 (Francis et al. 2002).	▪ Threshold based on Alberta population data.
	▪ Boreal-ecotype woodland caribou populations do not persist when total corridors >3 km/km^2 (B. Stelfox pers. comm.).	▪ Threshold identified by caribou biologists in Delphi process.

Table 5. Examples of established stream-crossing index guidelines.

Indicator	Guideline or Threshold	Comments
Stream Crossing Index	▪ >0.4 stream crossings by roads per square kilometre indicates risk of cumulative effect (BCF and BCE 1995b). ▪ <0.6 stream crossings by roads per square kilometre to protect bull trout (BCF and MELP 1999a).	▪ Part of the British Columbia Interior Watershed Assessment Procedure (IWAP). Stream crossing index is calculated by sub-watershed. ▪ Recommended British Columbia threshold; additional site-specific work required beyond this point.

2.4 APPLYING THRESHOLDS

Indicators present information about the likelihood of adverse cumulative effects, but provide no direct measure of the acceptability of those effects. Thresholds are derived standards used to define the point at which a resource indicator changes from an acceptable to unacceptable condition.

A perceived advantage of thresholds is that they allow development activities to proceed without detailed review until the defined threshold is reached. In other words, if the incremental effects of a proposed activity do not cause the defined threshold to be exceeded, then effects are concluded to be insignificant and the proposed activity is typically viewed as acceptable. Once the threshold range is reached however, additional review or regulation becomes necessary (Ziemer 1994; Axys 2001a).

Tiered chemical thresholds are commonly used for assessment and management of air and water quality. This concept is also applicable to ecological thresholds and is recommended for northeast British Columbia since it provides a clear and integrated framework for threshold derivation and implementation. With this approach, science-based and politically defined targets can be integrated with defined management actions so that operating rules are clear for all parties.

Tiered thresholds implicitly recognize the uncertainty inherent in our understanding of complex ecological relationships. In doing so, they provide a framework to gather data on actual responses and modify management actions as appropriate. As well, tiered thresholds provide the flexibility necessary for different land management regimes and ecological settings, and for a full spectrum of development proposals.

In northeast British Columbia, project proposals are likely to undergo one of three types of regulatory review:

1. **Routine Review:** Simple proposals with limited potential for significant adverse cumulative effects.
2. **Enhanced Review:** Normal proposals in sensitive areas or those with some potential for significant adverse cumulative effects.

3. **Complex Review:** Complex proposals with high potential for significant cumulative effects

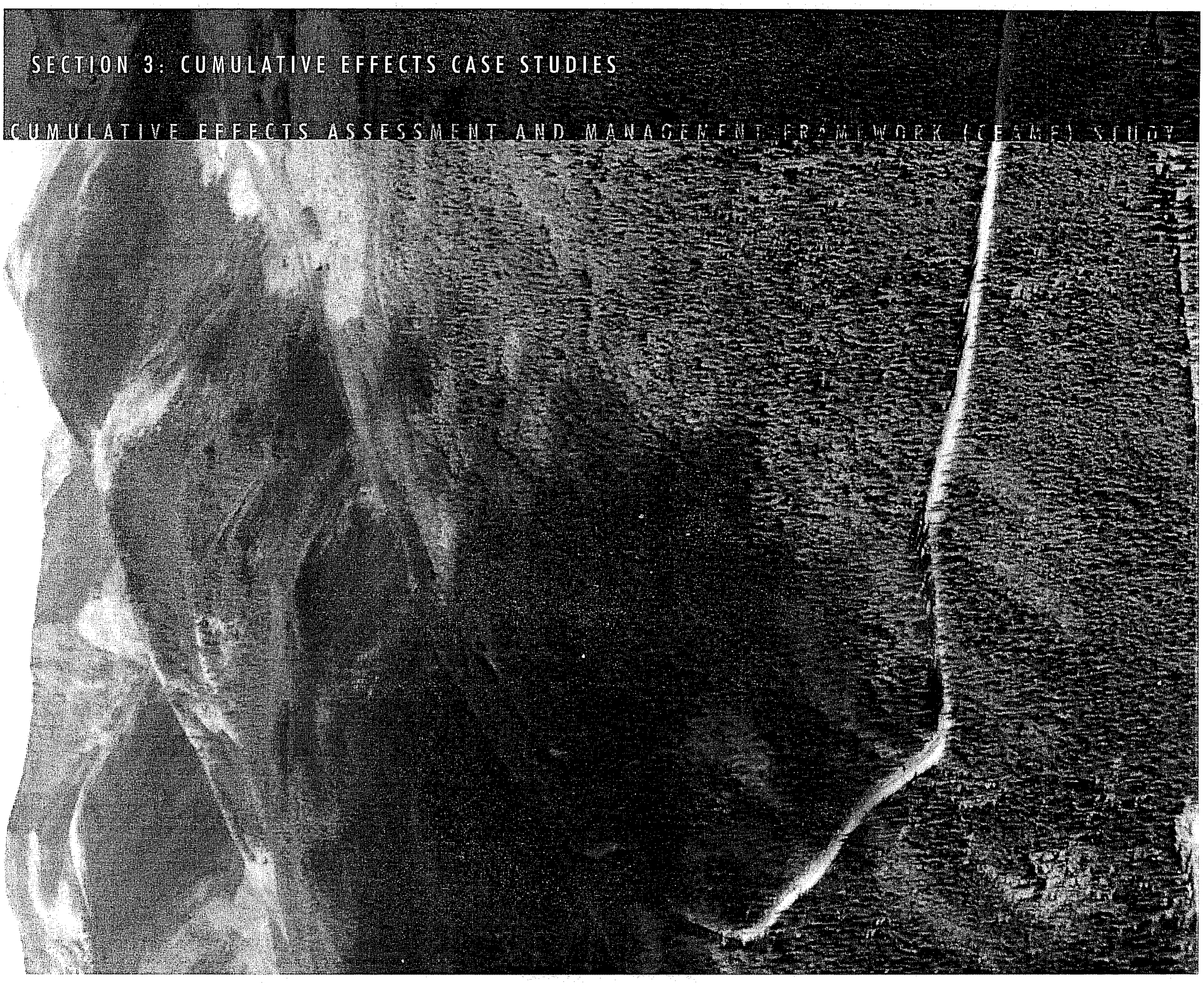
Table 6 summarizes desirable attributes of thresholds for each type of regulatory review. Further discussion of threshold application is provided in Section 4.

Table 6. Threshold attributes for different categories of regulatory review in northeast British Columbia.

Cumulative Effects Screening (Routine)	Cumulative Effects Evaluation (Enhanced)	Cumulative Effects Assessment (Complex)
Uses generalized thresholds.	Uses generalized and species-specific thresholds.	Uses species- and RMZ-, LU-, or WHA-specific thresholds.
Quickly and cheaply completed.	Intermediate cost and lead-time.	Highest cost and longest lead-time to complete.
Uses readily available data.	Site-specific data and field studies may be needed.	Site-specific data and field studies required.
Limited need for specialized expertise.	Specialized expertise generally needed.	Specialized expertise required.
Easily measured and enforced.	Measurable and enforceable.	Most difficult to measure and enforce.
Provides indirect measure of impacts.		Provides direct measure of impacts.
Examples: Maximum Access Density Maximum Disturbance Maximum Activity Level	Examples: Maximum Open Road Density Maximum Mortality Rate Maximum Clearing on Unstable Slopes	Examples: No Net Loss of Grizzly Bear Habitat Effectiveness No Net Fish Habitat Loss

SECTION 3: CUMULATIVE EFFECTS CASE STUDIES

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY



3. CUMULATIVE EFFECTS CASE STUDIES

Current and historical conditions were documented in two areas where petroleum development has occurred at different times and under different land management regimes. Resource Management Zones (RMZs) identified in approved Land and Resource Management Plans (LRMPs) were used as the basis for selecting case study areas to allow results to be applied to other areas of northeast British Columbia. The two areas selected were:

- Blueberry Case Study Area, included in the Jedney Enhanced Resource Development, Agriculture Settlement, Grazing Reserve, and Alaska Highway RMZs of the Fort St. John LRMP (1997): This 2,690 km^2 area is located northeast of the community of Wonowon (Figure 1), and is moderately to highly disturbed following more than 50 years of development. The area is characterized by rolling terrain, with mixedwood uplands and occasional black spruce (*Picea mariana*) muskeg; moose (*Alces alces*), caribou, furbearers, migratory songbirds, and Arctic grayling (*Thymallus arcticus*) are key species. The primary management objective for this area is to maintain or enhance resource extraction opportunities. Case Study boundaries were defined by the availability of historical air photographs and renewable resource data.
- Sukunka Case Study Area, included in the South Peace Enhanced Resource Management RMZ of the Dawson Creek LRMP (MEM et al. 1999): This 1,215 km^2 area is located southwest of Chetwynd (Figure 1), and is lightly to moderately disturbed following 30 years of development. The Sukunka area includes mixedwood and conifer forests on the Rocky Mountain foothills and front ranges; elk, grizzly bear, furbearers, Arctic grayling, and bull trout are key species. The primary management objective for this area is to encourage natural resource extraction and development (oil and gas, coal, timber). Case study boundaries were defined by RMZ boundaries and the availability of renewable resource data.

This section provides an overview of the detailed Blueberry and Sukunka Case Studies included in Appendices 2 and 3, respectively.

3.1 METHODS

3.1.1 GIS Model

A Geographic Information System (GIS) model was constructed for each study area from readily available government (e.g., TRIM II) digital data. This model included data on elevation, hydrology, forest cover, base features (roads, cutlines, pipelines, railway lines, facilities, clearings, communities), and LRMP management boundaries.

3.1.2 Development and Renewable Resource Trends

In each study area, information on historical human development patterns was generated for two points in time using aerial photographs. In the Blueberry Case Study area, photography from 1950 and 1970 was used; 1969 and 1981 photography was used in the Sukunka study area. General information on development trends in the region was obtained from the OGC and published and unpublished sources (O'Neill 1993; MOF 2002; Salmo unpub. data).

Hunter and trapper harvest data and pertinent inventory and management reports were obtained to document historical trends in harvest and inferred abundance. Representatives of MSRM and WLAP in Fort St. John were also contacted for additional information on renewable resource management and trends.

3.1.2.1 Wildlife Habitat Suitability

While all indigenous species may have some value in assessing environmental conditions and potential effects, evaluating every species in a cumulative effects assessment is impractical. An accepted approach is to select a complementary suite of representative species, groups, or guilds that are useful in quantifying or evaluating the effect of disturbance (Beanlands and Duinker 1983; Noss 1990; Cocklin et al. 1992; Smit and Spaling 1995; Noss et al. 1996).

The four wildlife species selected for the Blueberry and Sukunka Case Studies: moose, caribou, elk, and grizzly bear, are high profile or sensitive species for which reasonable data are available. Representative fish (Arctic grayling and bull trout), furbearer (marten, *Martes americana*), and forest bird species (black-throated green warbler, *Dendroica virens*) were also considered for suitability modelling. However, because there were limited or no historical data available, cumulative effects on these animals were not evaluated quantitatively.

Moose and elk are moderately abundant in both study areas and represent habitat generalists that are relatively tolerant of human disturbance. Woodland caribou and grizzly bear were selected because they are intolerant of human disturbance and generally require large areas of suitable habitat. The 'umbrella species' concept suggests that protection of habitat values and linkages for these large vertebrates will also provide protection for more than 90% of other species found in foothills areas (reviewed in Paquet and Hackman 1995).

Habitat suitability ratings were developed for these species using forest cover data provided by the provincial government. A four class rating system (High, Moderate, Low, Nil) was used. Trends in habitat availability and the amount of habitat in relatively undisturbed core areas were derived for each Case Study area, species, and RMZ. Core areas were defined as habitat greater than 500 m from 'high use features' (roads, trails, pipelines, railway lines, wellsites, communities, and clearings). Additional information on suitability rating development and analyses is provided in Sections 3.1.3 of Appendices 2 and 3.

3.1.2.2 Cumulative Effects Analyses

A number of land use and habitat indicators described in Section 3 were tested to evaluate the relationship between these cumulative effects indicators, development trends, and renewable resource trends. Selected indicators included: road density, cleared/disturbed area, core area, edge area, stream crossing index, riparian roads, and cleared riparian area. Patch size was also considered as part of core area analyses. Stepwise multiple linear regression was used with harvest or harvest success as the dependent variable.

3.1.2.3 Future Scenarios

The A Landscape Cumulative Effects Simulator (ALCES) developed by Forem Technologies Ltd. (www.foremtech.com) was used to visualize the effect of past and future development in the Blueberry Case Study area. Historical development trends were projected over a 100 year period (1950 to 2050) to examine land use patterns, forest age and structure, and wildlife habitat effectiveness.

Indicators used for this simulation were: moose habitat effectiveness; woodland caribou habitat effectiveness; total anthropogenic footprint (ha) and edge (km/km^2); road and trail edge (km/km^2); average forest patch size (ha); average forest age (years); and old growth forest (% of area). Fire regime was run as a constant 125 year cycle for softwood and 100 year cycle for hardwood as recommended by BCF and MELP (1999b). Projections of future land use were based on trends quantified in the Case Study. Three future energy development scenarios were simulated: low growth (1950 to 1998 average development rate); moderate growth (1970 to 1998 average development rate); and high growth (1970 to 1998 development rate plus 20%).

The objective of this simulation was to evaluate the capabilities of the ALCES model to conduct strategic-level simulations of regional landscapes, to provide projections of the natural range of variability, and to compare results provided by ALCES and conventional cumulative effects assessment methods.

3.2 DEVELOPMENT AND RENEWABLE RESOURCE TRENDS

This section summarizes information on past and projected future development and renewable resource trends provided in the Blueberry and Sukunka Case Studies (Appendices 1 and 2).

3.2.1 Development Trends

Active petroleum development in the region commenced in the late 1940's. Oil and gas production has occurred continuously since that time, but cyclical changes in the level of oil and gas exploration and production activity have occurred. Approximately 12,000 wells have been drilled in northeast B.C., with an average of 288 wells each year since 1960. Exploration activity has intensified in the last ten years, with an average of 539 wells per year (Figure 8). Seismic activity records are available only since 1982, but activity over this 20-year period has also continued cyclically, with peak activity in the early 1990's.

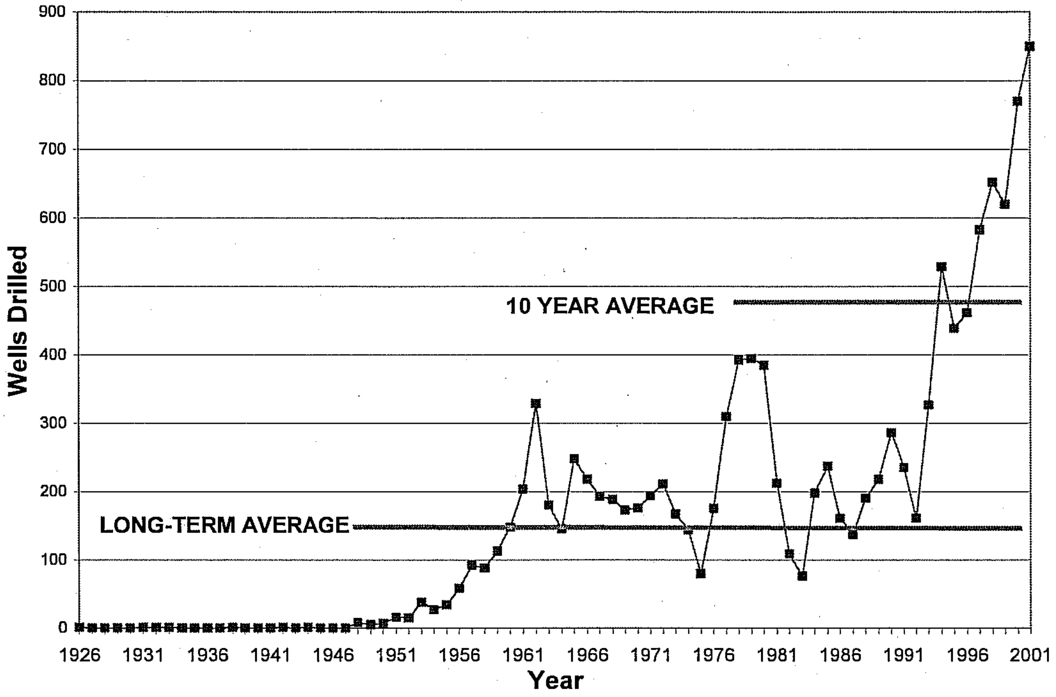


Figure 8. Wells drilled in northeast British Columbia, 1926 – 2001.

Enhanced resource development is the primary land use objective in most of the Blueberry and Sukunka Case Study areas. Existing infrastructure and administrative units in the Blueberry and Sukunka Case Study areas are mapped in Figures 9 and 10, respectively.

Petroleum development began in the early 1950's in the Blueberry area. Since that time, an average of 4 wells, 12 km of secondary roads, 50 km of truck trails, 125 km of cutlines, and 5 km of pipeline have been constructed each year. Annual average construction rates have increased for most features since 1970 to approximately 9 wells, 65 km of truck trails, 135 km of cutlines, and 7 km of pipeline.

In the Sukunka area, petroleum development began in the late 1970's. On average, approximately 1 well and 23 km of secondary roads, 5 km of truck trails, 21 km of cutlines, and 4 km of pipeline have been constructed each year since 1969 in the Sukunka area. Average construction rates for wells increased between 1981 and the present, to approximately 2 wells per year. Development rates for secondary roads and pipelines have remained consistent, while development rates for truck trails and cutlines have declined respectively to 3 km and 15 km per year, presumably due to a slowdown in coal exploration and implementation of low impact seismic techniques.

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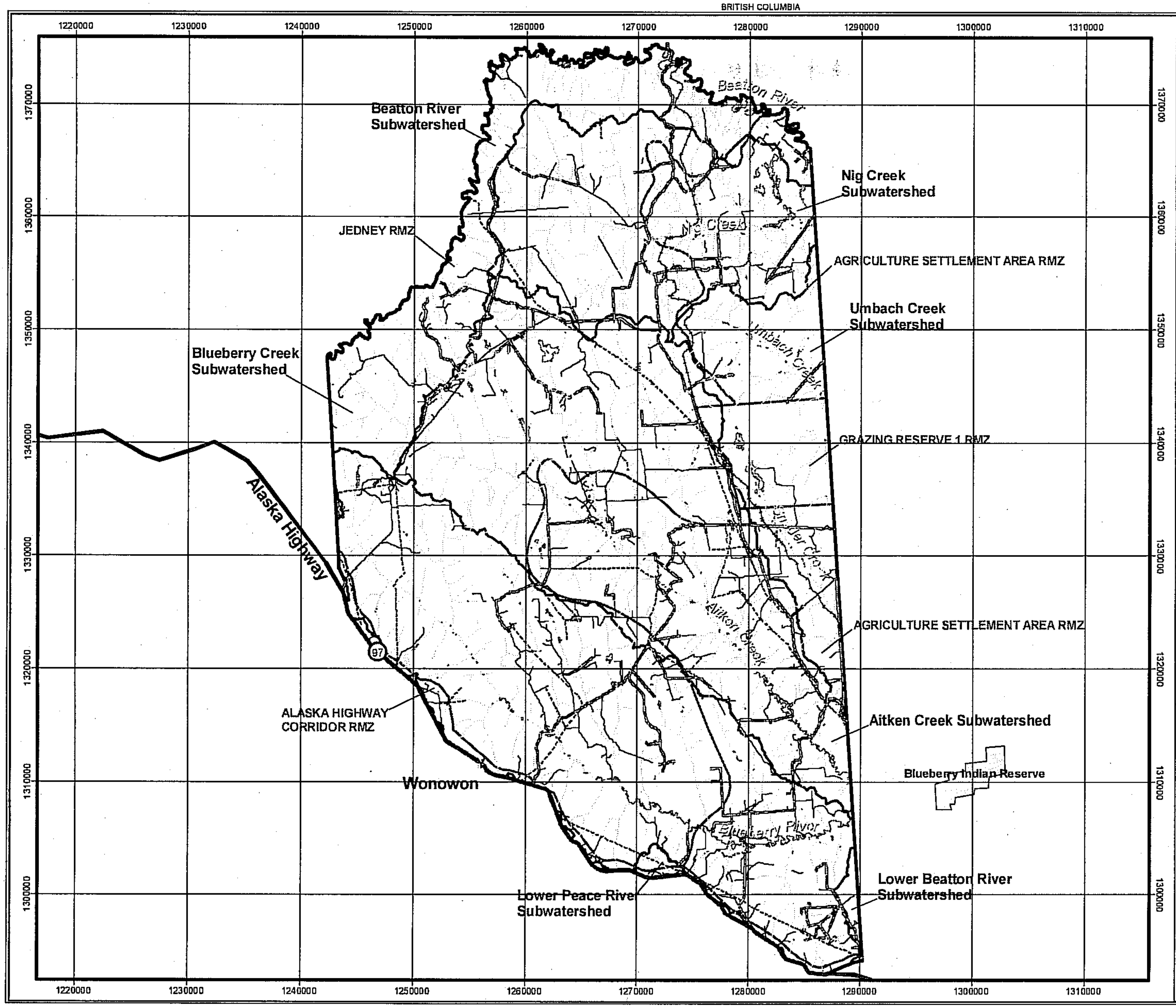

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Figure 9

Existing Infrastructure, Resource Management Zones (RMZ), and Subwatershed Boundaries in the Blueberry Case Study Area

LEGEND

- ▭ Study Area
- ▭ RMZ Boundary
- ▭ Subwatershed
- ▭ Indian Reserve
- Primary Highway
- Primary Road
- Secondary Road
- Rail Line
- Pipeline
- Y Municipality
- Hydrography
- Albers Coordinate Grid

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Map Scale 1: 335 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from the DEM. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data.

Projection:

Albers Equal Area Conic
Central Meridian: -126.0°

Datum:

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Coordinate System:

B.C. Albers Coordinate Grid

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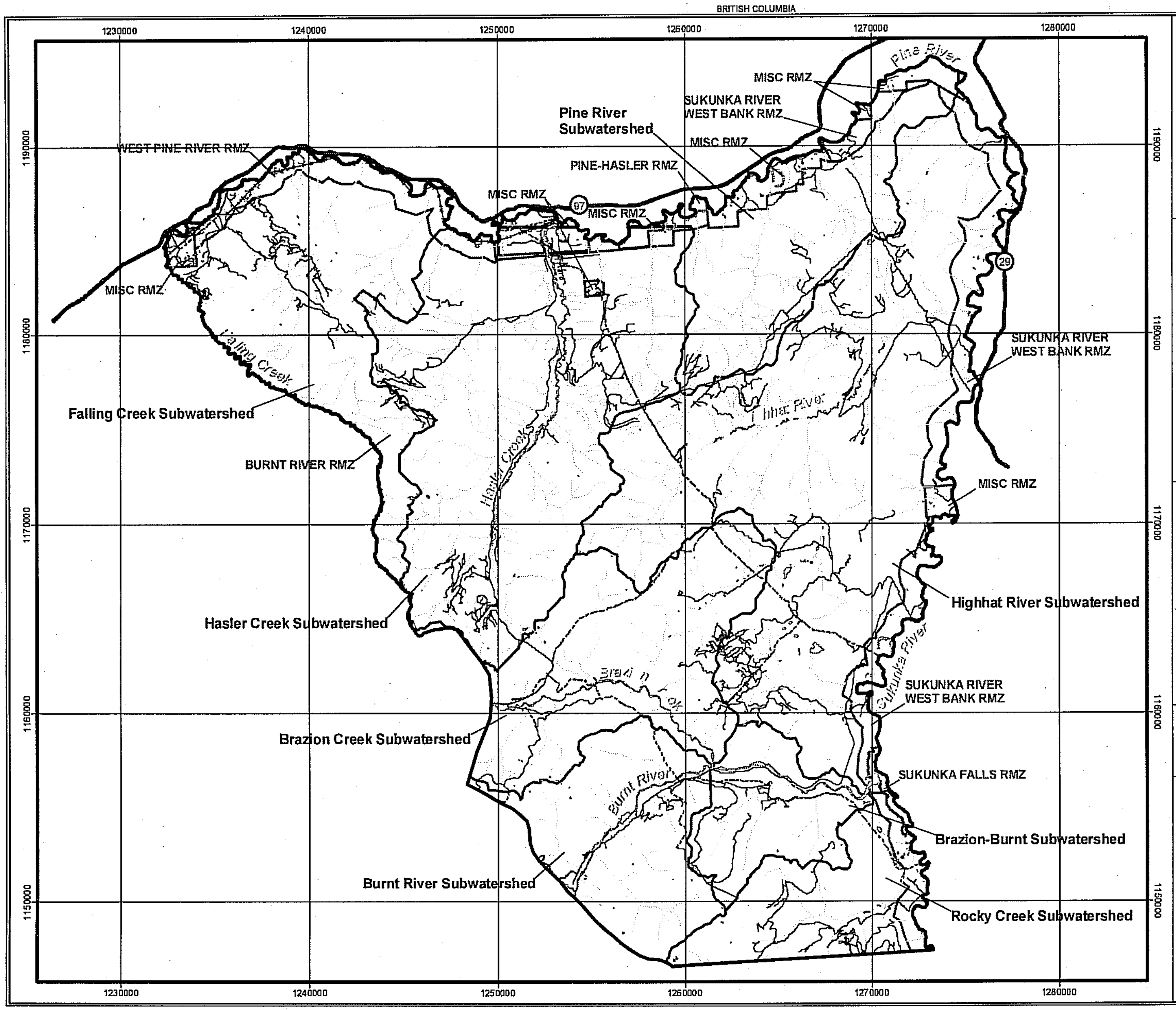

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Figure 10

Existing Infrastructure, Resource Management Zones (RMZ), and Subwatershed Boundaries in the Sukunka Case Study Area

LEGEND

☐ Study Area	Rail Line
☐ RMZ Boundary	Pipeline
☐ Subwatershed	Hydrography
Primary Highway	Albers Coordinate Grid
Secondary Road	

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Map Scale 1: 200 000

MAP INFORMATION

Sources:
Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Watershed boundaries derived by GAIA Consultants Inc. from a DEM. Primary Highway taken from ESRI maps and data.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

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3.2.1.1 Clearing and Disturbance

Petroleum development, agricultural and residential expansion, and forest harvest are the main development activities that have affected these areas. Petroleum development comprises 20% to 30% of the footprint in both study areas, but clearing for forest harvest and agricultural and residential conversion are also continuing (Figures 11 and 12).

In the Fort St. John area, agriculture has a long history; cattle ranching is the leading farm activity. Large areas of parkland have been converted to grazing and forage production (The ARA Consulting Group et al. 1996). At present, agricultural and residential clearings represent the largest footprint in the Blueberry Case Study area.

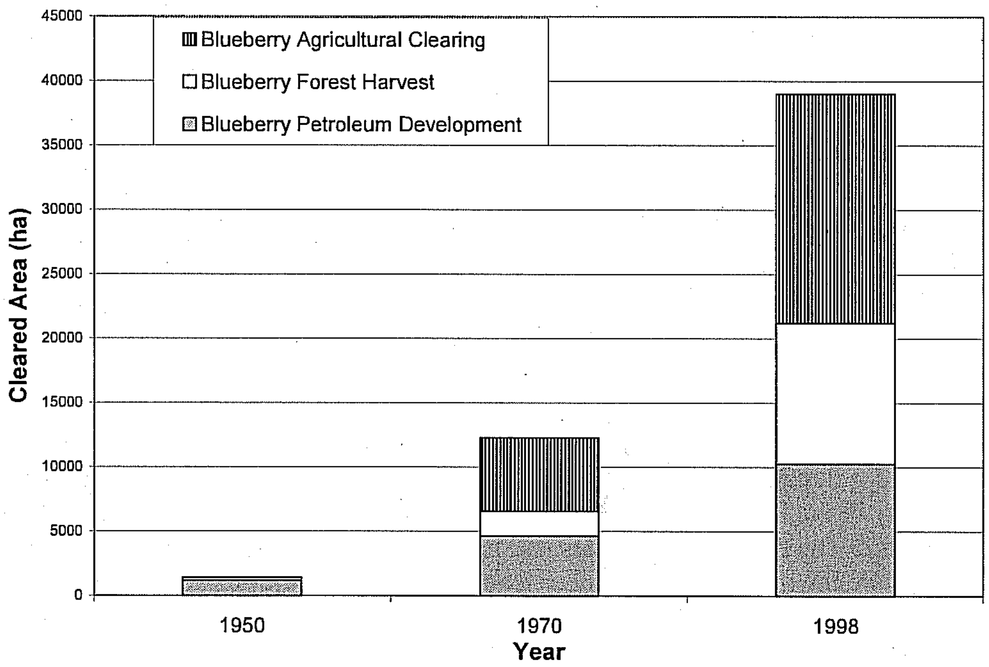

Figure 11. Forest clearing trends in the Blueberry Case Study area.

Forest harvest represents the largest footprint in the Sukunka Case Study area, where agricultural activities are largely restricted to main river valleys.

The Annual Allowable Cut was recently increased in the Fort St. John Forest District and combined coniferous and deciduous harvest is expected to increase in this area (MOF 2002). The Timber Supply Analysis in the Dawson Creek Forest District recommended a constant harvest of coniferous timber, but decreased harvest of deciduous timber (MOF 1996). Forest harvest represents the largest footprint in the Sukunka area, where agricultural activities are largely restricted to main river valleys.

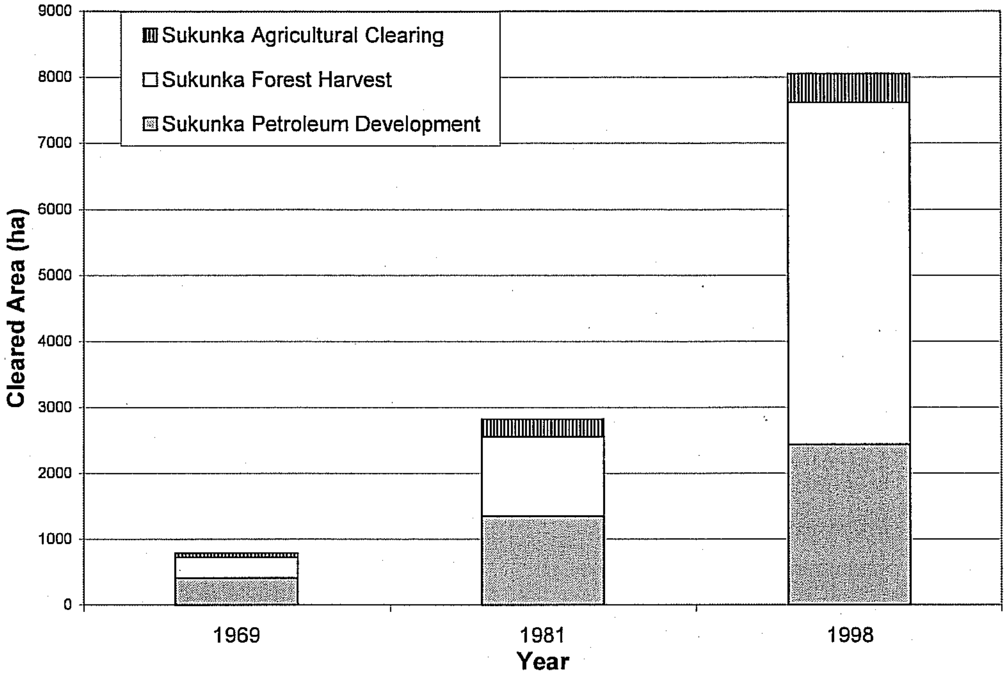

Figure 12. Forest clearing trends in the Sukunka Case Study area.

3.2.1.2 Access Density

The different development history of the Blueberry and Sukunka areas is also reflected in the linear corridor development trends summarized in Figures 13 and 14. Average road and trail density in the Blueberry area increased from 0.19 km/km^2 in 1950 to 1.6 km/km^2 in the late 1990's. The rate at which roads and trails have developed has increased since 1970. Cutlines are the most abundant linear feature in the Blueberry area; this is consistent with other petroleum development and multiple use areas of the Rocky Mountain eastern slopes (Salmo 1999, 2000; Antoniuk 2000). Total corridor density in the Blueberry study area currently exceeds 4 km/km^2 (Figure 13). Development of roads and linear corridors was similar in multiple-use forest and agriculture/settlement RMZs.

In the Sukunka area, average road and trail densities have been consistently lower than in the Blueberry area. They increased from 0.23 km/km^2 in 1969 to 0.8 km/km^2 in the late 1990's. Total corridor density currently exceeds 1.5 km/km^2. Secondary roads were the most common linear feature in both 1969 and the late 1990's (Figure 14). This appears to be related to several factors. First, the topographic relief of the Sukunka study area generally requires longer access roads to upland areas than are required in the rolling Blueberry area. Second, many roads and trails were constructed during a period of intensive coal exploration activity in the 1970's (the rate at which roads and trails have developed has decreased since 1981). Finally, because petroleum development of the Sukunka area occurred later, most geophysical activity in the early 1990's peak used 'low-impact' hand-cut, heli-portable programs, rather than the conventional ground programs used in the Blueberry area. This has reduced the footprint of cutlines in the Sukunka area, and demonstrates the value of project-specific mitigation for management of cumulative effects.

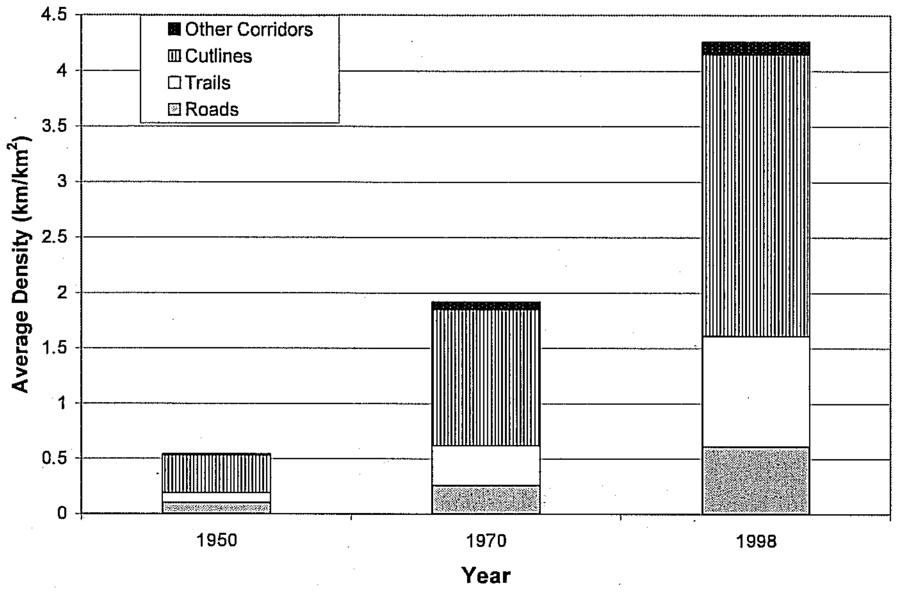

Figure 13. Corridor development trends in the Blueberry Case Study area.

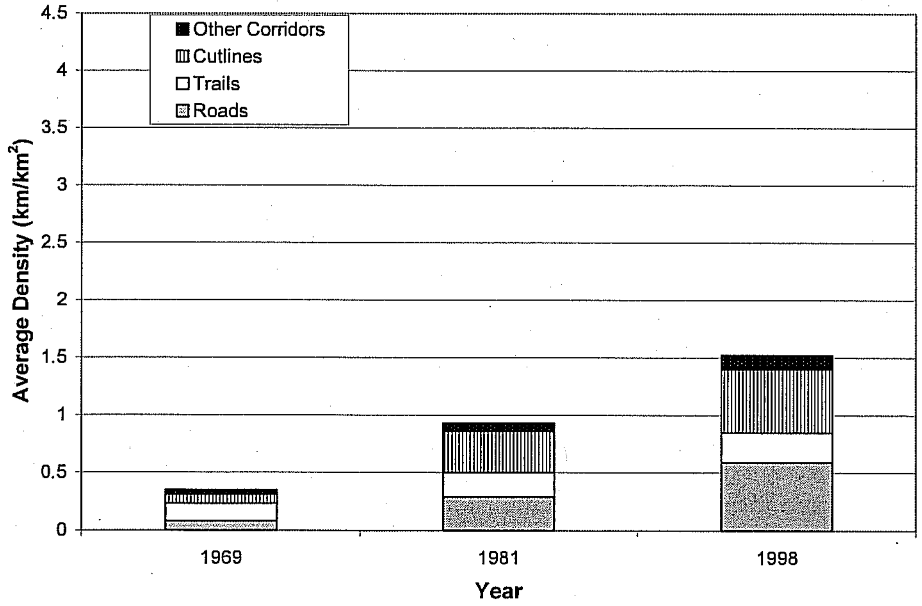

Figure 14. Corridor development trends in the Sukunka Case Study area.

The rate at which access corridors increased was linear in both Case Study areas over the 30 to 50 year analysis period. This demonstrates that the disturbance trajectory can be accurately predicted using the equations derived from the three historical analysis points. In addition, energy infrastructure development trends can be predicted from well drilling trends. The linear nature of these equations also indicates that they can reasonably be used to forecast future disturbance if development practices do not change (e.g., complete shift from conventional to low-impact seismic programs).

3.2.1.3 Core and Edge Areas

Trends in core and edge area availability in the Blueberry and Sukunka Case Study areas are summarized in Figures 15 and 16 respectively. Relatively undisturbed habitat (i.e., >500 m from high use features) has declined in both areas over the last 50 years. Edge area increased over the same period, but at a higher rate than cleared area; this reflects the non-linear nature of 'edge effects' described in Section 2.3.1. In both Case Studies, edge and core availability intersect when both represent approximately 40% of the study area. Theoretical models predict that species such as woodland caribou with low reproductive potential and specialized habitat needs will shift from a random to clumped distribution when their preferred habitat represents less than 80% to 40% of the landscape. For habitat generalists, this shift occurs at 35% to 10% of the landscape (Wilcove et al. 1986; Lee and Gosslink 1988; Laurance and Yensen 1991; Andren 1994; With and Crist 1995; Appendix 1).

In the Blueberry Case Study area, the core area decline rate was roughly linear and averaged 1.2% loss each year over the 50-year study period. Core areas currently comprise 15% of the Blueberry area landscape, less than 20% of that in 1950 (Figure 15). Loss of core area was similar in multiple use forest and agriculture/settlement RMZs.

The core area decline rate in the Sukunka Case Study area was curvilinear, and initially occurred at a much higher rate than was observed in the Blueberry area. The loss of core areas slowed considerably after 1981 due to the decline in road construction (Figure 16).

3.2.1.4 Patch Size

The size of core areas in both Case Study areas has changed from few very large contiguous patches to many fragments. As shown in Figures 17 and 18, the average size of remaining core areas decreased between each study interval and currently consists of a large number of very small fragments that provide limited security for large or intolerant species. The Blueberry Case Study area is much more fragmented than the Sukunka Case Study area, consistent with previously described development trends. ALCES simulations indicate that average forest patch size in the Blueberry Case Study area has decreased by 25% over the past 50 years (12 to 8 ha).

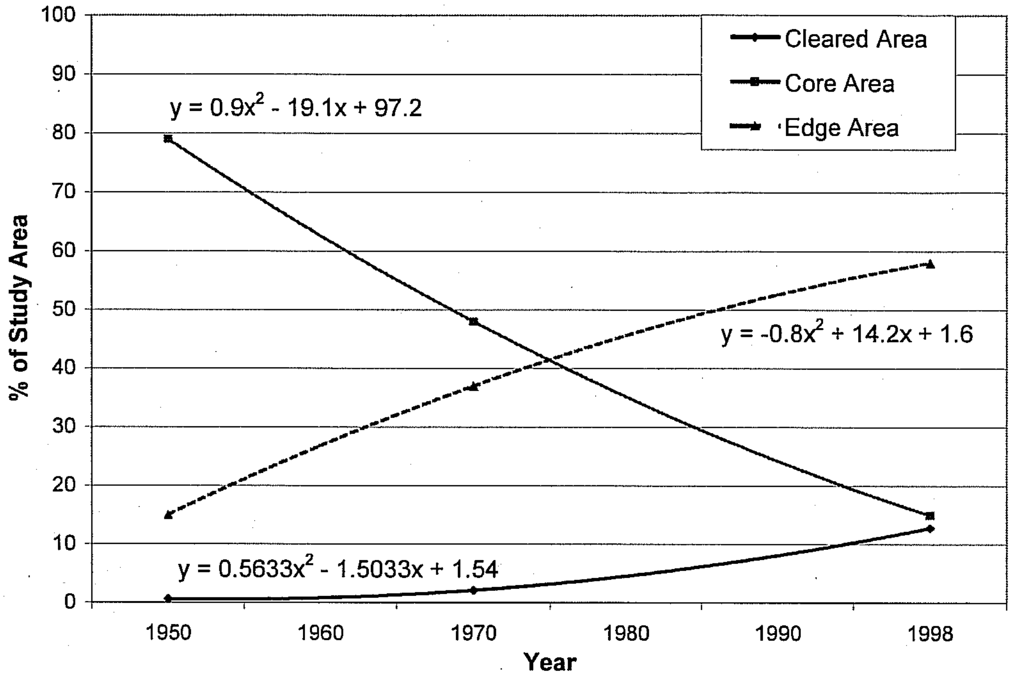

Figure 15. Trends in core, edge, and clearing in the Blueberry Case Study area.

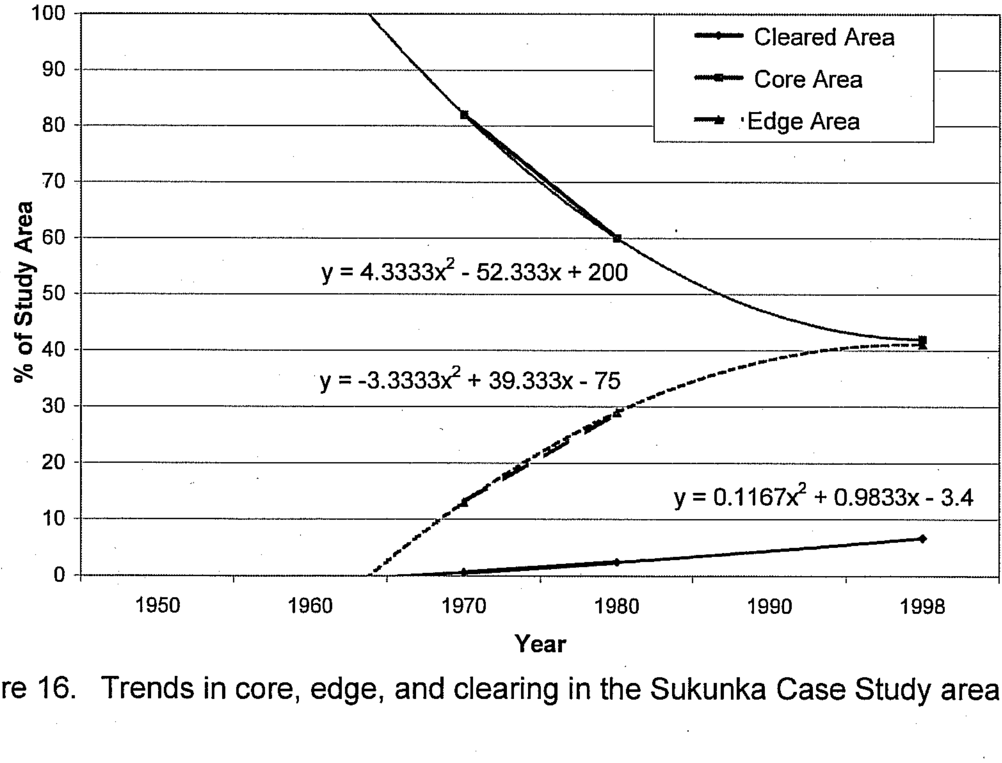

Figure 16. Trends in core, edge, and clearing in the Sukunka Case Study area.

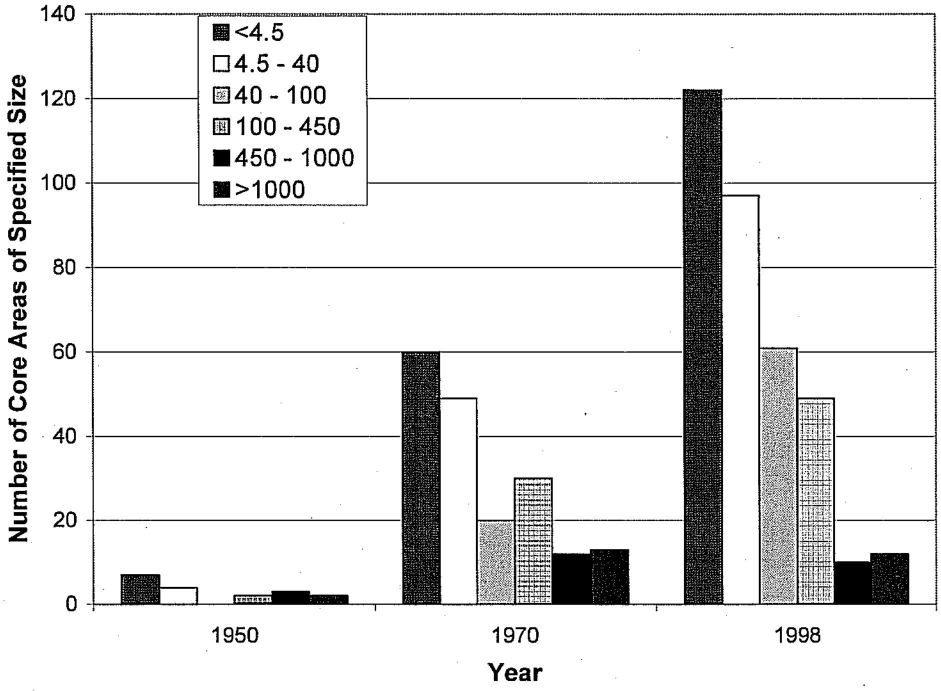

Figure 17. Core area size distribution in the Blueberry Case Study area.

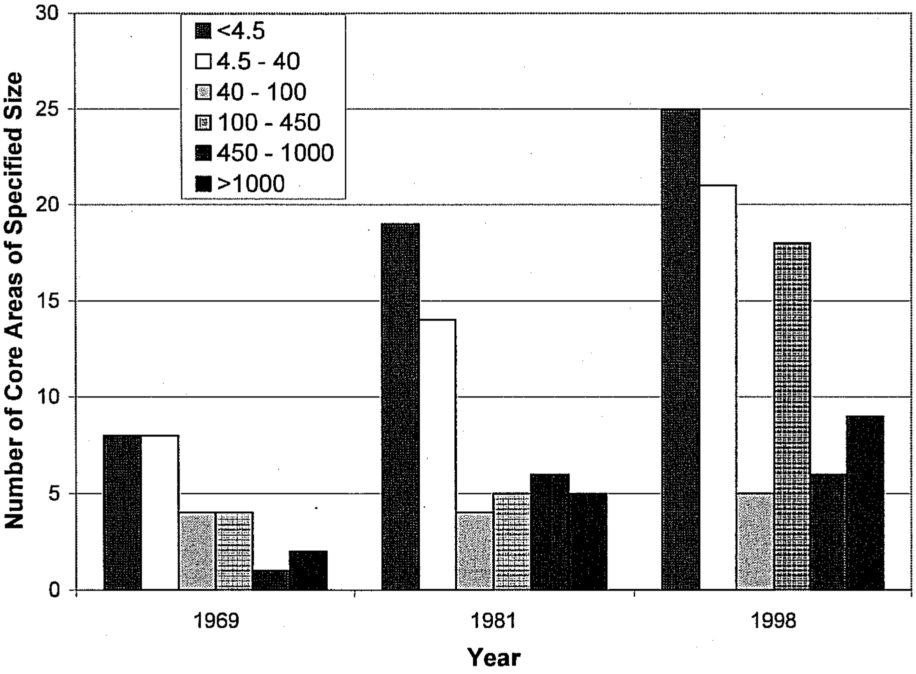

Figure 18. Core area size distribution in the Sukunka Case Study area.

3.3 RENEWABLE RESOURCE TRENDS

A summary of moose and woodland caribou trends in the Blueberry and Sukunka Case Study areas is presented here. These two representative species provide a contrast between two ungulates with moderate and low ecological resilience. Moose are a habitat generalist with moderate reproductive potential and are relatively tolerant of human disturbance. Woodland caribou are a habitat specialist with low reproductive potential and are comparatively intolerant of human disturbance. Additional information on elk, grizzly bear, and other species is included in the Case Study reports in Appendices 2 and 3.

Key factors limiting moose and woodland caribou populations are:

- human-caused direct and indirect mortality (sport, subsistence and illegal harvest, vehicle collisions, increased predation risk),
- natural abiotic and biotic factors (predation, disease, snow depth, fire),
- decline in habitat effectiveness, and
- habitat loss and alteration (clearing, fire suppression).

Naturally caused changes in fish and wildlife populations occur as a result of natural disturbances such as fire, disease, parasites, pests, floods, droughts, predation, and severe weather conditions. Winter snow depth is a critical factor affecting wildlife populations in northeast British Columbia; historical snow depth records for the Fort St. John airport are presented in Figure 19. Limiting snow depths are assumed to be 40 cm for deer, 50 cm for elk, and 65 cm for moose (Nietfeld et al. 1985). The 7-year period of mild winters beginning in 1984 provided very good conditions for ungulate population growth.

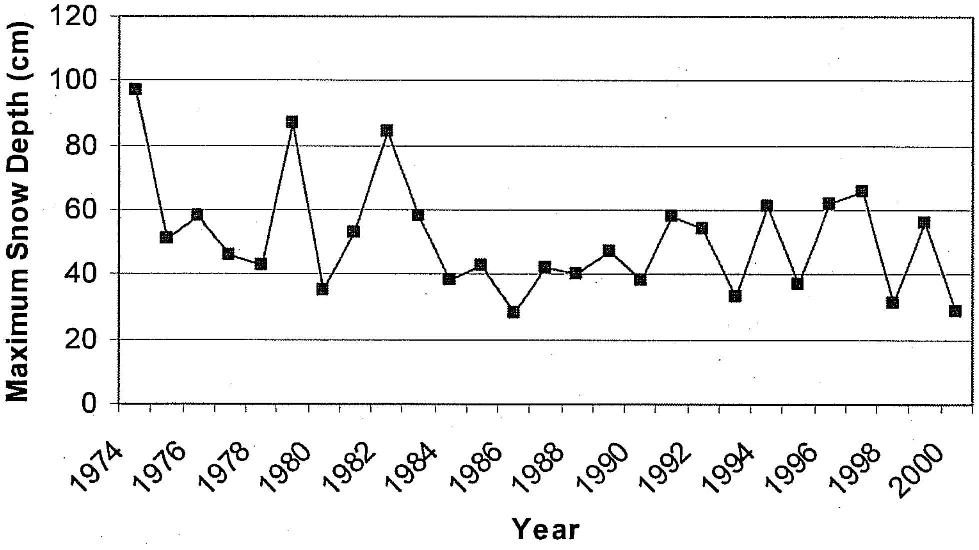

Figure 19. Maximum snow depth at Fort St. John airport.

3.3.1 Moose

Moose are highly sought after by recreational and subsistence hunters. They are the most abundant large mammal in the Blueberry Case Study area and approximately 65% of the area is rated as Moderate to High suitability habitat (Table 7, Figure 20). Moose are common but less abundant in the Sukunka area, with only one-third of the Case Study area rated as Moderate to High suitability habitat (Appendix 3).

Moose are common but less abundant in the Sukunka area, and only one-third of the area is rated as Moderate to High suitability habitat (Appendix 3).

Table 7. Current moose habitat suitability in the Blueberry Case Study area.

Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Blueberry Overall	13,165	5	158,933	60	82,680	31	8,260	3
Agriculture Settlement RMZ	9,022	10	59,564	64	21,720	23	2,818	3
Alaska Highway RMZ	317	7	3,057	65	757	16	542	12
Grazing Reserve RMZ	8	<1	6,108	67	2,581	28	375	4
Jedney Enhanced Resource RMZ	3819	2	90,204	58	57,623	37	4,525	3

ALCES simulations predict that moose habitat effectiveness has gradually declined in the Blueberry Case Study area over the last 50 years as average forest age has increased.

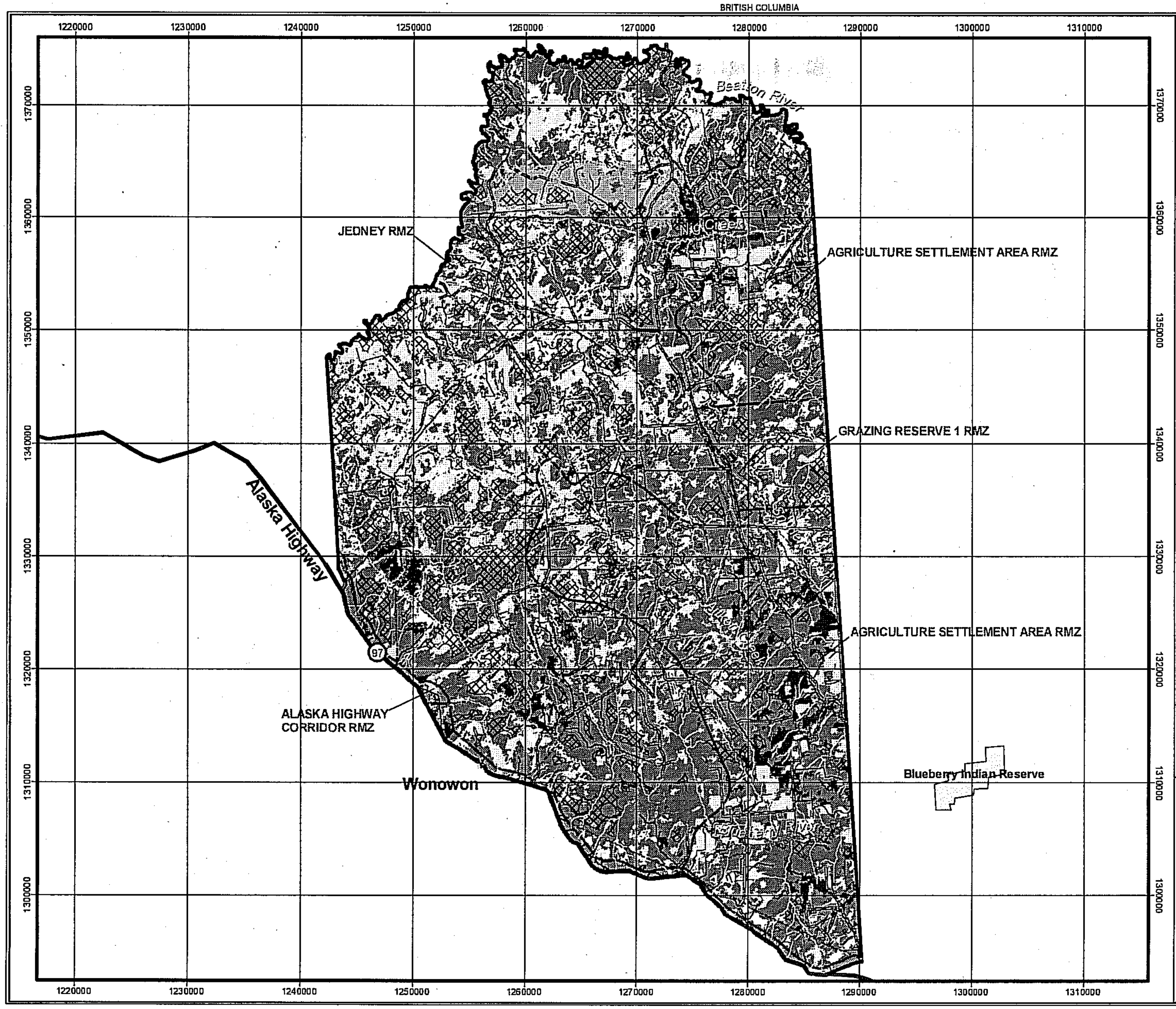

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Figure 20

Current Moose Habitat Suitability in the Blueberry Case Study Area

LEGEND

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GIS and Cartography by M.VanderWal and K.Graham

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4 2 0 4 8 12 Km

Map Scale 1: 335 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway, Municipality, and Indian Reserve taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:
Albers Equal Area Conic
Central Meridian: -126.0°

Datum:
NAD 83

Coordinate System:
B.C. Albers Coordinate Grid

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Random simulations of fire patterns were conducted with ALCES to estimate the natural range of variability of moose habitat in the Blueberry Case Study area (Figure 21). Each Monte Carlo simulation (shown in individual colour) was run over a 100 year period beginning in 1950. The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat). The habitat effectiveness range predicted for the Blueberry Case Study area is typical of productive boreal forest. These simulations demonstrate that moose habitat in this area has a large natural range of variability due to fire.

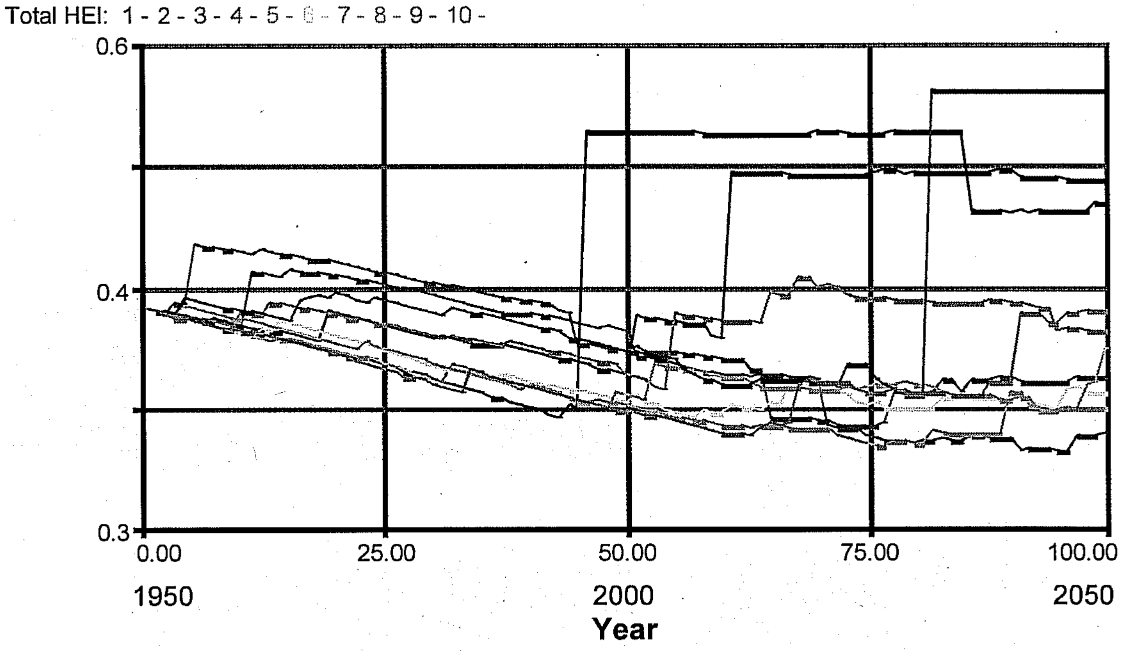

Figure 21. Predicted range of natural variability for moose habitat effectiveness in the Blueberry Case Study area (Habitat Effectiveness Index on y axis).

Limited population data are available for the two study areas, and trends in moose numbers must be inferred from isolated surveys and harvest statistics in Management Unit (MU) 7-45 (Blueberry) and 7-22 (Sukunka). In MU 7-45, population estimates derived from surveys in 1982 and 1998 were identical (2,200 animals with average density of 0.35/km^2), but the population was concluded to stable to decreasing in the early 1980's (Harper 1988), and stable or increasing more recently (MELP 1998). This suggests that although cyclical changes in abundance have occurred, the moose population in the Blueberry area has remained comparatively stable over the last twenty years. Harper (1988) reported that this is likely about half the population of the mid-1960's, and approximately one quarter of predicted habitat capability (Harper 1988). Predation and human mortality appear to be regulating the moose population in the Blueberry area.

Harper (1988) estimated that annual human-caused moose mortality was 17% of the population in MU 7-45 and 10% of the population in MU 7-22. Natural mortality was estimated to contribute an additional 5% in both areas. Recreational hunter kill and related crippling loss was identified as the largest source of mortality in both areas, and ranged from 6% to 11% of the MU 7-22 and 7-45 populations, respectively.

Moose harvest statistics from MUs 7-45 and 7-22 were used as a population index to evaluate changes in relative abundance. Analysis of historical moose harvest patterns in this region is confounded by changes in harvest regulation, and by increasing use of off-road vehicles that has improved access to previously remote areas. Nonetheless, although hunter effort has declined over the last 25 years, the average number of days required for a hunter to kill a moose has increased in MU 7-45 (Figure 22), and yearly harvest has declined. Moose harvest and hunter success in the Sukunka Case Study area remained relatively constant over the same period (Appendix 3).

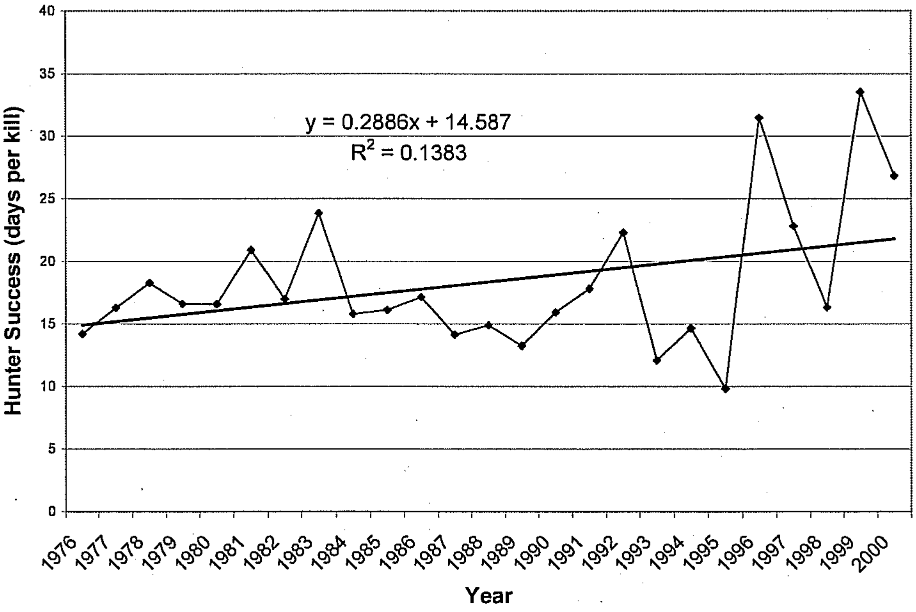

Figure 22. Historical moose hunter success in Management Unit 7-45 (Blueberry Case Study area).

Moose population estimates derived from surveys in the Blueberry area in 1982 and 1998 suggest that the population has been stable over the long-term. In contrast, moose harvest and harvest success in this area is slowly declining. Although changes in harvest could be interpreted as evidence of a population decline, it more likely represents harvest-related reductions in abundance of legal animals near disturbance features (Rempel et al. 1997; Schneider and Wasel 2000). Under these circumstances, the presence of relatively undisturbed (i.e., core) areas may be important for population persistence.

Core areas with High and Moderate Suitability moose habitat have declined in both the Blueberry and Sukunka areas over the last fifty years and currently comprise only 10% to 12% of available habitat (Figure 23). This indicates that most moose now reside in edge areas where disturbance and direct human mortality risk is increased and habitat effectiveness may be reduced. However, these local effects may be offset by reduced wolf and bear predation, greater availability of early seral stages, and restricted legal harvest such that population declines are not observed at the regional or management unit scale (Schneider and Wasel 2000).

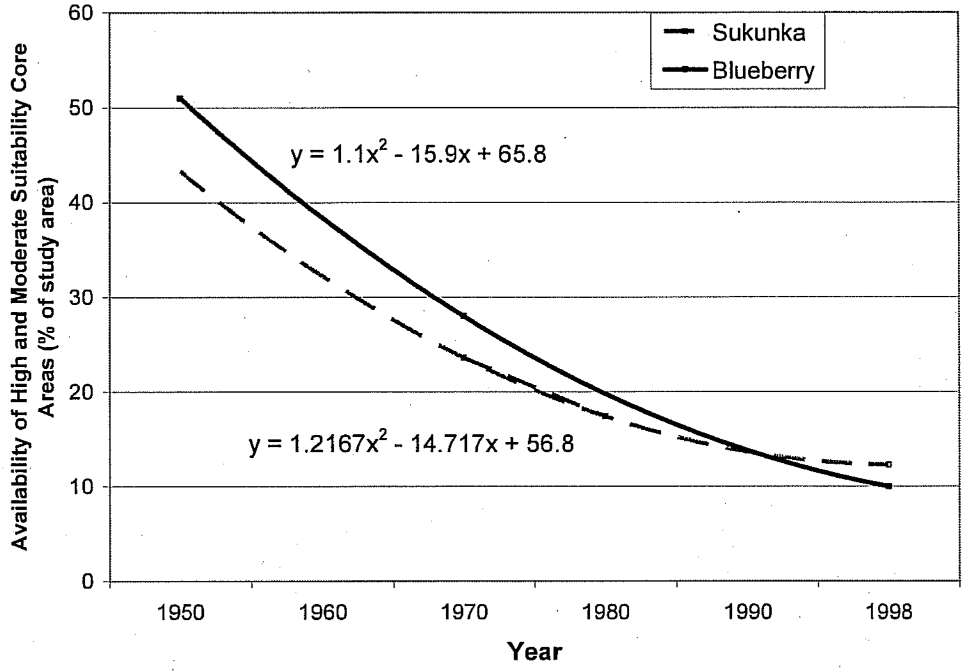

Figure 23. Trends in availability of Moderate and High suitability core habitat for moose.

In both areas, the portion of High and Moderate Suitability habitat within core areas remained relatively constant over the past 30 to 50 years. This indicates that development was randomly distributed throughout the Blueberry and Sukunka Case Study areas. It also suggests that generalized landscape analyses using indicators such as core area can be substituted for more detailed evaluations of moose habitat quality and availability at the regional scale.

ALCES simulations predict that moose habitat effectiveness in the Blueberry Case Study area will gradually decline in future as a result of ongoing forest harvest, access construction, agricultural conversion, and natural succession. Both the historical and projected future decline in moose habitat effectiveness in the Blueberry Case Study area are within the range of natural variability (Appendix 2).

Moose harvest and hunter success (days per kill) were compared to a variety of land use and habitat indicators to evaluate the effect of combined man-made disturbance on relative abundance. In the Blueberry area, yearly moose harvest success was inversely related to the level of disturbance (Figure 24) and directly related to the availability of core areas (Figure 25). This means that the highest yearly harvests tended to occur at earlier stages of fragmentation when more core area was available and disturbance (road, trail, and cutline density and cleared area) was lower.

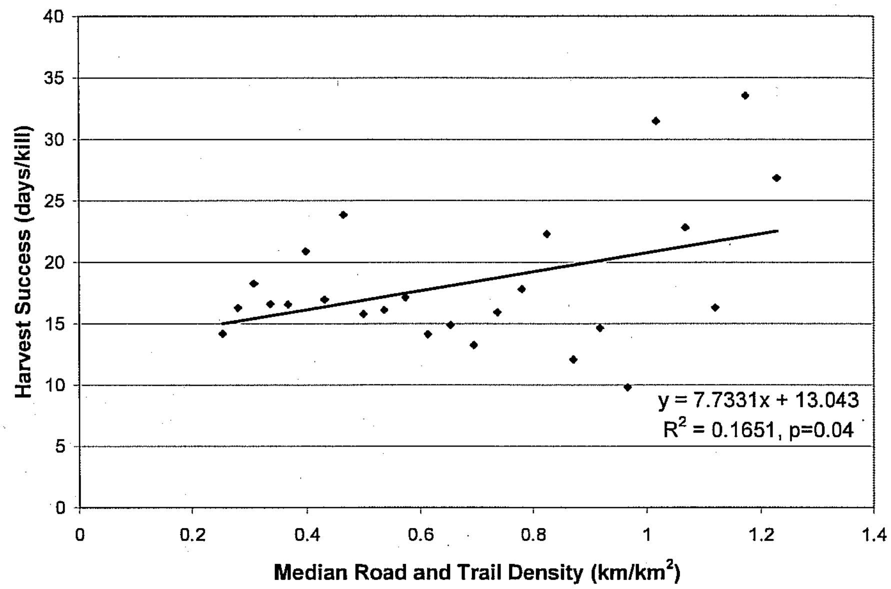

Figure 24. Relationship between moose harvest success and roads in the Blueberry Case Study area.

In the Blueberry area, median road and trail density provided a statistically significant prediction of harvest success (R^2= 0.17; p<0.05); regression equations based on all other linear corridor densities were nearly significant (R^2= 0.13 to 0.15; p<0.09). Land use indicators (total corridor density, road density, and trail density) individually provided better predictions than habitat indicators (cleared area, core area, edge area, good core area). Core area, a generalized habitat indicator, provided slightly better predictive ability than an indicator incorporating habitat suitability (i.e., moderate and high suitability core area). Multiple linear regression equations incorporating complementary disturbance and habitat indicators (e.g., median roads plus trails and core area; cleared area and core area) were able to explain more of the variability in annual harvest success (R^2= 0.28; p<0.04; Appendix 2).

There was no consistent relationship between land use or habitat indicators and moose harvest in the Sukunka study area (Appendix 3).

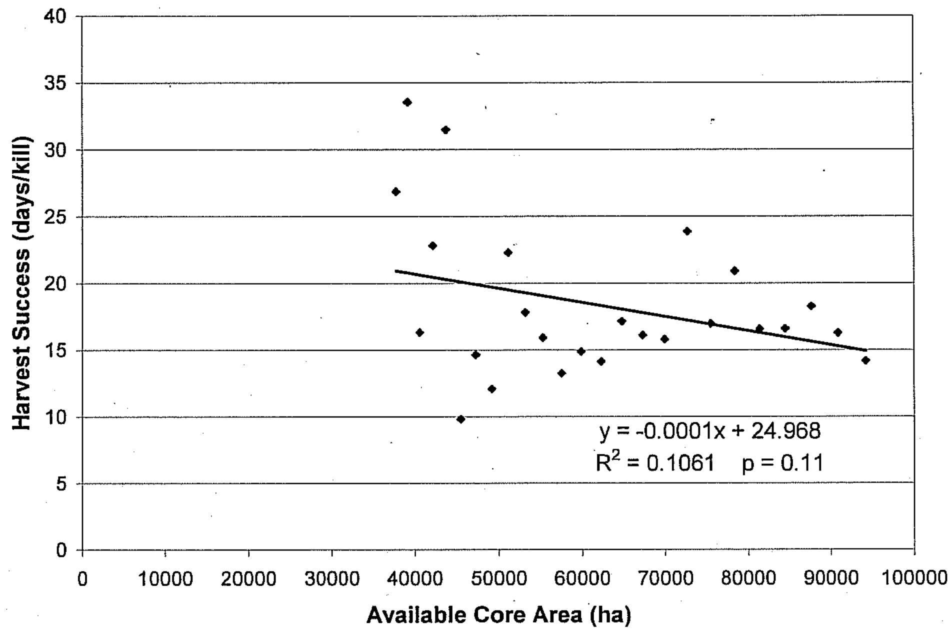

Figure 25. Relationship between moose harvest success and core area in the Blueberry Case Study area.

3.3.2 Woodland Caribou

Woodland caribou occur at low densities in the Sukunka Case Study area. Just over 10% of the area, mainly isolated patches of alpine tundra and subalpine forest is rated as Moderate to High suitability habitat for this species (Figure 26, Table 8). In the Blueberry Case Study area, where woodland caribou have historically been documented at low densities, Moderate to High suitability caribou habitat is limited to mature and old seral lodgepole pine (*Pinus contorta*) forest and black spruce lowlands present on approximately 6% of the area (Appendix 2).

Woodland caribou population data from these two areas is extremely limited, and trends must be inferred from regional surveys and MU 7-22 (Sukunka) harvest statistics. Harper (1988) concluded that a population crash of approximately 75% occurred in this region in the early 1970's, possibly due to a series of deep snow winters in the late 1960's combined with predation. Concurrent declines in woodland caribou populations were also observed in other populations in southern British Columbia and western Alberta (Edmonds and Bloomfield 1984; Stelfox and Stelfox 1993; Harding and McCullum 1994; Dzus 2001). Harper (1988) identified population-limiting factors as predation and loss of critical wintering habitat.

Table 8. Current woodland caribou habitat suitability in the Sukunka Case Study area.

Analysis Unit	Suitability Class							
	High		Moderate		Low		Nil	
	Area (ha)	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*	*Area (ha)*	*%*
Sukunka Overall	940	<1	14,511	12	88,255	73	17,811	15
Burnt River RMZ	940	<1	14,259	13	80,943	74	13,886	13
Misc RMZ	0	0	42	1	1,965	64	1,065	35
Pine-Hasler RMZ	0	0	0	0	469	79	126	
Sukunka Falls and West Bank RMZs	0	0	78	1	3,354	59	2,261	40
West Pine R. RMZ	0	0	132	6	1,524	72	474	22

Annual direct caribou mortality in the Sukunka and Blueberry areas is very low. Sport harvest has not been allowed in the Blueberry Case Study area for at least 20 years. In the Sukunka area, harvest is restricted to trophy bulls, and reported harvest since 1976 averages one animal every 3 years (Appendix 3). While vehicle mortality of woodland caribou is an issue in some areas (e.g., along the Alaska Highway in the vicinity of the Prophet River), it is very low in the Sukunka area (Antoniuk 1994). There was no relationship between land use or habitat indicators and woodland caribou harvest in the Sukunka study area (Appendix 3).

Relatively undisturbed core areas with High and Moderate suitability woodland caribou habitat have declined in both the Blueberry and Sukunka areas over the last fifty years and currently comprise less than 6% of available habitat (Figure 27). In the Sukunka Case Study area, available core area (Figure 16) is below the 50% caribou persistence threshold (Table 2, Appendix 1), and High and Moderate suitability core area is well below this threshold. This suggests that the probability of woodland caribou persistence in the Sukunka Case Study area is reduced.

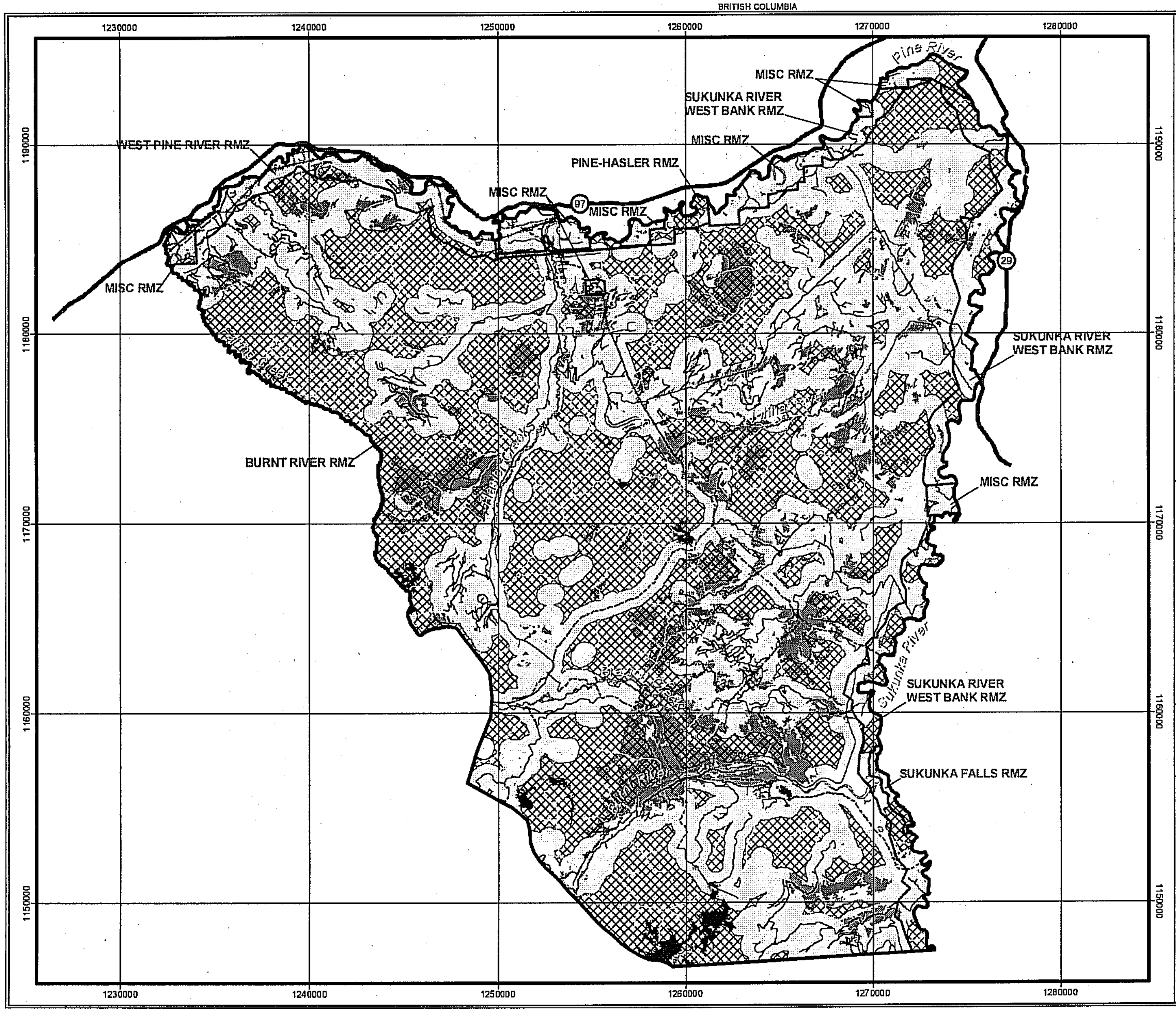

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Figure 26

Current Caribou Habitat Suitability in the Sukunka Case Study Area

LEGEND

- ▭ Study Area
- ▭ RMZ Boundary
- ▨ Core Area
- Primary Highway
- Secondary Road
- Rail Line
- Pipeline
- Hydrography
- Albers Coordinate Grid

Caribou Habitat Suitability Rating

- ☐ Nil
- ░ Low
- ▓ Moderate
- ■ High

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E-Mail: gis@gaiaenv.com
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Map Scale 1: 200 000

MAP INFORMATION

Sources:

Transportation features (roads, pipelines, and railways) were provided in digital format by AXYS Environmental Consulting Ltd., from B.C. TRIM data. RMZ boundaries and hydrography provided by the B.C. Ministry of Sustainable Resource Management. Primary Highway taken from ESRI maps and data. Habitat Suitability and Core Areas created by GAIA Consultants Inc. based on criteria provided by Salmo Consulting Inc.

Projection:

Albers Equal Area Conic
Central Meridian: -126.0°

Datum:

NAD 83

Coordinate System:

B.C. Albers Coordinate Grid

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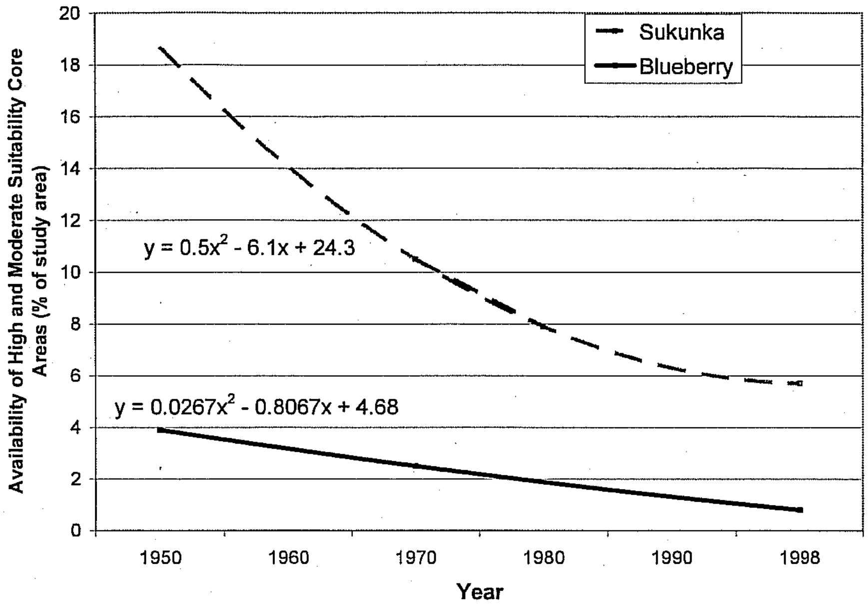


Figure 27. Trends in availability of Moderate and High suitability core habitat for caribou.

Random simulations of fire patterns were conducted with ALCES to estimate the natural range of variability of woodland caribou habitat in the Blueberry Case Study area (Figure 28). Each Monte Carlo simulation was run over a 100 year period beginning in 1950.

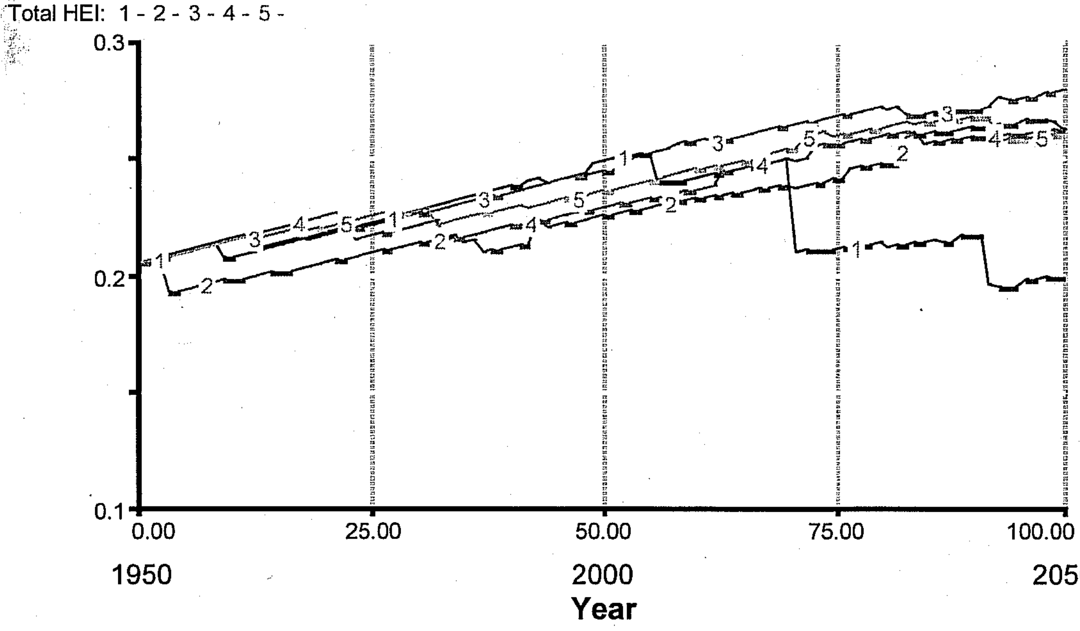


Figure 28. Predicted range of natural variability for caribou habitat effectiveness in the Blueberry Case Study area (Habitat Effectiveness Index on y axis).

The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat). The habitat effectiveness range predicted for the Blueberry Case Study area is somewhat low relative to occupied caribou range in the boreal forest. These simulations demonstrate that in the absence of human disturbance, woodland caribou habitat in this area is gradually improving as forest age increases and that natural variability due to fire is low in this area.

At present, total access corridor density in the Blueberry Case Study area exceeds the 3 km/km^2 woodland caribou persistence threshold (Table 4, Appendix 1). Available core area (Figure 15) is well below the 50% caribou persistence threshold (Table 2, Appendix 1), as is High and Moderate suitability core area (Figure 27).

An ALCES simulation was also conducted to evaluate the effects of human development on caribou habitat effectiveness in the Blueberry Case Study area. The simulation was begun in 1950 and uses development trends calculated for this area; habitat effectiveness was assumed to be lost near disturbance features due to edge effects (see Section 2.3.1 and Appendix 1). These simulations indicate that the Blueberry area provided no effective habitat for woodland caribou by 1980 (Figure 29) due to indirect effects of clearing, land conversion, and access corridor construction. This loss is well below the range of natural variability (Figure 28).

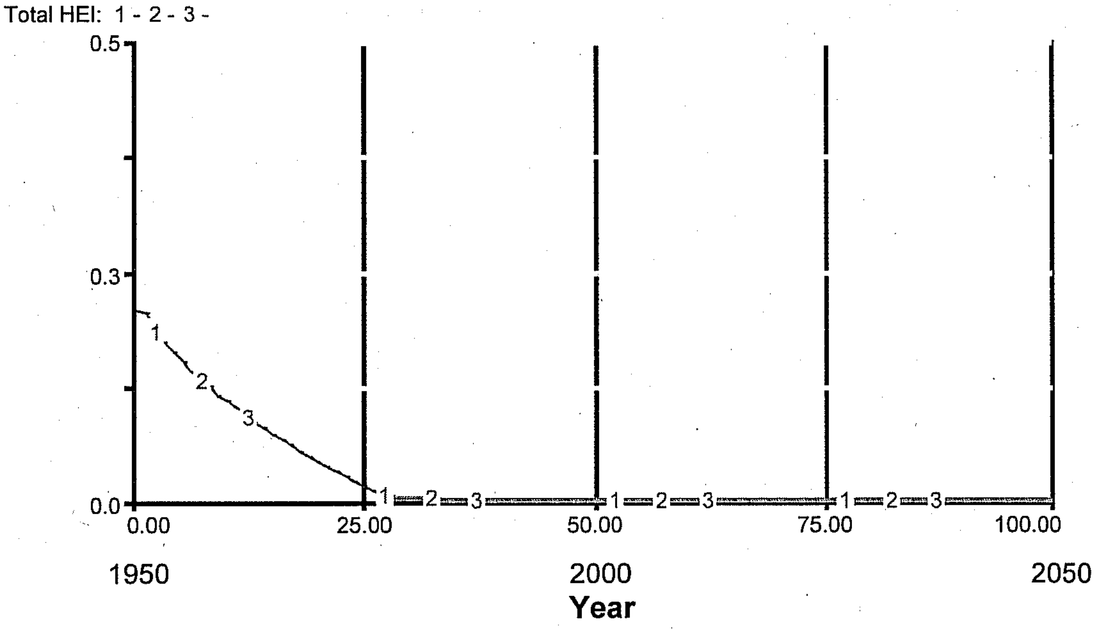


Figure 29. Predicted caribou habitat effectiveness in the Blueberry Case Study area with human development (Habitat Effectiveness Index on y axis).

Cumulative effects evaluations using several independent land use and habitat-based methods consistently conclude that woodland caribou are unlikely to persist in the Blueberry Case Study area. This is consistent with observations that this area received only occasional woodland caribou use by the early 1980's (Harper 1988).

3.4 APPLICABILITY OF LAND USE AND HABITAT INDICATORS

This section evaluates the suitability of the land use and habitat indicators considered most appropriate for cumulative effects assessment and management in northeast British Columbia.

3.4.1 Access Density

Access density is considered to be a useful land use indicator because it integrates the many ecological effects of habitat loss, alteration, barriers, mortality, and disturbance (Forman and Hersperger 1996). Case Study results confirm that access density can be used to document cumulative effects in northeast British Columbia.

Road density, trail density, and total corridor density provided statistically significant ($p<0.05$) predictions of moose harvest in the Blueberry Case Study area (Appendix 2). This finding is consistent with studies from elsewhere that demonstrate increased mortality risk near roads and trails (Appendix 1).

Average road and trail density was also found to be a good predictor of remaining core area in both Case Studies. The combined graph provided in Figure 30 demonstrates that availability of relatively undisturbed core areas decreases exponentially as road and trail density increases. In the Blueberry and Sukunka areas, 60%, 40%, 30%, and 10% core area thresholds summarized in Table 2 correspond to average road and trail densities of 0.4 km/km^2, 0.72 km/km^2, 0.97 km/km^2, and 1.82 km/km^2, respectively.

Although road and trail density appears to be a practical cumulative effects indicator, the Case Studies also demonstrate that documented relationships between road density and large wildlife species may not be directly applicable to northeast British Columbia. Animal response to habitat and disturbance features such as roads can be considered at two scales of analysis. At the regional scale, individuals or groups select home ranges or territories that meet all their life history need (2nd order selection). Within this home range or territory, individuals and groups select or avoid areas based on site-specific features (3rd order selection; Rettie and Messier 2000; Apps et al. 2001; Szkorupa 2002). For example, wolf packs appear to select areas with low road densities and low densities of humans in populated landscapes. In many remote areas however, wolves appear to select areas close to roads, trails, and seismic lines. This suggests that it is not the physical feature the road represents that wolves avoid, but the positive correlation between road density and number of encounters with humans (reviewed in Whittington 2002). Prey species, including moose, caribou, and elk, appear to respond to disturbance in the opposite manner (Dyer 1999; Schneider and Wasel 2000), presumably to reduce the risk of wolf predation.

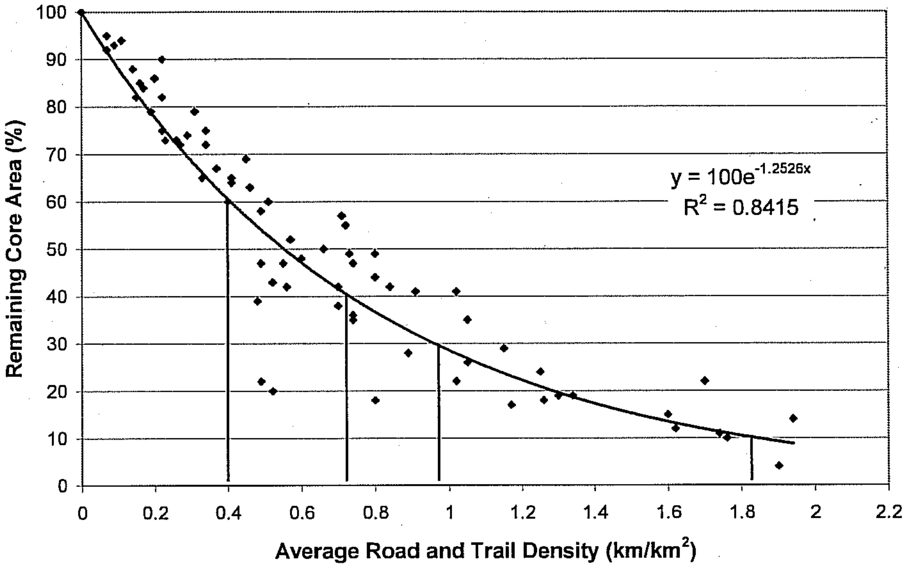


Figure 30. Relationship between road and trail density and remaining core area.

Northeast British Columbia has relatively low road and population densities when compared with most locations where road density effects have been studied. O'Neill (1993) estimated that 20% of cutlines in the region were passable by four-wheel drive vehicles, but concluded that actual use of these linear features was low. This is similar to findings in areas of the Alberta foothills with similar population density (Kansas and Collister 1999; Salmo unpub. data).

In addition, as noted in Appendix 1 (Section 2.3.4), physiological and behavioural responses of individuals may not be translated into reductions in animal numbers, particularly for species with high reproductive rates, species able to habituate to repeated disturbance (e.g., elk), or populations adjacent to protected or wilderness areas. For example, established models (Section 2.3.3, Appendix 1) predict that elk habitat effectiveness in the Blueberry and Sukunka study areas has been reduced by more than 35% due to construction of roads and trails (Figures 7 and 30). Realized reductions in habitat effectiveness have not affected local populations, however, as the expansion of the road and trail network has coincided with a dramatic increase in elk populations in these areas. O'Neill (1993) also concluded that loss in habitat effectiveness is not a significant issue for many species in this region.

Another issue relates to the way in which road or access density indicators are calculated. Most documented road density relationships and thresholds are based on average (mean) values. The average value is a measure of central tendency and is most applicable to samples with a symmetrical or normal (e.g., bell curve) distribution. When samples are asymmetrical or skewed however, calculated average road density is greatly influenced by extremely high values. In these cases, the median (middle measurement) is the preferred method to describe central tendency (Zar 1984).

Figures 31 and 32 present access density values calculated for 1 km^2 'cells' in the Blueberry and Sukunka Case Study areas. Because road and trail curves are skewed to the left, calculated average road and trail densities are much larger than calculated median densities. This discrepancy is greatest at earlier stages of fragmentation, as observed in the Sukunka area. In addition, moving window analyses are particularly sensitive to boundary effects (Ake 1995), which can further bias average values. As linear features and associated fragmentation increase, the frequency distribution becomes more symmetrical. For example, when all corridors in the Blueberry area were combined, the current average (5.9 km/km^2) and median (5.2 km/km^2) were closer (Figure 31).

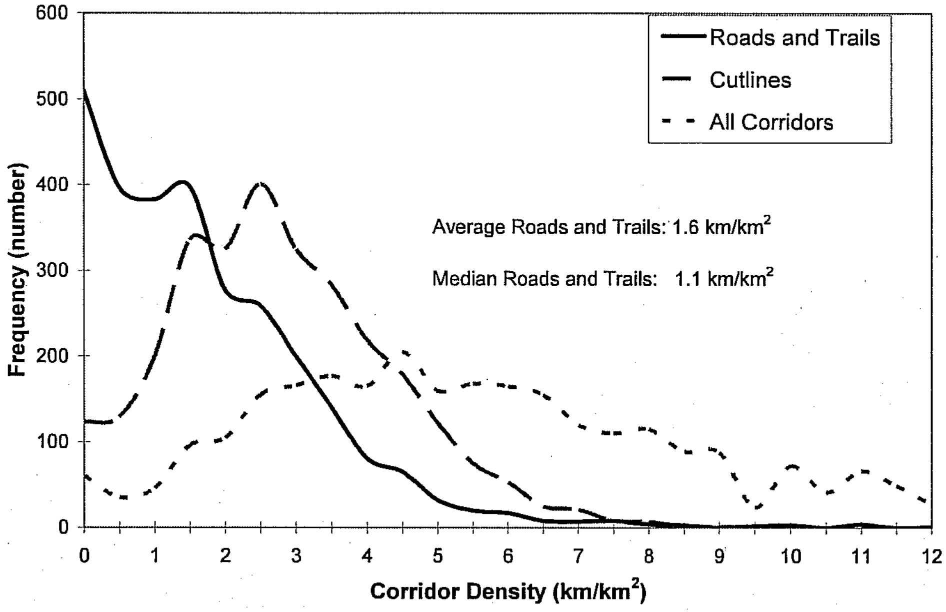


Figure 31. Current linear feature frequency in the Blueberry Case Study area.

In the current study, median road and trail density was the indicator that best predicted moose and elk harvest, and was a better predictor than average density. Although average access density is the normal reporting convention, use of median access density is considered to be more appropriate in forested areas of northeast British Columbia.

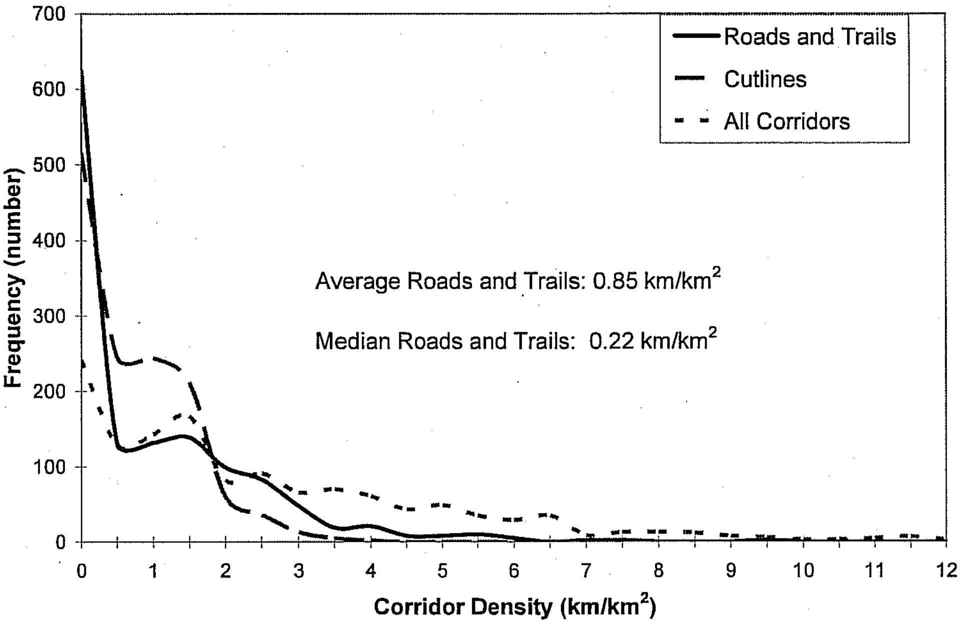


Figure 32. Current linear feature frequency in the Sukunka Case Study area.

3.4.2 Stream Crossing Index

Stream crossing indices were calculated for all subwatersheds in the Blueberry and Sukunka Case Study areas using TRIM II hydrography. Watershed cumulative effects risk was rated as High in both the Blueberry and Sukunka Case Study areas; this suggests that further field investigation is warranted to document actual risk (BCF and BCE 1995b).

TRIM II hydrography data are believed to dramatically overestimate the actual length of stream present in the field, so comparative analysis was undertaken in the Blueberry Case Study area using readily available 1:50,000 scale digital hydrography data. The TRIM II data identified more than 3 times as many streams as the smaller scale (1:50,000) data in each subwatershed. Watershed riparian indicators calculated with 1:50,000 hydrography data were significantly ($P<0.01$) higher than those calculated with TRIM II data – this elevated the riparian cumulative effects hazard in the Case Study area from Low to High. Stream crossing indices calculated with smaller scale data were significantly ($P<0.02$) lower than those calculated with TRIM II data – this reduced the watershed cumulative effects hazard from High to Medium.

Smaller scale (1:50,000) hydrography data are considered to be most appropriate for calculation of watershed cumulative effects indicators because they more accurately identify potential fish-bearing watercourses.

3.4.3 Core Area

Remaining core area is considered to be one of the most practical cumulative effects indicators. This habitat index provides a useful complement to access density by identifying the availability and location of areas where minimal human impacts have occurred. In fragmented landscapes, these areas have increased importance for population persistence; application of a minimum core area indicator can help minimize further fragmentation.

Loss of core area occurred at a much higher rate than did clearing, reflecting the non-linear nature of edge effects. The core area decline rate differed between the two study areas as a result of different development patterns. In both Case Study areas however, observed trends were consistent with theoretical fragmentation models that have identified critical changes at around 40% to 60% core area for habitat specialists such as woodland caribou and interior forest songbirds.

There is a generally accepted cumulative effects method that was developed to calculate core security areas for grizzly bear (e.g., Gibeau et al. 1996, Appendix 1). This method requires information on seasonal habitat suitability, disturbance features, and assumed or actual human use of these features on a seasonal basis. This method has recently begun to be applied to a variety of other large mammals, including moose. In the Blueberry and Sukunka Case Studies, generalized core area availability was found to have equal predictive power for moose and elk population indices as a more detailed (and costly) indicator that integrated habitat suitability. This indicates that core area can be used as a generalized landscape indicator for tolerant habitat generalists such as moose and elk. More detailed, species-specific evaluations will be required for intolerant or sensitive species, such as woodland caribou, that rely on relatively large and isolated patches of suitable habitat for persistence.

3.4.4 Patch and Corridor Size

Insufficient data on species abundance and distribution were available to test effects of patch and corridor size. In both case study areas, core areas changed from a few very large contiguous patches to a many fragments over the 30 to 50 year analysis period. Smaller fragments provide limited security for large or intolerant species, so patch and corridor size should be integrated into core area analyses to quantify those areas with value for focus species.

3.4.5 Utility of Existing Data

The Case Studies also evaluated the utility of readily available data for use in cumulative effects models and assessments. For reasons summarized below, the availability and quality of existing data affected study conclusions.

The readily available TRIM II digital data provided to be insufficient to accurately identify disturbance features. Most significantly, many clearings are not identified, so it is impossible to distinguish industrial, commercial, and recreational facilities from forest cutblocks, houses, and agricultural fields. In addition, information on the age of the feature, reclamation status, and intensity of use is not available; this is critical for differentiating between high-use and low- or no-use features.

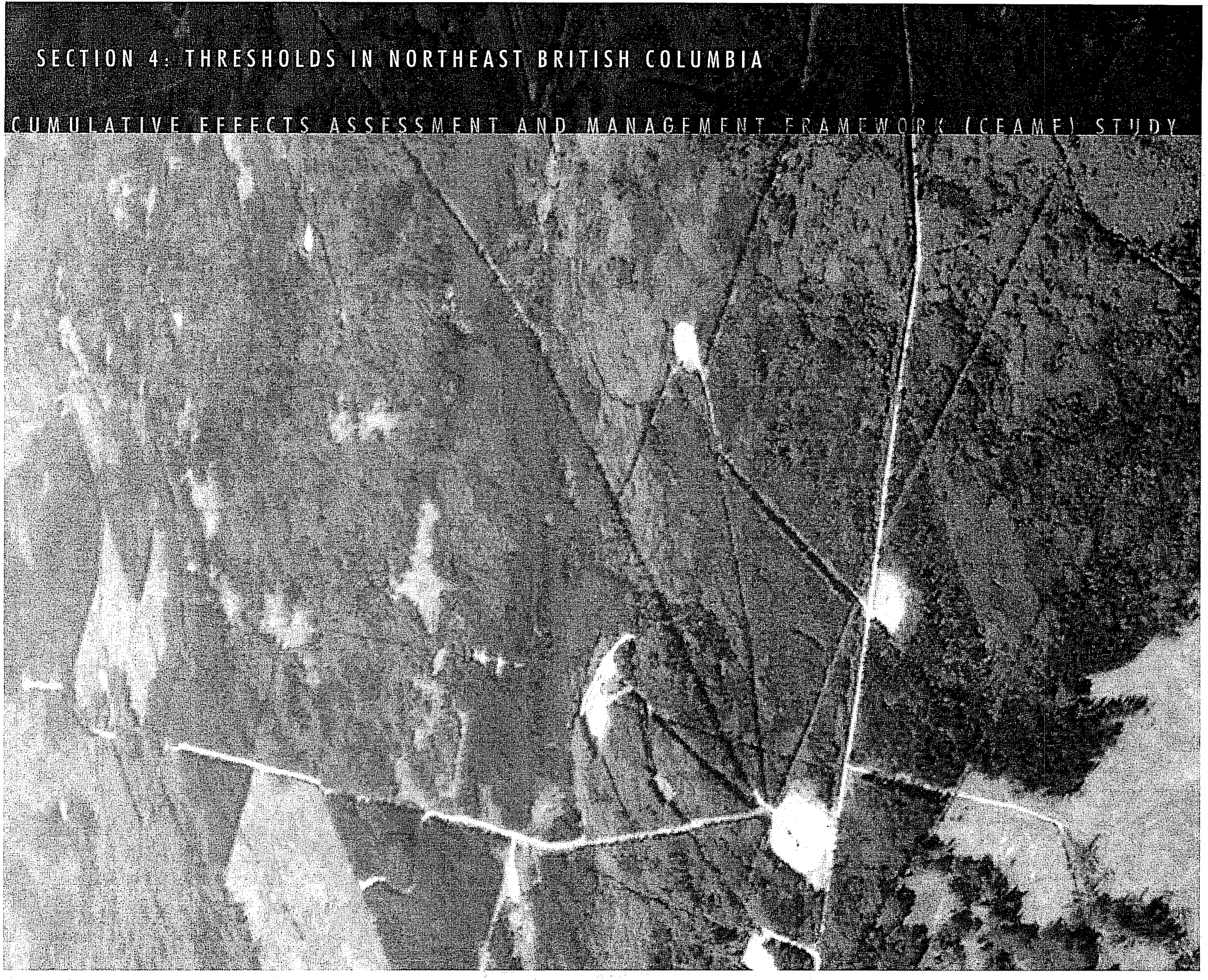
Existing forest cover data available from the British Columbia Provincial Government are known to be inaccurate and do not include insufficient information to develop reliable habitat suitability ratings. The Provincial Government is currently developing wildlife habitat maps based on the 1:250,000 Broad Terrestrial Ecosystem Classification scheme (BEI; RIC 1998) that are designed to be more suitable for cumulative effects analyses. In addition, medium to large scale Terrestrial Ecosystem Mapping (TEM; RIC 1999) is available for some areas. Use of these maps would enhance the consistency and accuracy of habitat suitability ratings and also reduce the cost to the applicant.

Analyses of watershed indicators are sensitive to the scale of the hydrography layer used. The readily available TRIM II digital data includes numerous computer-generated watercourses that do not occur in the field. This causes critical stream-length based indicators (riparian area cleared, stream crossing index) to be inaccurate. For this reason, watershed indicators should be calculated using the 1:50,000 watershed polygons and stream network provided in the British Columbia Watershed Atlas. This information data is considered to be most appropriate for this indicator because it more accurately identifies potential fish-bearing watercourses.

Finally, the evaluation of relationships between development and renewable resource trends was primarily hindered by the lack of data on species abundance and distribution. In particular, the original plan to include a Case Study in a muskeg-dominated area important for woodland caribou could not be achieved due to a lack of information on the boreal ecotype in this region.

SECTION 4: THRESHOLDS IN NORTHEAST BRITISH COLUMBIA

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY



4. THRESHOLDS IN NORTHEAST BRITISH COLUMBIA

Cumulative effects management is largely focused on defining how and where human activities can be continued without irreversible net harm to habitat, fish and wildlife populations, or biodiversity. Most cumulative effects ultimately result from the combined effects of small routine projects or activities. Nevertheless, the potential cumulative effects of these everyday activities are rarely considered in a formal way. This is at least partly due to the perception that complex, expensive, and time-consuming technical methods such as species-specific habitat modelling are required. Available literature and practice in other jurisdictions demonstrates that cumulative effects indicators can be used to quickly and economically assess the risk of adverse cumulative effects.

A suite of four complementary land use and habitat indicators was identified as the most appropriate for assessing and managing cumulative effects on fish and wildlife habitat and populations in northeast British Columbia. These indicators quantify the area affected directly and indirectly by access corridors and the number and size of relatively undisturbed areas. They are:

Land Use Indicators

1. Access density (km of linear corridors per unit area).
2. Stream crossing index (number of crossings per km of stream).

Habitat Indicators

1. Core area (% of analysis area).
2. Patch and corridor size (area in ha or width in m).

This section discusses recommended cumulative effects indicators, presents candidate thresholds for each indicator, outlines a process to use these thresholds for cumulative effects assessment and management, and identifies implementation and data needs.

4.1 CUMULATIVE EFFECTS THRESHOLDS

Indicators present information about the likelihood of adverse cumulative effects, but do not directly measure the acceptability of these effects. Thresholds are objective, science-based standards used to define the point at which the indicator changes from an acceptable to unacceptable condition.

Established chemical thresholds are available to help proponents and regulators identify the point or range at which cumulative effects on air and water quality changes from an acceptable to an unacceptable condition. This allows development activities to proceed without detailed review until a defined threshold is reached. Once the threshold range is reached however, additional review or regulation is implemented.

The British Columbia Approved Water Quality Guidelines (MELP 2001) are an example of science-based thresholds. Water quality problems are considered non-existent if the substance concentration is below the guideline value. In cases where the substance concentration exceeds its guideline, an enhanced evaluation of water quality is desirable. In some instances, local 'Water Quality Objectives' may be developed to protect the most sensitive water use at a specific location, accounting for local circumstances (MELP 2001).

There is inevitably some uncertainty with science-based thresholds, and economic, social, and technical considerations are normally incorporated when thresholds are established. Regulators may build in a safety margin by establishing a threshold below the point of irreversible effects or below the lowest point at which a behavioural, physiological, or population-level effect has been detected. In other cases, regulators may adopt a less stringent threshold that provides a lower, but still adequate level of protection at less cost to the proponent or society. Regardless, the rationale for threshold derivation should be clear and the process used to derive the threshold should be transparent.

Ecological thresholds have not been as widely applied as chemical thresholds, but thresholds based on meaningful land use, habitat, or population indicators can also be used to evaluate the acceptability of project-specific and cumulative effects. All the indicators identified in the literature review provided in Appendix 1 have some value for resource management. Resource managers in other jurisdictions have concluded that the most practical thresholds are land use and habitat indicators that quantify the effect of human development. Candidate thresholds for northeast British Columbia are provided in Section 4.4.2.

4.2 CASE STUDY FINDINGS

The applicability of recommended land use and habitat indicators was tested in the Blueberry and Sukunka Case Studies provided in Appendices 2 and 3. The presence of apparent thresholds was also investigated. Conclusions based on these indicators were also compared to those obtained with a more detailed method that examined predicted habitat quality for moose, woodland caribou, elk, and grizzly bear.

4.2.1 Development Trends

In both Case Studies, the area directly affected by linear features and clearings has increased at a consistent and predictable rate over the last thirty to fifty years. The rate of core habitat decline was much more rapid than the rate of forest clearing; core area loss was highest during the first fifteen to twenty years of development. These trends were consistent in both study areas, even though the rate of core area decline differed between the two areas due to their differing development patterns.

Development appeared to be randomly distributed across the study areas and the amount of high and moderate suitability habitat remained relatively constant for all species over the evaluation period. Road and trail density was the best predictor of remaining core area. Observed trends were consistent with theoretical fragmentation models that have identified critical thresholds of 40% to 60% core area for habitat specialists (e.g., woodland caribou, interior forest birds). Fragmentation has decreased forest patch size and there are now a large number of very small fragments that provide limited security for large or intolerant species. The abundance of old growth forest has declined in prevalence in 'productive' forest stands and increased in 'non-productive' forest stands.

4.2.2 Renewable Resource Trends

A direct comparison between development and renewable resource trends was limited by the lack of quantitative data on historical fish and wildlife populations. Wildlife harvest statistics from the last twenty-five years were used as a population index to indirectly evaluate the relationship between human activity, habitat availability, and wildlife populations. Median road and trail density provided statistically significant ($p<0.05$) predictions of moose and elk harvest trends over the last twenty-five years. Habitat indicators incorporating suitability ratings performed no better than generalized indicators.

Moose and elk populations have not been measurably affected by ongoing petroleum development, forest harvest, and agricultural conversion. Current moose habitat effectiveness in the Blueberry area is predicted to be within the range of natural variability, and the moose population has remained relatively stable over the last twenty years. However, localized reductions in moose density and changes in sex and age ratios have likely occurred as a result of legal harvest. Elk populations in the Blueberry and Sukunka Case Study areas have increased dramatically, coincident with expansion of the road and trail network. These results demonstrate that land use thresholds developed in more populated areas may overstate cumulative effects risk in northeast British Columbia.

Although the Blueberry Case Study area historically supported woodland caribou, this area received only occasional caribou use by the early 1980's (Harper 1988). Simulations conducted with ALCES indicate that caribou habitat effectiveness has been dramatically reduced by clearing and access development; this decline is well below the range of natural variability (Figures 28, 29). Other land use and habitat-based evaluations also concluded that woodland caribou are unlikely to persist in the Blueberry Case Study area. Woodland caribou in the Sukunka Case Study area appear to be at increased risk from combined activities.

Habitat loss, fragmentation, direct and indirect mortality, and disturbance have also increased the risk of cumulative effects for both sensitive and tolerant species. Implementation of better methods to assess and manage cumulative effects is warranted.

4.3 TIERED THRESHOLDS

Tiered ecological and land use thresholds are recommended for northeast British Columbia. Tiered air and water quality thresholds are already used in British Columbia, and ecological thresholds be derived and implemented as part of a clear and integrated framework. With this approach, science- based and politically defined Cautionary, Target, and Critical thresholds are defined to reflect increasing degrees of concern. These thresholds are then integrated with defined management actions so that operating rules are clear for all parties. Figure 33 illustrates the tiered threshold model defined by the Clean Air Strategic Alliance (CASA) for management of potential acidification input (AENV and CASA 1999). This model identifies three receptor-based management tiers: Critical, Target, and Cautionary Thresholds.

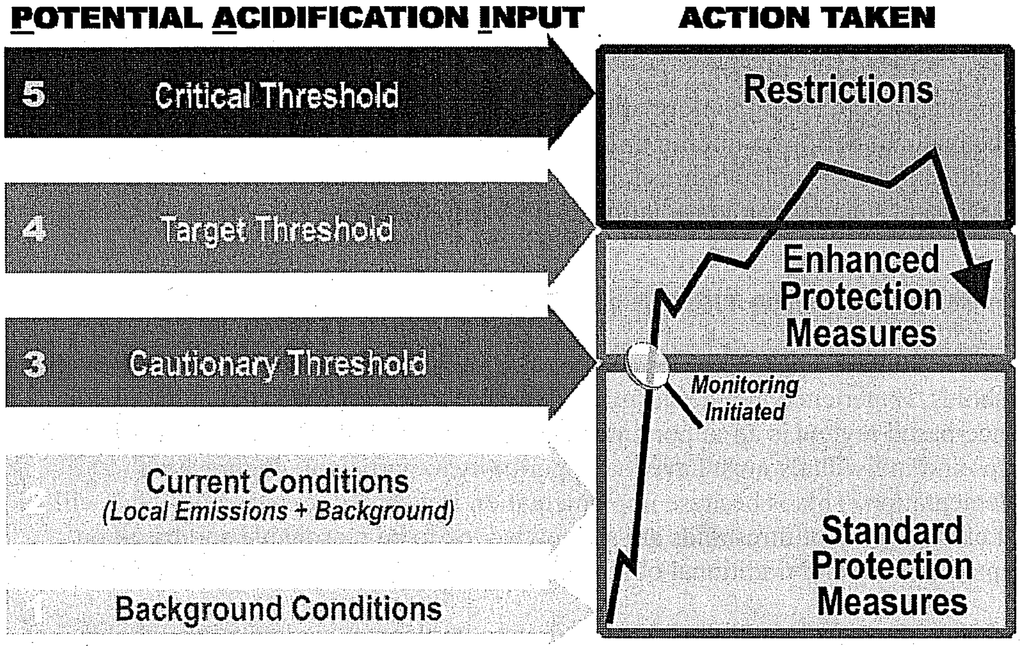


Figure 33. Development of tiered cumulative effects thresholds.

In this graphic, the red line in the Action Taken box represents the status of the cumulative effects indicator (here, potential acidification input).

Critical Thresholds reflecting minimum habitat parameters (or maximum land use) can be established using the lowest observed effects level (Bull 1991, 1992), the range of natural variability, the probability and severity of an undesirable effect (Francis and Shotton 1997), or population parameters such as predicted risk of population extinction or persistence (Lande 1987; Lamberson et al. 1992). As shown in Figure 33, management action is designed to keep the cumulative effects indicator below this threshold.

Target Thresholds reflect the desired value or range of habitat parameters. As shown in Figure 33, the desired condition was identified as 40 to 70% habitat availability, with the Target Threshold set at 40%. The Target Threshold represents the point at which 'Restrictive Protection Measures' would be initiated.

No Net Habitat Loss is an example of a Target Threshold that is routinely applied to protect fisheries habitat. Although unavoidable habitat loss may be legally authorized at the regulator's discretion, it requires implementation of Restrictive Protection Measures, namely negotiation of a formal agreement to compensate for lost habitat.

Cautionary Thresholds reflect the point at which monitoring or 'Enhanced Protection Measures' would be implemented to slow the rate of change and determine actual ecological response. As shown in Figure 33, cooperative or project-specific monitoring is initiated once the Cautionary Threshold is exceeded. Monitoring helps ensure that sufficient local data exist to confirm scientific predictions of target and critical thresholds, along with the benefits of prescribed management actions.

Where there is not enough information to define a threshold value or range, a decision can be made to define an interim threshold between the Cautionary and Target Thresholds. The sustainable threshold would be established only after further monitoring, research, and stakeholder consultation (AENV and CASA 1999).

4.4 IMPLEMENTING TIERED THRESHOLDS

This Case Studies report provides a suite of cumulative effects indicators and candidate thresholds. Experience in other jurisdictions clearly demonstrates that although this science-based review is an important initial step in threshold development, all affected groups and individuals must have the opportunity to participate in threshold implementation. This is because implementation is a shared responsibility that will be most effective where thresholds are acknowledged to be reasonable and based on accepted science and traditional observation (see also Volume 1, Section 4.6.2).

The following process will likely be required to implement ecological thresholds in northeast British Columbia:

1. Develop explicit definitions of acceptable change,
2. Adopt candidate thresholds as a foundation for further discussion,
3. Evaluate the ecological and economic implications of threshold implementation,
4. Develop standardized analysis, reporting, and review methods,
5. Provide required land use data in a consistent and readily available format,
6. Implement a pilot study to validate thresholds and optimize analysis, reporting and review methods, and
7. Continue monitoring to refine thresholds and management actions.

Further discussion of this threshold implementation process is provided below. The specifics provided here are intended to reflect the resource management and review regime in the region. The actual process will need to be developed with participant input.

4.4.1 Defining Acceptable Change

In northeast British Columbia, the three established LRMPs provide direction on acceptable change as defined by a wide array of groups. The thresholds presented here have been directly linked to designated 'Provincial Land Use Categories' in Table 9.

Table 9. Level of protection based on Provincial Land Use Categories.

Protected Areas and Special Management Areas:

These lands are managed to protect specific ecological values. They are considered primary source habitat for all species; they provide relatively undisturbed areas for wilderness and backcountry recreation. Thresholds should be established below the lowest detected effect level for Identified Wildlife or the most sensitive species to provide a **100% level of protection** (a Very Low Risk as defined by MELP 2000).

General Management Areas and Identified Landscape Management Units:

These multiple use lands are managed for a wide variety of resource values. They are secondary source habitat for most species; they provide a mixture of undisturbed and modified areas. Thresholds should be established below the lowest observed effect level for most species to provide a **90% level of protection** (a Low Risk as defined by MELP 2000). More protective thresholds may be established in defined Landscape Management Units.

Enhanced Resource Development and Agriculture/Settlement Areas

These multiple use lands are managed for intensive resource development in full compliance with best management practices. They are neutral or sink habitat for most species and consist primarily of human-modified areas. Thresholds should be established to provide an **80% level of protection** (a Moderate Risk as defined by MELP 2000). More protective thresholds may be established in defined Landscape Management Units.

Quantitative protection levels have been included here to help visualize acceptable change. A 90% level of protection infers that 10% of species or ecosystems in a defined area may be subject to adverse effects.

Natural range of variability can also be used to establish acceptable change, as reflected in the Landscape Unit Planning Guide (BCE and MELP 1999b). Case Study results suggest that the ALCES model is one option to help define natural range of variability for a range of indicators.

4.4.2 Candidate Thresholds

Figures 34 and 35 respectively present graphical summaries of road density and core area guidelines and thresholds identified in the literature review (Appendix 1). These guidelines and thresholds, as well as the Case Studies (Appendices 2 and 3), were used to generate candidate tiered road density and core area thresholds for northeast British Columbia (Table 10).

The candidate thresholds provided in Table 10 were derived to reflect conditions in northeast British Columbia, the levels of protection inferred from Provincial Land Use Categories, and the following environmental management principles established by MELP (2000) for regulation of activities affecting the environment:

Sustainability:	Resources should not be used beyond their capacity to be naturally replenished, both in quality and quantity, for the well-being of future generations.
Precautionary Principle:	The onus of proof should be on parties undertaking actions that could cause serious or irreversible environmental damage to provide beyond a reasonable doubt such that no damage will be caused.

4.4.2.1 Landscape Road and Trail Density

Access density is a land use indicator that integrates many ecological effects of habitat loss, alteration, barriers, mortality, and disturbance. Case Study results confirm that this indicator can help document the risk of cumulative effects in northeast British Columbia. Three candidate access density thresholds have been identified: landscape road and trail density, watershed road and trail density, and total corridor density. Road and trail density would be used for generalized landscape and watershed analyses while total corridor density would be used for analysis in designated woodland caribou habitat.

Road and trail density thresholds have been detected or proposed to protect both terrestrial and aquatic systems (Figure 31). Established standards may not be directly comparable because there have been considerable differences in the type of linear features included in road density calculations. Candidate road and trail density thresholds for northeast British Columbia are provided in Table 10.

Combined road and trail densities must be calculated in a standardized manner to ensure that project proposals are evaluated consistently and equitably. The recommended approach here is to include those features most likely to receive high use in this region. This would include primary roads, secondary roads, truck trails passable by four-wheel drive vehicle, and designated off-highway or all-terrain vehicle (OHV/ATV) trails. Other linear features such as utility corridors (pipelines, powerlines, and railway rights-of-way) and cutlines are less likely to receive high use. When calculated on this basis, road and trail density was found to be a good predictor of moose and elk harvest success and remaining core area in the Blueberry and Sukunka Case Studies.

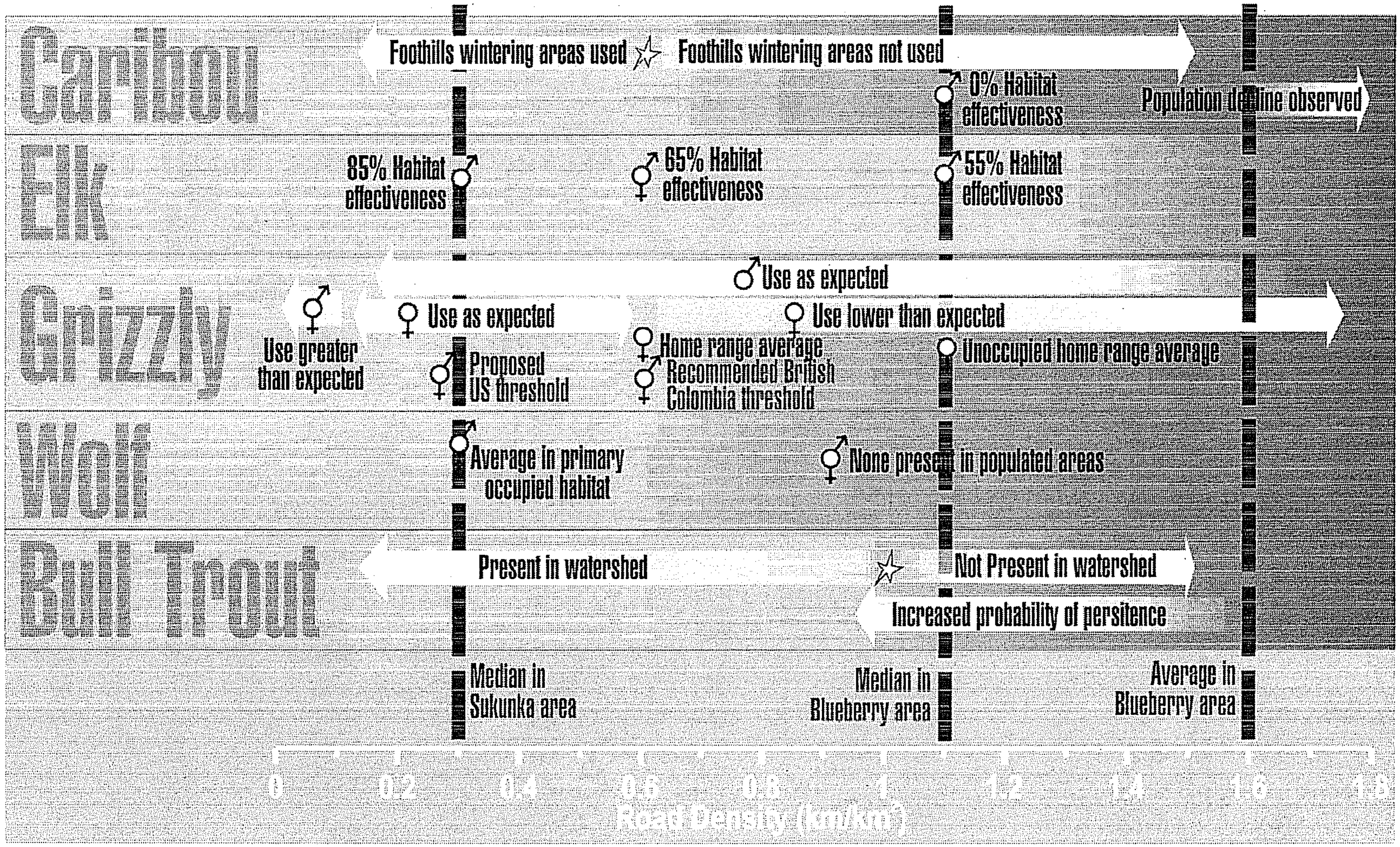


Figure 34. Documented access density effects for selected fish and wildlife species.

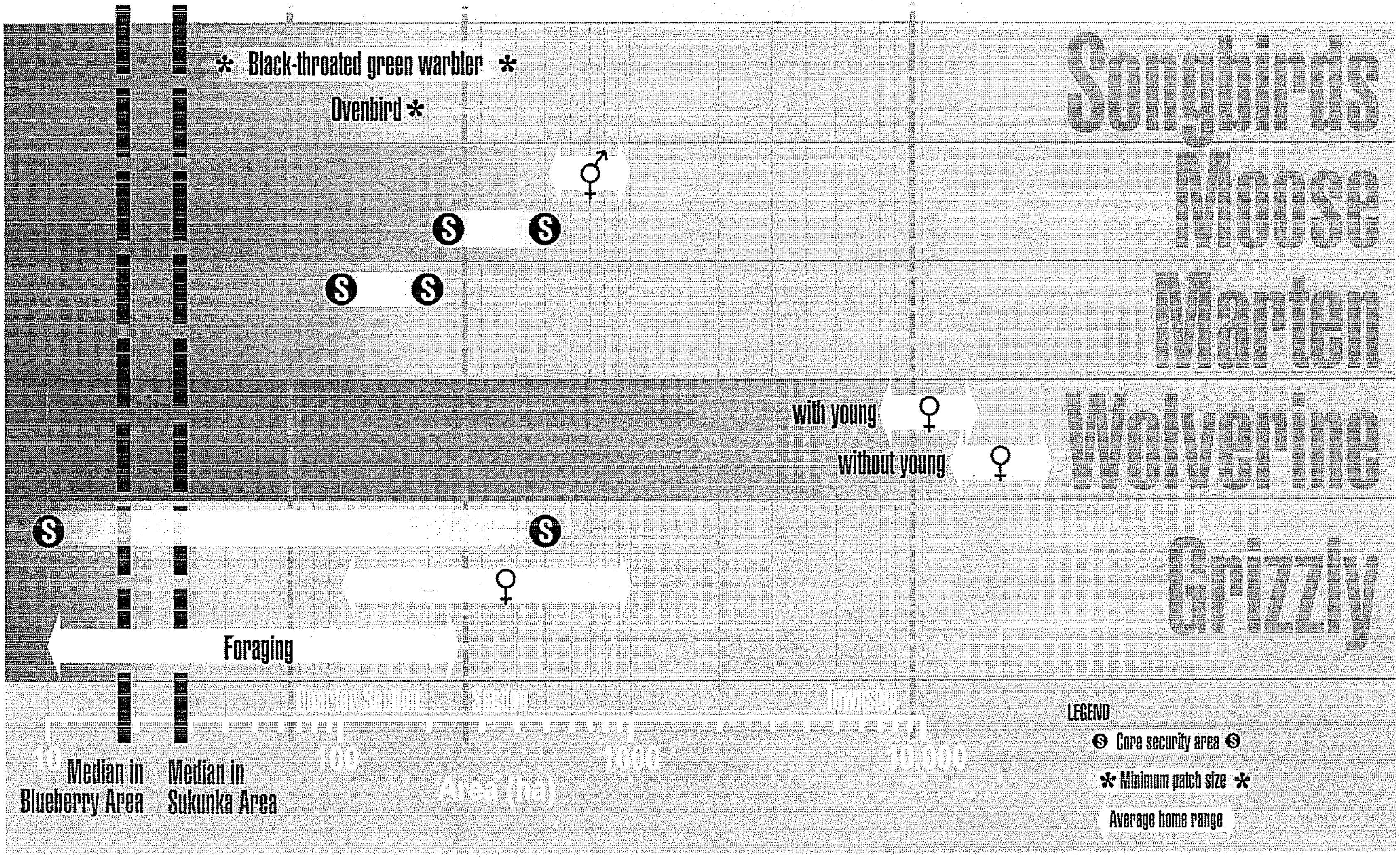


Figure 35. Documented core area, minimum patch size, and home range areas for selected wildlife species.

Table 10. Tiered threshold implementation in northeast British Columbia.

Indicator	Threshold by Land and Resource Management Plan Designation		
	Enhanced Resource Development Areas	General Resource Management Areas	Special Resource Management Areas
Candidate Generalized Thresholds			
Landscape Road and Trail Density (open primary and secondary roads, truck trails, and designated ATV trails)	**Cautionary:** Median 0.6 km/km^2 (calculated for threshold analysis area)[1]. **Target:** Median 1.0 km/km^2 (calculated for threshold analysis area)[1]. **Critical:** Median 1.2 km/km^2 (calculated for threshold analysis area)[1].	**Cautionary:** Median 0.4 km/km^2 (calculated for threshold analysis area)[1]. **Target:** Median 0.6 km/km^2 (calculated for threshold analysis area)[1]. **Critical:** Median 0.9 km/km^2 (calculated for threshold analysis area)[1].	**Cautionary:** Median 0.2 km/km^2 (calculated for entire RMZ). **Target:** Median 0.3 km/km^2 (calculated for entire RMZ). **Critical:** Median 0.4 km/km^2 (calculated for entire RMZ).
Watershed Road and Trail Density (open primary and secondary roads, truck trails, and designated ATV trails)	**Cautionary:** Median 0.9 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Target:** Median 1.7 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Critical:** Median 2.4 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2)	**Cautionary:** Median 0.6 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Target:** Median 0.9 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Critical:** Median 1.7 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2)	**Cautionary:** Median 0.3 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Target:** Median 0.6 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2) **Critical:** Median 0.9 km/km^2 in watershed(s) with proposed activity (between 50 and 500 km^2)

Table 10. Tiered threshold implementation in northeast British Columbia (cont.).

Indicator	Threshold by Land and Resource Management Plan Designation		
	Enhanced Resource Development Areas	General Resource Management Areas	Special Resource Management Areas
Generalized Core Area (area outside 500 m buffer around high-use features, including primary and secondary roads; truck and ATV trails; wellsites; industrial, commercial, and recreational facilities; communities; and permanent residences)	**Cautionary:** 50% core areas greater than 4.5 ha and 350 m wide (calculated for threshold analysis area)[1]. **Target:** 40% core areas greater than 4.5 ha and 350 m wide (calculated for threshold analysis area)[1]. **Critical:** 20% core areas greater than 4.5 ha and 350 m wide (calculated for threshold analysis area)[1].	**Cautionary:** 65% core areas greater than 200 ha and 350 m wide (calculated for threshold analysis area)[1]. **Target:** 50% core areas greater than 200 ha and 350 m wide (calculated for threshold analysis area)[1]. **Critical:** 40% core areas greater than 200 ha and 350 m wide (calculated for threshold analysis area)[1].	**Cautionary:** 85% core areas greater than 1000 ha and 500 m wide (calculated for entire RMZ). **Target**: 75% core areas greater than 1000 ha and 500 m wide (calculated for entire RMZ). **Critical**: 65% core areas greater than 1000 ha and 500 m wide (calculated for entire RMZ).
Candidate Species-Specific Thresholds			
Woodland Caribou – Total Corridor Density (open primary and secondary roads, truck trails, designated ATV trails, pipeline and powerline rights-of-way, railways, and conventional cutlines)	**Cautionary:** Median 1.5 km/km^2 (calculated for threshold analysis area)[1]. **Target:** Median 1.8 km/km^2 (calculated for threshold analysis area)[1]. **Critical:** Median 3.0 km/km^2 (calculated for threshold analysis area)[1].	**Cautionary:** Median 1.2 km/km^2 (calculated for threshold analysis area)[1]. **Target:** Median 1.5 km/km^2 (calculated for threshold analysis area)[1]. **Critical:** Median 1.8 km/km^2 (calculated for threshold analysis area)[1].	**Cautionary:** Median 1 km/km^2 (calculated for entire RMZ). **Target:** Median 1.2 km/km^2 (calculated for entire RMZ). **Critical:** Median 1.5 km/km^2 (calculated for entire RMZ).

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[1] – Threshold analysis area includes all BSGS 1:20,000 map sheets intersected by the project plus immediately adjacent sheets; minimum 450 km^2.

Thresholds provided in Table 10 are based on median values rather than average values used elsewhere. Road and trail frequency distributions were skewed in both the Blueberry and Sukunka Case Studies, and median values provided better estimates of central tendency than did average or mean values.

Analysis Area

Identification of appropriate analysis area (spatial boundaries) is a critical component of environmental assessment. Selection of a very large analysis area increases the likelihood that an effect will be judged to be of no concern because it is relatively small in comparison. In contrast, selection of a small study area prevents consideration of incremental and cumulative effects that are best evaluated over larger areas.

A map sheet-based approach is recommended for northeast British Columbia to simplify data collection and spatial analyses. TRIM II digital data are readily available from the provincial government and provide the most comprehensive and current information for this region. To be consistent, total road and trail density should be calculated for all BSGS 1:20,000 map sheets directly affected by the project and all adjoining sheets. This translates to a minimum of six map sheets covering a 450 to 500 km^2 area; this is consistent with landscape-level planning (MSRM 2002a) and sufficiently large to allow consideration of the 'big picture'. This scale is ecologically meaningful for the large, mobile animal species that are most susceptible to access-related cumulative effects.

An advantage of a map sheet-based approach is that it allows a regional database of land use features to be generated over time as a result of independent submissions by project proponents (Eccles et al. 1994). This is considered to be the most practical and economic method of generating the required database, since the incremental cost to each proponent would be low, and the most active development areas would be included at early stages.

The revegetation status of existing roads and trails should also be considered, because this is known to affect animal response (e.g., Mace et al. 1996). Roads and trails can be considered impassable if:

- woody vegetation greater than 1.5 m in height has become established (roughly 10 to 15 years post-construction in this area),
- the road has been reclaimed, or
- access control measures have been implemented, and no evidence of use is present.

For initial screening purposes, all roads and trails should be considered to be open, unless field data confirm that they are impassable. To allow this to be tracked, age and revegetation status should be added as attributes for each linear feature.

Candidate Threshold Derivation

The numerical values for generalized landscape thresholds provided in Table 10 were established as follows.

The Critical Threshold for special resource management areas (median <0.4 km/km^2) was set below the 0.6 km/km^2 threshold identified for persistence of the most sensitive species (caribou, grizzly bear, bull trout persistence; Figure 34). This critical threshold is defined to be protective of all species over the long-term. The Target Threshold for special resource management areas (median <0.3 km/km^2) was set to an average home range value known to be used by these sensitive species, which also reflects the proposed United States threshold for grizzly bear recovery (Figure 34). The Cautionary Threshold for special resource management areas (median <0.2 km/km^2) was arbitrarily set below the target threshold to ensure that enhanced protection measures are implemented at early stages of fragmentation. Use of the entire RMZ as the spatial boundary for these analyses is intended to ensure that assessment and management occurs at the largest practical scale.

The Critical Threshold for general resource management areas (median <0.9 km/km^2) was set at the midpoint between the Target Threshold and existing conditions in the Case Study areas. This threshold cannot be assumed to provide adequate protection for the most sensitive species over the long-term, but it appears to be sufficient to allow more tolerant species (elk, wolf) to persist. The Target Threshold for general resource management areas (median <0.6 km/km^2) was set to the threshold identified for persistence of the most sensitive species (caribou, grizzly bear, and bull trout persistence; Figure 34). This threshold represents the desired road and trail density in much of the region, and would trigger restrictive protection measures to reduce further fragmentation. The Cautionary Threshold for general resource management areas (median <0.4 km/km^2) was set to be consistent with the Critical Threshold for special management areas in order to ensure that enhanced protection measures are implemented at early stages of fragmentation.

The Critical Threshold for enhanced resource development areas (median <1.2 km/km^2) was set to reflect existing conditions in the Case Study areas. This threshold may not ensure persistence of the most sensitive species over the long-term (caribou, grizzly bear, and bull trout), but it appears to be sufficient to ensure persistence of most species of management concern. The Target Threshold for enhanced resource development areas (median <1.0 km/km^2) was set based on access density-core area relationships (Figure 30) to ensure persistence of a wide range of birds and mammals (Andren 1994). The Cautionary Threshold for enhanced resource development areas (0.6 km/km^2) was set to the threshold identified for persistence of the most sensitive species (caribou, grizzly bear, and bull trout; Figure 34). This threshold would trigger enhanced protection measures to reduce further fragmentation.

4.4.2.2 Watershed Road and Trail Density

Watershed road and trail density is an indicator of cumulative risk of erosion and peak flow. This indicator should be calculated for all subwatersheds directly affected by the project (i.e., all those in which roads, rights-of-way, or facilities would be constructed). Subwatersheds include drainages 50 to 500 km^2 in size based on the 1:50,000 British Columbia Watershed Atlas. For watershed analyses, linear features should be considered to be revegetated if complete vegetation cover is present over the entire right-of-way, and there is no evidence of use. The numerical values for generalized watershed thresholds provided in Table 10 were established as follows.

Candidate Threshold Derivation

The Critical Threshold for special resource management areas (median <0.9 km/km^2) was set at the 0.3 hazard index level defined in the Interior Watershed Assessment Process; (IWAP; BCF and BCE 1995b). This is considered to represent low risk of peak flow and surface erosion effects over the long-term. The Target Threshold for special resource management areas (median <0.6 km/km^2) was set at the 0.2 hazard index level defined in the IWAP (BCF and BCE 1995b) to represent very low risk of long-term watershed effects. The Cautionary Threshold for special resource management areas (median <0.3 km/km^2) was at the 0.1 hazard index level defined in the IWAP (BCF and BCE 1995b) to represent very low risk of long-term watershed effects.

The Critical Threshold for general resource management areas (median <1.7 km/km^2) was set at the 0.6 hazard index level defined in the IWAP (BCF and BCE 1995b). This is associated with moderate risk of peak flow and surface erosion effects. The Target Threshold for general resource management areas (median <0.9 km/km^2) was set at the 0.3 hazard index level defined in the IWAP (BCF and BCE 1995b), to represent low risk of long-term watershed effects. The Cautionary Threshold for general resource management areas (median <0.6 km/km^2) was at the 0.2 hazard index level defined in the IWAP (BCF and BCE 1995b) to represent very low risk of long-term watershed effects.

The Critical Threshold for enhanced resource development areas (median <2.4 km/km^2) was set at the 0.8 to 0.9 hazard index level defined in the IWAP (BCF and BCE 1995b). This is associated with high risk of peak flow and surface erosion effects. The Target Threshold for enhanced resource development areas (median <1.7 km/km^2) was set at the 0.6 hazard index level defined in the IWAP (BCF and BCE 1995b). This is associated with moderate risk of peak flow and surface erosion effects. The Cautionary Threshold for enhanced resource development areas (median <0.9 km/km^2) was set at the 0.3 hazard index level defined in the IWAP (BCF and BCE 1995b), to represent low risk of long-term watershed effects.

4.4.2.3 Minimum Core Area

Minimum core area is a useful complement to road and trail density since it identifies areas with minimum human disturbance. Although the total area of remaining core could be accurately predicted from road and trail density in the Blueberry and Sukunka Case Studies, information on the location and size of these areas is important so that fragmentation of remaining core areas can be avoided or minimized wherever possible.

As with road and trail density, there have been considerable differences in core area calculations. A common approach is to include a 500 m zone of influence around all potential high use features. In northeast British Columbia, these are assumed to include: primary and secondary roads; truck trails passable by four-wheel drive; designated ATV/OHV trails; wellsites; industrial, commercial, and recreational facilities; and communities. To provide sufficient security, core area patches should meet minimum width and size criteria that reflect the desired level of protection and target management species.

Activity setbacks (buffers) are commonly used to avoid or reduce local project-specific effects (Axys 2001a, b; Appendix 1). Ideally, buffers used to calculate landscape and watershed scale indicators such as core area should be based on established setbacks to help integrate assessment and management at all scales.

Analysis Area

The same map sheet-based approach specified for road and trail density is also recommended for generalized core area analyses, i.e., all BSGS 1:20,000 map sheets directly affected by the project and all adjoining sheets. This translates to a minimum of six map sheets covering a 450 to 500 km^2 area.

Candidate Threshold Derivation

The numerical values for generalized landscape thresholds provided in Table 10 were established as follows.

The Critical Threshold for special resource management areas (>65% large core areas) was set above the 60% threshold calculated for boreal-ecotype woodland caribou and proposed for grizzly bear (Table 2). This conservative threshold is intended to represent the current level of uncertainty associated with this indicator, and the variable habitat suitability present in core areas. The Target Threshold for special resource management areas (>75% large core areas) was set in between proposed thresholds for grizzly bear recovery and the Critical Threshold. The Cautionary Threshold for special resource management areas (>85% large core areas) was set above thresholds for grizzly bear recovery.

The Critical Threshold for general resource management areas (>40% moderately large core areas) was set at the threshold calculated for interior habitat specialists (Table 2). The Target Threshold for general resource management areas (>50% moderately large core areas) was set at the observed 50% caribou threshold. The Cautionary Threshold for general resource management areas (>65% large core areas) was set to be consistent with the Critical Threshold for special management areas; this would initiate monitoring to determine whether this threshold can be relaxed while still providing adequate long-term protection.

The Critical Threshold for enhanced resource development areas (>20% small core areas) was set at the midpoint of the minimum habitat thresholds identified by Andren (1994). The Target Threshold for enhanced resource development areas (>35% small core areas) was set above the minimum habitat thresholds predicted for habitat generalists (Table 2). The Cautionary Threshold for enhanced resource development areas (>50% small core areas) was set at the observed boreal-ecotype caribou and above the interior species threshold to provide additional protection and to be consistent with the Target Threshold for general resource management areas.

4.4.2.4 Species-Specific Thresholds

All three generalized landscape and watershed-based thresholds are intended for application throughout the region. In areas with local sensitivity ('hot spots'), species-specific thresholds will likely be required to provide enhanced protection and supplement the generalized land use and habitat thresholds.

Specific candidate thresholds developed for boreal-ecotype woodland caribou are provided in Table 13. This species is extremely sensitive to cumulative effects of habitat fragmentation and disturbance for reasons described below. Caribou population declines have been documented in other areas of western Canada with development footprints similar to those that currently exist in northeast British Columbia.

Generalized road and trail density thresholds included only potential high-use features because access effects on most wildlife species appear to be related to traffic volumes, out-of-vehicle activity, and predation rather than the physical presence of the feature (Appendix 1). However, reduced caribou use has been documented adjacent to linear corridors independent of the level of activity in some (Dyer 1999), but not all areas (Oberg 2001). Although no clear relationship has been demonstrated, linear corridors may increase predation by providing packed travel routes for wolves, thus increasing their search efficiency and range (Bergerud et al. 1984). This may be especially significant for woodland caribou. In north central Alberta, wolf predation rates for caribou were higher in proximity to linear corridors (Stuart-Smith et al. 1997; James and Stuart-Smith 2000), but wolves avoided these features in west central Alberta (Kuzyk 2002). Research will be required to determine actual response of boreal- and northern-ecotype caribou in northeast British Columbia.

Candidate thresholds are intended to be protective and are set at or below the lowest detected effect level identified for this species (Appendix 1). Given the scientific uncertainty that currently exists, the candidate woodland caribou thresholds include all linear-rights-of-way greater than 3 m in width. Passable features of this size could increase winter predation and harassment risk from wolves and snow machines.

Candidate Threshold Derivation

The Critical Threshold for special resource management areas (median <1.5 km/km^2) was set below the 1.8 km/km^2 threshold identified for boreal-ecotype caribou (Table 2). The Target and Cautionary Thresholds for special resource management areas (respectively median <1.2 km/km^2 and <1 km/km^2) were arbitrarily set below this threshold to ensure that monitoring and restrictive measures are implemented at early stages of development in designated caribou range.

The Critical Threshold for general resource management areas (median <1.8 km/km^2) was set at the persistence threshold identified for boreal-ecotype caribou (Table 2). The Target and Cautionary Thresholds for special resource management areas (respectively median <1.5 km/km^2 and <1.2 km/km^2) were arbitrarily set to be protective and consistent with special resource management area thresholds.

The Critical Threshold for enhanced resource development areas (median <3 km/km^2) was liberally set to the maximum value where woodland caribou could persist (Table 4, Appendix 1) because existing corridor density likely exceeds this threshold in much of the region. The Target Threshold for enhanced resource development areas (median <1.8 km/km^2) was set at the persistence threshold identified for boreal-ecotype caribou (Table 2). The Cautionary Threshold for enhanced resource development areas (median <1.5 km/km^2) was set to be consistent with other resource management areas.

4.4.3 Economic and Ecological Implications

The land use footprint in some areas of northeast British Columbia currently exceeds one or more candidate thresholds. Regional stakeholders will understandably be concerned about the effects of threshold implementation and will need to be convinced that they provide an appropriate balance between environmental protection and economic development.

Formal evaluations are recommended to allow government, industry, and other regional groups to understand the implications of cumulative effects assessment and management. A variety of integrated management models are available for such a task. In a recent review of predictive modelling tools, the ALCES landscape simulator was concluded to be the most comprehensive because it incorporates all potential land uses. Its greatest strength was considered to be its ability to incorporate user-defined changes so that the effect of various development scenarios and management options can be visualized (Salmo et al. 2001). ALCES was modified and applied in the Blueberry Case Study specifically to evaluate its suitability for northeast British Columbia.

This brief overview identifies some challenges that will need to be explicitly considered by regional resource managers and users prior to threshold implementation. Current 'Landscape road and trail density' exceeds the candidate Cautionary, Target, and Critical thresholds in the overall Blueberry study area. In the Jedney RMZ, the candidate Target Threshold is currently exceeded, and the candidate Critical Threshold would be exceeded by 2010 if historical road and trail construction trends continue.

One hundred year simulations were conducted with ALCES to visualize road and trail growth between 1950 and 2050 (Figure 36). Actual development rate was used between 1950 and present. Three future scenarios were modelled: Low growth (line 1 = actual 1950 to 1998 average development rate), Moderate growth (line 2 = actual 1970 to 1998 average development rate), and High growth (line 3 = actual 1970 to 1998 average development rate plus 20%).

The Blueberry Case Study area is extensively developed at present, and the projected future development footprint was not highly sensitive to the growth rate used. These projections indicate that restrictive protection measures should be applied in the near future to reduce further cumulative effects risk in the Jedney Enhanced Resource Development RMZ.

As noted previously, forest fragmentation is at earlier stages in the Sukunka Case Study area, and candidate Target and Critical thresholds are not currently exceeded. If historical road and trail construction trends continue, the candidate Target and Critical thresholds would be surpassed by 2024, and 2030, respectively.

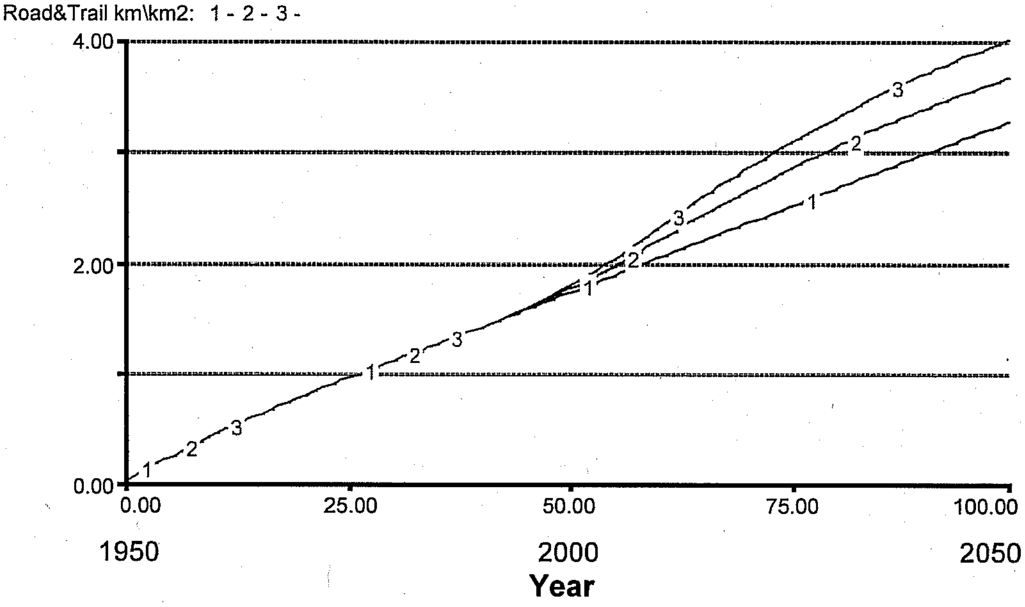


Figure 36. Projected road and trail density in the Blueberry Case Study area, 1950 to 2050 (1 = Low growth scenario; 2 = Average growth scenario; 3 = High growth scenario; road and trail density (km/km^2) on y-axis).

The potential benefit of enhanced and restrictive environmental protection measures in the Blueberry study area was also modelled with ALCES. Projected trends in future road and trail density with and without restrictive protection measures are depicted in Figure 37 (note change in scale on y-axis from Figure 36).

The simulation in Figure 37 assumed that restrictive protection measures were implemented in 1950 as development in the Blueberry Case Study area began. The simulation shows that restrictive environmental protection measures such as cooperative road planning, aggregated cutblocks, and multiple well pads can substantially slow increases in road density.

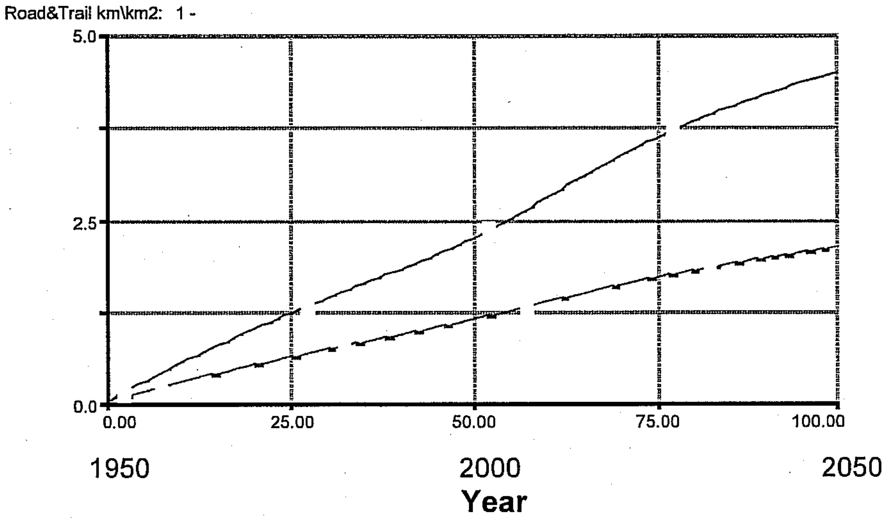


Figure 37. Comparison of projected road and trail density in the Blueberry Case Study area without (#1) and with (#2) restrictive protection measures (road and trail density (km/km^2) on y-axis).

The simulated effect of these same enhanced and restrictive protection measures on woodland caribou habitat effectiveness is depicted in Figure 38. The Habitat Effectiveness Index (HEI) plotted on the y-axis ranks the quality of habitat on a scale from 0 (no value in the area) to 1 (entire area has high quality habitat; Section 3.3.2). This simulation also assumed that restrictive protection measures were implemented in 1950 as development in the Blueberry Case Study area began.

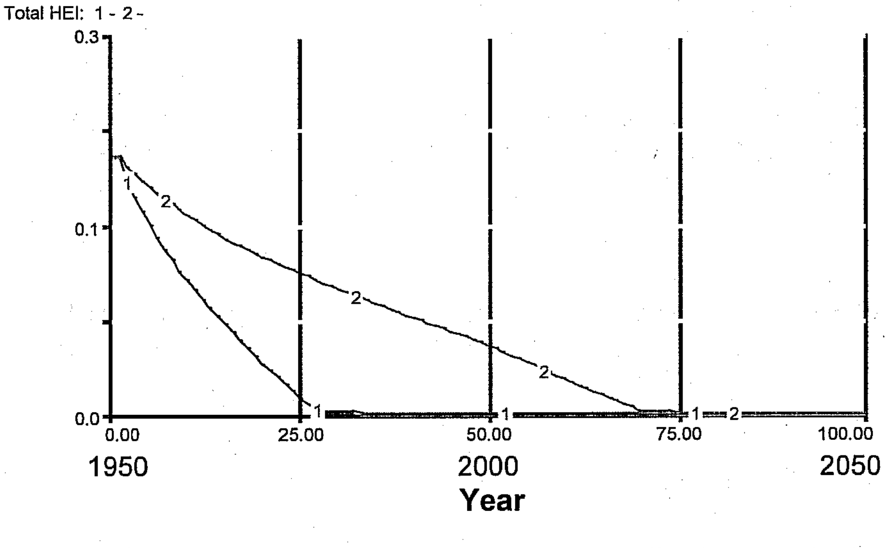


Figure 38. Comparison of projected caribou habitat effectiveness in the Blueberry Case Study area without (#1) and with (#2) restrictive protection measures (Habitat Effectiveness Index on y-axis).

Figure 38 demonstrates that enhanced and restrictive protection measures that reduce the growth of the access corridor and clearing network can reduce cumulative effects risk. This is particularly true for species such as woodland caribou that are extremely sensitive to edge effects. The Sukunka Case Study area provides a regional example of these benefits. Low-impact seismic programs have been required in this area since the early 1990's; this has reduced the rate of habitat fragmentation and disturbance relative to the Blueberry Case Study area (Section 3.2.1)

4.4.4 Project Analysis, Reporting, and Review

In northeast British Columbia, application of tiered thresholds would provide the opportunity to:

- encourage performance and results-based management,
- clearly link management actions with cumulative effects indicators,
- provide the flexibility required for different land management regimes and ecological settings, and
- provide the flexibility necessary for the full spectrum of development proposals (i.e., simple, normal, and complex).

Implementation options span the range from a primary government role to a primary land user role. Past experience demonstrates that the active support and participation of both groups will be needed. The implementation approach presented here is intended to provide an example of how cumulative effects indicators and thresholds can be incorporated in the existing project review process. This approach assumes the following:

- all resource managers and users share the responsibility for assessment and management of cumulative effects,
- the level of assessment, review, and environmental protection will be related to the potential risk of adverse cumulative effects,
- management actions will be explicitly linked to thresholds so that resource users can choose the most effective method of achieving them,
- resource managers are responsible for providing clear guidance on the calculation and application of tiered thresholds, for providing the information necessary to complete these evaluations in a timely and efficient manner, and for ensuring that rules are consistently and fairly applied,
- proponents are responsible for defining a project's contribution to cumulative effects in the land management area in which the activity is proposed and for participating in cooperative regional initiatives, and
- cooperative research and monitoring will be conducted in selected areas to provide information necessary to refine established thresholds and management actions.

In northeast British Columbia, project proposals are likely to undergo one of three classes of regulatory review:

Routine Review:	Simple or normal proposals with limited potential for significant adverse cumulative effects.
Enhanced Review:	Simple or normal proposals in sensitive areas or those with some potential for significant adverse cumulative effects.
Complex Review:	Complex proposals with high potential for significant cumulative effects.

The desired attributes of indicators and thresholds for each review class were described in Section 2.4 (Table 6). Table 11 provides additional information on how project analysis, reporting, and review requirements could be integrated with prescribed management actions for each class of review. This table also identifies the incremental cost of cumulative effects threshold implementation. A decision tree is provided in Figure 39 to demonstrate how thresholds can be applied by proponents and regulators for cumulative effects assessment and management.

4.4.4.1 Routine Review: Cumulative Effects Screening

'Cumulative Effects Screening' would be conducted for simple or normal projects with limited potential for significant adverse cumulative effects (i.e., outside sensitive areas such as designated caribou habitat). This is expected to include most applications made in the region.

Cumulative Effects Screening would require proponents to include calculations of the generalized landscape and watershed indicators provided in Table 10 with their applications. These calculations would use standardized methods and readily available public data to allow submissions to be quickly and economically prepared. Calculations would identify the current value for each indicator and the projected value with the addition of the proposed project, and relate these to the thresholds for the land management area(s) in which the project is located. This would enable proponent and regulators to explicitly assess the potential for significant adverse effects.

Management Actions

If Cumulative Effects Screening concludes that all indicators will be within established Cautionary Thresholds, best environmental management practices would apply and no further management or review action would be required (green pathway on Figure 39).

If Cumulative Effects Screening concludes that one or more indicators will exceed Cautionary Thresholds, but be within Target Thresholds, enhanced environmental management practices would be implemented for the project and cooperative monitoring would be initiated in the appropriate land management area(s) (blue pathway on Figure 39). Enhanced practices could include specific measures to reduce wellsite size, right-of-way width, or line-of-sight.

Table 11. Review and management actions associated with tiered thresholds.

Type of Project	Management Action		
	Project Review		Protection Measures
	Submission Requirements	Incremental Cost	
Cumulative Effects Screening (Routine Review)	1. Calculate generalized landscape and watershed indicators with project using standard methods and public data and compare to generalized thresholds.	<$10,000	Enhanced Site-Specific Protection measures where Cautionary Threshold exceeded or site-specific conditions warrant. Restrictive Protection Measures where Target Threshold exceeded; proponent option to conduct enhanced Cumulative Effects Evaluation. Project automatically moved to enhanced or detailed review where Critical Threshold exceeded.
Cumulative Effects Evaluation (Enhanced Review)	1. Calculate generalized landscape and watershed indicators with project using standard methods and public data and compare to generalized thresholds. 2. Provide enhanced evaluation using site-specific data or species-specific thresholds and evaluations.	$10,000 - $100,000	Enhanced Site-Specific Protection measures where Cautionary Threshold exceeded or site-specific conditions warrant. Restrictive Protection Measures where Target Threshold exceeded; proponent option to implement field studies to validate road, trail, and cutline status and use. Project rejected or moved to detailed review where Critical Threshold exceeded; proponent option to identify offsite compensation or cooperative programs to achieve no net loss.
Cumulative Effects Assessment (Complex Review)	1. Prepare General Development Plan for proposed activities. 2. Prepare Impact Assessment to identify significant fish and wildlife habitats and other resource values; include detailed cumulative effects assessment using appropriate modelling and assessment techniques for focus species. 3. Conduct landscape simulations to evaluate risk and uncertainty where appropriate.	>$100,000	Enhanced Site-Specific Protection measures where Cautionary Threshold exceeded or site-specific conditions warrant. Restrictive Protection Measures where Target Threshold exceeded; proponent option to implement field studies to validate land use and focus species status. Restrictive Environmental Protection Measures become base case in Special Management Areas (e.g., Besa-Prophet Pre-Tenure Plan, MSRM 2002b). Project rejected where Critical Threshold exceeded; proponent option to identify offsite compensation or cooperative programs to achieve no net loss.

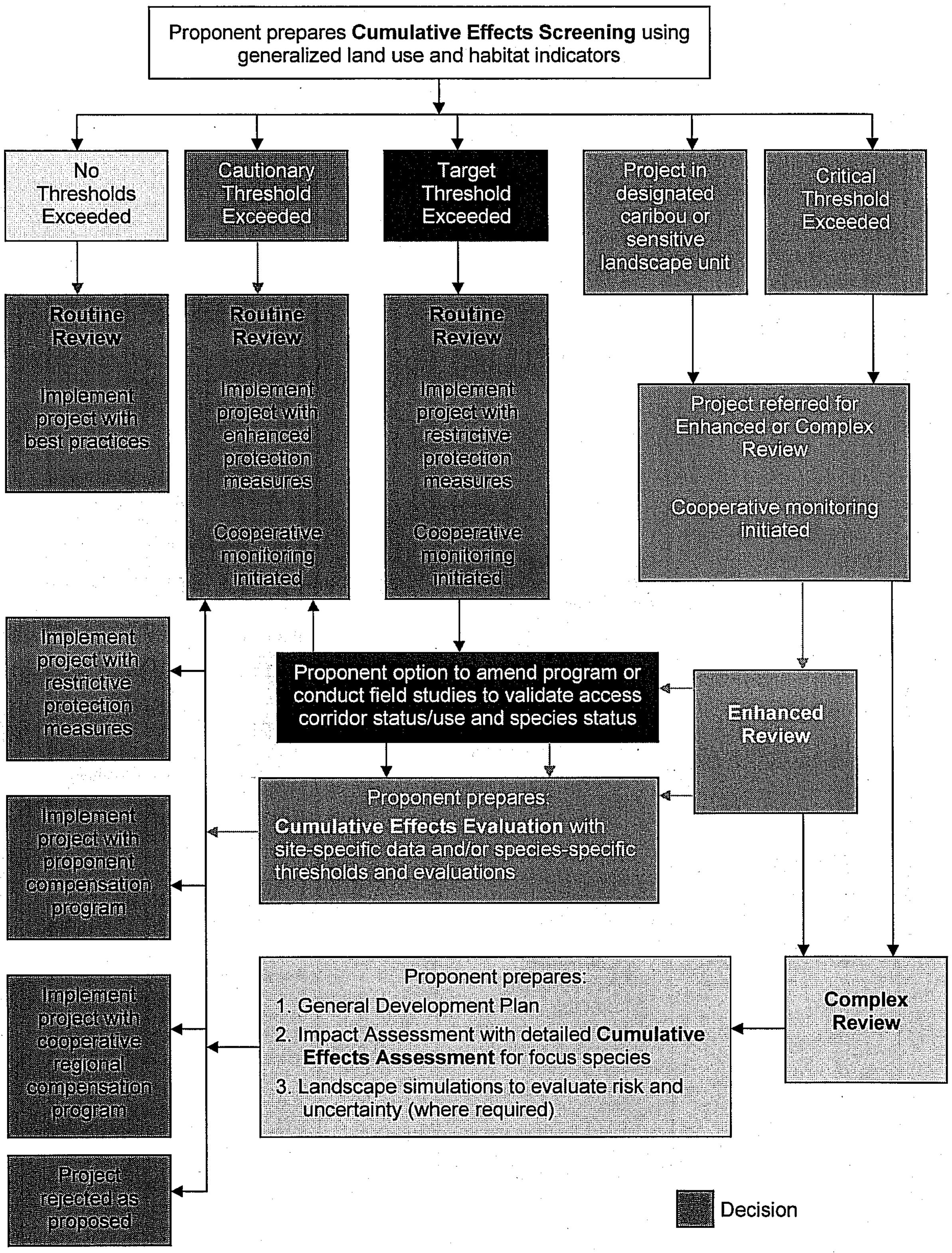


Figure 39. Decision tree for tiered threshold implementation.

If Cumulative Effects Screening concludes that one or more indicators will exceed Target Thresholds, but be within the Critical Threshold, restrictive environmental management practices would be implemented for the project and cooperative monitoring would be initiated in the appropriate land management area(s). The proponent could choose to conduct field studies to update the readily available public database and improve the accuracy of the indicator calculations by identifying impassable or low-use features that could be removed from subsequent calculations. This would remove some of the inherent conservatism of this approach and would frequently revise indicators downward to values below established thresholds (purple pathway on Figure 39).

Enhanced and restrictive management practices include project initiatives such as alternate routing and siting, or avoidance of core areas. They also include joint project and regional initiatives such as cooperative road planning designed to mitigate or compensate cumulative effects. Cooperative effects management options are discussed in more detail in Section 4.5 of CEAMF Volume 1.

If Cumulative Effects Screening concludes that one or more indicators will exceed the Critical Thresholds, the project would automatically be put through enhanced or detailed review (Table 11; orange pathway on Figure 39).

4.4.4.2 Enhanced Review: Cumulative Effects Evaluation

For simple or normal projects in sensitive areas with some potential for significant adverse cumulative effects (e.g., 'hot spots' such as designated caribou habitat or Landscape Units), Cumulative Effects Screening would be supplemented with site-specific data and/or species-specific evaluations. These 'Cumulative Effects Evaluations' would consider the availability of sensitive habitat, or the actual status and use of roads and trails. This would allow simplifying and conservative assumptions to be modified where appropriate, using data specific to the proposed area of activity.

Enhanced Cumulative Effects Evaluation would also use standardized methods and protective species-specific thresholds (e.g., candidate caribou thresholds in Table 10) applicable to the land management area(s) in which the activity is proposed.

Management Actions

If Cumulative Effects Screening and Evaluation concludes that all indicators will be within established landscape, watershed, and species-specific Cautionary Thresholds, best environmental management practices would apply and no further management or review action would be required (identical to green pathway on Figure 39, but with species-specific thresholds considered).

If Cumulative Effects Screening and Evaluation concludes that one or more indicators will exceed Cautionary Thresholds, but be within Target Thresholds, enhanced environmental management practices would be implemented for the project (orange pathway on Figure 39). Enhanced practices include specific measures to reduce wellsite size or right-of-way width or manage access.

If Cumulative Effects Screening and Evaluation concludes that one or more indicators will exceed Target Thresholds, but be within the Critical Threshold, restrictive environmental management practices would be implemented for the project (orange pathway on Figure 39). Restrictive practices include off-site compensation to achieve no net access creation in the land management area(s) in which the activity is proposed. They also include joint project and regional initiatives discussed in more detail in Section 4.5 of CEAMF Volume 1.

If Cumulative Effects Screening and Evaluation concludes that one or more indicators will exceed the Critical Thresholds, the project would be subject to detailed review (yellow pathway on Figure 39).

4.4.4.3 Complex Review: Cumulative Effects Assessment

Detailed 'Cumulative Effects Assessments' would continue to be applied to large, reviewable projects, as well as to smaller projects in sensitive or specially designated areas such as the Muskwa-Kechika Special Management Area.

The Cumulative Effects Assessment would be based on a General Development Plan (OGC 2002) or Development Plan (MSRM 2002b), and include standardized analysis for generalized landscape and watershed thresholds along with detailed, species-specific analyses (Table 11, Figure 39). These could include habitat availability and effectiveness, core security analyses, and friction models to examine critical movement corridors (Salmo et al. 2001). Population viability and landscape level simulation models such as ALCES could also be applied to allow risk and uncertainty to be formally evaluated. Landscape simulations could examine the range of natural variability, extirpation risk, and conservation area design.

Management Actions

Review decisions and associated management actions for detailed Cumulative Effects Assessment would be similar to those described above for routine and enhanced reviews (Table 11; Figure 39). In Special Resource Management Areas, restrictive protection measures would become the minimum requirement.

The proposed project would be rejected if one or more Critical Thresholds are exceeded and an acceptable project-specific or cooperative no net loss compensation program cannot be identified.

4.4.5 Data Needs

Publicly available land use and resource data for northeast British Columbia are more comprehensive than those found in many other jurisdictions. Nevertheless, the current database discourage routine consideration of cumulative effects because:

- proponent access to government TRIM II digital data is restricted and the time required to negotiate access is too long for routine and enhanced project review,
- insufficient information is provided with TRIM II digital data to determine current disturbance feature status and use intensity,
- accurate terrestrial and aquatic habitat maps are not available for all areas, and existing forest cover data increase the cost and duration of cumulative effects evaluations and assessments with questionable gains in accuracy,
- TRIM II data are not regularly updated to reflect recent land use,
- TRIM II data include numerous watercourses that do not actually exist in the field, thereby reducing the utility of watershed indicator evaluations, and regional data on fish and wildlife species abundance and distribution are limited.

The threshold implementation approach described here will require a common source of easily available data that is regularly updated and can be readily accessed and used by regulators, proponents, and other interested groups and individuals. This database will require time and resource commitment to be developed.

Although the government must ultimately be responsible for database maintenance, regardless of who is assigned that task, the approach described here will streamline database development by using proponent submissions to incrementally build and update it. To be effective, this will require standardized data sharing and access protocols as well as standard analysis and reporting methods.

4.4.6 Pilot Study

Available literature and experience in other jurisdictions indicates that development and implementation of tiered ecological thresholds is a practical and effective method for assessing and managing cumulative effects. This report has provided a suite of recommended ecological indicators and candidate thresholds in northeast British Columbia. It has also described an approach for threshold implementation using the existing resource management and review process.

This information provides a foundation for threshold development and implementation. However, it is impractical to assume that this can immediately be applied to the entire region. The 'adaptive management' process originally conceived by Holling (1978) suggests that proposed management actions should be rigorously tested before they are widely applied.

A pilot study is recommended to test the candidate thresholds and implementation process and ensure that they provide an appropriate balance between environmental protection and socio-economic interests, i.e., they reflect 'acceptable change' as defined by regional stakeholders. Stakeholders who will be affected by threshold implementation should be involved in designing and evaluating the pilot. This will allow the ecological, economic, and social implications of threshold implementation in northeast British Columbia to be explicitly considered.

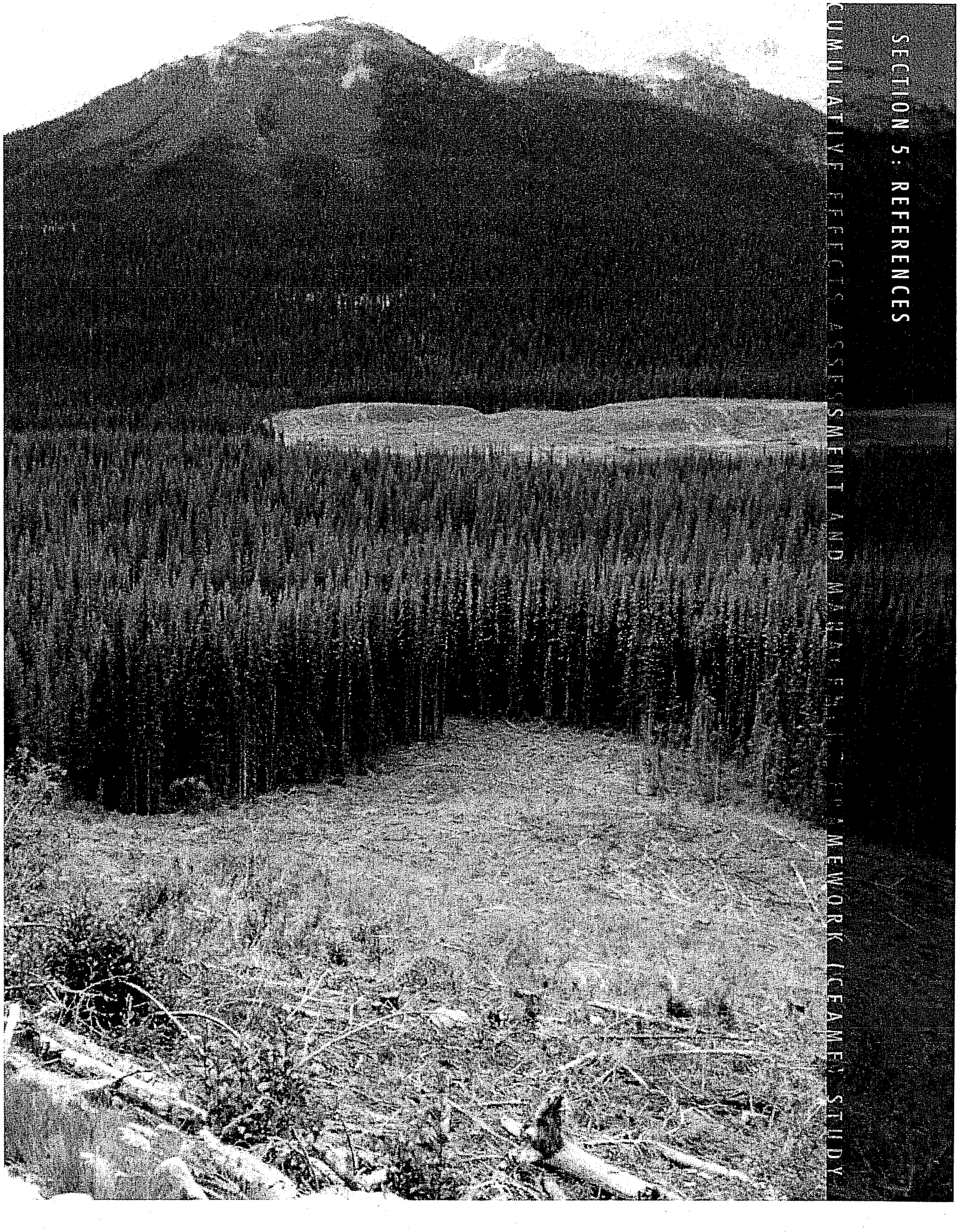
Two pilot study areas are proposed for consideration. Both are located in Enhanced Resource Development Areas that have elevated risk of cumulative effects because they have been moderately to highly disturbed and provide known habitat for boreal- and northern-ecotype caribou. As demonstrated in the Case Studies, this species is extremely sensitive to cumulative effects of habitat fragmentation and disturbance. Both areas have existing data that can be used to enhance our understanding of ecological response to combined natural and human disturbance and to test management actions that will effectively and practically address cumulative effects.

The two candidate areas are:

> The western half of the **Jedney Enhanced Resource Development RMZ** located immediately east of the Alaska Highway in the Fort St. John LRMP area. Approximately one-third of this area was included in the Blueberry Case Study area. This area provides year-round habitat for boreal-ecotype woodland caribou, and is known to provide year-round habitat for an undetermined number of woodland caribou. Both boreal- and northern-ecotypes may be present. It was excluded from the Blueberry Case Study due to a lack of historical data, but the results of the Case Study would be directly applicable. Intensive monitoring of the caribou herd and validation of land use features and habitat would be required.
>
> A portion of the **Etsho Enhanced Resource Development RMZ** located east of Fort Nelson. This area provides year-round habitat for a boreal-ecotype caribou herd. Collection of detailed habitat use data through GPS telemetry was initiated by Slocan Forest Products Ltd. in 2000 and is currently ongoing. Collection of wolf and black bear GPS telemetry data has also recently been initiated as a component of the caribou research project. These data have not yet been analyzed, but would provide valuable information on the caribou habitat selection as well as their response to land use features, human activity, and predators. The benefits of enhanced and restrictive protection measures could also be tested.

SECTION 5: REFERENCES

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY



5. REFERENCES

5.1 PERSONAL COMMUNICATIONS

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APPENDICES

CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT FRAMEWORK (CEAMF) STUDY