Patchwork Policy, Fragmented Forests:

In-situ oil sands, industrial development, and the ecological integrity of Alberta's boreal forest

Gail MacCrimmon and Thomas Marr-Laing

May 2000

Pembina Institute
for Appropriate Development

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The Pembina Institute, in collaboration with others in the Oil Sands Environmental Coalition (OSEC), has maintained a longstanding engagement in working for environmental protection limits and controls to oilsands development. The Institute has written this paper in the interests of advancing understanding of the urgent need to establish a mechanism to manage cumulative impacts of industrial development on the boreal forest of northeastern Alberta.

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About this Paper

The Pembina Institute, in collaboration with others in the Oil Sands Environmental Coalition (OSEC), has maintained a longstanding engagement in working for environmental protection limits and controls to oil sands development, with a particular focus on the management of emissions of air pollutants. The Institute has written this paper in the interests of advancing understanding of the urgent need to establish a mechanism to manage cumulative impacts on the boreal forest of northeastern Alberta. At present, regulators are assessing oil sands projects as well as conventional oil and gas projects on a project-by-project basis. These approvals are being granted without an understanding of the impacts of existing industrial activity on the broader boreal forest ecosystem, or the environmental implications of further disturbance to this ecosystem from rapid developments in heavy and conventional fossil fuel reserves in the region. Lacking a comprehensive context and overall policy framework to guide development decisions, the province is establishing *de facto* policy on an incremental project-by-project basis.

This paper provides an overview of the environmental impacts that are already occurring from existing industrial activities as well as the potential cumulative impacts of new in-situ oilsands development. It outlines the elements of a "Boreal Forest Use Framework" that could assist in managing industrial activity within the limits of ecological sustainability. The possibility of increased confrontation and market-based actions as a consequence of inaction by industry and government are reviewed and recommendations are made for specific actions that need to be taken by government and industry, including actions by individual corporations.

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Sources:

† from Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 10. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

§ from World Resouces Institute. *Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report*, (Washington: World Resources Institute, 2000).

‡ courtesy of Suncor

* courtesy of World Wildlife Fund Canada

Executive Summary

Although Albertans tend to think of themselves as living in a Prairie province, in fact over half of the province is covered by boreal forest. The boreal forest is the focus of intense industrial activity including forestry, conventional oil and gas activity, and oil sands development. The ecological, social, and economic changes due to this rapid and massive development are far reaching. Dr. David Schindler,[1] one of the world's foremost fresh water ecologists, says that unless Canada drastically curtails industrial development in the North and protects the nation's least-conserved landscape, the next generation will not see the same white spruce, lake trout, and peat bogs that he has known. An industrial assault on the boreal, combined with a multitude of stressors from acid rain to climate change, is now degrading the forest so quickly that only a few northerly parts may survive intact as isolated parks. In Dr. Schindler's view, the boreal forest hasn't got much time left – less than 50 years.

Many of the impacts described by scientists are not readily apparent to the untrained observer. Missing the "forest" for the "trees," it is easy to be lulled by a sense that the boreal forest is vast and that human activities will not cause any irreversible damage. Unfortunately, there is no scientific basis for this complacent "business-as-usual" view. In fact, the evidence suggests that the boreal forest is highly fragmented and that its ecological integrity has been significantly compromised.

Given these clear warnings about the effects of intensifying industrial activities on the future of the boreal forest, there is rising concern about the cumulative impacts that will be imposed by a new wave of oil sands development using "in-situ" technology.

Oil sands deposits underlie an estimated 12 percent of Alberta. These oil rich deposits are thought to hold over 1.7 trillion barrels of oil, with some estimates as high as 2.5 trillion barrels. Since the 1970s, most oil sands projects have been surface mines in which sediments covering the oil-bearing bitumen sands were removed, then the oil sands were mined and processed to extract the bitumen. These projects, while causing irreversible changes to the landscape, have been limited to a small number of areas where the deposits are close enough to the surface that mining operations are technically and economically feasible.

Some 80 to 90 percent of the total recoverable reserves (approximately 240 billion barrels) are not accessible by surface mines and can only be recovered by technology that extracts the bitumen while leaving the surface sediments and oil sands in place. These so-called "in-situ extraction technologies, while not requiring the large open pits of surface-mined ores, still result in extensive disturbance to vegetation, wetlands, and wildlife due to the large network of seismic lines, roads and pipelines needed. In-situ technologies could potentially be applied throughout the oil sands regions in northern Alberta. Once in place, in-situ facilities can operate for 30 to 40 years.

Compared with other forested lands in Alberta, the northeastern boreal forest, has experienced relatively few impacts, but it is the region where initial in-situ operations will be developed. One such project has already been approved, three more are undergoing regulatory approval, and several more projects are expected within the next few years.

If new oil sands development, along with planned forestry and conventional oil and gas activities, is to be done in a manner that strives for ecological sustainability, then mechanisms are needed to: protect ecologically sensitive landforms, reserve representative areas as "laboratories" to advance scientific understanding of the forest and the effectiveness of reclamation activities, and to guide and coordinate industrial development in the boreal forest to minimize net disturbance.

Key elements of a framework to guide boreal forest land use in this way include establishing areas to be excluded from industrial development (referred to as "protected areas"), implementing linear disturbance limits to manage cumulative impacts where industrial activity would occur, and implementing access controls to limit the impacts of human disturbance.

Achieving ecological sustainability means more than simply minimizing and coordinating industrial activity within the forest. The timely establishment of protection from development for ecologically significant areas and the implementation of limits to the overall ecological disturbance that is permitted at any one time are essential.

The basic concepts outlined in this paper are part of the solutions that have been proposed by wilderness environmental groups through public consultations to develop the Forest Conservation Strategy and Special Places 2000 initiatives during the 1990s. Unfortunately, these multi-stakeholder negotiations have failed to protect the boreal forest in any meaningful way. The recent shelving of the redrafted Natural Heritage Act due to disagreement between the Ministers of Environment and Resource Development further underscores this lack of progress and lays bare the fundamental dilemma – that of a societal preparedness to moderate economic development within the constraints of ecological limits. Lack of progress through these processes is giving rise to legitimate concerns that moderation will be replaced by more strident approaches.

The corporate sector's long-term interest in developing the forestry, conventional oil and gas, and oil sands resources of northern Alberta means that companies need to do several things. Multilateral industry action is required to coordinate activities in the forest and implement best practices that minimize impacts. But, foremost, companies must make unilateral commitments to not develop resources in protected areas. The economic impact on such companies could be reduced if other companies shared access to resources outside these protected areas. The corporate sector must also pro-actively lobby and educate Alberta's political leaders about the essential environmental and economic logic of effective and meaningful protection of the boreal forest.

Alberta's political and corporate sectors need to move quickly to establish boreal forest policies along the lines of those proposed in this paper. Such leadership will advance the ecological sustainability of Alberta's economic development and forestall looming social conflict, with its attendant risks and costs to the corporate sector. Much of the requisite groundwork has already been completed, thanks to considerable research by industry, government, universities and research institutes, and environmental groups during the past ten years. The missing ingredient is the political understanding and will to implement what is clearly needed. This ingredient must be found quickly.

1 Ecology of the Boreal Forest

1.1 The Boreal Forest Ecosystem

The boreal forest, described as the world's largest ecosystem, circles the northern latitudes of Alaska, Canada, Finland, Scandinavia, and Siberia. It accounts for almost one-third of the earth's forested land and includes the world's largest expanses of wetlands and lakes.

The boreal forest occupies more than 60 percent of the total area of the forests of Canada and Alaska.[2] In Canada, the boreal forest stretches from the Yukon through northwestern British Columbia, the northern Prairies, southern Northwest Territories and Nunavet, northern Ontario and Quebec, the forested parts of Labrador and Newfoundland, and a small portion of northwestern New Brunswick.[3] Occupying 3.24 million square kilometres, the boreal forest extends north-south for almost 1,000 km and east-west for 9,000 km, covering 35 percent of Canada's total land area and making it Canada's largest ecosystem.

In Alberta, the Boreal Forest Natural Region covers just over 52 percent of the province (Figure 1). This Natural Region comprises most of the northern half of Alberta with a tongue extending into the southern part of the province from Barrhead to a point approximately 40 kilometres southwest of Olds. It extends roughly 935 kilometres north from latitude 51° 34' N to latitude 60° N (townships 30 to 126), and east to west across the province.[i] The Region is bounded by the Parkland, Foothills, and Canadian Shield Natural Regions.[4] Along with the latter two, it makes up most of what is referred to in Alberta as the "Green Area"; that is, the area of the province that is predominantly forested and owned by the Crown (Figure 2).

This large region is characterized by diverse topography, climate, and biology.[5] Based primarily on vegetation, geology, and landform characteristics, six sub-regions have been identified within the Boreal Forest Natural Region (Figure 1); they are the Central Mixedwood, Dry Mixedwood, Wetland Mixedwood, Sub-Arctic, Peace River Lowlands, and Boreal Highlands. The boundaries separating these sub-regions are somewhat arbitrary as large-scale changes in biophysical parameters in the Region tend to be subtle and gradual, and because the boundaries are actually transition zones rather than sharp divisions. This applies as well to the transitions between the Boreal Forest and the Foothills and Parkland Natural Regions.

In-situ development is proposed primarily for the Central Mixedwood and Dry Mixedwood sub-regions, which comprise 74 percent of the Boreal Forest Natural Region.

1.2 Ecological Perspectives

Climate is the defining characteristic of the boreal forest – short, cool summers with long hours of daylight and very long, cold winters. According to Pojar,[6] key soil-related features are "cold soil temperatures, poor drainage, thick, insulating feather moss/lichen/surface organic layers, low available nutrients" and discontinuous permafrost. The thick moss/organic layer of the forest floor has been described as a "key structural and functional component of the Boreal Forest" and these soil conditions combined with climatic factors result in "relatively slow tree growth."[7]

At both local and regional levels the boreal forest has been described as a "mosaic" of a relatively small number of forest types. Differences in site drainage, climate, aspect, elevation and soils, combined with a comparatively high frequency of disturbance events (the most well-known of which is fire) cause affected areas of forest to revert to earlier successional stages, creating this mosaic.[8] Despite these variations, the distinguishing vegetational feature of the boreal forest is a predominance of conifers (softwoods) such as spruce, pine, tamarack (larch), and fir. Deciduous (hardwood) species, where present, consist primarily of aspen, balsam poplar, and birch. Many deciduous shrubs, such as willow, may also be present.[9]

[i] one township equals 36 mi^2 or 93.23 km^2

The boreal forest has been described as a "simple formation" that, compared with tropical forests, is "species poor." However, the boreal forest is one of the least known and most poorly understood ecosystems in the world. As our knowledge of the biological diversity and ecological processes of the boreal forest improves, so will our understanding of species inventories and our appreciation for the actual levels of biodiversity. Tracts of old-growth boreal forest are proving to be particularly species-rich. In terms of ecosystem and landscape diversity at local and regional levels, boreal forests actually show larger changes within shorter distances than do tropical landscapes.[10]

The Canadian Forest Service estimates that Canada's forests contain approximately 140,000 kinds of living organisms, half of which have not yet been classified. Plants and vertebrate animals make up only five percent of boreal forest species, while invertebrates, fungi and microbial organisms make up over 90 percent. Precise numbers of vascular and non-vascular plant species[ii] in the boreal forest are not available. Far less is known about the pharmaceutical properties of organisms in the boreal forest than is known about those in tropical forests.[11] Based on range maps, Stelfox[12] conservatively estimated that Alberta's mixedwood boreal forest contains 38 plant families, including 600 vascular plants, 17 ferns, 104 mosses, 13 liverworts, and 118 species of lichen. Many of the essential ecological activities that occur in the boreal forest, such as nutrient cycling by soil organisms, occur underground and much remains unknown about these processes and the organisms involved.[13]

Wetlands, including lakes, river systems and peat lands, are another important component of the boreal forest.[14] Some authors estimate that wetlands cover 20 percent of Canada's boreal forest, excluding the Cordillera and Atlantic Seaboard areas. In addition to an estimated 1.5 million lakes, the boreal forest also contains some of Canada's largest river systems and associated wetlands, including the Churchill-Nelson River system and Alberta's Peace-Athabasca Delta.[15] Peat lands in the Prairie Provinces and Northwest Territories are estimated to cover 25 to 50 percent of the total land area. Apart from the internationally renowned Peace-Athabasca Delta, boreal forest wetlands are poorly known and their importance is under-appreciated.[16] Wetlands are among the most biologically productive natural ecosystems in the world. They produce large amounts of food and nutrients as vegetation breaks down and is released into adjacent streams and rivers. They provide habitat for species such as fish and amphibians but are also used for reproduction or migration by animals that live in other habitats.[17] [18]

[ii] Vascular plants have specialized tissues that conduct water and minerals up to the leaves, and sugar from the leaves to other parts of the plant. Non-vascular plants lack these specialized tissues.

2 The Value of Boreal Forests

Within the dominant industrial economic system the boreal forest is regarded as having a mainly utilitarian function. The forest's landscapes, ecosystems, flora and fauna, are viewed as "goods" or "natural resources" to be exploited for human benefit. The economic goods and services derived from the boreal forest include its landscapes and soils (used for settlement, agriculture, and recreation); water (for consumption, power generation and recreation); trees (for pulp and lumber); and rocks and mineral deposits, including energy reserves. Arguments to recognize intrinsic spiritual or aesthetic values of the forest, in their own right, are generally discounted or marginalized by the presently prevailing economic and political forces in Alberta.

Nevertheless, vestiges of a second, older, economy still do exist. For participants in this "bush," or "subsistence," economy practiced by some First Nations and Métis peoples, the forest is their home. It gives their lives a spiritual and cultural context, and it provides food (through fishing, hunting, trapping, and gathering), shelter, and clothing. For example, wildlife (such as moose and beaver) are hunted and trapped, while plants and fungi constitute important sources of food and medicinal ingredients. Although this economy does "use" forest resources, the philosophy and the impacts of this use differ considerably from those of the dominant industrial economic system.

Two studies in ecological economics have attempted to quantify the value of the goods and services provided by the natural world. Mosquin *et al.*[19] estimated the benefits that Canada derives from its biodiversity at $70 billion *per annum*, while Sawhill[20] estimated "the value of the world's ecosystem services and natural capital at some $33 trillion annually... almost double the gross national product of the entire global economy." Hammond[21] applied this kind of economic treatment with a boreal forest perspective. He determined that over a 50-year period, an average tree contributes $196,000 to the human economy through its ecological services, but that only 0.3 percent of a tree's value is returned when it is sold for pulp or lumber.

Current economic systems do not account for these services and thus the services are not properly valued. In conflicts between development and protection or preservation, conventional business accounting systems favour proposals to develop a natural resource because the economic benefits of such development are easy to document. The long-term benefits generated by **not** developing the resource have historically been harder to demonstrate and quantify. Any such benefits are likely to be complex, and their expression subtle, gradual, and occurring (in a political sense) over a long time. Considerable progress is now being made, through new disciplines such as ecological economics, in developing alternative economic accounting procedures that would first, measure the true cost of business activities to the environment, and secondly, measure production costs in terms that fully reflect their environmental costs.

2.1 Existence Values of Standing Natural Forests

A growing number of scientists and researchers in fields such as ecological economics are emphasizing the point that functional ecosystems – and the biological diversity they support – provide a broad range of critical ecological services and functions upon which humans ultimately depend for their survival.

2.1.1 Ecological Services and Functions

The boreal forest provides critical ecological services on both a landscape scale and at regional and local scales through the functioning of ecosystem components such as wetlands and soils. Functioning, intact boreal forest ecosystems play an integral and crucial role in cycling essential life-sustaining elements such as carbon, nitrogen, oxygen, and water. In addition to providing critical habitat for a diverse group of organisms, the boreal forest itself is an integral component of ecosystem biodiversity. This applies particularly to old-growth forests, which are recognized as important contributors to biodiversity at all spatial scales.[22]

Trees and other vegetation produce oxygen while absorbing carbon dioxide. Collectively, soils, peat lands, and plants are a huge carbon reservoir or "sink," storing carbon and slowing the effects of global climate change. On a global scale, boreal forests have significant effects on the seasonal and annual climatology of much of the northern hemisphere. They increase surface air temperatures and atmospheric moisture levels throughout the year. Although these effects are greater at northern latitudes, they extend to the tropics. On a regional scale, boreal forests influence rainfall, temperature, and local weather conditions. Forest ecosystems purify air by scavenging pollutants from the atmosphere, and they protect watersheds and water quality by regulating surface run-off, buffering the effects of floods and controlling erosion and sedimentation.

Boreal forest wetlands and peatlands prevent flooding by holding water much like a sponge. In this way, wetlands help maintain normal river levels and they filter and purify surface water. They accept water during storms and whenever water levels are high. When water levels are low, wetlands slowly release water. They also clean the water by filtering out sediments and decomposing vegetative matter, and they convert chemicals into usable forms. They act as permanent or temporary reservoirs (or sources) of chemicals, sediments, and nutrients. This ability of wetlands to recycle nutrients makes them critical in the overall functioning of the boreal forest.[23] [24] On a global scale they act as carbon dioxide (CO_2) sinks and methane (CH_4) sources.

Riparian ecosystems[iii] provide essential habitat for aquatic invertebrates, plants, and fish species and are ecologically valuable far beyond their size. They form a vital link between the drier upland catchment areas (such as the Birch Mountains, which contain the headwaters for many streams in the Central and Dry Mixedwood sub-regions) and their associated lowland ecosystems. Bilyk *et al* [25] note, "aquatic, wetland, and upland areas generally form integrated ecosystems. The degradation or fragmentation of one affects the quality and ecological functions of the others." Riparian areas, and their associated streams and wetlands, are also indicators of watershed health, as they are among the first landscape features to reflect damage from inappropriate management or natural events within the watershed.

2.1.2 Other Forest Values

The boreal forest is also valuable for the traditional aesthetic, spiritual, recreational, scientific, and conservation benefits it provides. Its wilderness aspects – remoteness, relative lack of disturbance, and solitude – have intrinsic symbolic and aesthetic value. Even as wilderness is becoming increasingly scarce, it is being recognized as a valuable commodity in its own right by the growing international eco-tourism industry.

The economic value of standing boreal forest has been largely ignored, but is real nonetheless. Much remains to be learned in the realm of forest science and it is difficult to predict the value of future discoveries, such as pharmaceutical compounds. However, retaining large undisturbed areas of boreal forest provides one critical and indisputable service: it gives us ecological benchmarks against which the condition and ecological integrity of intensely managed and increasingly fragmented forests can be evaluated.[26]

[iii] Riparian areas are those places adjacent to rivers, lakes or streams, consisting of the area of transition from an aquatic ecosystem to a terrestrial ecosystem. They have one or both of the following characteristics: distinctly different vegetation from adjacent areas, and/or species similar to adjacent areas but showing more vigorous or robust growth.

3 Impacts of Human Activity on the Boreal Forest

The 1999 report of the federal Senate Sub Committee, *Competing Realities: The Boreal Forest at Risk*, describes the world's boreal forest as being "under siege." Only about one-fifth of the world's forests remain "intact" or undisturbed. Half of these are the boreal forests of Alaska, Russia and Canada. Within Canada, intact forests are mainly in the northern part of the boreal forest, and were estimated in 1999 to comprise less than 35 percent of Canada's total boreal forest area.[27] At present "the boreal forest is undergoing anthropogenic changes of unprecedented magnitude and rapidity, many of whose effects are potentially irreversible."[28] These changes are due to a massive, and intensifying, increase in human activity, particularly industrial activity, in the boreal forest.

For many people, the boreal forest conjures up an image of a monotonous landscape where endless stretches of forest and muskeg are interrupted only by lakes and rivers. Unfortunately, the current reality of the boreal forest is quite different from this image. In spite of the escalating disappearance of Canadian wilderness, a "frontier" mentality still prevails in some places. This traditional view of nature as an obstacle to be overcome is still encountered in some areas of Alberta.

The range of human activity in the boreal forest is widespread and intense, and includes:

- Agriculture
- Forestry and wood fibre processing
- Conventional oil and gas exploration and production
- Mining
  - Oil sands
  - Mineral aggregates
  - Coal
  - Peat
  - Diamonds
- Power generation
  - Dams
- Recreation
  - All-terrain vehicle use
  - Sport hunting and fishing
  - Non-consumptive recreation
  - Consumptive uses of wildlife
  - Commercial and domestic hunting, fishing, and trapping
- Military uses
  - Cold Lake Air Weapons Range
- Urban development
- Transportation and utility corridors

Agriculture, forestry, conventional oil and gas, and mining are currently having the greatest impact on the boreal forest. The primary and most immediate impacts of these activities are habitat loss and habitat fragmentation. Habitat loss poses perhaps the greatest threat to the long-term ecological integrity of the boreal forest and is a common impact of all the identified human activities. The impacts and implications of habitat loss and habitat fragmentation are discussed in more detail below.

3.1 Habitat Loss and Habitat Fragmentation

Most human alteration of the boreal forest ecosystem takes one of two interrelated forms – habitat loss (often referred to as habitat destruction) and habitat fragmentation. Habitat loss occurs when the total original area of an ecosystem is reduced, resulting in the potentially irreversible loss of the area's natural vegetation and wildlife communities. Habitat loss includes "habitat conversion" where structurally and functionally complex ecosystems, such as forests, are converted to structurally simple habitats that support a small number of species, which represent only a fraction of the area's original biodiversity. Examples include the breaking up and conversion of shortgrass prairie to cropland by European settlers, the logging of old-growth forest and its replacement by even-aged stands of trees by forest companies, and the loss of habitat to urban expansion. Habitat fragmentation occurs when extensive and contiguous ecosystems are broken up into fragments of various sizes and shapes.

Fragmentation of forested landscapes usually takes place in a series of recognizable stages (Figure 3) that ultimately result in the conversion of "natural ecosystems into human-dominated ecosystems."[29] Fragmentation occurs on a variety of scales, from the landscape to the local level. As fragmentation progresses, some fragments, or "patches," will remain in contact with each other, and/or their parent forest, while others will be isolated to varying degrees. With continued development, fragments tend to get smaller and their level of isolation increases. Based on computer modelling, O'Neill *et al*.[30] suggested that the "critical level" for the remaining percentage of an original landscape is 59.28 percent, and that below this value the landscape becomes dissected into isolated patches.

As these landscape fragments become smaller, their value as habitat for many species decreases to the point where it is negligible or, worse, the patches become "mortality sinks" – small remaining areas of habitat that wildlife are forced to use, making them vulnerable to predators and parasites. An example is the narrow buffers of habitat left around streams and lakes.

This effect can be explained by examining the combination of patch size and the amount of "edge" versus the total area of the fragment. Ecological edges, or ecotones, occur "where two different plant communities or successional stages meet." [31] Theoretical models suggest that an edge area greater than 40-50 percent represents a threshold for ecological effects; i.e., the point at which the proportion of edge to interior area becomes large enough that cumulative adverse effects on sensitive species could be expected to occur.[32] [33] [34]

Edge conditions (such as microclimatology, which includes light levels, humidity, and windspeed) differ from conditions in the forest interior. The effects of edges are ecologically complex and not well understood. While edges benefit some species (usually habitat generalists such as white-tailed deer or moose), they adversely affect many others, such as woodland caribou, wolverines, and some neo-tropical migrant songbirds, such as Cape May and Bay Breasted warblers. Potential edge effects include exposure to ambient air pollutants, increased temperature and snow depth; increased brood parasitism, predation and competition; changes in vegetation diversity and structure, and changes in species composition and abundance. [35] [36] [37]

Patch size has significant implications for long-term species viability. Many species require a certain minimum area of intact forest, with its associated distinctive conditions of light, humidity, species composition, etc., in order to breed successfully. For any individual species to survive and persist within an isolated forest fragment, the fragment has to be large enough to accommodate the total area, in terms of cumulative home range, required by the "minimum viable population"[iv] of individuals of that species. To avoid inbreeding, populations must be able to exchange genetic material. However, if the isolated fragments containing individual animals are too far from other fragments containing individuals of the same species, or if individuals cannot move freely between patches due to lack of suitable habitat, then individuals will be reproductively isolated. Small populations that become reproductively isolated are subject to genetic drift [v] and tend to be more vulnerable to environmental impacts on population size and structure (e.g., disease outbreaks, predation and fire), making them more susceptible to extinction.[38]

Linear disturbances such as roads, seismic lines, and pipeline corridors, contribute to boreal forest fragmentation as they cause the formation of patches. They also have significant ecological implications themselves. For example, they provide corridors that predators (both human and animal) can use to gain access to areas that were previously remote and inaccessible. Using the

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[iv] A minimum viable population is an estimate of the smallest viable population that will persist over a given period of time, e.g. 500 years, or with a specified level of certainty (e.g., 95 percent).

[v] Genetic drift is the effect of population size alone on allele and genotype frequencies. As part of sexual reproduction, gametes are produced, each of which contains one of two alleles (gene type) for a given trait. Which of those alleles gets passed on to the offspring produced during reproduction depends on which gamete, by chance, goes into forming the offspring. In a population of reproducing organisms some alleles are passed on more than would be expected due to chance, because of the random union of gametes. Therefore, in the overall population, the allele frequency for specific traits will fluctuate up or down at random, from generation to generation. This process is known as "genetic drift." The effects of genetic drift are strongest in small populations where, for example, it is possible for one allele to be completely lost from a population over time, resulting in a loss of genetic diversity.

edges of linear disturbances or clear cuts, predators such as skunks, weasels, foxes, magpies, jays, crows, and domestic pets (especially cats) can penetrate up to 600 metres into a forest. These predators can cause considerable mortality of the eggs and nestlings of ground-nesting birds.[39]

The ecological impacts of fragmentation are more complex and subtle than those of direct habitat loss. Effects may only be manifest over long periods of time and may be difficult to detect, even by trained observers. As fragmented forests may still appear functional and healthy, at least on a superficial basis, they can give casual observers the impression that fragmentation is not significantly affecting ecological integrity.[40] The effects of fragmentation are also cumulative; the more fragmented a habitat already is, the greater the number of extinctions that will be caused by further fragmentation. As such extinctions can occur many generations after the original fragmentation, Tilman *et al.* have referred to the species losses as representing an "extinction debt" that is the future ecological cost of current habitat destruction."[41]

3.2 Agriculture

Despite the challenging climatic conditions and short growing season, agriculture, as the oldest, major primary industry, is responsible for the largest amount of habitat loss in the boreal forest, and economically marginal lands continue to be cleared for agriculture.

Alberta's land base is divided into two main areas or zones. The White Area is settled, cultivated, and predominantly privately owned, while the Green Area consists mainly of forested areas owned by the Crown on behalf of the people of Alberta. As of March 31, 1995, the Green Area made up 351,381 km^2 or 53 percent of the total area of the province. Between March 1995 and December 1997 the Green Area was reduced by 2,330 km^2 to 349,051 km^2, demonstrating the continuing expansion of the White Area at the expense of the Green Area. In terms of habitat loss, the boundary between the White Area and the Green Area is the most dynamic and the largest-scale "fragmentation frontier" in the province.[42]

The overwhelming majority of agricultural activity in the boreal forest has occurred in the Dry Mixedwood and adjacent Central Mixedwood sub-regions. Large-scale settlement of the Dry Mixedwood sub-region occurred during the late 1800s and early 1900s and agricultural activity in this sub-region has continued since then. "Settlers" can still buy Green Area land with the proviso that they "improve it" – that is, clear the forest cover.

A number of damaging environmental impacts are associated with agriculture. Cropping activities can involve forest clearing and fragmentation, and draining of wetlands, and they can result in soil erosion and air and water pollution from herbicide, pesticide, and fertilizer applications.

Cattle ranching can also fragment the forest. In 1997, there were at least 1,300 grazing leases in the boreal forest covering an area of 3,770 km^2, or over 40 townships of public land.[43] Livestock grazing occurs predominantly in the Dry Mixedwood, Central Mixedwood, and the Peace River Lowlands sub-regions. Cattle ranching results in direct habitat damage and loss through grazing, and through "range improvement" which often translates into forest clearing. Habitat loss can also occur through forest clearing for additional pasturelands or hayfields. Loss of habitat for sensitive species such as grizzly bears has been one serious consequence of the transfer and sale of public lands to the agricultural sector.

Livestock can damage or kill native vegetation, accelerate soil erosion (particularly on slopes) and compact soil, pollute water bodies with sediment and manure, and compete with wildlife for forage. Riparian areas are extremely vulnerable to environmental degradation due to cattle activity. Over-grazing can result in ecological simplification and loss of species. Ranchers have also been known to carry out aggressive control programs against wildlife species that they see as undesirable, such as grizzly bears, wolves, and ground squirrels. Livestock can transmit disease to wildlife, which then ironically can become the target of control measures when ranchers become concerned that wildlife may transmit disease to the livestock species that gave it to them in the first place.[44] [45] Disease transmission is also a concern with game ranching, or "farming," an increasingly common agri-industry practice.

3.3 Conventional Oil and Gas

Although the forest industry may eventually have the largest impact on the boreal forest, the industry with the most pervasive and intense ecological footprint within the boreal forest as a whole is the conventional oil and gas industry. The boreal forest contains, either wholly or partly, 80 named oilfields and 306 natural gas fields,[46] and the level of activity continues to intensify. Conventional oil and gas activity has created a vast and extensive "spider web" of well sites, seismic lines, and pipelines throughout the boreal forest. The most significant impacts of conventional oil and gas exploration, development, and production, are as follows:[47]

- Habitat destruction and fragmentation due to forest clearing for access roads and seismic exploration, airstrips and helicopter pads, pipeline and power line rights-of way, well sites, gas plants, and compressor stations.
- Increased sedimentation in streams and river crossings downstream of roads and pipeline corridors, especially during the construction and use of such corridors. Sediment loadings can damage fish habitat.
- Air emissions of sulphur dioxide and nitrogen oxides contribute to direct exposure effects and acidic deposition, which has widely-documented impacts on lakes, forests, crops, and buildings. Nitrogen oxides, in concert with emissions of volatile organic compounds are key in the formation of ground level ozone, which can adversely affect humans and animals and reduce productivity of agricultural crops and forests. Toxic compounds such as benzene, toluene, xylene, and polycyclic aromatic hydrocarbons (PAHs) are also common emissions. Some of these emissions are known to be carcinogenic as well as persistent and bio-accumulative within the ecosystem. Many of these emissions contribute to the presence of particulate matter – tiny pieces of solid and liquid matter small enough to be suspended in the air and known to seriously affect respiratory function and have links to respiratory and cardiac disease. Emission sources include flaring from gas plants and wells, among others.
- The release of significant volumes of greenhouse gases (such as carbon dioxide and methane), which contribute directly to global climate change.
- Contamination of soils, surface water, and groundwater by hydrocarbons, salts, or heavy metals as a result of well blowouts; and gas or oil leaks or ruptures from pipelines, or from storage and processing facilities.
- Spills or leaks of drilling fluids at the well-head or from sump pits, or spills of chemicals (such as hydrogen chloride) used to enhance production, that may result in soil and water pollution.
- Groundwater contamination that may occur as a result of well casing leaks or ruptures.
- Noise due to construction and use of pipelines, roads, compressor stations, cut lines, and gas plants, and well drilling and servicing and seismic activity, which can disturb wildlife.
- Wildlife mortality due to collisions with lease-road traffic, or so-called "problem wildlife" that may be shot by seismic crews or drilling crews due to safety concerns.
- Injury to and mortality of small mammals such as mice, voles, squirrels, and muskrats, as a result of the explosives used in seismic program shot-holes.

Of a total of 255,566 well sites, including oil sands boreholes, drilled in Alberta (based on data to June 1997), 88,588 or 34.8 percent were in the boreal forest. Most of these wellsites were located in the Dry Mixedwood and Central Mixedwood Regions (see Table 1). Wellsite density across the boreal forest is shown in Figure 4.

Table 1. Number and Density of Well Sites in the Boreal Forest and its Sub-regions Based on Alberta Energy and Utilities Board Data (data to June 1997) [48] [vi]

Boreal Forest Sub-Region	Number of wells	Wells per km²	km² per one well
Central Mixedwood	40,692	0.2632	3.80
Dry Mixedwood	40,377	0.4012	2.49
Wetland Mixedwood	5,224	0.1359	7.36
Sub-Arctic	418	0.0190	52.63
Peace River Lowlands	3	0.0003	3,348.62
Boreal Highlands	1,874	0.0882	11.33
The Boreal Forest as a whole	88,588	0.2553	3.92

One of the most significant impacts of oil and gas activity is the seismic geophysical exploration techniques that have been used since the 1950s. Between 1979 and 1995, applications for almost 2.3 million kilometres of seismic line were approved for the province, with approximately 924,016 km being in the Green Area. Cut lines in the Green Area can be up to eight metres wide, with a width of six metres considered to be "low impact."[49] Such seismic lines have been described as just another kind of clearcut.

Stelfox and Wynes[50] found that seismic lines cut between 1995 and 1998 on the Peace River Pulp Division Forest Management Agreement (FMA) area varied from one to seven metres in width, with five metres being the most common. They also found that the density of seismic lines exceeds 4 km/km² in numerous townships. New seismic technologies allow the use of narrow "low-impact" or "avoidance" seismic lines that can still provide reliable information on deposit characteristics. It appears that these types of seismic lines are being used more commonly in areas that have been deemed sensitive from environmental or wildlife perspectives. However, seismic lines of one metre in width make up less than one percent of all of the seismic lines shot.[51]

Annual total lengths of seismic line approved for the White Area and the Green Area between 1986 and 1995 are shown in Table 2.

[vi] Areas with the highest density of well sites are the Hay River/Zama Lake/Rainbow Lakes area, the Fort McMurray, Grande Prairie, and Cold Lake regions, and the southernmost portion of the Dry Mixedwood sub-region. Assuming a conservative well site size of one hectare (see endnote 58), as of 1998, a cumulative area of at least 885.88 km² had been cleared for well sites. This area is equivalent to 9.5 townships.

Table 2. Kilometres of Seismic Line Exploration Programs Approved in Alberta for the Years Between 1986 and 1995, Based on Alberta Environment Land and Forest Service data[52]

Year	Length of Seismic Lines Approved (km)		
	White Area	**Green Area**	**Total**
1986	15,611	44,831	96,442
1987	77,477	57,270	134,747
1988	63,233	46,852	110,085
1989	55,201	44,982	100,183
1990	46,895	51,542	98,437
1991	45,508	24,556	70,054
1992	55,380	27,409	82,789
1993	82,000	58,652	140,652
1994	92,979	53,922	146,901
1995	85,481	49,190	134,671
10 Year Totals	665,765	459,206	1,114,961

Based on the assumption that the boreal forest represents 63 percent of the Green Area, and using an average cut line of eight metres, an estimate of the area of the boreal forest cleared due to seismic activity since 1979 is 4,971 km^2, or 53.32 townships.[53] Even using the more conservative average of five-metre cutlines from Stelfox and Wynes, the area cleared is still 3,107 km^2, or 33.33 townships.

Pipelines are another significant form of habitat loss and fragmentation related to the oil and gas industry (Table 3). At the end of 1996, there were nearly 73,103 kilometres of oil and gas collection pipelines crossing the boreal forest. This number only reflects the pipeline network administered by the Alberta Energy and Utilities Board (AEUB) and does not include that administered by the National Energy Board. Based on a conservative average corridor width of 15 metres, at least 1,096.5 km^2, or 11.8 townships of the boreal forest have been cleared for pipeline rights-of-way.[54]

The distribution of pipelines in northwestern Alberta is extensive but patchy, with densities ranging from 0-30 km per township. Gas pipelines are far more common than oil pipelines. In northwest Alberta, gas pipelines account for 63 percent of pipeline length and 64 percent of the area cleared for pipelines. For both kinds of pipelines, the majority of the kilometres of pipeline and the area disturbed, are due to smaller-diameter pipelines. These smaller-diameter pipelines (<35 cm bore diameter) are far more common than large-diameter pipelines in northwest Alberta, and account for 85 percent of pipeline length and 75 percent of the area cleared for pipelines.[55]

Table 3. Total Length (and Density) of Oil and Gas Industry (Collection Network) Pipelines within the Boreal Forest (based on AEUB data to year end 1996)[56]

Boreal Forest Sub-Region	Pipeline Length (km)	Pipeline Density (km/km²)
Central Mixedwood	23,963.14	0.16
Dry Mixedwood	41,659.18	0.41
Wetland Mixedwood	6,033.03	0.16
Sub-Arctic	234.61	0.01
Peace River Lowlands	0.00	0.00
Boreal Highlands	1,212. 93	0.06
Total for the Boreal Forest	73,102.89	0.21

Probably the most ecologically significant impact of the oil and gas industry has been the construction of well site and facility access roads. While accurate data for the total extent of this system is extremely difficult to obtain, in northwest Alberta as of 1993, there were 14,988 km of low-grade roads and 2,509 km of high-grade roads. Most of the low-grade roads on public lands in northwest Alberta are constructed by the petroleum industry to access and develop potential oil and gas reserves.[57] Using some assumptions[vii] [58] it is estimated that there are 141,740 km of access roads in the boreal forest, an area equivalent to 2,126 km^2, or 22.8 townships.[59]

While the area of forest lost to oil and gas development is of concern, the indirect ecological consequences of the access network created by the industry are even more problematic.[60] Once established, seismic lines and roads are generally used by a variety of individuals, including extensive use by the public for recreational purposes,[61] and the roads can be very difficult to remove. Access control remains an issue for both industry and stakeholders.

3.4 Forestry

Since 1996, 3,360 km^2 (equivalent to 36.04 townships) have been logged on Crown-owned lands within the boreal forest.[62] Most of this logging has occurred in the Central Mixedwood sub-region (Table 4). Within individual townships in the boreal forest, the area cut ranges from zero to 29 percent (in township 77, Range 17, W4M).

Table 4. Total Area of Boreal Forest that has been Logged on Crown Lands in each Sub-region, from 1996 to November 1997 (based on Alberta Environment Land and Forest Service data)[63]

Boreal Forest Sub-Region	Total Area (ha.)	% of Total
Central Mixedwood	225,247	67.03
Dry Mixedwood	52,693	15.68
Wet Mixedwood	44,721	13.31
Sub-Arctic	716	0.21
Peace River Lowlands	300	0.09
Boreal Highlands	12,357	3.68
	336,035	100.00

[vii] A previous author calculated an average access road length for the Green Area of 3.2 km per well, but noted that exploration and gas well access roads tend to be longer than this average, while production and exploration and oil well access roads tend to be shorter. The fact that many well sites are located in the White Area means that this average is difficult to apply to the Green Area as a whole. A value of half the average access length of 3.2 km., and an average access road width of 15 metres were used to estimate the length and area of access roads in Alberta (see endnote 104).

Figure 5 indicates the distribution and relative amount of forest cutover (per township) in the boreal forest. Compared to the heavily-logged Foothills Natural Region, the proportion of the boreal forest affected by logging appears fairly small, thus far. However, this situation will change rapidly as levels of forest activity increase dramatically in the boreal forest.[64]

The history of logging in Alberta indicates a clear provincial trend of moderately increasing allocation and harvest levels from 1930 to 1975, followed by a period of rapid increase from 1975-1996.[65] The significant increase in logging activity in northwest Alberta is due largely to new technologies that enabled the cost-effective pulping of hardwood tree species. This led to approximately $4-billion of new forest industry investment in what has been referred to as a "fibre rush,"[66] including some developments (such as two pulp mill megaprojects) that were highly controversial. The harvest volume data from this time presented by Stelfox and Wynes for northwest Alberta[67] reflects this development.

From 1966 to 1996, the harvest of softwood volume increased from an annual harvest of approximately 200,000 cubic metres to 1,400,000 cubic metres. The harvest of hardwood trees (primarily aspen) did not occur to any significant extent until the late 1980s when it grew quickly to an annual harvest of approximately 1,700,000 m^3 by 1996. While hardwoods made up an insignificant proportion of harvest volumes prior to 1989, they now account for over half of the total volume harvested.[68] The *1996 State of the Environment Report for Canada* notes, "The most recent and ongoing trend in human disturbances in the Boreal Plains ecozone is the increased rate of forest harvesting, especially of the previously little-used aspen stands. This increase is most evident in Alberta, where the annual area of land harvested increased by 125 percent between 1975 and 1993."[69]

Throughout Canada, over 220 million hectares have been licensed to logging companies. These licenses are of two principal types: area-based tenures and volume-based tenures. Area-based tenures are usually 20 to 25 years in duration. Tenure holders are responsible for timber harvesting and forest management for a specific area. In return they pay stumpage fees, rents, and/or royalties. Increasingly, these companies are being required to take on other management responsibilities, such as reforestation of logged areas. Volume allotments are typically shorter in duration and may not require the tenure holder to be responsible for forest management.[70]

Canada's Forests at a Crossroads: An Assessment in the Year 2000 reports that the commercial forest zone in Alberta occupies an area of 42,985,000 ha. This is the total area managed for timber production. Of this total area, 25,474,00 ha are allocated to some form of forest tenure, but there is some uncertainty as to how much of this area is allocated to forestry. For example, according to *Competing Realities: The Boreal Forest at Risk* the percentage of Crown land in Alberta allocated to forestry is 70.2 percent. The same report also notes that a significant proportion of the unallocated boreal forest consists of land with low volumes of wood fibre.[71] Based on *The Status of Alberta's Timber Supply,* [72] as of January 1995, 94.4 percent and 72.8 percent of the province's net coniferous and deciduous annual cuts respectively, have been allocated. But a review of various data sources, suggested that the figures may actually be closer to 98.6 percent and 83 percent respectively.[73] Regardless, it is clear that an overwhelming percentage of Alberta's forested lands have been allocated to forest harvesting.

In Alberta, twelve major forestry companies currently hold Forest Management Agreements (FMAs) on provincial Crown lands, as shown in Figure 6. The three most highly allocated boreal sub-regions are the Central Mixedwood, Wet Mixedwood, and the Boreal Highlands (Table 5). The numbers in Table 5 do **not** include Commercial Timber Permits, Quota Holders, or Local Timber Permits outside of FMAs.

Table 5. Area of the Boreal Forest Allocated to Forest Management Agreements (as of November 1997), by Sub-region[74]

Boreal Forest Sub-Region	**Percent of Sub-Region Allocated to FMAs**
Central Mixedwood	54.47
Dry Mixedwood	15.50
Wet Mixedwood	57.58
Sub-Arctic	7.5
Peace River Lowlands	-
Boreal Highlands	66.26

Clear cutting has been, and continues to be, the dominant forest harvesting method, used in 88 percent of all harvest operations in Canada between 1920 and 1996.[75] It is the preferred method used by the overwhelming majority of logging operations in the boreal forest in Alberta,[76] with various forms of partial cutting being used rarely.[77] Average cut block size for northwest Alberta during 1989-1996 was 27.09 ha for hardwoods and 17.79 ha for softwoods.[78]

From the perspective of cost and labour efficiency, the most desirable forest stand type for clear cutting is an even-aged, single species plantation. Conventional forest management and silvicultural practices are designed to generate an assured, long-term supply of stands (of the desired commercial tree species) as close to this "ideal" as possible. This has had far-reaching implications for the original structural diversity, age-class distribution, species composition and ecological functioning of natural forests now managed for timber production. Some of the ecological implications of clear cutting include:

- Old forest stands are targeted first for cutting. Alberta's "Timber Harvesting Planning and Operating Ground Rules" [79] state, "Timber that is the oldest ….should be given priority for harvest." In their comments on an earlier (1987) but similar version of this ground rule, Peterson *et al*.[80] note "that ground rule makes quite clear the underlying policy about old forest management in Alberta."
- Establishing rotation ages of 80-120 years for conifers and 50-70 years for deciduous stands[81] means that old-growth and so-called "decadent" stands that are cut will never be allowed to replace themselves.
- Clear cutting results in widespread habitat loss and fragmentation, soil damage (especially compaction from the use of logging-related machinery), increased sedimentation in streams due to increased run-off from clear cuts but also from erosion along access routes, potential severe erosion if watersheds are logged, alteration and disruption of local hydrological patterns, a net loss of nutrients, local microclimatic changes, and the potential for regional climate modification where widespread clear cutting occurs. Some, although not all, of these impacts can be reduced by methods such as harvesting in winter, when soils are frozen, to minimize soil compaction.
- Silvicultural practices of concern include mechanical site preparation techniques that disrupt local soil and hydrological systems, promoting the growth of desired species but suppressing competitor species characteristic of early successional stages; and replanting to a monoculture of seedlings that may have been hybridized or genetically engineered, resulting in a loss of genetic diversity compared with naturally regenerated stands.
- Widespread changes occur in overall species composition, from coniferous to mixed and deciduous stands, due to a combination of logging and fire suppression.
- Forestry access roads are a very important factor in habitat loss and fragmentation. For a forestry company to remain economically viable, no individual tree can be more than 150 metres from the closest road.[82] This results in a grid of roads throughout forested areas, which can then be used by other industries (such as conventional oil and gas) and by the public for recreational purposes.

The federal government estimates that 90 percent of all forest harvest occurs in primary and old-growth forests. This practice maximizes short-term yields at the expense of long-term production rates. At present harvest rates, remaining old-growth forests over 150 years old will have disappeared by 2012, while old-growth forests older than 120 years will be gone by 2041.[83]

Old-growth stands have unique ecological and structural characteristics. For example, Stelfox[84] "conclusively demonstrated that old-growth Aspen mixedwood stands are more structurally diverse/functionally complex and support a richer overall diversity of species than other seral stages."

According to the October 15, 1995 draft of the *Alberta Forest Conservation Strategy*: [viii] [85]

- Some wildlife species have an absolute requirement for old-growth forest habitat or the characteristics it provides. The limited knowledge of species habitat requirements for many species makes the maintenance of old-growth forest a priority.
- Old-growth forests are a vital source of genetic variation.
- Old-growth forests provide diverse recreational uses and have spiritual significance. Although wilderness recreation does not require old-growth forest, the tranquility and beauty provided by old growth are unquestioned.

According to the American Forestry Association, old-growth forests are essentially "a non-renewable resource" and the Society of American Foresters states "that there is no evidence that old-growth conditions can be reproduced silviculturally."[86] The AFCS recommended, "lands in (Alberta's) system of protected areas include areas of natural old growth unaffected by industrial activity." Stelfox[87] notes that "in landscapes manipulated intensively (e.g., conventional clear cut logging), a large amount of the area should be established as reserves to serve as ecological benchmarks and to compensate for problems caused by intensive forestry."

The use of clear cutting rather than other methods of forest harvest, and how well clear cuts mimic natural disturbance are matters of ongoing public debate. Natural disturbance processes such as fire significantly affect the structure and composition of the boreal forest. It has become popular to suggest that "clear cuts equal fire." The suggestion is that clear cutting can be designed to closely mimic the ecological effects and functions of fire, particularly given fire suppression, as the dominant disturbance mechanism in the boreal forest.[88] Fire cycles have durations ranging from 40-60 years for low-intensity ground fires, to over 200 years for stand-replacing fires. The available science indicates that clear cuts do not mimic fire disturbance, although further research is needed.[89] Some major differences are that clear cutting typically removes more biomass and nutrients from a site than do burns, which are often patchy and discontinuous. Residual standing trees that have value to wildlife are common in burns but uncommon in clear cuts. In cases where trees are felled by fire, they provide large woody debris and protected runways and cover for small mammals.

Since 1997, three independent reports have examined Canada's progress toward sustainable forest management: the National Forest Strategy Coalition Blue Ribbon Panel; the National Round Table on the Environment and the Economy; and the federal Senate Subcommittee on the Boreal Forest. All three reports identified momentous challenges and management transitions that are still required. For example, the Senate Subcommittee report states, "It appears that we have reached the point where potentially transforming concepts are widespread."[90] Forest accords, a variety of conservation strategies, and a range of criteria and indicators have been developed, often with a great deal of public participation, to measure progress in sustainable development and use of forests. "Yet institutions, management planning, and forestry practices 'on the ground' have not, in most cases, seen significant change."[91] Case studies estimate that the rate of logging would have to decline across Canada by 10-25 percent in the boreal forest and by 30-40 percent on the

[viii] The Alberta Forest Conservation Strategy (AFCS) was never ratified but was replaced by the Alberta Forest Legacy developed by Alberta Environmental Protection; it proposed an implementation framework for sustainable forest management.

coast of British Columbia in order to address broader forest sustainability objectives.[92]

In summary, Gordon[93] points out, "To assume that our harvesting systems have thus far done no damage to our forests both in terms of reduced biodiversity and loss of genetic diversity, and that we are not anticipating further mass losses in future harvesting operations, is naïve in the extreme."

3.5 Mining

At present, the area being mined in the boreal forest is relatively small compared with the overall size of the region. However, "The local environmental degradation they [mining operations] entail is inevitably and invariably severe."[94] Mining is carried out for coal, mineral aggregate (sand and gravel), peat, and oil sands. Diamond exploration is also occurring in the boreal forest. Oil sands mining is discussed separately in this report.

3.5.1 Coal

Alberta is the largest producer of coal in Canada. Three of the province's 12 active coal mines are located in the Dry Mixedwood sub-region, and all three are strip mines. Impacts include habitat destruction and fragmentation, wildlife disturbance, and air and water pollution. Reclamation can also cause habitat modification, through practices such as the use of non-native seed mixes.

3.5.2 Mineral Aggregate

Mineral aggregate mining is a rapidly growing industry in Alberta. In 1995, there were approximately 1,000 pits in Alberta operated by about 300 private and public sector producers.[95] Ecological impacts related to these operations include habitat loss, wildlife disturbance, air pollution from dust and emissions and, potentially, groundwater contamination or impairment and the disruption of local hydrological regimes, as many pits are located next to rivers.

3.5.3 Peat Mining

As of March 1997, surface material licenses had been issued for 17 peat-mining operations in the boreal forest. These leases cover an area of 68.79 km^2 in the southern Dry Mixedwood sub-region and the southernmost Central Mixedwood Region. Due to the lengthy periods of time required for their formation, peat lands are, in practical terms, a non-renewable resource. The degree of ecological degradation resulting from peat mining is disproportionately large compared with the size of the areas being mined. Peat land ecosystems are not very resilient and are highly sensitive to stress and environmental change. Peat lands that were formed over thousands of years can be lost very quickly, with potentially severe impacts on regional biodiversity. Other impacts of peat land destruction include the release of greenhouse gases (mainly carbon dioxide and methane) to the atmosphere, and the release of contaminants stored in these deposits (such as mercury and lead) to surrounding rivers and lakes.

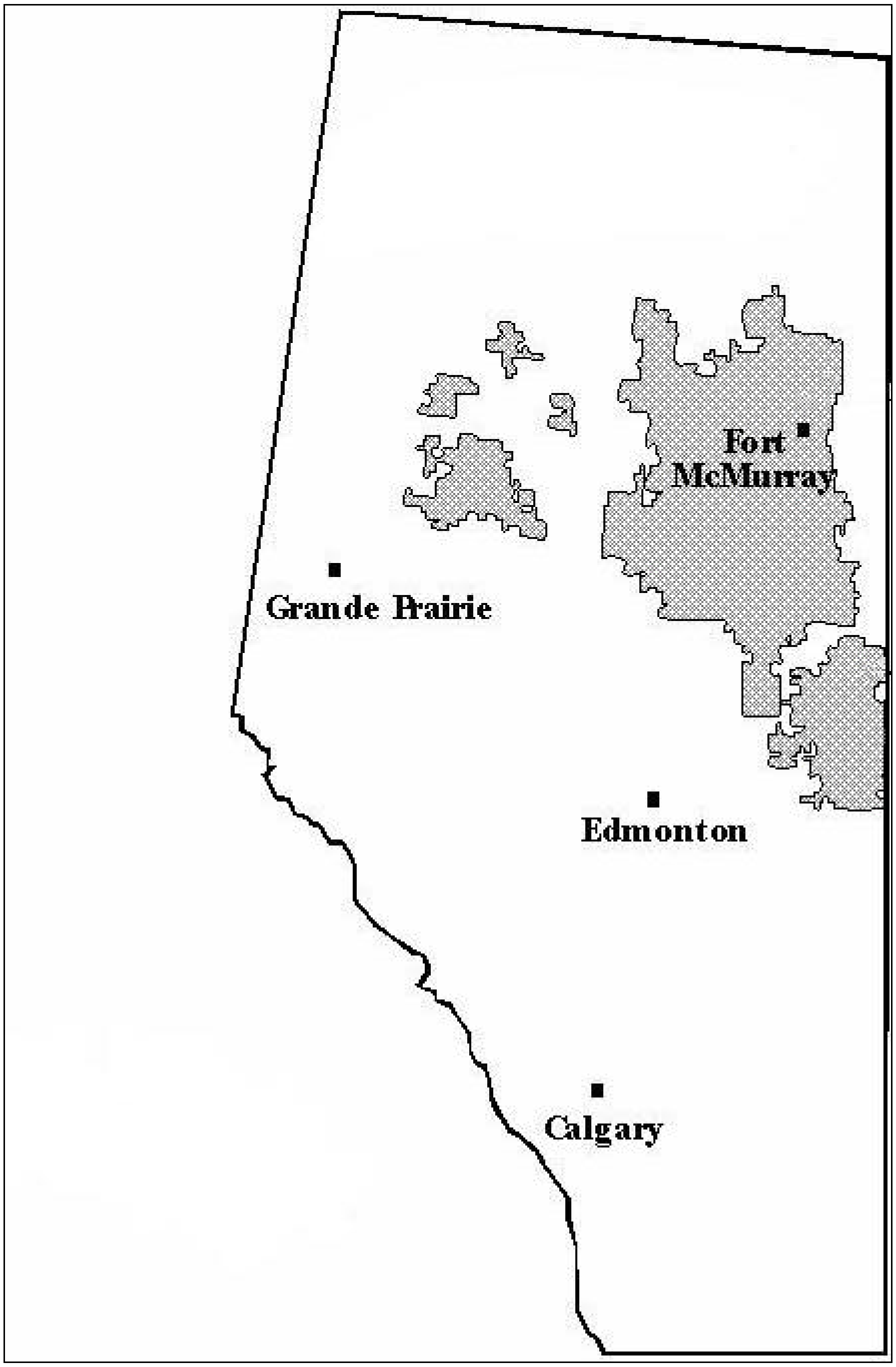
3.5.4 Diamonds

Forty-four million hectares of mineral claims were registered in Canada in 1997. Claims increased by 232 percent over 1996, due mainly to the interest in potential diamond properties.[96] According to the Alberta Geological Survey, the boreal forest completely encompasses two diamond "trends" (Buffalo Hills and Fort McKay), and includes portions of two others (Peace River and Vegreville). Considerable diamond exploration is occurring in Alberta, with 80 percent of the leases for this purpose located in the boreal forest.[97]

3.5.5 Oil Sands Surface Mining

Three major oil sands deposits are recognized: the Athabasca Wabiskaw-McMurray (Athabasca), Peace River, and Cold Lake deposits (Figure 7). The Athabasca Oil Sands deposit is by far the largest, comprising over 78 percent of Alberta's oil sands reserves. Virtually the entire extent of the oil sands deposits lies within the boreal forest. Only 10 to 20 percent of the oil sands deposits can be surface mined (i.e., the deposits generally have less than 75 metres of overburden);[98] these are found in the Athabasca Wabiskaw-McMurray deposits, a 37-township (3,450 km^2) area known as the surface mineable area (Figure 8).

Figure 7 Oil Sands Deposits in Alberta



A number of environmental impacts are associated with oil sands surface mining projects, including: [99] [100]

- large scale, long-term (more than 50 years) habitat destruction that can never be completely restored to pre-development conditions
- macro-scale landscape modifications to landscape appearance, shape, watershed capability, and soils capability
- habitat loss and fragmentation due to tailings ponds, access corridors, transmission lines, roads, bridges, processing facilities, and other infrastructure
- soil and water contamination due to production mine sludge (tailings and various solid wastes)
- the potential contamination of surface waters and groundwater (e.g., the Athabasca, Muskeg, and Steepbank rivers from tailings pond leakage and/or dike failure)
- oiling and poisoning of birds landing in the tailings ponds
- alteration of local hydrological and hydrogeological regimes (e.g., muskeg drainage, impacts to surrounding wetlands)
- direct and indirect impacts on local wildlife populations (e.g., mortality, disturbance, disruption of movement)
- release of large quantities of atmospheric emissions, with local and regional effects including water and soil acidification, ground level ozone formation, a fertilization forcing effect on some plant species, and the presence of air toxics; emissions include sulphur dioxide (SO_2), oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and particulate matter
- the release of large quantities of greenhouse gases, such as carbon dioxide and methane, which contribute to global climate change and impede Canada's ability to meet international commitments to reduce greenhouse gas emissions.

Although SO_2 emissions have declined somewhat, emissions of NO_x and VOCs are predicted to rise as bitumen production increases. In 1997 bitumen production was 382,000 bpcd (barrels per calendar day) with SO_2 emissions of 271 tpcd (tonnes per calendar day) and NO_x emissions of 78 tpcd. It is currently estimated that by 2010, based on approved and publicly announced projects, bitumen production will have grown to 2,268,000 bpcd. During this period, SO_2 is predicted to increase to 404 tcpd and NO_x to increase to 406 tcpd.

The impacts of regional air emissions are currently receiving attention from industry, regulators and members of the public. One of the key drivers for this attention is emerging evidence that the cumulative impacts of existing and projected emissions may result in detrimental impacts to sensitive forest soils and wetlands, and that ground level ozone concentrations will increase. The risks of these impacts were noted prior to the significant expansion of the industry, currently underway.

The comment made by Legge *et al*.[101] is still valid: "It is not a question of whether the complex emissions associated with oil sands development will cause ecological modifications because they will; it is rather a question of the rate and magnitude of ecological modification which is critical." These emissions contribute to global climate change (CO_2), direct concentration effects, and acidic deposition (through SO_2 and NO_x). Human and animal health may be affected through cumulative exposure to chemicals associated with water and air emissions produced as a result of oil sands mining operations. These effects may also be felt well beyond the region due to the long-range transport of pollutants in air and water.

3.6 Cumulative Effects of Existing Development on the Boreal Forest

Cumulative effects refer to the combined and multiple environmental impacts that all human activities have across a broad area over time. The cumulative effects of disturbances to land, emissions to air and water, and human use of resources can alter, impair and destroy ecosystem function. Ecosystems have a finite capacity to accept and assimilate these effects. This finite capacity is referred to as the "environmental limit" or "environmental threshold."

It is evident from the previous discussion that human activity in the boreal forest has led to considerable, obvious physical modification. Physical fragmentation of a forested landscape results in its ecological fragmentation – that is, the subdivision of original habitats and ecosystems.[102] The challenge is determining what the ecological implications of this fragmentation are. The question is, compared with its original condition, "at what level of fragmentation is a forested landscape still capable of performing its normal ecological functions?"[103] This concept, known as "habitat effectiveness," provides an approximate measure of ecological "intactness" or integrity. Habitat effectiveness can be defined simply as "the percentage of available habitat usable by an animal."[104]

Using fragmentation itself as an indicator for ecological integrity has limited value, as we presently lack the scientific understanding to set a definitive threshold level for fragmentation, above which we would expect the ecological integrity of the boreal forest to be compromised. It is also difficult to determine what constitutes a significant effect on ecological integrity. A more consistently useful and effective predictor of habitat effectiveness is road density. Although by no means perfect, road density has been found to account for at least 60 percent of the variation in habitat effectiveness.[105] The caveat is that in order to be useful, any such analysis must include not only roads but also other linear disturbance corridors, such as seismic lines, pipeline rights-of-way, railways, and power lines that can functionally be used as roads.[ix] An analysis of linear disturbances or "access densities" is a more practical indicator that can be used as a management tool. It can be defined for a given geographical area and the information is relatively accessible.

Figure 9 illustrates the effects of forest habitat loss and fragmentation on forests across Canada.[106] The map shows areas of converted forest, accessed forest, and un-accessed forest. Converted forest lands are defined as lands converted from a historic forest or forest condition to non-forest land. Accessed forest lands are defined as lands within one kilometre of a known access corridor. Access corridors include roads, trails, railways, pipelines (oil and gas), hydroelectric and telephone transmission lines, seismic lines, and known motorized backcountry routes, such as snowmobile trails. Un-accessed forest lands are those more than one kilometre from a known access corridor.[107] Throughout Canada, six percent of all forested lands have been converted to non-forest lands, while 30 percent of all forested lands are accessible (within one kilometre of an access corridor). The degree of human impact on Alberta's forests is also evident. Alberta has the second highest percentage of forest converted (after Prince Edward Island) and the second highest percentage of forest accessed (second to New Brunswick) (see Table 6).

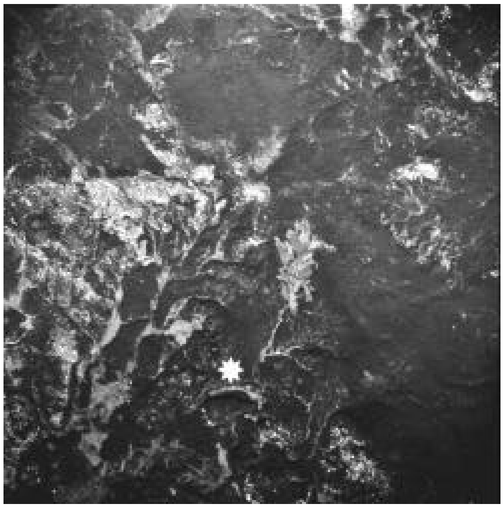
[ix] In the context of habitat effectiveness "roads" are defined as any right-of-way that can be traveled by 1) motorized means, including cars, ATVs, snowmobiles, "dirt bikes," and snowmobiles; and 2) by humans using non-motorized access methods – foot, horseback, or mountain bikes. Even if hiking, cycling, and horseback trails are eliminated from consideration, all seismic cutlines of two metres or more in width (that is, passable on an ATV or snowmobile) constitute *de facto* roads for habitat effectiveness analyses.

Table 6. Forest Conversion and Access by Province[108]

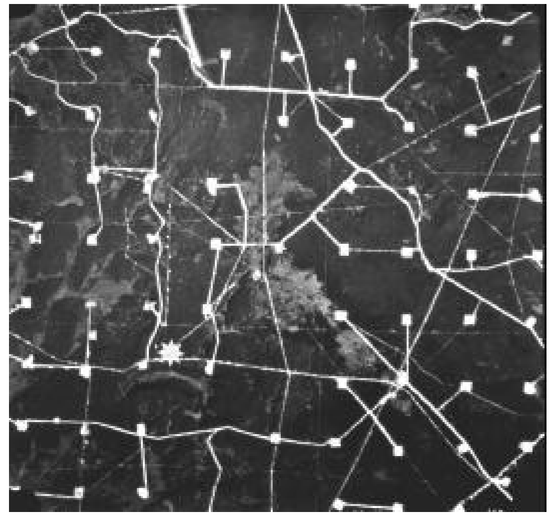
Province	Converted Land (000 hectares)	Percent of Forest Converted	Total Remaining Forest (000 hectares)	Accessed Forest (000 hectares)	Percent of Forest Accessed
Alberta	9,035	21	33,259	27,518	83
British Columbia	849	2	48,184	30,137	63
Manitoba	3,304	8	40,289	5,074	13
New Brunswick	239	3	6,612	5,797	88
Newfoundland	15	0	16,813	668	4
Nova Scotia	203	4	4,879	3,035	62
N.W.T	1	0	46,517	1,217	3
Nunavut	0	0	1,977	0	0
Ontario	3,858	5	78,721	21,849	28
Prince Edward Island	211	46	250	153	61
Quebec	1,468	2	80,948	16,898	21
Saskatchewan	7,270	19	31,558	5,841	19
Yukon	1	0	12,929	1,252	10
Total	26,454	6	402,936	119,439	30

An examination of the impacts of human activity was carried out for the Western Canadian Sedimentary Basin. This area occupies 545,000 km^2 of Alberta and northeastern British Columbia and has been the focus of intensive industrial activity (Figure 10). Fifty years ago this area was still mostly free of roads and other linear access features. How much this has changed is evident in the photographic sequence of the Swan Hills area in Alberta, which spans the years from 1949 to 1991 (Figure 11). This sequence provides a classic example of how industrial activity has contributed to habitat loss and fragmentation. Although it is dramatic, the sequence is by no means unique in this area.

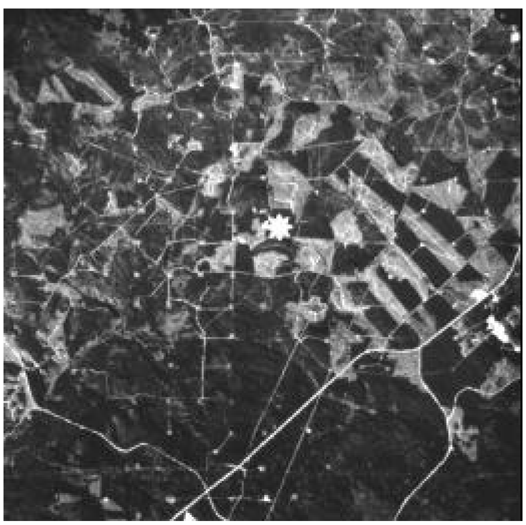
Analysis shows that forests have been fragmented by more than 1.3 million kilometres of linear disturbances. The resulting average access density is currently 2.4 km/km^2. To provide some ecological context to this figure, sensitive species such as wolves are almost never found where there are more than 0.45 km of roads per km^2. These linear disturbances have fragmented the forest into patches of various sizes and shapes. Of the 11,978 remaining patches, only 745, or six percent, are larger than 9 km^2. The average size of these patches is 64 km^2. [109]



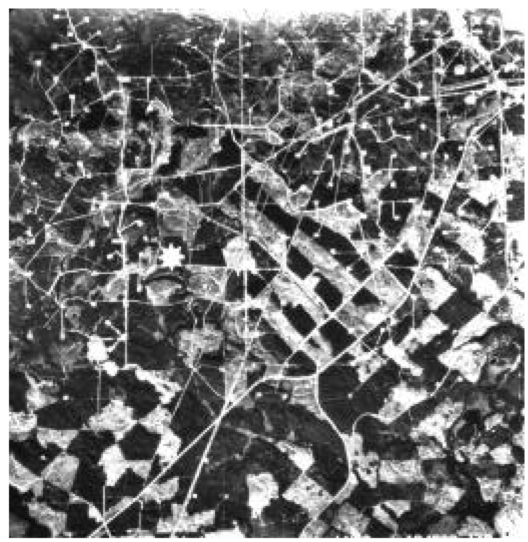
1949



1964



1982



1991

Figure 11 Photo-Mosaic Showing Increasing Conversion and Fragmentation in the Swan Hills Region of Alberta. White stars in the photographs indicate the same reference point. Photographs are not all the same scale.

(Photographs compiled by Richard Thomas, from Global Forest Watch, 2000)

A linear disturbance analysis done for Alberta echoes these findings, showing that the boreal forest is highly fragmented (Figure 12). Sawyer and Haskins[110] calculated and mapped four sets of linear disturbance-related parameters for the boreal forest, as follows:

- Linear disturbance densities: The total lengths of all boreal forest linear disturbances were amalgamated.
- Roadless Areas: defined as "those areas with linear disturbance densities of zero km/km^2, which is effectively those areas that are more than 900 metres from a linear disturbance.
- Stream crossing densities: This measure was deemed important due to the numerous direct and indirect ways that linear disturbances can adversely affect aquatic habitat. For example, the B.C. Forest Service noted that stream crossing densities of 0.7 km/km^2 indicate a high risk of surface erosion and, when used in conjunction with other measures such as road density, can be considered a general measure of ecosystem integrity.[111]
- Core habitat areas were derived by buffering linear disturbances by 500 metres on each side and eliminating any of the resulting areas that were less than 10 km^2 in size. Their distribution in the boreal forest is indicated in Figure 13. As is clear from this figure, the majority of, and the largest remaining, core habitat areas are in northeastern Alberta within the Central Mixedwood sub-region, along the Saskatchewan border east and northwest of Fort McMurray, and adjacent to the southern and western margins of Wood Buffalo National Park.

Sawyer and Haskins[112] used these parameters to rank the six boreal forest sub-regions according to the degree that they have been affected and fragmented by human activity. The results of these analyses are presented in Table 7.

Using this ranking procedure, the authors concluded that the Peace River Lowlands and the Dry Mixed Wood are the least and most compromised sub-regions respectively. In order of decreasing ecological integrity the sub-regions are ranked as follows: Peace River Lowlands, Sub-Arctic, Boreal Highlands, Central Mixedwood, Wetland Mixedwood, and Dry Mixedwood. The mixedwood sub-regions, where in-situ development is likely to occur, are the most ecologically degraded sub-regions in the boreal forest. Based on the linear disturbance analysis, Sawyer and Haskins concluded that the boreal forest is now a highly fragmented landscape and its ecological integrity has been significantly compromised.

There is a question of how much of the boreal forest can still be considered "wilderness." This is not merely an academic exercise, as protecting wilderness is an essential element of habitat conservation. Lansky points out,[113] "the best way to protect native wildlife species is to protect the environment to which they adapted over thousands or even millions of years. And the best way to protect that environment is to leave it alone – to let it be wilderness." To try to answer

Table 7. Summary of key linear disturbance analysis-derived statistics used to rank the boreal forest natural region's six sub-regions according to their remaining degree of ecological integrity (intactness)[112]

Boreal Forest Sub-Region	% of sub-region that is roadless	% with > 1 km/km^2 road density	% in which stream crossings exceed 1 per km^2	% of sub-region in core areas	Ecological Integrity Ranking (1 = best; 6 = worst)
Central Mixedwood	17.5	67	28	19.0	4
Dry Mixedwood	4.1	84	30	4.6	6
Wet Mixedwood	5.5	82	39	5.4	5
Sub-Arctic	24.1	52	35	27.8	2
Peace River Lowlands	79.0	11	2	82.4	1
Boreal Highlands	19.1	64	36	22.1	3
	12.8	71	30	14.0	

this question, townships within the boreal forest were screened for disturbance footprints from all human activities including oil and gas, forestry, linear disturbances, backcountry fishing or hunting camps or lodges, and so on. The townships found to be free of any such disturbances are shown in Figure 14, indicating that outside of Wood Buffalo National Park, very little of the boreal forest can actually be described as "wilderness."[114] Based on this analysis, the following conclusions were reached.[115]

- In terms of the Region's remaining wilderness townships (and their equivalent area), less than nine percent of the Region (including Wood Buffalo National Park) still exists in a pristine natural condition.
- Outside remaining wilderness and core habitat areas, the ecological integrity of the Boreal Forest Natural Region has been moderately to seriously compromised by human activities.[116] According to the World Resources Institute, the only "frontier forests" (i.e., "large, ecologically intact, and relatively undisturbed natural forests") remaining within this Natural Region are located in Wood Buffalo National Park.[117] A large-scale program of ecological restoration (e.g., Cairns, 1994)[118] will be required to mitigate this damage.
- By global standards, the rate of environmental modification in the Boreal Forest Natural Region has been rapid. Deforestation rates between 1961 and 1986 in the northern Dry Mixedwood sub-region, and from 1949/50-1994/95 in the southern Dry Mixedwood sub-region, almost match and exceed (respectively) those reported for Amazonia from 1975-1988.[119]
- Practices such as fire suppression, trapping, and wildlife management to benefit a handful of economically valued species (through old-growth liquidation, establishment of rotation ages, etc.) mean that most of Alberta's boreal forests are now managed and manipulated and no longer wholly naturally functioning ecosystems. The pace and scale of human activity and development in this Natural Region continue to accelerate.
- Creation of an extensive network of access corridors throughout the Boreal Forest Natural Region – principally by the oil and gas and forestry industries – is considered to be the single most significant factor contributing to the Region's ongoing loss of ecological integrity. As numerous ecologists and conservation biologists[120] [121] [122] have stated with respect to a broad spectrum of conservation issues, **controlling access** is the key to maintaining ecologically functional habitats and viable populations of species. However, it is the **cumulative** environmental impacts of these industries, together with those of the host of other activities occurring here, that comprise the ultimate threat to the long-term maintenance of biological diversity in the Region.
- Meaningful measures, enacted soon, to reduce the extent of the present Boreal Forest Natural Region access network and to more strictly control the types of activities and levels of ingress upon it will be required to safeguard critical habitat for wide-ranging species such as Woodland Caribou.

Finally, climate change is the wild card in any discussion of the future of the boreal forest.[123] Global climate change is predicted to have a major impact on Canada's forests. Average global temperature could increase by 1°C. to 3.5°C. by the end of the century, but warming will not be uniform across the planet or within Canada. High latitudes are expected to warm much more than the global average. Canada's mean temperature may increase by 5 to 10°C., more than three times the global average. Although fire is a natural part of boreal forest ecosystems, the scale and intensity of fires is expected to increase if climate change occurs as expected. With predictions of a doubling of CO_2 over the next century, some scientists have predicted close to a 50 percent increase in fire intensity with a possible similar increase in the area burned. On the southern boundary of the boreal forest, fire severity may double. To remain within similar climatic conditions, boreal forest species would have to migrate northward at between 1.5 and 5.5 kilometres per year, a rate that is likely beyond the adaptive capabilities of most species. The net result is that the boreal forest may shrink to half its current size.[124] The threat of global warming should refocus attention on the extremely important, non-consumptive values of the boreal forest, particularly the ecological services, such as carbon storage, that it provides.

4 In-situ Oil Sands Development

Surface mining techniques have been the predominant method of bitumen extraction to date. However, in-situ extraction technologies are now being promoted as a way to "recover the resources with less impact to the land, air, and water than traditional oil sands mining methods."[125] Given the significant impacts on the boreal forest from existing industrial activity, the Pembina Institute, among others, has raised concerns about additional impacts from the expansion of in-situ oil sands development in this region.

4.1 In-Situ Oil Sands Impacts

In-situ extraction techniques are used where the overburden (that is, the amount of material overlying the oil sands deposits), is too thick for surface mining techniques to be used. This is generally the case where overburden thickness exceeds 75 metres.[126] Eighty to ninety percent of oil sands deposits are too deep to be surface mined and require some form of in-situ technique for their recovery. In-situ techniques do not require clearing of large surface areas or excavation of overburden to extract oil from the oil sands, but they do have other environmental impacts.

Often the bitumen is too thick to move on its own within the oil sands deposit and various techniques have been developed, using steam or solvents,[127] to extract the bitumen. At present, the most commonly used technique is Steam Assisted Gravity Drainage, or SAGD. The SAGD process involves drilling pairs of horizontal wells into the oil sands formation. The top well injects steam into the formation where it rises through the oil sand and heats the bitumen. This liquefies the bitumen and causes the steam to condense to water. The water and fluid bitumen drain to the bottom horizontal production well where they are collected and pumped to the surface.

These projects require a complex infrastructure involving:

- a central processing facility for water treatment, steam (or solvent) generation, and separation of the bitumen, produced water and produced gas, with associated lime sludge ponds and storm water collection ponds;
- a network of well pads, each with a number of well-pairs for steam (or solvent) injection and bitumen extraction;
- steam and production pipelines to transport steam from the central plant to the well pads, and to return produced bitumen, produced fluids, and produced gas from the well pads to the central processing facility;
- internal infrastructure to service the well pads, such as roads and sumps for oily wastes;
- associated infrastructure such as an electrical transmission line to provide power, and a natural gas supply pipeline to provide energy for the large quantities of steam required;
- a water source, usually from groundwater wells drilled into local aquifers;
- possibly wells for wastewater disposal; and
- possibly an upgrader associated with the project, or more commonly, a diluted bitumen, or "dilbit," export pipeline to send the diluted bitumen to another location for upgrading.

A list of project activities that could result in environmental impacts was drawn from the Environmental Impact Assessments for three recent in-situ project applications (PanCanadian Christina Lake,[128] Petro-Canada MacKay River,[129] and Alberta Energy Company Foster Creek[130]).

Environmental impacts are broken down into the specific phases of the project, from preliminary activities through project construction, operation, and finally project abandonment. A serious concern with in-situ development is that most of the environmental disturbance caused by the project occurs during the preliminary activities, before any regulatory approval is sought for the project. Coordination with other industries and shared access corridors can potentially reduce this pre-approval disturbance. For example, a pilot project carried out between AlPac and Gulf's proposed Surmount in-situ oil sands development projected a 47 percent savings in roads and a $3-million savings in the first phase of the project by integrating activities.[131] However, such synergies are not always possible either because other industries are not active in the area of a proposed oil sands development, or the time frames for activities do not match. Therefore, pre-approval disturbance can often be a much higher percentage of the total project-related disturbance.

Preliminary Activities

These activities occur prior to the start of any major construction activities within the lease area. During this phase, drilling is carried out to better define the oil sands resource, field surveys are done to refine the project design, and some project infrastructure is constructed.

- Access clearing (roads, seismic, rights-of-way)
- Seismic exploration
- Exploratory drilling
- Associated workforce (that is, human presence)

Construction

This phase involves the construction of the central plant facility and all the facilities necessary for bitumen extraction, including:

- Access
- Clearing of pads and the plant site
- Drilling of well pairs
- Central plant facility construction
- Steam and production pipelines
- Electrical facilities
- Ancillary facilities (for example, landfills and disposal pits)
- Construction camp
- Workforce
- Electrical transmission lines

Operations

The operations phase refers to the operation and expansion of drilling pads, including:

- Well servicing
- Steam (or solvent) injection
- Bitumen production
- Central plant operation
- Emergency disposal well facilities
- Water use and/or contamination
- Ancillary facilities
- Workforce
- Pipelines
- Upset events (pipeline rupture, well failure, fire, etc.)

Abandonment

Once the first well has completed its life cycle, the abandonment phase occurs concurrently with the operation phase, so that well pads are progressively reclaimed as they come to the end of their operational life as the project proceeds. Abandonment includes the removal of all above ground facilities, removal of any contaminated soils, and reclamation of the disturbed areas as laid out in the Conservation and Reclamation plan approved by Alberta Environment.

Abandonment involves:

- Well capping
- Removal of plant facilities
- Removal of well pads and roads
- Site reclamation
- Removal of ancillary facilities

The life cycle of an individual in-situ oil sands project covers approximately 30 years. The environmental impacts of development of individual in-situ projects are similar to those of conventional oil and gas projects, including: habitat loss and fragmentation due to the drilling of large numbers of injection and recovery wells; the construction of access roads, pipeline and transmission line corridors; and processing and storage facilities. Sources of environmental impacts include potential contamination of surface waters, aquifers, soils and the atmosphere resulting from emissions generated during the extraction and upgrading phases of the operation. Noise from facility operations and human activities associated with the project can disturb wildlife populations. The difference between in-situ projects and conventional oil and gas projects is that SAGD in-situ projects can potentially use large quantities of water, often from groundwater aquifers although water may also be drawn from lakes or rivers. In-situ projects also use a considerable amount of energy to generate steam, thereby producing NO_x and, potentially, SO_2 as well as significant amounts of greenhouse gases (e.g., CO_2), further contributing to regional acidification and loading of ground level ozone.

4.2 Cumulative Impacts of In-Situ Oil Sands Development

In-situ oil sands industry representatives argue that if the oil sands resource is to be developed, in-situ projects have significantly fewer environmental impacts than surface mining oil sands operations and are a far preferable extraction technology. In a project-by-project comparison of equal areas this is arguably the case. In-situ projects do not have the large-scale environmental impacts that are of such concern with surface mining operations (e.g., end pit lakes, consolidated tailings, and permanent modifications to the landscape as a result of clearing and overburden excavations). Although there are concerns with the project-related impacts of individual developments, the overriding concern with in-situ development is the potential cumulative impacts of these developments, which can be discussed under five main points.

First, in-situ development has the potential to be geographically widespread throughout the oil sands deposits in the boreal forest, particularly compared with the area presently being surface mined (Figure 15). Only a small portion of the Athabasca oil sands area is accessible through surface mining techniques; the rest of the Athabasca and all of the Peace and the Cold Lake oil sands areas will require in-situ techniques for bitumen recovery.

In-situ oil sands reserves are also much larger than surface mineable reserves (Figures 7 and 8). Only a small portion of the in-place bitumen reserves has been developed thus far. As of 1998, in-place reserves for surface mining and in-situ projects were one- and five-billion cubic metres respectively. Applying conservative recovery factors to the entire Alberta oil sands yields a value for initial established reserve volumes of 6.4 billion m^3 for surface mineable oil sands, but 19.1 billion m^3 for in-situ areas (Table 8).[132] The Alberta Energy and Utilities Board (AEUB) also estimated the reserve that could be recovered before the resource is depleted (the ultimate potential). The ultimate potential for surface mineable reserves is estimated at 10 billion m^3, but the estimate for in-situ reserves is 39 billion m^3, **almost four times** greater.[133]

Table 8. Established and Potential Bitumen Reserves in Alberta

	Reserves ($m^3 \times 10^9$)		
	In-Place	Initial established	Ultimate potential
In-Situ			
Approved Projects	5.0	0.39	
Disclosed Projects	6.3	0.49 †	
Oil Sands Areas	245.3	19.1 †	39.0
Mining			
Approved Projects	1.0	0.64	
Disclosed Projects	3.2	2.14 †	
Oil Sands Areas	24.1	6.4	10.0

† estimates, not yet established by AEUB.

Second, assuming that societal use of fossil fuels continues, and therefore fossil fuel resource development continues, in-situ development could occur in the boreal forest for a very long time. Depending on the accuracy of the assumptions used to assess Alberta's future reserve potential, the active period of conventional exploration and extraction will likely be another 40-70 years. In contrast, oil sands activity could potentially continue for 200-300 years.[134]

Third, although in-situ development causes less environmental impact than surface mining, it does cause environmental disturbance and impacts. Considering the already ecologically degraded and fragmented state of the boreal forest, it can be argued that **any** additional disturbance may have a disproportionately large impact on the ecological integrity of the boreal forest. Given the concerns with the state of the boreal forest, it is prudent to examine any new industrial development carefully.

Fourth, the northeastern portion of the province previously identified as having most of the remaining core habitat also has the most potential for in-situ development. As unfragmented core habitat is increasingly rare, any development, whether from in-situ or other industrial use occurring in these remaining areas of unfragmented boreal forest is of concern. Such unfragmented areas have high ecological value and should remain undeveloped.

Finally, at present, regulators are assessing projects on a project-by-project basis. While environmental impact assessments, of varying quality, are being conducted for these projects, the scope of these assessments is limited in time and areal extent. Decisions are being made by regulators to grant development of individual projects without having first determined what the cumulative impacts of in-situ development are on the boreal forest and whether the ecological integrity of the boreal forest ecosystem will be compromised by further development. The result is development of *de facto* policy on an incremental basis.

In-situ development is a significant new threat to the ecological integrity of the boreal forest when the potential impacts of this development are considered along with those that already exist. Although some development appears inevitable with the approval of the PanCanadian Christina Lake project it is also apparent that extensive development cannot proceed unless an overall strategy is in place.

5 Conclusions and Recommendations

5.1 A Boreal Forest Use Framework

This paper has described the inherent values of a natural, ecologically stable boreal forest, and outlined the interplay of human activities that are causing significant cumulative and potentially irreversible damage to the forest. It argues for effective and meaningful protection of representative areas of Alberta's boreal forest.

To achieve such protection, a broad, holistic, ecosystem-based policy framework for managing cumulative impacts must be established. In this way, growth in new in-situ oil sands development, along with planned forestry and conventional oil and gas activity, can occur in a manner that is ecologically sustainable.

To be meaningful and effective, such a boreal forest use framework must contain the following key elements:

a) Protection of ecologically significant areas that are excluded from industrial development
b) Establishment of "reserve areas" large enough to support ecological integrity
c) Implementation of linear disturbance limits in areas assigned to industrial development
d) Access controls to reduce the impacts of human disturbance
e) Coordination of development activities between industries and development of best practices and procedures for individual industries to minimize net disturbance to the boreal forest

Currently, no provincial policy tool provides for such a framework.[x]

5.1.1 Protection of Ecologically Significant Areas

Areas identified as having high environmental, cultural, or ecological significance must be excluded, in perpetuity, from any form of industrial or commercial development, and must be properly buffered to ensure their long-term sustainability. Research undertaken for the Special Places 2000 program and for wilderness non-government organizations has identified the prime candidate sites for protection (see Figure 16, and Appendix I for more details).[135] No further scientific research is needed to move forward with protection of these sites. Legislative mechanisms must be established to properly protect these sites and should take precedence over other land use legislation. This legislation should also ensure that protected areas are not subordinate to other land uses. The management goal would be to phase out existing industrial development, remove and reclaim linear disturbances, and institute access controls for remaining access corridors within a short period of time (e.g., less than five years).

The key issues are to find the political will to establish these areas and to negotiate the terms under which previously allocated reserves of oil, gas and forest resources will be fairly withdrawn from development. Groups such as the World Wildlife Fund (WWF), Canadian Parks and Wilderness Society (CPAWS), and the Federation of Alberta Naturalists (FAN) have worked with CAPP (the Canadian Association of Petroleum Producers) to develop means to deal with these issues.[xi]

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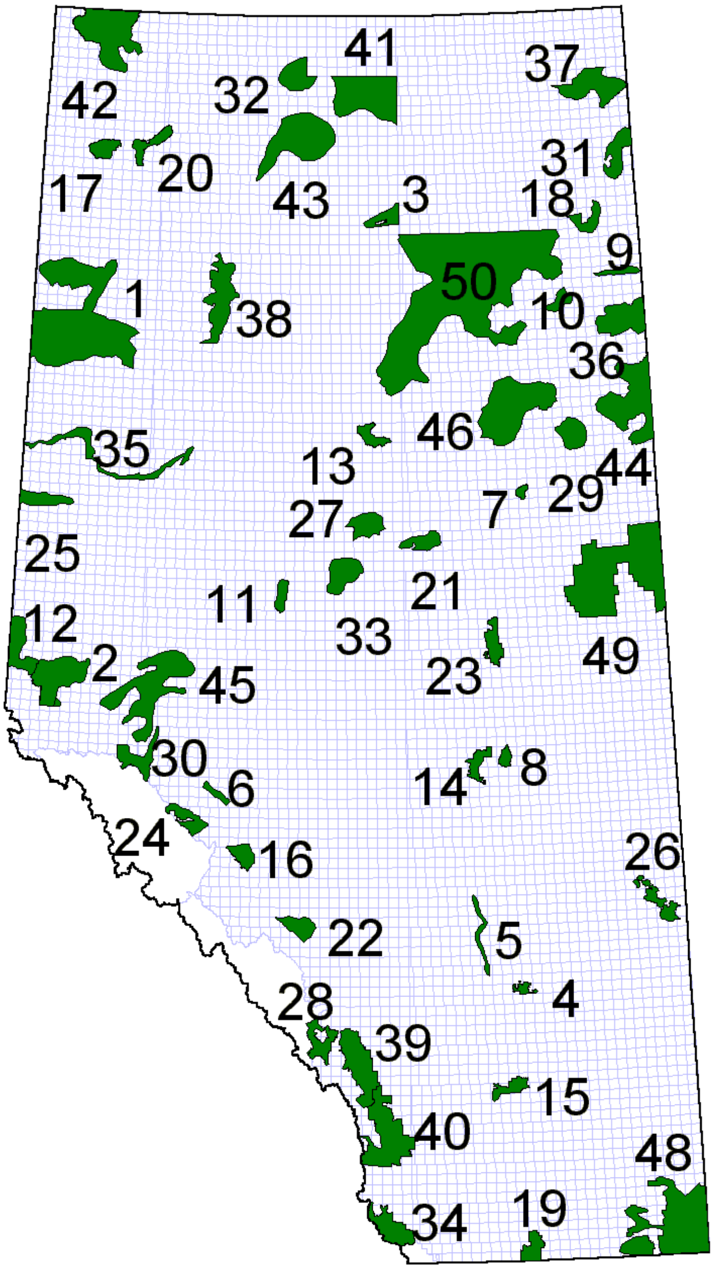
[x] Various regulatory policy tools (such as Alberta Energy and Utility Board and Alberta Environmental Protection Act approvals mechanisms, integrated resource plans, forest company management plans, etc.) are in use and provide for assessment and management of project specific development. However, these tools are not, in and of themselves, adequate for comprehensive, integrated, region-wide management. Alberta Environment's Regional Sustainable Development Strategy (RSDS) initiative could provide a vehicle in which to house such a framework in due course. However, the establishment of protected areas would be required *a priori*. With RSDS' longer-term focus and reliance on adaptive management, it would be challenged to deal with the impacts of current development in a timely, preventative manner.

[xi] Example of these tools include lease exchanges, land swaps, voluntary relinquishment of non-renewal of leases, monetary compensation to give up mineral tenures or operating facilities, incentives for accelerated pool depletion, royalty credits in exchange for relinquishment of leases, and directional drilling from outside the boundary of a Special Place.

Figure 16 World Wildlife Fund Canada's Top 50 Areas for Protection in Alberta



Name	Num.	Area, km^2
Chinchaga	1	6529
Caw Prairie	2	1615
Harper Creek	3	401
Hand Hills	4	154
Tolman	5	322
Coal Highlands	6	180
Crow Lake	7	112
Beaverhill Lake	8	184
Marguerite River	9	227
McClelland Lake	10	300
Goose-Wallace	11	300
Torrens	12	1549
Trout Delta	13	360
Beaver Hills	14	392
Majorville	15	393
Wapiabi	16	415
Hay-Zama	17	418
Richardson River	18	432
Twin River	19	455
Lower Chinchaga	20	464
Fawcett Lake	21	481
Clearwater	22	513
Amisk	23	526
Cardinal	24	537
Pouce Coupe	25	559
Sounding-Bodo	26	574
Martin Mountain	27	647
Ribbon	28	662
Stony Mountain	29	679
Brule-Wild Hay	30	715
Old Fort River	31	733
Caribou Slope	32	766
Otauwau	33	869
Castle	34	895
Peace River	35	994
Firebag River	36	1265
Wylie Lake	37	1345
Cache Creek-Wolverine San	38	1514
Hand Hills	39	1553
Livingstone	40	2132
Caribou Plateau	41	2306
Cameron Hills	42	2456
Margaret-Ponton	43	2485
Clearwater-Gypsy	44	2512
Little Smoky	45	2848
Athabasca Rapids	46	2989
Onefour	48	3857
Primrose	49	5282
Birch-Wabasca	50	13502

The establishment of protected areas is a necessary pre-condition to subsequent negotiations to establish other “reserve areas” for preservation and to determine linear disturbance limits.

5.1.2 Establishment of “Reserve Areas”

The federal Senate Subcommittee on the boreal forest recommended that a system of natural landscape-based forest use regimes be established. Such a system would allocate the boreal forest into three distinct management categories. Up to 20 percent of total boreal forest area would be intensively managed for timber and fibre production, while another 20 percent would be set aside as protected areas. The remaining 60 percent would be managed at a less intensive level over a broader area to retain a relatively natural mixture of tree species and ages for the sake of preserving biodiversity while attempting to accommodate the full range of forest users and communities.[136]

Wilderness groups in Alberta have endorsed the Senate Subcommittee’s recommendation of protecting 20 percent of the boreal forest natural region. The Pembina Institute also supports this recommendation, however, the Institute would propose a slightly different strategy for managing the remaining 80 percent of the land base. This strategy envisions areas outside of protected areas being divided into two categories. One management category would be “development areas” where industrial and commercial development would be permitted, but within a management framework (discussed in more detail below) designed to minimize loss of ecological integrity and biodiversity.

The second management category would include setting aside areas of the boreal forest as unfragmented “reserve areas” in which development would not be permitted for a period of time. These areas would be large enough to maintain ecological integrity, support biodiversity, act as laboratories for scientific inquiry, and serve as “ecological benchmarks” against which to assess the success of reclamation efforts in other parts of the forest.

It is essential that these areas not be viewed in isolation, but within the context of a structurally and functionally inter-connected ecosystem. These reserve areas must be connected with surrounding areas that are excluded from development and with surrounding set-aside areas in order to maintain critical ecological links such as wildlife corridors, wetlands for migratory birds, and others. The preservation of river valley and riparian habitat is an example of how such ecological linkages should be maintained. These areas are ecologically complex, have high biodiversity, and are extremely important to wildlife both for critical habitat and as wildlife corridors. On a landscape scale, river valleys link geographically extensive and ecologically diverse habitats.

Areas set aside as unfragmented “reserve areas” of the forest, outside of ecologically protected areas would not be barred or “sterilized” indefinitely from development. Once other areas subject to development have been successfully reclaimed and their original ecological integrity and biodiversity restored, development could occur in an area originally set aside as a reserve. Limited development within these set-aside areas may also be possible, but would only occur under extremely stringent conditions. The burden of proof to demonstrate that resources could be developed without jeopardizing the ecological integrity of the area would fall to the proponent. In such situations, land offsets would be required to maintain the overall percentage of land to be left undeveloped.

5.1.3 Implementation of Linear Disturbance Limits

In areas where industrial activity is permitted, these activities should be coordinated and managed to minimize cumulative impacts. Retaining as much of the pre-existing ecological integrity as possible would allow industry to more quickly reclaim and restore the region to its original state once industrialized resources have been depleted. This would then create the opportunity for industry to earn access to resources located in undeveloped “reserve areas.”

To facilitate management of these regions, three linked tools need to be developed and implemented:

- a limit to the maximum acceptable habitat loss within a given area, represented as “km^2 disturbed area per km^2 total area;

- a limit to the maximum acceptable linear disturbance density within a given area, represented as "km of linear disturbance per km^2"; and
- access controls.

As a condition of operating in the areas where industrial activity is allowed, industry would be required to coordinate its activities to meet linear disturbance density targets and provide access controls.

5.1.4 An Existing Multi-stakeholder Mechanism for Regional Management

Once a framework has been established with the key elements discussed above, existing governmental and multi-stakeholder mechanisms such as the Regional Sustainable Development Strategy (RSDS) and the Cumulative Environmental Management Association (CEMA) could be used to determine the location and size of areas for preservation, negotiate linear disturbance limits, and establish access controls. Some of the concerns with industrial development in the region have been identified by the CEMA as issues to be addressed. With responsibility for coordinating and developing policies for environmental management in the Athabasca region, and with many of the key stakeholders already participating, the RSDS initiative and the CEMA can provide a suitable structure to undertake this work.

RSDS-CEMA stakeholders could make use of existing management tools to assist in this work. One example is the Alberta Landscape Cumulative Effects Simulator (ALCES) presently being used in the Alberta Chamber of Resources' Integrated Landscape Management (ILM) initiative, discussed in more detail below. This tool can be used to assess existing impacts to the boreal forest and can model the implications of future impacts associated with diverse development scenarios.[xii] Most of the data necessary to run this model is already collected by various government agencies and the necessary modeling work could be done in a relatively short timeframe at reasonable cost.

5.1.5 Industry Coordination and Best Practices

The activities of the forestry, conventional oil and gas, and oil sands industries in areas allocated for development need to be coordinated to minimize impacts. Each industry also needs to establish and benchmark those "best practices" that reduce the disturbances caused by individual companies. Optimizing industrial activities would retain more of the current integrity of the forest and reduce the amount of time required to restore the area's ecological integrity, thereby enabling industrial development to move into "reserve" areas previously restricted from development.

The Alberta Chamber of Resources' ILM initiative could be very useful.[137] Although not a true multi-stakeholder group, this industry-to-industry initiative is intended to develop actions that reduce industries' collective environmental footprint, improve the science and understanding of how to best coordinate activities among industries, review existing regulations and policies that may impede footprint minimization, and recommend any appropriate changes. Another useful activity includes the EUB Mineable Oil Sands Development Strategy (MODS), which focuses on coordinating development of a specific oil sands ore body within the Athabasca oil sands region, i.e., the Muskeg River basin. To ensure that a full range of views and ideas is considered, representatives working within these initiatives should be involved with multi-stakeholder groups such as the CEMA.

Examples of oil and gas "best practices" include the use of low-impact or "avoidance" techniques, such as hand clearing, to prepare seismic lines.

[xii] ALCES has been used previously to model the impacts of conventional oil and gas, surface mining, and in-situ oil sands activity on AlPac's Forest Management Agreement area. The model showed that 90,000 ha of this area is already under roads, pipelines, powerlines, and seismic lines. A further 13,640 ha are currently under well sites and other processing facilities, (equivalent to approximately one year's annual allowable cut). The model predicted that given the predicted frequency of fire, and based on conservative estimates for energy sector development, within 30 years AlPac will no longer be able to harvest timber at the rate necessary to supply its pulp mill with the 2.4 million m^3 per year of wood fibre that it was designed to process.

This method can reduce the width of the cut line to about 1.5 metres.[138] Another low-impact technique is referred to as "limbing"; it can be used to clear a line-of-sight and does not require the removal of trees or shrubs, which can reduce impacts even more. Existing lines and rights-of-way should be used where possible. This reduces impacts as well as operating costs. "Plugging" – selectively planting trees at access points to seismic lines – helps control unauthorized access by hunters and recreational users. Imposing "bends" or "dog-legs" on seismic lines reduces line-of-sight impacts.

The sharing of seismic information between competing companies is another example of exemplary practice. Data sharing would reduce the need for duplicative seismic exploration activity and would reduce impacts. Some sharing and re-selling of seismic data is already occurring through company-to-company trading of data, data brokers, and companies that conduct speculative seismic data collection. However, competition still results in unnecessary seismic impacts. An industry protocol or regulatory system that required or further promoted this activity would reduce surface impacts associated with seismic data collection.

5.2 Implications of Inaction

Leading wilderness environmental groups, such as the Alberta Wilderness Association, Canadian Parks and Wilderness Society, World Wildlife Fund, and the Federation of Alberta Naturalists, have been advocating elements of this boreal forest land-use framework for many years. Through the 1990s, these organizations, along with industry and government, invested substantial resources in consultations to develop the Forest Conservation Strategy and Special Places 2000 program.

Considerable research was conducted as part of these and other processes, providing valuable information to use in making conservation and management decisions. The environmental community and industry were also able to negotiate agreements on how to proceed. But despite the participants' good faith and hard work, public opinion polls demonstrating consistent strong support for conservation, and the preparedness of industry to implement solutions, these initiatives have so far failed to secure any meaningful protection for the boreal forest.

Withdrawal of the redrafted Natural Heritage Act from the Alberta Legislature's order paper due to disagreement between the Ministers of Environment and Resource Development is the most recent breakdown. The public airing of this disagreement lays bare the fundamental obstacle to progress on forest protection – that of the preparedness of our current political leadership to moderate economic development and financial gain within the constraints of ecological limits.

Although negotiated processes have not produced meaningful results, the underlying drivers to establish such policies – conflict between the need to protect a representative portion of the forest and the economic imperative to industrialize the forest's resources – mean that this issue will not go away.

The loss of credibility of negotiation is forcing moderate groups to adopt more aggressive strategies and is encouraging other environmental groups to enter the debate. The recent actions of Greenpeace International indicate the attention that can be brought to industrial activities in this province. Reviewing strategies used successfully elsewhere in Canada, the United States, and Europe during the past ten years, these more aggressive strategies can be expected to include direct confrontation in the forest on a project-by-project basis, as well as market-directed actions – likely to be focused on customers in the United States. Project-by-project actions would increase costs for project proponents and would delay regulatory approval decisions. Market-based actions could directly affect corporate revenues as well as provincial royalties. Both types of strategies would undermine public credibility and confidence in public and private sector institutions.

Moving these issues from debate to direct action would significantly increase the risk and uncertainty faced by industry in proceeding with plans to develop the province's resource base and would further undermine Alberta's environmental reputation.

5.3 Actions Needed

Clearly, the fundamental challenge in this issue is one of political will to implement solutions. Not enough members of Alberta's political leadership understand the essential, compelling environmental and economic logic for effective and meaningful protection of the ecological sustainability of the boreal forest. Given its demonstrated inability to balance economic development and ecological sustainability over the last ten years, greater political pressure clearly must be brought to bear. Those within government who do understand the long-term societal importance of protecting representative portions of the forest must redouble their efforts to educate their Cabinet and backbench colleagues.

And industry, along with other stakeholders, must begin to implement actions that directly help to create the appropriate conditions for government action. With their long-term interests in forestry, conventional oil and gas, and oil sands resources in northern Alberta, the corporate sector has a particularly crucial role to play in the pro-active lobbying and education of Alberta's political leaders. This role is especially important, as government agencies have consistently maintained that no solutions can be endorsed without industry support. The most important outcome of these activities would be the timely, formal, legal protection of candidate protected areas from industrial development, as identified through the Special Places 2000 program.

To facilitate and allow time for this to occur, companies must make unilateral commitments to not develop reserves located in protected areas and to quickly phase out any existing activities from these areas. If the government is not prepared to consider compensation for such commitments, then industry itself should facilitate company-to-company negotiations for the sharing of access to resource reserves controlled outside of these protected areas in order to more fairly distribute the economic burden of these commitments.[xiii]

Companies operating in the boreal forest need to begin to directly implement decisions to coordinate their activities, and to establish best practices that minimize cumulative impacts.

Given the failure of earlier consultations, establishment of protected areas is a necessary precondition for the involvement of the environmental community in any subsequent work to establish "reserve areas," linear disturbance limits and develop policies to coordinate industrial development.

Once candidate sites are protected, the work to determine suitable "reserve areas," establish linear disturbance limits, establish access controls, and to develop policies to coordinate industrial development could be done within RSDS-CEMA. A multi-stakeholder working group within RSDS-CEMA could focus on the short-term task of negotiating interim targets and guidelines for use by industry in developing projects, and to assist regulators in assessing project applications. This work would contribute to longer-term efforts, building the knowledge required to provide ongoing refinement of such policies and management tools.

Resolution of these issues in a timely and meaningful manner is essential. Although our society cannot prevent change to the boreal forest ecosystem, we can manage the impacts to slow down the rate of further losses and to ensure that as much as possible of the boreal forest's original ecological integrity is retained. Albertans have consistently shown that the protection of the boreal forest is important. The question is whether we have the foresight and will to address these issues while we still have acceptable options for doing so, or if we will further delay to the point where both political and ecological options are even more severely constrained.

[xiii] An example of such a process used in another jurisdiction is the one that followed Ontario's controversial Lands for Life proposal. In order to deal with fundamental disagreements Premier Harris set up a "principled negotiation" process whereby the forest industry and a few environmental non-government organizations were sequestered for a period of about a week in order to develop a solution that would both complete the system of protected areas for northern Ontario **while** guaranteeing a wood supply to the forest industry. It is interesting to note that it was industry that approached the government, insisting that the issue of protected areas be resolved. Further detail on this dispute negotiation process is available at http://www.mnr.gov.on.ca/mnr/oll/ofaab/index.html

Appendix I. WWF: 'Top 50' Key Landscape Areas of Interest

Based primarily on the series of reports by Alberta Environmental Protection that examined the distribution of biological and physical landscape features and, where relevant and possible, the spatial scales of ecosystem processes, WWF identified 50 Key Landscapes to represent much of the ecological diversity of the six natural regions and twenty natural subregions that comprise Alberta. Available data describing the known ecological characteristics and landscapes of the natural regions and sub-regions was considered. Existing land uses and land ownership were incorporated as constraints to the identification of the 'Top 50' key landscape areas of interest in this analysis and as constraints in boundary selection.

WWF's 'Top 50' Key Landscapes[1]

Key Landscape	*Km²*	*Key Landscape*	*Km²*
Amisk	526	Little Smoky	2945
Athabasca Rapids	2990	Livingstone	2117
Beaverhill Lake	185	Lower Chinchaga	465
Birch-Wabasca	13502	Majorville	394
Bistcho	2456	Marguerite-Kame	227
Brule-Wild Hay	716	Martin Mountain	648
Cache Creek-Wolverine	1515	Maybelle-Delta	1988
Cardinal	537	McClelland	300
Caribous	6923	Old Fort	734
Castle	895	Onefour-Pakowki	3810
Caw Prairie	1615	Otauwau	870
CFB Wainwright	306	Peace River	994
Clearwater	514	Pouce Coupe	559
Clearwater-Gypsy-Gordon	2512	Primrose	5687
Coal Highlands	180	Red Deer River	322
Crow Lake	112	Slave River	769
Dune Point	95	Sounding-Bodo	574
Edgerton	86	South Saskatchewan	152
Firebag	1265	Stony Mountain	679
Goose-Wallace	301	Torrens	863
Handhills	155	Trout Delta	360
Harper	401	Twin River	452
Hay-Zama	418	Upper Chinchaga	3741
Kananaskis-Bow	2216	Wapiabi	715
Kilarney-Reflex	27	Wylie Lake	1346
		Total	**72,163**

[1] A small portion of this total is privately-owned land (e.g., Red Deer River, Peace River) that is only included for reasons of scale.

The 'Top 50' key landscape areas of interest were also determined based on the representation of Alberta's Natural History Themes, particularly Level I NHTs, and of WWF's enduring features of the landscape, in combination with land use constraints and public land ownership. As a result of the latter consideration, not all Level I NHTs nor all sub-regions (e.g., especially the Foothills Parkland) are included in the 'Top 50.' Special efforts will be particularly required to secure an adequate level of protected areas in these areas. The sizes of the proposed areas are "draft" and subject to confirmation.

The 50 Sites

AMISK (526 KM^2)

Natural Subregion: Dry Mixedwood 526 km^2

Description:

- One of the most diverse river valleys in the Dry Mixedwood
- Includes deep glacial spillway
- Significant waterfowl production and staging area
- Part of significant White-tailed Deer and Moose wildlife corridor
- Adjacent to Long Lake Provincial Park and Whitearth Valley Natural Area
- This is the only 'Top 50' site in the southern Dry Mixedwood and other options are extremely limited

ATHABASCA RAPIDS (2,990 KM^2)

Natural Subregion: Central Mixedwood 2,990 km^2

Description:

- Inter-provincial waterway
- Part of one of the largest, longest, most diverse and most productive rivers in the Mixedwood Boreal Forest of Canada
- Scenic
- Deeply incised valley with many rapids and bedrock outcrops
- Spawning Lake Whitefish and other important fish species
- Important moose and fur-bearer habitat

BEAVERHILL LAKE (185 KM^2)

Natural Subregion: Central Parkland 185 km^2

Description:

- RAMSAR site
- One of most important migratory waterfowl and shorebird habitat areas in western North America
- Exposed mudflats, vegetated shorelines and islands
- Piping Plover breeding lake
- One of handful of sites in Central Parkland and other options are extremely limited

BIRCH-WABASCA (13,502 KM^2)

Natural Subregions:

Central Mixedwood 4,535 km^2
Subarctic 3,270 km^2
Boreal Highlands 5,698 km^2

Description:

- One of most diverse and intact hill systems in the Boreal Forest of Alberta
- Provincially significant California Gull colony
- High landform and vegetation diversity
- Large plateau supporting boreal and subarctic and some foothills species
- Important Osprey and Bald Eagle nesting areas
- Important fishery
- Key moose and fur-bearer habitat
- Adjacent to Wood Buffalo National Park

BISTCHO (2,456 KM^2)

Natural Subregion: Subarctic 2,456 km^2

Description:

- Large, shallow, eutrophic lake
- Excellent waterfowl staging and production area
- Subarctic vegetation
- Rare species

BRULE-WILD HAY (716 KM^2)

Natural Subregions:

Alpine 58 km^2
Subalpine 284 km^2
Montane 57 km^2
Upper Foothills 317 km^2

Description:

- One of most diverse Upper Foothills habitat complexes in Alberta
- Critical elk and moose habitat
- Adjacent to Jasper National Park

CACHE CREEK-WOLVERINE (1,515 KM^2)

Natural Subregions: Dry Mixedwood 1,515 km^2

Description:

- One of most important moose ranges in northern Alberta
- Diverse vegetation
- Sand-dune wetland complexes
- Rare species

CARDINAL (537 KM^2)

Natural Subregions:

Alpine 178 km^2
Subalpine 360 km^2

Description:

- Nationally significant alpine features and vegetation
- Diverse wetlands-springs complex
- Many rare species
- Key habitat for Grizzly Bear and Wolverine
- Adjacent to Jasper National Park

CARIBOUS (6,923 KM^2)

Natural Subregion:

Dry Mixedwood 374 km^2
Wetland Mixedwood 159 km^2
Subarctic 5,737 km^2
Boreal Highlands 651 km^2

Description:

- Significant Woodland Caribou and Wood Bison habitat
- Sphagnum- black spruce dominated peat plateau
- Old growth forest slopes
- Dissected valleys
- Of importance for protection to Little Red River Cree Nation

CASTLE (895 KM^2)

Natural Subregions:

Alpine 137 km^2
Subalpine 487 km^2
Montane 268 km^2

Description:

- Highly diverse Rocky Mountain landscapes
- Extremely high concentrations of rare species
- Important for Grizzly Bear
- Spectacularly scenic
- Adjacent to Waterton Lakes National Park

CAW PRAIRIE (1615 KM^2)

Natural Subregions:

Alpine 108 km^2
Subalpine 1,098 km^2
Montane 105 km^2
Upper Foothills 286 km^2
Lower Foothills 18 km^2

Description:

- Critical ungulate, including Woodland Caribou, and carnivore, including Grizzly Bear, habitat
- High diversity of Rocky Mountain and Foothills landscapes and vegetation
- Adjacent to Wilmore Wilderness Park

CFB WAINWRIGHT (306 KM^2)

Natural Subregion: Central Parkland 306 km^2

Description:

- Nationally significant riparian habitats
- Key deer habitat
- Diverse breeding bird communities
- Extensive sand plains and sand dunes
- Sharp-tailed Grouse dancing grounds

CLEARWATER (514 KM²)

Natural Subregions:

Subalpine 44 km²
Upper Foothills 470 km²

Description:

- One of the most diverse and productive Foothills streams in Alberta
- Key ungulate habitat
- High fish diversity
- Diverse riparian areas
- Variety of breeding birds
- Adjacent to Bighorn Wildland Recreation Area

CLEARWATER-GYPSY-GORDON (2512 KM²)

Natural Subregion: Central Mixedwood 2,503 km²

Description:

- High landform and vegetation diversity
- Unusual landforms (bedrock stacks)
- Rare species
- Significant spring features
- Adjacent to Whitemud Falls Ecological Reserve

COAL HIGHLANDS (180 KM²)

Natural Subregion: Upper Foothills 180 km²

- Description:
- Diverse Upper Foothills habitats
- Old growth forests
- Extensive willow-alder shrublands
- Wet meadows
- High wildlife diversity
- Rare species

CROW LAKE (112 KM²)

Natural Subregion: Central Mixedwood 112 km²

Description:

- Excellent representation of Central Mixedwood Boreal Forest
- Rare vegetation species
- High vegetation and landform diversity
- Adjacent to Crow Lake Ecological Reserve

DUNE POINT (95 KM²)

Natural Subregion: Dry Mixedgrass 95 km²

Description:

- Diverse coulee woodlands, shrubbery, grasslands, slopes, dunes and riparian habitats
- Rare species
- High bird diversity
- Key deer and Pronghorn habitat

EDGERTON (86 KM²)

Natural Subregion: Central Parkland 86 km

Description:

- One of most diverse sand hill complexes in Parkland of Alberta
- Inter-dune fen complexes
- Riparian areas
- Sharp-tailed Grouse dancing grounds

FIREBAG (1,265 KM²)

Natural Subregion: Central Mixedwood 1,265 km²

Description:

- One of most untouched areas in Alberta's Boreal Forest

GOOSE-WALLACE (301 KM²)

Natural Subregions:

Upper Foothills 224 km²
Lower Foothills 77 km²

Description:

- Highest point in Swan Hills
- Significant plant species
- Old growth forests
- Rare species
- Adjacent to Goose Mountain Ecological Reserve

HANDHILLS (155 KM^2)

Natural Subregion: Northern Fescue 155 km^2

Description:

- One of most prominent hill systems in Plains of Alberta
- Lush fescue grasslands, of international significance
- Rare birds and plants
- Disjunct species
- Springs
- High bird diversity
- Key deer habitat
- Adjacent to Hand Hills Ecological Reserve

HARPER (401 KM^2)

Natural Subregion: Central Mixedwood 401 km^2

Description:

- One of most diverse wetland/upland complexes in Central Mixedwood
- Old growth forests
- Springs
- Caves
- Adjacent to Wood Buffalo National Park

HAY-ZAMA (418 KM^2)

Natural Subregion: Wetland Mixedwood 418 km^2

Description:

- Internationally significant for birds
- RAMSAR site

KANANASKIS-BOW (2216 KM^2)

Natural Subregions:

Alpine 329 km^2
Subalpine 1,135 km^2
Montane 96 km^2
Lower Foothills 699 km^2
Foothills Parkland 15 km^2

Description:

- Nationally significant Montane and Foothills habitats
- Critical range for ungulates and carnivores
- Concentration of rare species
- Adjacent to many protected areas

KILARNEY-REFLEX (27 KM^2)

Natural Subregion: Central Parkland 27 km^2

Description:

- Major nesting area for Piping Plover
- Internationally significant for shorebird migration
- Many mammals, amphibians and reptiles

LITTLE SMOKY (2,945 KM^2)

Natural Subregions:

Subalpine 305 km
Upper Foothills 2,278 km^2
Lower Foothills 363 km^2

Description:

- Critical Woodland Caribou habitat
- Key Grizzly Bear habitat
- Key Arctic Grayling fishery
- High diversity of ecological features

LIVINGSTONE (2,117 KM^2)

Natural Subregions:

Alpine 39 km^2
Subalpine 839 km^2
Montane 581 km^2
Lower Foothills 31 km^2
Foothills Parkland 626 km

Description:

- Nationally significant Montane and Parkland habitats and landscapes
- Diversity of birds and mammals
- Critical ungulate and carnivore habitat
- Concentration of rare species
- Scenic
- Adjacent to several protected areas

LOWER CHINCHAGA (465 KM^2)

Natural Subregion: Wetland Mixedwood 465 km^2

Description:

- High diversity of riparian habitats
- Old growth forests
- Important fur-bearer habitats

MAJORVILLE (394 KM²)

Natural Subregions:

Dry Mixedgrass 58 km²
Mixedgrass 335 km²

Description:

- Significant tract of remaining Mixedgrass subregion
- Burrowing Owls
- Numerous wetlands, many ephemeral
- Important for birds of prey

MARGUERITE-KAME (227 KM²)

Natural Subregion: Central Mixedwood 227 km²

Description:

- Largest area of deeply dissected kame in Alberta
- High vegetation diversity
- Adjacent to Marguerite Wildland Park

MARTIN MOUNTAIN (648 KM²)

Natural Subregions:

Central Mixedwood 105 km²
Dry Mixedwood 31 km²
Lower Foothills 511 km²

Description:

- Eastern-most Foothills outlier in province
- High landform diversity
- Unique plant communities including disjunct populations
- Extensive peatland complexes with patterned fens
- Adjacent to Lesser Slave Lake Provincial Park

MAYBELLE DELTA (1,988 KM²)

Natural Subregions:

Central Mixedwood 655 km²
Peace River Lowlands 964 km²
Athabasca Plain 368 km²

Description:

- Internationally significant portion of Peace-Athabasca Delta
- RAMSAR wetland
- Unique paleodunes
- Adjacent to the rest of the delta in Wood Buffalo National Park

MCCLELLAND (300 KM²)

Natural Subregion: Central Mixedwood 300 km²

Description:

- Significant duck staging area
- Important Bald Eagle nesting area
- Rare vegetation species and unique fens
- Sandhill Crane nesting habitat
- Sinkhole features

OLD FORT (734 KM²)

Natural Subregion: Athabasca Plain 734 km²

Description:

- Diverse area of river delta, dunes, glacial outwash
- Pine forests, wetlands and riparian habitats

ONEFOUR-PAKOWKI (3,810 KM²)

Natural Subregions:

Montane 93 km²
Dry Mixedgrass 2,656 km²

Description:

- Nationally significant, large block of grassland and lake
- Concentration of rare species
- Diversity of breeding birds
- Key ungulate habitat
- Diversity of landscapes and vegetation
- Adjacent to several protected areas

OTAUWAU (870 KM²)

Natural Subregions:

Upper Foothills 417 km²
Lower Foothills 452 km²

Description:

- Highly diverse landscapes and vegetation
- Rare species
- Old growth forests
- Variety of wetlands

PEACE RIVER (994 KM^2)

Natural Subregion: Peace River Parkland 994 km^2

Description:

- Nationally significant, diverse and productive river valley
- Key ungulate and fur-bearer habitat
- Important for birds of prey and waterfowl
- Diverse vegetation
- Adjacent to several protected areas

POUCE COUPE (559 KM^2)

Natural Subregions:

Dry Mixedwood 14 km^2
Lower Foothills 539 km^2

Description:

- Diverse stream valley
- Key Moose and fur-bearer habitat
- Trumpeter Swan habitat

PRIMROSE (5,687 KM^2)

Natural Subregions:

Central Mixedwood 5,663 km^2
Dry Mixedwood 23 km^2

Description:

- Highly diverse landscapes and vegetation
- Important fur-bearer and ungulate habitat
- Woodland Caribou
- Old growth forests
- Adjacent to Lakeland Provincial Park

RED DEER RIVER (322 KM^2)

Natural Subregions:

Central Parkland 229 km
Dry Mixedgrass 93 km^2

Description:

- Diverse valley habitat
- Diversity of breeding birds
- Key deer habitat
- Rare species
- Adjacent to Dry Island Buffalo Jump Provincial Park

SLAVE RIVER (769 KM^2)

Natural Subregions:

Peace River Lowlands 599 km^2
Kazan Upland 174 km^2

Description:

- American White Pelican colonies
- Exceptional Peregrine Falcon nesting and foraging habitat
- Key ungulate habitat
- Key fisheries habitat
- Adjacent to Wood Buffalo National Park

SOUNDING-BODO (574 KM^2)

Natural Subregions:

Central Parkland 310 km^2
Dry Mixedgrass 262 km^2

Description:

- Nationally significant for Piping Plovers
- Internationally significant for large block of aspen parkland and northern fescue

SOUTH SASKATCHEWAN (152 KM^2)

Natural Subregion: Dry Mixedgrass 152 km^2

Description:

- Nationally significant
- Spectacular canyon
- Adjacent to Suffield, one of largest remaining blocks of native grassland in Canada
- Concentration of significant species
- Adjacent to proposed Suffield National Wildlife Area

STONY MOUNTAIN (679 KM^2)

Natural Subregions:

Central Mixedwood 248 km^2
Boreal Highlands 431 km^2

Description:

- Summit and slopes of Stony Mountain
- High wetland diversity
- Old growth forests
- Woodland Caribou habitat

TORRENS (863 KM²)

Natural Subregions:
Alpine 85 km²
Subalpine 391 km²
Upper Foothills 343 km²
Lower Foothills 38 km²

Description:
- High diversity of Rocky Mountain and Foothills habitats
- Important for ungulates and carnivores
- Adjacent to Kakwa Wildland Park

TROUT DELTA (360 KM²)

Natural Subregions:
Central Mixedwood 206 km²
Boreal Highlands 154 km²

Description:
- One of most diverse areas in Central Mixedwood of Alberta
- High landform, wildlife and vegetation diversity
- Important wetlands

TWIN RIVER (452 KM²)

Natural Subregion: Mixedgrass 452 km²

Description:
- Valleys of north and south Milk Rivers
- Nesting birds of prey
- Rare species
- Key Pronghorn and deer habitat

UPPER CHINCHAGA (3,741 KM²)

Natural Subregions:
Wetland Mixedwood 359 km²
Upper Foothills 374 km²
Lower Foothills 2,997 km²

Description:
- High landform and vegetation diversity
- Old growth forests
- Trumpeter Swan nesting habitat
- Important for fur-bearers
- Grizzly Bear and Moose habitat

WAPIABI (715 KM²)

Natural Subregions:
Subalpine 134 km²
Upper Foothills 566 km²

Description:
- One of most diverse and undisturbed areas in Foothills
- Critical ungulate range and movement corridor
- Key carnivore habitat
- Important fishery
- Adjacent to Bighorn Wildland Recreation Area

WYLIE LAKE (1,346 KM²)

Natural Subregions:
Athabasca Plain 15 km²
Kazan Upland 1,331 km²

Description:
- Bedrock outcrops
- Series of shallow and deep lakes
- Disjunct species
- Uncommon, sensitive and colonial nesting birds
- Adjacent to several protected areas

Representation of Alberta's Natural Regions and Subregions

The area of each of the 'Top 50' sites within each natural subregion is listed in tables at the end of this discussion. The total area of both the 'Top 50' sites and existing protected areas (i.e., or areas needing upgrading in protection or management) are listed in Table 1. These sites total about 22% of Alberta's area.

Boreal Forest Natural Region

The total area – 'Top 50' plus existing protected areas – within the Boreal Forest Natural Region totals 81,819 km^2 or about 23.6% of the region (i.e., area of 346,963 km^2). Four major considerations influenced, to varying degrees, the selection of the 24 (i.e., of the 'Top 50') sites: (1) areas that are conflict-sensitive – consequently, areas that are uncommitted to industrial uses (2) areas that are least fragmented to date and publicly-owned land (i.e., this applied particularly to the Dry Mixedwood) (3) areas of value to Woodland Caribou (i.e., this applied particularly to the Subarctic and Boreal Highlands Subregions), (3) areas that are ecologically separated and important (i.e., in order to capture the full diversity of this large region), and (4) areas that are connected to Wood Buffalo.

The areas for protection within the Central Mixedwood total 38,696 km^2 or about 25% of the subregion. The Central Mixedwood area within the 'Top 50' sites totals 19,209 km^2 or about 12.4% of the total Central Mixedwood area, therefore about one-half is within the 'Top 50' sites. The 19,209 km^2 is within thirteen sites: Athabasca Rapids, Birch-Wabasca, Clearwater-Gipsy-Gordon, Crow Lake, Firebag, Harper, Margeurite-Kame, Martin Mountain, Maybelle-Delta, McClelland, Primrose, Stony Mountain and Trout Delta. Important considerations in selecting these areas include all four points listed above.

The areas for protection within the Dry Mixedwood total 3,971 km^2 or about 4% of the subregion. The Dry Mixedwood area within the 'Top 50' sites totals 3,440 km^2 or about 3.4% of the Dry Mixedwood Subregion, therefore most is within the 'Top 50' sites. The 3,440 km^2 is within 6 sites: Amisk, Cache Creek-Wolverine, Caribous, Martin Mountain, Pouce Coupe and Primrose. The first three sites are the most important due to: (1) their larger size thereby maximizing ecological integrity, and; (2) their geographic separation from each other, thereby maximizing biodiversity. The Caribous area is part of a larger site that consists of Boreal Highlands, Subarctic and Wetlands Mixedwood subregions. The Caribous site is also connected with Wood Buffalo. Publicly-owned land comprises only 41% of this subregion.

The areas for protection within the Wetland Mixedwood total 9,249 km^2 or about 24% of the subregion. The Wetland Mixedwood area within the 'Top 50' sites totals 1,401 km^2 or 3.6% of the Wetland Mixedwood Subregion, therefore most is within existing protected areas. The 1,401 km^2 is within four sites: Caribous, Hay-Zama, Lower Chinchaga and Upper Chinchaga. Particularly important considerations in selecting these areas were: (1) connection with adjacent subregions within some of the 'Top 50' sites (e.g., Caribous and Upper Chinchaga (2) exceptional biological significance (e.g., Hay-Zama is a RAMSAR site), and (3) geographic separation form other sites to maximize biodiversity.

The areas for protection within the Subarctic total 12,632 km^2 or about 57% of the subregion. The Subarctic area within the 'Top 50' sites totals 11,463 km^2 or about 52.1% of the Subarctic Subregion., therefore most is within some of the 'Top 50' sites. The 11,463 km^2 is within three sites: Birch-Wabasca, Bistcho and Caribous, with the largest portion in the Caribous. Particularly important considerations in selecting these areas were Woodland Caribou range and connection with Wood Buffalo National Park.

The areas for protection within the Peace River Lowlands total 9,176 km^2 or about 91% of the subregion. The Peace River Lowlands area within the 'Top 50' sites totals 1,564 km^2 or about 15.6% of the Peace River Lowlands Subregion, therefore most is within existing protected areas, namely Wood Buffalo National Park. The 1,564 km^2 is within two sites: Maybelle Delta and Slave River. The most important consideration in selecting these areas were securing the internationally significant Peace-Athabasca Delta, most of which is within Wood Buffalo National Park.

The areas for protection within the Boreal Highlands total 8,095 km^2 or about 38% of the subregion. The Boreal Highlands Subregion area within the 'Top 50' sites totals 6,934 km^2 or about 32.7% of the Boreal Highlands Subregion, therefore most is within some of the 'Top 50' sites. The 6,934 km^2 is within four sites: Birch-Wabasca, Caribous, Stony Mountain and Trout Delta, with the vast majority within Birch-Wabasca. Particularly important considerations in selecting these sites include: (1) topographic, aspect and geographic range of Boreal Highland areas, and (2) connection with Wood Buffalo National Park.

Rocky Mountain Natural Region

The total area – 'Top 50' plus existing protected areas - within the Rocky Mountain Natural Region is 33,696 km^2 or about 72.9% of the region (i.e., area of 46,267km^2). There were two major considerations in the selection of the 11 (i.e., of the 'Top 50') sites: (1) connection between existing protected areas and areas within the 'Top 50' (2) ecological value.

The areas within the Alpine total 12,482 km^2 or about 86% of the subregion. The Alpine area within the 'Top 50' sites is 934 km^2 or about 6.4% of the total Alpine area. The 934 km^2 is within 7 sites: Brule-Wild Hay, Cardinal, Castle, Caw Prairie, Kananaskis-Bow, Livingstone and Torrens. The Alpine areas of the Cardinal and Castle sites have exceptional biological elements (e.g., rare and disjunct species) that should be protected. These and the Alpine areas of the other sites provide ecological connections between existing protected areas and areas within the seven 'Top 50' sites.

The areas within the Subalpine total 18,477 km^2 or about 72% of the subregion. The Subalpine area within the 'Top 50' sites is 5,077 km^2 or about 19.7% of the total Subalpine area, therefore most is within existing protected areas. The 5077 km^2 is within ten sites: Brule-Wild Hay, Cardinal, Castle, Caw Prairie, Clearwater, Kananaskis-Bow, Little Smoky, Livingstone, Torrens and Wapiabi. The Subalpine areas of these sites provide ecological connections between existing protected areas and areas within the ten 'Top 50' sites.

The area within the Montane is 2,727 km^2 or about 46% of the subregion. The Montane area within the 'Top 50' sites is 1,200 km^2 about 20.0% of the total Montane area. The 1,200 km^2 is within six sites: Brule-Wild Hay, Castle, Caw Prairie, Kananaskis-Bow, Livingstone and Onefour-Pakowki. These six Montane areas are exceptionally rich in biological elements and provide corridors for species using surrounding subregions. The Whaleback portion of the Livingstone site, for example, is a center of ecological diversity and productivity and provides important seasonal migration corridors for large carnivores, ungulates and songbirds, as well critical reproductive and over-wintering habitat for a variety of species.

Foothills Natural Region

The total area – 'Top 50' plus existing protected area - within the Foothills Natural Region is 11,426 km^2 or about 12.1% of the region (i.e., area of 94,790 km^2). There were two major considerations in the selection of the 14 (i.e., of the 'Top 50') sites: (1) connection with existing protected areas and/or other areas within the 'Top 50' (2) ecological value, and (3) geographic distribution within the seven sub-areas identified by Alberta Environmental Protection (1996) based on geologic and geographic criteria.

The area within the Upper Foothills is 5,637 km^2 or about 19.2% of the subregion. The Upper Foothills area within the 'Top 50 sites is 5,455 k or about 18.6%, therefore the vast majority is within portions of the 'Top 50' sites. The 5,455 km^2 is within ten sites: Brule-Wild Hay, Castle, Caw Prairie, Clearwater, Coal Highlands, Goose-Wallace, Little Smoky, Otauwau, Torrens, Upper Chinchaga and Wapiabi. Important considerations, other than those listed above, in selecting these sites include: (1) caribou range (e.g., Little Smoky and Caw Prairie), and (2) exceptional ecological value (e.g., Castle, Caw Prairie, Brule-Wild Hay, Little Smoky).

The area within the Lower Foothills is 5,789 km^2 or about 8.8% of the subregion. The Lower Foothills area within the 'Top 50' sites is 5,725 k or about 8.7%, therefore the vast majority is within portions of the 'Top 50' sites. The 5,725 km^2 is within ten sites: Caw Prairie, Goose-Wallace, Kananaskis-Bow, Little Smoky, Livingstone, Martin Mountain, Otauwau, Pouce Coupe, Torrens and Upper Chinchaga. Important considerations, other than those listed above, in selecting these sites include: (1) caribou range (e.g., Upper Chinchaga, Little Smoky and Caw Prairie), and (2) exceptional ecological value (e.g., Caw Prairie, Little Smoky, Kananaskis-Bow).

Canadian Shield Natural Region

The total area – 'Top 50' plus existing protected area - within the Canadian Shield Natural Region is 3,970 km^2 or about 24.8% of the region (i.e., area of 16,021 km^2). There were two major considerations in the selection of the 4 (i.e., of the 'Top 50') sites: (1) connection with existing protected areas (2) ecological value, and (3) geographic distribution within the two subregions.

The area within the Athabasca Plain is 1,398 km^2 or about 19.7% of the subregion. The Athabasca Plain area within the 'Top 50' sites is 1,117 km^2 or about 15.7% of the subregion, therefore the vast majority is within portions of the 'Top 50' sites. The 1,117 km^2 is within three sites: Maybell-Delata, Old Fort and Wylie Lake.

The area within the Kazan Upland is 2,572 km or about 28.8% of the subregion. The Kazan Upland area within the 'Top 50' sites is 1,505 km^2 or about 16.9% of the subregion, therefore slightly more than one-half is within portions of the 'Top 50' sites. The 1,505 km is within two sites: Slave River and Wylie Lake.

Parkland Natural Region

The total area – 'Top 50' plus existing protected areas - within the Parkland Natural Region totals 2,925 km^2 or about 4.7% of the region (i.e., area of 62,480 km^2). Two major considerations influenced the selection of the 9 (i.e., of the 'Top 50') sites: (1) areas that are publicly-owned land (2) areas that are least fragmented, largest, intact blocks.

The areas for protection within the Central Parkland total 1,221 km^2 or about 2% of the subregion. The Central Parkland area within the 'Top 50' sites totals 1,145 km^2 or about 2.1% of the total Central Mixedwood area, therefore the vast majority is within the 'Top 50' sites. The 1,121 km^2 is within six sites: Beaverhill Lake, CFB Wainwright, Edgerton, Kilarney-Reflex, Red Deer River and Sounding-Bodo. An important consideration in selecting these areas, in addition to the two points listed above, include exceptional ecological value (e.g., Beaverhill Lake as a RAMSAR site, plus all the other sites). Publicly-owned land comprises only 8% of this subregion.

The areas for protection within the Foothills Parkland total 710 km^2 or about 16.1% of the subregion. The Foothills Parkland area within the 'Top 50' sites totals 641 km^2 or about 14.6%, therefore the vast majority is within the Top 50 sites. The 641 km^2 is within two sites: Kananaskis-Bow and Livingstone, with most being within Livingstone. Publicly-owned land comprises only 24% of this subregion.

The areas for protection within the Peace River Parkland total 994 km^2 or about 21% of the subregion. There is only one site within the Peace River Parkland greater than 10 km^2, the Peace River. Only 15 % of this subregion is publicly-owned land. The Peace River site is an exceptional area along the Peace River valley, from the B.C. border to the town of Peace River. Although most the site is mapped within the Dry Mixedwood Boreal Forest, the south-facing slopes at least are characteristic of the Peace River Parkland subregion, and so are counted in that subregion for the purposes of this report.

Grassland

The total area – 'Top 50' plus existing protected areas - within the Grassland Natural Region totals 6,157 km^2 or about 6.4% of the region (i.e., area of 96,426 km^2). Four major considerations influenced, to varying degrees, the selection of the 8 (i.e., of the 'Top 50') sites: (1) areas that are uncommitted to industrial uses (2) areas that are least fragmented (3) areas of publicly-owned land (i.e., this applied to all sites but especially to the Foothills Fescue), and (4) areas that are ecologically separated and important (i.e., in order to capture much of the diversity of this region).

The areas for protection within the Dry Mixedgrass is 3,595 km^2 or about 7.7% of the subregion. The Dry Mixedgrass area within the 'Top 50' sites totals 2,961 km^2 or about 6.3% of the total Dry Mixedgrass area, therefore the majority is within the 'Top 50' sites. The 2,961 km^2 is within four sites: Dune Point, Majorville, Onefour-Pakowki and South Saskatchewan. The Onefour-Pakowki site may be globally significant for its intact size relative to the grasslands of North America.

There are no 'Top 50' areas recommended for protection within the Foothills Fescue subregion. Only 12% of this subregion is publicly-owned land and they are scattered parcels and highly fragmented or altered from their native state. No significant publicly-owned blocks could be located. It is critically important to maintain the biodiversity values of the existing protected areas, Fish Creek and Ross Lake.

The areas for protection within the Northern Fescue is 683 km^2 or about 4.4% of the subregion. The Northern Fescue area within the 'Top 50' sites totals 510 km^2 or about 3.3% of the ttoal Northern Fescue area, therefore the large majority is within the 'Top 50' sites. The 510 km^2 is within three sites: Handhills, Red Deer River and Sounding-Bodo. As the Sounding-Bodo site is highly fragmented, the Handhills site may be the finest example of intact Northern Fescue in the world.

The areas for protection within the Mixedgrass is 1,850 km^2 or about 9.6% of the subregion. The Mixedgrass area within the 'Top 50' sites totals 1,846 km^2 or about 9.6% of the total Mixedgrass Subregion, therefore the vast majority is within the 'Top 50' sites. The 1,846 km^2 is three sites: Majorville, Onefour-Pakowki and Twin River. Only 26% of this subregion is publicly-owned land. These three sites are highly significant, relatively intact blocks.

WWF's 'Top 50' Key Landscape Areas of Interest, by Subregion

Subregion 1 – Central Mixedwood

Key Area of Interest	Area (km^2)	% of Sub-region
Athabasca Rapids	2990	
Birch-Wabasca	4535	
Clearwater-Gypsy-Gordon	2503	
Crow Lake	112	
Firebag	1264	
Harper	401	
Marguerite-Kame	227	
Martin Mountain	105	
Maybelle-Delta	655	
McClelland	300	
Primrose	5663	
Stony Mountain	248	
Trout Delta	206	
Total	**19,209**	**12.4%**

Subregion 2 – Dry Mixedwood

Key Area of Interest	Area (km^2)	% of Sub-region
Amisk	526	
Cache Creek-Wolverine	1515	
Caribous	374	
Martin Mountain	31	
Pouce Coupe	14	
Primrose	23	
Total	**3,440**	**3.4%**

Subregion 3 – Wetland Mixedwood

Key Area of Interest	Area (km^2)	% of Sub-region
Caribous	159	
Hay-Zama	418	
Lower Chinchaga	465	
Upper Chinchaga	359	
Total	**1,401**	**3.6%**

Subregion 4 – Subarctic

Key Area of Interest	Area (km^2)	% of Sub-region
Birch-Wabasca	3270	
Bistcho	2456	
Caribous	5737	
Total	**11,463**	**52.1%**

Subregion 5 – Peace River Lowlands

Key Area of Interest	Area (km^2)	% of Sub-region
Maybelle-Delta	964	
Slave River	599	
Total	**1,564**	**15.6%**

Subregion 6 – Boreal Highlands

Key Area of Interest	Area (km^2)	% of Sub-region
Birch-Wabasca	5698	
Caribous	651	
Stony Mountain	431	
Trout Delta	154	
Total	**6,934**	**32.7**

Subregion 7 – Alpine

Key Area of Interest	Area (km^2)	% of Sub-region
Brule-Wild Hay	58	
Cardinal	178	
Castle	137	
Caw Prairie	108	
Kananaskis-Bow	329	
Livingstone	39	
Torrens	85	
Total	**934**	**6.4%**

Subregion 8 – Subalpine

Key Area of Interest	Area (km^2)	% of Sub-region
Brule-Wild Hay	284	
Cardinal	360	
Castle	487	
Caw Prairie	1098	
Clearwater	44	
Kananaskis-Bow	1135	
Little Smoky	305	
Livingstone	839	
Torrens	391	
Wapiabi	134	
Total	**5,077**	**19.7%**

Subregion 9 – Montane

Key Area of Interest	Area (km^2)	% of Sub-region
Brule-Wild Hay	57	
Castle	268	
Caw Prairie	105	
Kananaskis-Bow	96	
Livingstone	581	
Onefour-Pakowki	93	
Total	**1,200**	**20.0%**

Subregion 10 – Upper Foothills

Key Area of Interest	Area (km^2)	% of Sub-region
Brule-Wild Hay	317	
Caw Prairie	286	
Clearwater	470	
Coal Highlands	180	
Goose-Wallace	224	
Little Smoky	2278	
Otauwau	417	
Torrens	343	
Upper Chinchaga	374	
Wapiabi	566	
Total	**5,455**	**18.6%**

Subregion 11 – Lower Foothills

Key Area of Interest	Area (km^2)	% of Sub-region
Caw Prairie	18	
Goose-Wallace	77	
Kananaskis-Bow	699	
Little Smoky	363	
Livingstone	31	
Martin Mountain	511	
Otauwau	452	
Pouce Coupe	539	
Torrens	38	
Upper Chinchaga	2997	
Total	**5,725**	**8.7%**

Subregion 12 – Athabasca Plain

Key Area of Interest	Area (km^2)	% of Sub-region
Maybelle-Delta	368	
Old Fort	734	
Wylie Lake	15	
Total	**1,117**	**15.7%**

Subregion 13 – Kazan Upland

Key Area of Interest	Area (km^2)	% of Sub-region
Slave River	174	
Wylie Lake	1331	
Total	**1,505**	**16.9%**

Subregion 14 –Foothills Parkland

Key Area of Interest	Area (km^2)	% of Sub-region
Kananaskis-Bow	15	
Livingstone	626	
Total	**641**	**14.6%**

Subregion 15 – Peace River Parkland

Key Area of Interest	Area (km^2)	% of Sub-region
Peace River	994	
Total	**994**	**21.3%**

Subregion 16 – Central Parkland

Key Area of Interest	Area (km^2)	% of Sub-region
Beaverhill Lake	185	
CFB Wainwright	308	
Edgerton	86	
Kilarney – Reflex	27	
Red Deer River	229	
Sounding-Bodo	310	
Total	**1,145**	**2.1%**

Subregion 17 – Dry Mixedgrass

Key Area of Interest	Area (km^2)	% of Sub-region
Dune Point	95	
Majorville	58	
Onefour-Pakowki	2656	
South Saskatchewan	152	
Total	**2,961**	**6.3%**

Subregion 19 – Northern Fescue

Key Area of Interest	Area (km^2)	% of Sub-region
Handhills	155	
Red Deer River	93	
Sounding-Bodo	262	
Total	**510**	**3.3%**

Subregion 20 – Mixedgrass

Key Area of Interest	Area (km^2)	% of Sub-region
Majorville	335	
Onefour-Pakowki	1059	
Twin River	452	
Total	**1,846**	**9.6%**

TOTAL AREA	**72163 km^2**	**10.1%**

Table 1 Area of existing protected areas (or areas needing upgrading) and WWF's 'Top 50' landscapes

Natural Subregion	Existing Sites or those needing upgrading	WWF's 'Top 50' Key Landscapes	Total	% of Subregion
1. Central Mixedwood	19,487	19,209	38,696	25
2. Dry Mixedwood	531	3,440	3,971	4
3. Wetland Mixedwood	7,848	1,401	9,249	24
4. Subarctic	1,169	11,463	12,632	57
5. Peace River Lowlands	7,612	1,564	9,176	91
6. Boreal Highlands	1,161	6.934	8,095	38
7. Alpine	11,548	934	12,482	86
8. Subalpine	13,400	5077	18,477	72
9. Montane	1,537	1200	2,737	46
10. Upper Foothills	182	5455	5,637	19
11. Lower Foothills	64	5725	5,789	9
12. Athabasca Plain	281	1117	1,398	20
13. Kazan Upland	1067	1,505	2,572	29
14. Foothills Parkland	69	641	710	16
15. Peace River Parkland	-	994	994	21
16. Central Parkland	76	1,145	1221	2
17. Dry Mixedgrass	634	2,961	3,595	8
18. Foothills Fescue	29		29	<1
19. Northern Fescue	173	510	683	4
20. Mixedgrass	4	1,846	1,850	10
Total	**69,457**	**73,121**	**142,578**	**22%**

Conclusions and Implementation

Species depend on natural habitat for their survival. Protecting the range of natural habitats within natural regions will go a long way to ensuring species survival. Furthermore, sustaining key ecological processes and maintaining viable populations in protected areas is a key component of sustainable resource management. With a view to protecting environmental diversity, WWF Canada identified the 'Top 50' key landscape areas of interest for Alberta's Special Places program, within the six natural regions and twenty natural subregions comprising Alberta. These areas should receive Alberta's maximum legal designation, management and, in some cases, restoration.

These 'Top 50' sites focus on achieving significant representation of broad landscapes, or enduring features, and include key indicator species, such as grizzly and caribou. Some of these sites are nationally and internationally significant for their ecological values (e.g., Wood Buffalo areas, Onefour-Pakowki, Rocky Mountains/Foothills/Parkland areas). Some, if designated as protected areas, will be among the largest protected areas in Canada and possibly the world (e.g., the Wood Buffalo areas would comprise between 60,000 and 70,000 km^2 and the Rocky Mountain/Foothills/Parkland areas would comprise between 35,000 and 45,000 km^2).

In addition to these fifty sites, connectivity needs to be addressed in designing Alberta's network of protected areas. This report does not address the issue of connectivity. Theoretically, this approach of core protected areas that are connected will result in a significant range of Alberta's environmental diversity being protected. However, some less common elements with significant conservation value are likely to be missed within these fifty connected sites and a strategy to conserve these ideally should encompass a broad range of scales. And finally, areas outside of protected areas and their connections need to be sustainably managed.

Endnotes

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[1] Nikiforuk, Andrew. "Schindler's warning: will it be heard. A distinguished ecologist gives Canada's boreal forest 50 years to live and is alarmed at Ottawa's inaction. " The Globe and Mail, February 24, 2000. p. R9.

[2] Johnson, D., L. Kershaw, A. MacKinnon and J. Pojar. *Plants of the Western Boreal Forest and Aspen Parkland*. (Edmonton: Lone Pine Publishing, 1995). 392 pages.

[3] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 1. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).

[4] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 17. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[5] Achuff, P. and C. Wallis (1992) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 17. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[6] Pojar, J., (1996, p. 52) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 5. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[7] Ibid.

[8] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 28 . Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[9] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 10. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).

[10] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 3-4. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[11] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 12. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).

[12] Stelfox, B., (1995), p. 2-3 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 28. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[13] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 12. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).

[14] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 5. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[15] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 10. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).

[16] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 5. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[17] The Evergreen Project. Wetlands: Why are wetlands important? Online at http://mbgnet.mobot.org/fresh/wetlands/why.htm (April 14, 2000).

[18] U.S. Environmental Protection Agency. Values and Functions of Wetlands. Online at http://www.epa.gov/OWOW/wetlands/facts/fact2.html (April 14, 2000).

[19] Mosquin, T., *et al.* (1995) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 58. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[20] Sawhill, J.C., (1997), p. 5 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 58. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[21] Hammond, H. (1991) in Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 8. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[22] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.59. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[23] The Evergreen Project. Wetlands: Why are wetlands important? Online at http://mbgnet.mobot.org/fresh/wetlands/why.htm (April 14, 2000).
[24] U.S. Environmental Protection Agency. Values and Functions of Wetlands. Online at http://www.epa.gov/OWOW/wetlands/facts/fact2.html (April 14, 2000).
[25] Bilyk, L.P., *et al.* (1996), p. 52 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 52. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[26] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 61. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[27] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 9. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).
[28] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 10. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[29] Hunter, M.L. Jr., (1996) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 63. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[30] O'Neill, R.V., et al. (1997 p. 517) in Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 65. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[31] Grumbine, R.E., (1992) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 67. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[32] Wilcove, D.S., *et al.* (1986) *in* Salmo Consulting Inc. *Gulf Midstream Services Brazeau Pipeline Project: Cumulative Effects Evaluation* (Calgary: Salmo Consulting Inc. 1999), p. 14.
[33] Lee, L.C. and J.G. Gosselink. (1988) i*n* Salmo Consulting Inc. *Gulf Midstream Services Brazeau Pipeline Project: Cumulative Effects Evaluation* (Calgary: Salmo Consulting Inc. 1999), p. 14.
[34] Laurence and Yensen (1991) *in* Salmo Consulting Inc. *Gulf Midstream Services Brazeau Pipeline Project: Cumulative Effects Evaluation* (Calgary: Salmo Consulting Inc. 1999), p. 14
[35] Wilcove, D.S., *et al.* (1986) *in* Salmo Consulting Inc. *Gulf Midstream Services Brazeau Pipeline Project: Cumulative Effects Evaluation* (Calgary: Salmo Consulting Inc. 1999), p. 8.
[36] Laurence and Yensen (1991) *in* Salmo Consulting Inc. *Gulf Midstream Services Brazeau Pipeline Project: Cumulative Effects Evaluation* (Calgary: Salmo Consulting Inc. 1999), p. 8.
[37] Reed, R.A. *et al*. (1996) *in* Salmo Consulting Inc. *Gulf Midstream Services Brazeau Pipeline Project: Cumulative Effects Evaluation* (Calgary: Salmo Consulting Inc. 1999), p. 8.

[38] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 69. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[39] Ibid. p. 67 – 69.

[40] Ibid. p. 65.

[41] Tilman, D., *et al*. (1994) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 69. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[42] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 70. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[43] Ibid.,p. 75.

[44] Fleischner, T.L., 1994, *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 75. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[45] Struzik, E., 1992, *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 75. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[46] Ibid. p. 77.

[47] Ibid. p. 82 – 83.

[48] After - Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.80. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[49] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 77-81. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[50] A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's Natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.), section 9, p. 17).

[51] Brad Stelfox (personal communication, 1999)

[52] After - Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.80. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[53] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 81. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[54] Ibid.

[55] Stelfox, B. and B. Wynes, A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.1999), section 9, p. 24).

[56] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 81. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[57] Stelfox, B. and B. Wynes, A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.1999), section 9, p. 24).

[58] Horejsi, B.L, 1995, *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 81. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[59] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 81. Online at http://www.rmec.org/library /index.htm (April 14, 2000). p. 81 - 82.

[60] Ibid. p. 82

[61] Stelfox, B. and B. Wynes, A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.,1999), section 9, p. 24).

[62] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 88. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[63] After - Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.88. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[64] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13,* (Edmonton: Alberta Environmental Protection, 1998), p. 89. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[65] A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.), section 8 p. 17).

[66] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13,* (Edmonton: Alberta Environmental Protection, 1998), p. 89. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[67] A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.), section 8, p. 17.

[68] Ibid. section 8, p. 17 – 20.

[69] Government of Canada (1997) The State of Canada's Environment – 1996 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 89. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[70] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p. 48 – 49.

[71] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 17. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).

[72] Alberta Environmental Protection (AEP) *The Status of Alberta's Timber Supply* (1996) p. 17 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 89. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[73] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 153. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[74] After - Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.155. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[75] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p. 49.

[76] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13,* (Edmonton: Alberta Environmental Protection, 1998), p. 92. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[77] A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.), section 8, p. 31.

[78] Ibid. section 8, p. 41.

[79] Alberta Environmental Protection (AEP). *Alberta Timber Harvest Planning and Operating Ground Rules,* (Edmonton: Land and Forest Services, 1994) p. 3 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 92. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[80] Peterson, E.B., *et al*,.(1995), p. 36 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 92. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[81] Alberta Environmental Protection (AEP). *The Status of Alberta's Timber Supply*. Land and Forest Service, Forest Resource Branch (Edmonton: Alberta Environmental Protection, 1996) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 92. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[82] Brad Stelfox (personal communication, 1999)

[83] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p. 54.

[84] Stelfox, B., (1995) in Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 95. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[85] Alberta Forest Conservation Strategy Steering Committee (AFCSSC). *Alberta Forest Conservation Strategy*. Draft of October 21, 1995 (Edmonton: AFCSSC), p. 17 – 18 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 95. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[86] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 8. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[87] Stelfox. B., (1995) p. 277 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 95. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[88] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 93. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[89] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p. 51.

[90] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. 5. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).

[91] Ibid.

[92] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p. 55.

[93] Gordon, A.G., 1996. *The sweep of the boreal in time and space, form forest formations to genes, and implications for management*. (The Forestry Chronicle, 72, no. 1, p. 19 – 30) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 93. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[94] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 96. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[95] Edwards, W.A.D., (1995) in Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 96. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[96] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p. 112.

[97] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 97. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[98] Sadler, K. and R. Houlihan. *Oil Sands Development in Alberta – An AEUB Perspective*. (Calgary: Alberta Energy Utilites Board, 1998) p.1.

[99] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.84 - 87. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[100] Smith. D. *Athabasca Oil Sands Development Backgrounder* (unpublished, 1998).

[101] Legge, A. (1981) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 87. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[102] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.116. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[103] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.116. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[104] Horejsi, B.L., 1994 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.116. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[105] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.116. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[106] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p 35.

[107] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p 103.

[108] Ibid. p. 29.

[109] Ibid. p. 30.

[110] Sawyer, M.D. and Haskins, W.P. (1997) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.116. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[111] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.124. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[112] Sawyer, M.D. and Haskins, W.P. (1997) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.131. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[113] Lansky, M. (1993) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.133. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[114] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.133. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[115] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.161 - 162. Online at http://www.rmec.org/library /index.htm (April 14, 2000).

[116] Sawyer, M.D. and Haskins, W.P., (1997) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p.131 - 132. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[117] Bryant D., (1997) p. 23 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 161. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[118] Cairns, J. Jr., (1994) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 161. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[119] Mahar, D.J., (1989) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 161. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[120] Horejsi, B.L., (1986) p. 119 - 120 *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 161. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[121] Matlack, G.R., (1993) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 161. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[122] Noss, R.F., (1995) *in* Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 161. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[123] Alberta Environmental Protection. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region, Protected Areas Report #13*, (Edmonton: Alberta Environmental Protection, 1998), p. 162. Online at http://www.rmec.org/library /index.htm (April 14, 2000).
[124] World Resouces Institute.Canada's Forests at a Crossroads: An Assessment in the Year 2000: A Global Forest Watch Canada Report, (Washington: World Resources Institute, 2000), p. 22.
[125] Suncor Energy Inc. Firebag In-situ Oil Sands Project: Public Disclosure Document. (Calgary: Suncor Energy Inc. January 27, 2000).
[126] Sadler, K. and R. Houlihan. *Oil Sands Development in Alberta – An AEUB Perspective*. (Calgary: Alberta Energy Utilites Board, 1998) p.1.
[127] Luhning, R. and C. Luhning. The Vapex Process: Non-Thermal Recovery of Bitumen and Heavy Oil for Improved Economics and Climate Change Advantage. Presented at the Canadian Heavy Oil Association Conference, Beyond 2000, The Future Looks Heavy, in Calgary Alberta, Canada, November 24, 1999.
[128] Golder Associates Ltd. 1998. Christina Lake Thermal Project, Environmental Impact Assessment, Volume 2. Prepared for Van Horne, a business unit of PanCanadian Resources by Golder Associates Ltd.
[129] Axys Environmental Consulting Ltd. 1998. *MacKay River Project, Environmental Impact Assessment, Volume 3, Part 1: Biophysical and Resource Use Assessment*. Prepared for PetroCanada Oil and Gas, Calgary, Alberta by Axys Environmental Consulting Ltd., Jacques Whitford Environmental Ltd., Hydroconsult EN3 Services Ltd., Komex International Ltd., R.L. & L. Environmental Services LTd., and Frickie Creek Consulting Corporation.
[130] EBA Engineering Consultants Ltd. 1999. *Foster Creek In-Situ Oil Sands Project. Environmental Impact Assessment*, *Volume 2*. Prepared for AEC East, a business unit of Alberta Energy Company Ltd. by EBA Engineering Consultants Ltd., RL & L Environmental Services Ltd., Axys Environmental Consulting Ltd., Jacques Whitford Environmental Ltd.
[131] Miller, P. *Integrated Landscape Management: Alberta Chamber of Resources.* Presented at the National Environmental Law Conference, Calgary, Alberta, March, 2000.
[132] Sadler, K. and R. Houlihan. *Oil Sands Development in Alberta – An AEUB Perspective*. (Calgary: Alberta Energy Utilites Board, 1998), p. 9.
[133] Ibid. p. 2.

[134] Stelfox, B. and B. Wynes, A Physical, Biological, and Land-Use Synopsis of the Boreal Forest's natural Regions of Northwest Alberta, (Edmonton: Daishowa-Marubeni International Ltd.1999), section 9, p. 1 and 7-8).
[135]Canadian Association of Petroleum Producers, Canadian Parks and Wilderness Society, World Wildlife Fund Canada, and the Federation of Alberta Naturalists. *Petroleum and Natural Gas Exploration and Development and the Alberta Special Places 2000 Initiative: Meeting the Challenge*. Statement of Consensus and Outstanding Issues, February 12, 1998.
[136] Senate Subcommittee on the Boreal Forest, *Competing Realities: The Boreal Forest at Risk* (Ottawa: Standing Senate Committee on Agriculture and Forestry, 1999) p. i - ii. Online at http://www.parl.gc.ca/36/1/parlbus/commbus/senate/com-e/rep-e.htm (April 14, 2000).
[137] Miller, P. *Integrated Landscape Management: Alberta Chamber of Resources.* Presented at the National Environmental Law Conference, Calgary, Alberta, March, 2000.
[138] Oil and Natural Gas Industry Foundation Paper, Background Information on the Ability of the Industry to Contribute to Greenhouse Gas Emission Reductions, for the National Climate Change Secretariat, September 1998.