CONSERVING CANADA'S NATURAL CAPITAL: THE BOREAL FOREST

Al-Pac Case Study Report – Part 1
Management Objectives

Prepared for the

National Round Table on the Environment and the Economy

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This case study has been commissioned as background research for the NRTEE's Conserving Canada's Natural Capital: The Boreal Forest program. The views expressed in the case study are those of the authors, and do not necessarily represent those of the National Round Table, its members, or the members of the program's Task Force.

Executive summary

This is Part 1 of a three-part case study report examining conservation issues within the Alberta-Pacific Forest Industries (Al-Pac) Forest Management Area (FMA) in northeastern Alberta. The goal of the present document is to highlight a range of management objectives that would promote the conservation of natural capital in the Al-Pac FMA. The other two parts of the case study report examine regulatory and fiscal barriers to achieving these objectives and policy options for promoting them. The case study was commissioned by the National Round Table on the Environment and the Economy (NRTEE) as part of its Conserving Canada's Natural Heritage: The Boreal Forest program.

The specific questions examined in this document are: What key conservation values should be promoted in the Al-Pac FMA? What indicators of natural capital correspond to these conservation values, and what human activities affect these indicators? And, finally, what specific management objectives for land uses in the Al-Pac FMA could be adopted to promote the conservation of natural capital?

Conservation values relevant to the case study area were drawn from the criteria of sustainable forest management identified by the Canadian Council of Forest Ministers. They include biological diversity, ecosystem condition and productivity, soil and water resources, global ecological cycles (e.g., carbon), and economic and social benefits. Potential trends in indicators corresponding to these conservation values were projected using a simulation model initialized with a description of current landscape composition and inputs defining rates of landscape change and resource development in the case study area. These trends are intended to foster an understanding of the challenges involved in achieving specific management objectives that would promote one or more conservation values.

The following is a brief summary of values that would be promoted by each management objective, relevant land use impacts and trends in related indicators.

<u>Maintain total forest cover</u>

This management objective would promote several conservation values, including the conservation of biodiversity, soil resources, water quality and carbon storage. Causes of deforestation in the study area include forestry roads and landings, energy sector clearings (e.g., well sites, pipelines, roads, seismic lines, surface mines), agricultural expansion and climate change.

Forest cover in the study area has declined by approximately 3% over the past several decades due to industrial development primarily in the forestry and energy sectors. Continued industrial expansion over the next several decades would increase the industrial footprint by 150%, with an additional 4% of forest converted to industrial uses.

Maintain the natural disturbance regime

Natural disturbances in the form of forest fires, insect outbreaks and other disturbances have strongly influenced vegetation structure and composition in the study area since the retreat of glacial ice sheets approximately 10,000 years ago. Maintaining the natural disturbance regime within the region would promote the conservation of species that require early successional habitats and fire-created structures. It would also promote ecosystem productivity through the release of nutrients contained in living and dead vegetation. In mature forest stands that are logged, maintaining residual structures in the form of standing dead trees, downed logs and live trees in a manner approximating natural disturbance would promote the conservation of biodiversity.

Although modern fire suppression and control practices are in place, fire is still a major player in the study area, with an average of 0.5% of the forest burning each year. Salvage logging in a portion of these burned stands reduces the legacy of natural disturbance in the future forest by removing standing dead trees and other structures used by many species. During conventional (non-salvage) logging of mature stands by clearcutting, the amount of residual structure remaining is limited, particularly in coniferous-dominated stands.

An implication of future natural disturbance is the difficulty of sustaining a constant supply of wood fibre. A timber supply analysis for Al-Pac's FMA, in which annual fire losses are considered, suggests that current harvest levels would be difficult to sustain for more than 40 to 60 years, after which significant shortages in available hardwood and softwood fibre are projected. Current harvest levels in the case study area were computed to be sustainable only if no wood is lost to forest fires.

Maintain old forest

Old forest stands generally contain the highest number of plant and animal species of all the successional stages in the boreal forest. Maintaining old forest within the range of natural variability would promote the conservation of species that require such conditions. It would also promote the conservation of above-ground carbon, productivity and aesthetic values.

About 10% of the study area is currently covered by older forest stands, or about 40% of the merchantable forest. Under the current forestry regulatory regime, future logging activity would reduce the supply of old forest considerably within the next several decades. The added effects of fire would accelerate this rate of loss, with the combined disturbances of logging and fire reducing the future supply of old forest below the range of natural variability.

Maintain key aquatic and hydrological features

The boreal forest provides numerous water-related services, including the recycling of water to the atmosphere, water filtration and wildlife habitat. Maintaining key aquatic and hydrological features would promote the conservation of biological diversity, soil and water resources. Industrial activities affect surface and groundwater in diverse ways, including by causing local disruption of groundwater flow around oil wells and oil sands mines, roads and forestry cutblocks. Logging can also affect the flow and biodiversity of streams and influence riparian vegetation near cutblocks. Point-source industrial inputs of organic material and toxins have raised concerns over human consumption of fish from the Athabasca River and its tributaries.

Historical and projected trends in water quality at the scale of the entire Al-Pac FMA are unavailable, but approximately 3% of wetland cover in the region has been converted to other land uses during the past several decades. Over the next several decades, it is estimated that an additional 4% of wetlands will be lost, mainly due to oil sands mining; roads are an additional threat to wetland integrity through flow disruption.

<u>Recognize and protect areas of traditional Aboriginal use and value</u>

This management objective is expected to provide socio-economic and cultural benefits for Aboriginal peoples while promoting conservation of natural capital throughout the FMA. Aboriginal peoples form a significant component of the population living within the area of research. Until very recently, Aboriginal peoples pursued a traditional way of life, based largely on hunting, fishing, trapping and gathering activities, and respect for and stewardship of the land were the foundations of their relationship with the forest. Protecting areas of traditional use and value to Aboriginal peoples and involving them in land and resource management decisions would help meet all of the conservation values identified earlier.

The development of conventional oil and gas, oil sands and forestry resources has profoundly affected the traditional way of life of the Aboriginal communities in the case study area. In many areas, traditional land- and resource-based activities can no longer be conducted—partly because some areas are physically impossible to use following development, and partly because of the negative impact of resource extraction on wildlife populations and on water quality and quantity.

<u>Establish areas within the managed forest where human impacts are prohibited or severely reduced</u>

Establishing additional protected areas in the study area would promote the conservation of biological diversity by fostering improved knowledge of the effects of human activities on regional flora and fauna, and by providing refugia for species and natural communities that are sensitive to human activities.

A total of 96,000 ha (1.5%) of the study area is designated as protected under provincial statutes or forestry ground rule designations (e.g., buffer zones). Options for establishing additional protected areas are declining within the Al-Pac FMA as resource development activities continue to reduce the area of undisturbed landscapes. Establishing protected areas in undeveloped landscapes is further complicated by resource allocation decisions that foster competition for land between industrial users and those who promote protected areas. For example, reducing the land base available for timber harvest would potentially reduce the sustainable level of wood harvest. Although reasonable levels of protection are an important stated societal value, attaining these in the case study area remains challenging because of conflicting historic and current resource allocation decisions.

Reduce linear disturbance density and manage human access

Roads and other linear developments are thought to have many negative ecological effects. Thus, reducing the rate of forest and landscape fragmentation by linear developments in the case study area would promote the conservation of biological diversity. Some wildlife species such as arctic grayling and woodland caribou are particularly sensitive to overharvesting and human disturbance along roads and other access routes such as seismic lines. Managing human access along linear features would help protect such species from further population declines.

There are currently over 100,000 km of linear developments in the Al-Pac FMA, with an average density of 1.8 km/km^2. If forestry activity persists at current levels, and if the energy sector expands at expected rates, the average density of linear developments will increase to over 5.0 km/km^2. This trend would have negative effects on many species. For example, woodland caribou habitat quality in the study area has declined by 23% over the past several decades, with further declines expected if trends in industrial development continue.

Maintain terrestrial carbon stocks and sinks

Carbon storage is a critical component of the global carbon cycle, which regulates the earth’s climate. As such, carbon storage is one of the vital ecosystem services provided by the boreal forest. In the boreal forest, most stored carbon is below ground, with peatlands responsible for the accumulation of large quantities of carbon due to slow decomposition rates in cold, saturated soils. The conversion of forested land and peatlands for roads, plant sites, mines, well sites and other land uses increases the rate at which carbon is released into the atmosphere. In addition, forest harvesting shifts the composition of a managed forest from older, carbon-rich stands to young stands that contain less carbon.

Simulated projections suggest that the amount of above-ground and below-ground carbon will decline over the next 50 years by approximately 22 million t. This trend would be accelerated by increased fire rates induced by climate change.

Introduction

This document is Part 1 of a three-part case study report commissioned by the National Round Table on the Environment and the Economy (NRTEE) as part of its Conserving Canada's Natural Heritage: The Boreal Forest program. The primary objective of this part of the report is to establish some common ground on a range of management objectives that could be used to promote the conservation of natural capital within the Alberta-Pacific Forest Industries (Al-Pac) Forest Management Area (FMA). These objectives provide the basis for the subsequent examination of regulatory and fiscal barriers to achieving these objectives and policy options for promoting them (which are reviewed in Parts 2 and 3). The present document includes a general overview of land use patterns and indicator trends within the Al-Pac FMA, along with the natural capital, resource values and other relevant characteristics of the area, the history of land and resource use, and potential land use trajectories.

The specific questions examined in this part of the report are as follows:

- What key conservation values should be promoted in the Al-Pac FMA? Examples of conservation values might include the maintenance of biodiversity, ecosystem condition and productivity, hydrological function and aquatic resources, contribution to the global carbon cycle, etc.

- What indicators of natural capital correspond to these conservation values, and what human activities may adversely affect these indicators? Examples of indicators of natural capital might include extent of forest cover, wetlands, old growth forest and undisturbed landscapes; persistence of natural disturbance regimes (and resulting landscape characteristics); quantity and quality of surface water; and carbon balance (i.e., greenhouse gas emissions and carbon sequestration). Examples of human activities that may affect these indicators include road building, timber harvesting, seismic exploration, oil and gas production (e.g., wells, surface mining), human access for recreation (including hunting and fishing), disruption of natural disturbance regimes and point/non-point sources of water pollution.

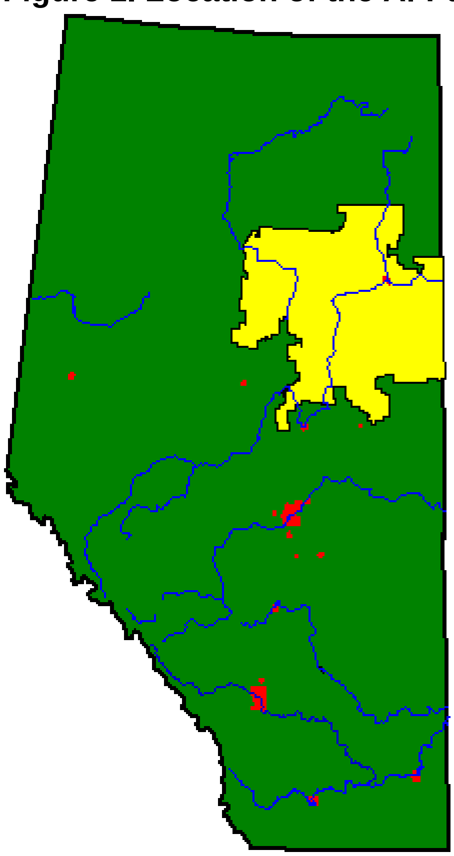
- What specific management objectives for land uses in the Al-Pac FMA could be adopted to promote the conservation of natural capital? Examples of management objectives might include:
    - maintain total forest cover;
    - maintain the natural disturbance regime (including land use practices that resemble, to the extent possible, patterns of natural disturbance);
    - maintain old forest within the natural range of variability across the landscape;
    - maintain key aquatic and hydrological features (e.g., surface water quality and quantity, wetlands);
    - recognize and protect areas of traditional Aboriginal use and value;

- establish areas within the managed forest where human impacts are prohibited or severely reduced (e.g., protected areas, roadless areas, ecological benchmark areas);
- reduce linear disturbance density and manage human access; and
- maintain terrestrial carbon stocks and sinks.

Overview of the case study area

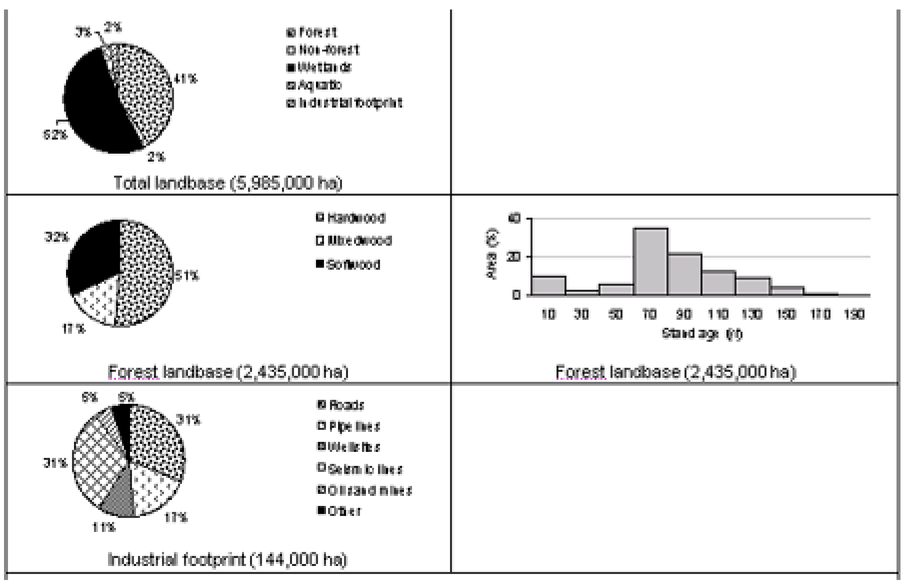
The case study area covers approximately 6 million ha (60,000 km^2) in northeastern Alberta (Figure 1). It includes all lands within the outer perimeter of the Al-Pac FMA, some of which are excluded from the area encompassed by Al-Pac's Forest Management Agreement; these exclusions include settlements, oil sands mines, fen/bog complexes, and Indian reserves. The area is bordered by agricultural lands to the south, Saskatchewan to the east and other forestry leaseholders to the west. Lands north of the study area include unallocated and relatively unproductive northern forest and Wood Buffalo National Park. Topography is generally flat except for several hill complexes and major river valleys. Most of the numerous small lakes, rivers and streams in the region feed into the Athabasca River and its tributaries. The typically boreal climate is characterized by long, cold winters and short, cool summers (Alberta Environmental Protection 1994b).

Figure 1. Location of the Al-Pac FMA in Alberta



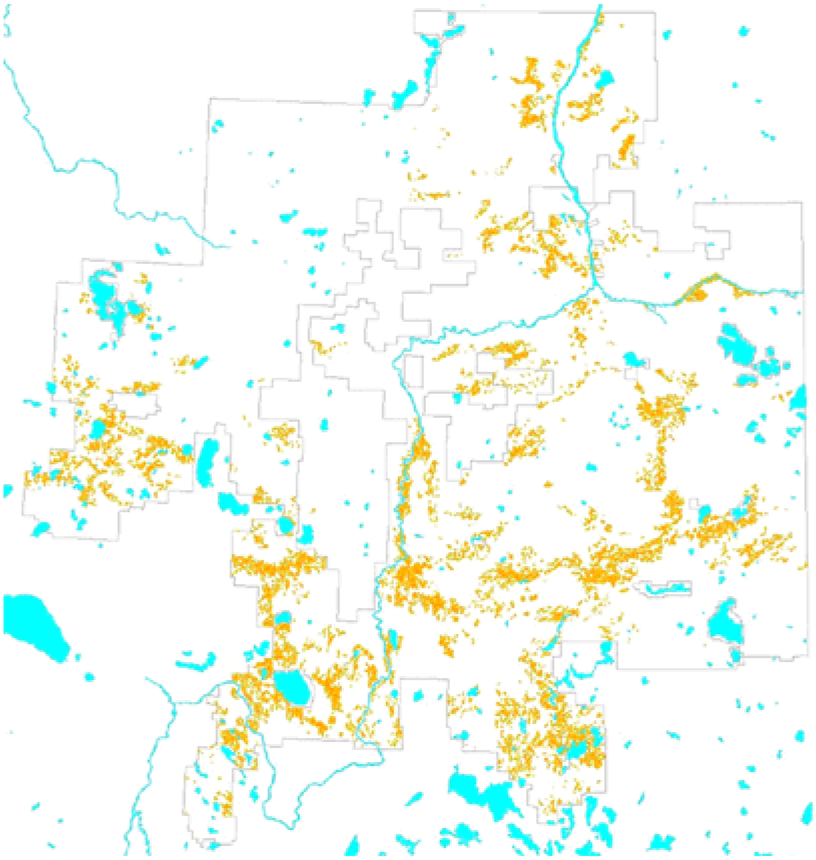
Regional vegetation is a complex mosaic dominated by upland forest communities and wetlands (Figure 2). Approximately half of the forest in the area consists of deciduous stands (mostly trembling aspen), one-third is dominated by softwood species such as spruce and pine, with the remainder composed of mixedwood communities of trembling aspen, white spruce and pine (Figure 2). The distribution, composition and structure of natural forest communities in the region have been strongly influenced by a history of frequent forest fires. Currently, about half of the forest originated on land subject to wildfire between 60 and 100 years ago; one-quarter is older than 100 years (Figure 2). Of the remaining stands younger than 60 years, approximately half are fire-origin, with the remainder originating on logged areas.

Figure 2. Composition of the Al-Pac FMA in 2003. Source: Al-Pac



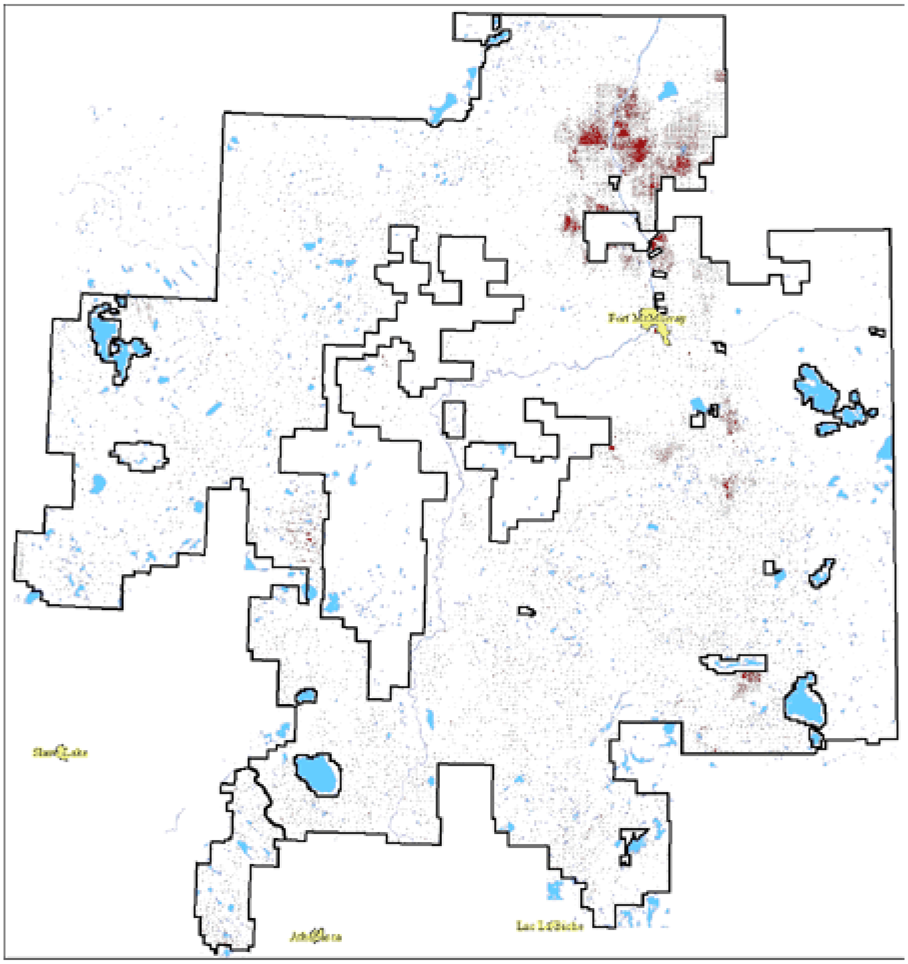
Two major industrial sectors dominate land use in the region: forestry and energy. Large-scale industrial forestry began in the early 1990s with the construction of the Al-Pac pulp mill near the town of Athabasca, 150 km northeast of Edmonton. Smaller-scale conifer harvesting has been occurring throughout the study area for several decades (Wetherell and Kmet 2000). To date, approximately 250,000 ha of forest have been harvested throughout the FMA (Figure 3).

Figure 3. Map showing the distribution of inventoried harvest areas in the Al-Pac FMA in 2003. Source: Al-Pac



The energy sector has been active since the 1940s, with approximately 30,000 wells having been drilled for conventional oil, natural gas and in situ oil sands (i.e., oil sands too deep below the surface for open pit mining) (Figure 4).

Figure 4. Distribution of well sites in the Al-Pac FMA in 2003. Source: Al-Pac



The density of wells in some parts of the study area approaches one well per hectare (Smith and Lee 2000). Most wells are located within a clearing approximately 1 ha in size, with an accompanying access road connected to the main transportation network. The distribution of pipelines and seismic lines in the region (most of which are associated with conventional gas production and exploration) is shown in Figures 5 and 6. Industrial roads, built primarily by the forestry and energy sectors, span approximately 25,000 km (Figure 7).

Figure 5. Distribution of pipelines in the Al-Pac FMA in 2003.
Source: Al-Pac

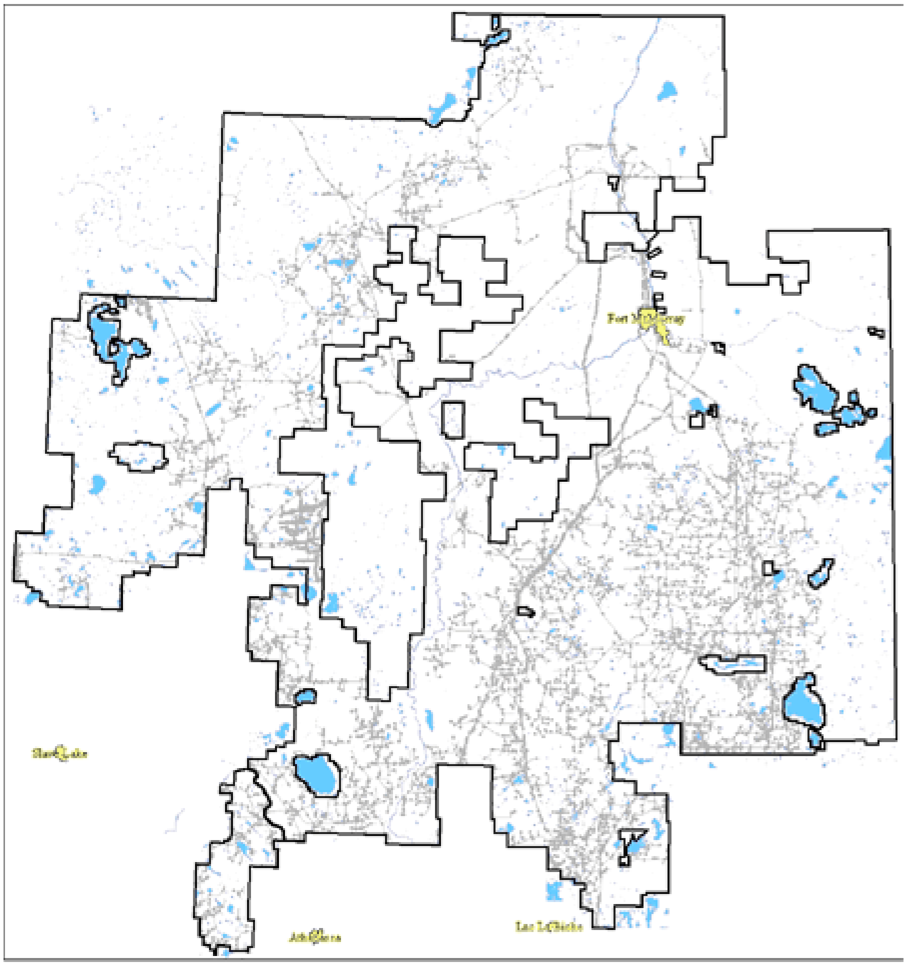


Figure 6. Distribution of seismic lines in the Al-Pac FMA in 2003.
Source: Al-Pac

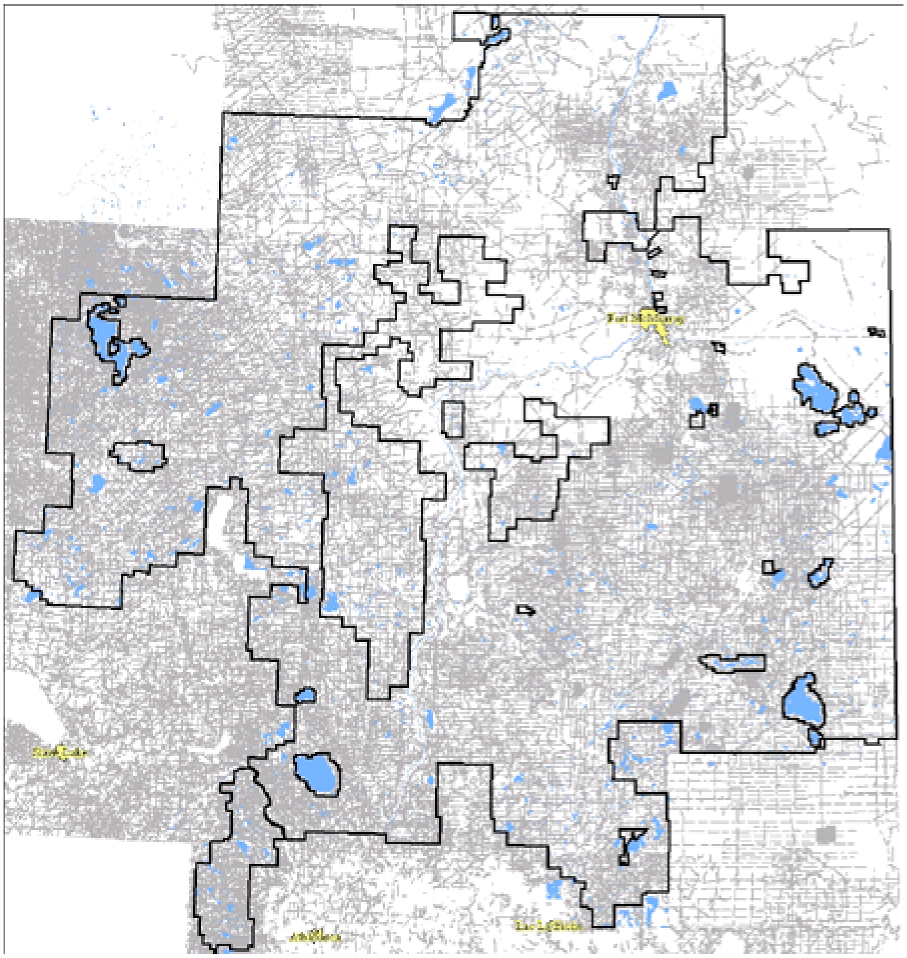
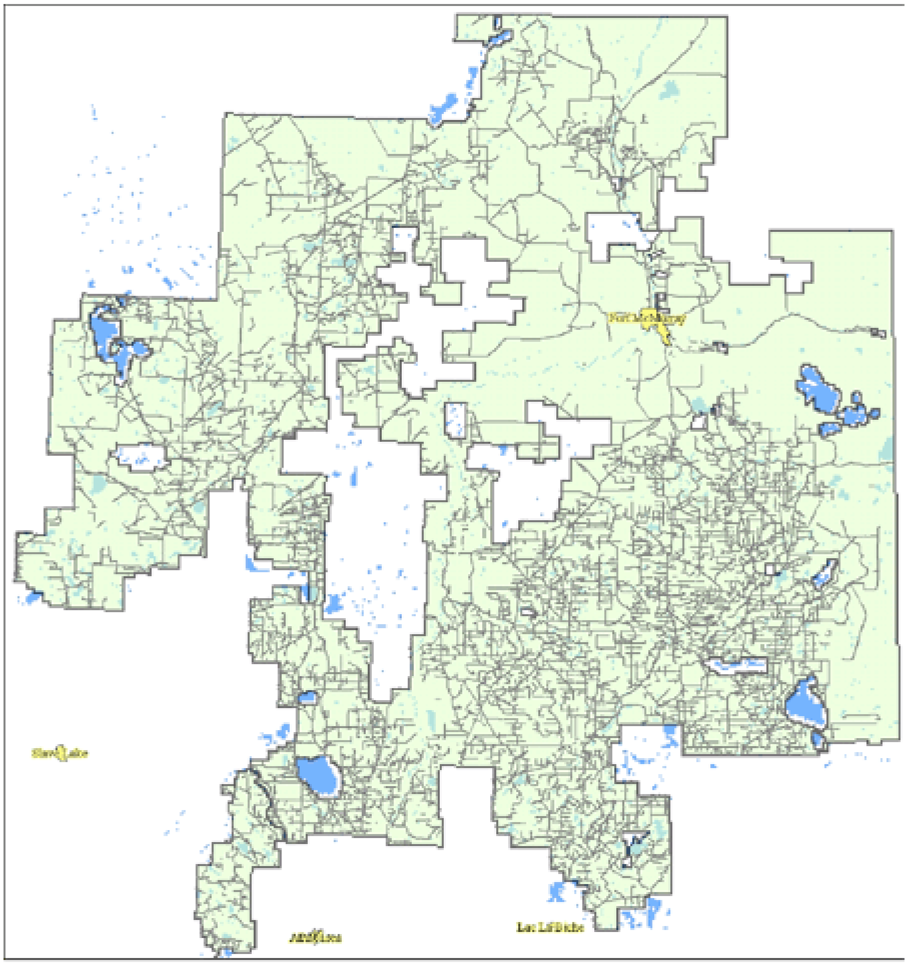


Figure 7. Distribution of minor roads in the Al-Pac FMA in 2003.
Source: Al-Pac



Bitumen is also extracted from oil sands via surface mining within a potential mineable area of 345,000 ha. A significant portion of the mineable area is within the Al-Pac FMA. Oil sands mines currently cover an area of approximately 7,000 ha in the northern part of the study area.

The industrial footprint, defined as lands under some form of development, occupies approximately 2% (144,000 ha) of the Al-Pac FMA (Figure 2). (Forestry cutblocks are not included in this total because they are rapidly regenerated after disturbance to their original cover type, i.e., native forest vegetation.) Almost two-thirds of the industrial footprint is associated with the exploration and production activities of the energy sector (e.g., seismic lines, well sites, access roads, pipelines, oil sands mines), with the remainder consisting of public and forestry roads, settlements and other infrastructure.

Most of the human population in the region lives in Fort McMurray and numerous smaller settlements. There are 10 Aboriginal communities and Indian reserves within the FMA, and several additional ones just outside the study area. The entire FMA is covered with registered traplines, and the Aboriginal population uses the land for hunting, fishing, trapping, harvesting and gathering, as well as for spiritual and cultural purposes. Various guide-outfitters work in the area, which is also used extensively for recreation, hunting and fishing, birdwatching and tourism. (Al-Pac 1999).

Key conservation values

Conservation may be defined as “the maintenance or sustainable use of the Earth’s resources in a manner that maintains ecosystems, species and genetic diversity and the evolutionary and other processes that shaped them” (NRTEE 2003b). In the context of this case study, the ecosystems, species, genes and ecological processes to be maintained in the Al-Pac FMA are considered to be natural capital, “assets in their role of providing natural resource inputs and environmental services for economic production” (NRTEE 2003b).

The NRTEE (2003b) identified three forms of natural capital:

- natural resource stocks, both renewable and non-renewable;
- land on which human activities can take place; and
- ecosystems that provide direct and indirect services.

Which aspects of natural capital should be promoted in the Al-Pac FMA? The Canadian Council of Forest Ministers (CCFM 2000) identified six criteria “that define a set of values Canadians want to enhance and sustain,” of which the first five most directly represent aspects of natural capital.

Criteria for sustainable forest management
1. Biological diversity
2. Ecosystem condition and productivity
3. Soil and water resources
4. Role in global ecological cycles
5. Economic and social benefits
6. Society's responsibility for sustainable development

Source: CCFM 2000.

The Government of Alberta, as a member of the CCFM and a signatory to the National Forest Strategy (National Forest Strategy Coalition 2003), has adopted the CCFM criteria and indicators framework for monitoring progress toward sustainable forest management. The five criteria related to natural capital (1 to 5) thus represent appropriate conservation objectives to be promoted in the Al-Pac FMA.

Indicators of natural capital

The purpose of the natural capital indicators proposed in this case study is to foster understanding of landscape conditions consistent with conservation values. They are similar to the national indicators promoted by the NRTEE’s (2003a) Indicators Initiative, modified for added relevance to the case study region. Note that one national indicator (the biodiversity index) has not yet been developed, but the NRTEE (2003a) has strongly recommended that development proceed under the auspices of the Canadian Biodiversity Index program (Federal–Provincial–Territorial Biodiversity Working Group 2003). See NRTEE (2003a) for a discussion of the relevance of each of these indicators to natural capital.

National indicators of natural capital
1. Air quality
2. Freshwater quality
3. Greenhouse gas emissions
4. Forest cover
5. Extent of wetlands
6. Biodiversity index (in development)

Source: NRTEE 2003a.

The indicators used in this case study are set out below:

Indicators of natural capital in northeastern Alberta
Forest cover
Area of industrial activity or "footprint"
Area of old forest
Long-term wood supply
Area of wetlands
Area of protected lands
Length of linear developments
Caribou habitat supply
Watercourse fragmentation by culverts
Above-ground carbon stocks

Potential trends in these indicators were projected using ALCES (A Landscape Cumulative Effects Simulator), a simulation model initialized with a set of rules defining the rates at which the area of each cover type, as well as the length of each linear feature, may change in the future. Such changes generally arise from land uses such as forestry and energy, and from natural processes such as forest fire and vegetation succession. Since the total area of the region remains constant throughout all simulations, an increase in the area of one cover type requires an equivalent decrease in the area of one or more other cover types. The model thus tracks potential changes in the composition of the study area and calculates outputs associated with natural resource production. Included in the model are inputs defining the rates at which industrial disturbances recover and are reclaimed to native vegetation (e.g., seismic lines, well sites). When reviewing simulation model results, it is appropriate to focus on the relative direction of projected trends, not precise numbers at any future point in the simulation interval. The simulations are intended to provide strategic-level insights and are not expected to be highly accurate in a given year. A more detailed description of the ALCES simulation model is available at www.foremtech.com.

Model inputs for the case study area were described previously (Schneider et al. 2003). For some variables, input values were revised to reflect changes in the landscape composition and estimated land use trajectories since the Schneider et al. (2003) study. Landscape composition, obtained from Al-Pac, was based on two sources of digital land cover information: Alberta Vegetation Inventory and Phase 3 Forest Inventory. The parameters used for timber supply analyses (e.g., harvest sequence, utilization standards, wood production) were drawn from Al-Pac's draft Detailed Forest Management Plan (Al-Pac 2004). Potential trends in future energy sector development were based on interviews with industry representatives conducted by Al-Pac's energy sector liaison officer (D. Pope, pers. comm.). Because the pace of oil and gas development is uncertain, projected trends used in model simulations were bracketed by 20% above and below this best guess.

Management objectives to promote conservation of natural capital

The management objectives identified in this case study provide a conceptual framework for subsequent discussions of regulatory and fiscal obstacles to conservation of natural capital and policy options to overcome such obstacles. They are drawn from the criteria and indicators of sustainable forest management identified by the Canadian Council of Forest Ministers (CCFM 2000), condensed and modified for relevance to the case study area. These objectives represent a series of measures that would promote one or more conservation values, including biological diversity, ecosystem condition and productivity, soil and water resources, global ecological cycles, and economic and social benefits. Historical and potential future trends in key indicators, and a discussion of important land use impacts, are intended to foster an understanding of the challenges involved in achieving each management objective.

The management objectives developed for this case study are as follows:

- maintain total forest cover;
- maintain old forest;
- maintain the natural disturbance regime;
- maintain key aquatic and hydrological features;
- recognize and protect areas of traditional Aboriginal use and value;
- establish areas within the managed forest where human impacts are prohibited or severely reduced;
- reduce linear disturbance density and manage human access; and
- maintain terrestrial carbon stocks and sinks.

Maintain total forest cover

Values promoted

Forest cover is among the most defining ecological characteristics of the Al-Pac FMA, occupying approximately 2.4 million ha or 41% of the study area. Maintaining forest cover would promote the conservation of biodiversity by providing habitat for forest-dependent species. It would also promote the conservation of soil resources essential for the production of wood fibre; soils also perform ecologically important roles in filtering and moderating the flow of surface and groundwater, and cycling nutrients. Additional ecosystem services include removal of air pollutants and moderation of local weather. Since forests contain the majority of the above-ground biomass and biotic carbon in the region, maintaining forest cover would also promote carbon storage. The economic and social benefits associated with forest cover are many. These flow from forestry, hunting and trapping of forest wildlife, fishing, recreational activities, and respect for cultural and spiritual values, including those held by Aboriginal people (Anielski and Wilson 2001).

Impacts of land use

Deforestation is a globally important problem with considerable local relevance, due to the dependence of local communities on the employment and revenues associated with wood production and the value of the ecological services described above. Causes of deforestation in the study area include forestry roads and landings, energy sector clearings (e.g., well sites, pipelines, roads, seismic lines, surface mines), industrial emissions, and forest clearing associated with agricultural expansion and timber harvest just south of the study area. Climate change poses an additional threat to forest cover, with increasing temperatures and drier soil conditions predicted to cause a gradual replacement of forested communities with grasslands (Bergeron and Flannigan 1995).

Indicator trends

Forest cover in the study area has declined by approximately 3% over the past several decades (Figure 8), having been replaced by industrial clearings associated with both the forestry and energy sectors. Most (80%) of the industrial footprint currently present in the region consists of linear developments (e.g., roads, pipelines, seismic lines), with the remainder composed of well sites, oil sands mines and cutblock landings (Figure 9). Continued industrial expansion over the next several decades would increase the industrial footprint by over 150%, to approximately 380,000 ha from the current 144,000 ha. Most of this increase is expected to be associated with oil sands mines, pipelines and roads (Figure 9). The net loss of forest cover during this period is estimated to be approximately 4% (Figure 8). In this projection, some features (e.g., major roads) are expected to last indefinitely, while others (e.g., narrow seismic lines) are expected to be much more short-lived.

Figure 8. Historical and projected trends in forest cover in the Al-Pac FMA

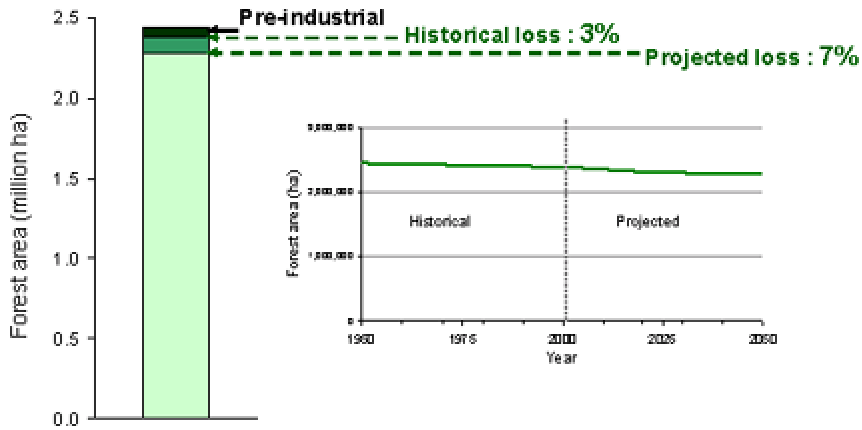
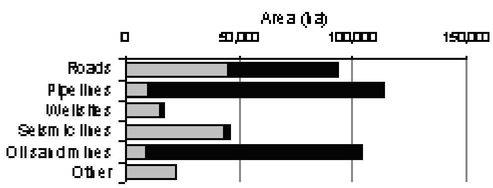


Figure 9. Projected changes in the industrial footprint in the Al-Pac FMA, 2000–50. Light shading indicates area in 2000; dark shading represents the additional area in 2050 under a moderate energy sector scenario



Maintain the natural disturbance regime

Values promoted

Natural disturbance is a defining aspect of the boreal forest, and it has historically been the strongest influence on vegetation structure and composition in the study area. Forest fires and other natural processes such as insect outbreaks, wind events and canopy gap dynamics have strongly influenced forest biodiversity and ecological processes at a range of spatial scales. A key characteristic of boreal natural disturbance regimes is their variability; disturbances are highly variable in size, frequency and intensity (Eberhart and Woodard 1987, Cumming 1997, Johnson et al. 1998, Stelfox and Wynes 1999). Maintaining a natural disturbance regime within the region would promote the conservation of species that require early successional habitats and fire-created structures; these include woodpeckers (Hobson and Schieck 1999), bark beetles and fire-dependent plants such as fireweed. Natural disturbances also promote ecosystem productivity by releasing nutrients contained in living vegetation and returning it to the soil. Some nutrients are also subsequently transported to nearby water bodies via surface and subsurface flow. Also, while forest fires release biotic carbon during combustion, much carbon remains in the form of tree boles that decompose slowly. In addition, younger seral stages created by fire sequester carbon at higher rates than the older stands they replace.

At the scale of individual forest stands, forests disturbed by natural processes contain a wide range of residual structures (Stelfox 1995, Lee and Crites 1999). For example, post-fire stands typically retain most of the biomass present prior to burning (Eberhardt and Woodard 1987). These residual structures, in the form of standing dead trees, downed logs and live trees that survive fire, provide habitat for numerous species. Increasing the proportion of logged stands containing residual structure thus would promote the conservation of biodiversity.

Impacts of land use

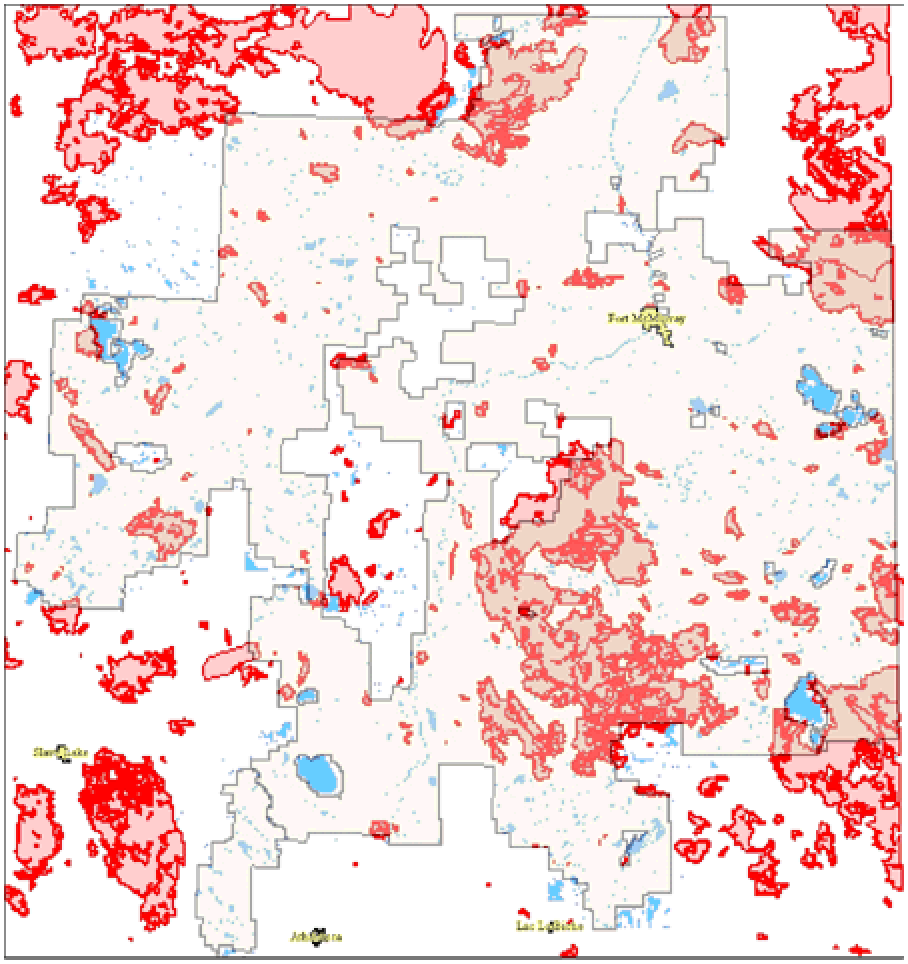
Modern fire suppression and control practices have been implemented in northeastern Alberta since the 1960s (Murphy 1985), although the degree to which these activities have successfully reduced the area burned is unclear (Cumming 1997, 2001). While the area burned may be smaller, many of the areas that do burn are subject to salvage logging. Salvage logging reduces the legacy of natural disturbance in the future forest by removing standing dead trees used by species such as woodpeckers and bark beetles (Lindenmayer et al. 2004).

Conventional (non-salvage) logging also affects forest stands by removing much of the structure that would otherwise remain after fire. In Alberta and elsewhere in Canada's boreal forest, clear-cutting is the primary logging method. Al-Pac has introduced modified clear-cutting to increase the retention of residual structure (Al-Pac 1999). On average, approximately 5% of merchantable volume is retained in the primarily deciduous stands logged by Al-Pac. While this represents a relatively narrow range of variability compared with natural disturbance, structured clear-cutting promotes the conservation of species that depend on such structures. However, coniferous stands harvested by quota holders generally contain little or no retained merchantable volume.

Indicator trends

Approximately 900,000 ha were burned by fire in the Al-Pac FMA between 1970 and 2003 (Figure 10), an average annual fire rate of around 0.5%, or 27,000 ha per year. Historical records suggest that prior to 1950, fires were more frequent (Andison 2003), burning at least 1% of the forest per year. It is possible that fire suppression during the past few decades has reduced the incidence of fire in the study area. Alternatively, recent weather and fuel conditions may have been less conducive to fire than several decades ago.

Figure 10. Distribution of fires in and around the Al-Pac FMA, 1970–2003. Source: Al-Pac



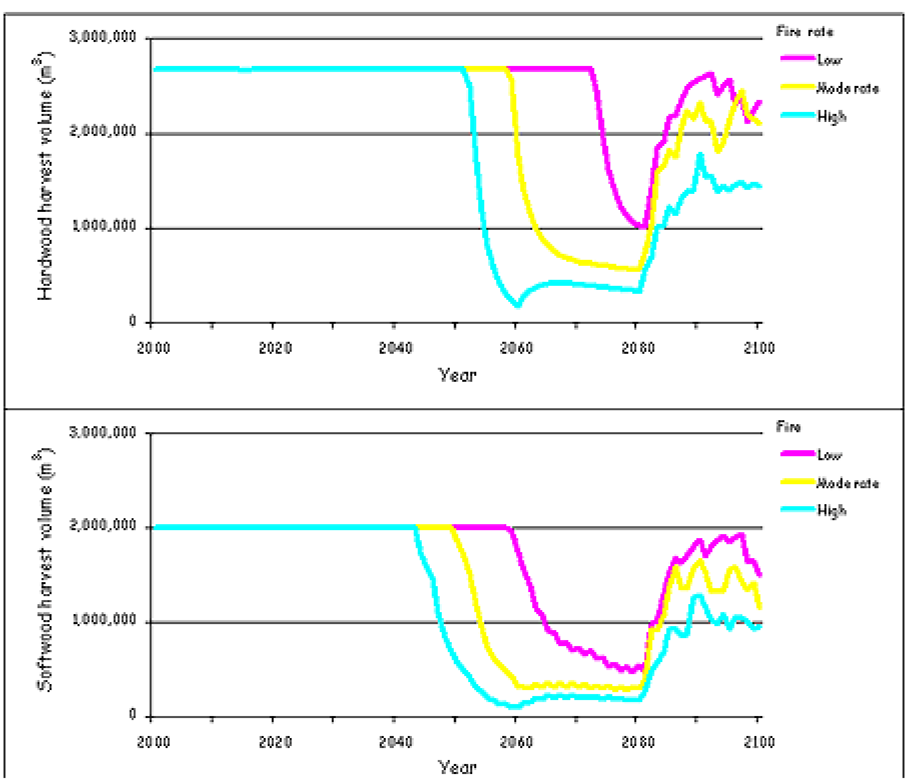
The extent of salvage logging in the study area is variable, but during the past decade it is estimated that approximately one-quarter of the merchantable forest that burned was subsequently salvage-logged (D. Pope, pers. comm.). A summary of salvage logging of stands burned in 1999 indicated that there were plans to salvage log 56% of the merchantable forest burned that year, although some of this area subsequently proved to be unsalvageable (Al-Pac 2004). Factors affecting the extent of salvage logging include road access and the recoverable volume of wood remaining. Also, mature stands that contain a relatively large volume of salvageable wood per hectare are more likely to be salvaged than younger burned stands.

The future extent of salvage logging (and thus of naturally disturbed areas) is difficult to predict because the future extent of forest fire is uncertain. If fires burn at a rate similar to before 1950 (1.25% per year, Andison 2003), then an average of 7,500 ha of forest would be salvage-logged each year. This assumes that future rates of salvage logging remain constant at 25%, which is probably conservative as an expanding road network increases the proportion of burned areas that are accessible. Because salvage logging is directed disproportionately toward mature stands that contain relatively high wood volume, the future supply of stands with a significant structural legacy would be limited.

The future extent of conventional (i.e., non-salvage) logging is more predictable than that of salvage logging. The area of conventionally logged stands in the study area is currently approximately 250,000 ha (Figure 3). By the year 2050, it is anticipated that an additional 500,000 ha will have been harvested. If Al-Pac remains the only operator leaving residual structure on its cutblocks, then approximately 30% of all cutblocks (i.e., in conifer-dominated stands) will contain little or no residual structure.

A related implication of future natural disturbance is the difficulty of sustaining a constant supply of wood fibre. Sustainable harvest levels in Canada's boreal forest generally do not factor in future losses associated with fire, because the future incidence of forest fire is uncertain (Armstrong et al. 1999). Instead, harvest levels are typically recalculated after major fire losses occur. A timber supply analysis for Al-Pac's FMA, in which annual fire losses are considered, suggests that current harvest levels (2.7 million m^3 hardwood and 2.0 million m^3 softwood per year) would be difficult to sustain for more than 40 to 60 years, after which significant shortages in available hardwood and softwood fibre are projected (Figure 11). Shortfalls caused by fire losses would increase the reliance of companies on salvage logging, further reducing the extent of naturally disturbed areas.

Figure 11. Projected trends in harvest volume to the year 2100 in the Al-Pac FMA under three potential scenarios of fire frequency: low (0.83% per yr); moderate (1.25% per yr); and high (2.5% per yr)



Maintain old forest

Values promoted

Old forest stands generally contain the highest number of plant and animal species of all the successional stages in the boreal forest. This is due to the diverse array of habitat conditions that develop over time, including relatively old, tall, large-diameter trees, standing dead and fallen trees, diverse forest floor micro-topography (pit and mound), canopy gaps created by fallen trees, and a wide range of tree ages and sizes due to ongoing recruitment in canopy gaps (Stelfox 1995). Many species reach their peak abundances in older seral stages (Angelstam and Mikusinski 1994, Schieck et al. 1995, Kirk et al. 1996). Thus, maintaining old forest within the range of natural variability would promote the conservation of species that require such conditions. It would also promote the conservation of above-ground carbon, as the volume of stored carbon tends to increase as stands get older. Older forests are also valued for their high rates of primary and secondary productivity, as well as for their aesthetic appeal.

Impacts of land use

Logging and fire are the primary causes of a projected reduction in the area of older forest stands in the study area. Logging, in particular, affects the area of older forest because older stands are harvested before younger stands (this enhances the long-term wood supply). The rate of wood production peaks at around 70 years in hardwood-dominated stands, and 90 to 100 years in softwood-dominated stands.

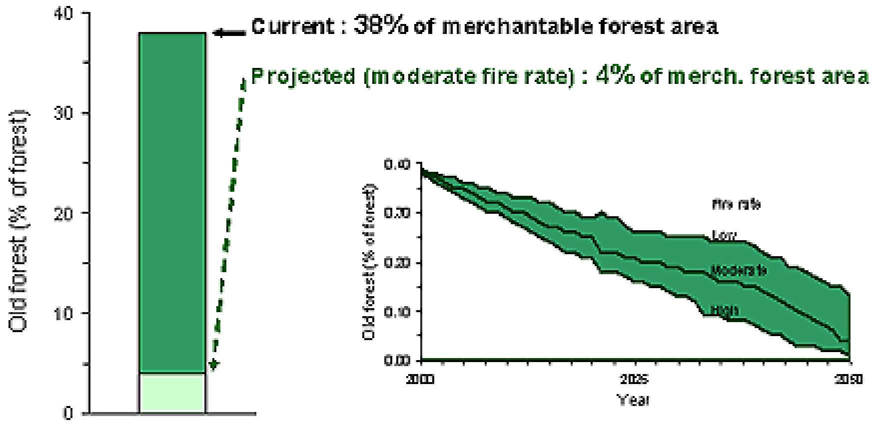
Declines in the area of older stands threaten the persistence of species that require these stands. The effects of habitat loss on some species are compounded by their negative response to fragmentation. For example, the density of black-throated green warblers is lower in smaller forest patches than larger ones (Schmiegelow unpubl. data).

Increased fire rates are predicted to occur in this region due to global climate change (Bergeron and Flannigan 1995, Bhatti et al. 2002), a trend that would further threaten the supply of older forest stands.

Indicator trends

Approximately 40% of the merchantable forest in the study area, or 10% of the total area, is covered by older forest stands (Figure 12). Historically, the area of old forest in the region has probably fluctuated considerably within a wide range of natural variability, and the amount at any given time thus represents a “snapshot” of many possible amounts. In an analysis of old forest supply in the Al-Pac FMA, Andison (2003) estimated the “natural” range of variability in older stands to be 8% to 33% of the land base.

Figure 12. Projected trends in the area of old forest in the Al-Pac FMA under three potential fire rates. (Fire rates as in Figure 11.)



Future logging activity in the study area would reduce the supply of old forest considerably within the next several decades (Figure 12). This is consistent with a maximum sustained yield policy in which “over mature” stands reduce the capacity of the land base to produce wood fibre (Alberta Environmental Protection 1994a, 1996). By the end of the first rotation (i.e., after several decades), old forests would be restricted to merchantable stands ineligible for harvest (e.g., riparian buffers, steep slopes) and non-merchantable stands. The added effects of fire would accelerate this rate of loss (Figure 12), with the combined disturbances of logging and fire reducing the future supply of old forest below the range of natural variability within the next few decades. Since fires burn both merchantable and non-merchantable stands, areas in which no logging takes place cannot be expected to provide substantial areas of old forest, particularly if fire rates increase due to climate change.

Maintain key aquatic and hydrological features

Values promoted

The boreal forest provides numerous water-related services, including the recycling of water to the atmosphere (via evaporation and evapotranspiration) and the filtration of water as it flows over the ground surface and through the soil (Thormann et al. 2004). Bodies of surface water such as wetlands, lakes and streams provide habitat for many species, including those that are truly aquatic (e.g., fish, loons) and those that require aquatic habitat for part of their life history (e.g., frogs, beavers, pelicans).

A dominant aquatic influence in the study area is the large area of wetlands. These are lands that are saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, water-dependent vegetation and various kinds of biological activity that is adapted to a wet environment. A combination of environmental factors, including flat topography, an abundance of poorly drained glacial deposits and cool, humid climate have resulted in extensive wetland areas throughout Alberta’s boreal forest (Vitt et al. 1996, Thorman et al. 2004). In the study area, wetlands are the dominant natural community type, covering just over half of the 6-million-ha land base. Most wetlands in the region are peatlands (e.g., fens and bogs), characterized by scattered, slow-growing stands of black spruce and treeless habitats dominated by grasses, sedges and mosses. Important ecological services provided by wetlands include water filtration, storage and moderation of flow regimes, carbon sequestration and wildlife habitat.

Reducing negative effects on water quality and quantity, in addition to reducing the rate at which wetlands are removed or degraded, would promote the conservation of biological diversity, soil and water resources, and carbon balance.

Impacts of land use

Many wetlands and water bodies in northeastern Alberta are fed by groundwater sources that may be sensitive to industrial activities such as the pumping of groundwater down in situ oil sands wells (Alberta Environment 2003) and the dewatering of aquifers near oil sands mines (Griffiths and Woynillowicz 2003). Roads may also disrupt water movement, leading to an impoundment of surface water that alters the distribution of surface and subsurface water (and associated plant communities) adjacent to the road (Poff et al. 1997, Thormann et al. 2004). Finally, water withdrawals from the Athabasca River in the oil sands area may lead to undesirably low flows, particularly during the winter when natural flows are frequently low.

Logging can temporarily alter local hydrologic regimes by altering groundwater recharge–discharge dynamics, the position of the water table and stream flow (Thormann et al. 2004), although the effects of logging on hydrological regimes appear to be similar to those of other disturbances such as fire (Carignan et al. 2000, Prepas et al. 2001, 2003). Harvesting of riparian vegetation can increase stream water temperature and exposure to ultraviolet radiation, which may alter stream invertebrate communities and contribute to increased algal growth (Thormann et al. 2004).

Threats to water quality in the study area include point-source pollution from the Al-Pac pulp mill and other pulp mills located upstream on the Athabasca River. Pulp mill residues are toxic to many aquatic and non-aquatic organisms (including humans), and the decomposition of organic material downstream of the mill during periods of low flow (i.e., winter) may deplete oxygen to levels that threaten the survival of fish. Contaminated water used during bitumen extraction from oil sands may leak from tailings ponds. Historically, logging and road construction have been shown to cause erosion and deposition of sediments into watercourses. However, regulations have largely eliminated this negative impact in most areas (Plamondon 1982 in Thormann et al. 2004).

Oil sands mining and to a lesser extent peat mining are the major causes of wetland removal in the study area. Because peat in wetlands accumulates very slowly, it is essentially a non-renewable resource (Pembina Institute 2001). In addition, the success of efforts to create wetland environments on reclaimed mine sites is unproven.

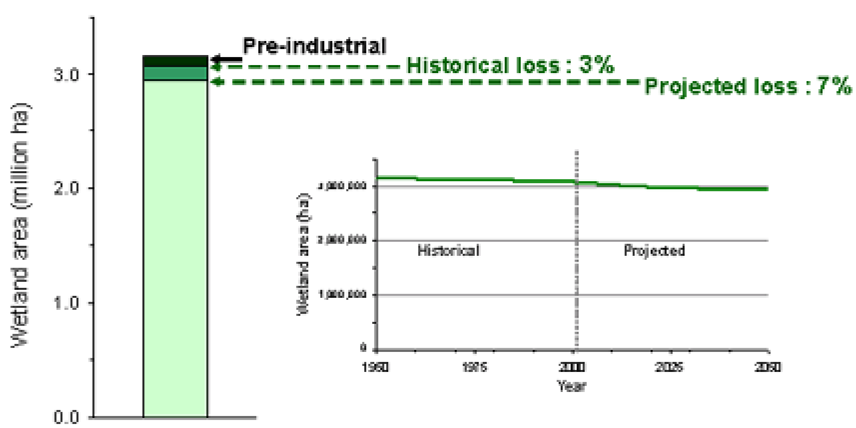
The indirect effects of industrial activity on wetlands (i.e., alteration of the hydrological regimes) may be more significant than the direct losses of wetlands from industrial clearing. As noted earlier, roads constructed through wetlands may impede the flow of surface and subsurface water, increasing the amount of accumulated surface water on one side of a road, while reducing water availability on the other side. This may turn may lead to plant mortality and habitat change adjacent to the road (Poff et al. 1997, Thormann et al. 2004). Factors influencing the type and severity of road effects on wetlands include road location relative to surface flow patterns, the abundance and size of culverts, and the porosity of materials used to construct the roadbed.

Groundwater removal during in situ oil production and dewatering of local aquifers during oil sands mining may also disrupt wetlands that depend on groundwater recharge (Griffiths and Woynillowicz 2003). An additional potential impact is local contamination of wetlands from industrial spills and mine tailings. Ground vegetation in wetlands may be particularly sensitive to industrial emissions and acidic precipitation, an impact that is probably restricted to the northern portion of the study area where refineries and other emission-causing plants are concentrated.

Indicator trends

Approximately 3% of wetland cover in the region has been converted to other land uses during the past several decades (Figure 13). Over the next several decades, it is estimated that an additional 4% of wetlands will be lost, mainly due to oil sands mining (Figure 13). Trends associated with the indirect effects of industrial activity on wetlands are difficult to quantify, but continued expansion of the transportation network in the region would potentially cause damage to extensive areas of wetlands.

Figure 13. Historical and projected trends in wetland area in the Al-Pac FMA under a moderate energy sector development scenario



Recognize and protect areas of traditional Aboriginal use and value

Values promoted

This management objective is expected to provide socio-economic as well as cultural benefits for Aboriginal peoples while promoting conservation of natural capital throughout the FMA.

Aboriginal peoples form a significant component of the population living within the area of research. In fact, the entire Al-Pac FMA is made up of lands that were extensively used by various Aboriginal groups for many generations. For example, the Fort McKay First Nations' traditional lands in the northeastern part of the FMA encompassed an area of approximately 38,000 km^2 (Fort McKay First Nations 1994). The traditional territory of the Bigstone Cree encompasses the western part of the Al-Pac FMA, from Peerless Lake in the north to Calling Lake in the south. Their traditional way of life was based largely on hunting, fishing, trapping and gathering activities and continued until the 1960s or 1970s, depending on the area. Respect for and stewardship of the land were the foundations of their relationship with the forest. Aboriginal people lived lightly on the land and "managed" its products wisely. Protecting areas of traditional use and value to Aboriginal people and involving them in land and resource management decisions would help meet all of the conservation objectives identified earlier.

Impacts of land use

The development of conventional oil and gas in the 1940s, of oil sands in the 1970s and of forestry resources on a major scale in the 1990s has profoundly affected the traditional way of life of the Aboriginal communities in the Al-Pac FMA. Most of the biophysical impacts of land use discussed above have directly affected the land and resources that Aboriginal people relied upon for their livelihood. In many areas, land and resource-based activities are now physically impossible (due, for example, to clear-cutting) or have been negatively affected due to the impact of resource extraction on wildlife populations and on water quality and quantity. In the Fort McKay area for instance, most people have stopped fishing in the Athabasca River as a result of the deterioration of the fishery resources and concerns over industrial pollution. Nevertheless, the connection with the land remains strong and is culturally critical, and a number of Aboriginal people still maintain an active "bush life."

Aboriginal communities started mapping their traditional lands in the 1980s, with government and industry funding. Traditional land use studies have now been completed for several communities within the FMA. These studies identify areas of traditional and current importance to bush economy users for hunting, trapping, fishing and gathering, as well as for spiritual and historical uses. They also illustrate the wealth of knowledge that exists among Aboriginal people in connection with the land. This knowledge is valuable for resource managers and developers, and it may help to provide a better understanding of the impact of industrial development on forest ecosystems and to develop more sustainable approaches to land and resource use.

Establish areas within the managed forest where human impacts are prohibited or severely reduced

Values promoted

Establishing additional protected areas in the study area would promote the conservation of biological diversity in various ways.

Contribution to knowledge

Limited scientific understanding and economic feasibility will always prevent resource managers from conducting their business in a way that eliminates negative ecological effects. Additional protected areas would help address this issue by fostering improved knowledge of the effects of human activities on regional flora and fauna. Indeed, several authorities argue that protected areas, in which industrial activity is either prohibited or severely restricted, are a critical element of sustainable forest management (Environment Canada 1994, Senate Subcommittee on the Boreal Forest 1999, NRTEE 2003b). By comparing ecological conditions in protected (or benchmark) areas with those in the rest of the landscape, researchers can gauge how far conservation objectives have been achieved on the working landscape. Because ecological conditions are geographically variable, many benchmark areas dispersed throughout the working landscape would provide more reliable comparisons than fewer benchmark areas, particularly if they are not widely dispersed. Adequate representation of different ecological zones is also considered an important criterion for protected area selection (Kavanaugh and Iacobelli 1995).

Conservation of biological diversity

Protected areas would promote the conservation of biodiversity by providing refugia for species and communities (such as older forest) that are sensitive to human activities. They would also provide sources of individuals, seeds, pollen and spores for introduction to the working landscape if conservation efforts there are unsuccessful. As well, large protected areas would foster the persistence of natural disturbance regimes such as forest fire, and they would provide a buffer against shifting environmental conditions associated with climate change. Corridors in which only limited and sensitive land use is permitted may also promote connectivity among protected areas and facilitate movement of certain wildlife species (Harrison 1992).

Improved market access for forestry companies

Forestry companies must demonstrate that their tenures contain ecological protected areas in order to achieve certain market certification standards, such as Forest Stewardship Council (FSC) certification (FSC 2000). Because certification provides an improved image in the international marketplace, establishing protected areas potentially results in greater market access for certified companies. Al-Pac is currently seeking FSC certification (S. Dyer, pers. comm). In a previous Detailed Forest Management Plan, Al-

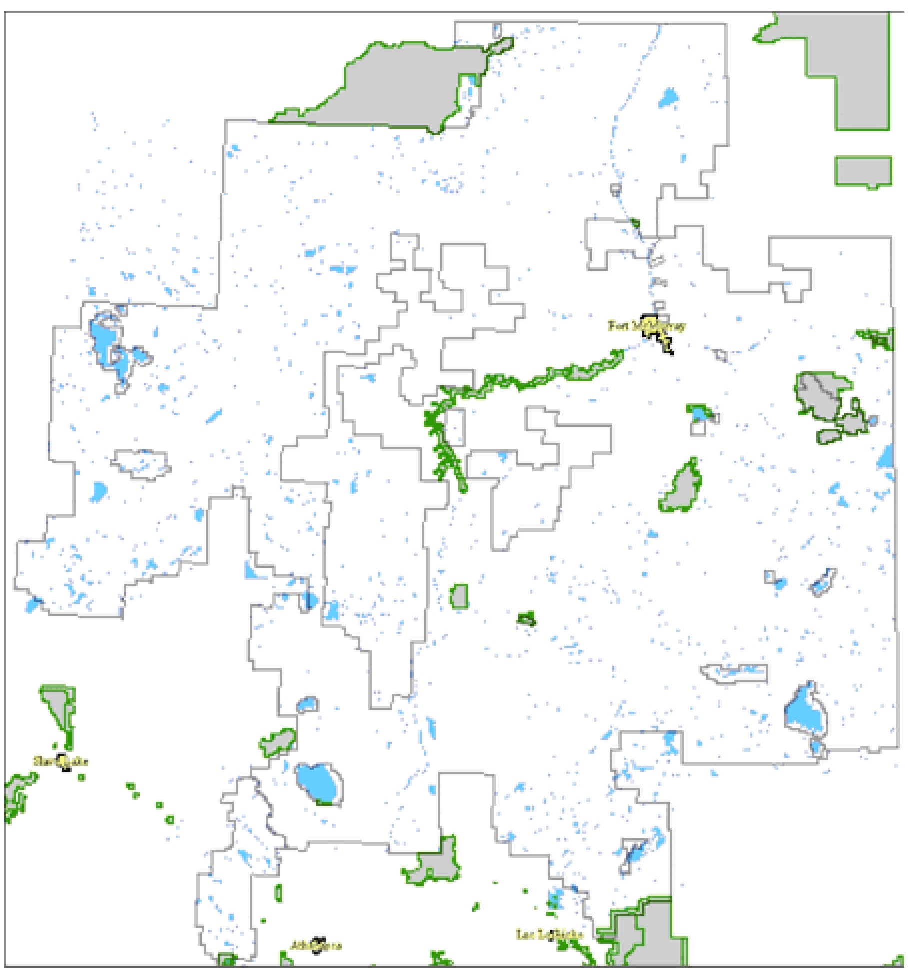
Pac proposed the protection of the Liege River watershed in the northwestern part of the FMA (Al-Pac 1999). This would have added an additional 140,000 ha of protected areas within or adjacent to the FMA. This was viewed by Al-Pac as a strategy to achieve its goal of sustaining all species within its FMA, a goal that is consistent with provincial direction to maintain species diversity (Alberta Environmental Protection 1998a).

Contribution to traditional way of life
Finally, the establishment of more protected areas would help meet the basic needs of Aboriginal communities and preserve areas that are critical to their cultural identity.

Impacts of land use

A total of 96,000 ha (1.5%) of the study area is designated as protected under provincial statutes or forestry ground rule designations (e.g., buffer zones) (Figure 14). (Some types of industrial activity may be permitted in parts of these areas.) The total area protected in the region would increase to 4.7% if the three large protected areas bordering the study area (Figure 14) were included in the total.

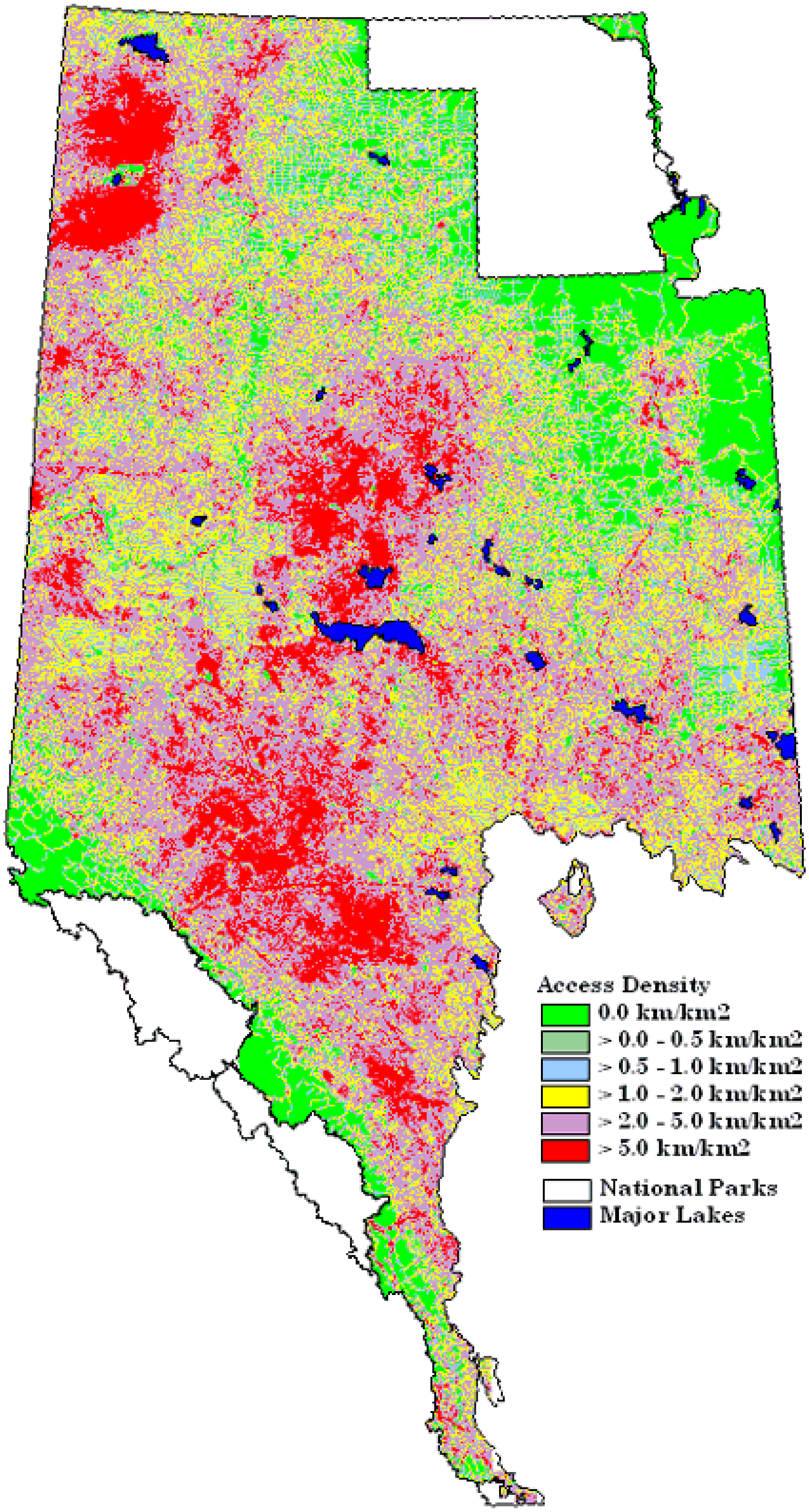
Figure 14. Map showing the location of protected areas in and around Al-Pac's FMA in 2003. Source: Al-Pac



The Senate Subcommittee on the Boreal Forest (1999) recommended that up to 20% of Canada's boreal forest be set aside as protected areas, including "areas of old growth boreal forest, areas used traditionally for native trapping, representative ecological areas and areas of significant wildlife habitat." Approximately 12% of the boreal forest natural region in Alberta is protected, although over 90% of this area is within Wood Buffalo National Park in the northern part of the province. One outcome of the provincial Special Places Program was to increase the level of protection of underrepresented landforms and ecological sub-zones (termed natural history themes) in Alberta to at least 2.75% of each natural history theme (Alberta Environmental Protection 1998b). Schneider (2002) recommended the addition of three large (500,000 ha) protected areas in and near the Al-Pac FMA (Birch Mountains, Athabasca Rapids, Cold Lake) plus a larger number of smaller protected areas to protect unique landscape features such as sand dune complexes and highly productive areas such as major river corridors.

An analysis of linear developments in the boreal forest natural region of Alberta outside Wood Buffalo National Park (Alberta Environmental Protection 1998b) concluded that approximately 13% of the region was roadless. A subsequent analysis of the Western Sedimentary Basin conducted by ForestWatch Alberta suggested that most of the Al-Pac FMA was within 1 km of an access corridor (including seismic lines) (Figure 15).

Figure 15. Density of roads, seismic lines and other linear disturbances in Alberta as of 1995–99. Source: Smith and Lee (2000)

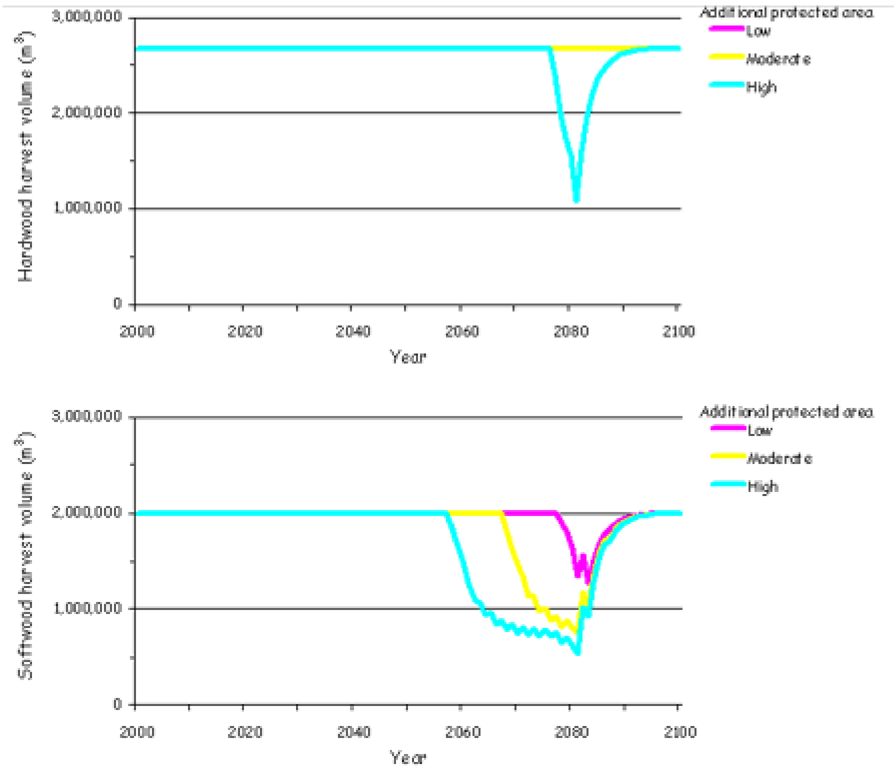


Indicator trends

Options for establishing additional protected areas are declining within the Al-Pac FMA as resource development activities continue to reduce the area of undisturbed landscapes (see Figures 3 to 7). Establishment of protected areas in undeveloped landscapes is further complicated by resource allocation decisions that foster competition for land between industrial users and those who want to promote protected areas. More than 80% of townships in the region contain one or more petroleum wells (a surrogate for other industrial activity), with most of the remaining 20% of townships under some form of resource tenure (Cumming and Cartledge unpubl. data). Because there is currently no requirement and little incentive to establish additional protected areas in the Al-Pac FMA, the future area of protected land will remain unchanged under the current management regime.

A major barrier to the establishment of protected areas is that they would potentially constrain the activities of the forestry and energy sectors. For example, removing an additional 10% of merchantable forest from lands available for timber harvest beyond the existing protected areas already in place would contribute to shortfalls in softwood (but not hardwood) supply (Figure 16). (This projection assumes future losses to fire are minimal; fires are expected to exacerbate future fibre shortfalls.)

Figure 16. Projected trends in harvest volume under alternative levels of additional protected area in the Al-Pac FMA. Low = 0%; moderate = 10%; high = 20% reduction of merchantable forest area available for harvest. Additional declines in wood availability associated with fire are not included in these projections



Reduce linear disturbance density and manage human access

Values promoted

Roads and other linear developments are thought to have many negative ecological effects (Reed et al. 1996, Forman and Alexander 1998, Trombulak and Frissell 2000), and reducing the rate of fragmentation by linear developments in the Al-Pac FMA would promote the conservation of biological diversity. Some wildlife species such as woodland caribou are also sensitive to human disturbance along linear corridors, and managing human access would help protect such species from further population declines. Reducing the amount of forest cleared for linear developments would also promote the conservation of above-ground carbon, as well as promote economic values by reducing the rate at which lands are removed from the forest-producing land base. Reducing the disruption of surface and subsurface water flow (which in turn would reduce the release of carbon to the atmosphere due to decomposition and methanogenesis) would further promote the conservation of above-ground and soil carbon.

Impacts of land use

Arguably the most significant negative effects of linear developments on biodiversity in the Al-Pac FMA are associated with woodland caribou. Caribou habitat is degraded by linear developments because caribou tend to avoid such features, probably due to increased risk of predation by wolves (Curatolo and Murphy 1986, James and Stuart-Smith 2000, Dyer et al. 2001). The habitat quality of approximately 48% of core caribou range in northern Alberta has been reduced due to proximity to linear developments and other industrial features such as well sites (Dzus 2001). Mortality of woodland caribou near roads and seismic lines is likely increased due to poaching and native hunting (Dzus 2001).

Effects of linear developments on other species are not as well documented, but preliminary evidence suggests that the abundance of several neotropical birds may be reduced in areas with high densities of linear developments (Schmeigelow and Cumming unpubl. data). Related research suggests increased nest predation on birds nesting adjacent to linear developments, particularly wide pipeline rights-of-way (Anderson et al. 1977, Fleming 2001). There is also some evidence that movement patterns of selected mammal species, including flying squirrels and pine marten, may be disrupted by linear developments (Marklevitz 2003).

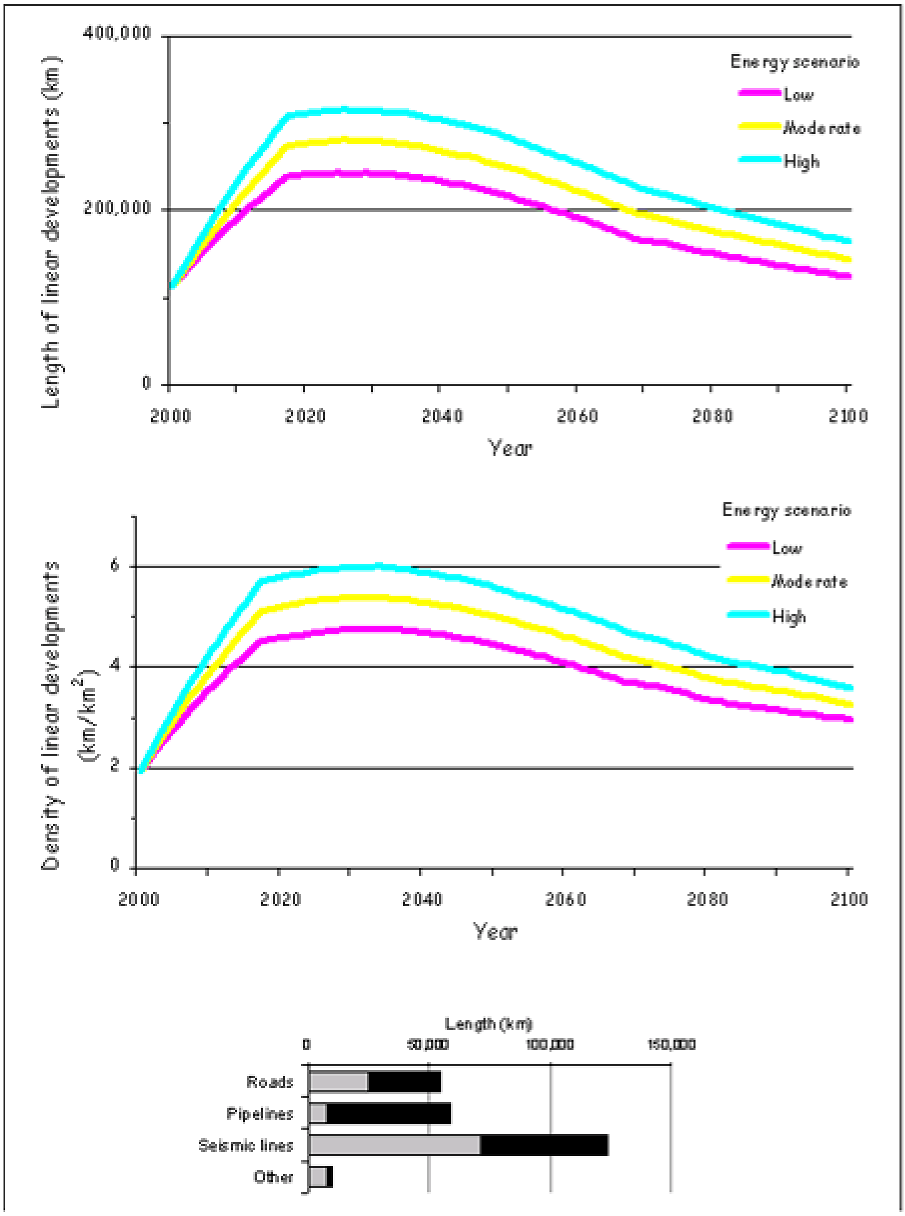
Poorly constructed or maintained road stream crossings can result in barriers to fish movements by creating hanging culverts, velocity barriers or low-head dams (M. Sullivan, pers. comm.). These barriers prevent fish from gaining access to upstream spawning areas or re-colonizing large areas after natural events such as droughts or winterkill. They may also isolate and fragment populations, threatening the long-term viability of sensitive species such as arctic grayling (Thormann et al. 2004). Roads, seismic lines and other linear developments that facilitate motorized access are thought to increase fishing pressure, particularly at watercourse crossings. Boreal fish populations may be far more sensitive to increased fishing pressure due to road access than to habitat change from logging and other forms of land use (Post and Sullivan 2002).

Other ecological effects of roads in particular include the disruption of surface water flow (Jones et al. 2000), potentially leading to upstream wetting and downstream drying, plus associated habitat change and release of biotic carbon. Roads have historically caused erosion and increased flow of sediments into streams, but this impact has been reduced by improved construction and design standards.

Indicator trends

There are currently over 100,000 km of linear developments in the Al-Pac FMA. Two-thirds of these features are seismic lines; the remainder are roads, pipelines and transmission lines (Figure 17). This represents an average density of 1.8 km/km^2 over the entire FMA, although linear development densities vary considerably among different parts of the FMA (Figure 15).

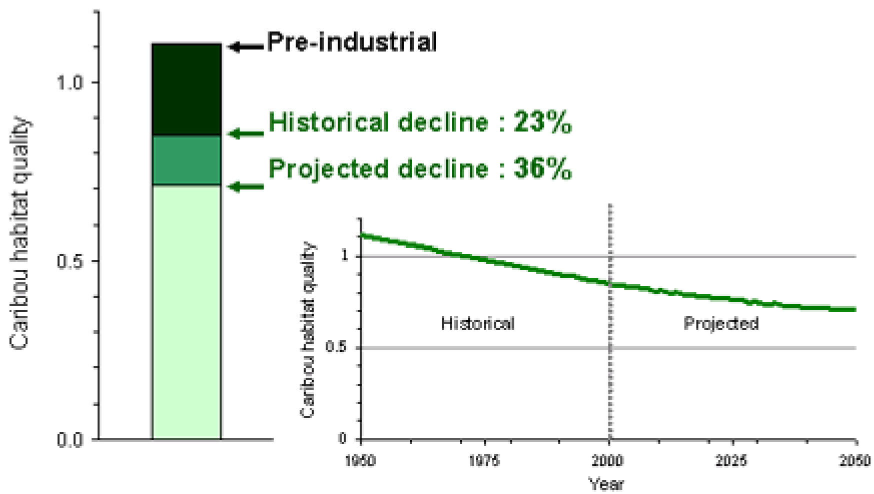
Figure 17. Projected trends in the length and composition of linear developments in the Al-Pac FMA. Lines in top two graphs represent projected trends under three scenarios of energy sector development (low, moderate, high). In the bottom graph, light shading indicates length in 2000, dark shading represents the additional length in 2050 under a moderate energy sector development scenario



If forestry activity persists at current levels, and if the energy sector expands at expected rates (D. Pope, pers. comm.), the average density of linear developments in the Al-Pac FMA will increase to over 5 km/km^2 (Figure 17). The forest sector requires additional haul roads and temporary in-block roads; the energy sector requires additional roads, pipelines and seismic lines.

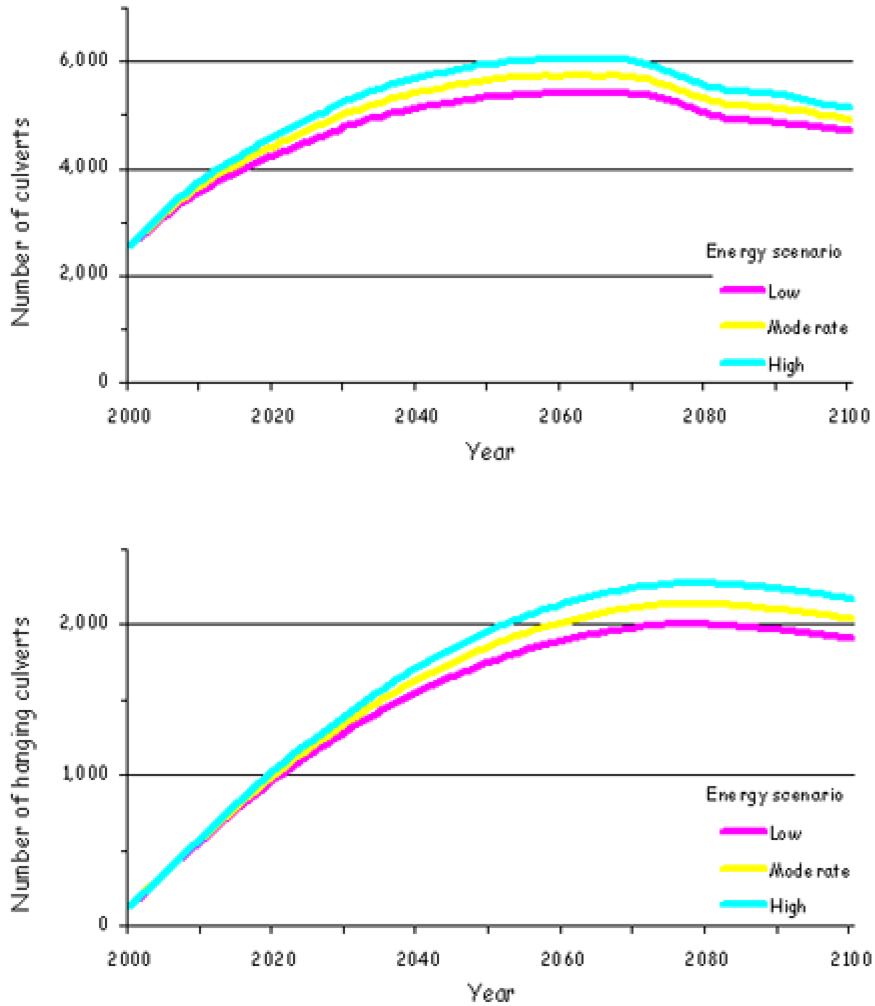
The implications of this increase in linear developments are perhaps most serious for woodland caribou. Populations throughout northern Alberta have probably declined in recent years (Dzus 2001), and recent research suggests some negative demographic trends. Declines in habitat quality due to avoidance of linear developments have been implicated as a major cause of this trend. A habitat model developed by the Boreal Caribou Committee suggests that habitat quality has declined by 23% over the past 50 years, and that further declines are expected (Figure 18).

Figure 18. Historical and projected trends in caribou habitat quality in the Al-Pac FMA under a moderate energy sector development scenario. Values below one represent demographic conditions that would result in declining populations



As noted above, linear developments may also cause fragmentation of streams. There are now approximately 2,500 stream crossings in the FMA, and the average length of stream between hanging culvert crossings that obstruct fish movement is 380 km. By 2030, the average length of stream between hanging culverts would be 40 km, a level that would impede natural fish movement and significantly increase the ease of human access to the region's stream network (Figure 19).

Figure 19. Projected trends in watercourse fragmentation in the Al-Pac FMA, 2000-2100. Lines represent projected trends under three energy sector development scenarios (low, moderate, high)



Maintain terrestrial carbon stocks and sinks

Values promoted

Carbon storage is a critical component of the global carbon cycle, which regulates the earth's climate. As such, carbon storage is one of the vital ecosystem services provided by the boreal forest. The potential significance of global climate change associated with increasing atmospheric carbon has been well documented. In the boreal forest, most stored carbon is below ground, with peatlands responsible for the accumulation of large quantities of below-ground carbon due to slow decomposition rates in cold, saturated soils. Reducing carbon emissions from disturbed vegetation and soil would promote the conservation of natural capital in the form of stored carbon.

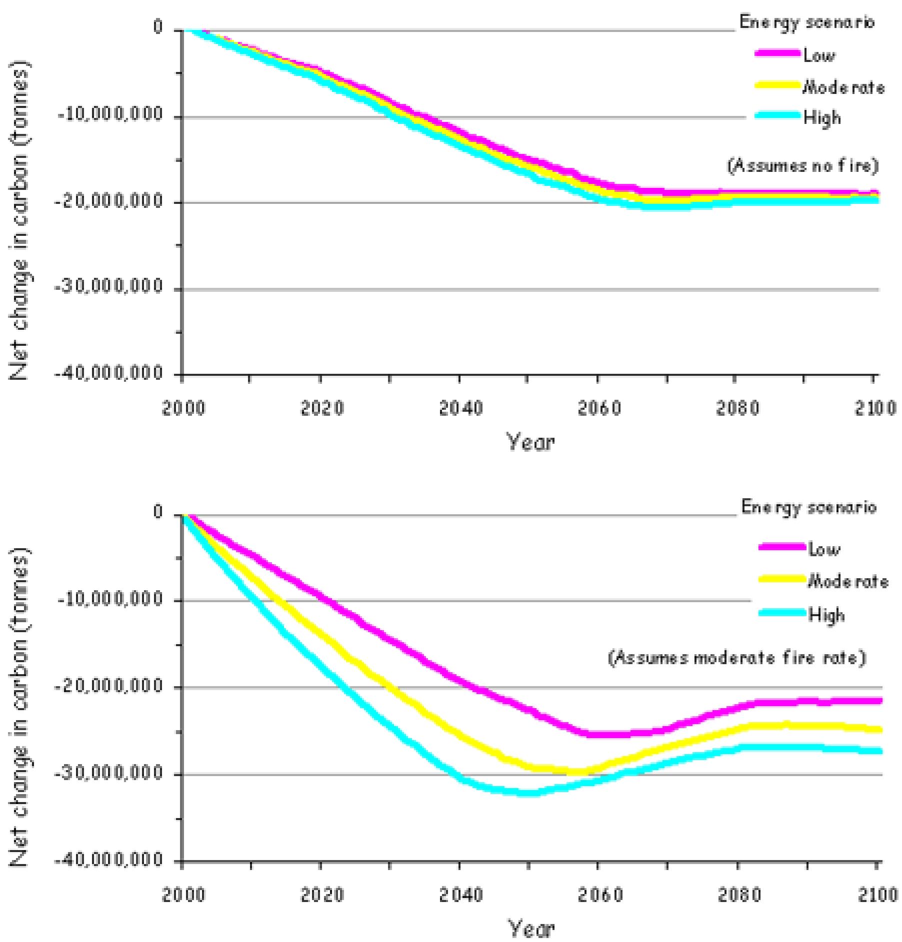
Impacts of land use

When forest vegetation is disturbed or cleared (for timber, roads, plant sites, mines, well sites or other uses), above-ground vegetation decomposes more quickly, increasing the rate at which carbon dioxide is released into the atmosphere. In addition, a dominant carbon sequestering agent (trees) is removed. Forest harvesting, in particular, also results in the conversion of older, carbon-rich stands to young stands that contain less carbon, and it may also temporarily cause soil saturation until vegetation becomes re-established. Saturated soils and submerged vegetation impounded by roads passing through wetlands may also release carbon through methanogenesis; wetland areas deprived of historical water sources may release carbon through organic decomposition.

Indicator trends

Simulated projections suggest that the amount of above-ground and below-ground carbon will decline over the next 50 years by approximately 22 million t (Figure 20). This trend would be accelerated by increased fire rates induced by climate change.

Figure 20. Projected trends in above-ground carbon in the Al-Pac FMA, 2000-2100. Lines represent projected trends under three energy sector development scenarios (low, moderate, high)



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