8

Alberta Oil Sands Development: Risks to Canadian Boreal Ecosystems

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The bitumen (oil sand) deposits of northeast Alberta are profound and generally acknowledged as the second largest remaining global reserve of oil. The size of the resource combined with the region's skilled workforce and proximity to the United States make Alberta's oil sands perhaps the most attractive unconventional oil deposit in the world. The vast majority of Alberta's oil sands are yet to be developed due to the high cost of production relative to conventional reserves. The lag in Peak Oil for Alberta's oil sands will create high economic and political pressure to develop the resource to help fill the gap left by declining availability of conventional reserves. Increasing anxiety about the security of Middle East oil is another factor contributing to the increasing availability of United States risk capital to develop this resource (Figure 8-1).

The infrastructure, resource demands, and effluents associated with production of Alberta's oil sands could be highly detrimental to wildlife and other environmental values, especially if ecological considerations are marginalized in the rush to develop the resource. In contrast, best management practices and an expanded protected areas network have the potential to offset at least some of the environmental impacts, and the high value of the resource and the region's stability should provide the economic and institutional ingredients needed to achieve high environmental standards. Indeed, access to key markets such as the United States may require ambitious environmental efforts due to the increased ecological literacy of consumers.

In this Chapter, we explore the environmental impacts of bitumen development in northeastern Alberta and assess the potential effectiveness of best practices, access management, and protected areas network expansion. Ecological consequences of historical development, including both conventional and bitumen oil extraction, are first chronicled to provide context. We applied the ALCES© land use simulation tool (www.alces.ca) to project the ecological impacts of future anticipated development in the region and assess the role of best practices in mitigating risk to ecological indicators. We acknowledge the willingness of the Alberta Land-use Secretariat to provide us with Lower Athabasca Regional Plan (LARP) data to complete these analyses. We further discuss the potential design and function of an expanded protected areas network. The land use simulations and conservation planning analyses that we present were completed to inform the Alberta Land-use Framework (ALUF), a regional land use planning process being coordinated by the Government of Alberta. We conclude the Chapter by describing the Framework and, more generally, the role of proactive planning in balancing the economic and ecological consequences of developing the world's remaining hydrocarbon reserves.

Alberta's Oil Sands Region

The Athabasca Oilsands, the largest of the bitumen deposits in Alberta, are located in the boreal forest natural region. Broad lowland plains and extensive hill systems typify it, with the primary physiographic regions including the Northern Alberta Lowlands, Northern Plains, and Saskatchewan Plains. Prominent topographic features include the Birch Mountains, Stony Mountains, Firebag Hills, and Richardson Sand Hills. A heterogeneous network of deciduous (aspen, birch) and coniferous (white spruce, black spruce, jack pine) forests intermixed with topographically depressed fen and bog complexes, scattered lakes, and main stem rivers and their tributaries characterize this bio-region. The Athabasca River Basin is the primary drainage basin in the region. Gray Luvisols with some Dark Gray Chernozemics soils found in the southern region dominate soils. Organic soils are common within the depressed regions containing fens and bogs. Temperatures are highly variable by season, with average maximum temperatures in the summer of 25º C, and average maximum winter temperatures of -15º C. Average minimum temperatures are 10º C in the summer and -20º C in the winter. Average precipitation (1951-1980) is 450-500 mm/year. Fire is the most important natural perturbation defining forest age, though arthropod outbreaks occur occasionally.

The biota of the region reflects the diverse landforms and plant communities of northeast Alberta, including 40 fish species (Nelson and Paetz 1992), five amphibians (Russell and Bauer 1993), one reptile (Russell and Bauer 1993), 236 birds (Francis and Lumbis 1979, Semenchuk 1992), and 45 mammals (Pattie and Hoffman 1992, Smith 1993). Based on distribution maps (Moss 1983, Vitt et al 1988), conservative estimates indicate a rich diversity of plants, including 600 vascular species, 17 ferns, 104 mosses, 13 liverworts, and 118 lichen species.

Although challenging to quantify, natural capital, such as biodiversity, provides important ecosystem services, such as water resources, sequestered carbon, and climate regulation. The non-market ecological goods and services (based on 17 elements) for the MacKenzie River Basin is estimated at $2,631/ha/year (Anielski and Wilson 2007). Concerns expressed by the environmental community emphasize the potential long-term harm that could occur to the region’s EGS by maximizing the short-term gain in GDP associated with extraction and processing of bitumen.

The findings of this report address the LARP region of northeast Alberta, an area that directly overlaps the Athabasca and Cold Lake bitumen deposits. The LARP region represents the first region to develop a strategic management plan under the auspices of the Alberta Land Stewardship Act passed in 2009.

Although this region has supported First Nation communities for thousands of years, and trapping for hundreds of years, it is only during recent decades that large-scale industrial development has emerged. The two dominant land uses, in terms of area affected, are the forestry and energy sectors. Both land uses have grown exponentially in harvest and extraction volumes during the past few decades (Figures 8-2 and 8-3). In addition to Alberta-Pacific Forest Industries, Inc. (Al-Pac), which holds a large hardwood-dominated Forest Management Agreement (FMA) that overlaps spatially with LARP, there exist a few smaller softwood allocations for quota holders. The Annual Allowable Cut (AAC) of Al-Pac is currently ~3.5 million m^3/year and about 2.7 million m^3/year of that full volume is harvested from the LARP study area.

It is difficult to quantify total volumes of bitumen “in-place”, but most sources provide estimates in the range of ~1,804 billion barrels (287 billion m^3) (ERCB 2010). Of this volume, existing technologies that are economically viable could remove ~170 billion barrels (27 billion m^3) (ERCB 2010). This volume is likely to increase as newer technologies emerge. The volume of bitumen removed to date (~6.9 billion barrels, 1.1 billion m^3)) represents less than 4% of the recoverable volume. Given assumptions of approved and projected new bitumen projects, the current annual production levels of 1.49 M bpd (0.24 M m^3/year) is expected to increase to 3.2 M bpd (0.51 M m^3/year) by 2019 (ERCB 2010).

Impacts of Future Oil Sands Development and Opportunities for Mitigation

Development of unconventional deposits such as oil sands is expected to accelerate in the future, in part to fill the gap in oil supply created by diminishing conventional reserves. Investment and production projections for Alberta's oil sands suggest a rapidly increasing rate of development (Figure 8-4). Concomitant with expanded oil sands production is increased environmental impacts due to growth in landscape disturbance, water and energy consumption, and emissions. Accelerated growth of the industry has raised concerns regarding reduced terrestrial and aquatic wildlife habitats due to its industrial footprint (Schneider and Dyer 2006) and reduced river flow (Schindler et al. 2007), water contamination (Holroyd and Simiertsch 2009), wildlife mortality at tailings ponds (Wells et al. 2008), loss of biological carbon storage (Lee and Cheng 2009), increased CO_2 emissions (Raynolds et al. 2006), and acid rain (Prebble et al. 2009).

Exploring the Future Consequences of Development

We evaluated the potential future effects of expected development trajectories using the ALCES land use simulation tool. ALCES generates projections for a wider range of environmental and socioeconomic indicators under alternative assumptions about land-use policies and ecological processes. Here we present results for the following subset of the wide array of biodiversity, water, land, and economic indicators that were assessed in simulations to inform a land use planning process being led by the Government of Alberta (ALCES Group 2009): anthropogenic footprint, forest age, water consumption, woodland caribou, an index of fish community integrity, and carbon dioxide and nitrous oxide emissions. Simulations explored the response of these indicators to development trajectories 100 years into the future.

ALCES is well suited to assess strategic-level implications of development trajectories in the region due to its capacity to simulate the cumulative effects of the major types of land use (hydrocarbon extraction, forestry, agriculture, residential) and natural processes (fire, insect outbreaks, and meteorology). Using an annual time-step, the model applies natural disturbances and successional trajectories as well as anthropogenic footprints (well sites, mines, seismic lines, pipelines, roads, cut blocks, settlements, and farmland) associated with simulated resource production rates that have user-defined life spans. The first-order impacts tracked by ALCES are on resource supply and landscape composition, which are then translated into a variety of indicator variables using equations.

To provide a starting point for the simulations, the current composition of the 93,000-km^2 study area was quantified using inventories of vegetation and anthropogenic features. Extractions of two types of hydrocarbons were included in simulations: mineable bitumen that is extracted using open-pit mines and in-situ bitumen that is extracted using technologies such as steam-assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS). Bitumen development followed a pattern of increasing extraction to peak production followed by a gradual decline, as per the Hubbert-Naill model (Naill 1973). Reserve sizes and production rates were based on government projections (Figure 8-4), as were intensities, such as disturbance per unit of resource production, for seismic lines, well pads, and pipelines (Bob Nichol, consultant to Alberta Energy, personal communication). ALCES also attempted to maintain the annual allowable wood harvest allocated by the government to forestry companies in the region (2.75 million m^3/yr). Available merchantable timber was based on growth and yield curves, and constrained by harvest eligibility of forest types and age classes and by deletions from the active forestland base to account for inaccessible stands and protected areas. Forests were also disturbed by fire in order to assess the cumulative effect of natural and anthropogenic disturbances. A 1.25% annual burn rate across forest types and seral stages was simulated based on fire research for the region (Armstrong 1999). Although the regional fire regime is stochastic, fire was simulated as deterministic so that random fluctuations in annual burn rate did not obscure the effects of alternative land-use strategies. Disturbed stands were assumed to regenerate to their pre-disturbance forest type.

Other land uses in the region include agriculture and road network expansion. Future agricultural activity was simulated based on a government-endorsed projection that current cropland area (240,554 ha) will expand by 350 ha/year over the next 50 years and 700 ha/year thereafter. Highways grew at a rate of 35 km/year, while secondary roads grew by an average of 31 km/year. In addition, roads required to access timber were assumed to cover 3% of cut blocks and 0.5 km of access road was assumed associated with each well pad. Highways were simulated as permanent features, whereas secondary, in block, and well pad access roads had life spans of 25, 10, and 30 years, respectively. Culverts were applied to secondary, in block, and well pad access roads to account for intersections between road and stream networks. Culverts can be detrimental to fish habitat if they “hang”, which refers to the tendency of the downstream end of a culvert to become suspended above the stream because of scouring by outflow. Hanging culverts can prevent fish passage, thereby fragmenting fish habitat and potentially decreasing access to fish spawning and rearing areas (Park et al. 2008). The abundance of hanging culverts in simulations was estimated based on the density and age-class distribution of culverts.

Simulations explored two strategies for mitigating the potential impacts of development in the region: best practices and access management. Best practices refer to the best available strategies, within technological and economic constraints, for limiting environmental degradation per unit of resource production. Access management refers to reducing motorized public movement along a suite of industrial and natural features, including roads, trails, seismic lines, pipelines, watercourses and lakes. Increased public access facilitated by an expanding industrial footprint can increase angling and hunting, activities that may contribute to fish and wildlife declines in the region (Sullivan 2003). Best practices and access management were simulated at moderate and high levels to consider the implications of realistic and optimistic assumptions regarding the effectiveness of these strategies. Seven scenarios defined by various levels of best practices and access management were explored: business as usual (BAU: no best practices or access management); moderate best practices combined with each level of access management (none, moderate, and high for a total of three simulations); and high best practices combined with each level of access management (for a total of three simulations). The set of seven simulations allowed us to explore the incremental benefits of implementing best practices and, subsequently, access management.

The suite of best practices assessed in simulations was identified through consultations with experts from relevant government departments and industry. Included were strategies for minimizing the size and duration of footprint, old forest protection, water conservation, and emissions reduction (Table 8-1). The effect of access management scenarios on fish and wildlife was based on the outcomes of workshops held with government biologists and wildlife managers (Sullivan 2009). Moderate and high access scenarios were defined as 50% and 75% reductions, respectively, in public motorized use through road restrictions, designated trails, and motor restrictions on lakes. Under the BAU scenario, access management was defined as being generally unregulated leading to extensive human access and heavy use (angling) at most lakes.

Woodland caribou and an index of native fish integrity were evaluated to consider impacts to terrestrial and aquatic wildlife. Woodland caribou is a focal species for the region due to its threatened status and sensitivity to both forest age and industrial footprint density. The effect of simulated landscape transformations on woodland caribou was assessed using a model that relates woodland caribou finite rate of increase (lambda, λ) to anthropogenic edge density and forest younger than 30 years (Boutin and Arienti 2008). Based on caribou data from Alberta, the model estimated the relationship between caribou finite rate of increase and two attributes of landscape composition (linear features and forest younger than 30 years) by the following formula:

$$\text{Finite rate of increase} = (1.0184 - 0.0234) \times (\text{linear feature density} - 0.0021) \times \text{percent of forest younger than 30 years}$$

A sustained λ value less than 1 implies eventual extirpation of caribou from the region. Moderate and high access management was assumed to increase λ by 0.0075 and 0.015, respectively, based on expert opinion (Sullivan 2009). Impacts of development on the fish community were assessed using the Index of Native Fish Integrity (INFI), a measure that conveys changes in abundance and composition of fish species with a value ranging from 1.0 (undisturbed community) to 0 (highly disturbed). The relationships between INFI and human access, stream network fragmentation, and water use were based on a workshop held with regional fishery experts (Lagimodiere and Eaton 2009).

In addition to evaluating indicators at the regional scale, subregional performance was assessed by developing maps of simulated landscape composition and indicator status midway into the simulation period (year 60). Maps were produced using ALCES Mapper, a companionmapping tool for ALCES that creates spatial representations that are consistent with ALCES outputs. Rather than apply industrial development uniformly across the study area, the location of development was influenced by existing industrial infrastructure, the spatial distribution of resources such as bitumen and timber, and land use zones such as protected areas that were excluded from development. Maps of caribou and INFI status were created based on spatial representations of simulated landscape composition and access management. Access management varied spatially, with reduced access management in agricultural and settled areas, and the mineable bitumen zone. When mapping INFI, status was expressed in terms of risk. Risk was assessed based on percent departure from the indicator's estimated Range of Natural Variability (RNV) as estimated from 100 simulations that included stochastic meteorology, but excluded industrial development. The risk levels, based on criteria developed by the International Union for Conservation of Nature (IUCN), were as follows: stable (less than 10% from RNV); low risk (10–50% from RNV); moderate risk (50–70% from RNV); and high risk (greater than 70% from RNV).

Simulation Results

Anthropogenic footprint increased rapidly from approximately 7–10% of the landscape during the first 25 years of the simulation as development outpaced reclamation. By the end of the simulation, the footprint covered over 11% of the landscape and was focused in the southern and central portions of the study area where bitumen and timber reserves are prevalent. Best practices have the potential to achieve large reductions in the energy sector footprint through accelerated reclamation and reduced footprint intensity. When best practices were applied, simulated peak density of anthropogenic edge was approximately half of that projected in the BAU scenario (Figures 8-5 and 8-6). Another large landscape alteration apparent from the simulations was reduced abundance of older forest, a consequence of forestry activity in the region (Figure 8-7). In contrast to the projected changes in landscape composition, the simulated impact of land use on river flow was relatively minor. Water extraction by industry and settlements peaked at almost 8% of main stem river flow in February when riverine systems in the region experience their lowest flow and are therefore most susceptible to water removal.

Caribou finite rate of increase (λ) associated with the current landscape was estimated to equal 0.95, suggesting that the existing landscape is not capable of supporting a viable caribou population. This conclusion is supported by an assessment of management options for the region's caribou herds that determined that functional habitat was insufficient to maintain caribou in the region beyond two to four decades (Athabasca Landscape Team 2009). In the absence of best practices, λ was simulated to decline over the next quarter century and then to slowly recover (Figure 8-8). The pattern mirrors the simulated trend in anthropogenic edge density (Figure 8-5), demonstrating the influence of the industrial footprint on the species. It is thought that the anthropogenic footprint is detrimental to caribou because it promotes invasion by moose, deer, and wolves, ultimately leading to levels of predation that the caribou population cannot sustain (James et al. 2004). Woodland caribou are susceptible to predation due to their low reproductive rate and inability to escape predators, such as wolves. By minimizing and reclaiming industrial footprint, implementation of best practices decreased the maximum anthropogenic edge density by over 50% and, as a result, improved simulated λ relative to the BAU simulation (Figure 8-8). Access management had the effect of further improving λ, although the improvement was small because human access (hunting or vehicle collisions) is thought to be only a minor contributor to caribou mortality. Importantly, λ remained below 1 across all simulations suggesting that caribou are likely to be extirpated from the region despite aggressive mitigation strategies, with the exception of caribou herds located in the northern portion of the study area where bitumen deposits do not exist (Figure 8-9).

As with caribou, the current landscape was estimated to support a degraded fish community relative to natural conditions. This assessment is consistent with fish surveys and research in northern Alberta that have demonstrated wide-spread declines in recreational fisheries, primarily due to unsustainable rates of angling (Post et al. 2002). The INFI was simulated to continue to decline with future development (Figure 8-10), approaching a value of 0 which is indicative of fish communities dominated by small fish such as suckers, minnows, and chub and almost devoid of sport fish such as walleye, pike, and Arctic grayling (Lagimodiere and Eaton 2009). Contributing to the decline was fragmentation of the stream network as hanging culverts became more prevalent due to increased road density. Relative to BAU, best practices reduced stream network fragmentation through improved culvert maintenance and reduced road density. As a result, the decline in INFI was not as sharp in the best practice simulation. Even with best practices, however, the fish community was well below natural conditions, largely due to angling pressure that increased as the region’s population grew.

The failure of fishing regulations to sustain northern Alberta fisheries is due to both the region’s cold climate and the high angling pressure. Cool temperatures result in a low productivity fishery that requires more than 10 years to produce large fish. Angling pressure is two orders of magnitude higher than fisheries in other Canadian provinces such as Saskatchewan, Manitoba, and Ontario due to the rapidly growing human population and the relatively small number of lakes (Sullivan 2003). When access management was simulated, INFI improved dramatically due to a drop in angling pressure (Figure 8-10). The dramatic response of INFI to human access is consistent with boreal fishery research (Post et al. 2002, Sullivan 2003) and emphasizes the susceptibility of the region's fisheries to angling pressure. Simulated future status of INFI differed substantially across watersheds, reflecting differences in fragmentation and, especially, angler access (Figure 8-11). Watersheds with low human population density, such as the far north, or high access management were simulated to support more intact fish communities.

In addition to disturbing landscapes, oil sands production emits a variety of pollutants. Oil sands CO_2 emissions intensity is greater than that of conventional oil, primarily because more energy is required during refining. The high emission intensity combined with rapidly escalating production makes the oil sands a significant contributor to greenhouse gas (GHG) emissions. Today's emissions of approximately 40 megatonnes CO2-equivalent (Mt CO2-e) accounts for 5% of Canada's GHG emissions of 747 Mt CO2-e in 2007 (Environment Canada 2007). Due to continued growth in oil sands production, CO_2 emissions were simulated to more than triple within the next 25 years, and then gradually decline as production diminishes. Peak simulated emissions of 130 Mt CO2-e accounts for almost one quarter of Canada's Kyoto target of 558.4 Mt CO2-e, emphasizing that controlling oil sands GHG emissions represents a substantial challenge. The government of Alberta estimates that emissions intensity can be reduced by almost half using strategies that are within technological and economic constraints. Implementing these practices reduced peak GHG emissions to just over 60 Mt CO2-e. While this is an obvious improvement compared to existing practices, it still represents a 50% increase in GHG emissions relative to today. More ambitious emissions intensity efforts (Raynolds et al. 2006) or reduced production or both may therefore be required if oil sands production is to be within the bounds of an increasingly carbon-constrained world.

Other emissions of concern are potential acid inputs such as sulphur dioxide and nitrous oxides due to their contribution to acid deposition. The study area contains waters that are susceptible to acidification due to the low alkalinity of some lakes located in the Canadian Shield and upland northern areas (Trew 1995). Acidification can be very detrimental to aquatic ecosystems, in severe cases leading to large reductions in species diversity (Schindler et al. 1985). Nitrous oxide and sulphur dioxide emissions were projected to almost double in the BAU simulation. At their peak, projected nitrous oxide emissions exceeded the 86,000 tonnes/year preliminary regional threshold for nitrous oxides by approximately 100%. Although best practices were able to reduce substantially simulated nitrous oxide emissions, the emission threshold was still surpassed by 30,000 tonnes/year. It would therefore appear that lakes in the region might be at risk of acidification due to projected growth in oil sands production.

Bitumen extraction in the region is likely to increase rapidly, in part to fill the production gap caused by declining conventional reserves. Landscape disturbance, human access, and emissions associated with projected rates of production would contribute to continued decline in regional fish and wildlife populations and increased greenhouse gas emissions. Application of best practices has the potential to reduce substantially disturbance and emission intensities. Results from simulations demonstrate, however, that the reduction was insufficient to avoid declines in wildlife due to the rapid escalation of production. Access management was highly successful at improving INFI, emphasising the need to limit angling pressure if the region’s fish populations are to recover. Access management was modestly successful for improving the status of black bear, moose, and wolverine, but did not contribute meaningfully to maintenance of regional caribou populations. In the next section, we consider the potential role that conservation areas could play in mitigating regional impacts to wildlife.

The Role of Conservation Areas

Even in the presence of aggressive efforts to minimize impacts, disturbance caused by bitumen development in the region will be substantial. Allocating a portion of the landscape to conservation is a potential mechanism for offsetting at least some of the impacts on wildlife. Protected areas can contribute to regional conservation goals by representing ecological community types, preserving rare features, maintaining habitat for species negatively affected by development, and providing examples of natural ecosystem function. Existing protected areas networks are typically inadequate to achieve these goals (see also Czech 2005, Dietz and Czech 2005). Twelve percent of the world's landscapes are protected (Chape et al. 2003), yet representation of all species and ecosystem types in a region typically requires substantially higher levels of protection, typically 25-75% (Noss and Cooperrider 1994). Although protected areas presently cover only seven percent of the LARP region, the government has expressed its intent to increase protection to at least 20% of the region. This is consistent with the region's multi-stakeholder Cumulative Environmental Management Association that recommended 20-40% of the region be set aside for conservation (SEWG 2008).

To assess the potential contribution of increased protection, we considered design requirements of conservation areas to improve on the goals of representation and ecological benchmarks. Maintaining representative examples of ecological community types is a coarse-filter approach to conservation planning that is based on the assumption that conserving the range of native community types will also conserve the majority of species. Although this assumption is largely untested, representation remains the only practical strategy for identifying conservation areas that potentially represent a region's biodiversity. Ecological benchmarking refers to the concept of maintaining examples of natural ecosystems to provide controls for management experiments needed to develop knowledge for sustainable management (Schmiegelow et al. 2006).

While beneficial for conservation goals, ecosystem protection reduces availability of resources for economic growth. Protection can therefore come into conflict with socioeconomic goals. We evaluated the economic implications of an expanded conservation areas network by assessing the degree to which bitumen reserves would be made inaccessible. Efforts were made to balance economic and ecological objectives by minimizing the presence of bitumen reserves within protected areas. This is consistent with the triad land use zoning strategy that seeks to overcome conflict between ecological and economic objectives by dividing a region's land base into three categories: mixed-use (also referred to as extensive), protection, and intensive-use. High resource production generated by the intensive-use component of the landscape makes up for the drop in production caused by protection and ecosystem-based management practices. The triad was developed as a strategy to maintain timber supply through forest plantations while increasing the use of sustainable forestry practices and protected areas on the remainder of the landscape (Hunter 1990). The zoning strategy is equally applicable to the production of other commodities from the forestland base including fuel (Hunter 2002), and is potentially well suited to the LARP region due to the intensive nature of bitumen development and the aggregated distribution of bitumen deposits (Figure 8-12). The triad has been proposed as a strategy for balancing the region's ecological and economic objectives (SEWG 2008).

We adopted a 30% representation goal of each the study area's eight natural subregions and fourteen land cover types. Natural subregion is a coarse level of ecosystem classification characterized by vegetation, climate, elevation, and latitudinal or physiographic differences (Natural Regions Committee 2006). Land cover reflects the finer scale mosaic of forest, wetland, and aquatic ecosystem types that occur across the study area. Exploratory analyses determined that using natural subregions and land cover types as representation attributes struck a suitable balance between ecological detail and economic cost. Thirty percent was selected as the representation target because it is the mid-point of the 20-40% protected area goal recommended for the region by the Cumulative Environmental Management Association (SEWG 2008). A conservation areas network satisfying the representation goals was designed using MARXAN, software that applies optimization to select a conservation area network that achieves representation targets at the least cost (Ball and Possingham 2000, Possingham et al. 2000). The analysis used 10 km^2 cells (townships) as building blocks for the conservation areas network, and forced MARXAN to include existing protected areas and exclude areas that are heavily disturbed (greater than 10% converted). The conservation area design with the lowest cost identified by MARXAN (Figure 8-13) achieved the 30% representation goals at a cost of excluding 3.7% of bitumen volume from development. It is therefore apparent that protecting a substantial and representative portion of the planning region to safeguard regional biodiversity from future development can be achieved at low economic cost. The exception is the southern-most natural subregion, which is already too disturbed by agriculture to make the 30% representation goal feasible.

To identify potential ecological benchmarks in the planning region we collaborated with the Canadian BEACONs Project (BEACONs), a research initiative led by Dr. Fiona Schmiegelow of the University of Alberta that is focused on developing conservation area strategies that provide ecological benchmarking capacity to facilitate adaptive management of boreal ecosystems. To function as an ecological benchmark, a conservation area should be representative of the natural conditions of the region, free from human activities that interfere with ecological processes, and large enough to capture ecological processes and maintain all species in the presence of the fire regime (Canadian BEACONs Project 2008). Of these characteristics, size is typically the most constraining requirement and the majority of existing conservation areas are too small to act as ecological benchmarks. To act as an ecological benchmark, a conservation area should be larger than the maximum expected natural disturbance to provide internal recolonization sources. The planning region's largest conservation area (200,000 ha) is substantially smaller than the maximum fire size (500,000 ha), underscoring the need to improve benchmarking capacity.

To consider strategies for improving the benchmarking capacity of the conservation areas network, BEACONs identified candidate benchmarks in the planning region using the Benchmark Builder (Version 15). The Benchmark Builder is software designed to automate the design of candidate ecological benchmarks in Canada's boreal forest. When designing candidate benchmarks, the Benchmark Builder considered hydrologic connectivity, landscape intactness, size, and biophysical representation. Hydrologic connectivity and landscape intactness were assessed to identify areas with intact aquatic and terrestrial ecosystems whereas size was assessed to identify areas that were larger than the maximum fire size. Candidate ecological benchmarks identified by the Benchmark Builder were then compared in terms of overlap with bitumen reserves and representation of natural subregions in order to consider compatibility with other conservation area objectives, for example, minimizing cost and ecological representation. The analysis determined that the option best able to provide benchmarking capacity at minimum cost while also contributing to natural subregion goals was creation of two nearby protected areas that spanned a total of 1,156,518 ha (10.9% of the region) and contained 2.0% of the region's bitumen. As was the case with representation goals, we therefore conclude that expanding the conservation areas network to improve ecological benchmarking capacity should not be cost-prohibitive.

To summarize, we were able to identify options for expanding the conservation areas network that would protect 30% of each natural subregion and land cover type and establish ecological benchmarks, while excluding only a small portion of the region's bitumen from extraction. We conclude that increasing the conservation areas network is a cost-effective strategy for safeguarding regional biodiversity from increased disturbance that can be expected with accelerated bitumen extraction. The viability of a large protected areas network in the presence of continued bitumen extraction is due to the aggregated distribution of bitumen that permits the establishment of large protected areas that have minimal overlap with bitumen reserves. It is important to note that this compatibility would not hold if the conservation areas network was designed to maintain viable caribou herds. Caribou herds in the region overlap with bitumen deposits and, as a result, are at risk to future development. Maintaining caribou in the region beyond the next couple of decades requires aggressive actions including: the establishment of large (thousands of square kilometres) caribou conservation areas where the rate of development (including bitumen extraction) is strictly controlled; rapid reclamation of existing footprint; and a long-term wolf control program to limit predation (Athabasca Landscape Team 2009). Other ecological impacts will similarly not be addressed through protection alone, such as emissions that contribute to greenhouse gas concentrations and acid deposition. It is therefore apparent that some impacts on expanded bitumen extraction cannot be avoided through management practices or the establishment of cost-effective conservation areas. These unavoidable tradeoffs between ecological integrity and economic activities represent the greatest challenge facing land use planning in the region. Required is a societal decision regarding the appropriate balance between economic growth and ecological sustainability.

Planning Land Use to Balance Hydrocarbon Development and Wildlife Conservation

The oil sands and their development trajectory remain a controversial issue at local, regional, provincial, national, and international scales. Much has been written (see Nikiforuk 2008 and Kelly 2009 for an overview) about the potential for Alberta's bitumen-based hydrocarbons to contribute to the North American fuel stock, to sustain Alberta's and Canada's economy, to reduce North American dependency on Middle East oil, and its environmental footprint and relatively "dirty" image in comparison to other energy alternatives.

Given that the majority of Alberta's bitumen is currently destined to a UNITED STATES market, UNITED STATES policies (and related market demand and pricing) will weigh heavily on the pace and tempo of bitumen production in Alberta. Recent policy initiatives emerging in the U.S., such as California's Low Carbon Fuel Standard (LCFS), that requires an assessment of the full life cycle carbon intensity of alternative fuel stocks, may influence the attractiveness of Alberta's oil sands to the United States from both an investment and commodity importation perspective. Market demand for future bitumen is further obscured by the emergence of offshore markets, such as the recently announced Enbridge Northern Gateway Project that would move Alberta's bitumen by pipeline to coastal British Columbia, and subsequently by super-tankers to Asian markets, such as China. As such, a potential loss or reduction in United States market demand for bitumen would certainly have a large impact on Alberta's oil sand play, but this theoretical reduction might be offset by new offshore markets.

From a land use perspective, Alberta's supercharged economy has spawned a host of related issues and challenges at all spatial scales. A province that only a few decades back was perceived as vast with few people is now viewed as small and crowded with conflicting land use objectives and disgruntled land use players.

Against this backdrop, the Alberta government has embarked on an ambitious initiative of regional planning called the Alberta Land-use Framework (ALUF). This integrated planning process, mandated by the recently enacted Alberta Land Stewardship Act, has numerous objectives that focus on creating a strategic vision of land use trajectories that balance economic, social, and environmental objectives in Alberta. This new legislation is omnibus in nature, and effectively trumps other Acts that may be in conflict with its intent. Rather than tackling the entire province as one geographic unit, the ALUF has stratified the province into seven regions that are broadly based on regional watersheds and municipal boundaries. The initial stratum examined by the ALUF is the Lower Athabasca Regional Plan, a region that contains the majority of bitumen deposits in Alberta.

Guided by goal-posting directives from Alberta's Cabinet, each ALUF region completes its work using a Regional Advisory Council (about a dozen individuals representing major stakeholder groups) and a Regional Planning Team comprised of government employees providing disciplinary expertise. This work is overseen by the Land-use Secretariat. As their title suggests, the primary goal of the Lower Athabasca Regional Plan is to construct a plan that can be submitted to Cabinet for consideration and, hopefully, approval and implementation. The primary objectives of the plan include (Morris Seiferling, Director of Alberta Land-use Framework, personal communication):

- A strategic level plan for land and natural resource use on public and private lands that defines regional outcomes for economic, environmental and social indicators
- An alignment of provincial strategies and policies at the regional level
- A determination of specific trade-offs and appropriate land and natural resource management for each region
- A quantitative description of the cumulative effects of the combined land use trajectories and the identification of specific thresholds and targets for key indicators

The wording of the Alberta Land Stewardship Act and the ALUF indicate a commitment of the Government of Alberta to adopt an integrated approach to resource stewardship. Examples of integrated approaches include integrated resource management (IRM), integrated environmental management, integrated catchment management, watershed management, bioregional planning, and integrated landscape management. These various monikers all share a common approach characterized by a proactive, holistic, systems-based, and integrated approach to environmental problems.

While numerous definitions of integrated resource management exist, the description offered by Cairns and Crawford (1991) is directly relevant to the goals of the ALUF:

"*Coordinated control, direction or influence of all human activities in a defined environmental system to achieve and balance the broadest possible range of short- and long-term objectives*."

For the ALUF to achieve a reasonable level of success, four essential characteristics that distinguish proper Integrated Resource Management (IRM) from "reactionary" management will need to be respected. These elements are drawn from Wikipedia's description of IRM prepared by Carlson and Stelfox (http://www.eolss.net/).

1. ***Inclusive***. IRM considers the broad spectrum of ecological, social, political, and economic factors and large spatial and temporal scales that define environmental issues. In contrast to mono-disciplinary management approaches such as sustained yield, IRM demands a multidisciplinary approach that engages diverse perspectives and skill sets. Decision-making is a collaborative process involving the public. There exists an explicit recognition that empirical science alone cannot lead to a solution, but rather that a society informed by science can better arrive at optimal land use trajectories.

2. ***Interconnective***. IRM evaluates how different components of ecological and human systems interact. This system dynamics approach recognizes that ecosystems are complex systems with emergent properties that cannot be ascertained through reductionism and that, as a result, environmental problems cannot be solved by compartmentalization.

3. ***Goal-oriented***. IRM is goal-oriented and proactively plans for a desired state. The goals are typically broad and defined through a collaborative process involving diverse stakeholders. The goal-setting process therefore not only fosters a proactive perspective, but also inclusivity and broad ownership in planning outcomes.

4. ***Strategic***. Goal setting also focuses attention on key elements of the system of concern. This focus is needed to address strategically environmental issues amongst the complexity and uncertainty of environmental systems. IRM’s strategic approach is adaptive and intentionally seeks to improve knowledge of the ecological and social effects of land use. At the same time, IRM is precautionary to limit the risk of unanticipated and undesirable impacts.

Given the early stages of the ALUF, it is premature to comment on how well it will serve Albertans in defining and implementing sustainable land use trajectories for the seven regions.

The Government of Alberta should be applauded for launching this initiative, but stakeholders (public, government, industry) have yet to learn the full extent of tough decisions that attend a well-crafted integrated land use plan.

It is clear, however, that the Government's highest priority for the LARP is the extraction of bitumen. Work completed to date by LARP confirms that historical bitumen production, in concert with forestry and other land uses, have significantly compromised the performance of selected ecological indicators, and that increased levels of bitumen production will lead to further reductions in performance. Some of this risk to ecological indicators can be mitigated through the adoption of industrial best practices, the implementation of access management policies, and the designation of an expanded network of protected areas. The balance between bitumen production and resource revenues, on the one hand, and the integrity of ecosystems on the other, has not yet been determined but is the topic of much dialogue within LARP.

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Tables

Table 8-1. Best practices included in land use simulations.

Best practice	Description (values in parentheses represent BAU, realistic BP, and optimistic BP, respectively)
Minimize energy sector footprint	Greater dependency on directional drilling, in order words, placing more wells on a single pad (10, 17, 25 wells/pad)
	Develop pipelines along road corridors to reduce overall footprint (20%, 40%, and 60% of pipeline footprint overlapping with roads)
	Periodic reclamation of old seismic lines (0%, 5%, and 10% of existing seismic lines every 5 years)
	Minimize the width of new seismic lines to accelerate reclamation time (21, 10, and 2 year lifespan)
	Accelerated reclamation of well pad after production has ceased (10, 5, and 0 year reclamation lag)
	Accelerate reclamation of surface mines after production has ceased (10, 5, and 0 year reclamation lag)
Minimize forestry sector footprint	Accelerate in block road reclamation after timber harvest (10, 7.5, and 5 years reclamation lag)
	Larger cut blocks to reduce road requirements

Table 8-1. Continued.

Best practice	Description (values in parentheses represent BAU, realistic BP, and optimistic BP, respectively)
Maintain older forest	Avoid harvesting some older stands to maintain older forest (older forest targets of 0, 9%, and 18% of merchantable forest). Attempt to offset timber supply cost of old forest protection through in genetic improvement and increased utilization standards (0, 5%, and 10% increase in merchantable timber volume)
Hung culvert replacement	Remove and replace hung culverts (2, 5, and 10% annual replacement of hung culverts)
Emissions reduction	Reduce CO_2 emissions by the mineable bitumen sector (0.55, 0.40, and 0.25 tonne/m^3 bitumen production) Reduce CO_2 emissions by the in-situ bitumen sector (0.535, 0.405, and 0.275 tonne/m^3 bitumen production) Reduce NO_x emissions associated with bitumen production (0.000693, 0.000589, 0.000485 tonne/m^3 bitumen production)
Water conservation	Reduce net water consumption by the mineable bitumen sector (2.5, 2.15, 1.75 m^3/m^3 bitumen production) Reduce net water consumption by the in-situ bitumen sector (7.4, 5.0, 2.7 m^3/m^3 bitumen production)

Figures

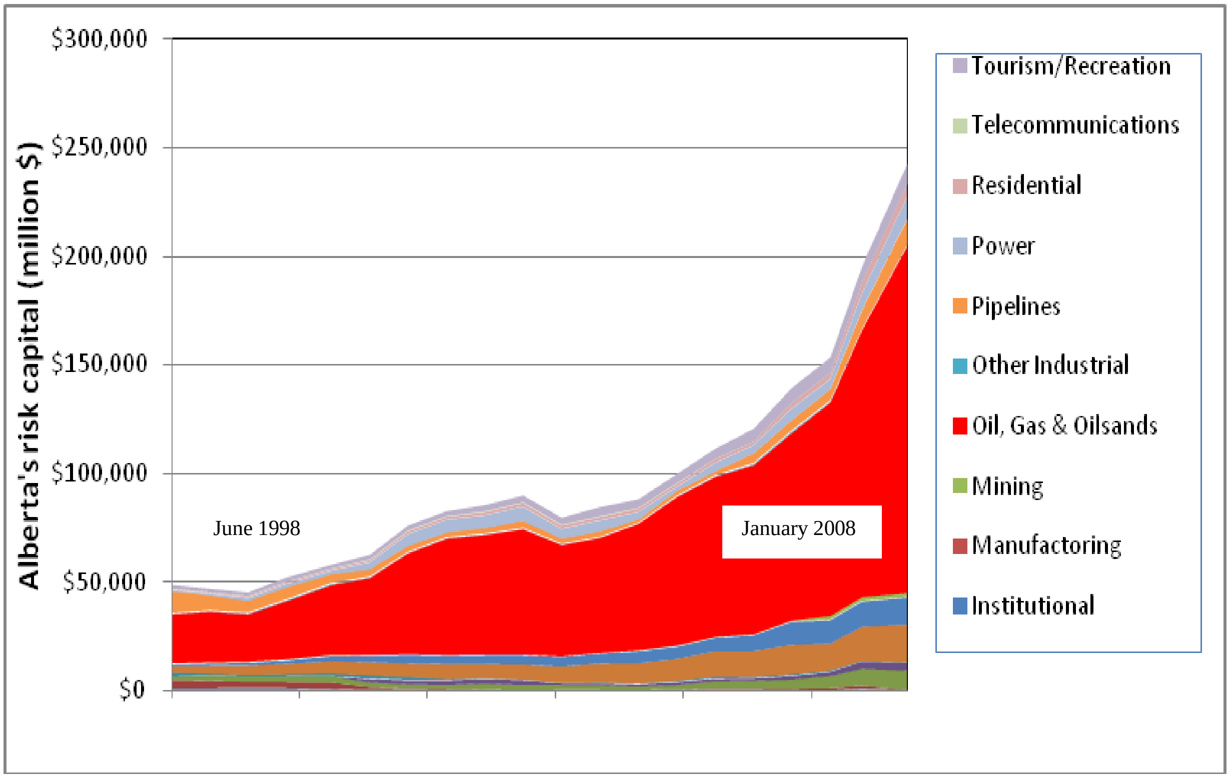


Figure 8-1. Alberta’s risk capital by sector between 1998 and 2008.

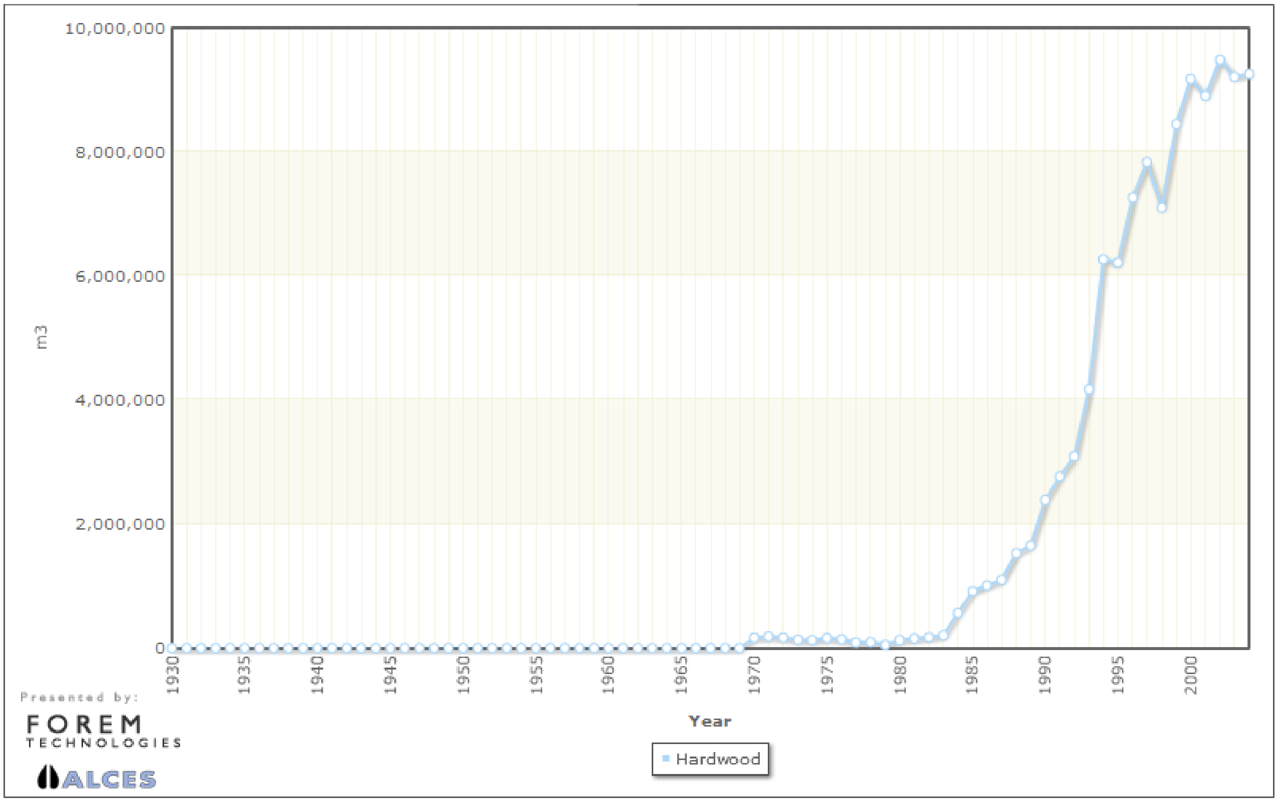


Figure 8-2. Temporal trend in annual hardwood harvest in Alberta. The annual allowable harvest volume of Al-Pac in northeast Alberta represents the single largest allocation in Alberta at 3.5 M m^3/year.

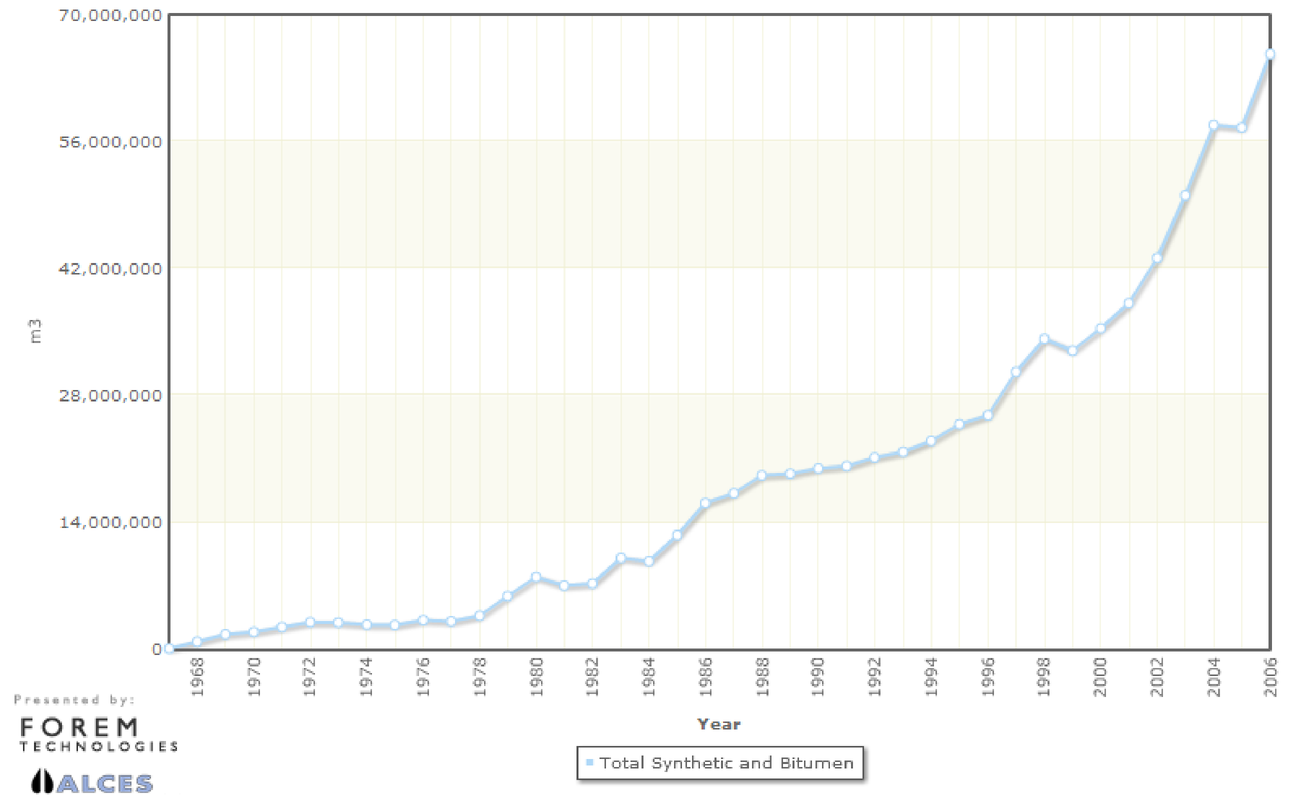


Figure 8-3. Temporal trend in bitumen (synthetic and raw) in Alberta. The majority of bitumen is produced in northeast Alberta from the Athabasca and Cold Lake deposits.

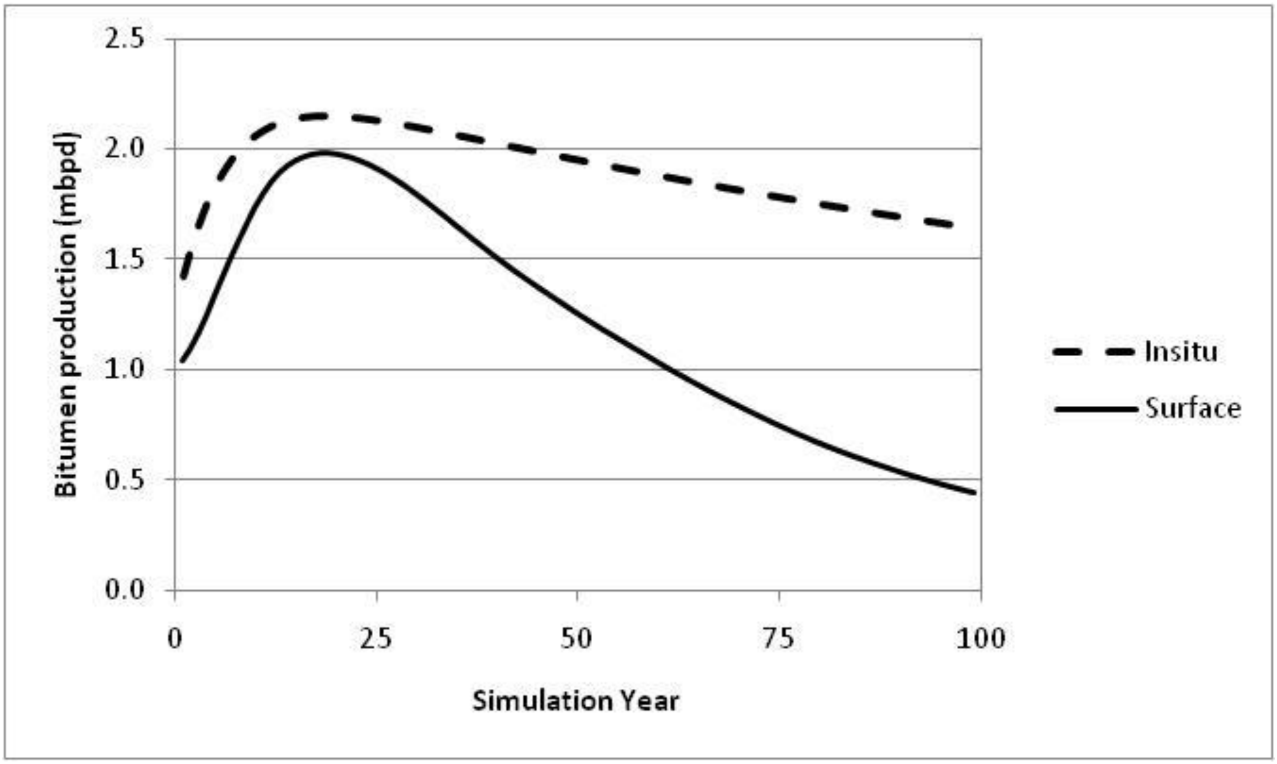


Figure 8-4. Projected annual in-situ and mineable bitumen production from the study area over the next 100 years.

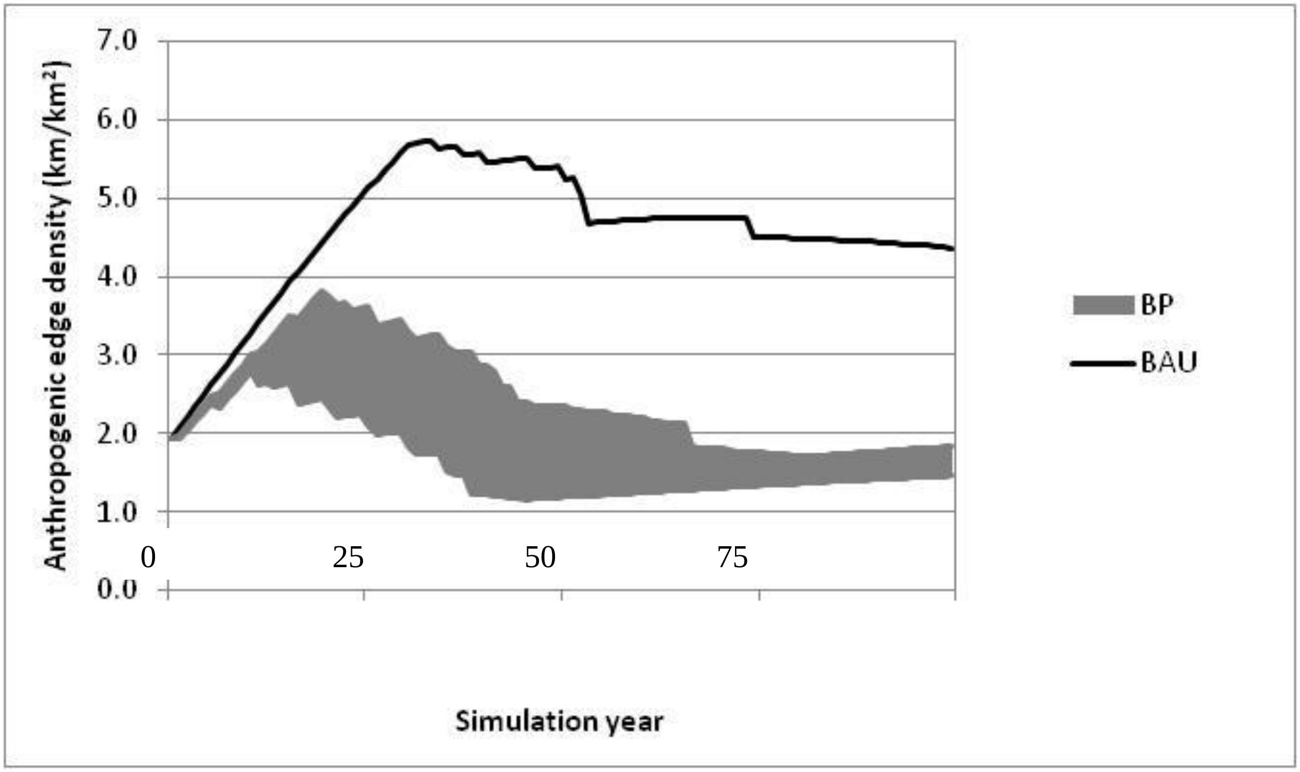


Figure 8-5. Simulated anthropogenic edge density in the study area over the next 100 years under business as usual practices (BAU) and best practices (BP) land-use scenarios in ALCES. Best practices are presented as a band to reflect the range in indicator response associated with realistic to optimistic implementation of the best practices.

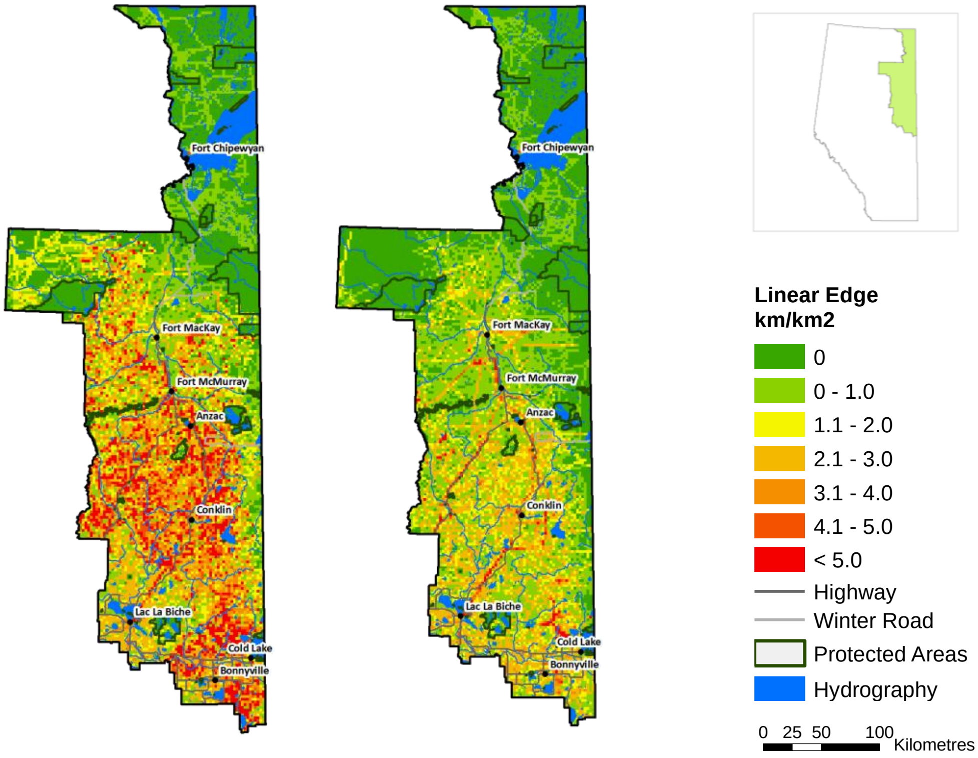


Figure 8-6. Anthropogenic edge density at simulation year 60 under business as usual (left) and high best practices (right) scenarios.

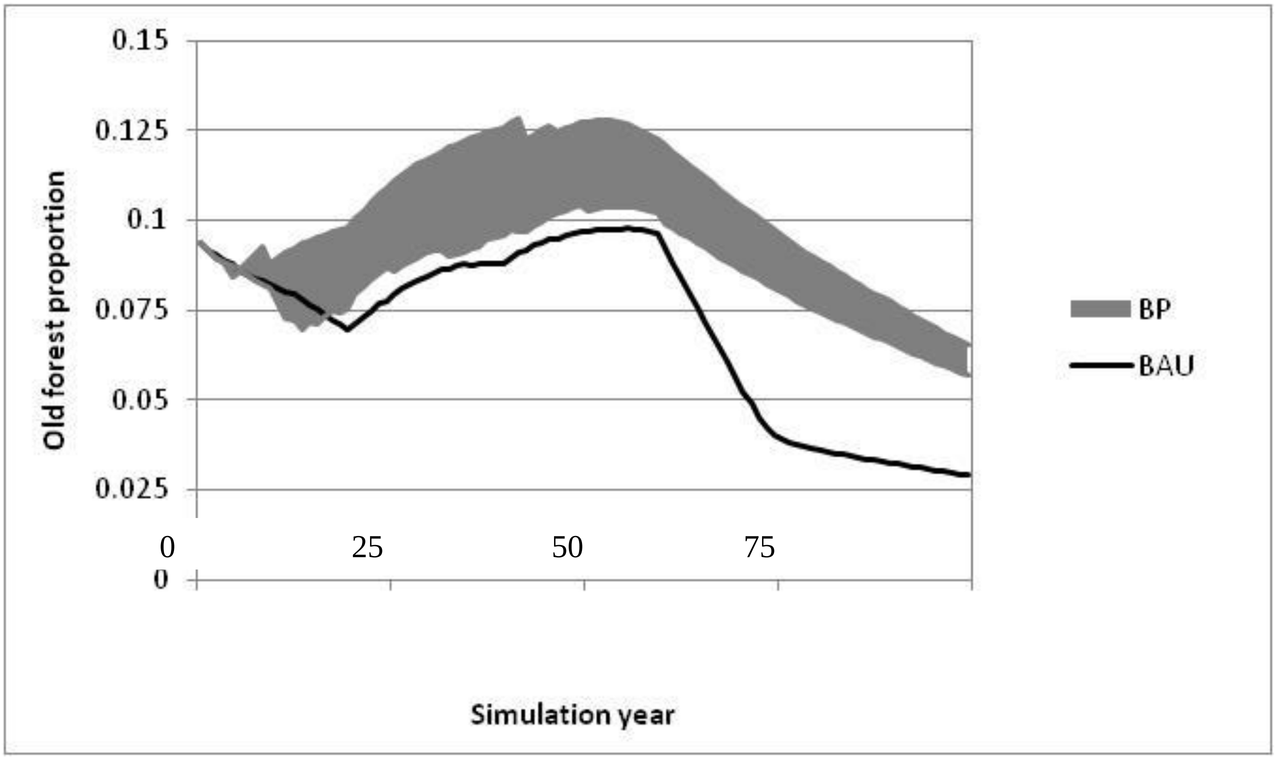


Figure 8-7. Simulated proportion of forest that is older than 120 years in the study area over the next 100 years under business as usual practices (BAU) and best practices (BP) land-use scenarios in ALCES. Best practices are presented as a band to reflect the range in indicator response associated with realistic to optimistic implementation of the best practices.

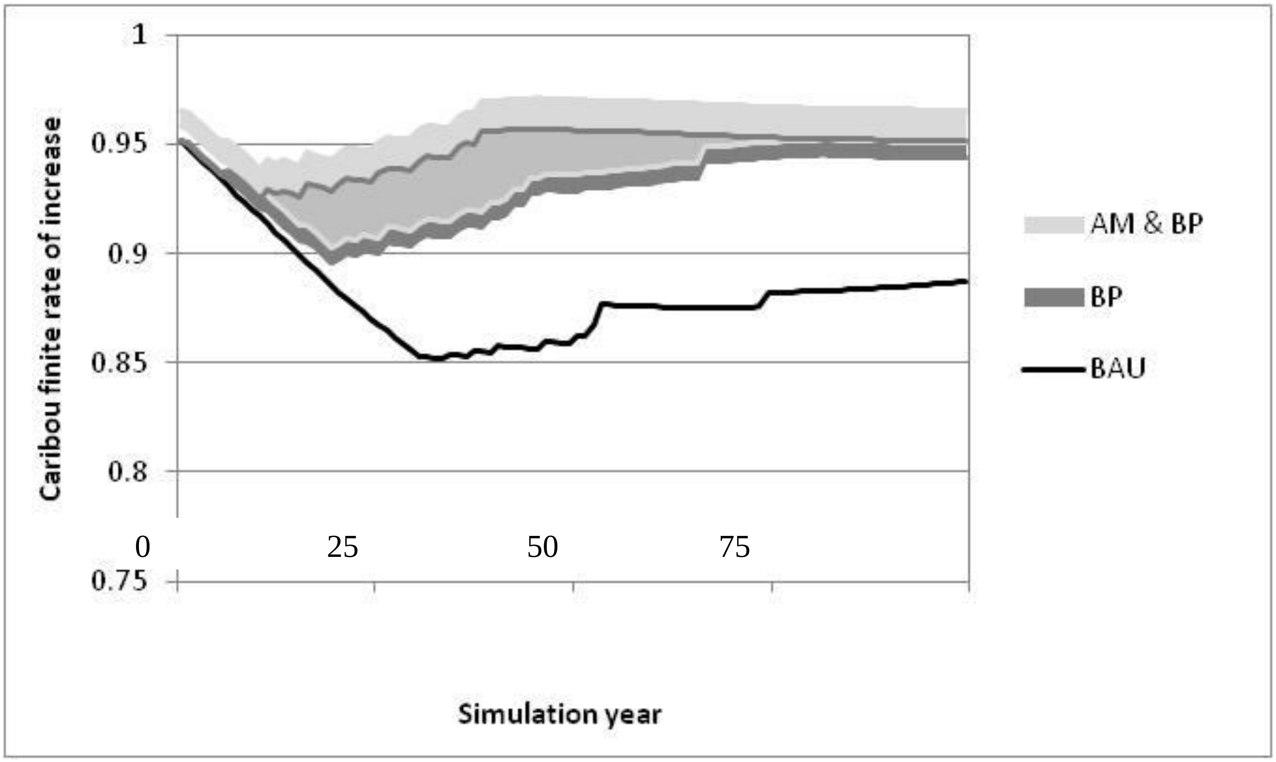


Figure 8-8. Simulated caribou finite rate of increase area over the next 100 years under business as usual practices (BAU), best practices (BP), and access management plus best practices (AM & BP) land-use scenarios in ALCES. BP and AM & BP are presented as bands to reflect the range in indicator response associated with realistic to optimistic implementation of the mitigation strategies.

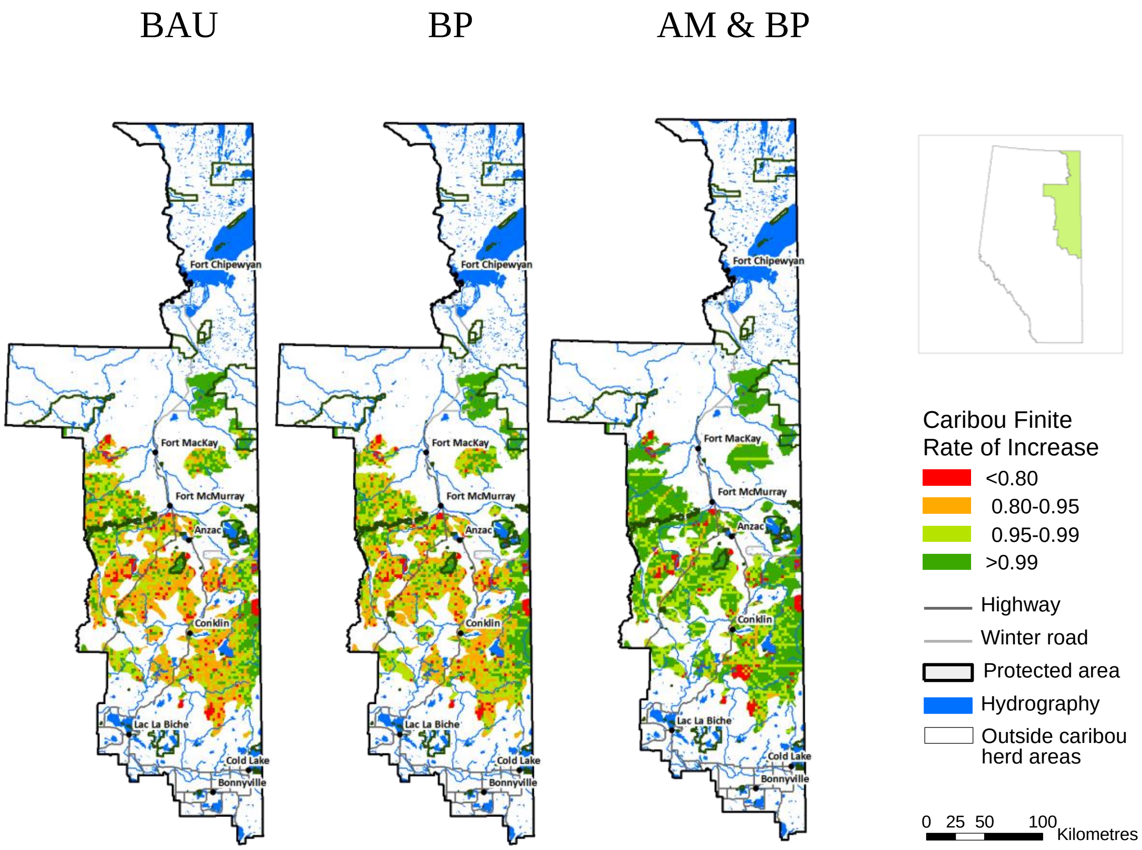


Figure 8-9. Caribou finite rate of increase across the study area at simulation year 60 under business as usual (BAU), high best practices (BP), and high access management and high best practices (AM & BP) scenarios. Herd areas are from the University of Alberta ILM Lab (2008).

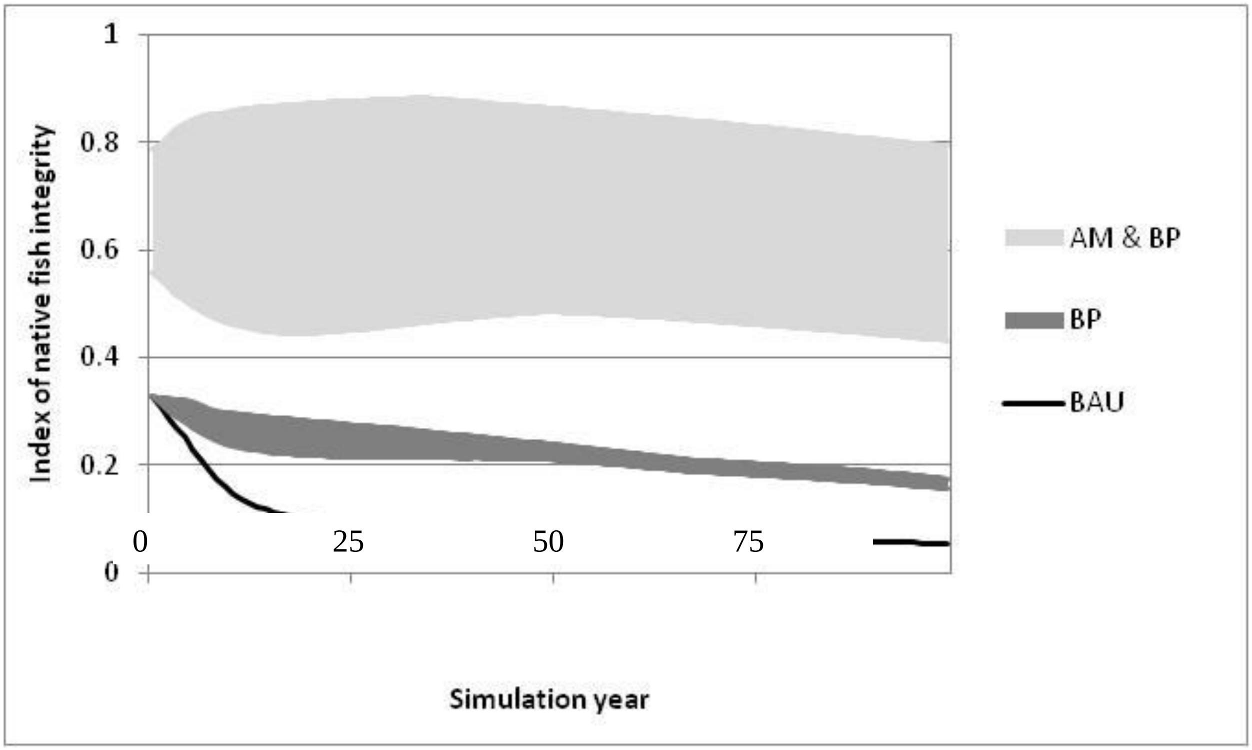


Figure 8-10. Simulated index of native fish integrity over the next 100 years under business as usual practices (BAU), best practices (BP), and access management plus best practices (AM & BP) land-use scenarios in ALCES. BP and AM & BP are presented as bands to reflect the range in indicator response associated with realistic to optimistic implementation of the mitigation strategies.

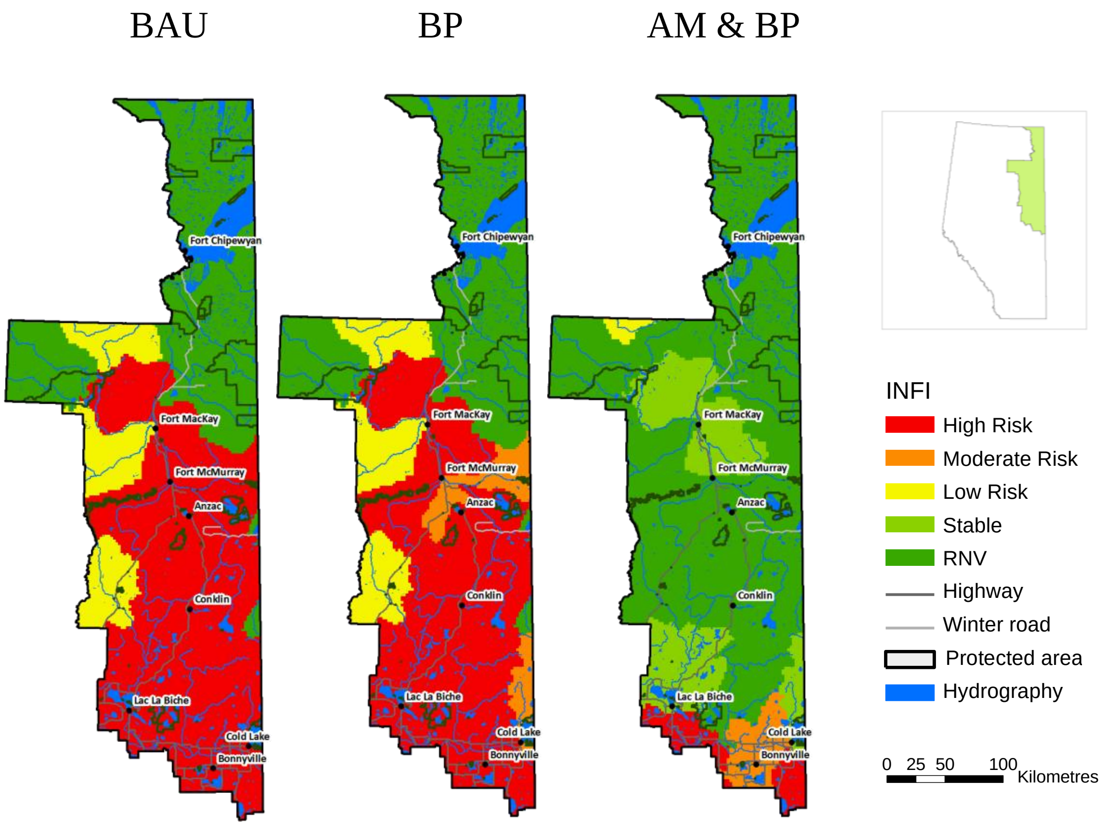
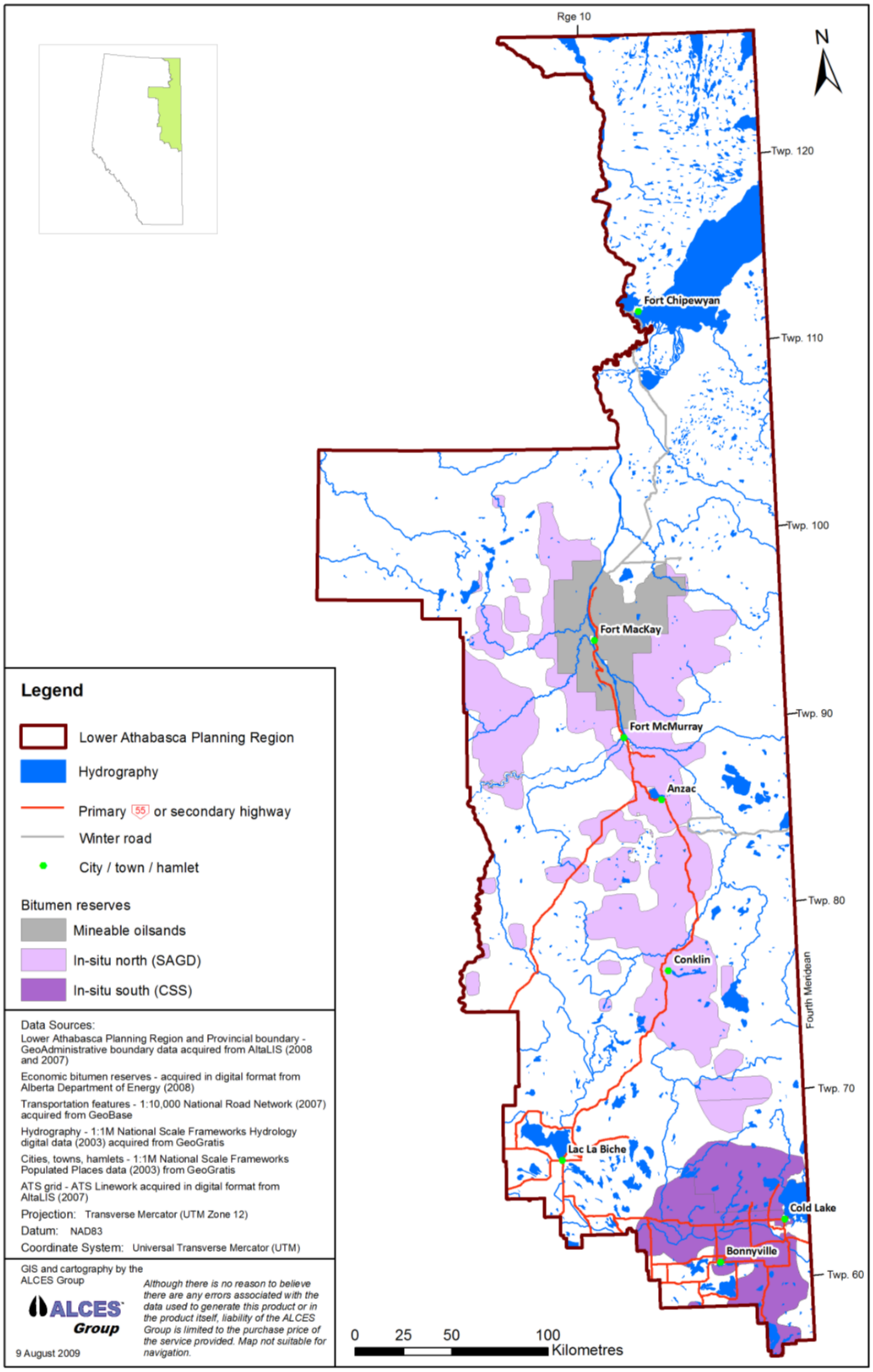


Figure 8-11. Status of the index of native fish integrity (INFI) across the study area at simulation year 60 under business as usual (BAU), high best practices (BP), and high access management and high best practices (AM & BP) scenarios.



Data Sources:

Lower Athabasca Planning Region and Provincial boundary - GeoAdministrative boundary data acquired from AltaLIS (2008 and 2007)

Economic bitumen reserves - acquired in digital format from Alberta Department of Energy (2008)

Transportation features - 1:10,000 National Road Network (2007) acquired from GeoBase

Hydrography - 1:1M National Scale Frameworks Hydrology digital data (2003) acquired from GeoGratis

Cities, towns, hamlets - 1:1M National Scale Frameworks Populated Places data (2003) from GeoGratis

ATS grid - ATS Linework acquired in digital format from AltaLIS (2007)

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

GIS and cartography by the ALCES Group

Although there is no reason to believe there are any errors associated with the data used to generate this product or in the product itself, liability of the ALCES Group is limited to the purchase price of the service provided. Map not suitable for navigation.

Figure 8-12. In-situ and mineable oilsands deposits in the study area.

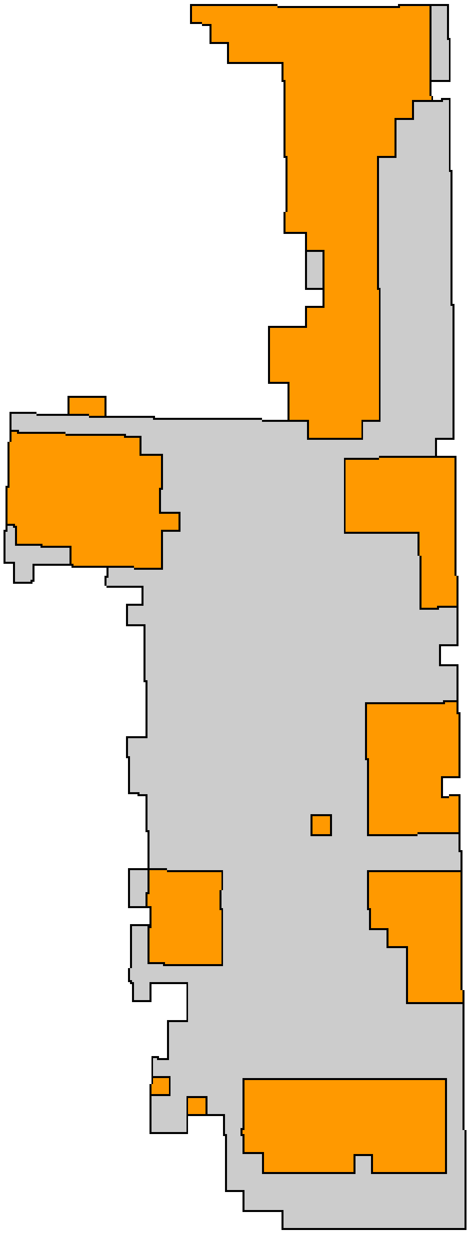


Figure 8-13. Least cost conservation area network (orange) identified using MARXAN for representing 30% of each natural subregion and land cover type.