Chapter 11
Alberta Oil Sands Development and Risk Management of Canadian Boreal Ecosystems

Matthew Carlson and J. Brad Stelfox

The bitumen (oil or tar sand) deposits of Northeast Alberta, Canada, 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 USA make Alberta's oil sands perhaps the most attractive unconventional oil deposit in the world. Recently, significant oil sand investment from China into Alberta has demonstrated the importance of Alberta's bitumen reserves as a strategic fuel source to emerging mega-economies. 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 US and Chinese risk capital to develop this resource (Fig. 11.1).

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. However, the high value of the resource and the region's stability should provide the economic and institutional ingredients needed to achieve high environmental standards that are needed to offset at least some of the environmental impacts. Indeed, access to key markets such as the USA 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 as mitigation tools. Ecological consequences of historical development are first chronicled to provide context. The ecological impacts of future anticipated development are then considered

M. Carlson (✉) · J. B. Stelfox
ALCES Group, PO Box 61196, Kensington RPO, Calgary, AB T2N 4S6, Canada
e-mail: mcarlson@alces.ca

J. B. Stelfox
e-mail: bstelfox@alces.ca

© Springer Science+Business Media New York 2014
J. E. Gates et al. (eds.), *Peak Oil, Economic Growth, and Wildlife Conservation,*
DOI 10.1007/978-1-4939-1954-3_11

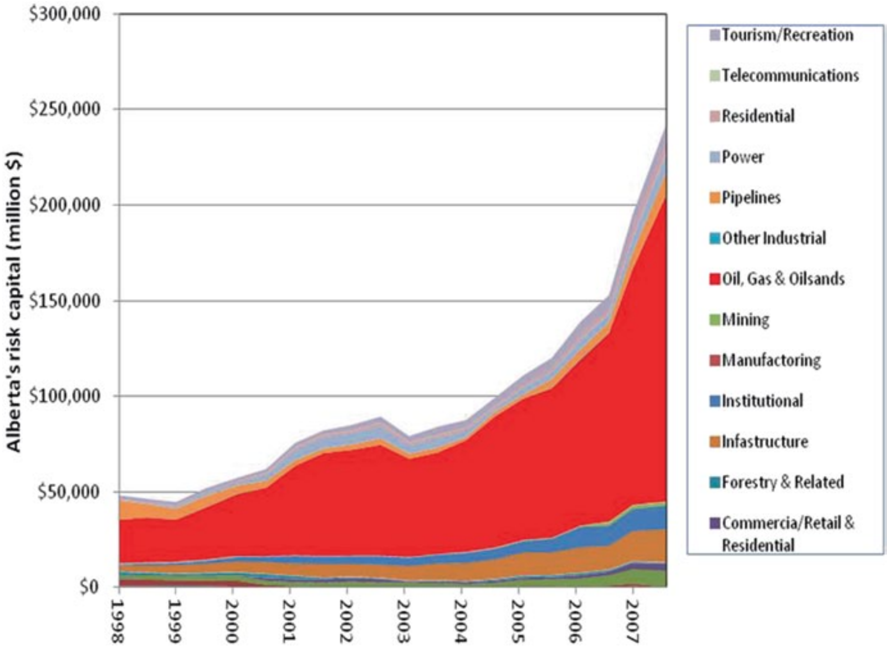

Fig. 11.1 Risk capital allocated by sector and years 1998–2007 in Alberta, Canada

using outcomes from the ALCES© land-use simulation tool (www.alces.ca). The potential roles of best practices and protected areas are also evaluated. 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, and we acknowledge the Alberta Land Use Secretariat (https://landuse.alberta.ca) for permission to present the results in this chapter. We conclude 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 findings of this chapter address the Lower Athabasca region of Northeast Alberta, an area that directly overlaps the Athabasca and Cold Lake bitumen deposits. The region is the first for which a land-use plan has been developed under the auspices of the Alberta Land Stewardship Act passed in 2009, and the boundary of the study area discussed in this chapter is the regional boundary adopted for the planning process. It is a region consisting of broad lowland plains and extensive hill systems, 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 (*Populus* sp.), balsam poplar (*Populus balsamifera*), birch (*Betula* sp.)) and coniferous (white spruce (*Picea glauca*), black spruce (*Picea mariana*), jack pine (*Pinus banksiana*)) forests intermixed with topographically depressed fen and bog complexes, scattered lakes, and main stem rivers (most notably the Athabasca River) and their tributaries characterize this bioregion. Temperatures are highly variable by season, with average maximum temperatures in the summer of 25 °C (77 °F), and average maximum winter temperatures of −15 °C (5 °F). Average minimum temperatures are 10 °C (50 °F) in the summer and −20 °C (–4 °F) in the winter. Average precipitation (1951–1980) is 450–500 mm (17.7–19.7 in) per 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 [25], 5 amphibians [33], 1 reptile [33], 236 birds [12, 37], and 45 mammals [29, 38]. Based on distribution maps [22, 42], 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, regional natural capital provides important ecosystem services, such as water resources, sequestered carbon, and climate regulation. The nonmarket ecological goods and services (EGS) for the MacKenzie River basin, which overlaps with the planning region, is estimated at $ 2631/ha (2.47 acres) per year [2]. 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 gross domestic product (GDP) associated with extraction and processing of bitumen.

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 (Figs. 11.2 and 11.3). A forestry tenure that overlaps with the region has an annual allowable cut of approximately 3.5 million m^3 (123.6 million ft^3) per year and about 2.7 million m^3 (95.3 million ft^3) per year of that full volume is harvested from the Lower Athabasca planning area.

It is difficult to quantify total volumes of bitumen "in place," but most sources provide estimates in the range of ~1804 billion barrels (287 billion m^3; [10]). Of this volume, existing technologies that are economically viable could remove ~170 billion barrels (27 billion m^3; [10]). 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. The current annual production of 1.74 million barrels per day (0.28 million m^3 per day) is expected to increase to 3.69 million barrels per day (0.59 million m^3 per day) by 2021 [10].

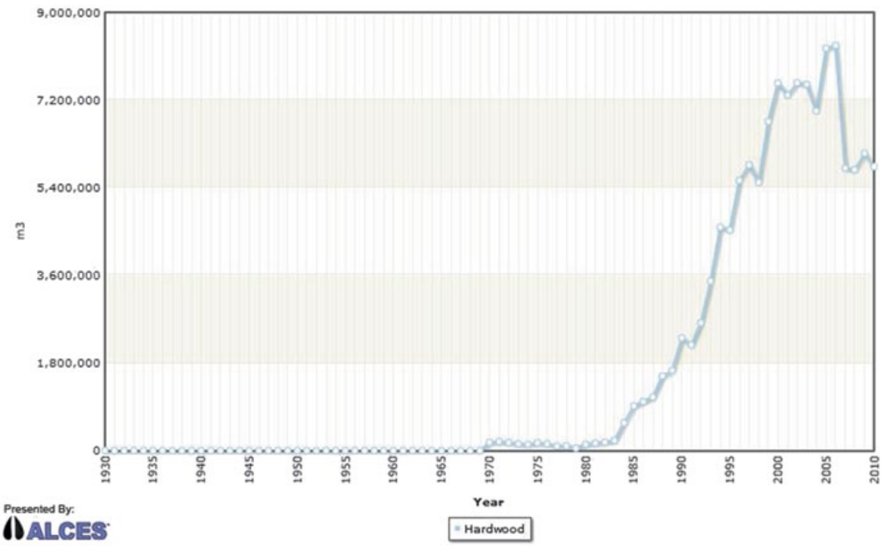

Fig. 11.2 An increase in annual hardwood harvest has occurred in Alberta, Canada, since the 1960s. The annual allowable harvest volume of Al-Pac in Northeast Alberta represents the single largest allocation in Alberta at 3.5 million m^3 (123.6 million ft^3) per year

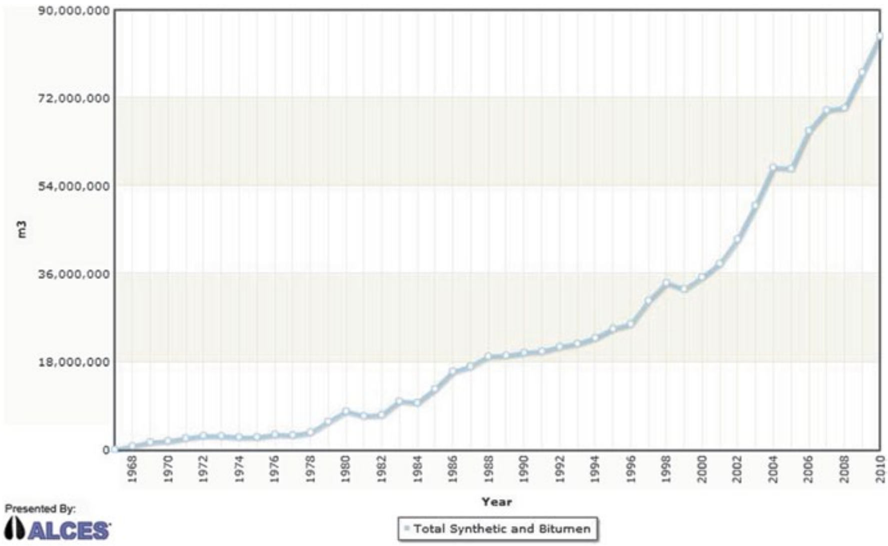

Fig. 11.3 An increase in bitumen (synthetic and raw) production has occurred in Alberta, Canada, since the 1960s. The majority of bitumen is produced in Northeast Alberta from the Athabasca and Cold Lake deposits. One cubic meter equals 35.3 ft^3

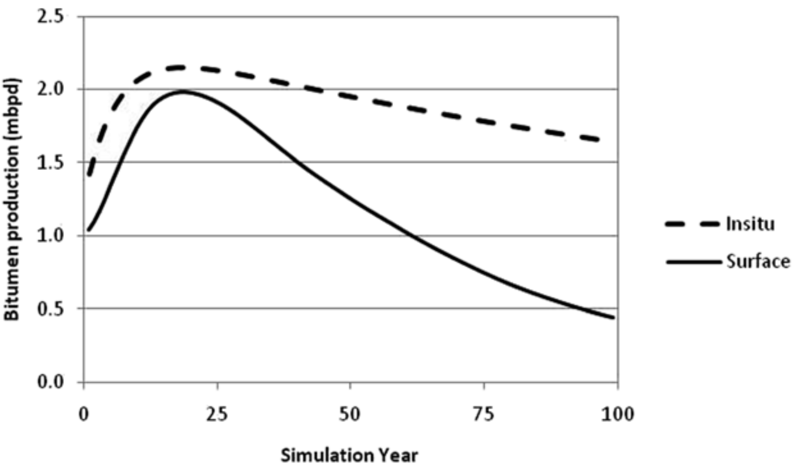

Fig. 11.4 Annual in situ and mineable bitumen production from the study area projected over the next 100 years

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 (Fig. 11.4). 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 habitat quality and quantity due to its industrial footprint [36] and reduced river flow [34], water contamination [14], wildlife mortality at tailings ponds [43], loss of biological carbon storage [20], increased CO_2 emissions [21], and acid rain [32].

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 wide 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 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 [1]: anthropogenic footprint, forest age, water consumption, woodland caribou, an index of fish community integrity, and carbon dioxide 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, transportation) 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 (35,908 $mile^2$) study area was quantified using inventories of plant community types, surface water, 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 [23]. Reserve sizes and production rates were based on government projections (Fig. 11.4), as were land-use footprint intensities (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 per year, 97.12 million ft^3 per year). 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 forest land-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 [44]. 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 predisturbance 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, 594,422 acres) will grow slowly over the next 50 years (approximately 100 ha (247 acres) per year) and increase more rapidly thereafter (approximately 500 ha (1236 ac) per year). Highways grew at a rate of 35 km (21.7 miles) per year, while secondary roads grew by an average of 31 km (19.3 miles) per year. In addition, roads required to access timber were assumed to cover 3 % of cut blocks and 0.5 km (0.3 mile) 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 [28]. 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. Public access facilitated by an expanding industrial footprint can increase angling and hunting pressure, activities that may contribute to fish and wildlife declines in the region [39]. 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 an exploration of 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 11.1). The effect of access management scenarios on fish and wildlife was based on the outcomes of workshops held with government biologists and wildlife managers [40]. Moderate and high access management 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 (INFI) were evaluated to consider impacts of land use on 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 [5]. A sustained λ value less than 1 implies eventual extirpation of caribou from the region. Based on caribou data from Alberta, the model estimates the relationship between λ and two attributes of landscape composition

Table 11.1 Best practices that were 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 other 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 life span)
	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-year reclamation lag)
	Larger cut blocks to reduce road requirements
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 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 metric ton/m^3 bitumen production)
–	Reduce CO_2 emissions by the in situ bitumen sector (0.535, 0.405, and 0.275 metric ton/m^3 bitumen production)
–	Reduce NO_x emissions associated with bitumen production (0.000693, 0.000589, 0.000485 metric ton/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)

BAU business as usual, *BP* best practices (linear features and forest younger than 30 years). Impacts of development on the fish community were assessed using the INFI, a measure that conveys changes in abundance and composition of fish species with a value ranging from 1 (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 [19].

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 companion mapping tool for ALCES that creates spatial representations that are informed by 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 increased with 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 to 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 resources 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 (Figs. 11.5 and 11.6). Another large landscape alteration apparent from the simulations was reduced abundance of older forest, a consequence of forestry activity in the region (Fig. 11.7) that was additive to the background fire rate. 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.

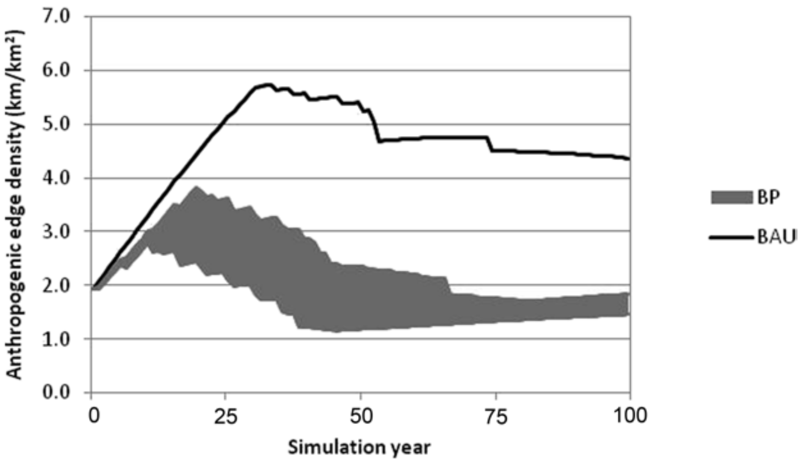

Fig. 11.5 Anthropogenic edge density simulated for the study area over the next 100 years under business as usual (BAU) practices and best practices (BP) land-use scenarios in ALCES. Best practices are presented as a band to reflect the range in indicator response associated with realistic to optimistic implementation of the best practices. One kilometer equals 0.6 mile; 1 km^2 equals 0.39 $mile^2$

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 concluded functional habitat was insufficient to maintain caribou in the region beyond two to four decades [3]. In the absence of best practices, λ was simulated to decline over the next quarter century and then to slowly recover (Fig. 11.8). The pattern mirrors the simulated trend in anthropogenic edge density (Fig. 11.5), demonstrating the influence of 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 [17]. Woodland caribou are susceptible to predation due to their low reproductive rate and relative 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 (Fig. 11.8). 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 at risk of extirpation 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 (Fig. 11.9).

As with caribou, the current landscape was estimated to support a degraded fish community relative to natural conditions. This assessment is consistent with

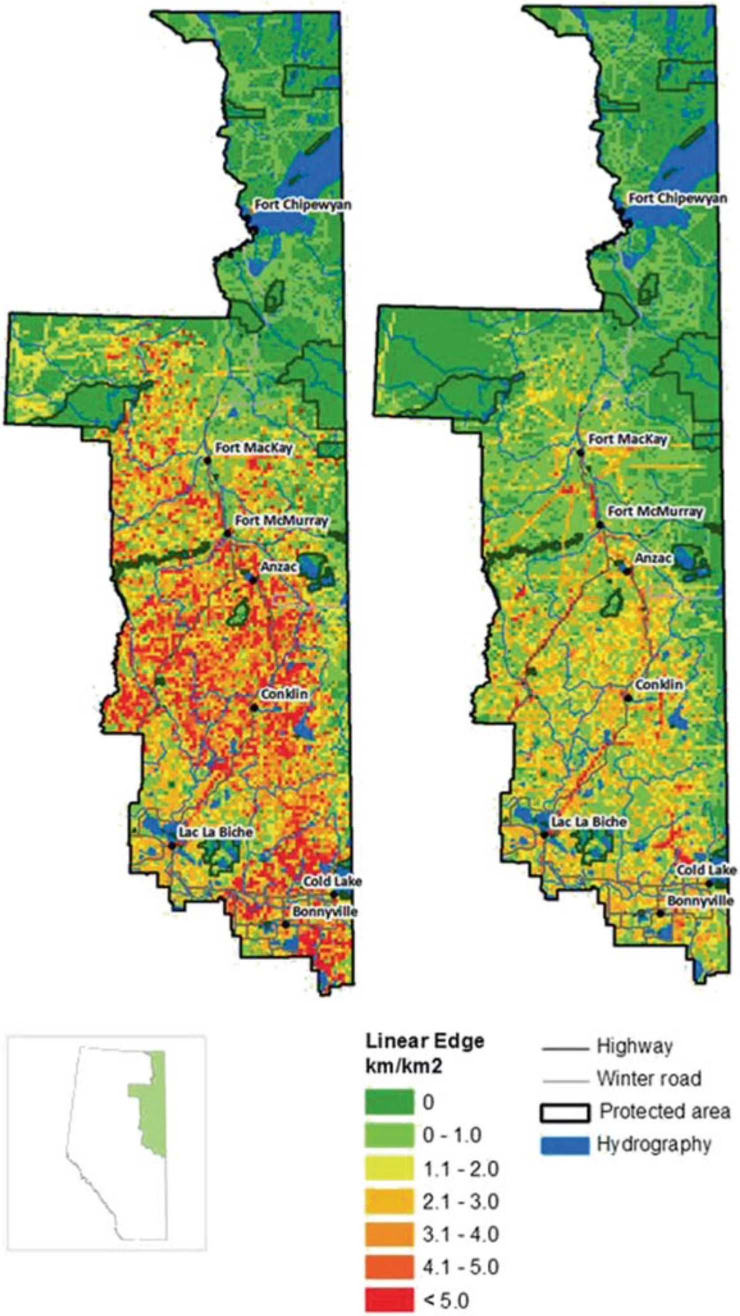

Fig. 11.6 Anthropogenic edge density simulated to occur at year 60 under business as usual (*left*) and high best practices (*right*) scenarios. One kilometer equals 0.6 mile; 1 km^2 equals 0.39 $mile^2$

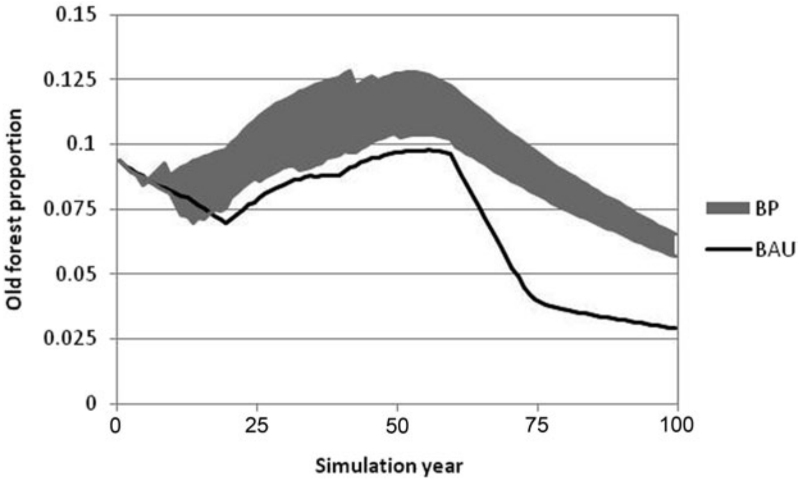

Fig. 11.7 The proportion of forest in the study area that is older than 120 years simulated over the next 100 years under business as usual (BAU) and best practices (BP) land-use scenarios in ALCES. Best practices are presented as a band to reflect the range in indicator response associated with realistic to optimistic implementation of the best practices

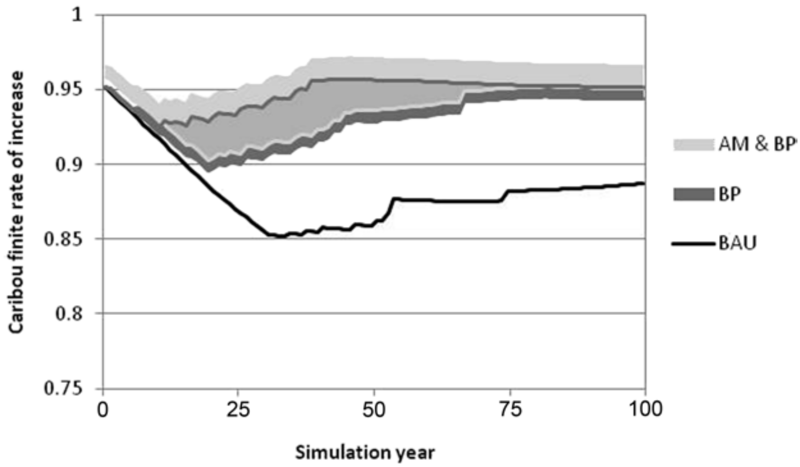

Fig. 11.8 The finite rate of increase of caribou simulated across the study area over the next 100 years under business as usual (BAU), best practices (BP), and access management plus best practices (AM & BP) land-use scenarios in ALCES. BP and AM & BP are presented as bands to reflect the range in indicator response associated with realistic to optimistic implementation of the mitigation strategies

fish surveys and research in northern Alberta that have found widespread declines in recreational fisheries, primarily due to unsustainable rates of angling [31]. The INFI was simulated to continue to decline with future development (Fig. 11.10),

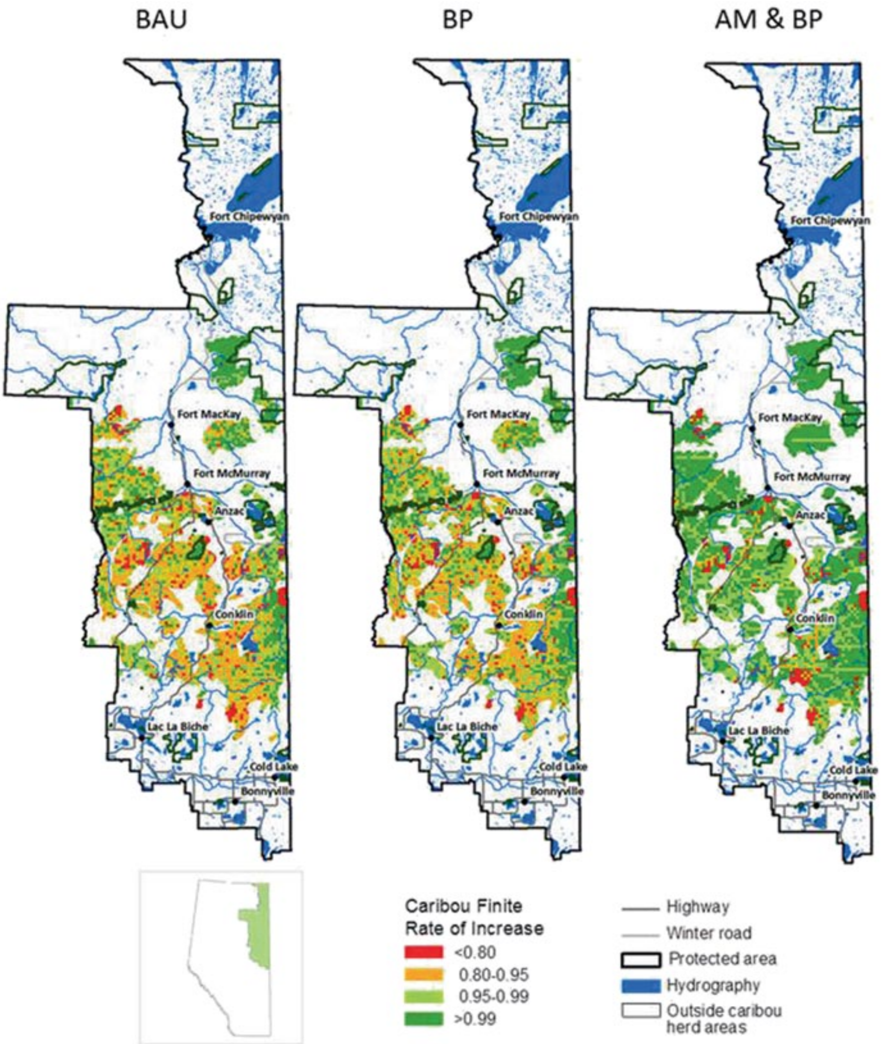

Fig. 11.9 The finite rate of increase of caribou simulated across the study area at year 60 under business as usual (BAU), high best practices (BP), and high access management and high best practices (AM & BP) scenarios

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 [19]. 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

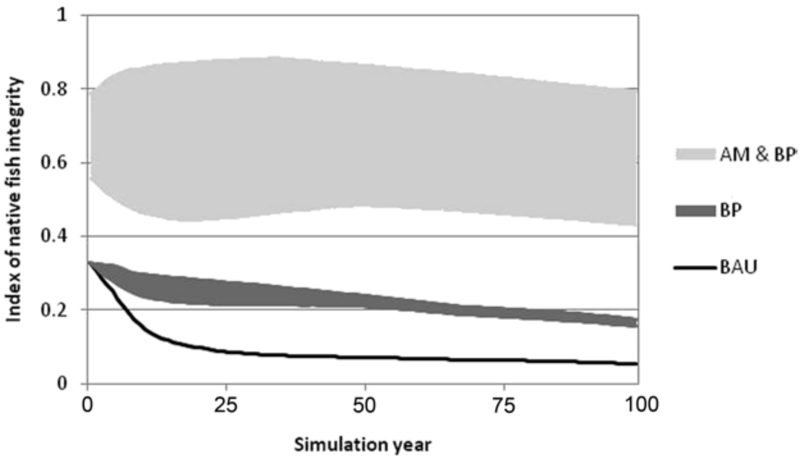

Fig. 11.10 Index of native fish integrity (INFI) simulated over the next 100 years under business as usual (BAU), best practices (BP), and access management plus best practices (AM & BP) land-use scenarios in ALCES. BP and AM & BP are presented as bands to reflect the range in indicator response associated with realistic to optimistic implementation of the mitigation strategies

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 [39]. When access management was simulated, INFI improved substantially due to a drop in angling pressure (Fig. 11.10). The dramatic response of INFI to human access is consistent with boreal fishery research [31, 39] 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 (Fig. 11.11). 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 million metric tons (44 million tons) CO_2-equivalent (Mt CO_2-e) accounts for 5 % of Canada's GHG emissions of 747 million metric tons (823 million tons) CO_2-e in 2007 [11]. Due to continued growth in oil sands production, CO_2 emissions were simulated to more than triple within the next 25 years, and then

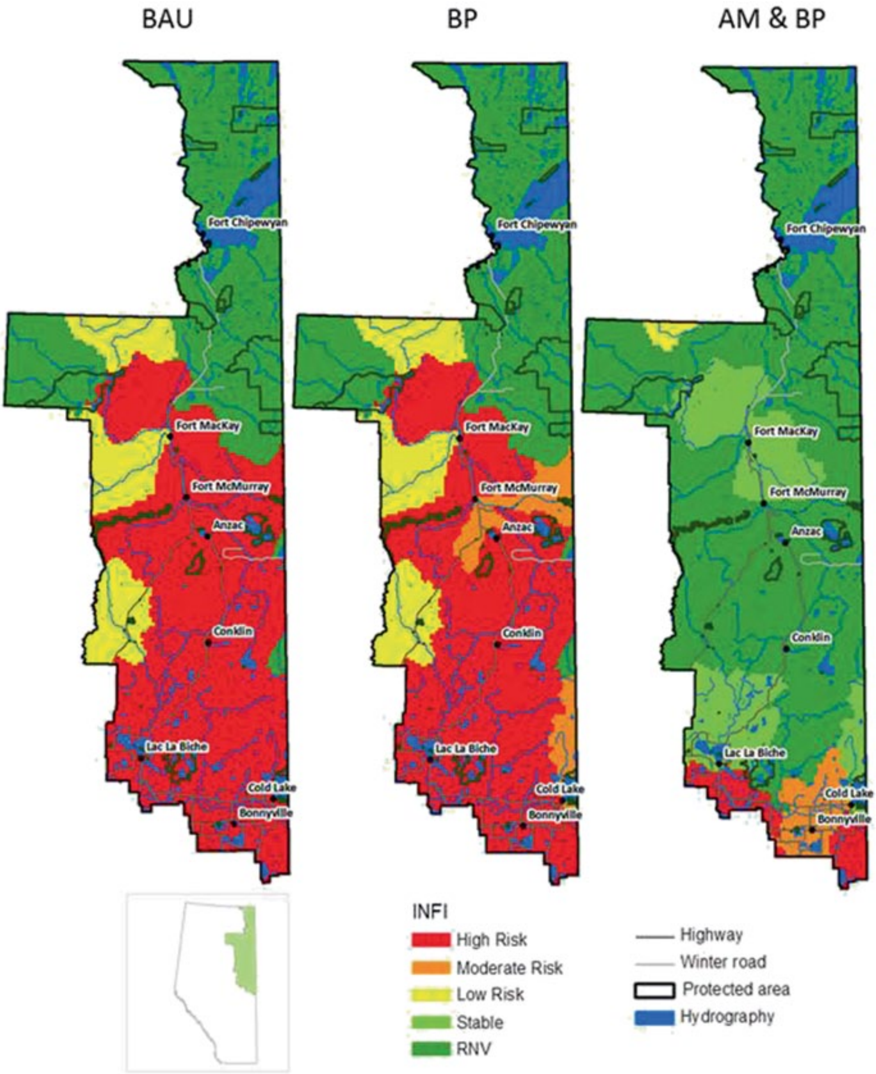

Fig. 11.11 Status of the index of native fish integrity (INFI) simulated across the study area at year 60 under business as usual (BAU), high best practices (BP), and high access management and high best practices (AM & BP) scenarios. RNV range of natural variability

gradually decline as production diminishes. Peak simulated emissions of 130 million metric tons (143 million tons) CO_2-e accounts for almost 24% of Canada's Kyoto target of 558.4 million metric tons (615.5 million tons) CO_2-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 metric tons (66 tons) CO_2-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 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.

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 GHG emissions. Application of best practices has the potential to substantially reduce disturbance and emission intensities. Results from simulations demonstrate, however, that the reduction is insufficient to avoid declines in wildlife due to the rapid escalation of production. Access management was highly successful at improving INFI, emphasizing 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 some other species (black bear (*Ursus americanus*), moose (*Alces americanus*), and wolverine (*Gulo gulo*)), 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. Twelve percent of the world's landscapes are protected [9], yet representation of all species and ecosystem types in a region requires substantially higher levels of protection, typically 25–75 % [27]. Prior to the preparation of Alberta's Lower Athabasca Regional Plan (LARP), 7 % of the region was protected. With the recent completion of the plan, protection will be elevated to over 20 %.

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 [35].

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 [15]. The zoning strategy is equally applicable to the production of other commodities from the forestland base, including hydrocarbons [16], and is potentially well suited to the LARP region due to the intensive nature of bitumen development and the aggregated distribution of bitumen deposits (Fig. 11.12). The triad has been previously proposed as a strategy for balancing the region's ecological and economic objectives [41].

We adopted a 30 % representation goal for each of the study area's 8 natural subregions and 12 land cover types. Natural subregion is a coarse level of ecosystem classification characterized by vegetation, climate, elevation, and latitudinal or physiographic differences [24]. 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. 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 [4, 30]. The analysis used 10 km^2 (3.86 $mile^2$) 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 (Fig. 11.13) 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 southernmost natural subregion, which is already too disturbed by agriculture to make the 30 % representation goal feasible.

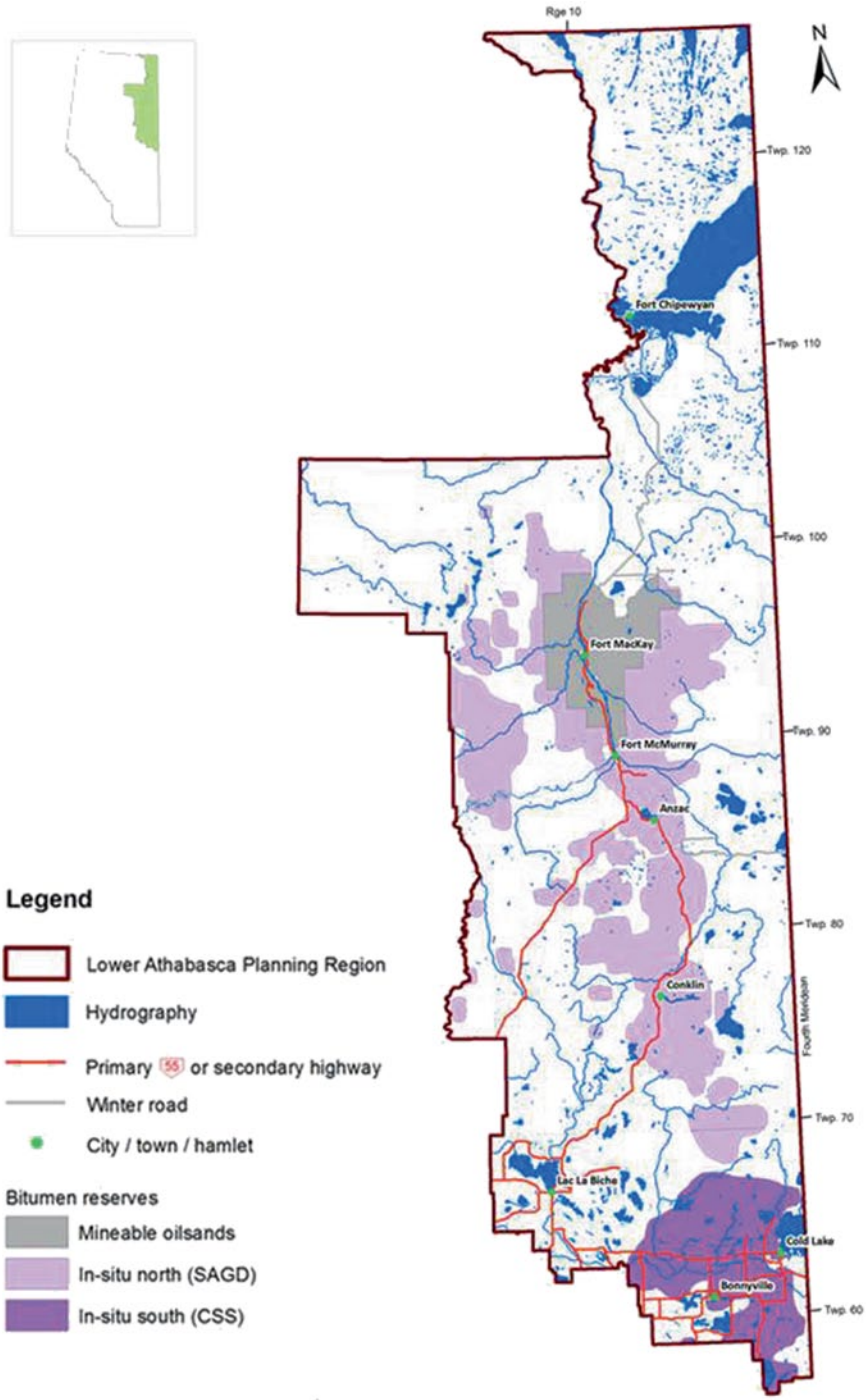

Fig. 11.12 Map of the in situ and mineable oil sands deposits found throughout the study area

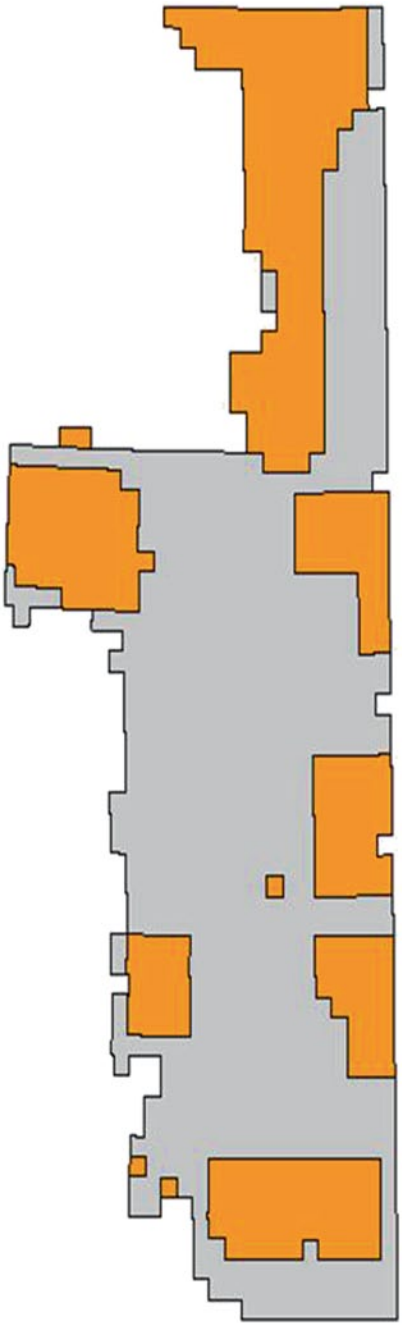

Fig. 11.13 The least cost conservation area network (orange) representing 30 % of each natural subregion and land cover type identified using MARXAN

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 [6]. 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, 494,211 acres) is substantially smaller than the maximum fire size (500,000 ha, 1,235,527 acres), 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 (2,857,818 acres; 10.9 % of the region) and contained 2 % 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 kilometers (miles)) 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 [3]. Other ecological impacts will similarly not be addressed through protection alone, such as emissions that contribute to GHG concentrations and acid deposition. It is therefore apparent that some impacts of 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 [26, 18] 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. 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 ALUF. This integrated planning process, mandated by the 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, 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 composed of government employees providing disciplinary expertise. This work is overseen by the Land Use Secretariat. The goal is to construct a plan that can be submitted to the cabinet for consideration and, hopefully, approval and implementation. The primary objectives of the plan include (Morris Seiferling, Director of ALUF, 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 IRM exist, the description offered by Cairns and Crawford [7] 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 IRM from "reactionary" management will need to be respected [8]. IRM is *inclusive* by considering the broad spectrum of ecological, social, and economic factors that define environmental issues. IRM is also inclusive with respect to participation, recognizing that empirical science alone cannot lead to a solution, but rather provides information needed by society to make sustainable land-use decisions. IRM is *interconnective* by evaluating how components of ecological and human systems interact. It thereby embraces a system dynamics approach that views ecosystems as complex systems with emergent properties that cannot be managed through compartmentalization. IRM is *goal orientated* by proactively planning for an explicitly defined desired state that reflects broad societal objectives. IRM is *strategic* by focusing on the key elements of systems that are typically highly complex and characterized by uncertainty.

The LARP, which is the first regional plan from the ALUF to be completed and accepted by the cabinet, compares favorably with the aforementioned IRM elements [13]. The plan is *inclusive* by seeking to optimize the economic potential of the oil sands while also managing landscapes, air, and water to maintain ecosystem function, biodiversity, and human health. The government of Alberta refers to the LARP as a cumulative effects management approach, whereby planning and implementation is integrative across sectors as well as socioeconomic and ecological objectives. As such, the LARP is *interconnective* and represents a shift from previous efforts that tended to focus on individual sectors or objectives in isolation. The plan also sets forth a *goal-orientated* approach that is intended to impose thresholds to ensure environmental objectives are not violated by future land use. Finally, the plan is *strategic* by focusing on the following seven directions that have broad economic, social, and environmental benefits: improved integration of industrial activities; timely reclamation of disturbed lands; management thresholds for air, water, and biodiversity; new conservation areas; strengthened infrastructure; new recreation and tourism areas; and inclusion of aboriginal peoples in land-use planning.

Despite being consistent with IRM concepts, it is premature to judge how well the process will serve Albertans in defining and implementing a sustainable land-use trajectory for the region. It is clear that the highest priority is the extraction of bitumen, which the plan expects to increase to 3.5 million barrels per day by the end of the decade. The plan seeks to balance this rapid economic growth with conservation, in part by protecting over 12,000 km (7456 miles) which increases the level of protection to over 20 % of the region. The new protected areas are relatively consistent with Fig. 11.13 and, as discussed previously, will support the conservation objective of representation. However, caribou herds are not well represented by the new protected areas and, as a result, the plan may be implicitly trading continued decline of the caribou population for economic growth generated by bitumen extraction. Environmental limits and management triggers have been established for air and surface water quality. However, thresholds remain to be developed for the arguably more challenging outcomes of groundwater, surface water quantity, and biodiversity. At the regional scale, the LARP's capacity to chart a sustainable future will be dictated by the degree to which these thresholds are able to limit land use to within the bounds of ecological integrity. Regional land use also has global sustainability implications, given the magnitude of its GHG emissions. The LARP does not address GHG emissions, however, and as such may fall short in its ability to guide sustainable land-use decisions from an international perspective.

Despite these gaps, the government of Alberta should be congratulated for the ALUF and the LARP. Sustainable land use is not an end point, but rather a process of ongoing decisions that govern the balance between economic and ecological objectives. Historical bitumen production, in concert with forestry and other land uses, has impacted ecological attributes; increased levels of bitumen production will further degrade their performance. LARP, if fully implemented, establishes a framework with the capacity to guide land-use decisions such that the ecological impacts of bitumen production do not violate societal objectives. If this potential of the LARP is realized, it will provide an important model for sustainable development of hydrocarbon reserves.

Acknowledgments The scenario analysis described in this chapter was funded by the Alberta government, and we thank the Alberta Land Use Secretariat for providing information and guidance. We also acknowledge the important contributions of our colleagues within the ALCES Group. We are grateful to the Canadian BEACONs project for identifying candidate ecological benchmarks in the planning region.

References

1. ALCES Group (2009) Lower Athabasca Regional Plan. ALCES III: Scenario Modeling Report. Package 2 (Best Practices). Unpublished report prepared for the Alberta Government Land-Use Secretariat, Edmonton, Alberta, Canada
2. Anielski M, Wilson S (2009) The real wealth of the Mackenzie region: assessing the natural capital values of a northern boreal ecosystem. Canadian Boreal Initiative, Ottawa, Ontario, Canada
3. Athabasca Landscape Team (2009) Athabasca caribou landscape management options report. Unpublished report submitted to Alberta Caribou Committee, Edmonton, Alberta, Canada. http://www.albertacariboucommittee.ca/PDF/Athabasca-Caribou.pdf. Accessed 26 July 2010
4. Ball I, Possingham H (2000) MARXAN (V1.8.2): marine reserve design using spatially explicit annealing. A manual prepared for The Great Barrier Reef Marine Park Authority, Townsville, Queensland, Australia
5. Boutin S, Arienti C (2008) Boreal Caribou Committee (BCC) equation reanalysis, final Report—November 26, 2008. Unpublished report prepared for the Alberta Caribou Committee Research and Monitoring Subcommittee by University of Alberta Integrated L and Management Laboratory, Edmonton, Alberta, Canada
6. Canadian BEACONs Project (2008) Creating a scientific foundation for conservation planning in boreal Canada. University of Alberta, Edmonton, Aberta; and Canadian Boreal Initiative, Ottawa, Ontario, Canada. http://www.beaconsproject.ca/resources.htm. Accessed 13 Oct 2009
7. Cairns J Jr., Crawford TV (eds) (1991) Integrated environmental management. Lewis Publishers Incorporated, Chelsea
8. Carlson M, Stelfox B (2010) Integrated resource management and planning. In: Hudson RJ (ed) Animal and plant productivity. Eolss Publications Incorporated, Mississauga, pp 390–404
9. Chape S, Blyth S, Fish L, Fox P, Spalding M, Compilers (2003) 2003 United Nations list of protected areas. IUCN (International Union for Conservation of Nature and Natural Resources), Gland, Switzerland and Cambridge, UK; and UNEP-World Conservation Monitoring Centre, Cambridge, UK
10. Energy Resources Conservation Board [ERCB] (2011) Alberta's energy reserves 2010 and supply/demand outlook 2011–2020. ST98–2011. Energy Resources Conservation Board, Calgary, Alberta, Canada
11. Environment Canada (2007) Canada's 2007 greenhouse gas inventory. Environment Canada, Gatineau, Quebec, Canada. http://www.ec.gc.ca/pdb/ghg/inventory_report/2007/som-sum_eng.cfm#s2. Accessed 13 Oct 2009
12. Francis J, Lumbis K (1979) Habitat relationships and management of terrestrial birds in Northeastern Alberta. AOSERP (Alberta Oil Sands Environmental Research Program) Report No. 78. Prepared for AOSERP by Canadian Wildlife Service, Edmonton, Alberta, Canada
13. Government of Alberta (2012) Lower Athabasca Regional Plan 2012–2022. Government of Alberta, Edmonton, Aberta, Canada

14. Holroyd P, Simieritsch T (2009) The waters that bind us: transboundary implications of oil sands development. The Pembina Institute, Drayton Valley
15. Hunter ML Jr (2010) Wildlife, forests, and forestry: principles of managing forests for biological diversity, 2nd edn. Prentice-Hall, Englewood Cliffs
16. Hunter ML Jr, Gibbs JP (2007) Fundamentals of conservation biology. Blackwell Publishing, Malden
17. James ARC, Boutin S, Hebert DM, Rippin AB (2004) Spatial separation of caribou from moose and its relation to predation by wolves. J Wildl Manag 68:799–809
18. Kelly G (2009) The oil sands: Canada's path to clean energy? Kingsley Publishing, Calgary
19. Lagimodiere M, Eaton B (2009) Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): description, rationale and modelling coefficients. Prepared for the Lower Athabasca Regional Plan by the Fish Element Team, Government of Alberta, Edmonton, Alberta, Canada
20. Lee P, Cheng R (2009) Bitumen and biocarbon: land use conversions and loss of biological carbon due to bitumen operations in the boreal forests of Alberta, Canada. Global Forest Watch Canada, Edmonton
21. McCulloch M, Raynolds M, Wong R (2006) Carbon neutral by 2020: a leadership opportunity in Canada's oil sands. The Pembina Institute, Drayton Valley
22. Moss EH (1983) Packer JG (ed) Flora of Alberta: a manual of flowering plants, conifers, ferns and fern allies found growing without cultivation in the Province of Alberta, Canada, 2nd edn. University of Toronto Press, Toronto
23. Naill RF (1973) The discovery cycle of a finite resource: a case study of U.S. natural gas. In: Meadows DL, Meadows DH (eds) Toward global equilibrium: collected papers. Wright-Allen Press Incorporated, Cambridge, pp. 213–256
24. Natural Regions Committee (2006) Natural regions and subregions of Alberta. Compiled by D. J. Downing and W. W. Pettapiece. Government of Alberta, Canada. Publication Number T/852
25. Nelson JS, Paetz MJ (1992) The fishes of Alberta, 2nd edn. University of Alberta Press, Edmonton
26. Nikiforuk A (2010) Tar sands: dirty oil and the future of a continent. Greystone Books, Vancouver
27. Noss RF, Cooperrider AY (1994) Saving nature's legacy: protecting and restoring biodiversity. Island Press, Washington, DC
28. Park D, Sullivan M, Bayne E, Scrimgeour G (2008) Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta's boreal forest. Can J For Res 38:566–575
29. Pattie DL, Hoffmann RS (1992) Mammals of the North American parks and prairies, 2nd edn. Self-published.
30. Possingham H, Ball I, Andelman S (2000) Mathematical methods for identifying representative reserve networks. In: Ferson S, Burgman M (ed) Quantitative methods for conservation biology. Springer-Verlag, New York, pp. 291–305
31. Post JR, Sullivan M, Cox SP, Lester NP, Walters CJ, Parkinson EA, Paul AJ, Jackson L, Shuter BJ (2002) Canada's recreational fisheries: the invisible collapse? Fish Manag 27:6–17
32. Prebble P, Coxworth A, Simieritsch T, Dyer S, Huot M, Walsh H (2009) Carbon copy: preventing oil sands fever in Saskatchewan. The Pembina Foundation, Drayton Valley, Alberta; Saskatchewan Environmental Society, Saskatoon, Saskatchewan; and Canadian Parks and Wilderness Society, Edmonton, Alberta, Canada
33. Russell AP, Bauer AM (2000) The amphibians and reptiles of Alberta: a field guide and primer of boreal herpetology, 2nd edn. University of Calgary Press, Calgary
34. Schindler DW, Donahue WF, Thompson JP (2007) Section 1: future water flows and human withdrawals in the Athabasca River. In Running out of steam? Oil sands development and water use in the Athabasca River-watershed: science and market based solutions. University of Alberta, Environmental Research and Studies Centre, Edmonton, pp 1–38

35. Schmiegelow FKA, Cumming SG, Harrison S, Leroux S, Lisgo K, Noss R, Olsen B (2006) Conservation beyond crisis management: a reverse-matrix model. BEACONs Discussion Paper No. 1, 2006. http://www.beaconsproject.ca/resources.htm. Accessed 13 Oct 2009
36. Schneider R, Dyer S (2006) Death by a thousand cuts: impacts of in situ oil sands development on Alberta's boreal forest. The Pembina Institute, Drayton Valley, Alberta; and Canadian Parks and Wilderness Society (CPAWS), Edmonton
37. Semenchuk GP (1992) The atlas of breeding birds of Alberta. Federation of Alberta Naturalists, Edmonton
38. Smith HC (1993) Alberta mammals: an atlas and guide. The Provincial Museum of Alberta, Edmonton
39. Sullivan MG (2003) Active management of walleye fisheries in Alberta: dilemmas of managing recovering fisheries. N Am J Fish Manag 23:1343–1358
40. Sullivan MG (2009) Conceptual framework for public motorized access management strategies for ALCES-LARP modelling projects. Unpublished report. Alberta Environment and Sustainable Resource Development (ESRD), Edmonton, Alberta, Canada
41. Sustainable Ecosystem Working Group [SEWG] (2008) Terrestrial ecosystem management framework for the regional municipality of Wood Buffalo. Cumulative Environmental Management Association, Fort McMurray, Alberta, Canada. http://cemaonline.ca/index.php/administration/doc_download/80-temf-framework-document. Accessed 10 July 2013
42. Vitt DH, Marsh JE, Bovey RB (1988) Mosses, lichens and ferns of northwest North America. Lone Pine Publishing, Edmonton
43. Wells J, Casey-Lefkowitz S, Chavarria G, Dyer S (2008) Danger in the nursery: impact on birds of tar sands oil development in Canada's boreal forest. Natural Resources Defense Council, New York, New York, USA; Boreal Songbird Initiative, Seattle, Washington, USA; and The Pembina Institute, Edmonton, Alberta, Canada
44. Wilson B, Stelfox JB, Patriquin M (2008) SEWG Workplan Facilitation and Modelling Project: data inputs and assumptions. Unpublished report prepared for the Cumulative Environmental Management Association, Fort McMurray, Alberta, Canada