Fort McKay Cumulative Effects Project

Technical Report of Scenario Modeling Analyses with ALCES®

Prepared for the Energy Resources Conservation Board on behalf of the Fort McKay Sustainability Department

DOVER COMMERCIAL PROJECT
Dover OPCO
ERCB Application No. 1673682

Prepared by: ALCES Group and Integral Ecology Group

25 March 2013

This Technical Report provides a complete description of methods, results, and conclusions from the scenario modeling component of the Fort McKay Cumulative Effects Project. The scenario modeling was conducted based upon simulations in the cumulative effects model – ALCES®. This report highlights the basic model assumptions, results and conclusions of the scenario analyses.

This report may be cited as:

Nishi, J.S., S. Berryman, J.B. Stelfox, A. Garibaldi, and J. Straker. 2013. Fort McKay Cumulative Effects Project: Technical Report of Scenario Modeling Analyses with ALCES®. ALCES Landscape and Land Use Ltd., Calgary, AB., and Integral Ecology Group, Victoria, BC. Prepared for the Fort McKay Sustainability Department, Fort McMurray, AB. 126 pp + 5 Appendices.

Any comments, questions or suggestions regarding the content of this report may be directed to:

Fort McKay Sustainability Department
P.O. Box 5360
Fort McMurray, AB. T9H 3G4.
(780) 828-4220

Additional copies of this report may be obtained by contacting:

Fort McKay Sustainability Department
P.O. Box 5360
Fort McMurray, AB. T9H 3G4.
(780) 828-4220

Executive Summary

Overview

The Fort McKay (FM) Cumulative Effects Project was completed by the ALCES Group in collaboration with the Integral Ecology Group. The project was initiated by the Fort McKay Sustainability Department as a means of responding to a long-held concern that the current project-specific environmental impact assessment (EIA) process is ineffective and invalid for gaining an understanding of the true effects of industrial bitumen development on the regional landscape and, by extension, on the ability to accommodate the practice of aboriginal and treaty Rights within this landscape.

Specific objectives of the project as defined by Fort McKay were:

- Facilitate community understanding and discussion about the effects of regional and project-specific industrial development, and about economic and environmental trade-offs inherent in that development.
- Articulate detailed management and mitigation strategies to best maintain the ecological integrity of Fort McKay's Traditional Territory.
- Support more informed and effective community engagement with industrial operators and government agencies on project-specific and cumulative regional effects, and on proposed strategies to address these effects.
- Support development of community-based monitoring of current environmental states, and the effectiveness of mitigation strategies.

For this project, we used the landscape simulation model ALCES® to explore the past, present, and future land use trajectories for the Fort McKay (FM) Study Area – an area exceeding 3.62 million (M) hectares and which comprises over 84% of Fort McKay's Traditional Territory. Our main purpose was to examine the effects of land use on a suite of economic, landscape, and biotic indicators in the Fort McKay Study Area.

Results showed that industrial land uses, along with associated footprints and infrastructure that are required to recover bitumen through both surface mining and in situ well extraction are, and will be, the predominant drivers of landscape change in the Fort McKay Study Area. A basic assumption in the model was that total bitumen production in the area would peak at ~3.5 million barrels per day (Mbpd; ~202 m^3/year) within the next 30 years. Over a 100 year future simulation period, the model projected a total cumulative production of ~17 billion m^3 of bitumen, of which ~65% would be developed through surface mining and the remaining 35% extracted through in situ wells.

The realized and potential future economic benefits of bitumen development for industry and government (including Fort McKay) are huge, with projected peak annual revenues from total bitumen approximating $130 billion within the next 50 years, and cumulative revenues approaching $11 trillion over a 100 year future simulation period. When tracked as either annual or cumulative revenues, the level of expected performance tied to the energy sector in the FM Study Area reflects an unprecedented magnitude of economic benefit, and the bitumen play is aptly described as an economic engine from both a provincial and national perspective (Timilsina, LeBlanc and Walden 2005) and (Burt, Crawford and Arcand 2012).

The environmental impact of this development is also huge. The cumulative effect of the energy sector footprint and its impacts on landscape and biotic indicators has been extensive to date, and will become increasingly significant and adverse over the decades to come. The biotic indicators of concern to Fort McKay and examined in this project included moose, fisher, native fish, and edible berries.

At the regional scale of the FM Study Area, moose and fisher Habitat Suitability Index (HSI) values have declined and are currently at the lower range of what would be expected naturally. But the effects at a local scale (i.e., the industrial landscape), which is aligned more closely to the geographic scale of daily experience to Fort McKay people, shows that current status of fisher, fish and edible berries have declined below what would be expected as their range of natural variability, and moose are at the lower range. During the next 100 years, the majority of the Traditional Territory will be transformed by industrial activity that will cause a regional loss in distribution and performance of key ecological indicators (including moose, fisher, fish and edible berries). In all scenarios, performance of key ecological indicators declined substantially.

A series of sensitivity analyses were completed to explore the consequences of alternative bitumen-extraction trajectories, various Best Management Practices (BMPs), access management, and a selection of protected-area networks. The results are similar to earlier efforts, which examined cumulative effects in the region Terrestrial Ecosystem Management Framework (Cumulative Effects Management Association (CEMA) 2008), and the Lower Athabasca Regional Plan (Government of Alberta 2012) scenario modelling (ALCES Group 2009). Much of Fort McKay's Traditional Territory has already experienced significant transformation by the bitumen development sector, and our analyses indicate that current performances of ecological indicators in the region are at levels below the "Range of Natural Variability" (RNV); levels supported in the pre-development landscape, on which Fort McKay's aboriginal and treaty rights are based.

Cumulative Effects and Key Issues

A principal characteristic of past and current impacts of bitumen development in the FM Study Area are linked to surface mining. Surface mining affects biotic indicators because it creates large polygonal features and footprints (i.e., surface mines, tailings ponds, disposal overburden) that primarily result in a direct loss of habitat throughout the construction and operational phases of a mine. Although a zone-of-influence can be attributed to surface mine features and associated footprints, the overall effect on habitat loss is largely tied to the direct footprint. In the Fort McKay Study Area, the mineable oil sands area has been delineated based on an economically viable combination of bitumen pay thickness and depth of overburden; the expectation is that all future surface mining will occur there. Although the long-term effects of surface mining to ecological indicators will be largely contained within the Mineable Oil Sands Area (MOSA), there remains considerable uncertainty about the value and utility that reclaimed and restored habitats from the intensively disturbed surface mine features will have for wildlife. Therein lays a key issue for Fort McKay: **will restored landscapes be able to grow and sustain healthy wild animal and plant populations that are desired and utilized through traditional hunting, trapping, and foraging activities?**

In comparison, the key characteristics of new and future impacts of bitumen development in the FM Study Area over the coming decades will be linked to an expanding footprint of access roads, seismic lines, pipelines, wells and well pads that are required to support in situ well extraction. The effect of increasing in situ bitumen development imposes some direct habitat loss, but the more important cumulative impacts will be expressed through:

- The extensive indirect effects of habitat fragmentation and reduced habitat effectiveness which will occur over a much larger proportion of the Traditional Territory.
- An increased potential for human access across the area due to an expanding and dispersed network of roads and linear features.

The magnitude and extent of the expected growth of in situ bitumen development emphasizes another key issue for Fort McKay: **to what extent will in situ infrastructure such as access roads and well pads become permanent features in order to facilitate the long-term extraction of remaining bitumen reserves as new and more efficient in situ well extraction technologies are developed?**

Recommendations

Results from the scenario analyses suggest the following integrated suite of management strategies:

- That the indirect impact on habitat will likely be effectively reduced through continued improvement and coordinated implementation of industry best practices that reduce footprint growth and hasten footprint reclamation.
- Implementation of a systematic and regional coordinated access management plan to manage and monitor access across the regional landbase will be a critically important management strategy to reduce the continued and unintended consequences of increased harvest pressure and mortality of wildlife and fish.
- Expanded protected areas that are “no-go” areas for industry will provide a building block for anchoring a land base that will prioritize production and sustainable harvesting of wild plants and animals to support traditional harvesting activities.

This project emphasized the importance of developing and implementing an access management strategy for the region, as the combination of increased road networks and regional human populations will substantially impact key wildlife species important to Fort McKay. As demonstrated by the Terrestrial Ecosystems Management Framework (TEMF) (Cumulative Effects Management Association (CEMA) 2008) and this project, access management is a key management lever that can significantly improve the performance of environmental indicators in the region. Strict adoption of BMPs can also serve as a very effective management tool to mitigate risks of industrial development to the environment. The BMPs applied in the Fort McKay scenario are considered rigorous, yet realistic, and are not the current standard for the region. Finally, establishing an expanded protected-areas network, larger than that outlined in the Lower Athabasca Regional Plan (LARP) (Government of Alberta 2012), can help mitigate the risk to environmental indicators. But none of these management strategies alone will solve the problems.

Conclusions

Unprecedented government-industry coordination and implementation of a suite of management practices (including expanded protected areas, aggressive access management, and dedication to continued development and implementation of BMPs to minimize and effectively reclaim footprint) are fundamental pre-requisites to an integrated strategy that has any reasonable likelihood of meaningfully addressing the future cumulative effects of bitumen development.

In the absence of a systematic and coordinated strategy – that includes expanded protected areas together with access management and coordinated footprint management and reclamation – the expected extent, rate, and pace of bitumen development will likely result in pervasive decline in key biotic indicators, as well as extirpation of local populations in core industrial foci within the Study Area. This will be accompanied by an equivalent functional loss in sustainable harvesting opportunities (moose, fisher, fish and edible berries), which are core land-based activities tied to the culture and traditional way of life for Fort McKay peoples.

The approaches applied in the Fort McKay cumulative effects study were similar to those used in both the TEMF (Cumulative Effects Management Association (CEMA) 2008) and LARP (ALCES Group 2009) and (Government of Alberta 2012). Against the backdrop of these three studies, we conclude the following:

1. The cumulative effects of the bitumen sector to key biotic indicators are significant to date, and will become increasingly adverse over the coming decades to the extent that it will profoundly affect the aboriginal and treaty rights of Fort McKay peoples.

2. When examining the full extraction trajectory of the bitumen sector, the effects of the in situ sector are likely more detrimental than that of the mineable sector, because they occur across a more extensive part of the Study Area.

3. Adoption of access management, an expanded protected area network, and aggressive beneficial or best management practices can, to a degree, mitigate the negative effects of the bitumen sector. However, neither of these measures, alone or in concert, can fully mitigate effects of industrial development, leaving significant residual adverse environmental impacts that exist today and will increase into the future.

4. The current structure and methodologies of project-specific EIAs deployed for the bitumen sector in northeast Alberta provide minimal insight into the highly probable

outcomes (economic, social, ecological) of this industry on the cultural and environmental interests of the Community of Fort McKay.

5. The effectiveness and utility of project-specific EIAs should be strongly reconsidered and replaced with proper regional cumulative effects assessments. Such a regulatory transition would allow all relevant stakeholders (including aboriginal communities like Fort McKay) to better understand the mitigation and management that is required for long-term sustainability, as well as the spectrum of benefits and liabilities that attend the bitumen sector in northeast Alberta. An improved understanding will reduce the likelihood of exceeding limits of land use disturbance that may result in irreversible harm and unanticipated negative impacts to indicators that arise from cumulative effects.

6. Managing cumulative effects and undertaking effective natural resource management that respects aboriginal and treaty rights requires active engagement of Fort McKay, and a new relationship with the Government of Alberta. This is an important challenge because *"… both the concept of cumulative impacts and the concept of aboriginal rights fundamentally challenge government's ability to continue to rely on large-scale, corporate resource extraction as a primary economic activity. As such, both concepts pose a potentially serious threat to those who perceive their interest as being in preserving 'business as usual.'"* (Tollefson and Wipond 1998).

Contents

Appendices

Appendix 1 – The Case for Cumulative Effects Assessment

Appendix 2 – ALCES Model Description

Appendix 3 – Hubbert-Naill Hydrocarbon Production Curve

Appendix 4 – ALCES Data Sources and Input Assumptions

Appendix 5 – Results of Sensitivity Analyses

Tables

Figures

List of Acronyms

AAC	Annual Allowable Cut
ALCES®	A Landscape Cumulative Effects Simulator
BAU	Business as Usual
BMPS	Best Management Practices
CAPP	Canadian Association of Petroleum Producers
CEMA	Cumulative Effects Management Association
CSS	Cyclic Steam Simulation
DF	Decimal Fraction
EIA	Environmental Impact Assessments
ERCB	Energy Resources Conservation Board
FM	Fort McKay
FMFN	Fort McKay First Nation
FMSA	Fort McKay Specific Assessment
FT	Footprint Type
HSI	Habitat Suitability Index
INFI	Index of National Fish Integrity
IRC	Industry Relations Corporation
LARP	Lower Athabasca Regional Plan
LT	Landscape Type
MOSA	Mineable Oil Sands Area
OHV	Off-highway Vehicle
RMWB	Regional Municipality of Wood Buffalo
RNV	Range of Natural Variability

RSA	Regional Study Area
SAGD	Steam-Assisted Gravity Drainage
SEWG	Sustainable Ecosystems Working Group
TEMF	Territorial Ecosystems Management Framework

Glossary of Terms

Aboriginal rights - Unique rights that First Nation, Metis and Inuit people of Canada hold by reason of having been independent, self-governing societies prior to the establishment of Canadian sovereignty. These rights are recognized and protected under Section 35 of the Constitution Act, 1982 and are part of the Common law in Canada. Aboriginal rights include the harvesting rights of the Métis, and the right to site specific cultural practices and features;

access management - A land use management tool that is directed to engage the public and stakeholders in consideration of future road development and management of use (motor vehicle and off-road-vehicle traffic) on existing roads and linear features. Effective access management is implemented as a systematic and regional coordinated plan to reduce access across the regional landbase, and would require government enforcement.

ALCES® - A Landscape Cumulative Effects Simulator - a landscape model which can simulate environmental and human-related changes and track a wide variety of environmental, biological, and socio-economic indicators as landscape change unfolds. ALCES is designed to explore and represent changes in land base composition caused by land uses and ecological processes.

Anthropogenic footprint – human-made permanent or temporary disturbance features that occupy space on the landscape such as roads, well-sites, transmission lines, towns, cities, mines, industrial plants.

BMP - Best Management Practices (BMP). A best practice is a method or technique that has consistently shown results superior to those achieved with other means, and that is used as a benchmark. In addition, a "best" management practice can evolve to become better as improvements are discovered. Best management practices are used to maintain quality as an alternative to mandatory legislated standards and can be based on self-assessment or benchmarking.

CEMA - Cumulative Environmental Management Association (www.cemaonline.ca), a multi-stakeholder group operating in the Regional Municipality of Wood Buffalo, Alberta. CEMA is a key advisor to the provincial and federal governments committed to respectful, inclusive dialogue to make recommendations to manage the cumulative environmental effects of regional development on air, land, water and biodiversity.

Community - The entire Community of Fort McKay includes First Nations members, Metis members and non-status members.

EIA - Environmental Impact Assessment. An assessment of the possible positive or negative impacts that a proposed project may have on the environment, together consisting of the environmental, social and economic aspects.

FMSD - Fort McKay Sustainability Department

Focus Group - a selected group of Fort McKay Community members to participate in the Fort McKay Cumulative Effects Project

Footprint type (FT) – an anthropogenic disturbance type (anthropogenic or human-made) classifications in ALCES

Industrial Study Area - The intensive oil sands industrial zone in and around the hamlet of Fort McKay, set as the Industrial Study Area for the Fort McKay Cumulative Effects Study, See Figure 5.

In situ operation - (i) a scheme or operation ordinarily involving the use of well production operations for the recovery of crude bitumen from oil sands

Integrated Land Management (ILM) - A strategic, planned approach to manage and reduce human footprint on the landscape.

Landscape type (LT) – discrete ecosystem (or broad habitat) classes used by the ALCES model that are not disturbed by development.

LARP - Lower Athabasca Regional Plan (Government of Alberta 2012), or pertaining to the land use plan for the Lower Athabasca Region.

MOSA - mineable oil sands area in northeastern Alberta (see Figure 5).

RMWB - Regional Municipality of Wood Buffalo. A specialized municipality located in northeastern Alberta, home to vast oil sand deposits, also known as the Athabasca Oil Sands, helping to make the region one of the fastest growing industrial areas in Canada. (http://www.woodbuffalo.ab.ca/).

RNV - Range of Natural Variation. The normal variation of a specific ecological indicator that occurs in response to the full suite of natural and episodic disturbances that characterize an ecological system.

Fort McKay Study Area – The main study area for the Fort McKay Cumulative Effects Project, including most of the Fort McKay traditional territory, with the exception of the northern portions located in Wood Buffalo National Park.

SAGD - steam assisted gravity drainage - an in situ production process using two closely spaced horizontal wells: one for steam injection and the other for production of the bitumen/water emulsion

SEWG – Sustainable Ecosystems Working Group, previously a working group in the Cumulative Environmental Management Association, now the Land Working Group

Simulation – the imitation of the operation of a real-world process or system over time. Computer models such as ALCES are designed to simulate real-world landscape changes due to natural fires and industrial activities.

Stochastic – A stochastic process is one whose behavior is non-deterministic; it can be thought of as a sequence of random variables.

TEMF - Terrestrial Ecosystem Management Framework (CEMA-SEWG 2008), a framework provided to the Government of Alberta that documented cumulative effects in the Regional Municipality of Wood Buffalo and recommended management actions to improve indicator performance following a triad land management approach.

Traditional land use study (TLUS) – Also known as "Traditional Use Studies"(TUS) and "Use and Occupancy Map Surveys" (UOM), TLUS are a form of social science investigation that brings together community knowledge with ethnographic, archival and sometimes archaeological information to provide clarity on places and values of cultural, economic, heritage or community importance. This is usually accomplished through the recording of oral history and map biographies in interviews with community elders and sometimes a larger representative sample of the community.

Treaty rights - Treaty 8) are the rights embodied by Treaty 8 as interpreted by the Courts and include the adherents' right to hunt, trap and harvest natural resources within their Traditional Territory, the right to pursue their way of life; and the right to the use, enjoyment and control of lands reserved for them.

Traditional Territory is the area of land upon which a First Nation is entitled to exercise its Treaty Rights

1 Introduction

1.1 Background

Fort McKay (FM) is a Cree, Dene and Métis community of over 800 people located in northeast Alberta about 45 km north of Fort McMurray. Although Fort McKay's Traditional Territory is more than 3 million hectares (ha) in size (Figure 1), Fort McKay's people, hamlet and Traditional Territory are centrally located within a landscape that is experiencing unprecedented industrial development in both geographic scale and intensity (Figure 2 and Figure 3). Infrastructure construction (surface mines, processing plants, seismic lines, well sites and pipelines) required to extract and process bitumen in northeast Alberta[1] will leave an extensive industrial footprint throughout the region during the next century, and will adversely affect the performance of key ecological indicators (e.g., moose, furbearers and fish) considered critical to maintaining Fort McKay's aboriginal and treaty rights.

The issue of cumulative effects of land uses in this region received significant attention through work undertaken between 2006 and 2008 by a regional multi-stakeholder organization, the Sustainable Ecosystems Working Group (SEWG) of the Cumulative Environmental Management Association (CEMA), which included (and still includes) representation from aboriginal, industry, government and non-profit sectors. The product of this work, referred to as the Terrestrial Ecosystems Management Framework (TEMF), reached the following conclusions (Cumulative Effects Management Association (CEMA) 2008):

1. That there was significant decline in ecological indicators in the region as a result of cumulative effects of industrial development (despite numerous project-specific Environmental Impact Assessments [EIAs] asserting the contrary), and that these cumulative effects could be expected to continue and accelerate in proportion to the increasing bitumen production noted above. Many of the indicators used in the TEMF are the same species and ecosystems that support the ability of Fort McKay community members to carry out their traditional activities, thus it is valid to conclude that the ability of Fort McKay community members to practice their traditional activities, both currently and in the future, has and will be similarly significantly affected.

2. That multiple regional-scale mitigation measures were necessary to address projected cumulative adverse effects, including the following recommendations:

    a) A "triad" approach should be developed to manage risk, where the regional landscape would be comprised of protected, intensive (mineable areas and in-situ development), and extensive "zones" (forest cutblocks, in-block roads) that would

[1] Energy Resources Conservation Board (2011; http://www.ercb.ca/learn-about-energy/energy-in-alberta/production-reserves) currently estimates established bitumen reserves at 26.8 Billion m^3; the vast majority of which will be extracted from the Athabasca Oil sand Reserves during the next century.

collectively balance ecological, social and economic objectives. Supporting analyses clearly demonstrated that the in-situ bitumen infrastructure was itself intensive in terms of its effects on a broad suite of ecological indicators. In essence, in situ was once considered to be an energy-extraction process that would have a lesser environmental impact than open pit mines, but it is now considered to have highly significant, albeit different, negative environmental consequences. This finding lead to an appreciation of the critical importance of establishing a large-scale protected-areas network to maintain regional performance of ecological indicators while industrial development occurs outside of these protected areas. The final TEMF included a formal recommendation to the Government of Alberta that 20% to 40% of the region (Regional Municipality of Wood Buffalo [RMWB]) should be protected from industrial land uses.

b) There should be aggressive implementation of access management, including restricting off-highway vehicle (OHV) access from 50% and 75% of designated intensive and extensive zones respectively, along with systematic reclamation of historic seismic lines to reduce use by humans and wildlife predators.

c) There should be continual improvement in development and implementation of more aggressive BMPs ("beneficial" or "best" management practices) for both the energy and forestry sectors that are above the *status quo*, to coordinate infrastructure development and mitigate the negative effects of land uses on the industrial land base (i.e., non-protected; see the TEMF for details) (Cumulative Effects Management Association (CEMA) 2008).

In addition, it became apparent to Fort McKay, and others, that only by undertaking a proper and regional cumulative-effects assessment was it possible to understand both the benefits and liabilities of development of the bitumen sector in northeast Alberta. As noted above, the comprehensive analyses completed during TEMF development revealed a major discrepancy in conclusions between proper regional cumulative-effects analyses and individual EIAs, which generally conclude that individual projects do not significantly affect environmental values.

The main reasons for the contrasting interpretation of the magnitude and extent of cumulative impacts to ecological indicators over the region are also the key deficiencies of current project-specific EIAs:

1. the baseline for ecological indicators comparison is too short a period and typically covers a one to five year monitoring period prior to a project proposal; and

2. the comparative baseline for project-specific EIAs changes over meaningful time (i.e., decades) as the landscape becomes more developed, and the assessments lack statistical power (Mapstone 1995) to detect changes, due in large part to a shifting baseline (Pauly 1995) and (Papworth, et al. 2009).

These problems led Fort McKay to the conclusion that the current project-specific EIA process is ineffective and invalid for gaining an understanding of the true effects of the bitumen sector on the regional landscape and, by extension, on the ability to accommodate the practice of aboriginal and treaty Rights within this landscape (see ***Appendix 1***).

The TEMF initiative was followed by the Lower Athabasca Regional Plan (LARP) (Government of Alberta 2012) of the Alberta Land Use Framework.[2] Although the LARP Study Area boundary was much larger than that used in the TEMF (it included additional municipalities to the south of RMWB), the results reinforced the findings of the TEMF.

Based on recommendations in the LARP, the Government of Alberta endorsed expanded protected areas (referred to as “conservation areas”) of approximately 22% of the Lower Athabasca Region (Government of Alberta 2012). However, “endangered species” (e.g., caribou) habitat requirements or plant-community representation do not appear to be the primary criteria used in the selection of the LARP-protected areas based on the size and location of the area. Rather, these areas were designed to have no or minimal market-grade bitumen, and thus to minimize conflict with the energy sector. Also, the conservation areas outlined in the LARP honour existing oil and gas tenure within these areas; as a result, some level of development might still occur on this “protected” land base.

The allowable uses in the LARP conservation areas are not in alignment with the TEMF recommendations (Cumulative Effects Management Association (CEMA) 2008) and therefore, will likely result in much less environmental protection in these areas (e.g., some industrial development is honoured, multi-use corridors and motorized public access for hunting, fishing and recreation is allowed). Consequently, the current protected area network under LARP is not adequate to sustain the environmental indicators required to support Fort McKay’s traditional land use activities in the context of an intensive and expanding industrial landscape. The LARP conservation areas overlap 12.6% of Fort McKay’s Traditional Territory.

In addition, all LARP conservation areas are at the periphery of the mineable oil-sands area and of Fort McKay’s Traditional Territory – the nearest boundaries of the new conservation areas are approximately 75 km to 100 km from Fort McKay. For people engaged in traditional land uses in Fort McKay, the LARP-protected areas have limited utility for the practice of traditional land use because of their peripheral location and the enormous industrial development occurring between the hamlet of Fort McKay and the protected areas. Furthermore, the LARP-protected areas permit some level of development within their boundaries so they are not fully protective of wildlife and ecosystem diversity. The ability to access and use these areas for traditional purposes is much more limited than it would be if the protected areas were closer to people’s homes and traplines. Protected areas alone will not mitigate all direct and indirect impacts from industrial development in the region.

---

[2] ***https://landuse.alberta.ca***

It is critical to note that although the protected areas identified in LARP will contribute to lessening the decline of critical habitat for species at risk and other wildlife as a result of industrial development, the suite of mitigation measures discussed in the LARP do not fully address projected environmental impacts of this development, leaving significant and adverse local and regional effects. For example, there is limited discussion and commitment in LARP with regards to access management and enforcement of aggressive and innovative BMPs for industry in the region. Also, although LARP contemplates development of a biodiversity framework, the content and timing of implementation are undeveloped; as LARP prioritizes development, options for mitigation and management of cumulative effects may be constrained significantly.

In 2010, the Fort McKay Industry Relations Corporation (now the Fort McKay Sustainability Department) conducted a Fort McKay Specific Assessment (FMSA), a supplement to the Shell Canada Limited Jackpine Mine Expansion and the Pierre River Mine Project application in response to the long-standing concern that a project-specific EIA process and associated Terms of Reference does not adequately address Fort McKay's needs for information necessary to determine the effects of the projects on Fort McKay's cultural heritage, as well as the environmental, traditional and cultural resources of importance to the community (Fort McKay Industry Relations Corporation (IRC) 2010). The FMSA included a project-specific assessment (for both the Jackpine Mine Expansion and Pierre River Mine projects) and a cumulative effects assessment, including environmental and cultural components (i.e., of biodiversity and cultural heritage).

The FMSA indicated that the principal stressor that adversely affects biodiversity is land disturbance (Fort McKay Industry Relations Corporation (IRC) 2010). This disturbance has the potential to negatively impact species populations, affect the integrity of ecosystems and their functions, alter landscapes and change their associated cultural values. Some of the main conclusions about biodiversity from this section of the FMSA included:

1. Significant adverse effects were observed for all biodiversity indicators when the planned development case[3] was compared to pre-development[4].

2. High biodiversity potential areas were reduced and replaced with moderate to low biodiversity potential areas during the planned development case and at mine closure. Fort McKay considered the increase in land with low biodiversity potential to be adverse and significant, since higher biodiversity potential lands were being replaced in the landscape.

3. A significant adverse effect was also demonstrated for the landscape heterogeneity indicator, where following mine closure the landscape is less diverse (more

---

[3] Planned Development Case was defined as existing and approved developments plus the proposed Shell projects plus planned development at the time the FMSA was prepared.

[4] In the FMSA, Fort McKay included a "pre-development scenario" to reflect the Community's view that the landscape function and diversity prior to any bitumen development was the most accurate baseline from which to assess affects. The exact date of the pre-development baseline varied by discipline and by ranges from 1954 to 1965.

homogenous) as a result of land disturbance, reclamation and conversion of wetland habitat to uplands.

Some of the key recommendations that came out of the FMSA included the need to:

- Establish limits on development which necessitates ground disturbance within Fort McKay's Traditional Territory.
- Establish protected areas to preserve and retain traditional land use opportunities and associated resources in close proximity to the Community of Fort McKay.
- Recognize that further mitigation measures and accommodation strategies need to be developed in consultation with Fort McKay, as protected areas and reclamation alone do not provide effective mitigation for the project-specific or cumulative loss of the traditional lands and resources upon which Fort McKay's culture and rights depend.

The findings of both the TEMF and LARP initiatives, as well as the FMSA, alarmed the Community of Fort McKay (Fort McKay Sustainability Department 2011). These analyses highlighted the pace and extent of industrial growth and its effects on key ecological indicators. Although Fort McKay has benefited economically from the bitumen sector, past EIAs have concluded that ecological indicators would not be significantly affected over a broad region. In contrast, results from the TEMF and LARP clearly demonstrated the extent to which aboriginal and treaty rights were, are, and will continue to be compromised if industrial development continues as currently contemplated in northeast Alberta (see also Fort McKay IRC 2010).

In 2011, the Fort McKay First Nation (FMFN), on behalf of both First Nation and Métis Community Association members residing in the hamlet of Fort McKay, commissioned its own cumulative effects study for the Fort McKay Traditional Territory, the Fort McKay Cumulative Effects Project. This technical report describes the simulation modeling component of that study.

1.2 Rationale

Today, many residents of Fort McKay benefit from participation in the industrial economy in the region, but also still greatly value their ability to conduct traditional land-use activities. Fort McKay's members continue to hold fur management licenses to many trapping areas within the Traditional Territory surrounding the Community, and continue traditional uses throughout the area.

Not only are these uses valued, but their continued viability is protected by the Constitution of Canada. As a result of the existing and future oil sands development in northeast Alberta, there are current and likely future effects to both the ecological integrity of Fort McKay's Traditional Territory, and to the capacity of this area to support healthy resources for traditional land uses. These effects are both direct, from the removal by industrial footprint of land available for traditional uses, and indirect, as a result of increased access and use of the land around Fort McKay by non-residents. These effects result in restriction and redirection of land uses by Fort McKay community members.

Fort McKay plays an active role in multi-stakeholder initiatives regarding regional land management, and has an explicit interest in protecting the ecological integrity and function of their Traditional Territory, and mitigating where protection is not possible or where degradation has already occurred. As industrial activities continue to increase and affect Fort McKay's Traditional Territory, there is a need for the Community to establish a clear understanding of the benefits and liabilities associated with cumulative land-use decisions in its territory, and to develop an approach to setting Community objectives for sustainable ecological and socio-economic conditions. To achieve this, Fort McKay completed this cumulative effects modeling project, directed by the Community and its technical representatives, to assess the status of environmental, social, and economic indicators in the Community's Traditional Territory.

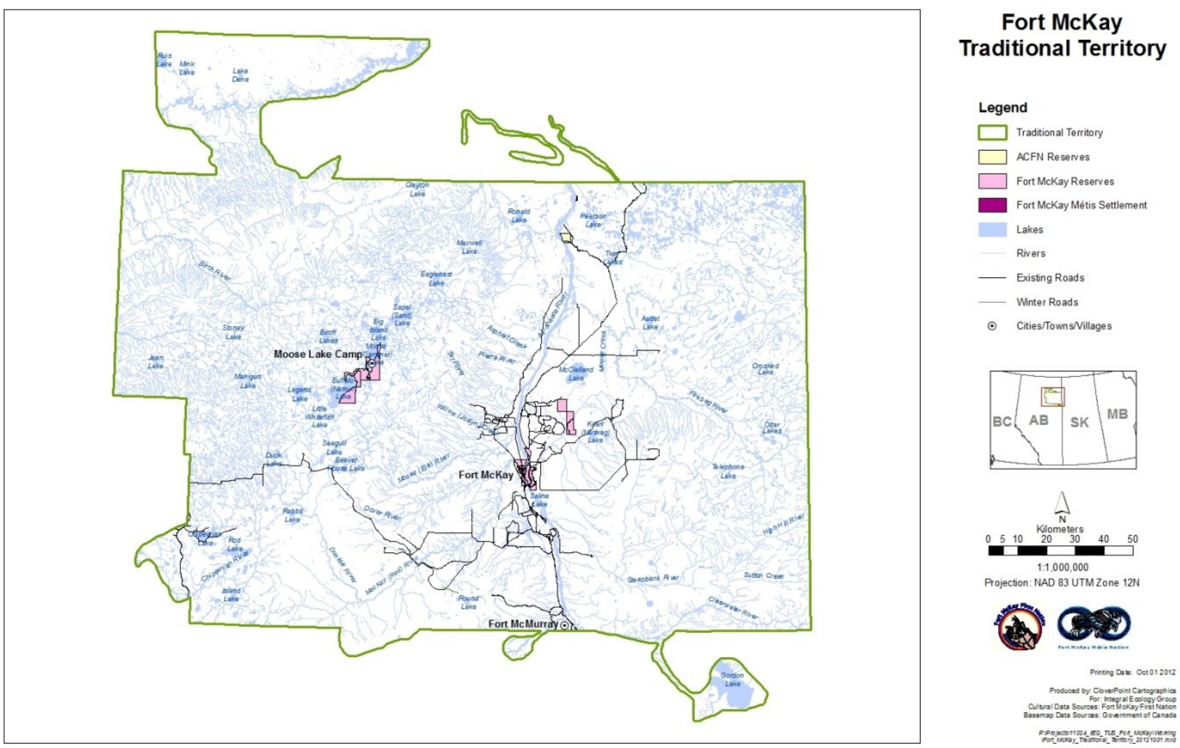


Figure 1: Location of Fort McKay's Traditional Territory in northeast Alberta, Canada

1.3 Fort McKay Cumulative Effects Project Objectives

There were four main objectives for this project:

- Facilitate community understanding and discussion about the effects of regional and project-specific industrial development, and about economic and environmental trade-offs inherent in that development.
- Articulate detailed management and mitigation strategies to best maintain the ecological integrity of Fort McKay's Traditional Territory.
- Support more informed and effective community engagement with industrial operators and government agencies on project-specific and cumulative regional effects, and on proposed strategies to address these effects.
- Support development of community-based monitoring of current environmental states, and the effectiveness of mitigation strategies.

2 Study Area

2.1 The Physical Landscape

The study area (3.62 million (M) ha), hereafter referred to as the "Fort McKay Study Area" or the "Study Area", is located within the boreal mixedwood forests of northeast Alberta (Figure 2), and includes the traditional lands of Fort McKay that occur south of Wood Buffalo National Park. The Study Area does not represent the entire Fort McKay Traditional Territory (Figure 1), as the portions located in the Wood Buffalo National Park were not included. Since the park is essentially protected, the community felt there was no need to include it in the study. The Study Area varies in elevation from generally 650 metres (m) to 700 m above sea level.

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 and one reptile (Russell and Bauer 1993), 236 birds (Semenchuk 1992), and 45 mammals (Pattie and Hoffmann 1992) and (Smith 1993). Based on distribution maps (Moss 1983) and (Vitt, Marsh and Bovey 1988), conservative estimates indicate a rich diversity of plants, including 600 vascular species, 17 ferns, 104 mosses, 13 liverworts and 118 lichen species.

2.2 Plant Community Structure

The boreal mixedwood forest is a mosaic landscape comprised of stands that vary in tree composition, age, size, shape and dispersion (Peterson and Peterson 1992). Trembling aspen and white spruce dominate boreal mixedwood on upland mesic sites with medium-textured soils. Past vegetation classifications in Alberta have largely focused on aspen as a seral stage for conifer-dominated climax communities (La Roi and Ostafichuk 1982). However, aspen can also occur as a climax community throughout the low and mid mixedwood eco-region. Balsam poplar, paper birch, black spruce, jack pine, tamarack, and balsam fir can be locally abundant throughout the boreal mixedwood forest.

Topographically depressed areas with impaired drainage are generally dominated by black spruce and tamarack, whereas willow communities are common near lake margins and continuous and intermittent streams. Pines are found primarily in xeric sites.

2.3 Natural Disturbances

Fire was the primary natural disturbance that shaped boreal forests (Johnson 1992). Vegetation patterns created by fire on the boreal landscape are complex and dynamic because fire cycles vary both in space (Payette, et al. 1989) and time (Bergeron 1991). In the absence of human land use, fire has a dominant role on the age class distribution of plant communities in many terrestrial ecosystems. The area burned frequently varies across years, resulting in plant communities with age class distributions that fluctuate over time; however, most EIAs do not address the implications of forest fires in their cumulative effects assessments, which results in an under-estimate of the total overall disturbance to

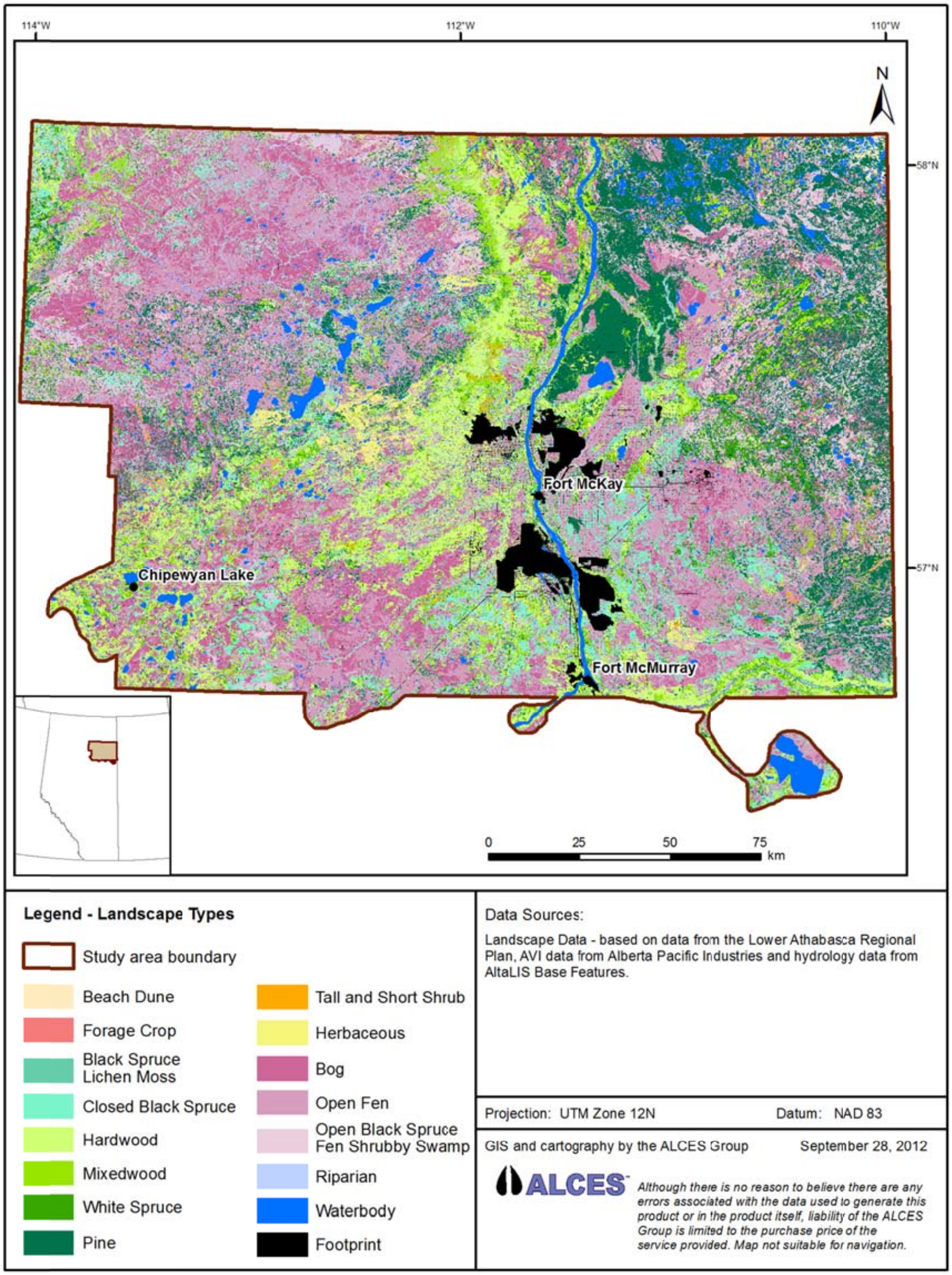


Figure 2: Landscape Types (Including Aquatic Features) in the Fort McKay (FM) Study Area[5]

[5] Section 3.7.3 provides detailed description of landscape types

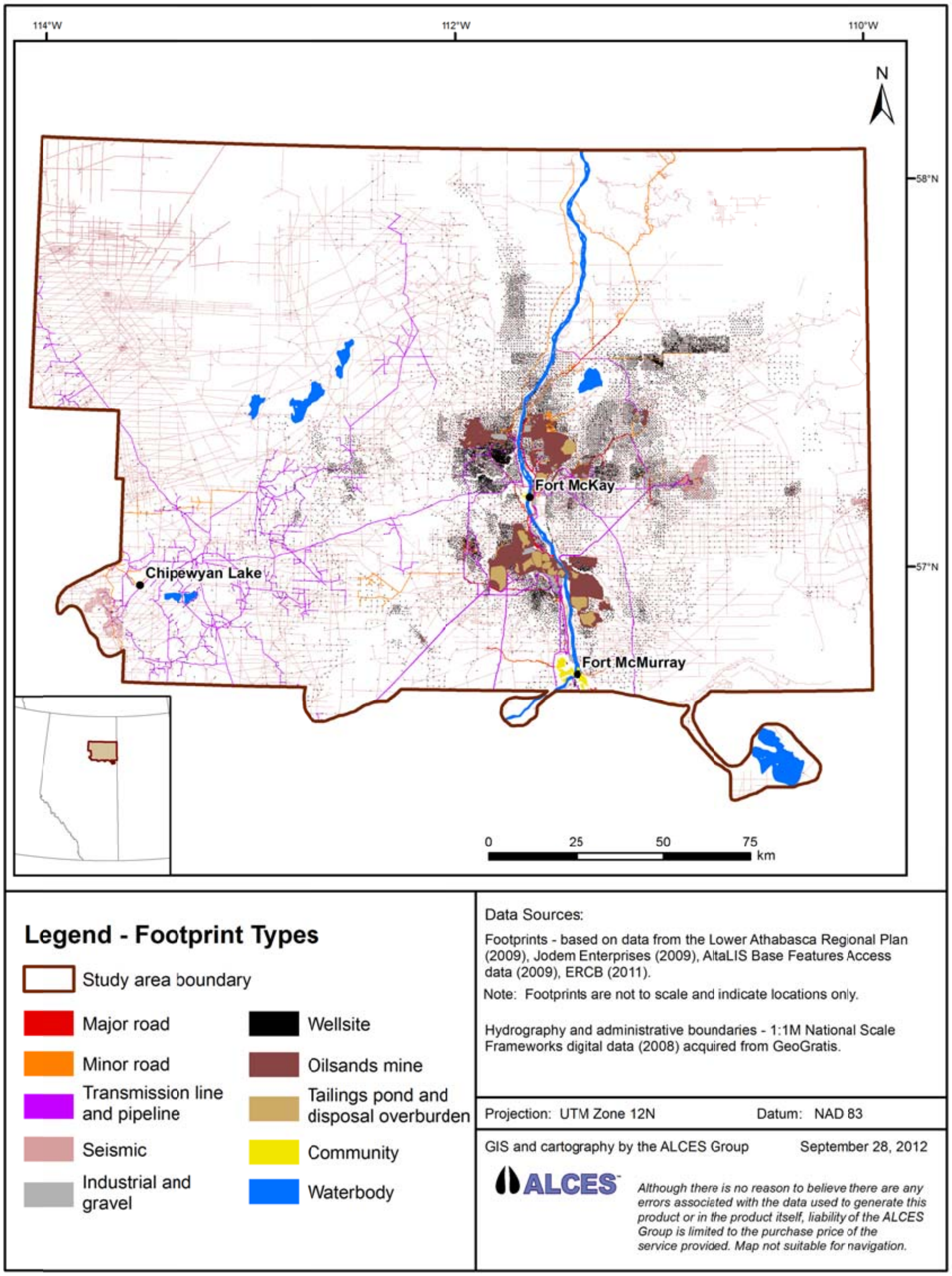


Figure 3: Current Anthropogenic Footprints in the Fort McKay (FM) Study Area[6]

[6] Section 3.2.4 provides a detailed description of footprint types.

the land base and the effect of natural fires on biotic indicators. Thus, in this project, we simulated the influence of a natural fire disturbance regime because it is a key component of landscape dynamics, and it has implications for ecosystem attributes that are influenced by forest age, such as wildlife habitat.

During recent decades, the role of natural disturbances in boreal forest systems has changed, as human land use practices have altered the intensity, recurrence and geographic extent of fire, flooding, and insect infestations. Improved fire suppression might have reduced the rate of wildfire in the boreal mixedwood forests of Alberta during the last several decades (Murphy 1985). In the boreal forests of Alberta, fire return interval increased from 38 years in pre-settlement times to 90 years by the late 1960s (Murphy 1985). However, anthropogenic disturbances are now common and growing in prevalence in Alberta’s boreal forests (Dancik, et al. 1990).

3 Methodology

3.1 Scenario Analysis through Simulation Modeling with ALCES®

For this project, we used the landscape simulation model ALCES®[7] to define, develop and explore land-use scenarios for the Fort McKay (FM) Study Area (***Appendix 2***). Scenario analysis methods explicitly explore uncertainty about alternative futures, and use the power and speed of contemporary simulation models to test concepts, conduct sensitivity analyses, challenge dogmas, and seek those elements of systems that have high impact and high uncertainty.

Scenarios are plausible, but structurally different descriptions of how the future might unfold and are used to provide insight into the challenges and opportunities of realistic future states (Duinker and Greig 2007) and (Mahmoud, et al. 2009). Alcomo[8] proposed the following working definition: *"a scenario is a description of how the future may unfold based on 'if-then' propositions and typically consists of a representation of an initial situation and a description of the key driving forces and changes that lead to a particular future state"* (Alcomo 2008).

Given this understanding of environmental scenario analysis, it is important to recognize that computer-based scenario simulations do not provide quantitative predictions or forecasts of conditions in any particular year, but they can be used to assess the influence of assumptions or management approaches, and to explore uncertainties and strategies for mitigating cumulative effects (Schneider, et al. 2003), (Carlson, et al. 2010) and for land use planning (North Yukon Planning Commission (NYPC) 2009). Although it is not possible to possess sufficient certainty about all deterministic and stochastic variables in complex systems to build forecast models that literally predict the future, the value of the future scenario is not to know and predict, but to *learn*. The emphasis on learning provides the context for the approach and methods we used in this study; learning provides the basis for understanding and exploring consequences of land use and the rationale for developing appropriate management strategies.

3.2 Simulation Metrics

Simulation runs in ALCES were 250 years in length, and were comprised of three discrete time periods to illustrate relative landscape changes over a historical context, and to provide a comparative baseline for exploring alternative future scenarios (Figure 4):

- The first 100 years (years 0-100) simulated dynamics of RNV from 1860 – 1960.
- The next 50 years (years 101-150) reflected the back-cast period (general period from onset of industrial land uses to current conditions) and is shown in figures as 1960 – 2010.

[7] http://www.alces.ca
[8] Pg. 15

- The future 100 years (years 151-250) represents a scenario intended to explore a plausible future driven by explicitly stated input assumptions from 2010 – 2110. The year 2010 is used as the current year, and temporal reference for discussion of scenario results in the recent past and over the 100 year future scenario timeframe.

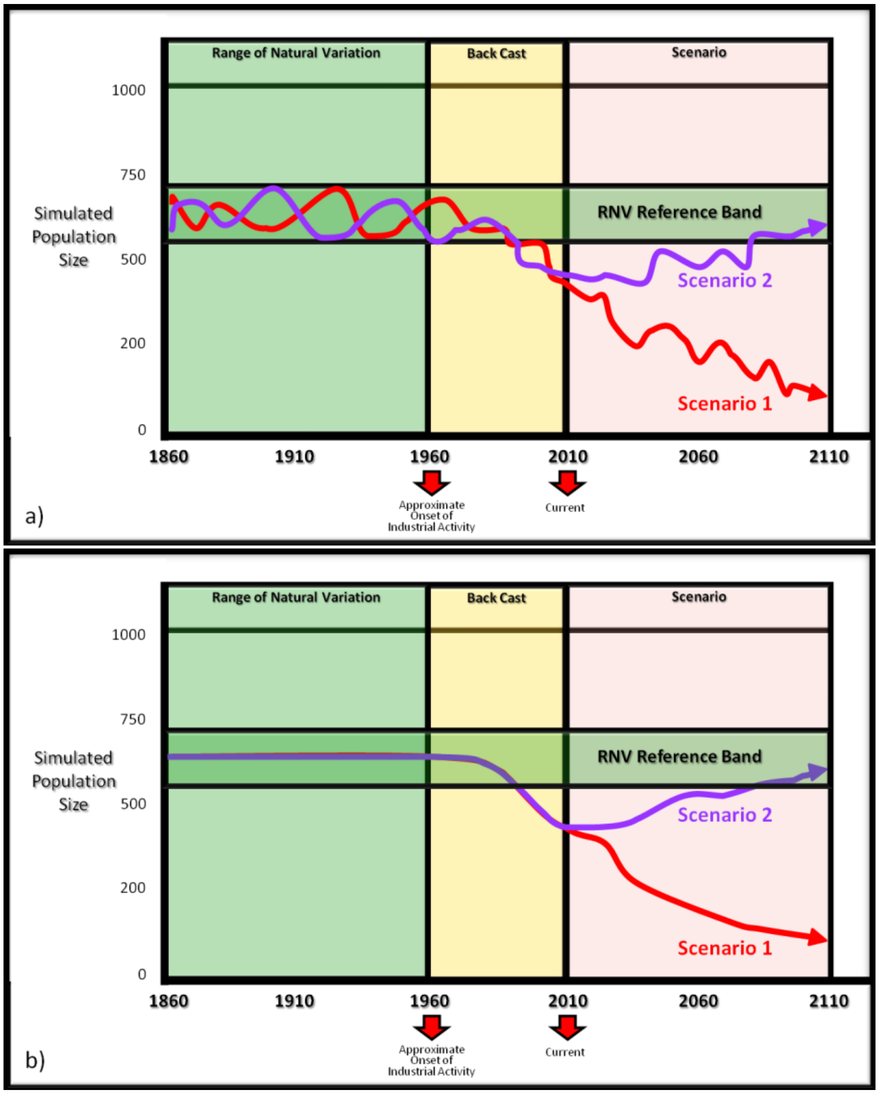


Figure 4: Format of Comparative Graphs Used to Illustrate Performance of Indicators over Three Time Periods, with Two Comparative Future Scenarios[9]

Figure 4 also illustrates a key consideration in conducting and presenting simulation model results, which is whether the model is run stochastically or deterministically. In a stochastic model, key variables are not described by unique values, but instead are represented by probability distributions, which include randomness. In contrast, a deterministic model has unique values defined for parameters in the model, which causes

[9] ALCES can be run with natural disturbances (e.g. forest fires) set to a) stochastic (random) or b) deterministic (constant).

the model to perform the same way for a given set of initial conditions. In this project we ran ALCES stochastically to estimate the range of natural variability in biotic indicators (Section 3.2.1), and ran the model deterministically to generate graphical results for indicators that would best reflect the comparative effects of different management levers (Figure 4), without the added noise introduced by random variability.

3.2.1 Range of Natural Variability (RNV) and Reference Points

Ecological indicators exhibit spatial and temporal variance, and this natural variability doesn't require the presence of humans or their land-uses. Since indicators such as moose, furbearers and fish would have responded numerically to natural stochastic changes in landscape characteristics (examples include water temperature, snow depth, forest age), it is important to understand and describe the "*range of natural variability*" (or RNV) of an indicator as a baseline reference for a pre-industrial landscape. RNV can be considered the normal variation (e.g., 95% confidence interval) of a specific ecological attribute such as species abundance, species distribution, or ecological processes (e.g., decomposition) that occurs in response to the full suite of natural and episodic disturbances that characterize an ecological system.

Using ALCES, we calculated the 95% confidence intervals of RNV for biotic indicators by generating datasets comprised of 50 and 100 year simulations with natural disturbances (i.e., fire) set to run stochastically. We used the 95% confidence intervals to illustrate RNV in graphs as a comparative baseline to evaluate trends of indicators in subsequent scenarios and sensitivity analyses.

The goal of using RNV as part of these analyses was to graphically illustrate an ecologically relevant reference band of variance to compare against current and future risk associated with a stated set of land use assumptions. An illustration of RNV for moose HSI is shown in Figure 5; the graph depicts 50 stochastic simulations superimposed on top of each other, and the light green RNV band highlights the upper and lower 95% confidence intervals from the simulated dataset.

Ecologists generally accept that the further land use conditions move indicators away from RNV (either above or below), the greater the level of risk to integrity or resilience of an ecological indicator (Holling 1973). The conceptual approach for using RNV as a benchmark for evaluating performance of ecological indicators is well established in the literature (for example see (Landres, Morgan and Swanson 1999), (Parsons, Morgan and Landres 1998), (Willis and Birks 2006) and (Wong and Iverson 2004). The concept of RNV and risk to ecological indicators has been broadly discussed by biologists within the Government of Alberta (Department of Environment and Sustainable Resource Development), and has been endorsed as a key measure by which to assess risk of ecological indicators examined in the Alberta Land-use Framework.[10]

The RNV for wild animals, fish and plants provides a useful benchmark for understanding impacts to aboriginal and treaty rights because it was the basis for supporting traditional

[10] ***https://www.landuse.alberta***

use of wildlife resources in the pre-industrial landscape. And avoidance of significant declines to RNV is necessary to sustain opportunities for traditional land use in future.

Figure 5 shows a green band that illustrates the 95% confidence intervals for 50 simulations of moose HSI in the Fort McKay Study Area.

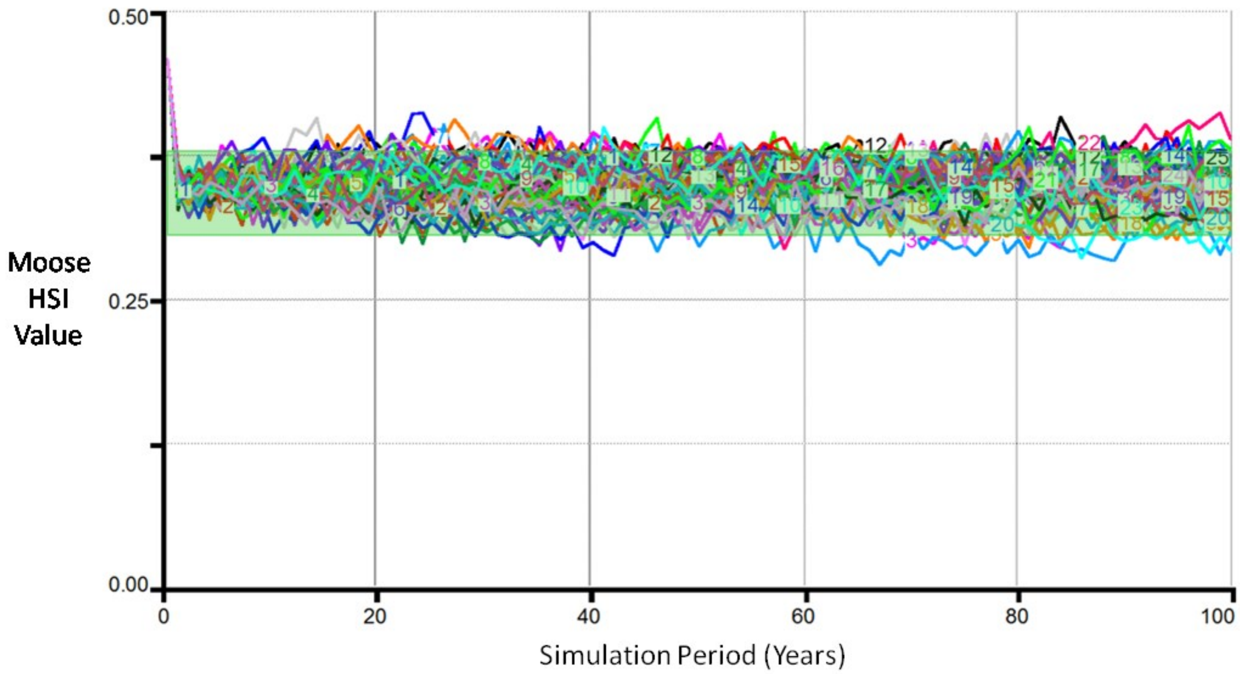


Figure 5: Range of Natural Variation (RNV) in the Fort McKay Study Area[11]

3.2.2 Reconstructing a Back-cast

With respect to industrial land-use, a 50-year back-cast was selected to represent the period from 1960 to present day, circa 2010. This back-cast period was used to represent the approximate onset of industrial activity in the Fort McKay Study Area, which coincided with the initial industrial-scale exploration and activity associated with the energy sector. The Alberta Land-use Historical Time Series Dataset (2012)[12] was used as an empirical basis for defining the back-cast period.

---

[11] Numbered lines in graph represent a unique simulation run. In this example, the variance in moose HSI is affected by a dynamic forest age class structure over time, which is driven by random fire events that are simulated based on a fire return interval appropriate to the boreal forest landscape of the study area. Variation in precipitation and snow depth also contributes to inter-annual variance in moose HSI values

[12] The Alberta Land-use Historical Time Series Dataset created maps at decadal intervals depicting the historical transformation of Alberta's landscape over the past century (1910 to 2010) (***http://www.abll.ca/library/Landuse_Data***). The general approach was to start with today's (circa 2010) landscape composition and remove anthropogenic footprints at rates consistent with the best available historical land-use data.

3.2.3 Simulating a Future Scenario

Alternative scenarios were run for 100 years into the future and designed to explore key assumptions and uncertainties about land use trajectories and management levers (see Section 3.2). In order to provide a clear graphic comparison of indicator performance between scenarios (including sensitivity analyses), we ran ALCES with forest fires set as a deterministic (i.e., constant) process, which meant that the annual area burned was based on the average annual rate for the fire return interval of the Study Area. The rationale for running simulations in ALCES with fire (and other natural processes) set as deterministic processes was so that the model outputs would be easier to interpret, and the effects of management levers would be clearer and not obscured by random variability.

3.2.4 Landscape Composition

3.2.4.1 Fort McKay Study Area

Classification of landscape types and footprint types for the 3.6 million ha Fort McKay Study Area were similar to recent scenario modeling work for CEMA-SEWG and LARP, which facilitated comparison of landscape characteristics, as well as performance of biotic indicators. Twenty landscape types and 14 footprint types were defined based on available geospatial data for the Fort McKay Study Area (Figure 3, and Table 1). Among the landscape types described for the Study Area, open fens, bogs, and pine forests represented the cover types with the largest surface area (Figure 6).

With respect to anthropogenic footprints, oil sands mines represented the largest polygonal features, whereas seismic lines represented the most extensive source of edge on the landscape today (Figure 7). Forest age class distributions for the Study Area were determined for Alberta Vegetation Inventory data, and were entered into ALCES among the ten seral stages, each of which is 20 years in length (***Appendix 4***). The landscape and footprint geospatial data were intersected in a geographic information system, and the resulting spatial distribution data were entered in to ALCES (***Appendix 4***).

Although the total area of anthropogenic footprint represented only 2.8% of the total Study Area (Table 5), the area influenced by the associated indirect footprint was substantially larger and varied with the buffer distance that was applied to the current direct footprint.

Figure 8 illustrates the range in percent of Study Area that was influenced by direct and indirect footprint (20%, 33%, 43% and 57%) as a function of buffer distance (100 m, 200 m, 300 m, and 500 m respectively)[13].

[13] The 100, 200, 300, and 500 meter buffer distances were selected for illustrative purposes as a plausible range of distances that reflect avoidance distances of large mammals to roads and other anthropogenic footprints (Dyer, et al. 2001), (Frair, et al. 2008), (Environment Canada 2011) and (Shanley and Pyare 2011). See (Lagimodiere 2013)

Table 1: Characteristics of Landscape Types (LT) and Footprint Types (FT) in the Fort McKay Study Area

	Landscape Type (LT)	ALCES LT Code	Current Area (ha)	Current Length (km)		Footprint Type (FT)	ALCES FT Code	Current Area (ha)	Current Length (km)
1	Hardwood	Hw	358,938	-	1	MajRd	MajRd	1,460	584
2	Mixedwood	Mw	212,560	-	2	Min Rd	MinRd	1,336	890
3	White spruce	WhSp	102,805	-	3	Gravel Pit	GrPit	2,377	227
4	Pine	Pine	509,575	-	4	Tranmission Line	TransLne	482	160
5	Closed Black Spruce	ClBlSpruce	228,655	-	5	Rail	Rail	-	-
6	Riparian Forest	RipF	264,413	-	6	Industrial Facility	IndFac	4,889	528
7	Open Black Spruce	OpBlSp	330,709	-	7	Disposal Overburden	DispOverb	4,547	137
8	Black Spruce Lichen Moss	BlSpLiMo	76	-	8	Urban	UrbanL	2,749	94
9	Open Fen	OpFen	733,655	-	9	Camps	RRCamp	300	6
10	Bog	Bog	580,289	-	10	Tailings Pond	TailPond	9,111	187
11	Native Herbaceous	Herb	40,613	-	11	Seismic	Seismic	12,501	31,252
12	Tall Shrub	TShr	4,119	-	12	Wellsite	Wellsite	15,013	6,448
13	Short Shrub	ShShr	10,436	-	13	Pipeline	Pipeline	5,103	4,252
14	Small Lotic (streams)	SmLo	3,395	33,950	14	Surface Mine	SurfMine	39,901	855
15	Large Lotic (rivers)	LaLot	16,477	1,750			SubTotal	99,769	45,620
16	Endpit Lake	EPLake	-	-					
17	Lentic (lakes)	Lentic	116,740	-					
18	Beach Dune	BeDune	5,497	-					
19	Cultivated Crop	CultCr	-	-					
20	Forage Crop	Forage Crop	40	-					
		SubTotal	3,518,992	35,700					
	TOTAL AREA OF STUDY AREA		**3,618,761**						

Note: Major roads had paved or gravel surfaces with a minimum width of 12.5 m, whereas minor roads were graveled or unimproved surfaces with an average width of 7.5 m.

3.2.4.2 Industrial Landscape Study Area

The size of a Study Area influences how performance of indicators is measured and tracked; a large Study Area might dilute the intensity and associated effects of land-use. Therefore, it is also useful to assess indicators at a finer scale to better understand the pace and intensity of land use activities, and the potential effects of land-use management strategies within the directly affected industrial area.

The predominant industrial land use within the Fort McKay Study Area was associated with bitumen extraction through oil sands mining and in situ wells, much of which was located in and around the hamlet of Fort McKay. Therefore, we also examined the effects of land use and potential benefits of management strategies on a smaller portion of the Study Area based upon the industrial zone around Fort McKay. The smaller Study Area was considered to more accurately reflect the development pressures that the Community of Fort McKay experiences.

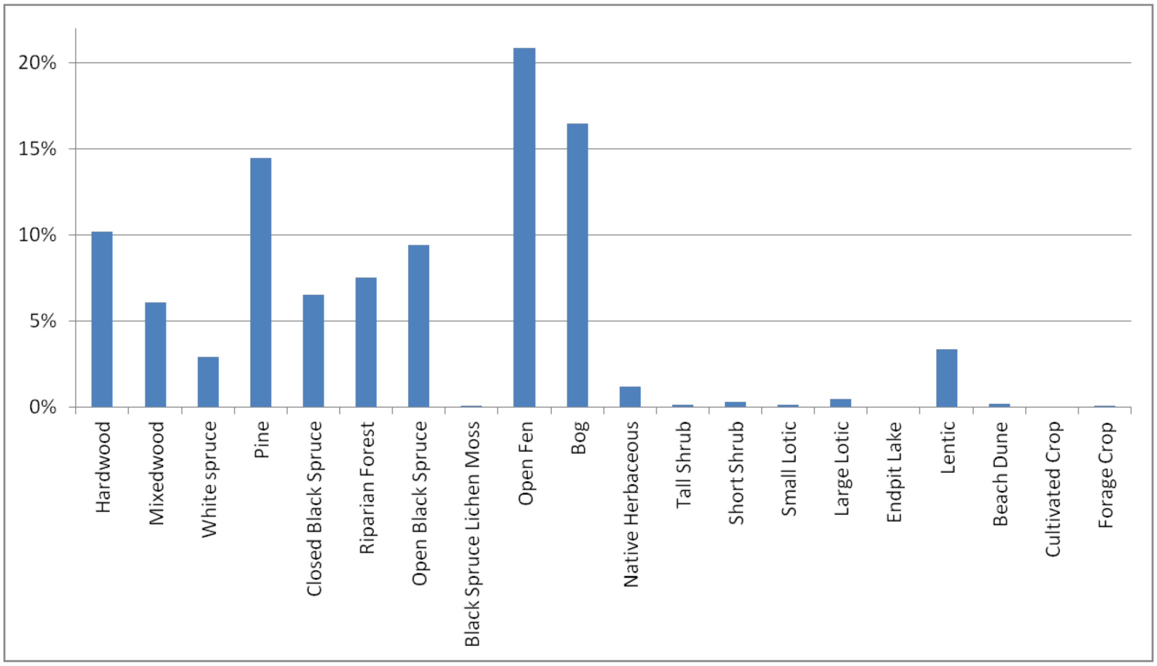


Figure 6: Relative Composition (% of total area) of Landscape Types within the Fort McKay Study Area

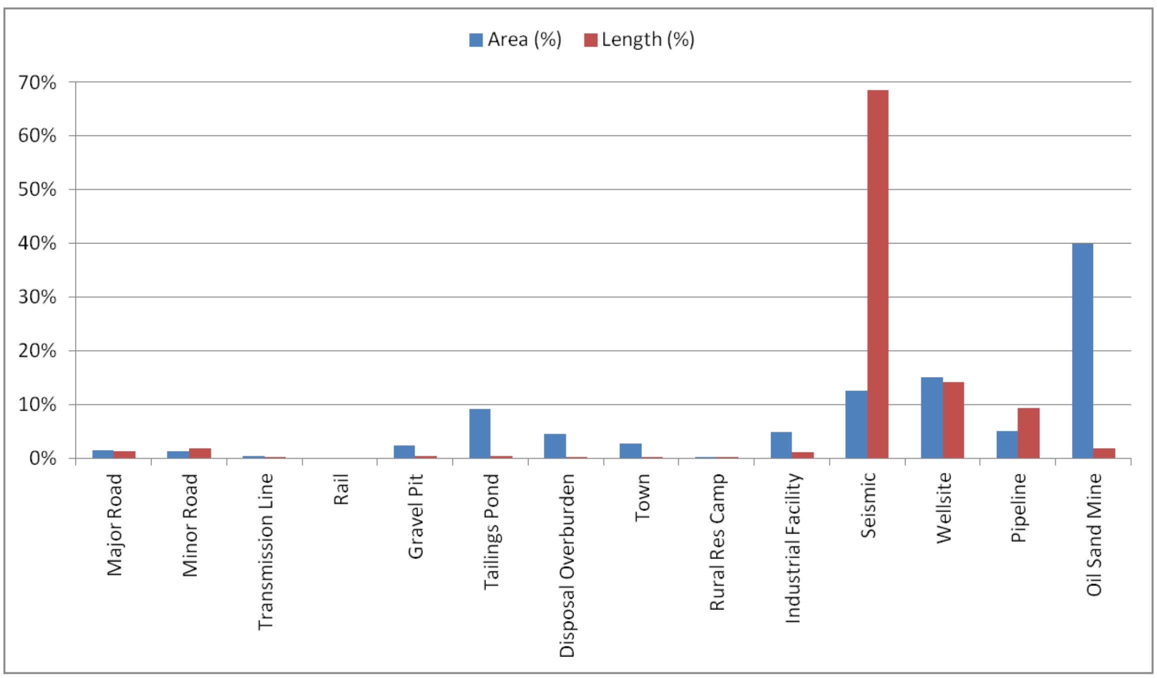
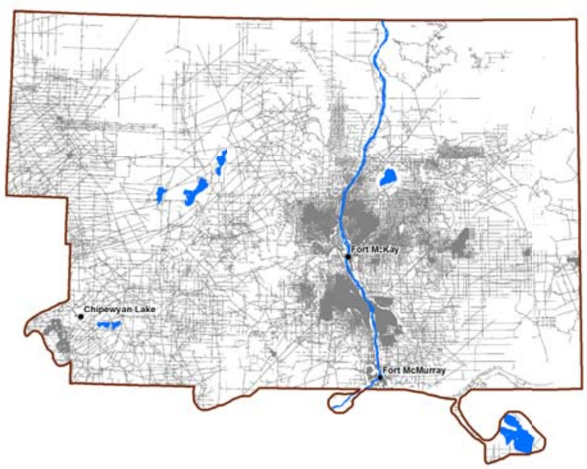
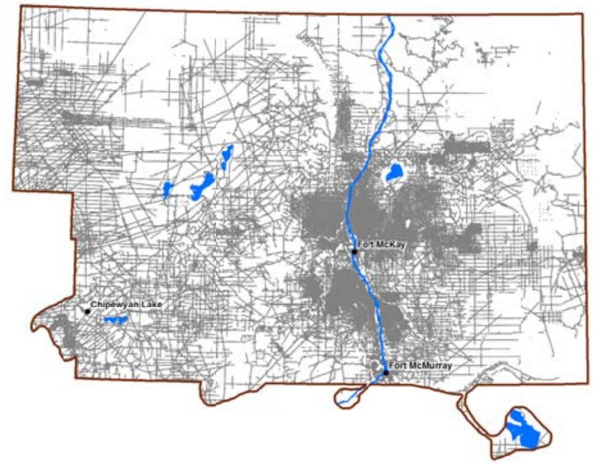


Figure 7: Relative Composition of Anthropogenic Footprints within the Fort McKay Study Area[14]

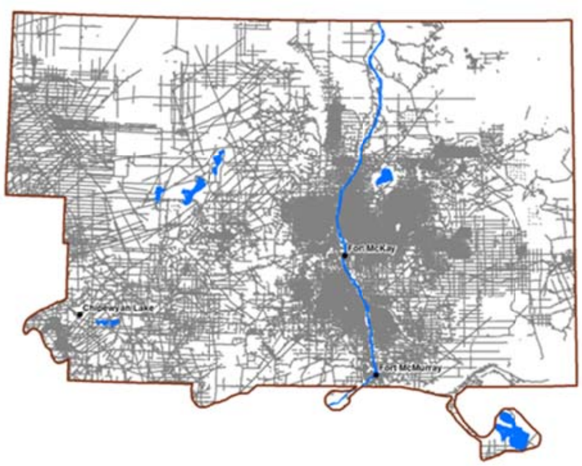
[14] Percent of area indicates the relative area (ha) that a footprint type accounts for relative to the total area of all anthropogenic footprints. Percent of length indicates the relative amount of edge (km) that a footprint type accounts for relative to the total length of all footprints.

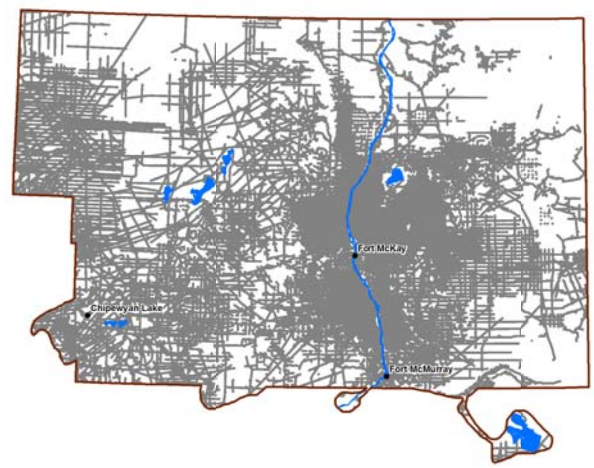




100 m buffer (20%)

200 m buffer (33%)





300 m buffer (43%)

500 m buffer (57%)

Figure 8: Effect of Variable Buffer Distances Applied to Current Anthropogenic Footprints in Fort McKay Study Area[15]

The main criterion for selecting a smaller portion of the Fort McKay Study Area was that the area was underlain by economic oil sands reserves and included:

a) The mineable oil sands area that is already under active development.

b) Areas that are likely to be developed initially through in situ well technology where bitumen pay depth is greater than 6 m (Energy Resources Conservation Board (ERCB) 2012).

[15] The numbers in parentheses indicate the percentage of the study area that is taken up by the direct footprint (~3%) and associated buffered areas.

Areas with bitumen pay depth less than 6 m were not selected for the smaller Study Area, as the assumption was that thicker bitumen pay deposits were economically viable and more likely to be developed first.

This secondary Study Area was 1.2 M ha, or 32% of the Fort McKay Study Area, and was designated the 'Industrial Landscape' (Figure 9). An intersection of landscape types and footprint types was conducted in order to parameterize a separate ALCES model with landscape composition data for the Industrial Landscape (Table 2). This model was subsequently used to explore sensitivity of indicators to management levers in the areas most likely to be directly affected by oil sands development in the near future.

Compared to landscape composition in the larger Fort McKay Study Area (Figure 6), the Industrial Landscape (Figure 10) had lower proportions of pine and higher proportions of hardwood and closed black spruce landscape types. The relative contributions of individual footprint types to total area and length of anthropogenic features was similar between the two Study Areas (see Figure 7 and Figure 11), with seismic lines having the largest contribution to edge and oil sands mines representing the largest area of footprints. However, the proportion of total footprint area in the Industrial Landscape was much higher than in the larger Fort McKay Study Area.

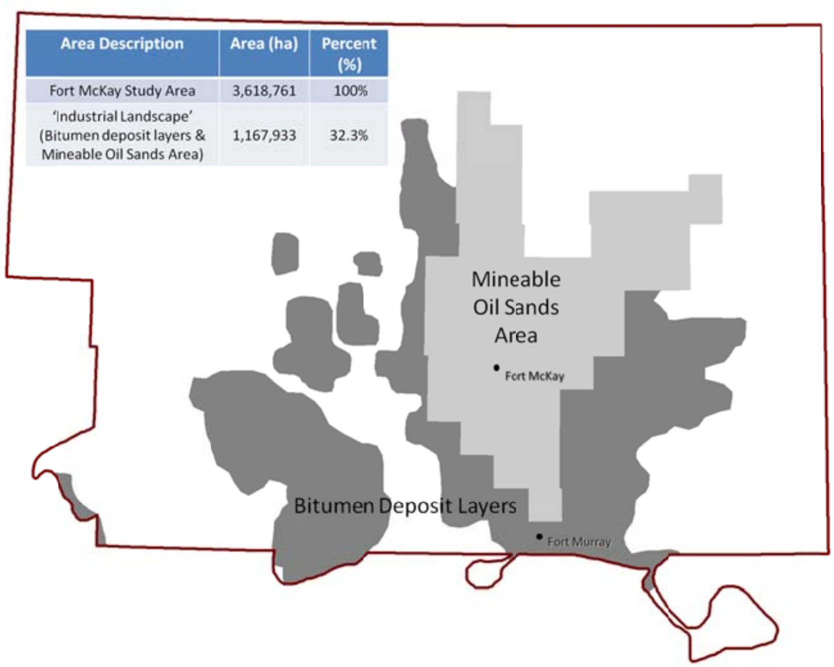


Figure 9: The 'Industrial Landscape' Study Area[16]

[16] The 'Industrial Landscape' Study Area (shown in the two shades of grey on the map) was selected within the larger Fort McKay study area, and was comprised of the area underlain by bitumen deposit layers > 6 m in pay thickness (bitumen in place for Athabasca SAGD area – Alberta Department of Energy 2008) and the mineable oil sands area as defined by ERCB (2012)

Table 2: Characteristics of Landscape and Footprint Types in the Industrial Landscape Study Area

Landscape Type (LT)	ALCES LT Code	Current Area (ha)	Current Length (km)	Footprint Type (FT)	ALCES FT Code	Current Area (ha)	Current Length (km)
1 Hardwood	Hw	175,857	-	1 MajRd	MajRd	1,362	545
2 Mixedwood	Mw	67,447	-	2 Min Rd	MinRd	751	501
3 White spruce	WhSp	37,970	-	3 Gravel Pit	GrPit	446	148
4 Pine	Pine	67,577	-	4 Tranmission Line	TransLne	-	-
5 Closed Black Spruce	ClBlSpruce	108,109	-	5 Rail	Rail	2,377	227
6 Riparian Forest	RipF	71,853	-	6 Industrial Facility	IndFac	9,111	187
7 Open Black Spruce	OpBlSp	62,979	-	7 Disposal Overburden	DispOverb	4,547	137
8 Black Spruce Lichen Moss	BlSpLiMo	33	-	8 Urban	UrbanL	2,706	93
9 Open Fen	OpFen	275,228	-	9 Camps	RRCamp	-	-
10 Bog	Bog	165,085	-	10 Tailings Pond	TailPond	4,715	509
11 Native Herbaceous	Herb	14,662	-	11 Seismic	Seismic	5,654	14,134
12 Tall Shrub	TShr	329	-	12 Wellsite	Wellsite	13,383	5,748
13 Short Shrub	ShShr	3,886	-	13 Pipeline	Pipeline	3,425	2,854
14 Small Lotic	SmLo	853	8,528	14 Surface Mine	SurfMine	39,901	855
15 Large Lotic	LaLot	8,896	945		SubTotal	88,378	25,937
16 Endpit Lake	EPLake	-	-				
17 Lentic	Lentic	18,679	-				
18 Beach Dune	BeDune	73	-				
19 Cultivated Crop	CultCr	-	-				
20 Forage Crop	Forage Crop	40	-				
	SubTotal	1,079,556	9,473				
TOTAL AREA OF STUDY AREA		**1,167,934**					

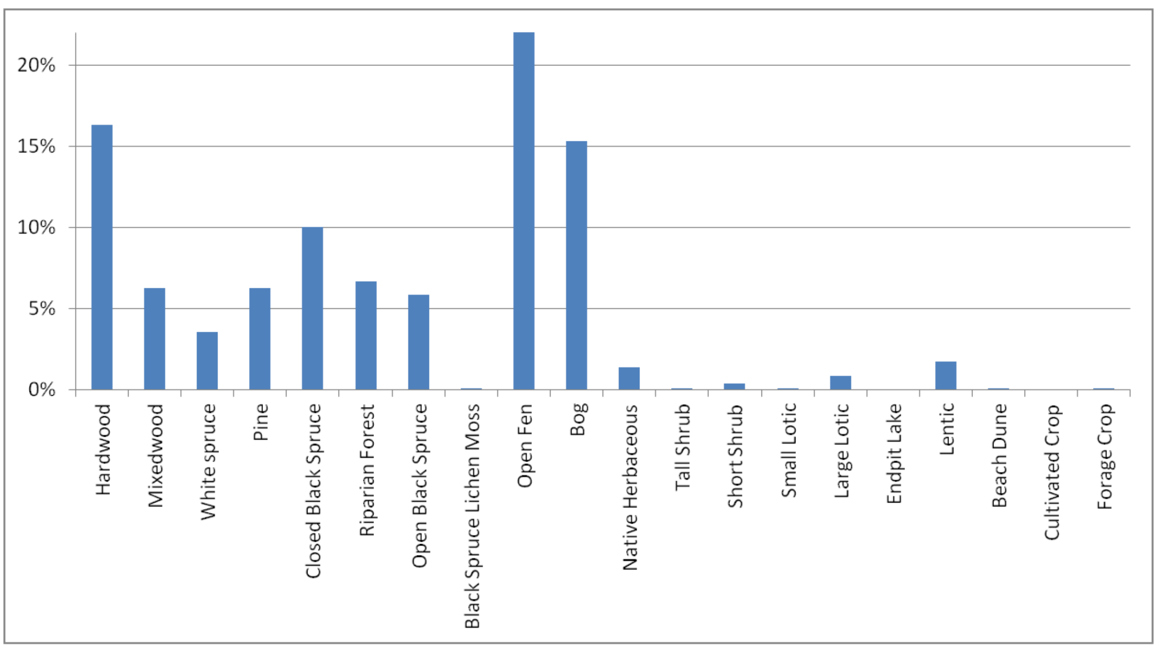


Figure 10: Relative Composition (% of total area) of Landscape Types within the Industrial Landscape Study Area

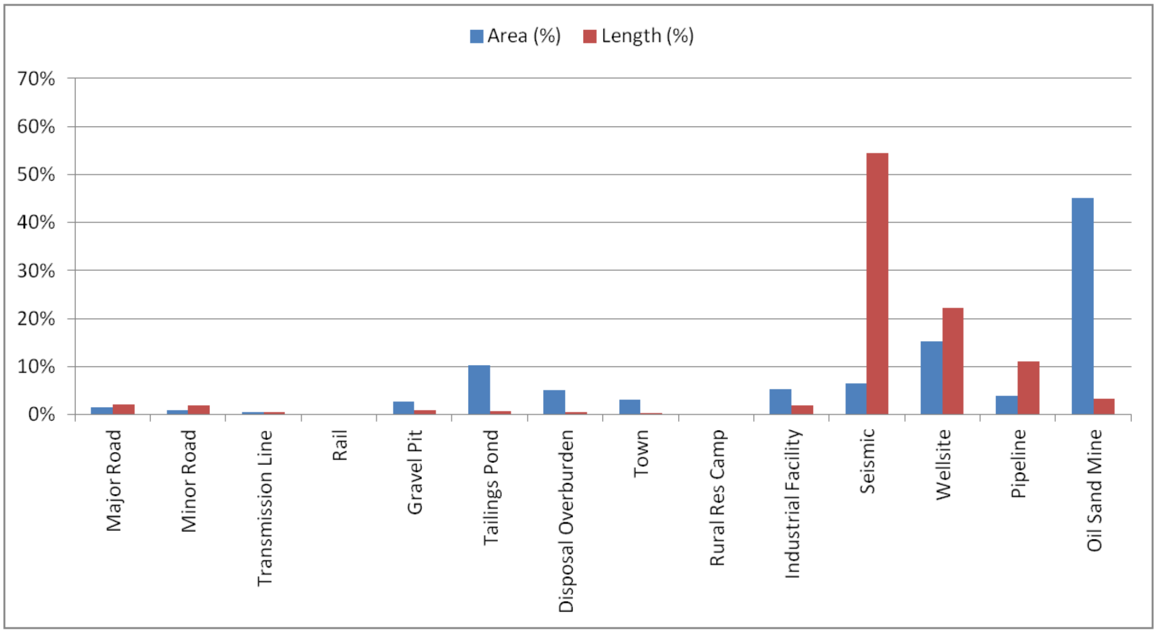


Figure 11: Relative Composition of Anthropogenic Footprints within the Industrial Landscape Study Area

3.3 Economic Indicators

Indicators are used to measure and monitor performance of specific components within a system. Useful indicators are able to provide insight into the performance of multiple components because they are, in fact, key drivers of processes and relationships within the system.

Since resource production in the Study Area is due primarily to the forestry and energy sectors, we selected and developed economic indicators to simulate plausible trends in production of commodities and derived levels of gross revenue and employment as highlighted in the bulleted list below:

- Hardwood (i.e., deciduous tree) production (m^3)
- Softwood (i.e., coniferous tree) production (m^3)
- Bitumen production (m^3) separated by mineable and in situ well extraction
- Bitumen revenue ($)

3.3.1 Hardwood and Softwood Production (m^3)

Annual hardwood and softwood production volumes (m^3) were simulated based on user-defined targets for timber harvest levels, which were estimated and area-weighted from the Annual Allowable Cut (AAC) available to respective forest companies. In its Forest Sector module (ALCES Group 2013), ALCES is designed to track and simulate area and age of five forest landscape types in the Study Area, where each forest landscape type is comprised of ten seral stages (in 20-year intervals) and with each seral stage having unique growth and yield equations for hardwood and softwood trees relevant to the Study Area. ALCES proceeds to annually harvest the land base on an oldest-first basis (searching out maximum wood volume and wood density), while respecting user-defined deletions such as green-up delay[17], inaccessibility, steep slopes, protective status, and buffer strips that reduce the proportion of each forest landscape type that is available to harvest.

3.3.2 Bitumen Production (m^3)

Bitumen is one of the thickest forms of petroleum, and occurs extensively throughout the Fort McKay Study Area in deposits associated with sand and partially consolidated sandstone. These oil sand deposits (also known as tar sands) collectively represent an immense and extensive hydrocarbon reserve in northeast Alberta, and will be key economic drivers to the Alberta and Canadian economies, as well as a major contributor to global heavy oil production in the future. Over the past several decades, the hydrocarbon sector has been the main driver of landscape transformation in the Study Area and associated economic productivity (i.e., jobs, royalties and gross revenues).

It is difficult to quantify total volumes of bitumen "in-place", but most sources provide provincial estimates in the range of ~1804 billion barrels (287 billion m^3) (Energy Resources Conservation Board (ERCB) 2011). Of this volume, economically viable existing technologies could remove ~170 billion barrels (27 billion m^3). This recoverable volume, and rate of production, is likely to increase as new technologies emerge.

The volume of bitumen produced to date (~6.9 billion barrels, 1.1 billion m^3) represents less than 4% of the recoverable volume, which emphasizes that production is in very early stages of development. Despite its budding emergence as a resource play, an important underlying assumption for bitumen production over its lifespan is that it will follow a generalized Hubbert-Naill hydrocarbon production curve where it will peak and decline (see ***Appendix 3***). Thus, given assumptions of approved and projected new bitumen projects in Alberta, the current annual production levels of 1.6 M bpd (0.26 M m^3/year) is expected to increase to 3.6 M bpd (0.57 M m^3/year) by 2020 (Energy Resources Conservation Board (ERCB) 2011), and to 5.3 M bpd (0.84 M m^3/year) by 2030 (Canadian Association of Petroleum Producers (CAPP) 2012).

Bitumen reserves in the Fort McKay Study Area are considered to be the largest in Alberta, and occur within the Wabiskaw-McMurray deposit (historically referred to as the Athabasca deposit). Estimates of initial bitumen in-place for the Wabiskaw-McMurray deposit was estimated at 152.4×10^9 m^3 of which 13.7% (20.8×10^9 m^3) occurs at a depth (i.e., less than 65 m) considered to be suitable for surface mining (Energy Resources Conservation Board (ERCB) 2012).

> *"Depending on the depth of the deposit, one of two methods is used for the recovery of bitumen. North of Fort McMurray, crude bitumen occurs near the surface and can be recovered economically by open-pit mining. In this method, overburden is removed, oil sands ore is mined, and bitumen is*

[17] The green-up delay represents the amount of time that must pass after a harvest event in order for the impacts of logging to be sufficiently diminished. Green-up delay is often considered to be the time that vegetation in a harvested area has been able to grow sufficiently to provide adequate cover for wildlife and hydrological buffering.

> *extracted from the mined material in large facilities using hot water. At greater depths where it is not economical to recover the bitumen through mining, in situ methods are employed. In situ recovery takes place both by primary development, similar to conventional crude oil production, and by enhanced development. Cyclic steam stimulation (CSS) and steam-assisted gravity drainage (SAGD) are the two main methods of enhanced development whereby the reservoir is heated to reduce the viscosity of the bitumen, allowing it to flow to a vertical or horizontal wellbore" (ERCB ST98-2012: Alberta's Energy Reserves 2011 and Supply/Demand Outlook)*

3.3.3 Revenue ($) from Bitumen

We used the Hydrocarbon Sector module in ALCES (ALCES Group 2013) to explore the consequences (benefits, liabilities) of exploration, extraction, processing, and translocation of hydrocarbons, which in this study was focused on oil sands mining and in situ SAGD well extraction. The module simulated growth of all relevant footprint types (seismic lines, well sites, well site access roads, pipelines, active mines, overburden dumps and industrial facilities), and placed all relevant footprint types on defined reclamation trajectories according to assumptions outlined in (Section 3.7.3.5). These were largely based on assumptions originally developed by CEMA-SEWG (Cumulative Effects Management Association (CEMA) 2008) and further refined through the LARP process (see ALCES Group 2009, Government of Alberta 2012). The coefficient to estimate gross revenue from oil sands was based on a value of $642 per m^3 of bitumen. A key assumption was that historical and future employment coefficients are set at constant 2012 values (0.0008 FTE/m^3 of produced bitumen (CEMA-SEWG).

3.4 Landscape Indicators

Human land uses might dramatically influence habitat loss and fragmentation. The development and reclamation of anthropogenic linear and polygonal features are often the key driving variables that determine temporal patterns in landscape characteristics. We selected the following landscape indicators to track and assess landscape health and integrity in the Fort McKay Study Area:

- Anthropogenic (human-built) edge density (km/km^2)
- Forest core area (fraction)
- Average forest age
- Percent (%) of landscape area that is natural and anthropogenic
- Watershed discontinuity

3.4.1 Anthropogenic (Human-built) Edge Density (km/km^2)

Human-caused linear features are a defining landscape driver for many biodiversity indicators. This is largely due to the increased direct and indirect disturbance caused by humans, plants, and animals that move, or expand along, the network of linear features. In some cases linear features can improve habitat for species such as moose, by providing access to younger plant communities and increased forage. This positive effect is often overridden by increased mortality to moose from motorists, hunters, fishers, trappers and animal predators using these linear features. Vehicle-wildlife collisions, intentional and unintentional disturbance or harassment, harvest, avoidance of habitat along linear features, and changes in predator-prey dynamics all contribute to the cumulative effects of linear features on wildlife.

Roads, other linear corridors, and polygonal features are widespread features of most landscapes, and are associated with negative effects on both terrestrial and aquatic ecosystem function (Trombulak and Frissell 2000). Access corridor density is considered to be the most useful landscape indicator because it integrates many ecological impacts of roads, human use, and vehicles (Forman and Alexander, Roads and their major ecological effects 1998), (Trombulak and Frissell 2000) and (Forman, Sperling, et al. 2003). Increased road density also causes increased water yield and sediment transport to streams, increased number of fish movement barriers, and has also been correlated with declines in salmonid species, including bull trout (Jones and Grant 1996), (Trombulak and Frissell 2000), (Stevens, Council and Sullivan 2010) and (MacPherson, et al. 2012).

Anthropogenic edge density (km/km^2) is tracked in ALCES as the sum of all edges from polygonal and linear features associated with human footprints within a given area. Edge is a measure of intensity of land use; edge density is a direct measure of the occurrence of human-built features such as seismic lines, pipelines, roads, well sites, airstrips, power transmission lines and gravel pits, and is a useful indicator for landscape fragmentation and issues relating to access within the land base.

3.4.2 Forest Core Area (Fraction)

Forest core area is defined as the area within a forested landscape patch that occurs beyond a specified depth-of-edge influence (i.e., edge distance) or buffer width (McGarigal, Cushman and Ene 2012); forest core area in ALCES is calculated within each forest landscape type based on a buffer width of 200 m from any anthropogenic feature. Forest core area contributes to the function of landscape patches and is inversely related to landscape fragmentation. In combination with edge density, forest core area provides insight into the degree of intact habitat and fragmentation, particularly for species that inhabit forested habitats and are sensitive to human presence or structural edges.

3.4.3 Average Forest Age

Average forest-stand age is an indicator that integrates the dynamics of forest age class structure into an area-weighted average of the forest landscape types within the Study Area. Average forest-stand age is an indicator of the cumulative disturbance rates that affect forest age class structure, and is a useful coarse-level indicator to understand effects on wildlife species that prefer young versus old forests. In ALCES, the age class structure of forests is tracked in ten seral stages, each of which is 20 years long. As such, forest age can be tracked between Seral Stage 1 (year 0 to 20) and Seral Stage 10 (year 180 to 200). Important drivers of forest age class structure include rates of fire, insect outbreaks and logging. In addition to forestry, the energy sector also influences forest age class structure because removal of trees from forested landscape types is a pre-requisite to construction of seismic lines, well sites and pipelines. These features begin a new successional sequence as young forests once they have been reclaimed.

Based on fire research in the region (Andison 2005), fire rates for land-use scenarios in northern Alberta (e.g., CEMA-SEWG and Lower Athabasca Regional Plan) have been simulated based on an 80-year fire return interval, which is equivalent to an annual burn rate of 1.25%. To simulate 'range of natural variability' in the Study Area (and see Section 3.2.1), fire was modeled as a stochastic process with 50 Monte Carlo simulations in ALCES to estimate the variability in forest age-class distribution and other metrics (i.e., residual fire islands) that can occur due to random variation in fire rate.

The stochastic fire regime was simulated as a random draw from a lognormal distribution with an average annual burn rate of 1.25% and a maximum annual burn rate of 10%. The lognormal is an appropriate statistical distribution for simulating fires in the boreal region. Here, the observed burn rate is highly variable across years, because low annual burn rates are punctuated occasionally by years with extremely large fires (Armstrong 1999). Fire is the dominant natural disturbance in the region, and disturbance by forest insects was not included in simulations.

3.4.4 Percent (%) of Landscape Area that is Natural and Anthropogenic

Natural areas are physical landscapes and native plant communities whose structure and function are shaped by natural disturbance regimes (i.e., fire, insects, flooding) and ecological processes. These areas are naturally dynamic and are not influenced by anthropogenic events or processes. Conversely, anthropogenic areas are comprised of the human-built features on a landscape. The proportion (%) of the Study Area that is natural or anthropogenic is a useful indicator, because the distribution and abundance of many native species of plants and animals are related to the amount and structure of natural landscapes.

Many native species are adversely affected by anthropogenic features (croplands, roads, settlements, linear features, industrial complexes), and their prevalence and distribution often declines as landscapes become more industrialized. Although abundance or distribution of some native species decline in landscapes defined by human land-use, other species might prosper. These species of plants or animals, often referred to as "exotic invasives" might be considered desirable or undesirable to different sectors of society. Anthropogenic area can also serve as a proxy for a host of other social or economic values of interest. For example, tracking the area of croplands, pastures, well pads or settlements is a strong correlate to other indicators such as crop production, cattle herd size, hydrocarbon production, or human population, respectively.

3.4.5 Watershed Discontinuity

Watershed discontinuity indicates the degree of fragmentation in lotic ecosystems (i.e., rivers, streams and creeks) that can adversely affect fish populations and communities; it can also be considered a measure of watershed fragmentation due to hanging culverts

(Lagimodiere and Eaton, Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): Description, rationale and modelling coefficients 2009). Fragmentation largely occurs through creation of movement barriers to fish, which in turn might limit access to habitat, impede spawning, and reduce genetic diversity by isolating populations.

Watershed fragmentation is primarily caused by hanging culverts and is a well-documented stressor on fish populations and distribution in boreal systems (Park, et al. 2008), (Stevens, Council and Sullivan 2010) and (MacPherson, et al. 2012); fragmentation is negatively related to habitat availability and consequently, fish community and population structure (Lagimodiere and Eaton, Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): Description, rationale and modelling coefficients 2009).

Previous work by CEMA-SEWG (2008) determined that watershed discontinuity is a key parameter that affects integrity of native fish communities in boreal landscapes, and those results provide the base assumptions in ALCES. In ALCES, watershed discontinuity is defined by a relationship between the density of hanging culverts (hanging culverts per kilometre of stream) and the proportion of the watershed lost to fish (Park, et al. 2008) because of linear discontinuities of streams (Lagimodiere and Eaton, Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): Description, rationale and modelling coefficients 2009). Watershed discontinuity has a null value (0%) in a natural ecosystem and approaches a value of 1 (100%) in a heavily industrialized landscape as occurrence of stream crossings and hanging culverts increases to the extent that the watershed is completely fragmented and inaccessible to fish.

3.5 Biotic Indicators

Wild animals and plants (biota) are sensitive indicators of ecological changes in boreal ecosystems caused by either natural disturbance regimes (Stelfox 1995), or human land-uses (see CEMA-SEWG 2008). Individual species might also represent significant value to aboriginal peoples because of spiritual, economic, recreational or subsistence values (Garibaldi and Turner 2004) and (Garibaldi 2009). As such, selecting and tracking biotic indicators can provide value to stakeholder groups assessing the consequences (benefits and liabilities) of defined land-use trajectories. The list of biotic indicators selected for this project reflects the importance of certain harvestable species (or communities) to the Community of Fort McKay, and are summarized below:

- Moose Habitat Suitability Index (HSI)
- Fisher Habitat Suitability Index (HSI)
- Index of Native Fish Integrity (INFI)
- Edible Berry Habitat Suitability Index (HSI)

ALCES provides a useful and quantitative means of assessing the response of biota to a dynamic landscape because it can track all relevant natural disturbance regimes and land uses, and temporal and spatial changes in specific structural elements found within each landscape type. By simulating natural disturbance regimes (i.e., fire) with appropriate spatial and temporal variance, it becomes possible to quantify the range of natural variability (RNV) of a species (or ecological process), and how its performance changes when landscapes are subjected to human land uses or altered natural disturbance regimes (see Section 3.2.1)

3.5.1 Moose Habitat Suitability

The response of moose habitat to changes in landscape composition was assessed using an HSI model developed for northeast Alberta. HSI models are knowledge-based (as opposed to empirical) models that can incorporate information from both empirical studies and expert knowledge.[18] The moose HSI model used in the Fort McKay Cumulative Effects Project was based on a review of peer-reviewed literature as well as expert opinion. It was initially developed through CEMA-SEWG (2008) (Fisher 2004), and subsequently revised through the LARP process.

The moose HSI model combines information related to habitat availability and quality to calculate a performance index that ranges from 0 to 1. Steps required to calculate the index are summarized below.

a) For each land cover type (including footprints), habitat "availability" is assessed as the product of its proportional abundance in the Study Area and the fraction of a given habitat type that overlaps with the distribution of a species. Habitat "value" is a parameter that expresses the utility of a cover type to the species, where 0 indicates no utility, and 1 indicates capacity to support the species' maximum density To account for habitat avoidance and increased mortality associated with human or land-use activity, the habitat availability of areas adjacent to footprints can be reduced by applying buffers to footprint, and down-weighting the availability of habitat within the buffer by applying a proportional use coefficient (i.e., the proportion of habitat within the buffer that is used). This, in effect, integrates the effects of avoidance and mortality in to the HSI model. Thus, by applying proportional use coefficients to buffers, the effective width of the buffers can be modified to account for management strategies of human access that would reduce avoidance or mortality of moose associated with footprints (Section 3.7.3.3).

b) Habitat quality is a value ranging from 0 to 1 that incorporates the effect of other landscape attributes on habitat, such as forest age or shrub biomass density. For each relevant landscape attribute, a response surface ranging from 0 to 1 dictates the relationship between habitat quality and the status of the attribute. Each attribute is given a weight, whereby the sum of weights equals 1. Habitat quality for each land-cover type is then calculated as the sum of the products of the quality of each habitat attribute and its weight.

c) Habitat suitability (i.e., HSI value) is then calculated as the sum of the products of each cover type's habitat availability and habitat quality.

The moose HSI assumes that deciduous forest has the highest habitat value, followed by mixedwood forest and shrubland, due to the capacity of these cover types to provide

[18] USGS; ***http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiintro.htm***

browse and cover (Table 3). To account for the impact of human access (i.e., hunting) to moose HSI, anthropogenic footprints were buffered by 50 m to 200 m when calculating habitat availability (Table 3). Buffer widths were reduced in scenarios where access management was applied based on interviews with Alberta wildlife management experts (Sullivan pers. comm., Edmonton). The 200 m buffer associated with existing seismic lines was reduced by 50% for future (i.e., simulated) seismic lines that were assumed to be low impact (i.e., seismic line width ≤ 1.0 m). In addition to assuming faster reclamation, one reason for cutting low impact seismic lines was to discourage their subsequent use as trails by people driving off-highway vehicles. Repeated off-highway vehicle traffic can turn seismic lines into permanent linear features (Lee and Boutin 2006). Although research has not yet assessed the extent to which human access is reduced along low impact seismic, it is likely that motorized access is more difficult along these narrow lines. For this study, we assumed a 50% reduction in human access (and therefore similar reduction in impacts to moose HSI) along low impact seismic in the absence of empirical data.

Within a given landscape type, forest age is assumed to be the only determinant of habitat quality (Table 4) for simulating RNV (seral stage is assigned a value of 1). Forest age is considered a useful proxy for such habitat elements as canopy height and composition, shrub density, and a suite of other structural (physiognomic) features. For non-RNV simulations, human density was also included as a minor habitat quality attribute (Table 4). The moose HSI was assessed separately in ALCES for protected and unprotected portions of the landscape, and an overall average HSI value was then calculated as an area-weighted average. When calculating HSI in protected portions of the landscape, anthropogenic footprint was considered to be negligible, whereas in unprotected portions of the landscape, ALCES applied user-defined buffers and habitat values to anthropogenic footprints.

Status of the moose HSI was assessed relative to an estimated RNV. RNV was computed by conducting multiple (generally 50 runs for 100 years each) Monte Carlo simulations in ALCES where natural disturbance regimes (fire, inter-annual variation in climate) were functioning in a stochastic manner (see Section 3.2.1). Departure from RNV was used to infer risk to species (e.g., moose) by applying a set of risk categories that are proposed by Alberta Sustainable Resources Development (H. Norris, AESRD, pers. comm.) and based on those used by the International Union for the Conservation of Nature (Sullivan pers. comm., Edmonton). See Section 3.6.1.

3.5.2 Fisher Habitat Suitability

The response of fisher habitat to landscape changes was also assessed using an HSI modeling approach. Similar to the moose HSI model, the fisher HSI model used in this project was developed for CEMA-SEWG in 2008 (Fisher 2004) and was further refined as part of LARP; it was based on a review of scientific literature and expert opinion.

For the fisher HSI model we assumed that upland coniferous and mixedwood forest have the highest habitat value due to the capacity of these cover types to provide cover and prey throughout the year (Table 5). Hardwood landscape types were assigned a habitat value of 0.5 because they are used in the summer and fall, but not often from winter through spring.

Table 3: Habitat Value by Landscape or Footprint Type for the Moose HSI Model[19]

MOOSE

	Habitat Value			Habitat Value			Buffer Use with respect to Access Management		
Landscape Type (LT)	Pyrogenic	Anthropogenic	Footprint Type (FT)	Anthropogenic	Edge? (Y/N)	Buffer Width	Off	On (Mod)	On (High)
1 Hardwood	0.93	0.93	1 Major Road	0.30	Y	200	0.25	0.50	0.60
2 Mixedwood	0.70	0.70	2 Minor Road	0.40	Y	100	0.25	0.50	0.60
3 White spruce	0.55	0.55	3 Gravel Pit	-	Y	200	0.25	0.50	0.90
4 Pine	0.40	0.40	4 Inblock Road	0.60	Y	50	0.90	0.90	0.90
5 Closed Black Spruce	0.40	0.40	5 Tranmission Line	0.50	Y	100	0.50	0.80	0.90
6 Riparian Forest	0.93	0.93	6 Rail	-	Y	100	0.25	0.50	0.60
7 Open Black Spruce	0.60	0.60	7 Industrial Facility	-	Y	200	0.25	0.50	0.60
8 Black Spruce Lichen Moss	0.20	0.20	8 Disposal Overburden	-	Y	200	0.50	0.80	0.90
9 Open Fen	0.20	0.20	9 Urban	-	Y	500	0.50	0.50	0.60
10 Bog	0.20	0.20	10 Camps	-	Y	100	0.50	0.50	0.60
11 Native Herbaceous	0.50	0.50	11 Tailings Pond	-	Y	200	0.25	0.50	0.60
12 Tall Shrub	0.70	0.70	12 Seismic	0.60	Y	200	0.50	0.80	0.90
13 Short Shrub	0.70	0.70	13 Wellsite	0.10	Y	100	0.50	0.80	0.90
14 Small Lotic	0.20	0.20	14 Pipeline	0.50	Y	100	0.50	0.80	0.90
15 Large Lotic	0.20	0.20	15 Surface Mine	-	Y	200	0.25	0.50	0.60
16 Endpit Lake	-	-							
17 Lentic	0.20	0.20							
18 Beach Dune	-	-							
19 Cultivated Crop	-	-							
20 Forage Crop	-	-							

Table 4: Habitat Element Weightings for Moose, and Corresponding Habitat Quality* Weightings for Seral Stages

Habitat Element Weightings	
Range of Natural Variability (RNV)	
Seral Stage	1
Non - Range of Natural Variability (RNV)	
Seral Stage	0.9
Human Density	0.1

	Seral Stages (Years)	Habitat Quality
1	1-20	1.0
2	21-40	0.9
3	41-60	0.4
4	61-80	0.2
5	81-100	0.1
6	101-120	0.1
7	121-140	0.2
8	141-160	0.3
9	161-180	0.4
10	181-200	0.6

*Note: A habitat quality value of 1.0 indicates a seral stage that is ideal habitat for moose, whereas a value of 0 indicates a seral stage that has no utility. A value of 0.5 indicates a seral stage that contains 50% of the value of a perfect seral stage.

[19] Derivation and application of coefficients for buffer width and modifiers for access management are explained further in Section 3.7.3.3

To account for the impact of human access, especially trapping, anthropogenic footprints were buffered by 100 m when calculating habitat availability (Table 5). As with the moose HSI, the buffer associated with future narrow seismic lines was reduced by 50% to incorporate the likely reduction in human access along these lines. It was assumed that seismic lines (≥ 2.75 m width) were considered to be "edge" to fisher, in contrast to low impact seismic lines (≤ 1 m width) which were not considered to be edge (Bayne, Lankau and Tigner 2011).

Habitat quality was determined by forest age, with older forests having higher quality due to the importance of canopy closure for cover, and large-diameter overstory trees for denning sites (Table 6).

The fisher HSI was assessed separately in ALCES for protected and unprotected portions of the landscape, and an overall average HSI value was then calculated as an area-weighted average. When calculating HSI in protected portions of the landscape, anthropogenic footprint was considered negligible. The status of fisher HSI was interpreted using risk categories that were based on departure from the estimate RNV.

Table 5: Habitat Value by Landscape or Footprint Type for the Fisher HSI Model[20]

FISHER

	Habitat Value			Habitat Value			Buffer Use with respect to Access Management		
Landscape Type (LT)	Pyrogenic	Anthropogenic	Footprint Type (FT)	Anthropogenic	Edge? (Y/N)	Buffer Width	Off	On (Mod)	On (High)
1 Hardwood	0.50	0.50	1 Major Road	-	Y	100	0.10	0.50	0.75
2 Mixedwood	1.00	1.00	2 Minor Road	-	Y	100	0.10	0.50	0.75
3 White spruce	1.00	1.00	3 Gravel Pit	-	Y	100	0.10	0.50	0.75
4 Pine	0.10	0.10	4 Inblock Road	-	Y	50	0.10	0.50	0.75
5 Closed Black Spruce	0.10	0.10	5 Tranmission Line	-	Y	100	0.10	0.50	0.75
6 Riparian Forest	1.00	1.00	6 Rail	-	Y	100	0.10	0.50	0.75
7 Open Black Spruce	-	-	7 Industrial Facility	-	Y	100	0.10	0.50	0.75
8 Black Spruce Lichen Moss	0.10	0.10	8 Disposal Overburden	-	Y	100	0.10	0.50	0.75
9 Open Fen	-	-	9 Urban	-	Y	100	0.10	0.50	0.75
10 Bog	-	-	10 Camps	-	Y	100	0.10	0.50	0.75
11 Native Herbaceous	-	-	11 Tailings Pond	-	Y	100	0.10	0.50	0.75
12 Tall Shrub	-	-	12 Seismic	-	Y	100	0.10	0.50	0.75
13 Short Shrub	-	-	13 Wellsite	-	Y	100	0.10	0.50	0.75
14 Small Lotic	-	-	14 Pipeline	-	Y	100	0.10	0.50	0.75
15 Large Lotic	-	-	15 Surface Mine	-	Y	100	0.10	0.50	0.75
16 Endpit Lake	-	-							
17 Lentic	-	-							
18 Beach Dune	-	-							
19 Cultivated Crop	-	-							
20 Forage Crop	-	-							

[20] Derivation and application of coefficients for buffer width and modifiers for access management are explained further in Section 2.7.1.3.

Table 6: Habitat Element Weightings for Fisher, and Corresponding Habitat Quality* Weightings for Seral Stages

Habitat Element Weightings	
Range of Natural Variability (RNV)	
Seral Stage	1
Non - Range of Natural Variability (RNV)	
Seral Stage	0.9
Human Density	0.1

	Seral Stages (Years)	Habitat Quality
1	1-20	0.0
2	21-40	0.0
3	41-60	0.4
4	61-80	0.7
5	81-100	1.0
6	101-120	1.0
7	121-140	1.0
8	141-160	1.0
9	161-180	1.0
10	181-200	1.0

*Note: A habitat quality value of 1.0 indicates a seral stage that is perfect for fisher, whereas a value of 0 indicates a seral stage that has no utility. A value of 0.5 indicates a seral stage that contains 50% of the value of a perfect seral stage

3.5.3 Index of Native Fish Integrity

Fisheries management in Alberta is focused on conservation of fish populations and habitat in light of increased angling pressure (Zwickel 2012), increased use of aquatic ecosystems from a growing human population (Alberta Sustainable Resource Development (ASRD) 2006), and increased demand for water by land use (Schindler and Donahue 2006). Populations of sport fish in boreal Alberta have been strongly influenced by human activity (Post, et al. 2002). Similarly, alteration and direct loss of habitat and changes in water quality as a result of anthropogenic land-uses also have an important effect on distribution and abundance of fish populations (Park, et al. 2008), (Stevens, Council and Sullivan 2010) and (MacPherson, et al. 2012).

In north-east and east-central Alberta, the resilience of fish populations and fish habitat is largely affected by the following anthropogenic key stressors (Lagimodiere and Eaton, Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): Description, rationale and modelling coefficients 2009):

- Fishing pressure (fish mortality from recreational, commercial, and subsistence fishing).
- Access (habitat fragmentation related to stream crossing and density of linear features).
- Land disturbance (direct alteration and loss of fish habitat);
- Climate change.
- Water demand and use.
- Reduced water quality (i.e., sediment and nutrient runoff and spills/accidental releases of pollutants).

The Index of Native Fish Integrity (INFI) is an important indicator on the resilience of fish communities because it describes both the response of fish populations to cumulative anthropogenic stressors, and the relative degree of effort and likelihood for recovering the fish community at a landscape scale. A reduction in INFI conveys changes in abundance of fish species (Figure 12) that are most likely to change in response to anthropogenic effects, such as rare fish, apex predators, common specialists, common generalists, and irruptives (i.e., fish that are able to grow very fast once they are released into a new environment or from the limiting effects of predators) (Stevens, Council and Sullivan 2010).

The status of the fish community was assessed using the INFI, a measure that conveys changes in abundance and composition of fish species with a value ranging from 1 (undisturbed “natural” community) to 0 (highly disturbed community). Fish communities associated with different INFI values are presented in Table 9.

INFI response to scenarios was estimated using relationships involving human population density, density of angler access, watershed discontinuity (Park, et al. 2008), and stream flow developed during a workshop held with regional fishery experts (Sullivan pers. comm., Edmonton). The workshop was held to inform scenario analyses completed by CEMA-SEWG in northeast Alberta (2008). However, the relationships between INFI and the risk factors were consistent across the project’s Study Area (Sullivan pers. comm., Edmonton).

Relationships were estimated with and without access, making it possible to explore the potential effectiveness of zoning to mitigate improved angler access facilitated by expanding industrial infrastructure. INFI was assessed separately in ALCES for protected and unprotected portions of the landscape, and an overall average INFI value was then calculated as an area-weighted average. When calculating INFI in protected portions of the landscape, road density, water consumption, and human access were assumed to be negligible.

3.5.4 Edible Berry Habitat Suitability Index (HSI)

Blueberry (*Vaccinium myrtilloides*) and bog cranberry (*Vaccinium vitis-idaea*) are important food-plant species for the Community of Fort McKay, and were the species of edible berries that were considered in development of a regional-scale, habitat suitability index model. We developed the edible berry HSI coefficients using a similar approach that has been used for wildlife species. The process we used to develop coefficients for this berry HSI were:

- Compile information on abundance of *V. myrtilloides* and *V. vitis-idaea* for ecosystems in the Study Area.
- Assign seral-stage modifiers to these abundance values; and
- assign footprint-type buffer effects.

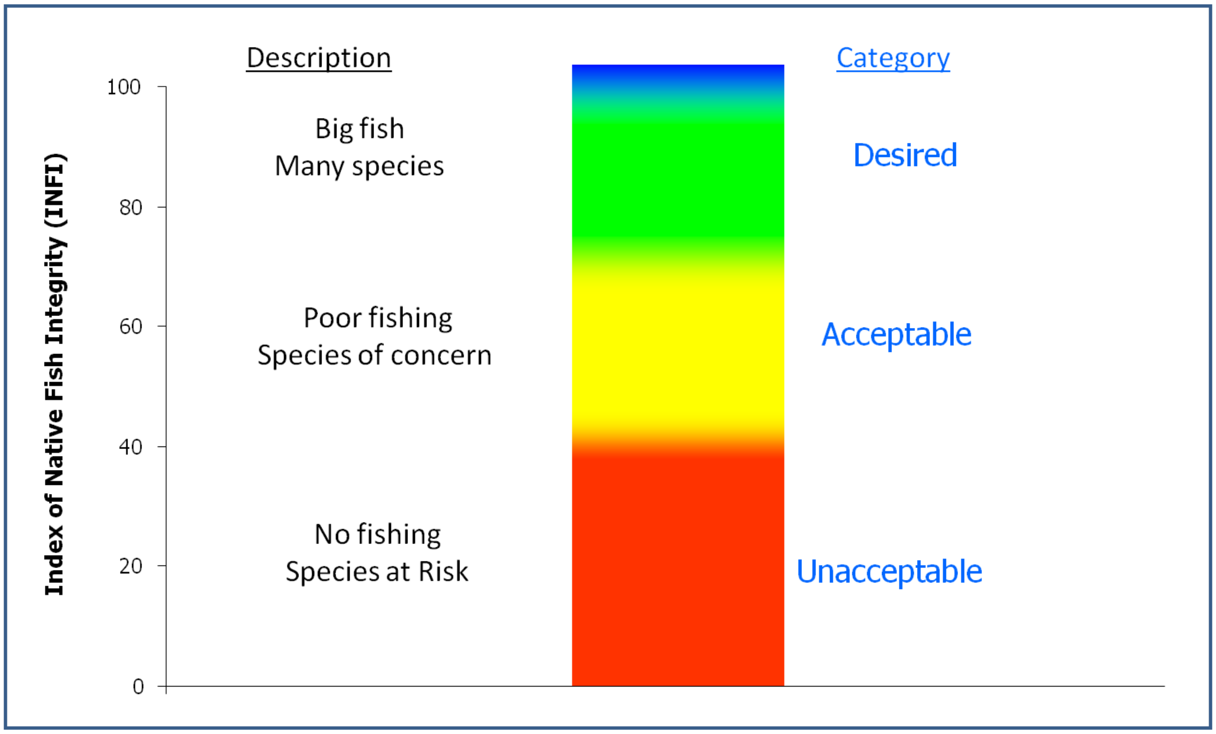


Figure 12: Interpretation of INFI Values[21]

[21] A Y-axis value of 100 is equivalent to a value of 1.00 in the INFI index used in this study.

Table 7: Fish Community Descriptions Associated with INFI Values of 1, 0.5 and 0[22]

Fish Habitat Type	INFI = 1	INFI = 0.5	INFI = 0
Rivers	Abundant walleye and pike (all sizes). Common catches of Arctic grayling, slimy sculpin, burbot, trout-perch, dace and suckers.	Abundant small walleye and pike, few large fish. Common catches of burbot, trout-perch, dace, and suckers. Few Arctic grayling and sculpin.	Very few small walleye and pike, few large fish. Rare catches of Arctic grayling and burbot, trout-perch and dace. Abundant suckers and fathead minnow.
Large Streams	Abundant Arctic grayling and small pike (depending on slope of stream). Common catches of larger walleye, pike, slimy sculpin, dace, suckers and lake chub. Rare catches of fat head minnow and brook stickleback.	Abundant small Arctic grayling and small pike (depending on slope of stream). Rare catches of larger walleye, pike, and Arctic grayling. Common catches of suckers, lake chub, fathead minnow and brook stickleback.	Few small Arctic grayling and small pike (depending on slope of stream). Very rare catches of larger walleye, pike, and Arctic grayling. Abundant catches of suckers, lake chub, fathead minnow and brook stickleback.
Small Streams	Abundant small Arctic grayling and small pike (depending on slope of stream). Common catches of dace, suckers, stickleback and fathead minnow.	Rare small Arctic grayling and small pike (depending on slope of stream). Common catches of suckers, stickleback and fathead minnow.	Very rare small Arctic grayling and small pike (depending on slope of stream). Abundant catches of suckers, stickleback and fathead minnow.
Large Lakes (> 300 ha)	Abundant walleye and pike (all sizes). Common catches of burbot and trout-perch.	Abundant walleye and pike. Few large fish. Rare catches of burbot, trout-perch, common catches of suckers, lake chub.	Very few small walleye and pike. Few large fish. Rare catches of burbot, trout-perch. Abundant catches of suckers, lake chub.
Small Lakes (< 300 ha)	No larger fish. Abundant brook stickleback and fathead minnows. Common catches of suckers and some small pike.	No larger fish. Abundant brook stickleback and fathead minnow. Common catches of suckers and some small pike.	

3.5.4.1 Compile Abundance Information

Information on the abundance of *V. myrtilloides* and *V. vitis-idaea* for ecosystems in the Study Area was compiled from three primary sources:

- Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996) (Sections 7, 8 and 10).

[22] (Sullivan 2006).

- Natural Ecosite and Plant Resource Summary for the Athabasca Oil Sands Region (Geographic Dynamics Corp 2007).
- An analysis of existing information on peatland vegetation in the RMWB: Phase 1 Peatland data compilation and summarization (Jacques Whitford AXYS 2007).

These sources contained estimates of percent cover of both *V. myrtilloides* and *V. vitis-idaea,* at the ecosite-phase level (for the first two references, above), and at the wetland-subclass level (for the third reference). The data were used to generate a mean cover value for the two berry species for each classified ecosystem (ecosite phase or wetland subclass). Since the ALCES landscape types were defined at a coarser level of classification than used in the reference sources, we developed a cross-walk that aggregated the proportion of each of the finer vegetation classes (i.e., ecosite-phases and wetland-subclasses) that would occur within the respective ALCES LTs. In order to accomplish this, mapping information was reviewed from industrial applications[23] in the area, which contained information on the proportion of mapped Study Areas occupied by ecosite phases and wetland subclasses. We used this information and the berry-cover information by ecosite phase and wetland subclass to create an aggregate, area-weighted berry-abundance metric.

For each ALCES landscape type the berry-abundance metric was determined based on the following parameters:

$$\frac{\sum (\%\,Cover\ of\ berries\ \times\ Area\ ecosite\ phase\ y)\ +\ (\%\,Cover\ of\ berries\ \times\ Area\ ecosite\ phase\ z)\ +\ \ldots.)}{\sum Area\ of\ all\ ecosite\ phases\ (y\ +\ z\ +\ \ldots)}$$

- Wetland subclasses were assigned to a corresponding ecosite phase (due to inconsistency in mapping use of ecosite phases or wetland subclasses for wetland ecosystems across industrial applications).
- Ecosite phases were assigned to ALCES landscape types following rules laid out in cross-walk tables (Appendix 4).
- These calculations were performed separately for the three different natural sub-regions (Boreal Highlands, Boreal Mixedwood and Canadian Shield) present in the Study Area.

Berry abundance values generated through these methods were then converted (i.e., normalized) to fractional values between 0 and 1 for each ALCES landscape type. Resulting berry HSI values for each ALCES Landscape Type are shown in Table 8.

[23] Sources included applications associated with the following industrial operators/projects: CNRL Horizon Oil Sands Project, Dover Commercial Project, Ivanhoe Tamarack Project, Shell Jackpine Mine Phase 1, Shell Jackpine Mine Expansion and Pierre River Mine, Imperial Kearl Oil Sands Project, Suncor Mackay River and Mackay River Expansion, Shell Muskeg River Mine Expansion, Synenco Northern Lights Project, Sunshine Oil Sands West Ells SAGD Project, Total Joslyn North Mine, Suncor Voyageur South Project, Suncor Fort Hills Oil Sands Project, Suncor Firebag In-situ Oil Sands Project, and Syncrude.

3.5.4.2 Seral-stage Modifiers

We reviewed published literature to find information on abundance (either cover or berry production) of *V. myrtilloides* and *V. vitis-idaea* by forest age class, but were unable to find published data that would assist in populating seral-stage modifiers with any resolution and accuracy. Given the absence of more detailed information, we took a generic approach, in which data on abundance of *V. myrtilloides* and *V. vitis-idaea* from the references noted above were assumed to largely come from mature forest stands.

Because of an average 80-year fire cycle in the Study Area, we assumed that seral stage 4 would have the highest occurrence of edible berries. With seral stage 4 as a reference, we adjusted values for other seral stages up or down depending on variations in berry abundance with stand age (Appendix 4).

The relationship between berry abundance and forest seral stage were based on an ecological understanding of overstory canopy closure and occupation, and on light levels that would reach the understory. We assumed that canopy closure would be lower and understory light levels would be highest in the first seral stage (0 to 20 years) due to incomplete site occupation by juvenile trees; similarly, seral stages 6 and older (age > 100 years) would have higher levels of understory light due to gap dynamics and canopy break-up. Seral-stage modifiers for berry HSI values are shown in Table 9.

3.5.4.3 Footprint Buffers

HSI values are affected not only by the ecological suitability of various landscape types, but also by the influence of different anthropogenic footprints. For example, quantity and quality of edible berries might be affected by industrial features and activities, an example being that emissions and deposition of dust are associated with a high density road network that carries a heavy vehicle transit load. These secondary effects were characterized using footprint buffers. Footprint buffers were applied in the berry HSI model based on two factors:

a) **Fugitive dust –** activity on some footprint types would generate dust that would land on berry-producing plants in proximity to the footprint (Brown 2009), and thus possibly reduce berry production (by reducing photosynthetic capacity of affected plants) and/or the perceived quality for consumption of dust-coated berries (Farmer 1993) and (Myers-Smith, et al. 2006).

b) **Perceived reductions in utility and/or quality –** berries in proximity to some substantial industrial footprints might not be harvested for human consumption, due to the perceived effects that these footprints would have on berry quality (e.g., concerns for traditional food safety).

Both of these buffer assumptions are based generally on information collected from community members in Fort McKay. Metrics on buffer width and habitat "discounting" within these buffers are presented in Table 8. It is also worth noting that for the purposes of this study, reclaimed anthropogenic landscape types (footprints) were given a null value for edible berries (Table 8). This rating reflects discussions from previous Community

Focus Group workshops and the current belief and use patterns of Fort McKay, where there are limited opportunities for berry harvest on reclaimed features despite almost 50 years of development and reclamation, and where community members believe that it would not be healthy to harvest berries from reclaimed features.

Table 8: Habitat Value by Landscape or Footprint Type for the Edible Berry HSI Model[24]

EDIBLE BERRIES

Landscape Type (LT)	Habitat Value: Pyrogenic	Habitat Value: Anthropogenic	Footprint Type (FT)	Habitat Value: Anthropogenic	Edge? (Y/N)	Buffer Width	Buffer Use with respect to Access Management: Off	On (Mod)	On (High)
1 Hardwood	0.11	-	1 Major Road	-	Y	100	0.10	0.75	0.90
2 Mixedwood	0.14	-	2 Minor Road	-	Y	10	0.10	0.75	0.90
3 White spruce	0.22	-	3 Gravel Pit	-	Y	100	0.10	0.75	0.90
4 Pine	0.92	-	4 Inblock Road	-	Y	0	0.10	0.75	0.90
5 Closed Black Spruce	0.02	-	5 Tranmission Line	-	Y	0	0.10	0.75	0.90
6 Riparian Forest	0.39	-	6 Rail	-	Y	0	0.10	0.75	0.90
7 Open Black Spruce	-	-	7 Industrial Facility	-	Y	100	0.10	0.75	0.90
8 Black Spruce Lichen Moss	-	-	8 Disposal Overburden	-	Y	1000	0.10	0.75	0.90
9 Open Fen	0.15	-	9 Urban	-	Y	0	0.10	0.75	0.90
10 Bog	0.62	-	10 Camps	-	Y	0	0.10	0.75	0.90
11 Native Herbaceous	-	-	11 Tailings Pond	-	Y	1000	0.10	0.75	0.90
12 Tall Shrub	-	-	12 Seismic	-	Y	0	0.10	0.75	0.90
13 Short Shrub	-	-	13 Wellsite	-	Y	0	0.10	0.75	0.90
14 Small Lotic	-	-	14 Pipeline	-	Y	0	0.10	0.75	0.90
15 Large Lotic	-	-	15 Surface Mine	-	Y	1000	0.10	0.75	0.90
16 Endpit Lake	-	-							
17 Lentic	-	-							
18 Beach Dune	-	-							
19 Cultivated Crop	-	-							
20 Forage Crop	-	-							

Table 9: Habitat Element Weightings for Edible Berries and Corresponding Habitat Quality* Weightings for Seral Stages

Habitat Element Weightings	
Range of Natural Variability (RNV)	
Seral Stage	1
Non - Range of Natural Variability (RNV)	
Seral Stage	1

	Seral Stages (Years)	Habitat Quality
1	1-20	1.0
2	21-40	0.7
3	41-60	0.8
4	61-80	0.8
5	81-100	0.9
6	101-120	1.0
7	121-140	1.0
8	141-160	1.0
9	161-180	1.0
10	181-200	1.0

*Note: A habitat quality value of 1.0 indicates a seral stage that is perfect for edible berries, whereas a value of 0 indicates a seral stage that has no utility. A value of 0.5 indicates a seral stage that contains 50% of the value of a perfect seral stage

[24] Derivation and application of coefficients for buffer width and modifiers for access management are explained further in Section 3.7.3.3.

3.6 Quantifying Risk

Many wildlife and fish species have been found to be negatively correlated to increasing levels of habitat disturbance. Increasing levels of surface disturbance and fragmentation generally represent increasing risks to native wildlife and fish populations, and to the integrity of ecological systems (Holling 1973); (Forman and Alexander 1998); (Trombulak and Frissell 2000). For these reasons, land use indicators such as surface disturbance and fragmentation (i.e., edge density and core area) are considered to be relevant and practical indicators of cumulative effects.

3.6.1 Ecological Indicator Risk Categories

The interpretation of potential changes in environmental indicators was aided by a standardized method for describing change that is both relevant and readily understood. For the biotic indicators such as moose, fisher and edible berries, HSI results were displayed against risk categories adopted from peer-reviewed criteria developed by the World Conservation Union (IUCN) and adopted by the international community, including Canada (Committee on the Status of Endangered Wildlife in Canada – COSEWIC), for evaluation of species at risk.

Indicator risk categories were based on the relative departure from the RNV reference band (i.e., the space between upper and lower boundaries of the RNV, see Figure 5). Colour-coded risk categories were ranked and illustrated along a scale declining from the best condition, scaled as 0% decline, to the most disturbed condition expected, scaled as 100% decline. When applying risk categories to simulation results, the lower 95% confidence interval of the estimated RNV was used as the undisturbed point of comparison.

Indicator risk categories were applied in the following manner, using four colour codes:

Green: representing stable and equivalent to the COSEWIC / IUCN classification of "Stable". Defined as a decline of no more than 10% from the undisturbed (RNV) state.

Yellow: representing low risk and equivalent to COSEWIC / IUCN classification of "Special Concern". Defined as a decline of 10% to 50% from the undisturbed (RNV) state.

Orange: representing moderate risk and equivalent to the COSEWIC / IUCN classification of "Threatened" or "Vulnerable". Defined as a decline of 50% to 70% from the undisturbed (RNV) state.

Red: representing high risk and equivalent to the COSEWIC / IUCN classification of "Endangered". Defined as a decline of more than 70% from the undisturbed (RNV) state.

3.7 Exploring the Future: The Business as Usual (BAU) and Fort McKay (FM) Scenarios

Currently the two dominant land uses in northeast Alberta, 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. However, within the Fort McKay Study Area, the energy sector is the predominant industrial land-use, and its activities are tied to bitumen development through surface mining and in situ well extraction. In this section, we provide an overview of the two scenarios explored for the future, and a general description of the respective suite of key management levers that were considered in these scenarios (Figure 13). We describe the detailed assumptions regarding the respective management levers in Section 3.7.3. Additional sensitivity analyses were conducted to understand the relative influence of management levers and scale of the study area on selected indicators.

We developed two scenarios, and multiple sensitivity analyses, to explore implications of alternative strategies for land use and bitumen development in the Fort McKay Study Area (Figure 13).

3.7.1 Business as usual scenario

The first was a 'business as usual' (BAU) scenario[25] that was based on a total peak bitumen production trajectory of 3.5 million barrels per day (Mbpd). This production trajectory was based upon approved bitumen production within the Study Area as of January 2011 (Government of Alberta 2011). This peak bitumen production value was also consistent with metrics adopted by both CEMA and the LARP initiatives (ALCES Group 2009).

In addition to the baseline assumption for bitumen development, other key assumptions of the BAU scenario included:

- Existing protected areas (circa 2010) in the Study Area that had been established prior to the official approval of the LARP in August 2012 (Government of Alberta 2012) were included.

- No access management, in-so-far as there was no coordinated regional access management (AM) strategy simulated in the BAU scenario. AM in this study is a tool that is meant to be a systematic and regional coordinated access management plan to reduce access across the regional landbase. This scale of AM is not currently occurring and it would require government enforcement. Although industry may conduct integrated land management initiatives at a local project level, there is no coordinated implementation strategy nor empirical monitoring that is being done to establish effectiveness of specific AM measures. Motorized use of roads, trails, and seismic lines by the public is considered both intensive and extensive.

- Adoption of assumptions from CEMA (2008) and LARP (ALCES Group 2009) to represent current (circa 2010) industry best (beneficial) management practices (BMP). In general, BMPs included reductions of required industrial footprint to extract resources, and faster reclamation of anthropogenic features. Selected energy, and aquatic best practices were deployed at two levels of effort - current and High BMPs (Section 3.7.3.4).

[25] The BAU scenario is best described as a future simulation that complies with known and expected development of all relevant natural disturbance regimes and land-uses. No major changes in current land-use policies are implied in the BAU scenario.

- Adoption of assumptions from CEMA (2008) for reclamation of oil sands mining footprints (see Section 3.7.3.5).

3.7.2 Fort McKay scenario

In comparison, the 'Fort McKay (FM) scenario' was designed to support Fort McKay's broader goal of enhancing and sustaining traditional land use in the traditional territory, and more specifically to:

a) Improve ecological performance of landscape and biotic indicators.

b) Promote stewardship of natural resources necessary for traditional land use.

The FM scenario was based upon the same assumptions for pace of bitumen production (3.5 Mbpd) and reclamation trajectories for surface mine footprints as the BAU scenario, but "activated" three additional management levers in the form of expanded protected areas, moderate access management, and aggressive industry best management practices (Figure 13).

- In the FM scenario, LARP conservation areas (Government of Alberta 2012) were included because at the time of assessment, it was plausible that the candidate areas would become protected areas in the future. The expanded protected area selected for the FM scenario was designed as an exploratory scenario to evaluate the significance and value of an expanded protected area within the Study Area. The location was chosen to incorporate the expanded protected area, proposed LARP conservation areas and to include an area that was culturally important to Fort McKay because of historical, current and planned future use.

- Moderate access management was envisioned to result in a reduction to approximately 50% of current levels of public motorized access, and would reflect a systematic, coordinated and enforceable access management plan across the Study Area.

- High BMPs focussed on aggressive but feasible practices focussed on the energy sector. The BMPs aimed to reduce and reclaim footprints and targeted four general themes: maintain stream continuity, reduce linear edge, accelerate footprint reclamation, and maintain old forests (Section 3.7.3.4).

Scenario	MANAGEMENT LEVERS	LEVEL	COMMENTS
Business As Usual (BAU) Scenario	Protected Areas (PA)	Existing	Figure 16 & 18
	Access Management (AM)	Current (no AM)	Table 16
	Best Management Practices (BMPs)	Current	Table 18
	Pace of Bitumen Development	1.0 X	3.5 Mbpd
	Reclamation	Oilsand mining footprints	Table 20
Fort McKay (FM) Scenario	Protected Areas (PA)	Expanded	Figure 17 & 18
	Access Management (AM)	Moderate	Table 16
	Best Management Practices (BMPs)	High	Table 18
	Pace of Bitumen Development	1.0 X	3.5 Mbpd
	Reclamation	Oilsand mining footprints	Table 20

Figure 13: Assumptions for the Business as Usual (BAU) and Fort McKay (FM) Scenarios[26]

3.7.3 Understanding Influence of Study Area Scale and Management Levers through Sensitivity Analyses

As described previously in Section 3.2.4.2, we defined and selected an Industrial Landscape Study Area to explore the effect of scale, i.e., study area size, on relative influence of management levers to indicator performance. All else being equal, we expected that biotic indicators tracked at the scale of the Industrial Landscape would do poorly compared to the larger Fort McKay Study Area, but the industrial smaller study area would provide a more direct test of how management actions might improve indicator performance.

We conducted a series of sensitivity analyses[27] to understand how variation in magnitude of management levers[28] and study area scale might influence indicator performance, and focus of the report on a comparison of the two scenarios, we present and discuss results of the sensitivity analyses in ***Appendix 5***.

[26] Used to explore effects of alternative land use management strategies in the Fort McKay study area.
[27] "Sensitivity analysis is the study of how the variation (uncertainty) in the output of a model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of a model. It is simply a technique for systematically changing parameters in a model to determine the effects of such changes." – Wikipedia
[28] In this context, a 'management lever' is a specific strategy or suite of tools that are used to cause a change in the trend or performance of an indicator in a system, whereby the amount of management applied is related to how far the lever is 'pulled' or activated. Thus sensitivity analysis of management levers in a simulation model involves running the model iteratively and systematically changing the management lever(s) for every iteration to assess the relative influence of management lever(s) on indicator(s).

3.7.3.1 Pace of Development

The Fort McKay ALCES model was designed and attributed to explore the consequences of alternative land use "what-if" scenarios. As described previously, industrial land use in the Fort McKay Study Area was comprised of the forestry and energy sectors, although forestry was conducted primarily as salvage logging, whereas surface mining and in situ well extraction of bitumen were the principle activities of the energy sector and the main drivers of land use in the region. In the subsequent sub-sections we describe our assumptions for resource production in both industrial sectors, but the reader is reminded that for the sensitivity analyses, we only varied bitumen development pace in the energy sector.

3.7.3.1.1 *Forestry (Logging)*

Alberta-Pacific Forest Industries Inc. (Al-Pac) is the primary timber harvest company that logs in the Fort McKay Study Area, and holds a large hardwood-dominated Forest Management Agreement (FMA). There also exist a few smaller softwood allocations for quota holders. The Annual Allowable Cut (AAC) of Al-Pac is ~3.8 million m^3/year (Alberta-Pacific Forest Industries Inc. (Al-Pac) 2006). Although the northern extent of Al-Pac's FMA occurs within the Study Area (Figure 15), logging in the Fort McKay Study Area is conducted primarily as a salvage operation prior to bitumen development (Wasel pers.comm., Boyle).

To simulate logging in ALCES, we estimated the AAC for hardwood and softwood within the Fort McKay Study Area by determining the "net available" merchantable area of forest landscape types within each of the Al-Pac FMUs that occurred in the Study Area, and then multiplied those areas by relevant estimates of tree growth, i.e., Mean Annual Increment. The product of this approach is a general index for a sustainable offtake. Growth and yield curves for the forest landscape types were adopted from CEMA-SEWG (***Appendix 4***). The estimated harvest targets for hardwood and softwood were 218,457 m^3/year and 346,453 m^3/year respectively (Table 10) and were consistently used as the estimates for hardwood and softwood AAC in the simulations.

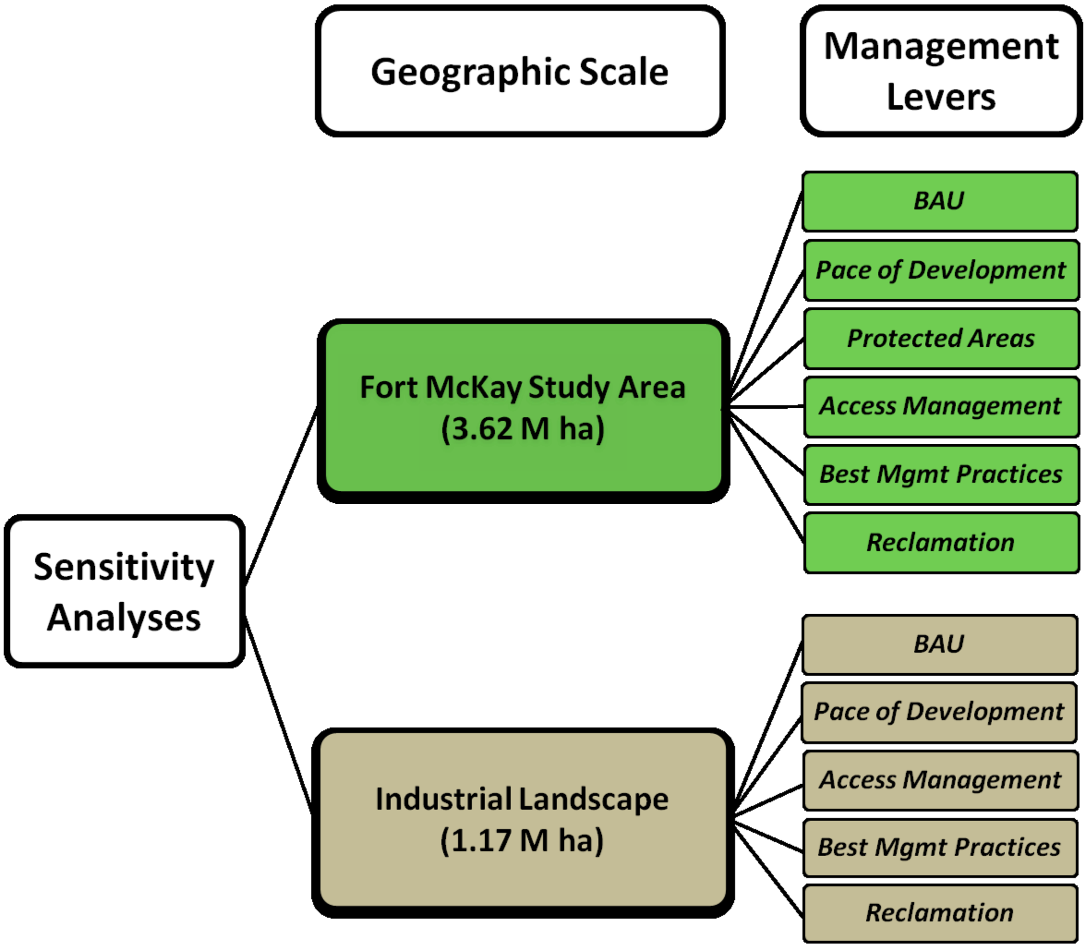


Figure 14: Conceptual Framework for Analyses that Were Done to Explore Sensitivity of Selected Indicators[29]

[29] Conceptual Framework for Analyses That Were Done to Explore Sensitivity of Selected Indicators to key management levers at two different geographic scales, including the broader Fort McKay study area, and a smaller study area referred to as the Industrial Landscape. Note that protected areas were not included as part of the Industrial Landscape.

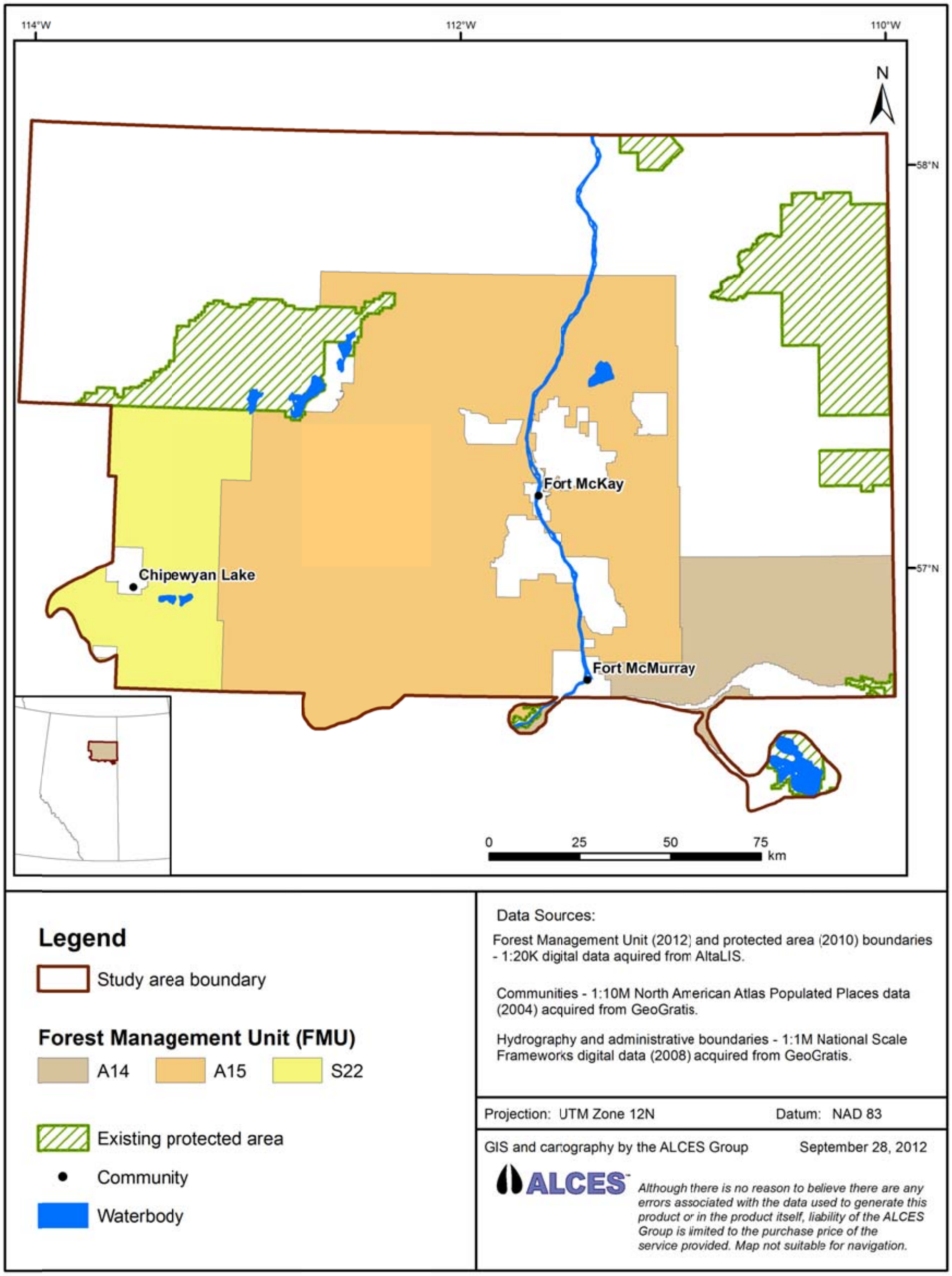


Figure 15: Forest Management Units of Alberta-Pacific Forest Industries within the Fort McKay Study Area

Table 10: Area of forest landscape types in Alberta Pacific Forest Industries Forest Management Units[30]

Area of Forest Landscape Types (ha)	Al-Pac FMU A14	A15	S22	Mean Annual Increment (m^3/ha/yr) Hardwood	Softwood
Hw	21,106	18,940	57,791	0.54	0.00
Mw	10,471	77,022	17,247	0.71	0.28
Pine	45,973	106,418	22,393	0.00	1.47
Wh Sp	6,247	30,726	5,120	0.00	1.43
Total	83,797	402,106	102,551		
Hardwood AAC (m^3/y)					
Hw	11,397	101,488	31,207		
Mw	7,434	54,686	12,245		
Pine	0	0	0		
Wh Sp	0	0	0		
Total	18,832	156,173	43,453	**218,457**	
Softwood AAC (m^3/y)					
Hw	0	0	0		
Mw	2,932	21,566	4,829		
Pine	67,580	156,434	32,918		
Wh Sp	8,933	43,938	7,322		
Total	79,445	221,939	45,068	**346,453**	

* (Cenovus FCCL Ltd. 2009)

3.7.3.1.2 *Energy (Bitumen Production)*

ALCES was used to simulate bitumen-related indicators (production, growth and reclamation of footprints, employment, revenues, royalties) through oil sands mining and in situ well extraction using SAGD technologies. Our principal assumption for bitumen production in the Study Area was that annual and cumulative bitumen production would conform to a general Hubbert-Naill production curve (see ***Appendix 3***) as adopted by simulation models developed through both the CEMA (Wilson, Stelfox and Patriquin 2008) and LARP initiatives. Based on historic known production values, and input from various relevant agencies examining the energy sector of northeast Alberta (Alberta Energy, Canadian Association of Petroleum Producers, and Energy Resources Conservation Board), peak productions were set at 3.5 Mbpd in 30 years (circa 2040) and would generate a cumulative production of ~12 billion m^3 from surface mining, and ~8 billion m^3 from in situ during the next 100 years (Table 11). Recoverable volume was based on characteristics of bitumen deposits and known technologies for bitumen recovery.

[30] Area of forest landscape types in Alberta Pacific Forest Industries Forest Management Units (ALPAC FMU) and derived estimates of Annual Allowable Cut (AAC) based on Mean Annual Increment coefficients for hardwood and softwood in the Fort McKay study area.

In order to develop a plausible bitumen production trajectory of 3.5 Mbpd, we estimated production for oil sands mining and in situ well extraction separately. Since the entire mineable oil sands area (MOSA) occurred within the Study Area (Figure 9), mineable oil sands production assumptions from CEMA-SEWG (2008) were directly applied. Since a specific bitumen reserve analysis was not available for the Study Area, we developed a plausible in situ production trajectory based on available information from CEMA-SEWG (2008) and ALCES Group (2009). We used the LARP derived cumulative in situ production levels for its moderate (4.0 Mbpd) and high (6.0 Mpbd) production scenarios and reduced them by 50% as an approximation to estimate cumulative in situ bitumen within the Fort McKay Study Area (Table 12).

We used CEMA-SEWG (2008) and associated references (Wilson, Stelfox and Patriquin 2008) to develop assumptions for well density, well lifespan, and average annual well production rates in order to estimate the total number of wells required to produce the total cumulative volume of in situ bitumen over the 100-year BAU future scenario (Table 11). Well density in the Study Area was a key variable because all other major industrial footprints associated with in situ bitumen development were tied to well construction, including access roads, seismic lines and pipelines.

An average production well lifespan of ten years was assumed. Although well production rates of 36,000 m^3/well/year are possible, these are attributed to wells situated in higher density oil sand deposits and are not likely to be maintained (CEMA-SEWG 2008). Much of the oil sand deposits in the FM Study Area are not of the highest bitumen depth, and since the simulation period was 100 years, an assumed well production rate of 18,000 m^3/well/year was considered plausible. These well production assumptions were used to develop a response curve for the annual number of in situ wells drilled, and integrated to generate annual and cumulative production trajectories for in situ bitumen over the 100-year future simulation.

Minor roads (primarily well access roads) and pipelines were designated as permanent features, based on the rationale that industry would develop new technologies (within the 100 year future scenario) to extract the previously unproduced bitumen, and it would be more cost-effective to maintain the road infrastructure. Well pads however, were reclaimed in the model.

The effect of a reduction in bitumen production was explored in a sensitivity analysis to examine the relative influence on footprint growth (Table 13).

Table 11: Assumptions Defining Volume of Bitumen Reserves and Production Metrics for the Fort McKay Study Area

Type	In Place Volume (m^3)	Historical Production (m^3)	Recoverable Volume (m^3)	Current Proven Volume (m^3)
Surface Mineable Bitumen	21 billion	710 million	12.0 billion	12.0 billion
In situ Bitumen (SAGD – steam assisted gravity drainage)	~47 billion*	45 million	8.0 billion	8.0 billion+

*Area-weighted extrapolation based on ERCB 2012 (see Appendix 4 – Table A4-9)
+Assumptions detailed in Table 12 and calculated as an average of total cumulative moderate and high production.

Table 12: Assumptions for In Situ Bitumen Production in the Fort McKay Study Area

Assumptions for Fort McKay (FM) Cumulative Effects Study: In situ Bitumen Production		
Lower Athabasca Regional Plan (LARP) bitumen production scenarios	Moderate (4 Mpbd)	High (6 Mbpd)
LARP estimates of total cumulative in situ bitumen production (m^3)	12,000,000,000	20,000,000,000
Estimated proportion of LARP bitumen production within FM Study Area	0.5	0.5
Estimates of total cumulative in situ bitumen production (m^3/well/year)	6,000,000,000	10,000,000,000
Assumption for well production metrics		
Production Well Lifespan (years)	10	10
Number of wells/pad	18	18
Average annual well production (m^3/well/year)	18,000	18,000
Cumulative well production over Lifespan (m^3)	180,000	180,000
Cumulative future number of wells required to produce	33,333	55,556

Table 13: Key Assumptions for Sensitivity Analyses of Bitumen Production

Sensitivity	Bitumen Production Trajectory Assumptions
	Oil sands mining & in situ (SAGD) well extraction
1	0.5X Projected Bitumen Production (1.75 Mbpd peak)
2	1.0X Projected Bitumen Production (3.5 Mbpd peak) (BAU & FM Scenarios)

3.7.3.2 Protected Areas

In the Fort McKay ALCES model, protected areas were defined as fractions (DF) of each landscape type within the Study Area, and were protected from current and future industrial development (i.e., forestry and bitumen development) and growth of associated anthropogenic footprints (Table 14). The BAU scenario used only existing protected areas

(Figure 16), while the FM scenario included an expanded protected area (Figure 17). This difference between scenarios was expanded in a sensitivity analysis to explore the relative influence of protected areas on biotic indicators (Table 15, and see ***Appendix 5***).

Table 14: Proportion (DF = decimal fraction) of Each Landscape Type (LT) That was Designated as Protected from Industrial Land Use for the Business as Usual (BAU) and Fort McKay (FM) Scenarios

Landscape Types	LT Designated Protection from Land use DF (BAU Scenario)	LT Designated Protection from Land use DF (FM Scenario)
Hardwood	0.02	0.21
Mixedwood	0.07	0.28
White Spruce	0.09	0.33
Pine	0.22	0.43
Riparian	0.11	0.44
Cl Bl Spruce	0.02	0.25
Open B Spr Fen Shr Swamp	0.19	0.55
Bl Spr Lichen Moss	0.00	0.02
Open Fen	0.08	0.36
Bog	0.08	0.37
Herbaceous	0.08	0.49
T Shrubland	0.01	0.35
S Shrubland	0.02	0.20
Small Lotic	0.11	0.43
Large Lotic	0.05	0.29
Endpit Lake	-	-
Lentic	0.29	0.56
Beach Dune	0.01	0.14
Cultivated	-	-
Forage Crop	-	-

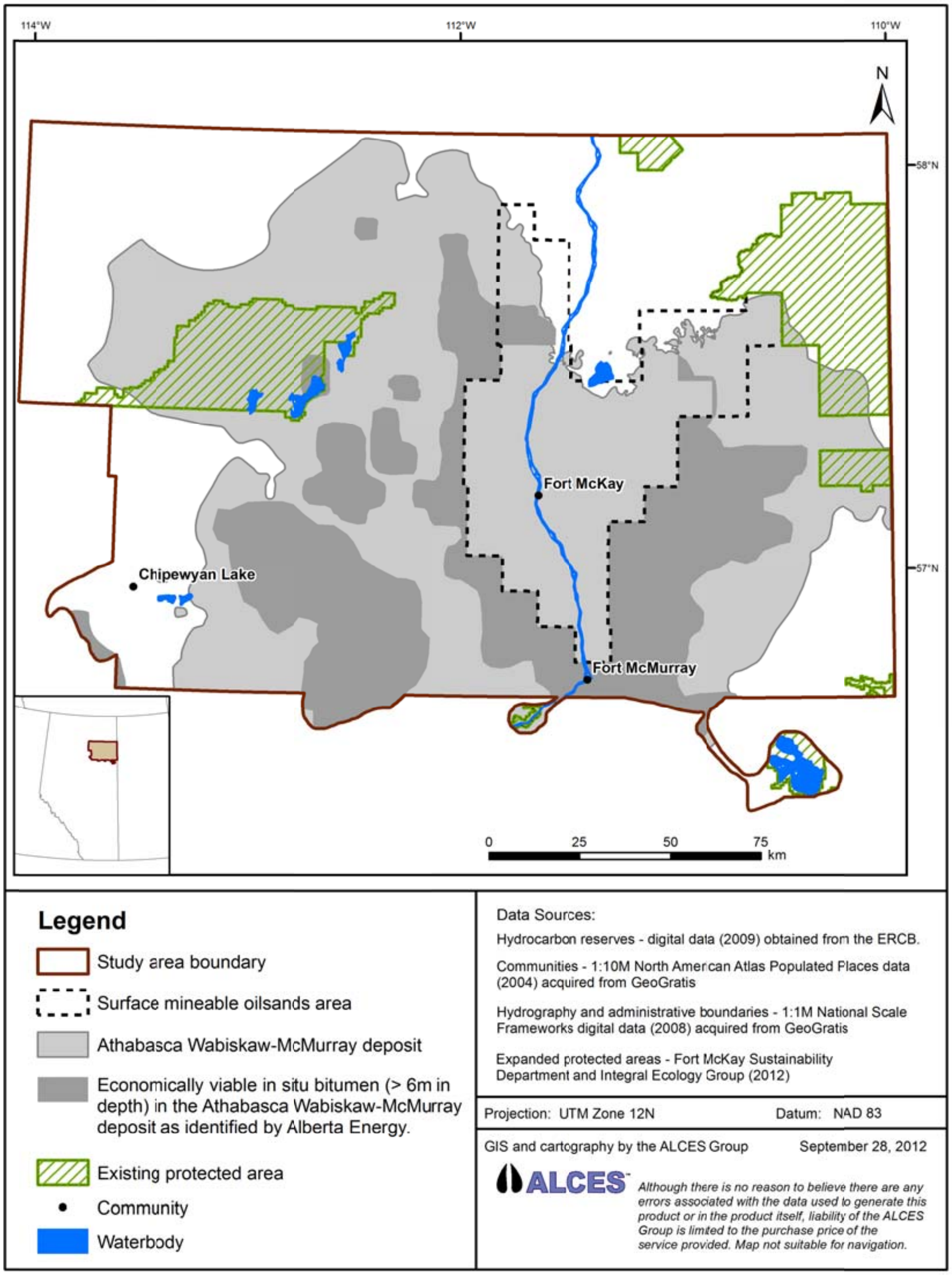


Figure 16: Bitumen Reserves and Existing Protected Areas within the Fort McKay Study Area As of August 2012[31]

[31] Bitumen reserves and existing protected areas within the Fort McKay study area as of August 2012, at the time of modelling. Note that existing protected areas were based on existing parks prior to the finalization of LARP.

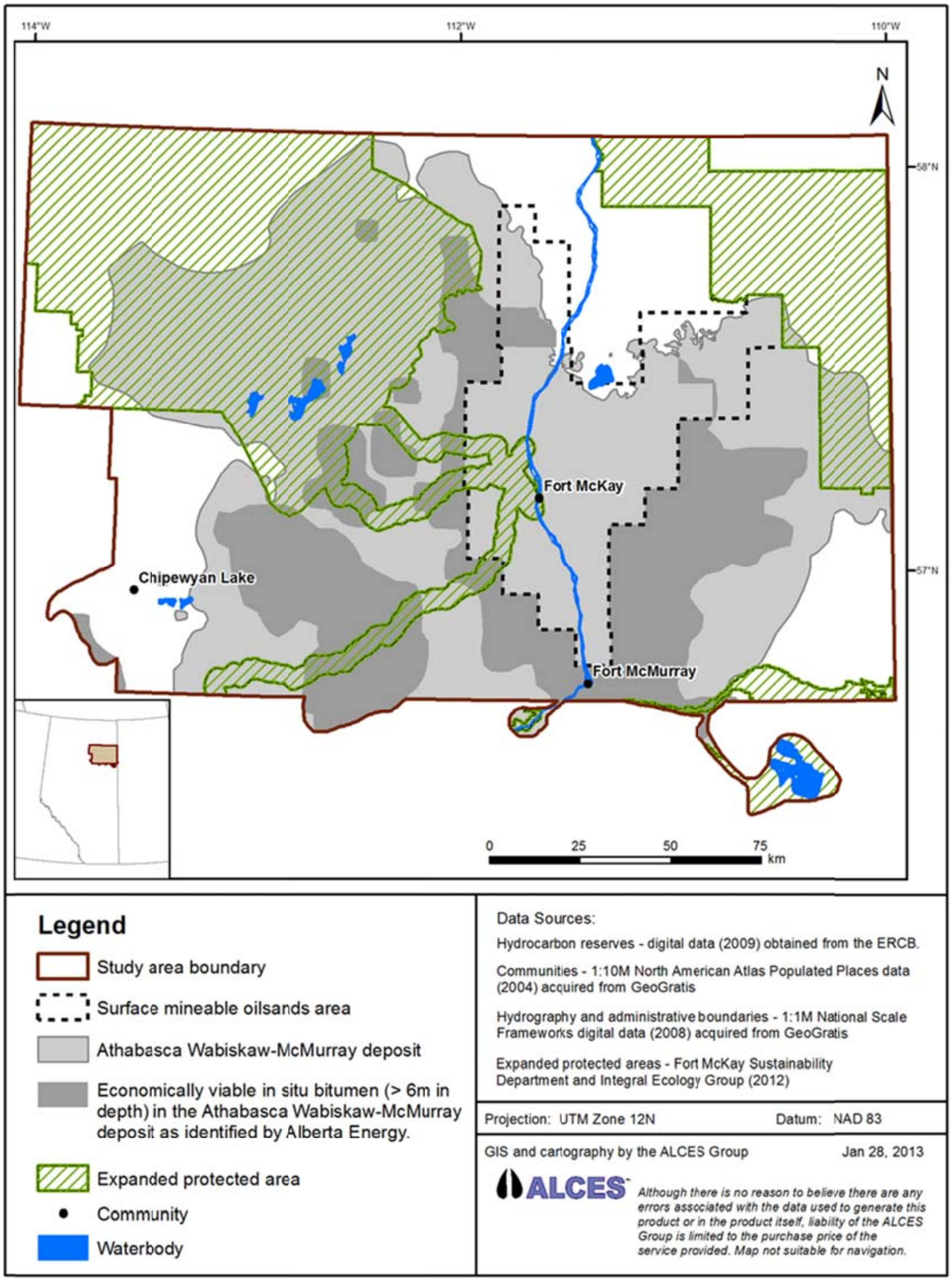


Figure 17: Bitumen Reserves and Overlap with an Expanded Protected Area Network within the Fort McKay Study Area[32]

[32] Note the expanded protected areas include conservation areas established in LARP.

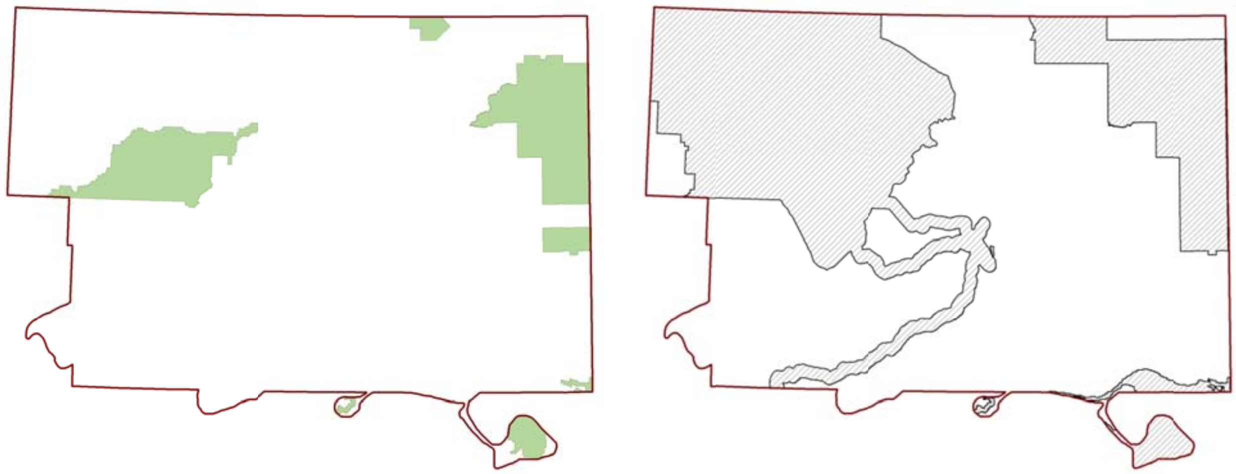
Table 15: Key Assumptions for Sensitivity Analyses of Protected Areas

Sensitivity	Protected Area Assumptions
1	No Protected Areas
2	Current Protected Areas (BAU Scenario)
3	Fort McKay Expanded Protected Areas (1X) (FM Scenario)
4	Fort McKay Expanded Protected Areas (1.25X)

Under the BAU scenario, the current (as of August 2012) protected areas network was determined to be 378,000 ha or ~10.4% of the Study Area (Figure 18). A potential expanded protected area network was developed as part of the FM scenario, which included proposed LARP conservation areas as well as areas of interest to the Fort McKay Community. The expanded protected area resulted in a tripling of the existing protected area network (1.42 M ha or ~39.2%) within the Study Area (Figure 18). The expanded protected area used in this study was designed as an exploratory scenario, and was not intended as an actual proposal for a protected area network design.

Criteria adopted to design and configure the expanded protected area in the FM scenario (Figure 18) were:

- Include existing protected areas (i.e., parks) and proposed LARP conservation areas.
- Apply a 10 km buffer around Fort McKay's non-industrial reserves at Moose Lake.
- Include lake watershed boundaries at Moose and Buffalo Lakes.
- Identify and select areas based on cultural considerations (e.g., informed by traditional land use data and community workshops).
- Emphasize connectivity, core areas, corridors, and connection to Wood Buffalo National Park.
- Consider inclusion of existing boreal caribou ranges in the FM Study Area.
- Consider a size that would be resilient to future fire regimes.
- Buffer a key traditional trail (e.g., from the Fort McKay hamlet to Moose Lake) and the Ells and MacKay rivers that are culturally important to Fort McKay (buffers were 1 km on either side).
- Buffer the hamlet of Fort McKay up to 5 km where possible (i.e., where development did not already exist).



Existing protected area (BAU Scenario):
378,483 ha (10.4% of Study Area)

Expanded protected area (FM Scenario):
1,420,579 ha (39.2% of Study Area)

Figure 18: Spatial Comparison of Existing Protected Areas in a BAU Scenario, versus a Fort McKay Scenario that Envisioned an Expanded Protected Area Network

3.7.3.3 Access Management

Access is a pre-requisite to land use, regardless of whether the activity is done in the pursuit of industrial, commercial, recreational or traditional interests. Traditional land use and occupancy by aboriginal peoples was maintained in boreal ecosystems via travel along natural water courses and maintenance of portages, seasonal trails and preferred camping sites. In recent decades, with the expansion of timber harvesting and oil and gas exploration in northeast Alberta, the construction of roads, seismic lines, pipelines and transmission lines has vastly increased the ability for non-industrial users (e.g., recreationalists, hunters, fishermen, trappers, campers) with motorized off-highway vehicles (quads, trucks, motorcycles and snow machines) to access what were previously remote or largely inaccessible areas of the boreal forest. Observed impacts of unmanaged access include reductions in fish and wildlife populations, reductions in distribution, and increases in disturbed and eroded lands, and loss of water quality (Sullivan pers. comm., Edmonton).

> *"Access management planning is a coordinated effort to reduce the impacts of road development on other values such as recreation, wildlife, fisheries and the environment. As a strategy, access management is primarily focused on managing the use of motorized vehicles by non-industrial users.*

In ALCES, the positive influence of access management on HSI-based indicators (moose, fisher, edible berries) was simulated through a reduction in effective buffer widths adjacent to linear features. The buffer widths represented the adjacent area where indicators are influenced by visual, physical, chemical, noise, and vegetation changes associated with the direct footprint. The size of this buffer varied greatly depending on indicator resilience, whether or not they are harvested, and how sensitive they are to human or predator activity.

In a BAU scenario with no access management, HSI values for biotic indicator species incorporated the effects of hunting and road kill (and road dust in the case of berries) through buffers that were applied to anthropogenic footprints such as roads during the calculation of habitat availability. Access management was modeled through reduced buffer widths, resulting in increased habitat availability and HSI values. Buffer width reductions associated with access management was computed based on interviews with Alberta wildlife management experts (Sullivan 2009); access management buffer coefficients for moose, fisher, and edible berries were included in Table 3, Table 5, and Table 8, respectively. Buffer widths were assumed to become incrementally smaller with moderate and high access management because of reduced levels of disturbance and mortality associated with linear features (Figure 19).

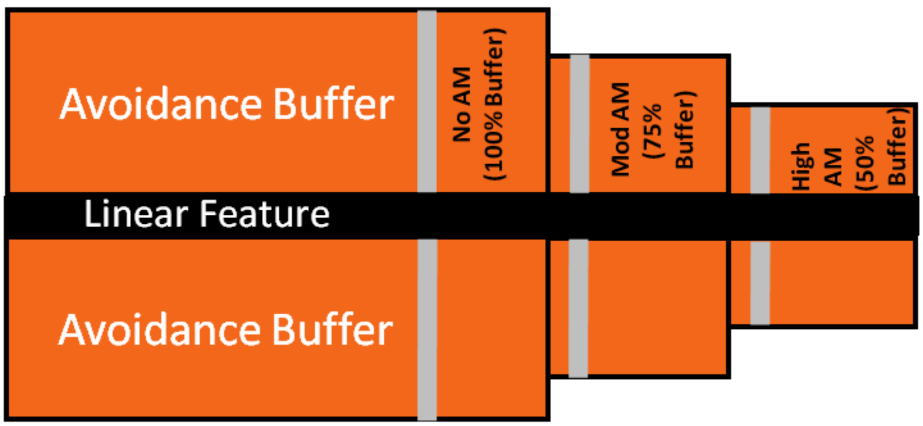


Figure 19: Conceptual Diagram Showing Width of Avoidance Buffer Associated with Anthropogenic Linear Features, and Generalized Effect of Access Management on Reducing Buffer Width[33]. Refer to Table 16 on Access Management Assumptions.

Key assumptions for sensitivity analysis of access management are summarized in Table 16 for each of the biotic indicators including moose, fisher, edible berries and INFI. Relative reductions in buffer width are described for each HSI-based indicator, whereas access management assumptions for INFI were tied to changes in fish harvest pressure.

The BAU scenario was defined by no effective access management, meaning that the non-industrial population had the ability to travel unconstrained on linear features (roads, pipelines, transmission lines, seismic lines). In contrast, moderate access management principles, conceptualized as a reduction to about 50% of current levels of public

[33] Conceptual diagram showing avoidance buffers associated with anthropogenic linear features. The effect of access management (AM) is shown as a sequential reduction in buffer width as efficiency increases from No AM (BAU), Moderate AM, and High AM.

motorized access, were applied in the FM scenario. Potential examples of moderate access management strategies include the following (Bentham 2007) and (Sullivan 2009):

- Unmanned access control gates to control public highway vehicle travel on industrial roadways.
- Seasonal timing restrictions that prohibit movement of vehicles during defined periods of the year.
- Regulations that prohibit hunting, trapping or fishing activities within defined distances from linear features.
- Road barriers to discourage access and encourage recovery and revegetation.
- Roll backs, tree-felling or other intentional obstructions intended to impede or discourage movement of people along seismic lines or access roads.
- Remove creek crossings, re-contouring to surrounding topography, re-vegetating or reforesting barriers at junctions with active access and to render linear corridors impassable.
- Remove sections of road grade (in peatland areas), wood bridges, log fills, culverts or snow fills before breakup to restore natural water flow.

In contrast to HSI indicators, INFI was calculated based on response surfaces that related the index to explanatory variables such as density of access, human population density, stream flow, and watershed discontinuity. These relationships were developed during an ALCES INFI workshop held with regional fishery experts (Table 16) (Lagimodiere and Eaton, Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): Description, rationale and modelling coefficients 2009).

The workshop was held to inform scenario analyses completed by CEMA in the Rural Municipality of Wood Buffalo, but the relationships between INFI and the risk factors were consistent across a much broader area of boreal Alberta (Sullivan pers. comm., Edmonton). The dose-response curves (or coefficients) represented by these relationships were professional estimates not quantitative measurements, but were suitable for strategic level modeling.

Two sets of response surfaces were generated by workshop attendees: both with and without access management, making it possible to explore the potential effectiveness of zoning to mitigate increased angler access facilitated by expanding industrial footprints. The primary influence of access management on INFI was simulated to affect two pathways:

a) Changes in linear edge density (roads, pipelines, and seismic lines) which facilitates vehicular access (including OHVs).

b) Changes in the amount of fishing pressure that is a function of the relative human density on the landscape.

Table 16: Key Assumptions for Sensitivity Analysis of Access Management

		Indicators			
Sensitivity	**Access Management (AM)**	**Moose (HSI)**	**Fisher (HSI)**	**Berry (HSI)**	**Index of Native Fish Integrity (INFI)**
1	**No AM (BAU Scenario)**	Variable buffer width ranging from 100 to 500 for most footprints. Use varied between 25-50%	10% use of buffer width in HSI model	10% use of buffer width in HSI model	Study Area is accessible to public (0% Access Management)
2	**Moderate AM (FM Scenario)**	2X increase in habitat effectiveness and population size. Modeled as an increase to 50-80% footprint buffer width use in the HSI model.	2X increase in habitat effectiveness and population size. 50% use of buffer width in HSI model	75% use of buffer width	50% Access Management
3	**High AM**	2.5X increase in habitat effectiveness and population size. Modeled as an increase to 60-90% footprint buffer width use.	3X increase in habitat effectiveness and population size. 75% use of buffer width in HSI model	90% use of buffer width	100% Access Management
Comments / Assumptions		Overall response of moose is predominantly shaped by behavioral (avoidance) and demographic response (i.e., hunter kills) associated with linear features	Key assumption is degree to which fisher perceive seismic lines to be an edge and mortality (avoidance) associated with linear features	Key assumptions (uncertainties) are influence of dust as a function of access and reclaimed habitats having no value to edible berries in comparison to pyrogenic habitats	INFI is more sensitive to fragmentation (hung culverts & watershed discontinuity)

Although the effect of human density is related to linear density because it creates access for anglers, further applied research is required to understand mechanisms and relative influences of linear density and human population density (Lagimodiere and Eaton, Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): Description, rationale and modelling coefficients 2009). Stream flow and watershed discontinuity were not considered to be directly sensitive to AM, and were linked to the issue watershed discontinuity and the management practice of replacing hung culverts.

INFI was assessed separately in ALCES for protected and unprotected portions of the landscape, and an overall average INFI value was calculated as an area weighted average for the Study Area. When calculating INFI in protected portions of the landscape, road density, water consumption, and human access were assumed to be negligible.

3.7.3.4 Best (Beneficial) Management Practices (BMP)

We recognize that industrial practices of the energy and forest sectors have always been dynamic, with constant innovation and deployment of new improved techniques. Clearly, the current suite of practices (BAU) used today represent the Best Management Practices of previous decades. For the purposes of this study, the BAU scenario held constant industrial practices such that current practices are propagated into the future for the full simulation period. In contrast, the Fort McKay scenario embraced the continued evolution of Best Management Practices. To explore the potential benefit of adopting additional BMPs in the Study Area, we compared and contrasted the performance of indicators under scenarios that included both BAU and BMP (Table 17).

Table 17: Key Assumptions for Sensitivity Analyses of Best (Beneficial) Management Practices

Sensitivity	Best Management Practices (BMP)
	Aquatic & Energy
1	Current (BAU Scenario)
2	High BMP (6 BMPs) (FM Scenario)

The BMPs summarized below for the energy sector were considered to be realistic and feasible based on guidance from industrial practitioners during similar work done through CEMA-SEWG (2008) (Cumulative Effects Management Association (CEMA) 2008), LARP (Government of Alberta 2012), and the Athabasca Landscape Team (2009) (Athabasca Landscape Team (ALT) 2009). A general description of relevant BMPs is outlined below, as well as a more detailed table of assumptions (Table 18).

1. Maintaining stream continuity
    a) Increased replacement rate of hanging culverts[34]
2. Reducing linear edge construction
    a) Increased directional drilling for in situ (SAGD, CSS) well pads.
    b) Increased spatial overlap of pipelines and roadways.
    c) Construct narrower seismic lines, which would have a faster reclamation rate than wide lines.
3. Increasing footprint reclamation rate
    a) Reduced reclamation lag for surface mines, overburden dumps and settling ponds.
    b) Reduced reclamation lag for abandoned in situ well sites.
    c) Pulse reclamation[35] of existing seismic lines.
4. Maintaining old forests
    a) Faster reclamation of industrial footprints back to forests.

3.7.3.5 Reclamation

Growth, distribution, lifespan and reclamation of footprint types comprise an important suite of assumptions in simulating anthropogenic land uses. Reclamation of footprints is a key factor for understanding the dynamic effects of human land uses and related mitigation activities on landscape characteristics and other ecological indicators. Footprint reclamation often has an important effect on ecological indicators, particularly those that are sensitive to landscape fragmentation or core area. Three basic characteristics of reclamation that were considered included:

1. The rate at which footprints reclaimed (i.e., footprint lifespan).
2. The landscape or habitat type to which a footprint is reclaimed (reclamation destination).

---

[34] Park et al. (2008), define hanging culverts as "an outfall that is elevated above the stream surface, which can fragment fish communities in streams by creating upstream movement barriers. Culverts (typically of corrugated or smooth metal tubular construction) are commonly used to provide crossings of low-order streams and can be serious impediments to upstream movement of aquatic organisms, such as fish, when their outfalls are elevated above the water surface (i.e., hanging culverts)."
[35] Regularly reclaim a fixed percentage of existing and future linear features (seismic lines) at defined intervals, i.e., a pulse.

3. Whether reclaimed landscape types had the same habitat value for ecological indicators as those that naturally regenerated after fire.

Table 18: Examples of Best (Beneficial) Management Practices (BMPs) and Quantitative Assumptions Used in the Fort McKay Scenario

Aquatic Management Levers	Intent and Description	Units	Business as Usual (BAU)	High BMP (FM)
Hanging culvert replacement	Reduce the level of lotic discontinuity on the landscape by removing and replacing “hanging” culverts	Percent of hanging culverts replaced annually	0%	10%
Energy Sector Levers	**Intent and Description**	**Units**	**Business as Usual (BAU)**	**High BMP (FM)**
Seismic line width	Narrower seismic lines will occupy less direct area of forest and will be faster to reclaim	meters	2.75 m (~25 y)	0.75 m (~5 y)
Seismic line pulse reclamation	A constant percentage of existing and future seismic lines are reclaimed or deactivated at defined intervals.	% (of seismic lines) / yr	0% / 0	10% / 5
Pipeline spatial overlap with roads	Increase spatial overlap between pipelines and roads to reduce the direct and indirect effects of these two linear features	%	0%	50%
SAGD well pad area (ha)	Increased well pad area to allow higher number of wells per pad	hectares	12 ha	15 ha
SAGD wells/pad	Greater dependency on directional drilling (i.e., placing more wells on a single pad), will result in less direct and indirect habitat loss	# wells / pad	18	25
Well site regeneration lag	Reduce linear edge density associated with well pads. Note: Access roads are assumed to be permanent features in the Fort McKay ALCES model.	Relative index	Well pad lives for 40 yrs	Well pad lives for 20 yrs
Surface mine reclamation lag	Increase reclamation rate trajectory of surface mine features (mines)	Relative index	30 yr (active mine life)	20 yr (active mine life)

Land-use footprints tracked in ALCES can be either permanent or transient. If footprints types were not permanent, then ALCES required input assumptions on the average footprint lifespan. ALCES adopted a second-order approach to reclaiming footprint types based on defined lifespans, which reflects our understanding that a mean lifespan does not adequately capture the variance in footprint lifespan when simulating the full suite of these features. For example, if well pads have a 20-year lifespan, then 5% of well pads are reclaimed annually, with oldest well pads being reclaimed first. For this project, many footprint types (major roads, minor roads, transmission lines, pipelines) were permanent.

Transient footprint types included inblock roads, seismic lines, well pads, and the polygonal features of surface mining. Each of these transient features was given a defined lifespan (Table 19).

Table 19: Footprint Reclamation Assumptions

Land-use Footprint	Defined Lifespan (y)	Reclamation Destination
Major Roads	Permanent	Not relevant
Minor Roads	Permanent	Not relevant
Gravel Pits	Permanent	Not relevant
Inblock Roads	3 years	Reclaimed to original Landscape Type
Transmission Lines	Permanent	Not relevant
Rail	Permanent	Not relevant
Industrial Features	Permanent	Not relevant
Urban	Permanent	Not relevant
Rural Residential	Permanent	Not relevant
Disposal overburden	30 years	Reclaimed to Landscape Types as per CEMA-SEWG assumptions in Table 20
Tailings ponds	30 years	Reclaimed to Landscape Types as per CEMA-SEWG assumptions in Table 20
Surface mine (oil sands)	30 years	Reclaimed to Landscape Types as per CEMA-SEWG assumptions in Table 20
Seismic Lines	Related to seismic line width (~25 year lifespan for seismic lines with 2.75 m average width)	Reclaimed to original Landscape Type
Well pads	40 years	Reclaimed to original Landscape Type
Well pad Access Roads	Permanent	Not relevant
Pipeline	Permanent	Not relevant

Accurate estimation of footprint lifespan is important: if lifespans are over-estimated, then the environmental effects of land-use trajectories might be exaggerated, while lifespan under estimates can lead to a corresponding under-estimation of environmental effects. For the majority of footprint types, the average lifespan is fixed. For seismic lines, we associated lifespan with average width, based on a relationship developed by CEMA-SEWG (2008): a seismic line width of 2.75 m had an approximate lifespan of ~25 years, while a narrow seismic line of 0.75 m had an average lifespan of ~5 years.

Once a given footprint had completed its defined lifespan, it was reclaimed in the ALCES simulator and then returned (or converted) back to a landscape type. For many footprints the reclamation destination is the original landscape type. Alternatively, the reclamation destination can be a user-directed landscape type based on typical reclamation trajectories for the region for a given disturbance type. For the Fort McKay study, key input assumptions for defining footprint reclamation of large polygonal footprints associated with surface mining were based on trajectories developed by CEMA-SEWG (2008)[36]. For example, in the case of surface mining, footprint types (i.e., overburden disposal, tailings ponds and mines), regardless of the original landscape types, were reclaimed to the user-defined destinations listed in Table 20.

Table 20: Reclamation Trajectory for Large Polygonal Footprint Types to User-directed Landscape Types[37]

User-directed Landscape Types (LTs)	Reclamation Trajectory
Mixedwood	52%
White Spruce	12%
Closed Black Spruce	1%
Bog	3%
Herbaceous	9%
Tall Shrubland	5%
Endpit Lake	18%
Sum	**100%**

As there is considerable uncertainty about the ability to restore and reclaim wetlands after surface mining in the oil sands area (Foote 2012) and (Rooney, Bayley and Schindler 2012), there are also concerns about the cumulative effects of the extensive footprint required for in situ well extraction of bitumen (Schneider and Dyer 2006). And there are associated uncertainties and knowledge gaps about whether in-situ footprints such as well pads, access roads, and pipelines can be suitably restored and reclaimed after decommissioning (Graf 2009), particularly in boreal wetlands (Osko 2010). Further, most companies indicate in their EIAs that they will progressively reclaim these features, unless development of new well extraction technology allows for continued or expanded operations, in which case they will continue to use and build on existing infrastructure. As a result, it is plausible that much of the in-situ infrastructure will persist on the landscape for longer than we anticipate at the time of project application and approval.

There is also considerable uncertainty about the actual wildlife habitat value of reclaimed industrial footprint. For example, most oil sands development companies indicate that they will reclaim to an equivalent land capability, to pre-disturbance conditions, or similar end land uses. But it is uncertain whether reclamation will provide effective habitat to wildlife, because there is not enough reclaimed habitat to well monitor the use by wildlife. Nevertheless, some stakeholders have asserted that reclaimed landscapes have reduced wildlife habitat value, whereas other industrial proponents have expressed the view that reclaimed landscapes might exceed habitat value created by natural disturbance regimes (Cenovus TL ULC 2011), (Marathon Oil Canada Corporation 2012) and (Dover Operating Corp. 2010):

[36] Trajectories were based on current closure plans submitted to regulators for oil sands mines, at the time of the CEMA-SEWG modelling.
[37] I.e., overburden disposal, tailings ponds and surface mines.

"Reclamation of the disturbed areas within the TLSA will encourage re-establishment of wildlife habitat in uplands and wetlands, restoring capability for traditional hunting and trapping activities." (Cenovus 2011, Volume 1, Section 13, p. 13-23)

"Reclamation objectives of the Project include:" … "reclaimed lands will provide for maintenance free, self-sustaining ecosystems with a similar range of potential end uses, including wildlife habitat and traditional use, compared to pre-disturbance conditions." (Cenovus 2011, Volume 1, Section 13, p.13-10)

"The C&R Plan aims to establish upland wildlife habitats compatible with similar areas in the surrounding ecosites." (Marathon 2012, Volume 1, Section 8.9.3, p.35)

"Over the long term, ecosystems that are re-established on disturbed lands are expected to be self-sustaining, capable of maturing naturally and will provide suitable habitat for resident and migratory wildlife species. The C&R Plan aims to establish diverse uplands wildlife habitats compatible with similar areas in the surrounding ecosites." (Dover 2010, Volume 1, Section 8.3.9.2, P.8-16)

To assess these uncertainties, we developed a sensitivity analysis to examine possible magnitudes of responses by key biotic indicators to reclamation of energy sector (i.e., bitumen production) footprints. This sensitivity analysis was established by varying three assumptions (Table 16):

1. Reclamation destinations for footprints associated with surface mining of oil sands.

2. Reclamation destinations for footprint associated with in situ well extraction of bitumen.

3. Discounting HSI values for landscape types that have been reclaimed from surface mine and in situ footprints.

Reclamation trajectories for surface mining footprint types had two potential settings: footprint types associated with surface mining would either reclaim to the original landscape types, or the footprint types would reclaim according to trajectories developed by CEMA-SEWG (Table 20).

Similarly, the base assumption for reclamation of in situ footprint types was that they would reclaim to original landscape types. The alternate assumption was that in-situ footprint types that occurred in one of four wetland landscape types would reclaim such that 50% would reclaim back to original LTs, and the other 50% would reclaim to a low-value wetland landscape type. This approach was taken to incorporate the current uncertainty over the ability to reclaim regionally common organic wetland types such as treed and shrubby fens and bog.

Table 21 summarizes the original distribution of in situ FTs within LTs across the Study Area as determined by geospatial analysis, and also shows the adjusted distribution in which the original proportions of in-situ FTs on three wetland LTs (i.e., Closed Black Spruce, Open Black Spruce Fen Shrubby Swamp and Bog) were reduced by 50%, with a proportional increase in the amount of Open Fen. The adjusted distribution provided the input data to ALCES to define the reclamation trajectories for in-situ FTs in sensitivity runs 5-7 (Table 22).

Table 21: Reclamation Trajectories Based On Actual and Adjusted Proportional Distributions for In Situ Footprints When They Occurred On Four 'Wetland' Landscape Types

	***IN SITU* FOOTPRINT TYPES**			***IN SITU* FOOTPRINT TYPES**		
	Distribution in Study Area			**Adjusted Distribution**		
WETLAND LANDSCAPE TYPES	MinorRoad	WellSite	Pipeline	MinorRoad	WellSite	Pipeline
Hardwood	0.2701	0.2197	0.2527	0.2701	0.2197	0.2527
Mixedwood	0.1187	0.0736	0.1017	0.1187	0.0736	0.1017
White Spruce	0.0370	0.0658	0.0542	0.0370	0.0658	0.0542
Pine	0.2532	0.1101	0.0523	0.2532	0.1101	0.0523
Riparian	0.0251	0.0188	0.0327	0.0251	0.0188	0.0327
Cl Bl Spruce	0.0808	0.1295	0.1515	0.0404	0.0648	0.0758
Open B Spr Fen Shr Swamp	0.0856	0.1982	0.1659	0.0428	0.0991	0.0830
Bl Spr Lichen Moss	0.0002	0.0001	0	0.0002	0.0001	0
Open Fen	0.0387	0.0706	0.0562	0.1494	0.2767	0.2707
Bog	0.0549	0.0845	0.1115	0.0275	0.0423	0.0558
Herbaceous	0.0275	0.0232	0.0137	0.0275	0.0232	0.0137
T Shrubland	0.0000	0.0007	0.0045	0.0000	0.0007	0.0045
S Shrubland	0.0073	0.0052	0.0029	0.0073	0.0052	0.0029
Small Lotic	0	0	0	0	0	0
Large Lotic	0	0	0	0	0	0
Endpit Lake	0	0	0	0	0	0
Lentic	0	0	0.0001	0	0	0.0001
Beach Dune	0.0009	0	0.0001	0.0009	0	0.0001
Cultivated	0	0	0	0	0	0
Forage Crop	0	0	0	0	0	0

Table 22: Sensitivity Analyses for Reclamation Assumptions of Footprint Types Associated with Surface Mining or In situ Well Bitumen Extraction; HSI Coefficients of Reclaimed Habitat were also Discounted

Sensitivity	Footprint Reclamation Destination		HSI Discount*
	Surface Mining	In Situ	
1	Original LT	Original LT	0%
2 (BAU & FM)	CEMA[+]	Original LT	0%
3	CEMA	Original LT	-20%
4	CEMA	Original LT	-40%
5	CEMA	50% Wetland**	0%
6	CEMA	50% Wetland	-20%
7	CEMA	50% Wetland	-40%

*Percent (%) discount applied to HSI values on reclaimed LTs

[+] Assumptions for reclamation of polygonal footprints associated with surface mining of bitumen were developed through CEMA-SEWG, and specified reclamation trajectories for gravel pits, overburden disposal, tailings ponds and surface mines as per Table 20.

**50% of In situ footprint types on wetlands reclaimed to original landscape types, and the remaining proportion was directed to fens

For habitat suitability, the base assumption was that HSI values for anthropogenic (i.e., reclaimed) LTs were the same as the pyrogenic HSI values. Alternate assumptions for anthropogenic LTs were to discount the HSI values by 20% and 40% (Table 23). As with the sensitivity analyses affecting in-situ reclamation destinations, this approach was adopted to incorporate into modelling results, current uncertainty on the efficacy of reclamation in returning critical habitat requisites.

Table 23: Original and Discounted Habitat Quality Coefficients Used As Inputs into a Sensitivity Analysis for Footprint Reclamation

Discounted HSI Values for Respective Landscape Types

Fisher			
		Discounted HSI	
LT	Original HSI Value	20%	40%
HW	0.50	0.40	0.30
MW	1.00	0.80	0.60
WhSP	1.00	0.80	0.60
Pine	0.10	0.08	0.06
ClBlSpruce	0.10	0.08	0.06
RipF	1.00	0.80	0.60
OpBlSp	0	0	0
BlSpLiMoss	0.10	0.08	0.06
OpFen	0	0	0
Bog	0	0	0
Herb	0	0	0
Tshrub	0	0	0
Sshrub	0	0	0
SmLotic	0	0	0
LaLotic	0	0	0
EPLake	0	0	0
Lentic	0	0	0
BeDune	0	0	0
CultCrop	0	0	0
ForageCrop	0	0	0

Moose			
		Discounted HSI	
LT	Original HSI Value	20%	40%
HW	0.93	0.74	0.56
MW	0.70	0.56	0.42
WhSP	0.55	0.44	0.33
Pine	0.40	0.32	0.24
ClBlSpruce	0.40	0.32	0.24
RipF	0.93	0.74	0.56
OpBlSp	0.60	0.48	0.36
BlSpLiMoss	0.20	0.16	0.12
OpFen	0.20	0.16	0.12
Bog	0.20	0.16	0.12
Herb	0.50	0.40	0.30
Tshrub	0.70	0.56	0.42
Sshrub	0.70	0.56	0.42
SmLotic	0.20	0.16	0.12
LaLotic	0.20	0.16	0.12
EPLake	0	0	0
Lentic	0.20	0.16	0.12
BeDune	0	0	0
CultCrop	0	0	0
ForageCrop	0	0	0

Berry			
		Discounted HSI	
LT	Original HSI Value	20%	40%
HW	0.11	0	0
MW	0.14	0	0
WhSP	0.22	0	0
Pine	0.92	0	0
ClBlSpruce	0.020	0	0
RipF	0.39	0	0
OpBlSp	0	0	0
BlSpLiMoss	0	0	0
OpFen	0.15	0	0
Bog	0.62	0	0
Herb	0	0	0
Tshrub	0	0	0
Sshrub	0	0	0
SmLotic	0	0	0
LaLotic	0	0	0
EPLake	0	0	0
Lentic	0	0	0
BeDune	0	0	0
CultCrop	0	0	0
ForageCrop	0	0	0

3.7.4 Mapping the Future: ALCES Mapper Assumptions

Maps of potential future landscape composition were created in ALCES Mapper by distributing simulated annual footprint creation and reclamation across the Study Area based on available spatial information. The spatial resolution for simulating landscape composition was based on a fishnet overlay with a grid cell size of 278 ha (1.67 km × 1.67 km: 1 section), resulting in ~13,000 cells in the Study Area. In a given simulation year, the amount of each footprint type created within each landscape type was equivalent to that simulated by ALCES.[38] New footprints were not allowed within protected areas. To avoid excessive aggregation of simulated footprint, the amount of a given footprint type within a grid cell was not allowed to exceed the 95th percentile of the current distribution of the amount of the footprint type per cell.[39] Timber harvest was assumed to disturb all merchantable forest within a selected cell to avoid excessive dispersion of cutblocks.

[38] The distribution of new footprint across land cover types in ALCES was based on the composition of those portions of the study area with unprotected resource potential within the corresponding growth mask.

[39] Because of the large amount of seismic footprint created over the simulation and the limited area in the mask, we raised the allowable amount of seismic growth per cell to the 97th percentile of current distribution to ensure that enough seismic was being created.

The location of the new footprint was random, but guided by resources availability[40] and inclusionary masks use as follows:

- Mine footprints (oil sands mine, disposal overburden, tailings pond) were distributed across the Mineable Oil Sands Area (MOSA). Location and timing of development within MOSA was based on project status from the Alberta Oil Sands Industry Quarterly Update, Spring 2012 (Government of Alberta 2012). In the first 14 years of the simulations, mine footprint was focused in areas within MOSA where developments were occurring, planned or proposed (Table 24, Figure 20).

- In situ footprint (i.e., seismic, wells, pipelines, minor roads, industrial plants, gravel pits) distribution was based mainly on bitumen density (m^3/ha) across reserves in the Athabasca Wabiskaw-McMurray deposit, with a bitumen pay thickness of 1.5 m or greater (Figure 21: In Situ Footprint Mask Used for Seismic, Well Site, Pipeline, Industrial, Minor Road and Gravel Pit Footprint Growth). In the first 29 years of the simulations, the distribution of in situ footprint was focused in economically viable bitumen reserve areas (as identified by Alberta Department of Energy 2008) as well as in locations where developments were occurring, planned or proposed. Those locations were based on the grid cells that contained planned or proposed in situ footprints. Location and timing of developments was based on project status from the Alberta Oil Sands Industry Quarterly Update, Spring 2012 (Government of Alberta 2012). From year 30 to the end of the simulations, in situ footprints were also distributed outside the economic bitumen reserves and within the known location of areas with bitumen pay thickness greater than 1.5 m.

- Forestry footprints (cutblocks, roads) were distributed across tenures based on their annual allowable cut. Simulated timber harvest was limited to Alberta Pacific Forest Industry's Forest Management Units occurring in the Study Area (A14, A15, and S22), and to forest exceeding the minimum harvest age (60 years for hardwood and mixedwood, 80 years for softwood). Only planned (i.e., non-salvage) harvest was mapped. To avoid double counting salvage harvest, planned harvest was restricted from growing in future bitumen and mining footprint areas (Figure 22).

- Settlements were expanded contagiously from existing settlement footprint (Figure 23).

- Camp footprint was distributed within the economic bitumen reserves (identified by Alberta Department of Energy 2008) with densities greater than 40,000 m^3/ha (Figure 24).

---

[40] Each cell was associated with a value, referred to as the mask value that expressed its relative likelihood of receiving a footprint type given the relative abundance of related resource types. When selecting the next cell in which to grow footprint, Mapper randomly selected a cell from an available list (i.e., unprotected cells with footprint below the maximum footprint threshold). Mapper then generated a random number between 0 and the maximum mask value across cells with non-zero mask values. If the random number was less than the selected cell's mask value, then the cell received footprint. Otherwise, the cell did not receive footprint during that year. This selection process distributed footprint across cells randomly but relative to the distribution of relevant resources.

- Infrastructure footprint (major road, transmission line) distribution followed an anchored growth pattern (new footprint started from existing footprint), and was only limited to not occurring within protected areas.

- Fires were distributed across the Study Area and location was insensitive to stand age. Fire events followed the size distribution assumed by CEMA (Wilson, Stelfox and Patriquin 2008). The size classes were organized into multiples of 200 ha for closer compatibility with the grid cell size used in Mapper. Fires tended to burn cells in their entirety but, similar to post-fire residuals, portions of cells were sometimes left unburned. The fire size distribution was: 79% of fires as one-cell events, 14% as two- to four-cells, 4% as five- to 36-cells and 3% as 36- to 360-cells.[41]

The spatial distribution of footprint reclamation was based on the age of footprint (i.e., oldest first). The only age information available for existing footprint was the drilling year for wells; all existing non-permanent footprint within a cell was assumed to have the same age as the average age of wells within that cell. Exceptions to the oldest-first reclamation pattern were made to more accurately represent the lifespan of footprint in certain situations. Seismic footprint outside the boundaries of hydrocarbon reserves was assumed to be conventional seismic, and therefore have an average lifespan of 60 years. As well, 'time to a near complete recovery' (< 5% remaining) of a cohort of seismic lines would be approximately 112 years based on median recovery rates (Lee and Boutin 2006).

Assumptions used in ALCES were applied in ALCES Mapper to calculate indicator performance at the scale of the fishnet grid cell. One exception was the index of native fish integrity, which was calculated at the scale of the tertiary watershed.[42] Land base composition, at the grid cell level for most indicators and at the watershed scale for INFI, were translated into indicator values using coefficients that were calculated from ALCES model assumptions, and based on the amount of footprint reclaimed and grown within a cell on an annual time step.

[41] CEMA assumed that burn area was distributed across size classes as follows: 1% as 0 ha to 10 ha, 2% as 11 ha to 100 ha, 4% as 101 ha to 1000 ha, 10% as 1001 ha to 10,000 ha, and 83% as 10,000 ha to 100,000 ha. This distribution was converted to % of fire events across size classes, and adjusted to accommodate slightly different size classes (i.e., combining and increasing the first two size classes to 0 ha to 200 ha to more closely match the grid cell size).

[42] Sub-Sub Drainage Areas, Atlas of Canada 1,000,000 National Frameworks Data, Hydrology – Drainage Areas, Water Survey of Canada; ***http://geogratis.cgdi.gc.ca***

Table 24: Data Sources Used to Guide Footprint Growth in ALCES Mapper in the Fort McKay Study Area through Inclusionary Masks Use

Sector	Footprints	Mask data	Source
Mining	Oil sands mine, disposal overburden, tailings pond	1) MOSA, 2) Planned, proposed development	1) LARP (ERCB 2009) 2) Location - digitized from EIAs; timing - Alberta Oil Sands Industry Quarterly Update, Spring 2012 (Government of Alberta 2012a)
In situ	Seismic, pipeline, well site, industrial, minor road, gravel pit	1) Economic bitumen reserves, 2) Planned, proposed development 3) Athabasca Wabiskaw-McMurray deposit	1) LARP (ERCB 2009) 2) Location - digitized from EIAs; timing - Alberta Oil Sands Industry Quarterly Update, Spring 2012 (Government of Alberta 2012a) 3) Digitized from ERCB ST98-2011: Alberta's Energy Reserves 2011 and Supply/Demand Outlook
In situ	Camp	Economic bitumen reserves > 40,000 m3/ha	LARP (ERCB 2009)
Forestry	Timber harvest, inblock road	Al-Pac FMUs (A14, A15, S22) outside the in situ and mining growth areas	Forest Management Unit (FMU) boundaries (2012) – digital data acquired from AltaLIS
Settlement	Town / city	10-km radius from existing town / city	Based on potential projected growth in ALCES Urban – Community growth simulator for Ft. McMurray (www.alces.ca/aref)
Infrastructure	Major road, transmission	Study Area, excluding protected areas	

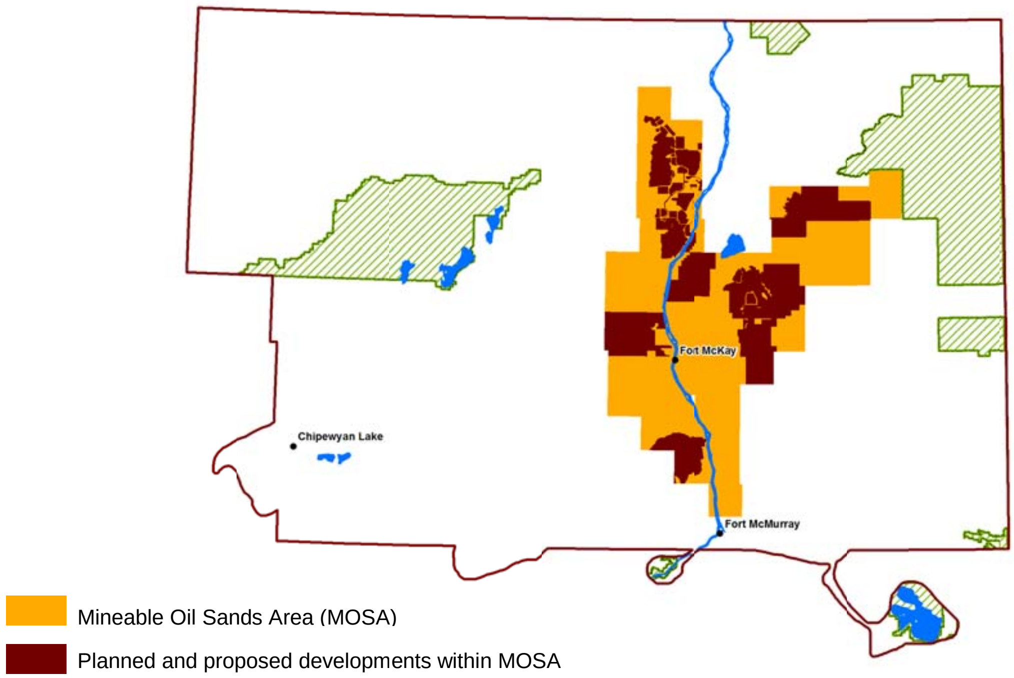


Figure 20: Mine Footprint Mask Used for Oil Sands Mine, Disposal Overburden and Tailings Pond Footprint Growth; Footprint Was Restricted from Growing within the BAU Protected Areas (Green Hatching)

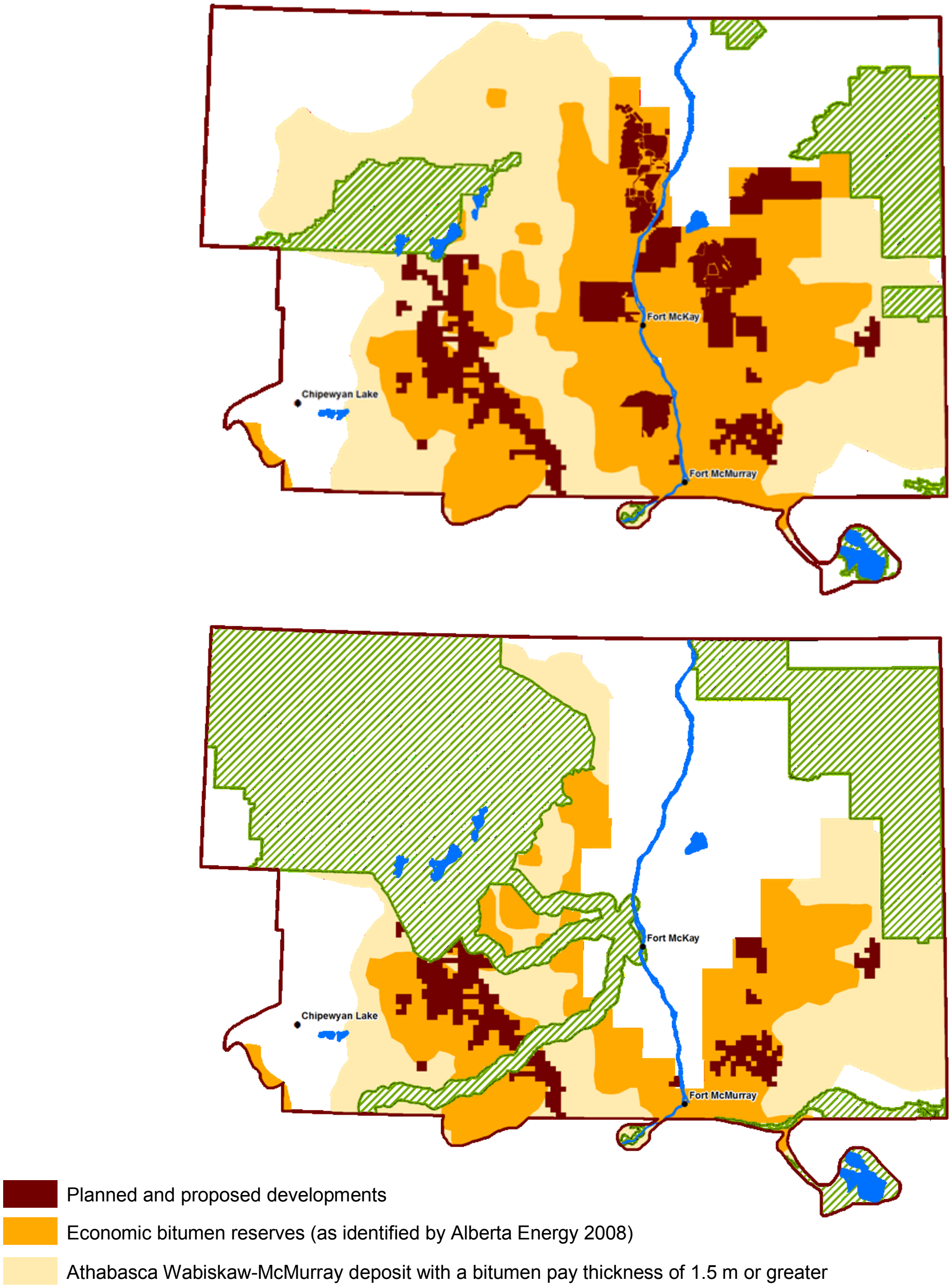


Figure 21: In Situ Footprint Mask Used for Seismic, Well Site, Pipeline, Industrial, Minor Road and Gravel Pit Footprint Growth[43]

[43] Footprint was restricted from growing within existing protected areas (green hatching) in the BAU scenario (top) and expanded protected areas in the Fort McKay scenario (bottom).

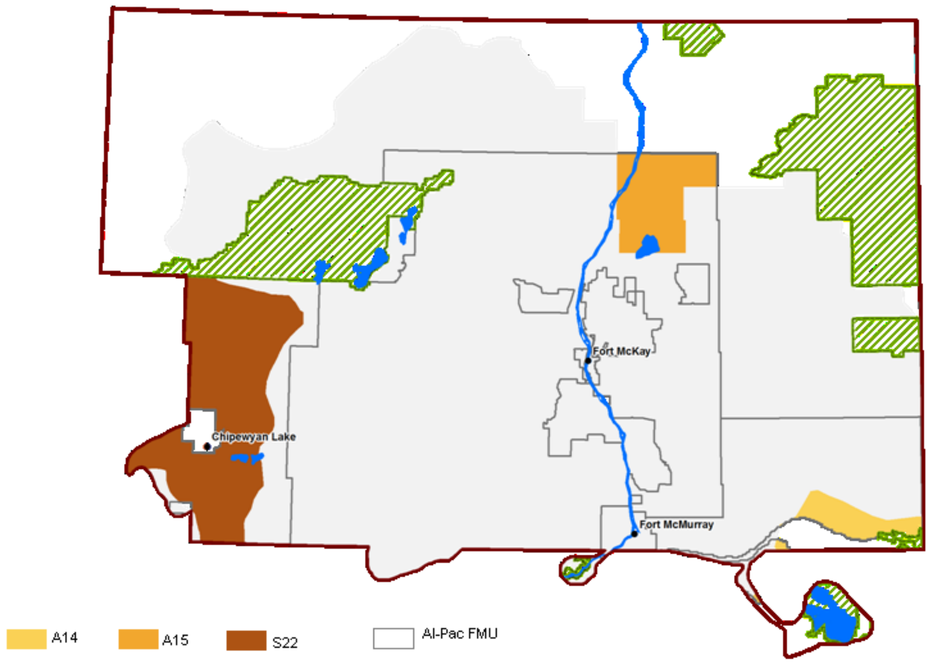


Figure 22: Forestry Footprint Mask Used for Directing Planned Growth of Timber Harvest and In=block Roads[44]

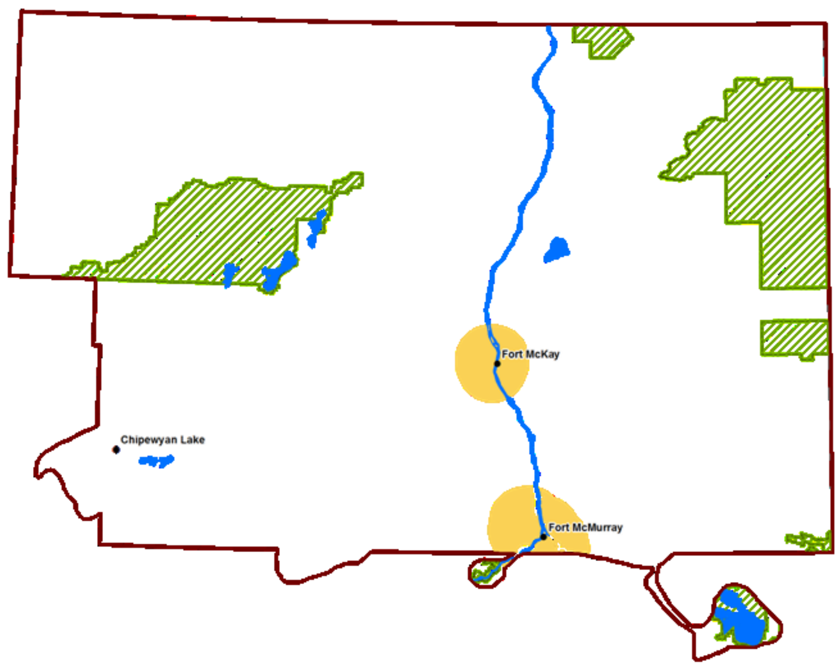


Figure 23: Settlement Mask Used to Direct Town Growth (Fort McMurray and Fort McKay)

[44] Darker colour indicates higher annual allowable cut, and therefore, higher mask value. Footprint was restricted from growing in bitumen and mining areas (light gray shading) and within protected areas.

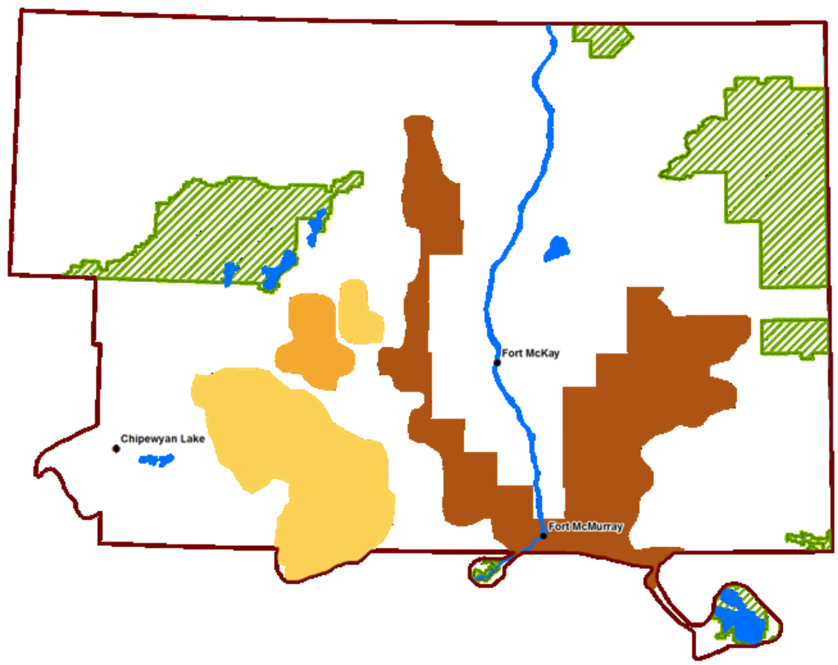


Figure 24: Camp Mask Used to Direct Camp Growth Related to the In Situ Energy Sector[45]

[45] Darker colour indicates higher density of bitumen in place and, therefore, higher mask value and increased likelihood of receiving camp footprint.

4 Results and Discussion

Since the onset of large-scale industrial activity in the Fort McKay Study Area, the collective footprints of the forestry and the energy sectors have led to significant landscape transformation, particularly in the central areas of the Study Area that are dominated by oil sands surface mining. To date, the cumulative effects of industrial activity have caused direct loss of natural landscape and wildlife habitat, and indirect reduction in performance of biotic indicators in areas adjacent to land-use footprints, which occur as linear or curvilinear (seismic lines, pipelines, access roads, transmission lines) or polygonal features (surface mines, tailings ponds, settlements, well sites, processing plants).

The simulations and scenario analyses suggest that bitumen production and associated economic indicators will grow substantially over the coming decades in order to meet approved and projected production levels. Future changes over the next 100 years to the structure and ecological function of the Fort McKay Study Area will be far greater in scale and pace than the changes observed to date that occurred during the past 50 years.

An important distinguishing characteristic of future bitumen development will be the increasing contribution of in situ well extraction to total bitumen production. Compared to the polygonal features associated with surface mining, footprints associated with in situ extraction have proportionally greater edge than area, and it is those linear features that will extend over a larger proportion of the Study Area and dramatically increase edge density, which in turn would further increase habitat fragmentation and reduce performance of several key biotic indicators.

Ecological indicators will continue to be reduced in integrity in the coming decades. The performance of these indicators might be improved markedly through a combination of management strategies that includes access management, continued improvement and application of industry "best management practices" and expanded protected area networks. Integration of these management strategies would require public access management coordination across the Study Area, beneficial management practices implementation that seeks to continually reduce footprint growth and accelerates reclamation, and incorporating expanded protected area strategies (of an appropriate scale) that explicitly addresses access management and harvesting of wild animals and plants as well as providing 'no-go' areas to industrial footprints.

Before reviewing the detailed results, the reader is reminded that although ALCES calculates production values and indicator performance at the scale of individual landscape types, that variance is integrated into the indicator metric as an average across the entire Study Area. Thus, ALCES results (i.e., output graphs and tables) are reported at the scale of the Study Area, which for the Fort McKay and Industrial Landscape Study Areas were 3.62 M ha and 1.17 M ha, respectively. In contrast, spatial results generated by ALCES Mapper were calculated and displayed across a Study Area at a grid scale of 278 ha, which is equivalent to a section (1 mile × 1 mile); or in the case of INFI, ALCES Mapper calculated performance at the scale of tertiary watersheds, which is an ecological relevant scale for fish.

4.1 Business as Usual (BAU) and Fort McKay (FM) Scenarios

The main differences between the BAU and FM scenarios occurred by contrasting three management levers – protected areas, access management and best management practices (Table 25). This section summarizes the comparative results of the BAU and FM scenarios for selected indicators. A key feature of the comparative graphs is that indicator trend lines are displayed for both the BAU and FM scenarios, and also for each of the three management levers that contributed to the FM scenario. The graphs were designed this way so that the reader could observe the relative contribution made by each management lever run individually and then applied together in the FM scenario.

Table 25: Comparison of Management Levers between Business as Usual (BAU) and Fort McKay (FM) Scenarios

Management Levers	Scenario	
	Business As Usual (BAU)	Fort McKay (FM)
Protected Areas	Existing	Expanded
Access Management	Current (no AM)	Moderate
Best Management Practices	Current (none)	High

4.1.1 Commodity Production

For both the BAU and FM scenarios for the Fort McKay Study Area, annual harvest targets for hardwood (~218,000 m^3) and softwood (~346,000 m^3) trees were sustained throughout the future simulation period of 100 years (Figure 25).

Simulated production of bitumen has been increasing during the past several decades in the FM Study Area and now occurs at a rate of ~1.5 M bpd (Figure 26) or ~87 M m^3/yr (Figure 27). Simulated patterns in annual production for total bitumen were consistent with a generalized Hubbert-Naill hydrocarbon production curve, and projected a peak production of ~3.5 Mbpd or ~202 M m^3/year (Figure 26 and Figure 27) within 30 years before beginning to decline; those bitumen production metrics were the same for both the BAU and FM scenarios.

Although bitumen production from surface mining has been the dominant extraction method historically and will remain so over the near future, in situ (SAGD) technologies are now being deployed in the region and are expected to grow in production during the next several decades. Simulation results suggested that annual production of bitumen from in situ (such as SAGD) technologies will grow and stabilize within 35 years, and subsequently match and exceed mine production within eight decades (Figure 26 and Figure 27).

Annual peak production of bitumen from surface mining was over two times the peak volumes produced through in situ extraction, but by year 2090 in the simulation (i.e., in ~80 years), in situ production exceeded mined bitumen. At the end of the 100-year future simulation period, total cumulative bitumen production approached ~16.9 billion m^3, with surface mining and in situ production contributing ~11.0 (65%) and ~5.9 (35%) billion m^3, respectively (Figure 28).

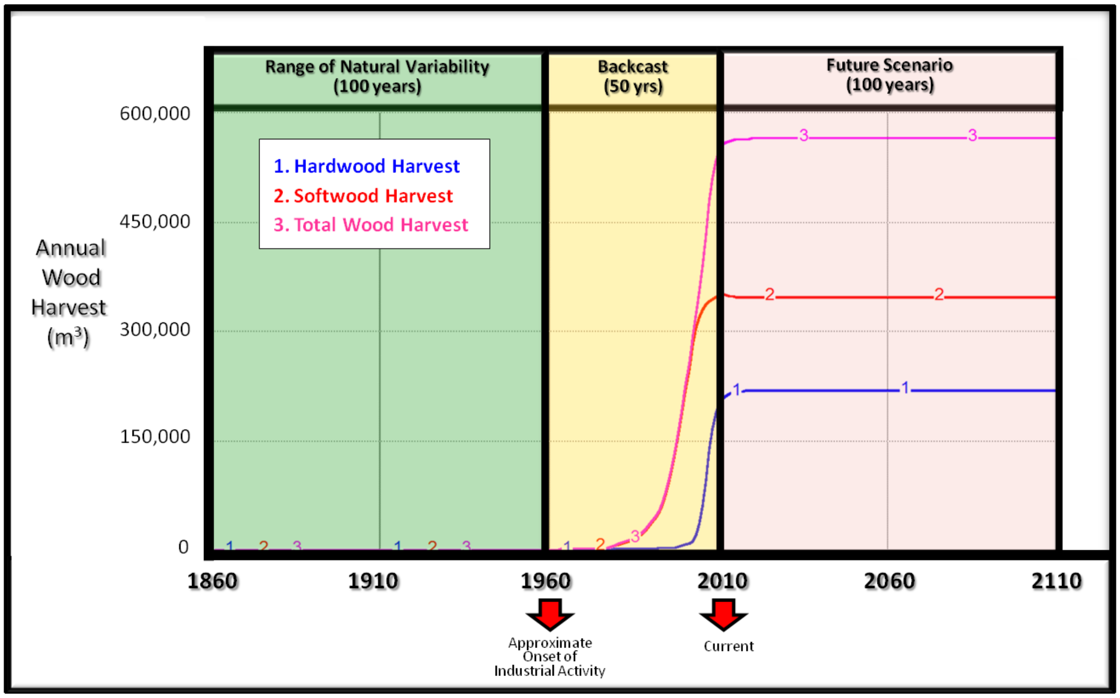


Figure 25: Annual Wood Harvest Volumes Simulated Under BAU & FM Scenarios in ALCES for the Fort McKay Study Area

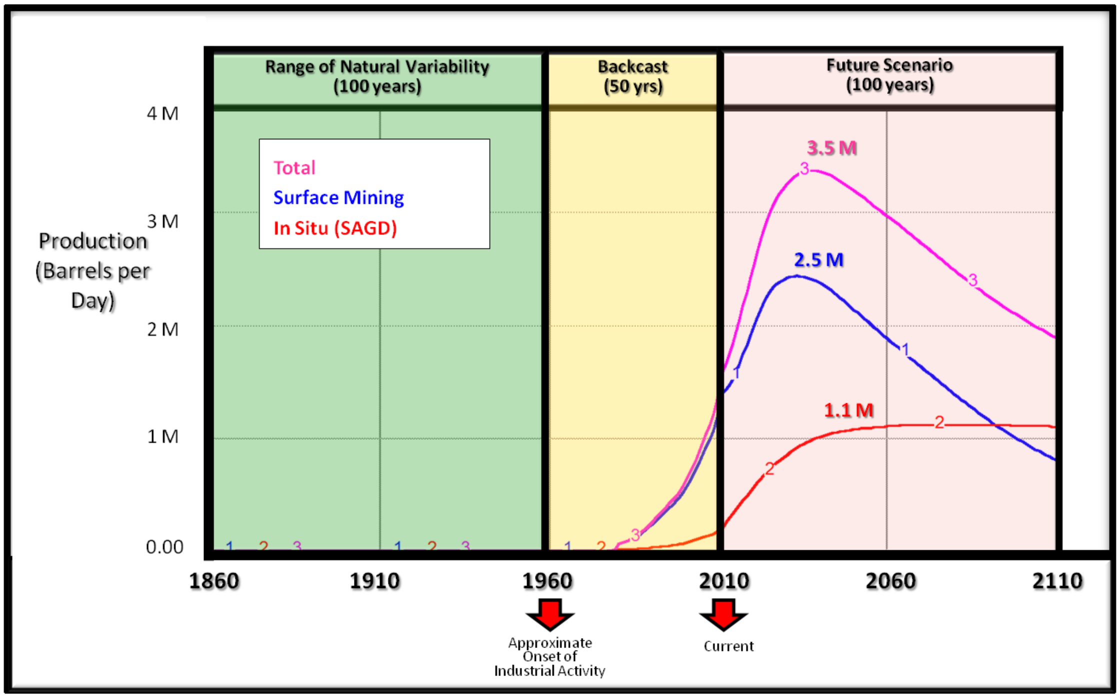


Figure 26: Annual Bitumen Production Volumes (million barrels per day) Simulated under BAU and FM Scenarios in ALCES for the Fort McKay Study Area

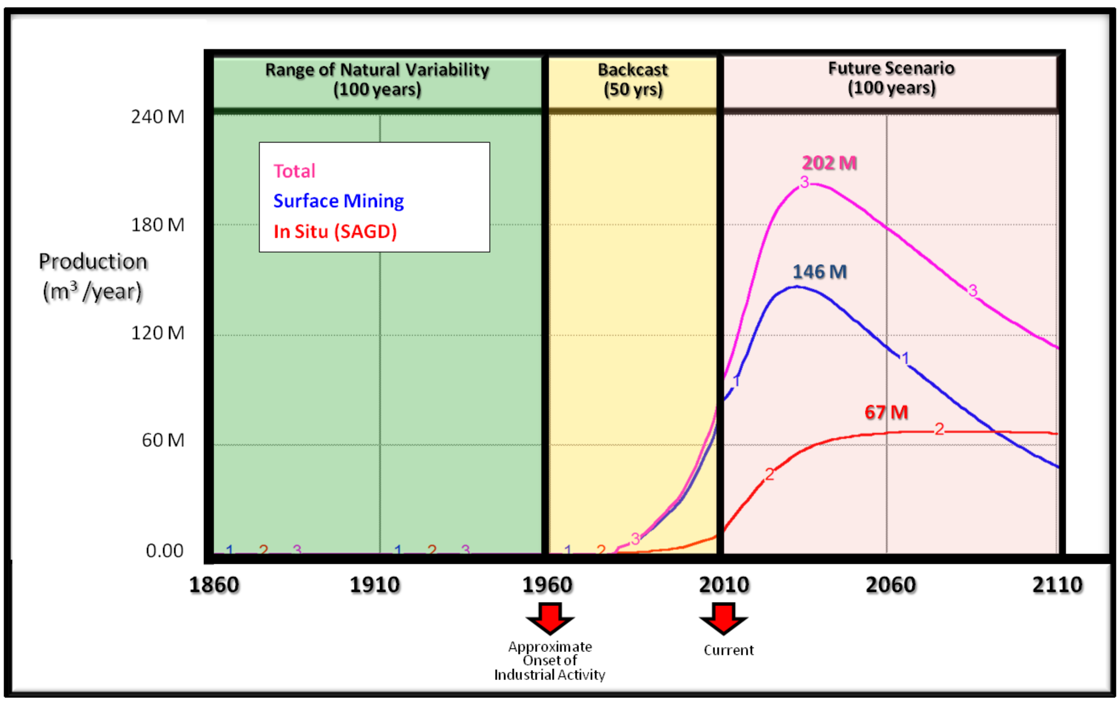


Figure 27: Annual Bitumen Production Volumes (m^3/year) Simulated under a BAU Scenario in ALCES for the Fort McKay Study Area

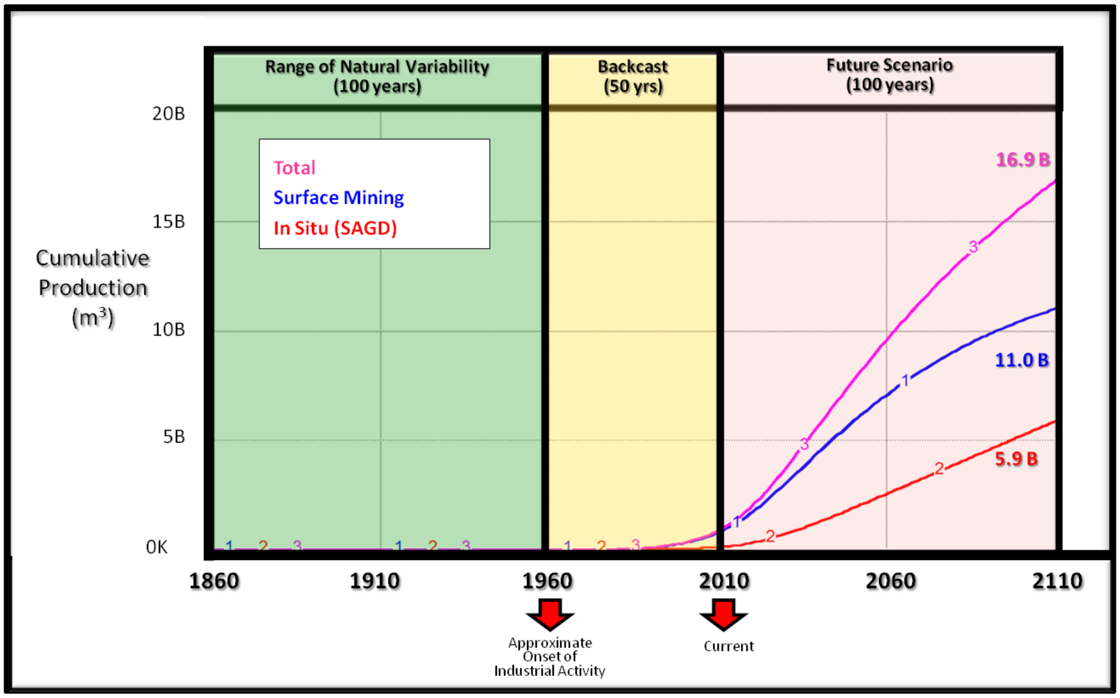


Figure 28: Cumulative Bitumen Production (m^3) Simulated under a BAU Scenario in ALCES for the Fort McKay Study Area

4.1.2 Revenue

Based on a key assumption that historical and future bitumen/oil commodity pricing remained constant at 2012 values (i.e., $642/m³; $100/barrel),[46] the gross annual revenue generated from bitumen production in the Study Area was currently ~$56B (Figure 29). Bitumen production gross revenue was expected to increase for 30 years, where it would achieve maximum annual values of ~$130B/yr (Figure 29). Beyond year 2040, bitumen production levels and annual values were simulated to decline incrementally.

As of 2010, simulated cumulative revenue from total bitumen production in the FM Study Area was estimated at $560B (Figure 30) of which 90% was attributed to oil sands mining. Those cumulative gross revenues were expected to increase to ~$10.8T within 100 years when ~17 B m^3 of bitumen would have been extracted and marketed.

[46] Readers who think the constant $642/m³ ($100/barrel) bitumen value used in these analyses is either too high or too low can simply apply an adjustment ratio to compute changes in annual or cumulative values. As long as market demand and price do not exhibit significant temporal variation, the shape of the gross annual and cumulative revenue curves from the FM study area would be unlikely to change.

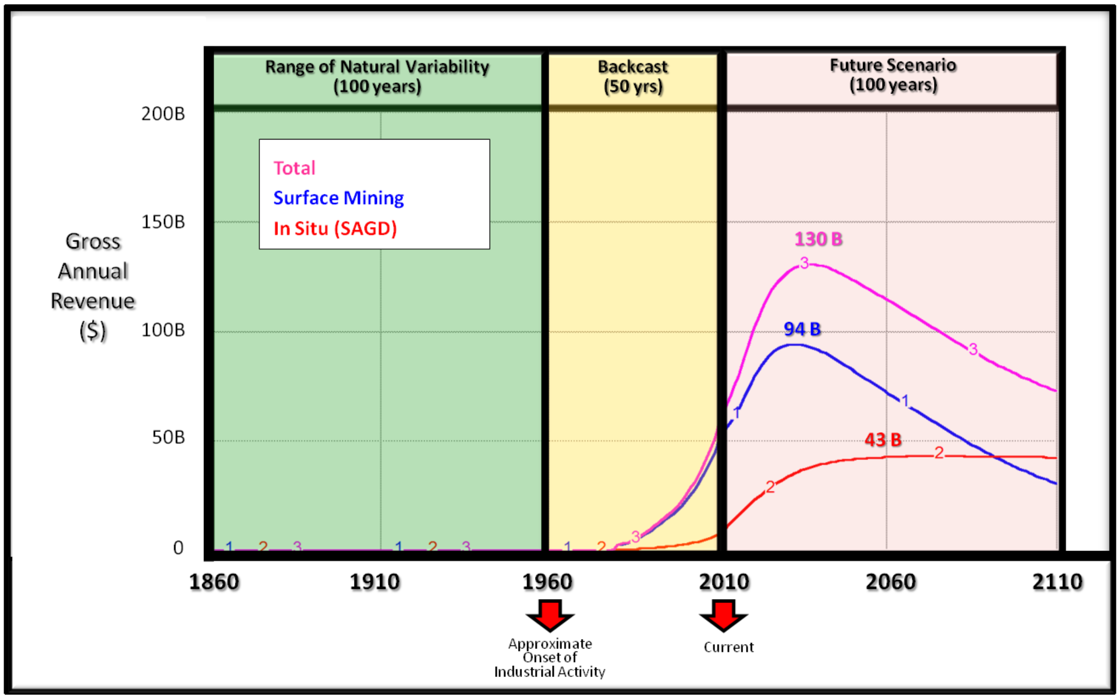


Figure 29: Annual Gross Revenue Generated from bitumen Production Volumes Simulated under a BAU Scenario in ALCES for the Fort McKay Study Area[47]

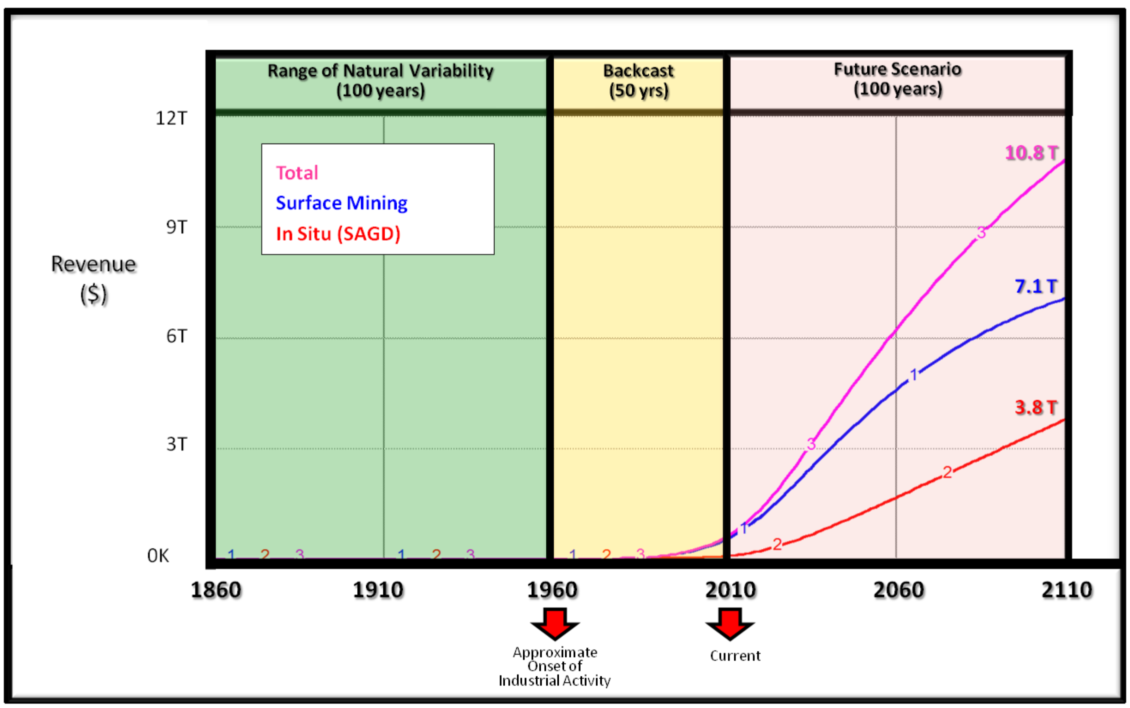


Figure 30: Total Cumulative Gross Revenue from bitumen Production Simulated under a BAU Scenario in ALCES for the Fort McKay Study Area[46]

[47] A key assumption was constant 2012 values for bitumen ($642/m3; 100$ per barrel).

4.1.3 Landscape metrics

The FM Study Area has undergone a significant transformation during the past 50 years. The greatest increase in anthropogenic features include the bitumen mining sector (~53,600 ha), in situ sector (~34,000 ha), with smaller increases in settlements (~3,000 ha), transportation (~1,500 ha) and parks (~378,500 ha).

Under a BAU scenario, by the conclusion of the future simulation period (2110), a total cumulative area of ~803,500 ha would be directly altered by the land-uses of transportation, residential and the energy sector. Of that gross area, ~428,500 ha are projected to be reclaimed and those reclaimed features include unused well pads and seismic lines. If the reclamation rates of energy sector footprints do not occur and inactive footprints do not revert back to the original landscape type (see Figure 31), then the net footprint of ~375,100 ha could be as large as the gross footprint of 803,500 ha. In comparison, the gross and net footprint for the FM scenario at year 2110 are ~718,300 ha and ~332,400 ha respectively.

Collectively, the footprints of the land-uses have led to significant landscape transformation in the FM Study Area, particularly to the central portion of the Study Area associated with the mineable oil sands area. Linear and curvilinear features (seismic lines, pipelines, access roads, transmission lines) and polygonal features (settlements, well sites, processing plants) have caused direct loss of natural landscape and wildlife habitat and have an indirect effect on those ecological processes that function at reduced performance when adjacent to either linear or polygonal land-use footprints. The simulation results suggest that future changes to the structure and ecological function of the FM Study Area will be greater in scale and pace than those that have occurred during the past 50 years.

4.1.3.1 Anthropogenic (Human-built) Edge Density (km/km^2)

Under the BAU scenario, which includes reclamation as per Table 20, average footprint edge density across the FM Study Area was at ~1.2 km/km^2 (in 2010) and will increase steadily throughout the 100-year future simulation period reaching 4.3 km/km^2 (Figure 32). An inflection point occurs at about year 2040 or 30 years into the future (Figure 32) when edge density is ~3.0 km/km^2.

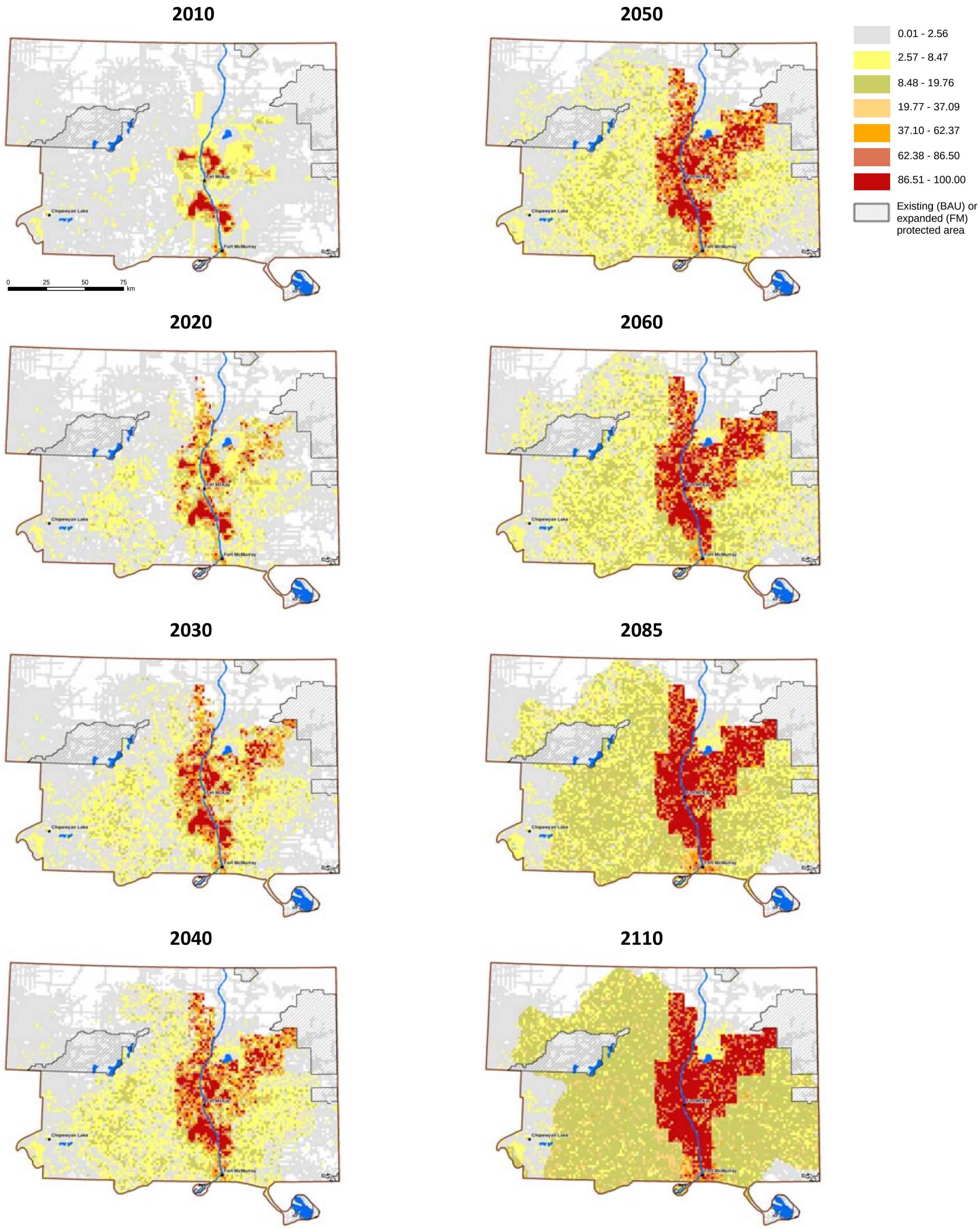


Figure 31: Projected future Changes in Percent (%) of Cell that is Anthropogenic Footprint, under a BAU Scenario and No Footprints Reclamation

This corresponds to a peak in bitumen production due to oil sands mining (Figure 27) when we expect the pace will slow for building infrastructure. Thus the overall trend of the BAU scenario shows that edge density increases most rapidly when both surface mining and in situ bitumen production are increasing, and continues to increase – at a slightly slower rate – after the peak in surface mining production due to the growth of linear footprints associated with in situ well extraction of bitumen.

In contrast, the pattern of edge density for the FM scenario exhibits a diverging and declining trend that occurs within 25 to 30 years, and corresponds to the adoption of narrow seismic lines and a reclamation lag for the standard-width seismic lines (2.75 m). Following reclamation of the wider seismic lines, the trend in edge density is driven by growth and reclamation rates of the narrow seismic lines; edge density slowly increases to an upper limit ranging of ~1.9 km/km² at the end of the simulation period (Figure 32).

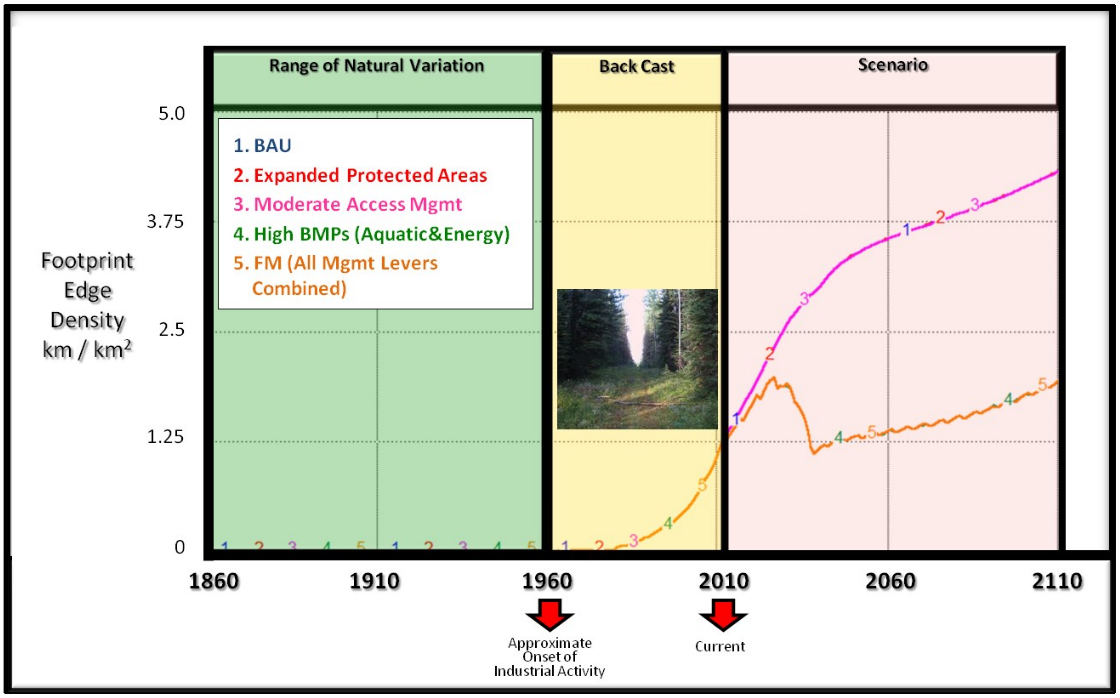


Figure 32: Comparative Trend in net Edge Density (km/km²) between the Business as Usual (BAU) and Fort McKay (FM) Scenarios

Compared to the BAU scenario, implementing best management practices in the FM scenario is the reason for the > 50% reduction in edge density at the end of the simulation period. The key BMPs driving this response are:

a) using low-impact narrow seismic lines, which had an average width of 0.75 m (average lifespan of ~5 years) versus 'standard' 2.75 m (average lifespan of ~25 years), and

b) pulse reclamation of seismic lines (10% every five years).

The spatial pattern of edge density at decadal intervals is compared across the BAU and FM scenarios in Figure 33 and Figure 34. The mapped sequences for the BAU scenario shows that edge density (primarily due to seismic lines and well access roads) is highest in the bitumen reserve areas that will undergo in situ bitumen extraction.

Based on the bitumen recovery assumptions, in situ development occurred in the deeper bitumen reserve areas first, and then between 2040 and 2050 the footprint extends into the remaining parts of the bitumen reserve. By the end of the 100-year future scenario period (year 2110), the pattern of edge density in the BAU scenario peaked and extended across the entire bitumen reserve area with edge densities ranging from 5 km/km^2 to 9^+ km/km^2.

In comparison, the timing of in situ development and its spatial extent is similar in the FM scenario, but the simulated edge densities increase to only half that observed in the BAU scenario. The main reason for this difference is the adoption of industrial BMPs which uses narrow seismic lines (0.75 m wide) and assumes pulse reclamation of seismic lines at a rate of 10% every five years.

Another important factor that is evident in the sequential maps of the two scenarios is the influence of protected areas on edge density. Because industrial activities and associated footprints are excluded from protected areas, no new footprints are grown in these areas and the edge density values reflect the gradual reclamation of existing linear features present in the protected areas prior to 2010. The net result is that edge densities within the expanded protected areas in the FM scenario, provide a much larger area that has comparatively minimal edge densities.

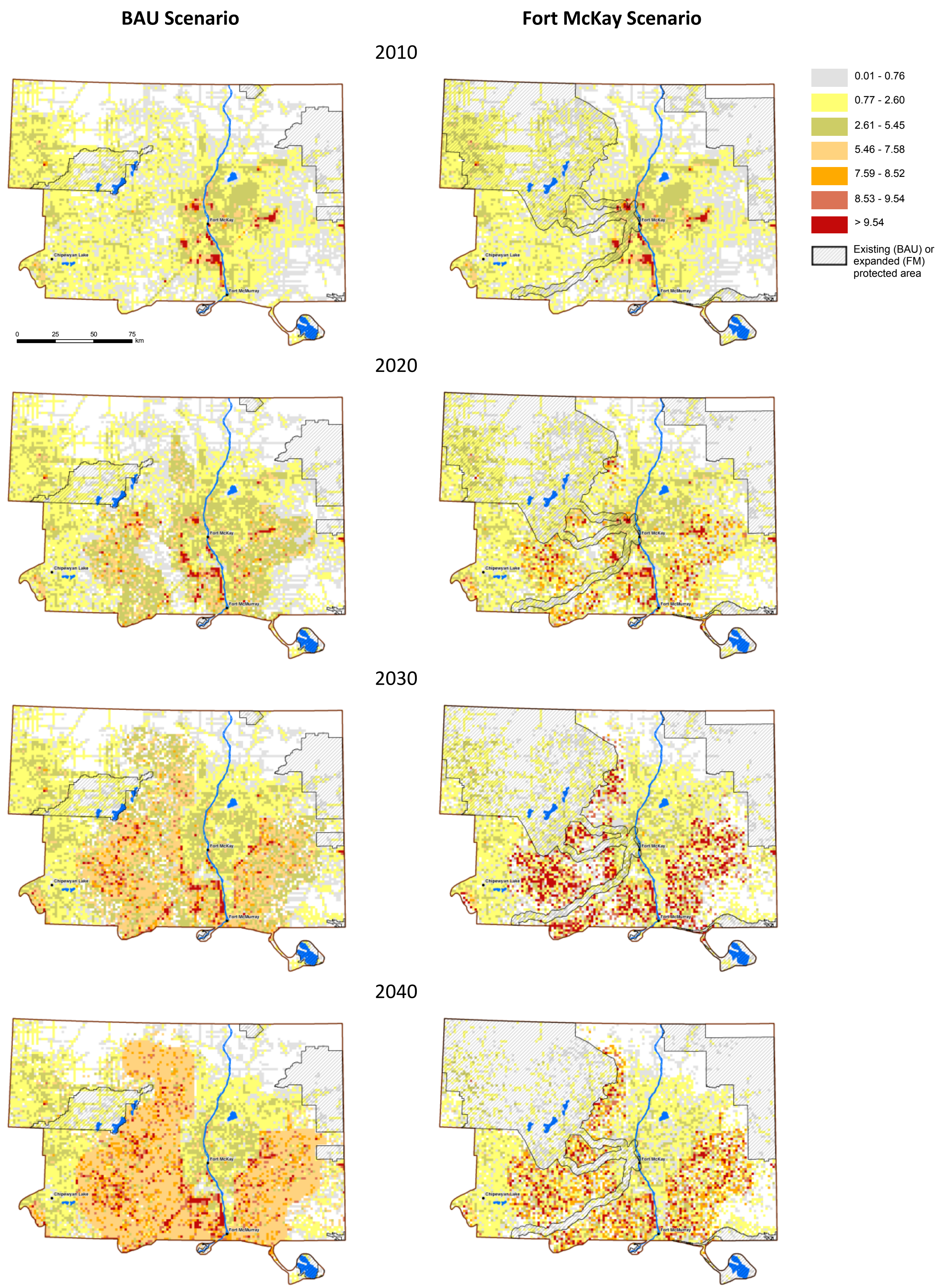


Figure 33: Projected Future Changes in Footprint Edge Density (km/km2), BAU and Fort McKay Scenarios, 2010-2040

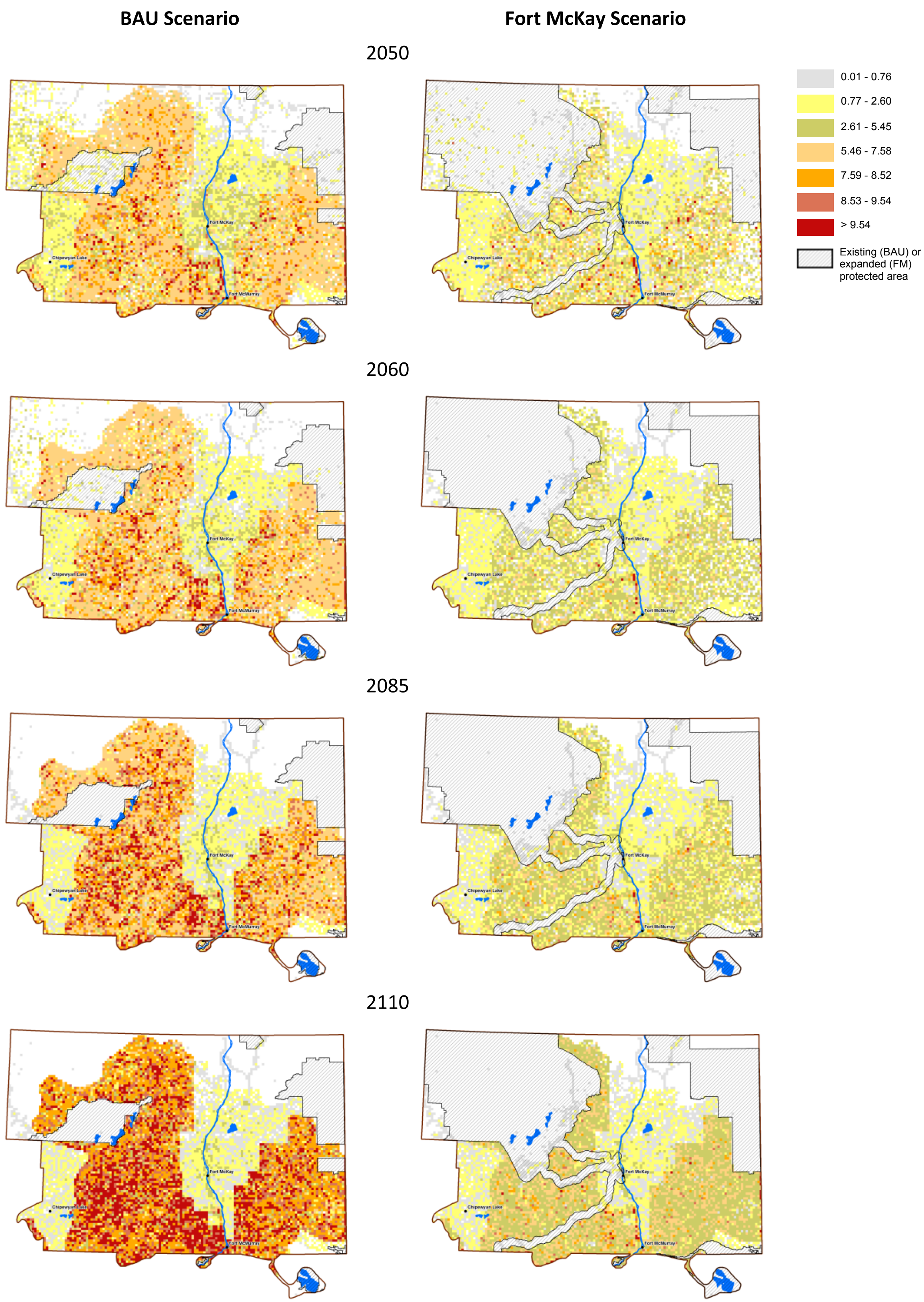


Figure 34: Projected Future Changes in Footprint Edge Density (km/km2), BAU and Fort McKay Scenarios, 2050-2110

4.1.3.2 Forest Core Area

Forest core area is a landscape metric that responds directly to anthropogenic features, so in the RNV period, the landscape is assumed to be completely intact. During the last half of the back-cast period, forest core area declined rapidly with the onset of industrial activity and anthropogenic footprints in the Study Area (Figure 35); core area declined by 80%, to only ~20% (0.20) of the forest area being ≥ 200 m from an anthropogenic footprint in 2010.

Relative to year 2010 as the start of the future scenario, the FM scenario shows a threefold increase in average core area during the future simulation period compared to BAU assumptions (Figure 35). The improved trend in core area was primarily a result of the expanded protected area network, which for the FM scenario was also about three times the size of the protected areas defined for the BAU scenario (Figure 18). The expanded protected area improved average core area at the Study Area scale, because it increased the area that was unfragmented by linear footprints and confined industrial footprints, especially seismic lines and access roads to a smaller proportion of the Study Area.

BMPs that incorporated low impact (i.e., narrow) seismic lines and pulse reclamation also contributed to a ~70% improvement in the core area metric relative to BAU. The reclamation lag of standard-width seismic lines is illustrated by the marked increase in core area that occurred within the first 30 years of the future simulation for the High BMP and FM scenario (Figure 35).

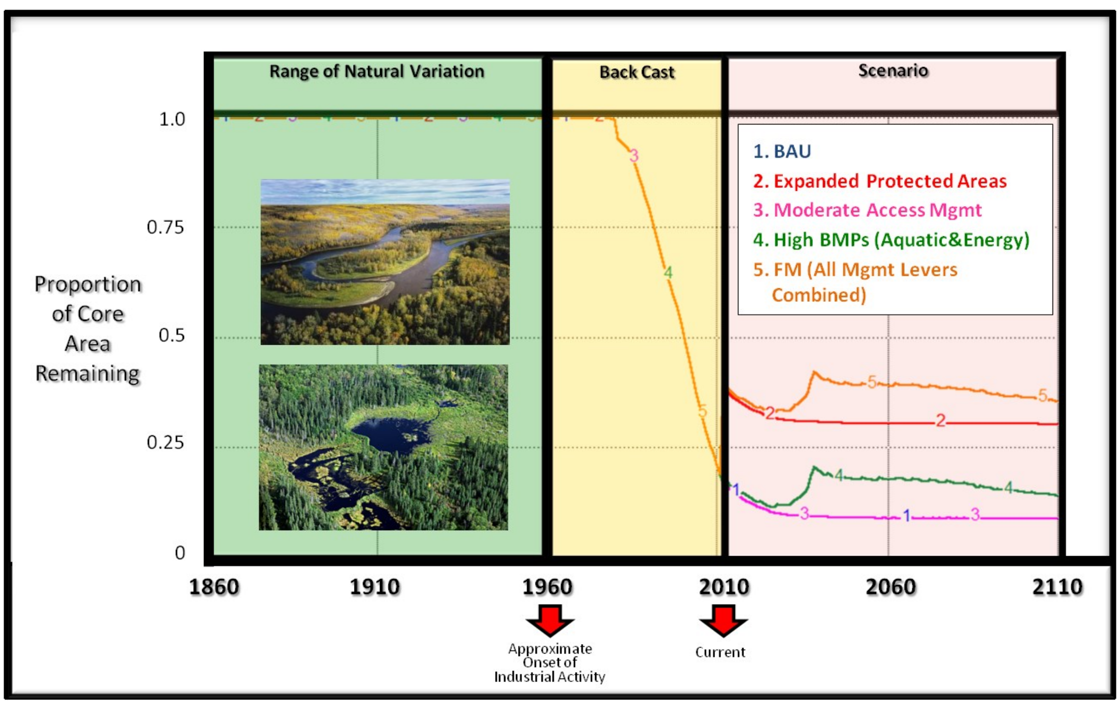


Figure 35: Comparative Trend in Core Area between the Business as Usual (BAU) and Fort McKay (FM) Scenarios

4.1.3.3 Average Forest Age

The RNV for average forest age has a mean value of 69 years with upper and lower 95% confidence intervals of 90 and 51 years respectively (Figure 36). At the end of the 50 year back-cast period, average forest age had become slightly younger at 62 years due to the combined effects of logging and energy sector development, along with fire. Through the future simulation period, average forest age declines further to 50 years by year 2060, and levels off below RNV around a long-term average age of 48 or 49 years at the end of the simulation for both BAU and FM scenarios.

The trend in average forest age over the Study Area was virtually the same between the BAU and FM scenarios (Figure 36). This is a reflection primarily of the identical fire regime occurring in both scenarios and the minor differences between the two scenarios with respect to continued growth and reclamation rates of the major polygonal footprints on the landscape such as the oil sands surface mines, tailings ponds, disposal overburden, and towns or cities.

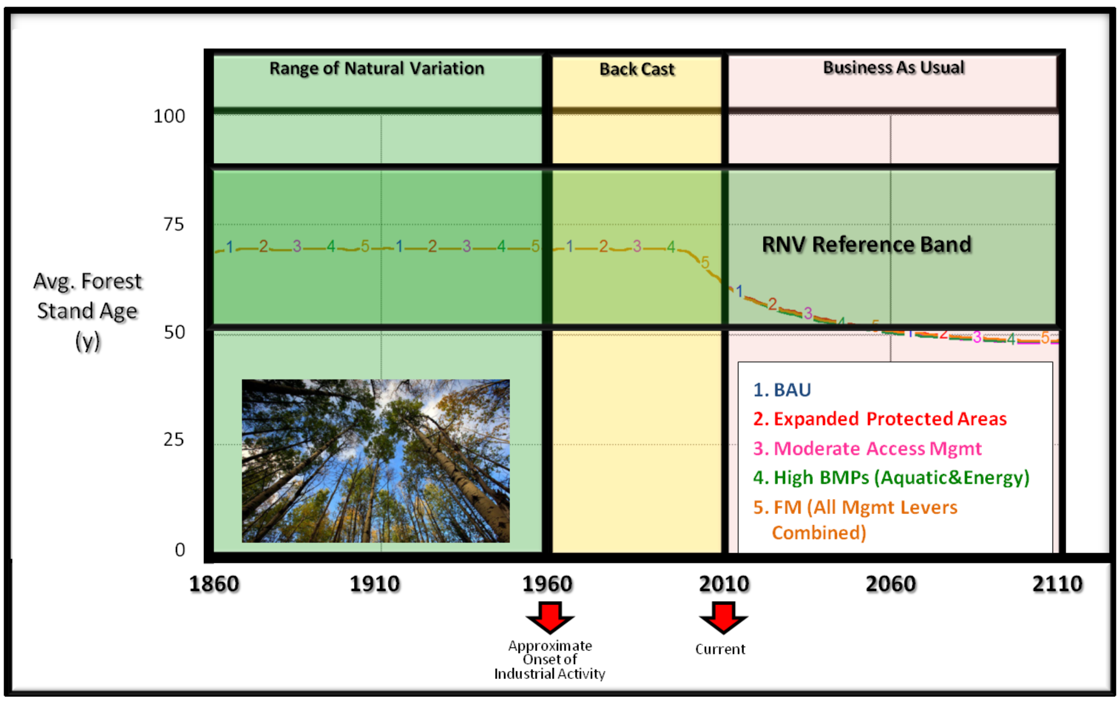


Figure 36: Comparative Trend in Average Forest Age between the Business as Usual (BAU) and Fort McKay (FM) Scenarios

Thus, land uses that disturb forest landscape types with large polygonal footprints, i.e., logging and surface mining, are a major anthropogenic driver pushing forests to become younger compared to RNV. Potential improvements through industry BMPs to reduce footprint growth of polygonal features or hasten the subsequent rates of reclamation are not of sufficient magnitude to result in increased forest age across the Study Area.

Furthermore, fire was the main natural disturbance affecting forest age, and we did not change assumptions regarding enhanced fire suppression rates for the simulations. The key result relating to forest age is that the combined effects of fire, logging and the energy sector will lead to significantly younger forests in the future, and reclamation cannot make up for this loss of older forests in this timeframe.

The influence of fire is apparent by comparing map sequences based on ALCES Mapper simulations of the BAU and FM scenarios (Figure 37 and Figure 38) which show no clear or consistent contrasting spatial pattern of average forest age for the two scenarios. These figures illustrates that random fire events occur across the Study Area resulting in a heterogeneous spatial pattern of forest ages, and shows that fire occurrences were equally likely within or outside protected areas.

4.1.3.4 Percent (%) of landscape Area That Is Natural and Anthropogenic

The proportion of the landscape that is natural describes the relative amount of land area that has not been affected by anthropogenic land use footprints; conversely, anthropogenic percentage is simply one minus the percent natural (i.e., % anthropogenic = 1 – % natural). Compared to the BAU scenario, the Fort McKay scenario displays minimal improvement in this metric (Figure 39); at the end of the 100 year future scenario, the natural proportion of the landscape is 0.86 compared to 0.85 for the BAU scenario.

An observable difference in the spatial patterns of the two scenarios (Figure 40 and Figure 41) is the large size of the extended protected area in the FM scenario compared to the current protected area in the BAU scenario. However, despite the difference in the size of protected areas, the overall extent and pattern of anthropogenic disturbance between the two scenarios is very similar for several reasons.

First, the largest polygonal footprints in the Study Area are associated with oil sands mining (i.e., surface mines, disposal overburden, tailings ponds) and human towns or cities, and the respective patterns of growth or reclamation of those features do not differ substantively between the two scenarios.

Secondly, the expanded protected area in the Fort McKay scenario includes the proposed LARP conservation areas, which were selected as part of the LARP planning process and were intended to minimize overlap with bitumen reserves.

Thirdly, despite the larger size of protected areas in the FM scenario, a key assumption is that overall bitumen production rates in the Study Area will not be different from BAU. Therefore, bitumen resource development is simulated at the same rate, but it occurs more intensively in a smaller part of the Study Area; the requirement for in situ infrastructure and footprint growth remain the same.

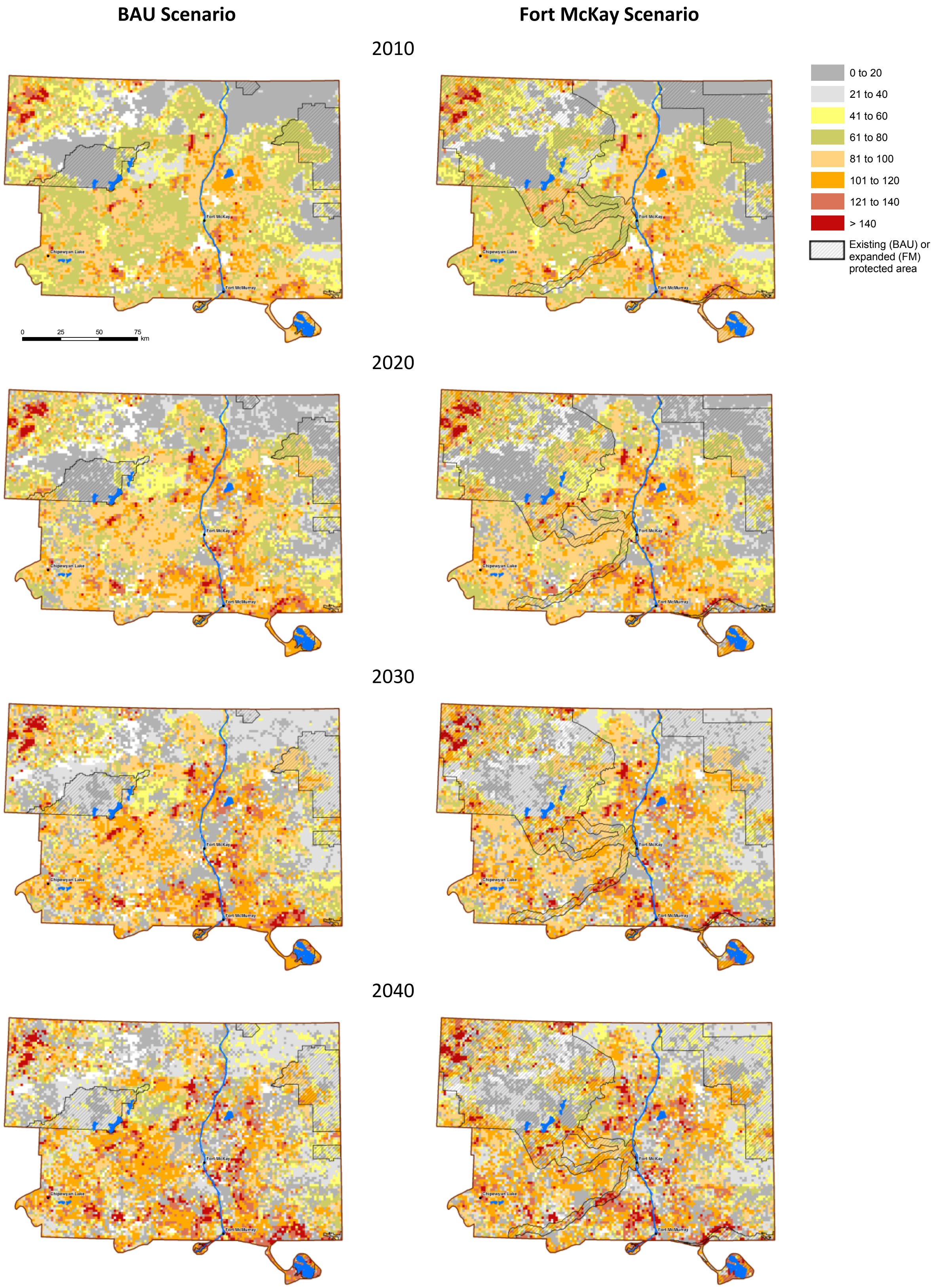


Figure 37: Projected Future Changes in Forest Age, BAU and Fort McKay Scenario, 2010-2040

Figure 38: Projected Future Changes in Forest Age, BAU and Fort McKay Scenario, 2050-2110

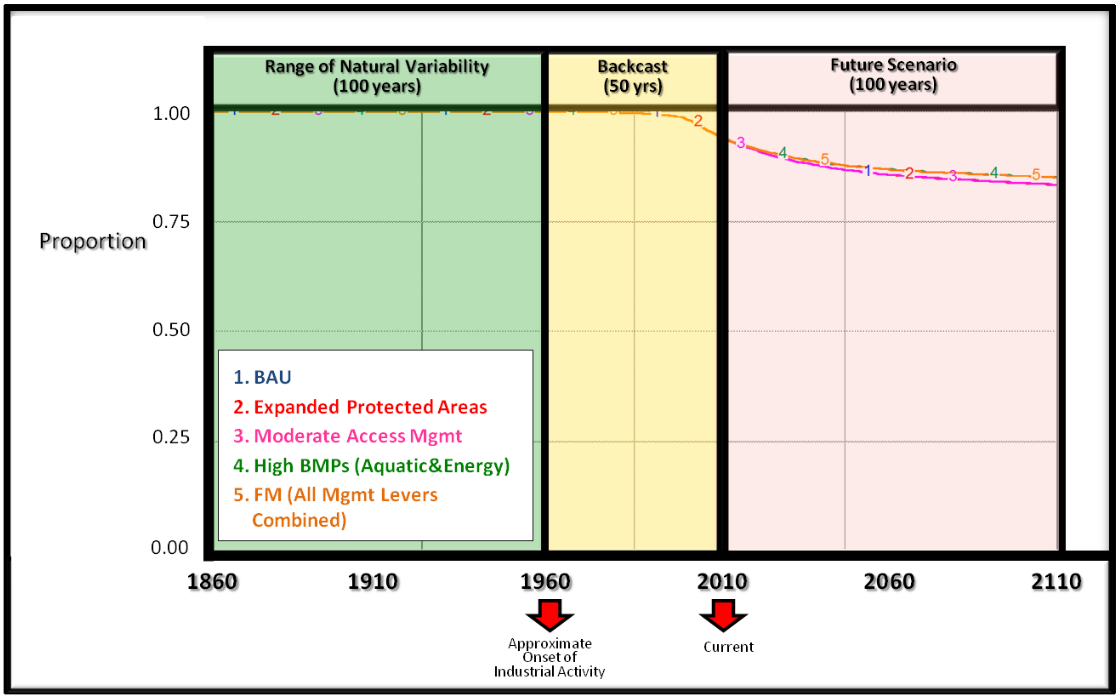


Figure 39: Comparative Trend in Proportion of Landscape that is Natural between the Business as Usual (BAU) and Fort McKay (FM) Scenarios

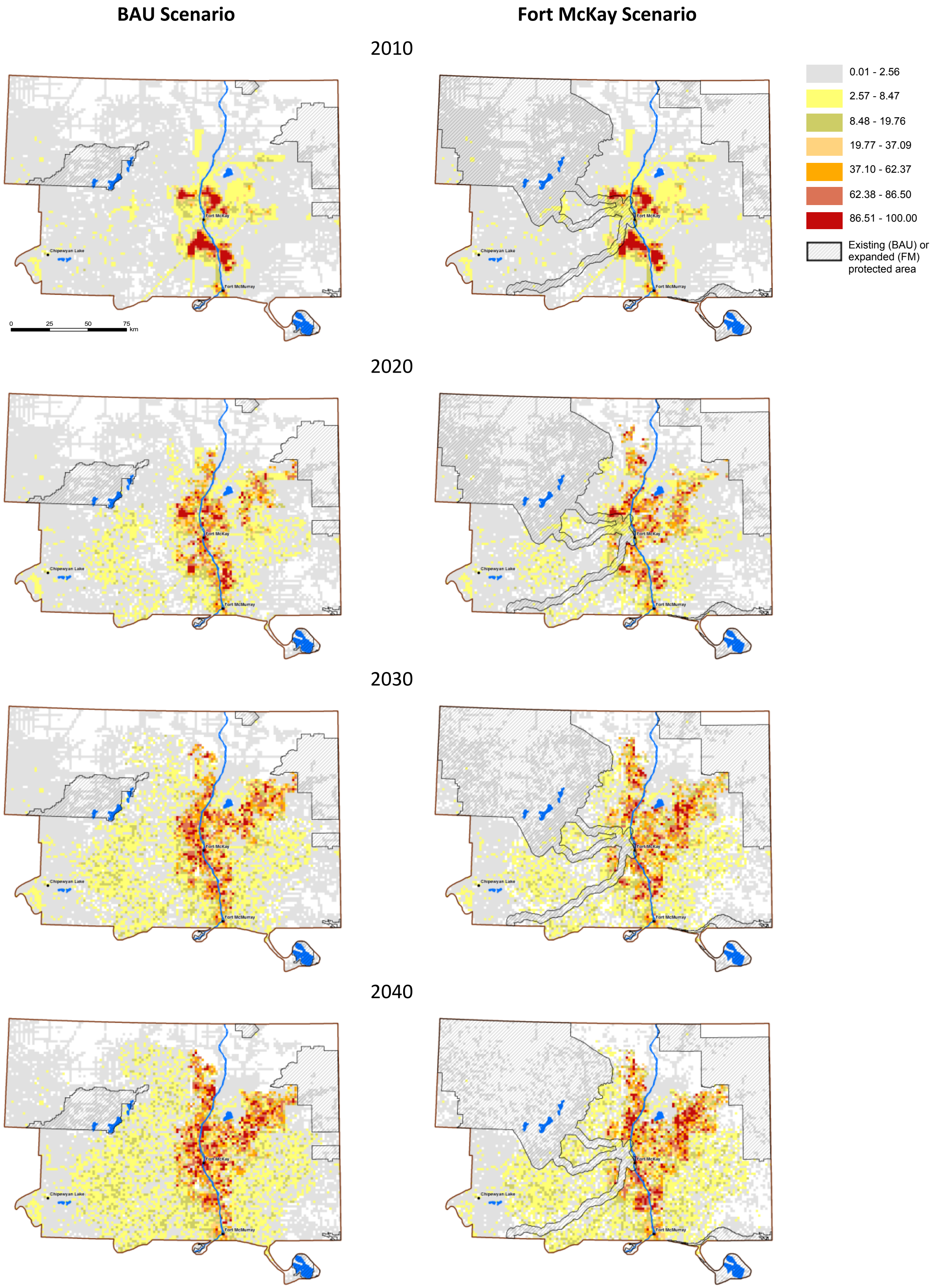


Figure 40: Projected Future Changes in Percent (%) of Cell that is Anthropogenic Footprint, BAU and Fort McKay Scenarios, 2010-2040

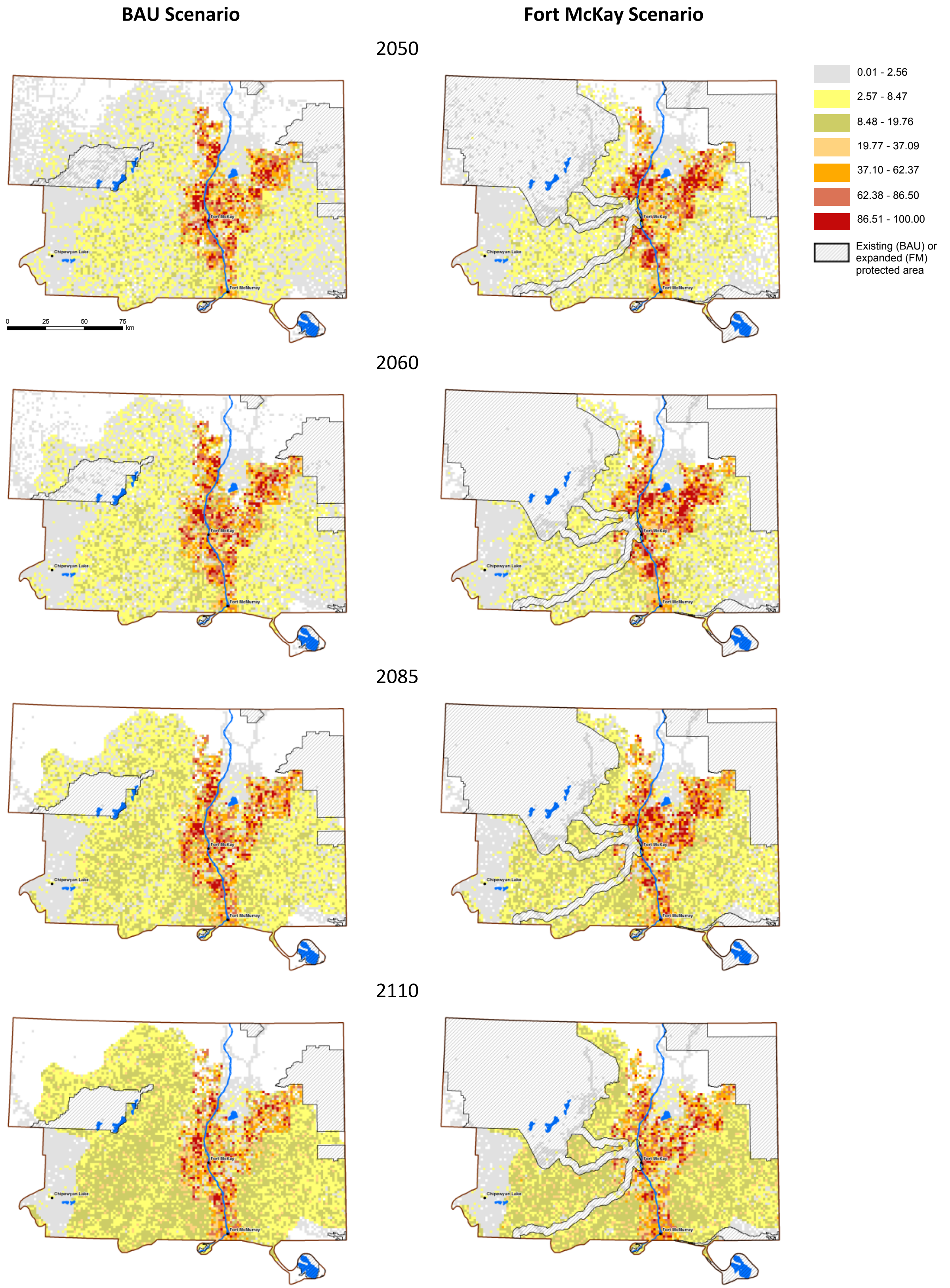


Figure 41: Projected Future Changes in Percent (%) of Cell that is Anthropogenic Footprint, BAU and Fort McKay Scenarios, 2050-2110

4.1.3.5 Watershed Discontinuity

Figure 42 shows the comparative trends in watershed discontinuity between the BAU and FM scenarios. Under the BAU scenario, watershed discontinuity increases exponentially and by the end of the simulation period, the fraction of watershed area that is fragmented due to hanging culverts was 0.46 (46%). In comparison, the trend in watershed discontinuity under the FM scenario had a slower rate of increase and is substantially lower (0.10) at the end of the simulation period. The application of aquatic BMPs (replacement of 10% of hung culverts annually) is the main contributor to improved performance of watershed discontinuity under the FM scenario. The expanded protected area also contributes to reduced watershed discontinuity compared to BAU assumptions because the expanded protected area reduces the proportion of the Study Area that is subject to linear footprint development and stream crossings by roads. Access management has no effect on watershed discontinuity.

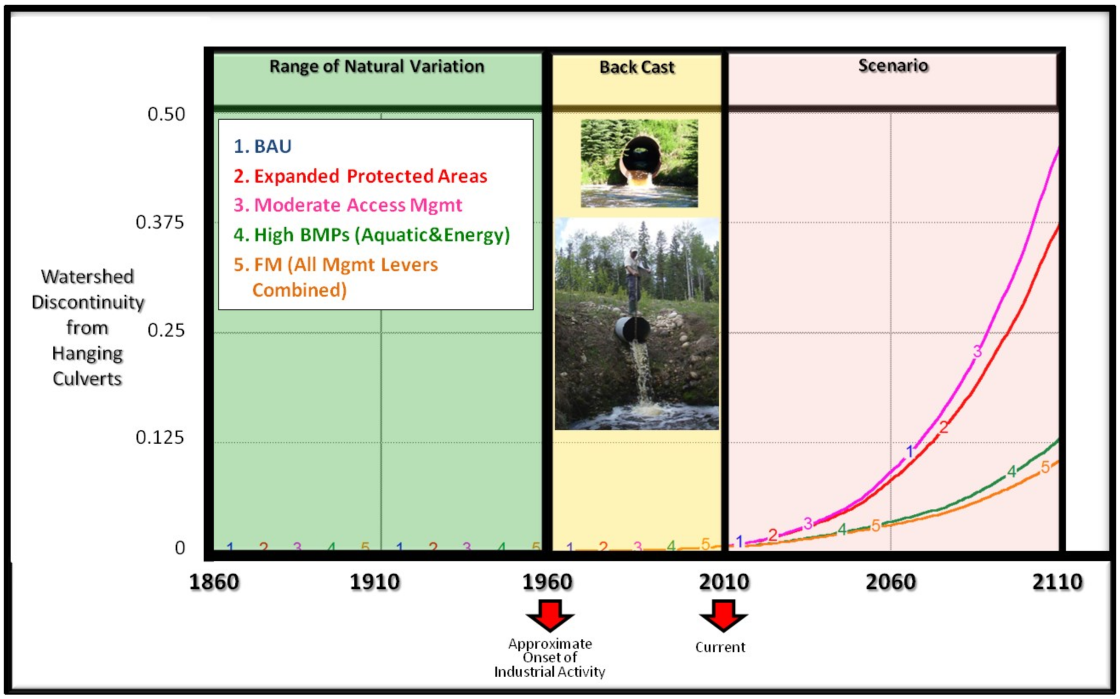


Figure 42: Comparative Trend in Watershed Discontinuity between the Business as Usual (BAU) and Fort McKay (FM) Scenarios

4.1.4 Biotic (Ecological) Indicators

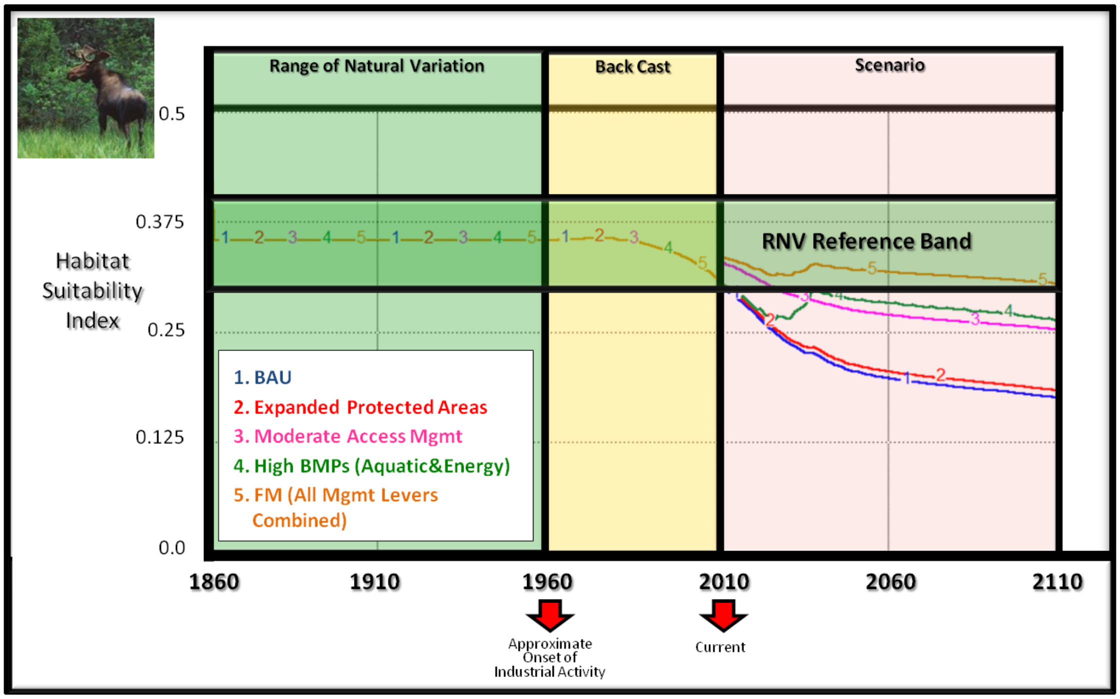
4.1.4.1 Moose Habitat Suitability Index (HSI)

During the RNV period, moose HSI values in the FM Study Area averaged 0.35 and varied between 0.31 and 0.39, indicating that not all landscape types were of maximum value or remained in an optimal age class structure for moose. Inter-annual and inter-decadal variation of moose HSI would have been caused by temporal variation in forest age class structure and snowpack depth, both of which would have affected food availability to moose and mortality rates.

During the past 50 year (the back-cast period), the quality of moose habitat had declined to the lower range of RNV (Figure 43), and the majority of this decline occurred in those areas where human population and the energy sector footprint were highest. The combination of high human and edge density reflects an elevated mortality factor and a concomitant decline in habitat effectiveness.

Under a BAU scenario, moose habitat quality was simulated to consistently decline over the next three decades, with an inflection point after year 2040 (Figure 43), which reflects a reduced rate of decline in the trend of moose HSI (i.e., flattening of the curve), and corresponds to the peak in total bitumen production (Figure 27). Moose HSI continues to decline to the end of the simulation period and ends at a value of 0.18, which is approximately half of the average RNV value, and is a risk level equivalent to the COSEWIC/ IUCN classification of 'Threatened" or "Vulnerable" (Figure 43). The declining pattern of moose HSI values is inversely related to the increasing pattern of edge density (Figure 32) in the Study Area. The declining trend for moose HSI under BAU assumptions is attributed to the growing anthropogenic footprint on the landscape and the associated increases in human density and access to moose mediated by increased edge (i.e., minor roads and seismic lines). Although land use footprints increases forage (browse) availability for moose, the corresponding increases in access by humans and associated increases in moose mortality along linear features overwhelm the benefits of additional forage production.

In comparison, the simulated trend in moose HSI values for the FM scenario projects an immediate increase relative to the year 2010 value as a result of access management, followed by a gradual and slow decline but continued occurrence within the lower RNV value (~ 0.32) at the end of the simulation period.



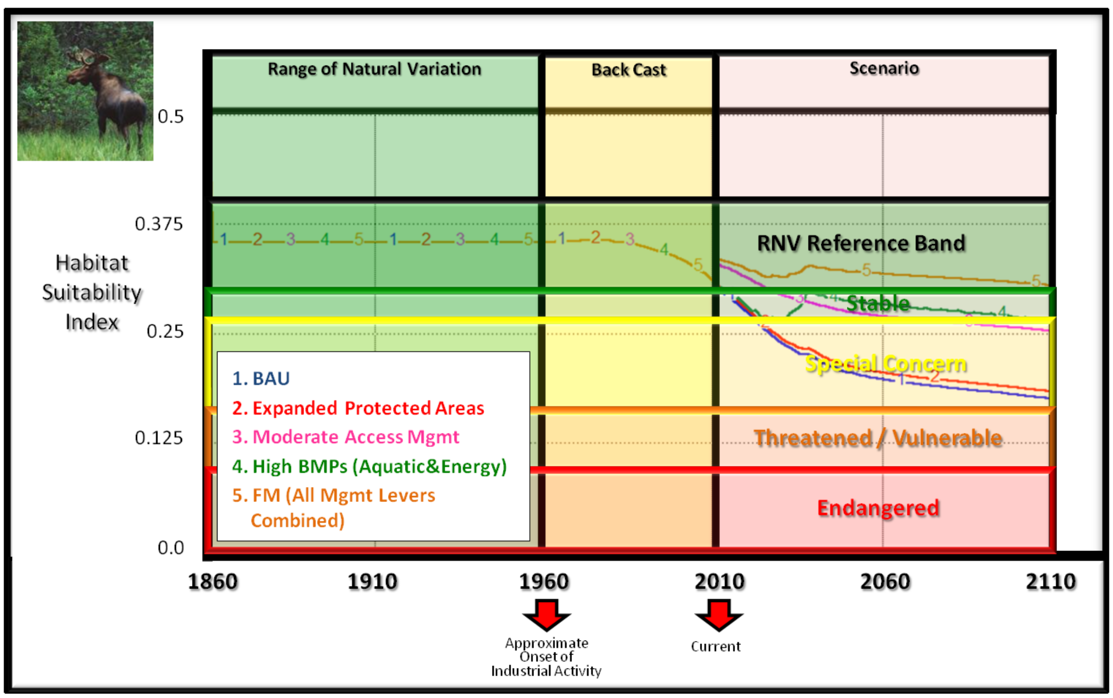


Figure 43: Comparative Trend in moose Habitat Suitability Index (HSI) between the Business as Usual (BAU) and Fort McKay (FM) Scenarios[48]

[48] Bottom graph shows risk criteria superimposed on HSI trend.

Of the three management strategies that vary between the BAU and FM scenarios, the industry BMPs that hastened seismic line reclamation through use of narrow lines and pulse reclamation have the greatest influence on improving moose HSI values, followed by access management (Figure 43 and Figure 44) because both management levers resulted in reducing access to linear features. The contribution of expanded protected areas is small and equivocal when moose performance is considered at the scale of the large Study Area, but protected areas are important spatially and at the local level to maintain healthy moose populations. Access management has the most immediate benefit to moose because it is modeled as an 85% reduction in buffer widths associated with anthropogenic footprints with a two-fold increase in habitat effectiveness (Table 16).

The beneficial effects of industry BMPs are expressed through the overall reduction in seismic lines that in turn reduce edge density; thus when energy sector BMPs were activated only, moose HSI reflected the trend pattern for edge density (see line #4 in Figure 43 and Figure 32). A key conclusion is that any management action that reduces linear features, or the ability of people to readily move through the landscape on linear features, will have a strong positive effect on moose habitat effectiveness.

The map sequences comparing the BAU and FM scenarios (Figure 45 and Figure 46) highlighted the following patterns.

- Moose HSI values are lowest in the mineable oil sands area for both scenarios.
- In the BAU scenario, moose HSI values are also comparably low in the areas that will be developed by in situ SAGD well extraction technologies.
- In comparison, the FM scenario results in an extensive improvement in moose HSI values across the entire Study Area.
- At a finer spatial scale, moose HSI values are highest in protected areas because no industrial footprint is allowed to grow in them.

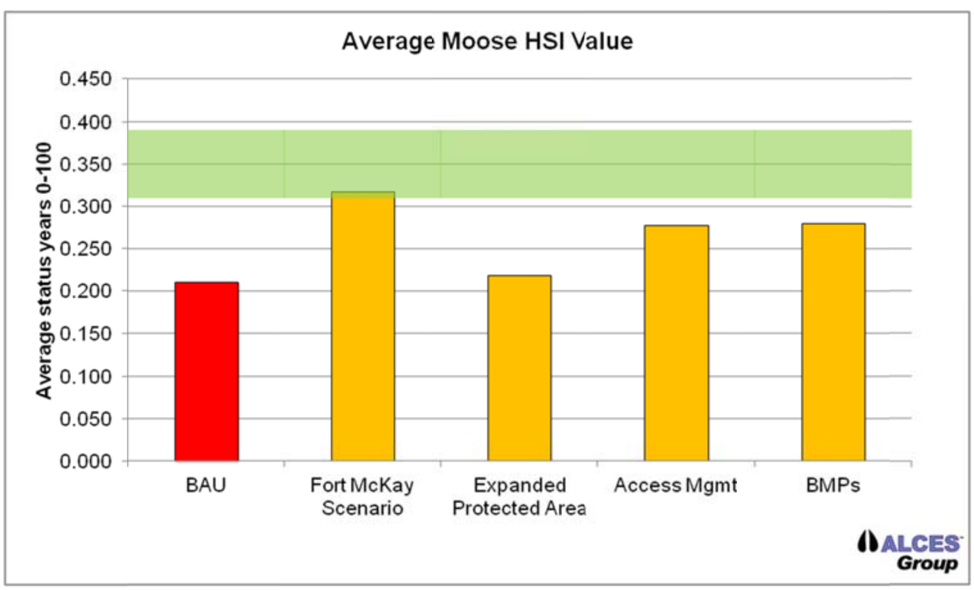


Figure 44: Comparative Influence of Management Levers on Moose HSI over a 100-year Future Simulation

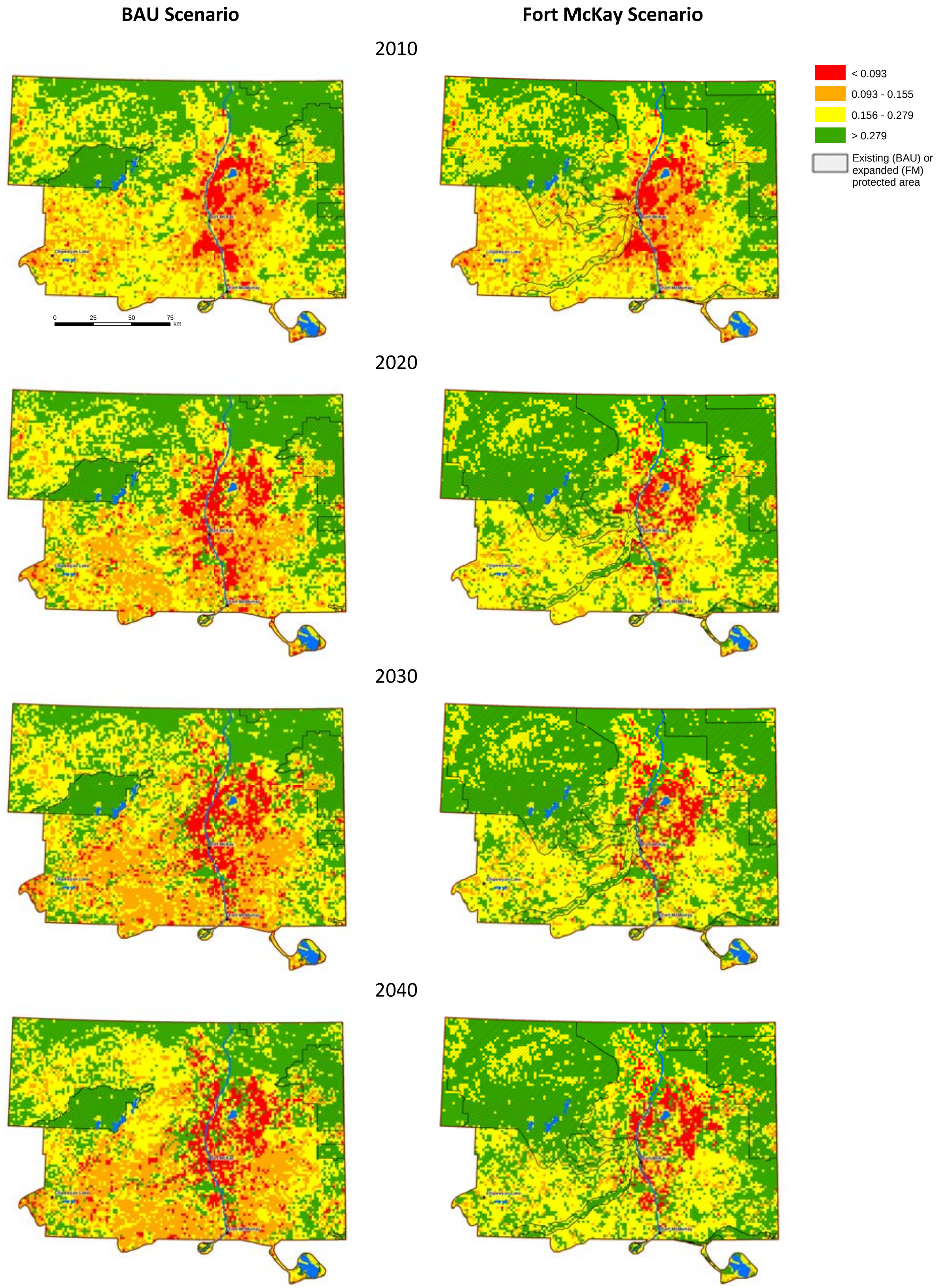


Figure 45: Projected Future Changes in Moose HSI values, BAU and Fort McKay Scenarios, 2010-2040

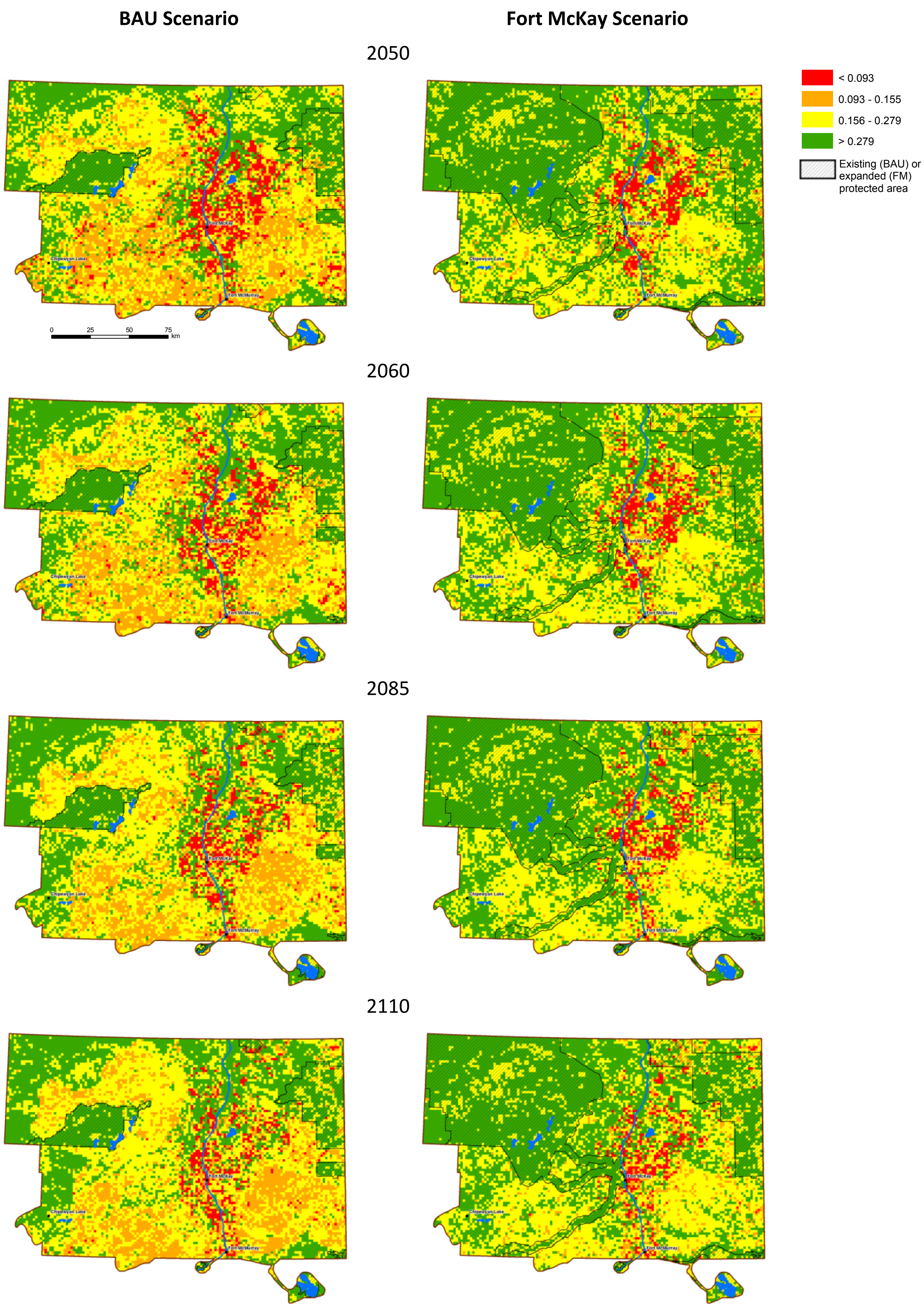


Figure 46: Projected Future Changes in Moose HSI values, BAU and Fort McKay Scenarios, 2050-2110

4.1.4.2 Fisher Habitat Suitability Index (HSI)

In contrast to moose, which prefer younger forests, fisher HSI inputs were weighted in favor of mid- to old-aged forest stands. Thus, in a boreal landscape with an 80-year fire return interval and average forest stand age of 69 years, fisher HSI is expected to be comparably lower than moose. Through the simulated RNV period, fisher HSI values averaged 0.15 and ranged between 0.13 and 0.19 (Figure 47).

During the 50-year back-cast period, the quality of fisher habitat in the Study Area had declined to the lower range of RNV (0.13; Figure 47). The onset of the decline is associated with growth of industrial land use associated with the forestry and energy sectors. A secondary factor contributing to HSI decline was the additive effects of fire and logging that is beginning to create a younger forest that is less well suited to fisher.

Under a BAU scenario, fisher habitat quality declines substantially over the next three decades. And similar to the HSI trend in moose, an inflection point occurs in the trend of fisher HSI after year 2040 (Figure 47), at which point the HSI value has been reduced to approximately 50% of the average RNV value.

From year 2040 onward, fisher HSI has a gradual and slow but sustained decline, with a final HSI value of 0.06, which is 40% of the RNV average value and fell within the middle of the “Threatened” risk band (Figure 47). Similar to moose, the declining trend of fisher HSI values is inversely related to the increasing pattern of edge density in the Study Area (Figure 25), but the decline for fisher is greater due to the loss of mature and older forest habitat in the future simulation.

Under the FM scenario, the simulated trend in fisher HSI projects an immediate increase of ~10% relative to the year 2010 value due primarily to BMPs on seismic lines and access management, followed by a gradual decline from 0.14 to converge around a HSI value of 0.11 at the end of the simulation period. The outcome of the simulation suggests that fisher HSI at the end of the scenario will remain below RNV and is considered “Special Concern” risk (Figure 47).

Of the three management strategies that were varied between the BAU and FM scenarios, industry BMPs has the greatest influence on improving fisher HSI, followed by access management (Figure 47 and Figure 48). The expanded protected area has a marginal effect when assessed at the scale of the Study Area (Figure 48), but at a local scale the protected areas maintain habitat intactness in core areas (see Figure 54 and Figure 55). There were two main reasons why industry BMPs have the strongest influence on fisher HSI.

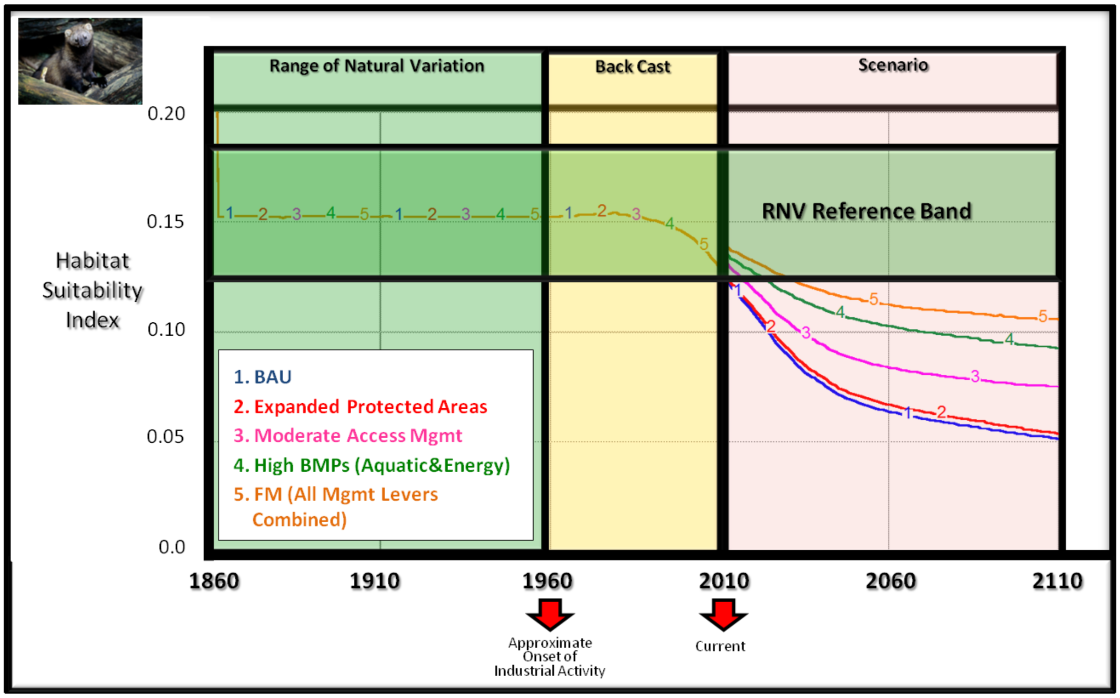
- Narrow seismic lines (0.75 m) and pulse reclamation of seismic lines dramatically reduced total edge density (and therefore fragmentation) in the Study Area.
- Recent studies by Tigner (2012) and Bayne, et al (2011) show that pine marten use conventional seismic lines approximately 80% less than forest interior locations (Tigner 2012), but that use does not differ between interior forests and narrow, low impact seismic lines that are ≤ 2m wide (Bayne, Lankau and Tigner 2011). In the HSI model, we assume that fisher will respond to seismic lines in a similar fashion to

marten. Thus conventional seismic lines in the BAU scenario are perceived to be edge for fisher, whereas narrow low-impact seismic lines in the FM scenario are not considered edge.

Access management contributes positively to improving fisher HSI because it is modeled as a 50% reduction in buffer widths associated with anthropogenic footprints and a two-fold increase in habitat effectiveness (Table 16). Thus when moderate access management is activated, habitat effectiveness increases.

The following observations were noted from a comparison of map sequences for fisher HSI between the BAU and FM scenarios (Figure 49 and Figure 50).

- Current fisher HSI values (year 2010) were lowest in the mineable oil sands area and in areas recently burned by large fires (in the northeast part of the Study Area).
- In the BAU scenario, fisher HSI values progressively decline throughout all the areas with bitumen reserves that are subsequently developed with in situ well technology, and associated densities of seismic lines and other linear features.
- The FM scenario shows substantial improvement to fisher HSI across the Study Area, including the areas with bitumen reserves. This is a result of implementing energy-sector BMPs, which incorporate narrow seismic lines, pulse reclamation, and a moderate level of access management.
- Protected areas appear to provide a net benefit, with improved fisher HSI values. This potential benefit is influenced by the variable effects of fires that occur randomly across the Study Area, including within protected areas.



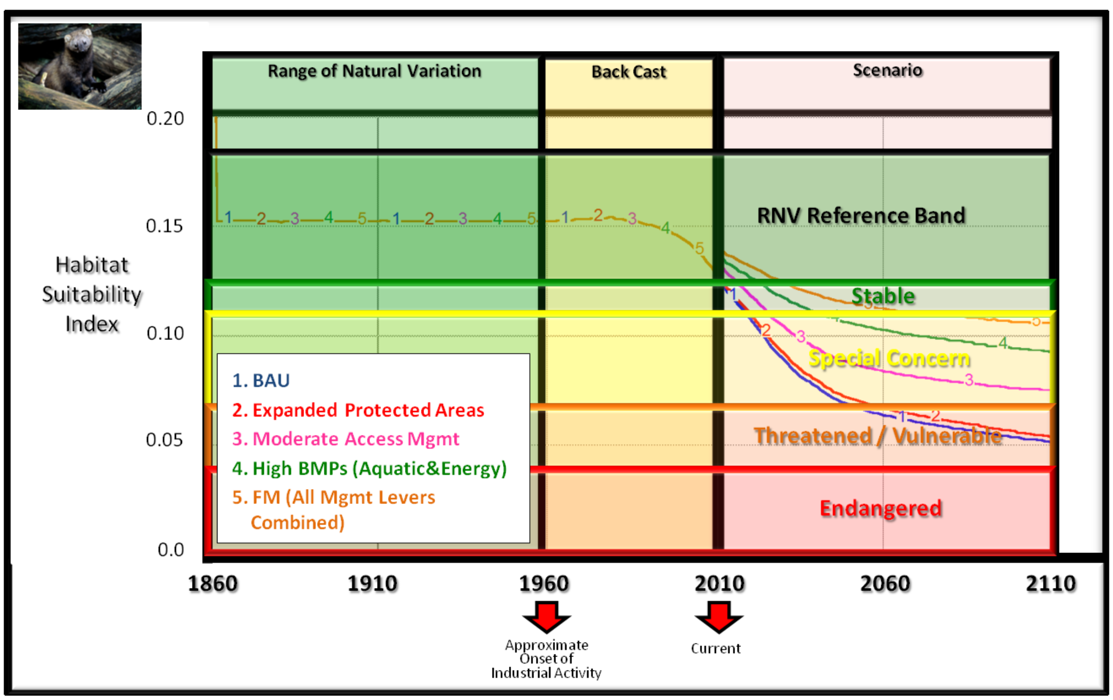


Figure 47: Comparative Trend in Fisher Habitat Suitability Index (HSI) between the Business as Usual (BAU) and Fort McKay (FM) Scenarios[49]

[49] Bottom graph shows risk criteria superimposed on HSI trend habitat suitability index.

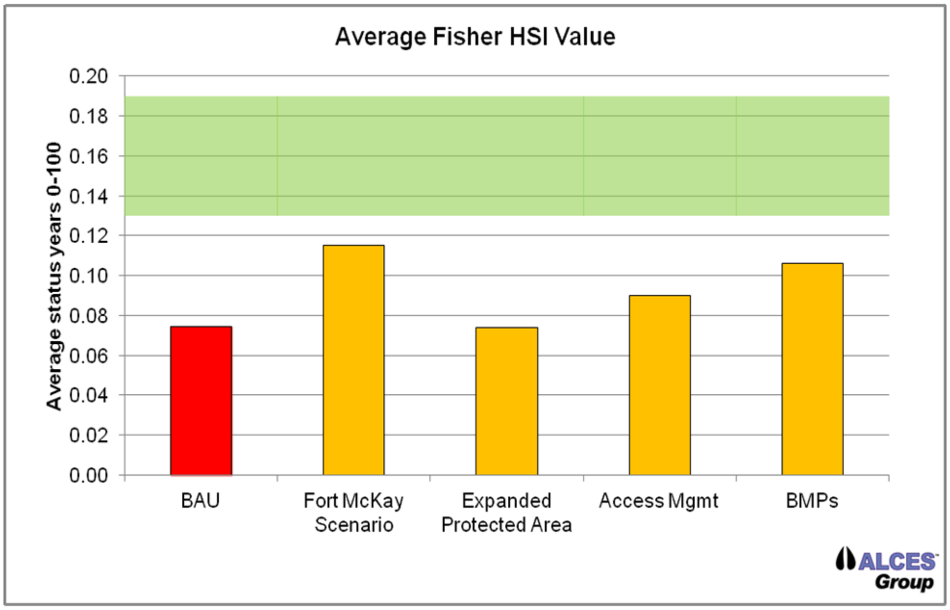


Figure 48: Comparative Influence of Management Levers on Fisher HSI Population Over a 100-year Future Simulation

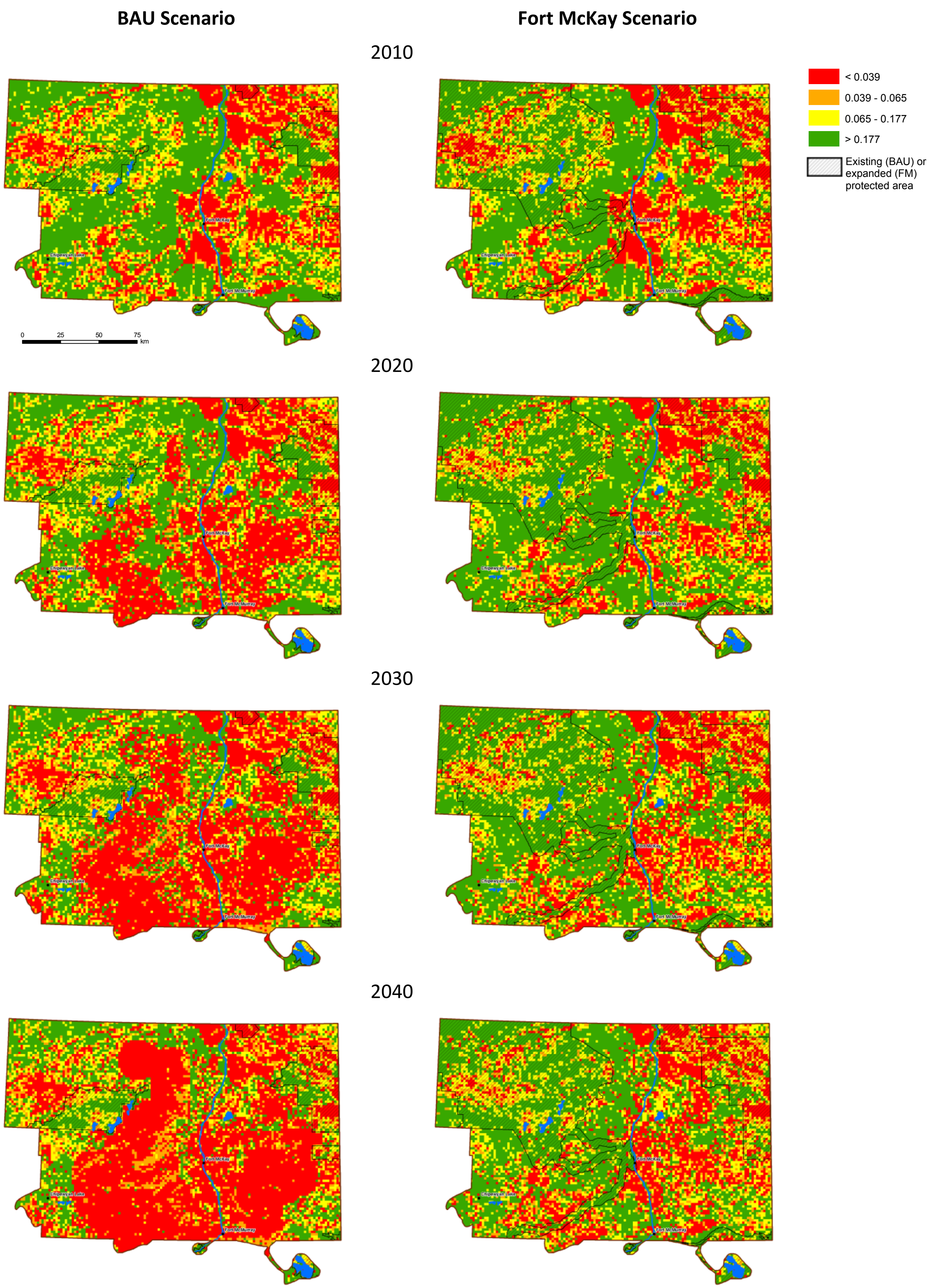


Figure 49: Projected Future Changes in Fisher HSI Values, BAU and Fort McKay Scenarios, 2010-2040

Figure 50: Projected Future Changes in Fisher HSI Values, BAU and Fort McKay Scenarios, 2050-2110

4.1.4.3 Index of Native Fish Integrity (INFI)

RNV values for the INFI, based on 50 runs in a pre-industrial period had a mean of 0.96, with upper and lower confidences limits of 1.0 and 0.84 respectively. The variance in INFI reflected an intact natural fish community subject to natural variation in precipitation and climate, but with no influence of industrial activity or humans; the assumption is that aboriginal peoples and their activities were inherent to the ecosystem and did not drive systematic landscape-level changes to fish communities.

In the latter half of the 50-year back-cast period, INFI at the scale of the Fort McKay Study Area declined dramatically to a current year 2010 value of ~0.38 (Figure 51). This change reflects a regional fishery in poor quality on the verge of collapse with respect to large size classes of sport fish (i.e., walleye and grayling) and a fishery that is generally categorized as unacceptable and experiencing conservation issues with fish species at risk.

The onset of decline in INFI is associated with growth of industrial (forestry, energy) land use, the consequences of fragmentation within watersheds, and a burgeoning human population with few restrictions on fishing access.

Under a BAU scenario, INFI is projected to plummet further over the next three decades, and to remain in a collapsed state for the rest of the 100-year simulation period. The continued decline in INFI is related to increased habitat fragmentation and watershed discontinuity due to hanging culverts, and the influence of unrestricted access and heavy fishing pressure from a growing regional human population (Figure 51).

The Fort McKay scenario reveals a marked improvement of the regional INFI status. Under this scenario, the trend in INFI is an immediate increase to 0.63, which represents an increase of ~165% relative to the year 2010 INFI value of 0.38 (Figure 51).

The increase is a result of the implementation of moderate access management practices that reduces both public access across the Study Area by 50% and associated fishing pressure and mortality of fish. Despite the initial improvement in INFI, the rate of decrease in trend of INFI is similar for both the BAU and FM scenarios as shown by the respective line graphs having similar slopes for the remainder of the future simulation period (Figure 51). INFI at the end of the FM scenario is considered poor and cautionary at 0.40, but is ten times greater than the INFI value reached at the end of BAU (0.04; Figure 51.

With respect to the FM scenario, access management provides the greatest benefit; average INFI value projected with only access management activated is 2.5 times greater than the average INFI value under BAU (Figure 52). In comparison, average INFI values for BMP are 13% greater than the average INFI value under BAU. The main effect of BMPs on INFI is through the replacement of hung culverts at a rate of 10% annually. Although replacing only 10% of hung culverts annually might seem low, the compounded effect through time is great. Compared to INFI values under BAU, the expanded protected areas do not provide a meaningful benefit to overall performance of INFI at the Study Area scale (Figure 52), but they do markedly improve INFI tertiary watersheds that occur within the protected area (Figure 53 and Figure 54).

When all three management levers are activated, the FM scenario increases average INFI by ~3.3 times relative to BAU assumptions (Figure 51 and Figure 52).

Comparisons of map sequences for INFI between the BAU and FM scenarios (Figure 53 and Figure 54) are summarized in the following observations.

- INFI values for year 2010 were the lowest in the mineable oil sands area and in areas recently burned by large fires (i.e., in the northeast part of the Study Area).
- In the BAU scenario, INFI values progressively decline throughout all tertiary watersheds that are intersected by bitumen reserves. INFI values decline in those areas due to hanging culverts that occur as a result of the extensive minor road network (i.e., well access roads) that accompany bitumen development through in situ well technology.
- Compared to BAU, the FM scenario shows improvement to INFI across the Study Area, including the areas with below-ground bitumen reserves. Improved trend of INFI in those areas is a result of implementing BMPs, which replaced 10% of hung culverts annually. Access management is also activated which reduces public access by 50% (compared to BAU assumptions), and contributes to improved INFI for tertiary watersheds in the FM Study Area.
- Tertiary watersheds that occur in the northwest region of the Study Area and mostly within the expanded protected area consistently maintain the highest INFI values in the FM scenario. INFI performance in protected areas is enhanced primarily due to the fact that minor roads are not constructed in those areas, therefore occurrence of hanging culverts is negligible and watershed discontinuity is low.

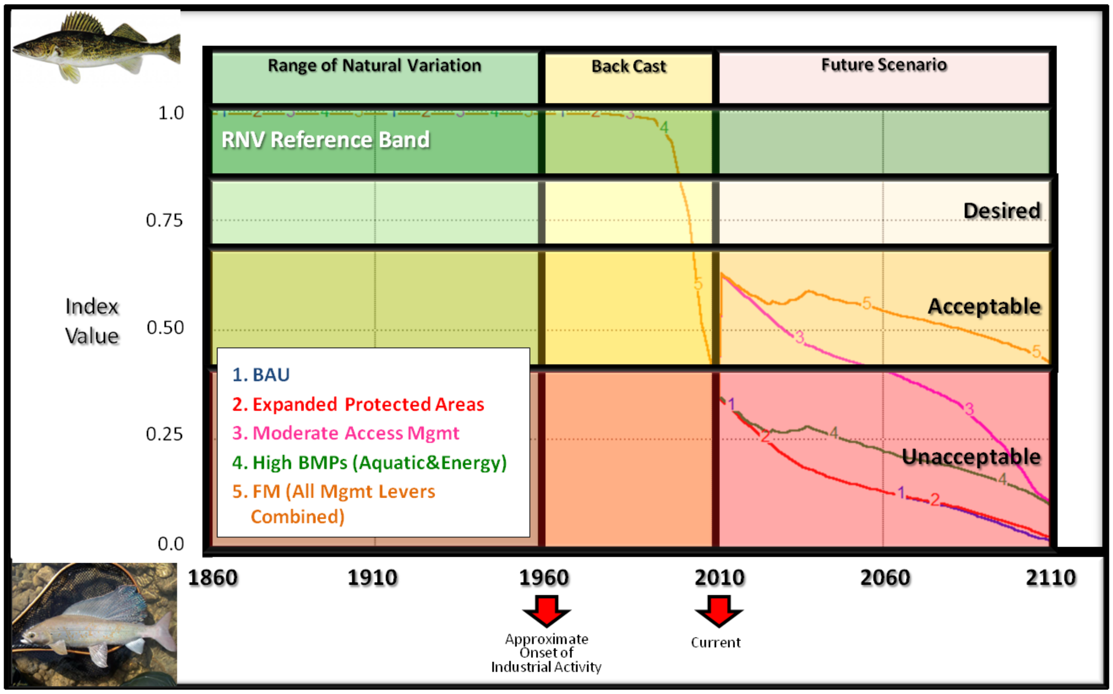


Figure 51: Comparative Trend in the Index of Native Fish Integrity (INFI) between the Business as Usual (BAU) and Fort McKay (FM) Scenarios

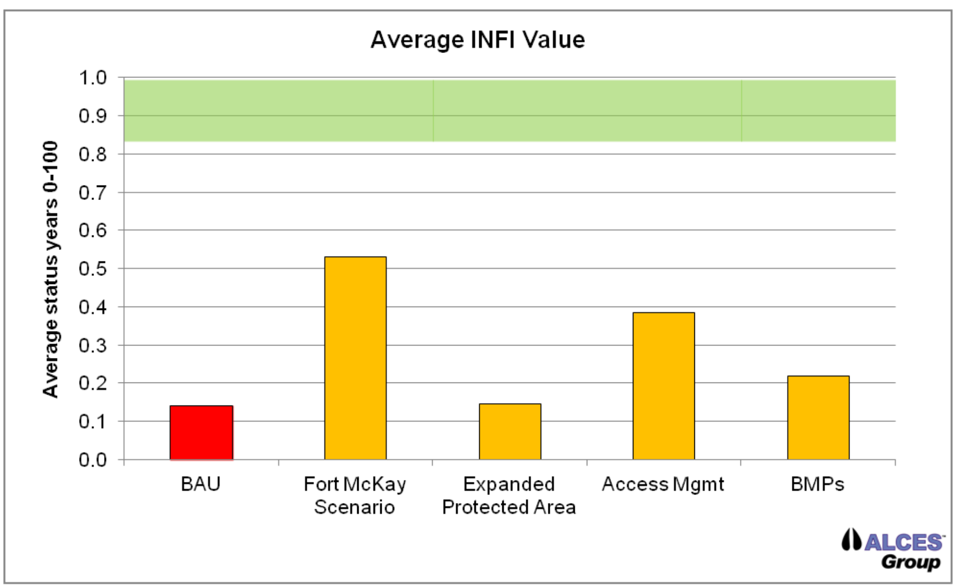


Figure 52: Comparative Influence of Management Levers on the Index of Native Fish Integrity (INFI) Over a 100-Year Future Simulation

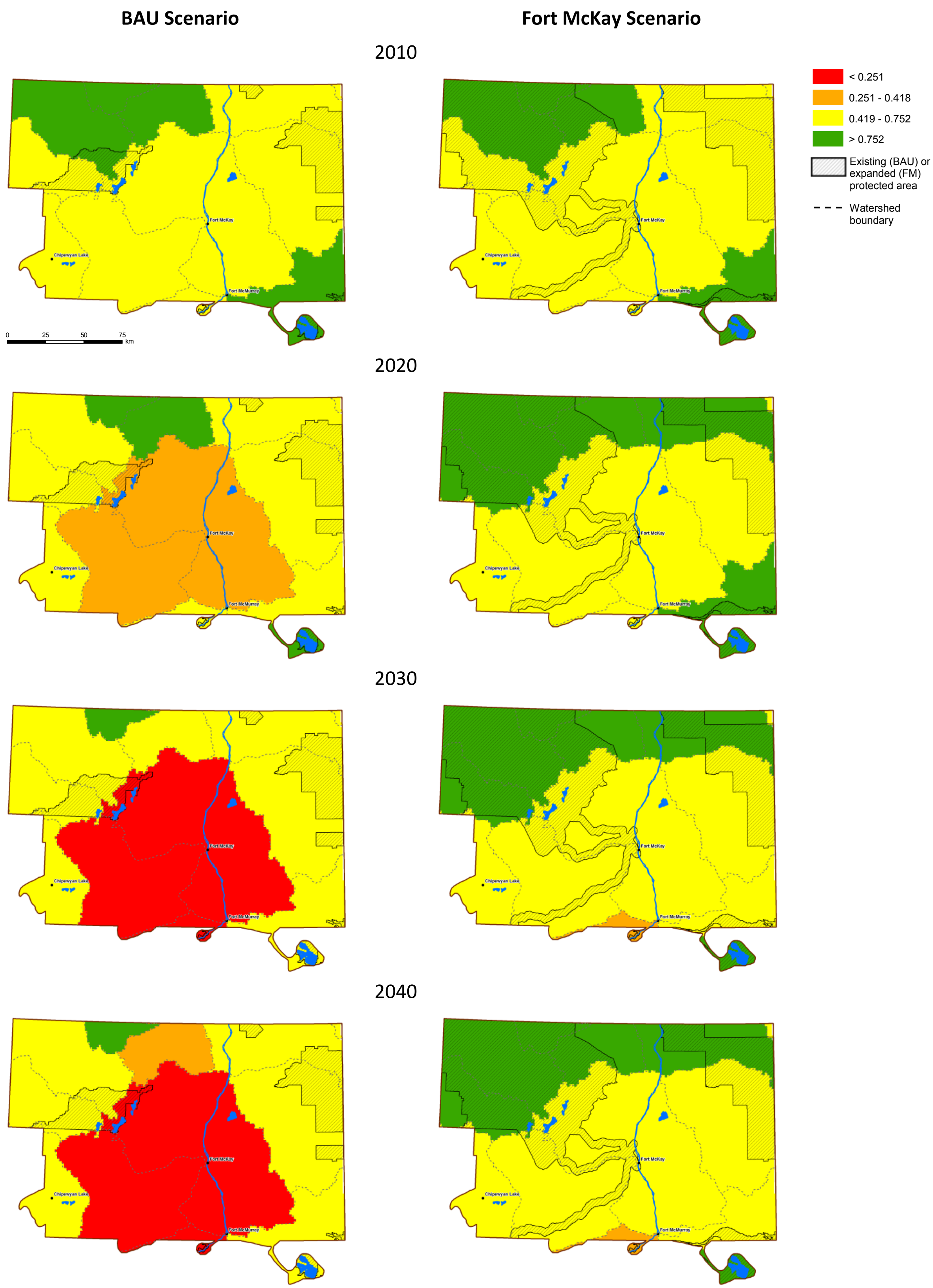


Figure 53: Projected Future Native Fish Integrity (INFI) Changes within Tertiary Watersheds, BAU and Fort McKay Scenario, 2010-2040

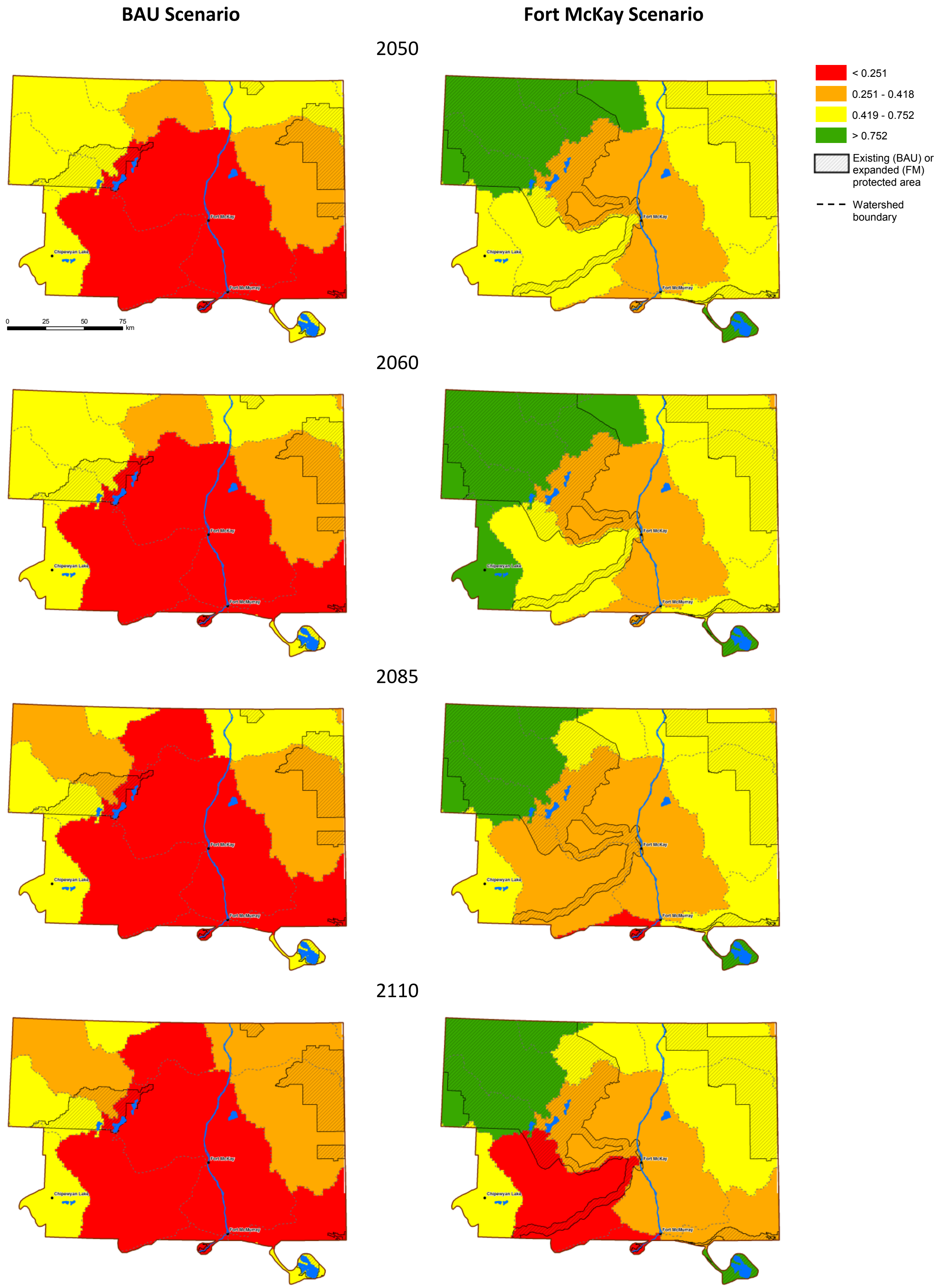


Figure 54: Projected Future Native Fish Integrity (INFI) Changes within Tertiary Watersheds, BAU and Fort McKay Scenario, 2050-2110

4.1.4.4 Edible Berry Habitat Suitability Index (HSI)

The amount and quality of habitat for edible berries varied during the RNV period because of inter-annual variation in climate and fire regimes, which in turn, created temporal and spatial variation in forest-age class structure. The RNV average for berry HSI is 0.30, with upper and lower confidence intervals of 0.32 and 0.25 respectively (Figure 55).

Simulated trends in berry HSI through the back-cast period did not deviate from the RNV average, thus current year 2010 value is 0.30 (Figure 55). Under BAU assumptions, the simulated initial rate of decline in berry HSI is approximately 0.06% per year, which means that average HSI will drop below the lower RNV confidence limit (0.25) after year 2040. A continued rate of decline in berry HSI is simulated for the remainder of the BAU scenario, such that the end value is 0.19 at year 2110 and categorized as “Special Concern” (Figure 55).

Under the FM scenario, the simulated trend in berry HSI has a slower rate of decline in comparison to BAU assumptions, to the extent that at the end of the 100 year future simulation period, berry HSI is projected to occur just below the lower RNV value. In comparison to the BAU scenario, the FM scenario improved overall performance of berry HSI by 10% (Figure 56). Access management provides the greatest benefit to berry HSI (Figure 56), which reflects the following model input assumptions.

- Under BAU assumptions, only 10% of the buffer width applied to anthropogenic features is considered suitable habitat to berries.
- In contrast under the FM scenario, moderate access management assumes that up to 75% of the buffer width assigned to anthropogenic features was suitable for berries, which is an optimistic assumption.

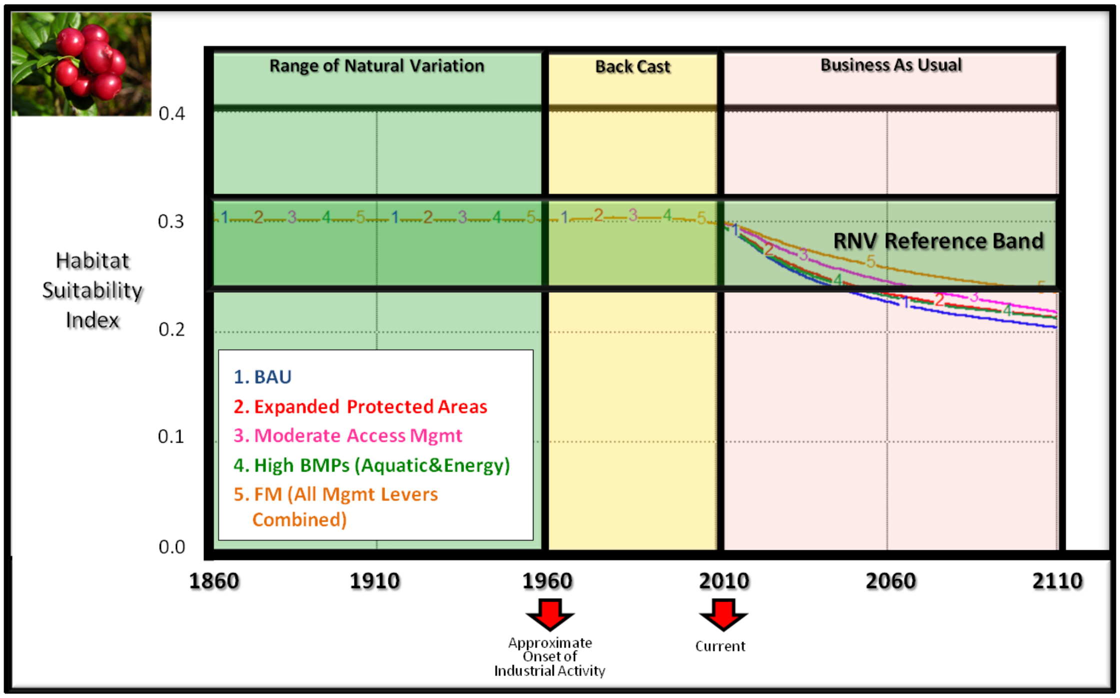
These assumptions for access management include the assumption that vehicular traffic will aerosolize dust from unpaved dirt roads and dust-covered paved roads and the dust would subsequently deposit on roadside shrubs and reduce either the productivity or consumptive desirability of the berries. The buffer distances from roads and other anthropogenic features are based on Fort McKay’s concern regarding the impact of dust. Thus, activation of moderate access management implies a reduction in vehicle traffic, which in turn would reduce the amount of roadside dust and increase suitable berry habitat compared to BAU assumptions. However, with the assumptions in the berry HSI model, polygonal anthropogenic features have the greatest buffer distances (surface mine, tailings pond and overburden disposal areas had 1000 m buffers), whereas the two linear features – major and minor roads – have buffer distances of 100 and 10 m respectively (Table 9). Thus the assignment of large buffer distance to polygonal features is reflected in the model results, which are less sensitive to growth, reclamation, and management strategies for roads.

Compared to average berry HSI performance under BAU assumptions, when applied independently, neither an expanded protected area strategy or activation of industry BMPs have a strong effect on increasing overall performance of berry HSI at the Study Area scale

(Figure 56). However, when all three management levers are activated, the FM scenario increases average berry HSI by ~10% relative to BAU (Figure 56) and just within the bottom range of the RNV.

Comparison of map sequences for berry INFI between the BAU and FM scenarios (Figure 57 and Figure 58) are summarized in the following observations.

- Berry HSI values in year 2010 were the lowest in the mineable oil sands area.
- In the BAU scenario, berry HSI values progressively decline in the central part of the Study Area associated with oil sands mining and the growth and reclamation of large polygonal footprints. Berry HSI values decline in these areas primarily because of the large buffer distances assigned to surface mines, tailings ponds, and overburden disposal areas. Also, another important model assumption is that landscape types that are reclaimed from anthropogenic footprints have no habitat value for edible berries species (Table 8). Thus, the large polygonal footprints in and around the mineable oil sands area represent a cumulative loss of suitable habitat to edible berry species through the simulation period; this modeled response within the mineable area shapes the overall response of edible berry HSI dynamics at the scale of the FM Study Area.
- Compared to BAU, the FM scenario shows improvement to berry HSI values within the mineable oil sands area. Access management is the primary driver for the improvement in berry HSI.



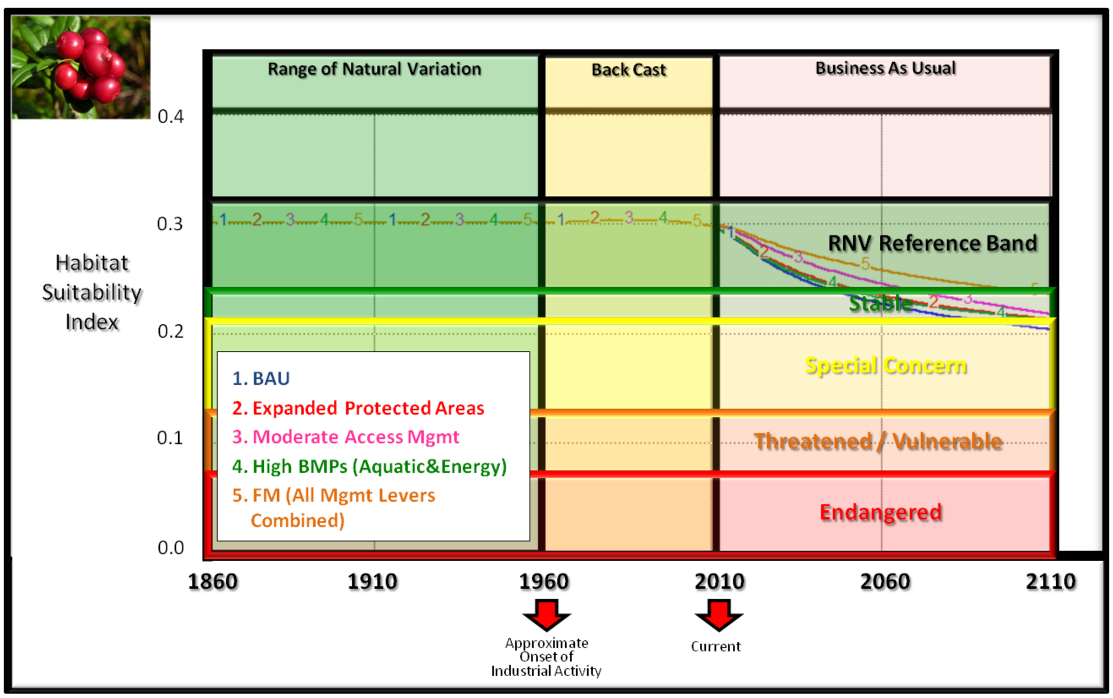


Figure 55: Comparative Trend in edible Berry Habitat Suitability (HSI) between the Business as Usual (BAU) and Fort McKay (FM) Scenarios

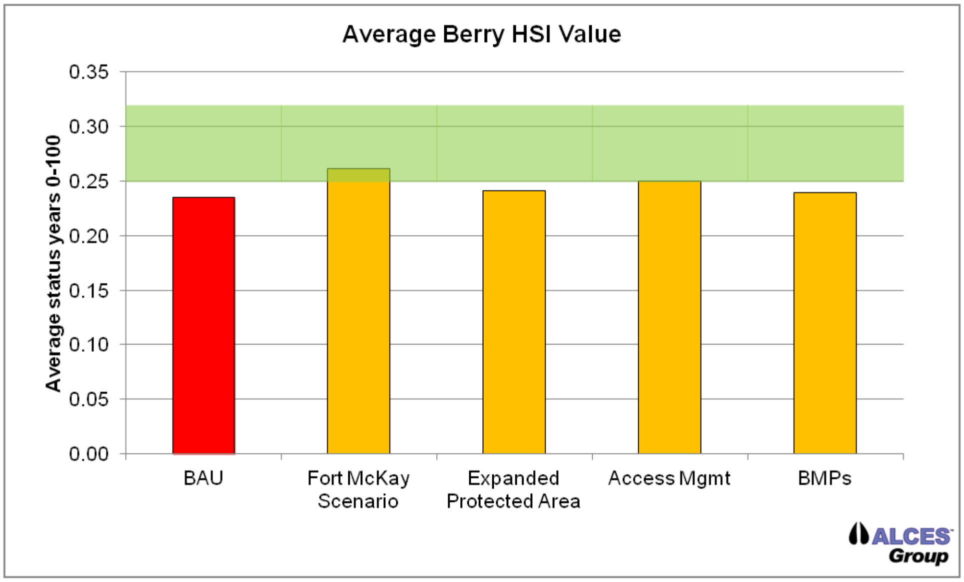


Figure 56: Comparative Influence of management Levers on the Edible Berry HSI Over a 100-Year Future Simulation

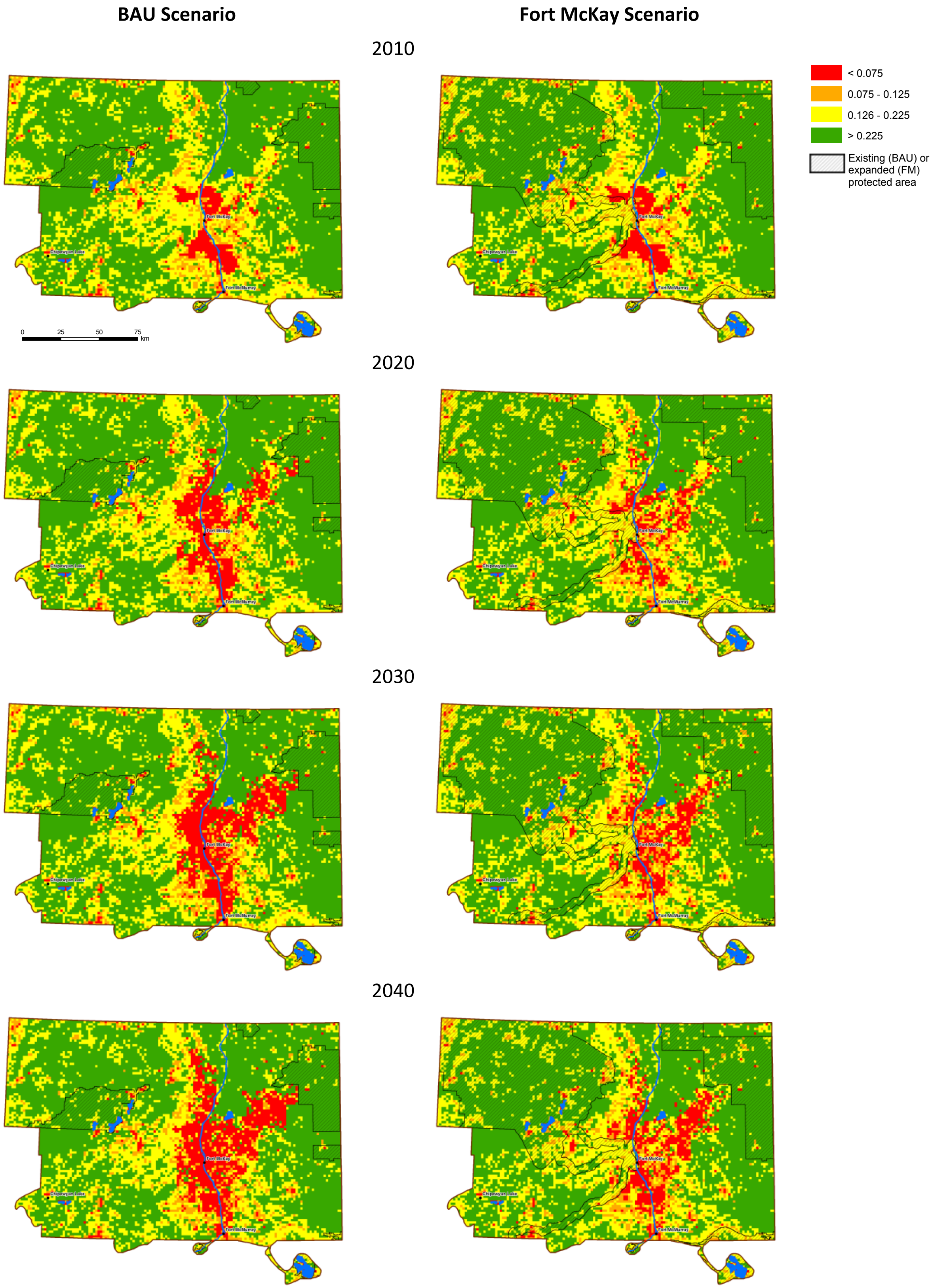


Figure 57: Projected Future Changes in the Berry HSI, BAU and Fort McKay Scenario, 2010-2040

Figure 58: Projected Future Changes in the Berry HSI, BAU and Fort McKay Scenario, 2050-2110

5 Key Issues, Recommendations and Conclusions

The cumulative effect of the energy sector footprint and its impacts on landscape and biotic indicators has been extensive to date, and will become increasingly significant and adverse over the decades to come. During the next 100 years, the majority of the Traditional Territory will be transformed by industrial activity and will cause a regional loss of distribution and performance of key ecological indicators (including moose, fisher, fish and edible berries).

5.1 Cumulative Effects and Key Issues

A principal characteristic of past and current impacts of bitumen development in the FM Study Area are linked to surface mining. Surface mining affects biotic indicators because it creates large polygonal features and footprints (i.e., surface mines, tailings ponds, disposal overburden) that primarily result in a direct loss of habitat throughout the construction and operational phases of a mine. Although a zone-of-influence can be attributed to surface mine features and associated footprints, the overall effect on habitat loss is largely tied to the direct footprint.

In the Fort McKay Study Area, the mineable oil sands area has been delineated based on an economically viable combination of bitumen pay thickness and depth of overburden; the expectation is that all future surface mining will occur there. Although the long-term effects of surface mining to biotic indicators will be largely contained within MOSA, there remains considerable uncertainty about the value and utility that reclaimed and restored habitats from the intensively disturbed surface mine features will have for wildlife. Therein lies a key issue for Fort McKay: **will restored landscapes be able to grow and sustain healthy wild animal and plant populations that are desired and utilized through traditional hunting, trapping, and foraging activities?**

In comparison, the key characteristics of new and future impacts of bitumen development in the FM Study Area over the coming decades will be linked to the expansive footprint of access roads, seismic lines, pipelines, wells and well pads that are required to support in situ well extraction. The effect of increasing in situ bitumen development imposes some direct habitat loss, but the more important cumulative impacts will be expressed through:

a) the extensive indirect effects of habitat fragmentation and reduced habitat effectiveness that will occur over a much larger proportion of the Traditional Territory, plus

b) an increased potential for human access due to an expanding and dispersed network of linear features.

The magnitude and the extent of the expected growth of in situ bitumen development emphasizes another key issue for Fort McKay: **to what extent will in situ infrastructure such as access roads and well pads become permanent features in order to facilitate the long-term**

extraction of remaining bitumen reserves as new and more efficient in situ well extraction technologies are developed?

5.2 Recommendations

Scenario analyses and results suggested the following:

- that the indirect impact on habitat might be effectively reduced through continued improvement and implementation of industry best practices that reduce footprint growth and hasten footprint reclamation;
- effective access management will be a critically important management tool to reduce the unintended consequences of increased harvest pressure and mortality of wildlife and fish; and
- expanded protected areas that are 'no-go' areas for industry might provide a building block for anchoring a land base that can prioritize production and off-take of wild plants and animals to support traditional harvesting activities.

This project emphasized the importance of developing and implementing an access management strategy for the region, as the combination of increased road networks and regional human populations will substantially impact key wildlife species important to Fort McKay.

As demonstrated by the TEMF (CEMA-SEWG 2008) and this project, access management is a key management lever that can significantly improve the performance of environmental indicators in the region. Strict adoption of BMPs can also serve as a very effective management tool to mitigate risks of industrial development to the environment. The BMPs applied in the Fort McKay scenario are considered realistic but rigorous and are not the current standard for the region.

Finally, establishing an expanded protected-areas network, larger than that outlined in the LARP (Government of Alberta 2012), can help mitigate the risk to environmental indicators, but protected areas alone will not solve the problem.

5.3 Conclusions

Unprecedented government-industry coordination and implementation of a suite of management practices (including expanded protected areas, aggressive access management, and dedication to continued development and implementation of BMPs to minimize and effectively reclaim footprint) are pre-requisites to an integrated strategy that has a reasonable likelihood of meaningfully addressing future cumulative effects of bitumen development.

However, despite implementation of coordinated management and mitigation, the expected extent, rate, and pace of bitumen development will likely result in diminished performance of key biotic indicators, as well as extirpation of local populations in core industrial foci within the Study Area.

This will be accompanied by an equivalent functional loss in sustainable harvesting opportunities (moose, fisher, fish and edible berries), which are core land-based activities tied to the culture and traditional economy of Fort McKay peoples.

The approaches applied in the Fort McKay cumulative effects study were similar to those used in both the TEMF (CEMA-SEWG 2008) and LARP (ALCES Group 2009, and Government of Alberta 2012). Against the backdrop of these three studies, we conclude the following:

1. The cumulative effects of the bitumen sector to key biotic indicators are significant to date, and will become increasingly adverse over the coming decades to the extent that it will profoundly affect Aboriginal and Treaty rights of Fort McKay peoples.

2. When examining the full extraction trajectory of the bitumen sector, the effects of the in situ sector is no less harmful, and possibly more detrimental, than that of the mineable sector.

3. Adoption of moderate access management, an expanded protected area network and aggressive beneficial or best management practices can, to a degree, mitigate the negative effects of the bitumen sector. However, neither of these measures, alone or in concert, can fully mitigate effects of industrial development, leaving significant residual adverse environmental impacts that exist today and will increase into the future.

4. The current structure and methodologies of EIAs deployed for the bitumen sector in northeast Alberta provide minimal insight into the highly probable outcomes (economic, social, ecological) of this industry on the cultural and environmental interests of the Community of Fort McKay.

5. The effectiveness and utility of project-specific EIAs should be strongly reconsidered and replaced with proper regional cumulative effects assessments, such as those presented here. Such a regulatory transition would allow all relevant stakeholders to better understand both the benefits and liabilities that attend the bitumen sector in northeast Alberta.

6. Managing cumulative effects and undertaking effective natural resource management that respects Aboriginal and Treaty rights requires Fort McKay's active engagement, and a new relationship with the Government of Alberta. Tollefson and Wipond (1998: p.389) remind us that the challenges are deep and suggest that (Tollefson and Wipond 1998):

    "… both the concept of cumulative impacts and the concept of Aboriginal rights fundamentally challenge government's ability to continue to rely on large-scale, corporate resource extraction as a primary economic activity. As such, both concepts pose a potentially serious threat to those who perceive their interest as being in preserving "business as usual."

6 Literature Cited

Alberta Sustainable Resource Development (ASRD). *Fish conservation strategy for Alberta.* Edmonton: Government of Alberta, 2006, 24.

Alberta-Pacific Forest Industries Inc. (Al-Pac). *Alberta-Pacific Forest Management Plan, 2006, Al-Pac Boyle AB. 200 pp.* Boyle: Alberta Pacific Forest Industries Inc., 2006, 200 pp.

ALCES Group. "ALCES User Manual." User Manual, Calgary, 2013.

ALCES Group. *Lower Athabasca Regional Plan ALCES III® Scenario Modeling Summary and Technical Results for Scenario Package One.* Unpublished Report, Calgary: ALCES Landscape and Land-use Ltd., 2009, 179.

Alcomo, A.J. (ed.). *Environmental futures: The practice of environmental scenario analysis.* Amsterdam: Elsevier, 2008.

Andison, D.W. "Natural levels of forest ageclass variability on the RSDS landscape of Alberta." Unpublished Report Submitted to CEMA-SEWG by Bandaloop Landscape-Ecosystem Services, Vancouver, 2005, 86.

Armstrong, G.W. "A stochastic characterization of the natural disturbance regime of the boreal mixedwood forest with implications for sustainable forest management." *Canadian Journal of Forest Research 29*, 1999: 424–433.

Athabasca Landscape Team (ALT). "Athabasca Caribou Landscape Management Options Report." Unpublished report submitted to the Alberta Caribou Committee Governance Board, 2009.

Bayne, E., H. Lankau, and J. Tigner. "Ecologically-based criteria to assess the impact and recovery of seismic lines: The importance of width, regeneration, and seismic density." Environmental Studies Research Funds Report No. 192, Edmonton, 2011, 98.

Beckingham, J.D., and J.H. Archibald. *Field guide to ecosites of Northern Alberta.* Special Report 5, Edmonton: Natural Resources Canada, Canadian Forest Service, Northwest Region, Northern Forestry Centre, 1996.

Bentham, P. *Audit of operating practices and mitigation measures employed within woodland caribou ranges.* Report prepared for Caribou Landscape Management Association (CLMA) and Forest Products Association of Canada (FPAC), Edmonton: Golder Associates, 2007.

Bergeron, Y. "The influence of island and mainland lakeshore landscapes on the boreal forest fire regime." *Ecology 72*, 1991: 1980–1992.

Burt, M., T. Crawford, and A. Arcand. *Fuel for thought: the economic benefits of oil sands investment for Canada's Regions.* Ottawa: Conference Board of Canada Publication 13-100, 2012, 74 pp.

Canadian Association of Petroleum Producers (CAPP). *Crude Oil Forecast, Markets & Pipelines.* Calgary: Canadian Association of Petroleum Producers, 2012.

Carlson, M., et al. "Informing regional planning in Alberta's Oilsands Region with a land-use similation model." Edited by D.A. Swayne, W. Yang, A.A. Voinov, A. Rizzoli and T. Filatova. *International Environmental Modelling and Software Society (IEMSs) 2010 International Congress on Environmental Modelling and Software Modelling for Environment's Sake, Fifth Biennial Meeting.* Ottawa, 2010.

Cenovus FCCL Ltd. *Christina Lake Thermal Expansion Project Phases 1E, 1F, and 1G, Forestry Baseline Report Appendix 5-IV.* Unpublished Report, Environmental Impact Assessment Amendment Application, Calgary: Cenovus FCCL Ltd. , 2009, 32.

Cenovus TL ULC. *Telephone Lake Project.* Application for Approval, Calgary: Cenovus Energy, 2011.

Cumulative Effects Management Association (CEMA). *Terrestrial ecosystem management framework for the Regional Municipality of Wood Buffalo.* CEMA - Sustainable Ecosystems Working Group, 2008.

Dancik, B., L. Brace, J. Stelfox, and B. Udell. "Forest management in Alberta. Report of the expert review panel." Department of Alberta Energy, Forestry, Lands and Wildlife, Government of Alberta, Edmonton, 1990, 128.

Dover Operating Corp. "Application for Approval of the Dover Commercial Project." Environmental Impact Assessment, 2010.

Duinker, P.N., and L.A. Greig. "Scenario analysis in environmental impact assessment: Improving explorations of the future." *Environmental Impact Assessment Review. 27*, 2007: 206-219.

Dyer, S.J., J.P. O'Neill, S.M. Wasel, and S. Boutin. "Avoidance of industrial development by woodland caribou." *Journal of Wildlife Management 65:*, 2001: 531-542.

Energy Resources Conservation Board (ERCB). *ERCB report shows over 2,300 successful oil wells were drilled in 2010, more than double the number drilled in 2009.* Press Release, Calgary: Energy Resources Conservation Board, 2011.

Energy Resources Conservation Board (ERCB). *ST98-2012: Alberta's Energy Reserves 2011 and Supply/Demand Outlook 2012–2021.* Calgary: Energy Resources Conservation Board, 2012.

Environment Canada. *Scientific assessment to inform the identification of critical habitat for woodland cairbou (Rangifer tarandus caribou), boreal population, in Canada: 2011 update.* Ottawa: Government of Canada, 2011, 102 pp. plus appendices.

Farmer, A.M. "The effects of dust on vegetation—a review." *Environmental Pollution. 79*, 1993: 63-75.

Fisher, J.T. *Populating the wildlife habitat suitability component of the ALCES model: fisher, moose, and black bear in north eastern Alberta.* Edmonton: Alberta Research Council, 2004, 22.

Foote, Lee. "Threshold Considerations and Wetland Reclamation in Alberta's Mineable Oil Sands." *Ecology and Society*, 2012, 17(1): 35 ed.: 11.

Forman, R.T.T., and L.E. Alexander. "Roads and their major ecological effects." *Annual Review of Ecology and Systematics. 29*, 1998: 207-231.

Forman, R.T.T., et al. "Road ecology." In *Science and Solutions*. Washington: Island Press, 2003.

Fort McKay Industry Relations Corporation (IRC). "Fort McKay Specific Assessment." Assessment, Fort McMurray, 2010.

Fort McKay Sustainability Department. *Fort McKay submission regarding the Draft Lower Athabasca Integrated Regional Plan 2011-2012.* Submitted to the Government of Alberta June 2011, Prepared for the Fort McKay First Nation and Fort McKay Métis Nation, 2011.

Frair, J.L., E.H. Merrill, H. Beyer, L. Morales, and J.M. Morales. "Thresholds in landscape connectivity and mortality risks in response to growing road networks." *Journal of Applied Ecology 45:*, 2008: 1504-1513.

Garibaldi, A. "Moving from model to application: Cultural keystone species and reclamation in Fort McKay, Alberta." *Journal of Ethnobiology 29(2)*, 2009: 323-338.

Garibaldi, A., and N. Turner. "Cultural keystone species: Implications for ecological conservation and restoration." *Ecology and Society 9(3)*, 2004: 1.

Geographic Dynamics Corp. "Natural ecosite and plant resource summary for the Athabasca Oil Sands Region." Final draft prepared for the Reclamation Working Group of the Cumulative Environmental Management Association, Fort McMurray, 2007.

Government of Alberta. *Alberta Oil Sands Industry Quarterly Update, Fall 2011, Reporting on the Period: June 4, 2011 to Sept. 2, 2011.* Edmonton: Government of Alberta, 2011, 16 pp.

Government of Alberta. *Alberta Oil Sands Industry Quarterly Update, Spring 2012, Reporting on the Period: Dec 3, 2011 to March 9, 2012.* Edmoton: Government of Alberta, 2012, 15.

Government of Alberta. *Lower Athabasca Regional Plan 2012-2022.* Edmonton: Government of Alberta, 2012.

Graf, M. *Literature Review on the Restoration of Alberta's Boreal Wetlands Affected by Oil, Gas and In Situ Oil Sands Development.* Prepared for Ducks Unlimited Canada, 2009.

Holling, C.S. "Resilience and stability of ecological systems." *Annual Review of Ecology and Systematics 4*, 1973: 1-23.

Jacques Whitford AXYS. "An analysis of existing information on peatland vegetation in the RMWB: Phase 1 Peatland data compilation and summarization." Prepared for the Reclamation Working Group of the Cumulative Environmental Management Association, Fort McMurray, 2007.

Johnson, E.A. *Fire and vegetation dynamics: studies from the North American boreal forest.* Cambridge: Cambridge University Press, 1992.

Jones, J.A., and G.E. Grant. "Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon." *Water Resources Research. 32*, 1996: 959-974.

La Roi, G.H., and M. Ostafichuk. *Structural dynamics of boreal forest ecosystems on three habitat types in the Hondo-Lesser Slave Lake area of north central Alberta in 1981.* RMD/35A, Research Management Division Report, Edmonton: Alberta Environment, 1982.

Lagimodiere, M. *Disturbance and access - Implications for traditional use land disturbance update.* Update report prepared for the Fort McKay Sustainability Department, Fort McMurray, Fort McKay: Lagimodiere Finigan Inc., 2013.

Lagimodiere, M., and B. Eaton. *Fish and fish habitat indicators for the Lower Athabasca Regional Plan (LARP): Description, rationale and modelling coefficients.* Prepared for the Lower Athabasca Regional Plan, Fish Element Team, Government of Alberta, 2009.

Landres, P.B., P. Morgan, and F.J. Swanson. "Overview of the use of natural variability concepts in managing ecological systems." *Ecological Applications 9*, 1999: 1179-1188.

Lee, P., and S. Boutin. "Persistence and developmental transition of wide seismic lines in the western Boreal Plains of Canada." *Journal of Environmental Management. 78*, 2006: 240-250.

MacPherson, L.M., M. Sullivan, A.L. Foote, and C.E. Stevens. "Effects of culverts on stream fish assemblages in the Alberta foothills." *North American Journal of Fisheries Management 32*, 2012: 480-490.

Mahmoud, M., et al. "A formal framework for scenario development in support of environmental decision-making." *Environmental Modeling and Software. 24*, 2009: 798-808.

Mapstone, B.D. "Scalable decision rules for environmental impact studies: effect size, Type I, and Type II errors." *Ecological Applications. 5*, 1995: 401-410.

Marathon Oil Canada Corporation. "Birchwood SAGD Demonstration Project and Environmental Protection & Enhancement Act (EPEA) Approval Application." Application for Approval, Calgary, 2012.

McGarigal, K., S.A. Cushman, and E. Ene. *FRAGSTATS Help User Manual v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps.* Amherst: Authors at the University of Massachusetts, 2012.

Moss, E.H. *Flora of Alberta. A manual of flowering plants, conifers, ferns and fern allies found growing without cultivation in the province of Alberta, Canada.* Revised by J.G. Packer. Vol. 2nd edition. Toronto: University of Toronto Press, 1983.

Murphy, P.J. *History of forest and prairie fire control policy in Alberta. Report T/77.* Edmonton: Alberta Energy and Natural Resources, 1985.

Myers-Smith, I.H., B.K. Arnesen, R.M. Thompson, and F.S. Chapin III. "Cumulative impacts on Alaskan arctic tundra of a quarter century of road dust." *Ecoscience. 13*, 2006: 503-510.

Nelson, J.S., and M.J. Paetz. *The fishes of Alberta.* Edonton: University of Alberta Press, 1992.

North Yukon Planning Commission (NYPC). *North Yukon Regional Land Use Plan - Nichih Gwanal'in - Looking Forward.* Final Recommended North Yukon Land Use Plan, Whitehorse: Yukon and Vuntut Gwitchin Governments, 2009.

Osko, T. *A Gap Analysis of Knowledge and Practices for Reclaiming Disturbances Associated with In Situ Oil Sands and Conventional Oil & Gas Exploration on Wetlands in Northern Alberta.* Fort McMurray: Prepared for the Cumulative Environmental Management Association, 2010.

Papworth, S.K., J. Rist, L. Coad, and E.J. Milner-Gulland. "Evidence for shifting baseline syndrome in conservation." *Conservation Letters. 2*, 2009: 93-100.

Park, D., M. Sullivan, E. Bayne, and G. Scrimgeour. "Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta's boreal forest." *Canadian Journal of Forest Research. 38*, 2008: 566-575.

Parsons, R., P. Morgan, and P. Landres. *Applying the natural variability concept: towards desired future conditions. Ecosystem Management of Forested Landscapes: Direction and Implementation.* Nelson: Ecosystems Management of Forested Landscapes Organizing Committee, 1998.

Pattie, L.D., and R.S. Hoffmann. *Mammals of the North American parks and prairies.* Vol. 2nd Ed. Edmonton, 1992.

Pauly, D. "Anecdotes and the shifting baseline syndrome of fisheries." *Trends in Ecology and Evolution. 10*, 1995: 430.

Payette, S., C. Morneau, L. Sirois, and M. Desponts. "Recent fire history of the northern Quebec biomes." *Ecology 70*, 1989: 656-673.

Peterson, E.B., and N.M. Peterson. *Ecology, management and use of aspen and balsam poplar in the prairie provinces.* Special Report 1, Edmonton: Forestry Canada, 1992.

Post, J.R., et al. "Canada's recreational fisheries: The invisible collapse?" *Fisheries 27*, 2002: 6-17.

Reeve, H.M., and R.E. McCabe. "Of moose and man." In *Ecology and management of the North American moose*, edited by A.W. Franzmann and C.C. Schwartz, 1-75. Boulder: University Press of Colorado, 2007.

Rooney, Rebecca C., Suzanne E. Bayley, and David W. Schindler. "Oil Sands Mining and Reclamation Cause Massive Loss of Peatland and Stored Carbon." *Proceedings of the National Academy of Sciences.* Stanford: National Academy of Sciences, 2012. 4933-4937.

Russell, A.P., and A.M. Bauer. *The amphibians and reptiles of Alberta.* Calgary: University of Calgary Press, 1993.

Schindler, D.W., and W.F. Donahue. "An impending water crisis in Canada's western prairie provinces." *Proceedings of the National Academy of Sciences 103.* 2006. 7210-7216.

Schneider, R., and S. Dyer. *Death by a thousand cuts - impacts of in situ oil sands development on Alberta's boreal forest.* Edmonton: Pembina Institute and Canadian Parks and Wilderness Society, 2006, 36.

Schneider, R., and S. Wasel. "The effect of human settlement on the density of moose in northern Alberta." *Journal of Wildlife Management. 64*, 2000: 513-520.

Schneider, R.R., J.B. Stelfox, S. Boutin, and S. Wasel. "lManaging the cumulative impacts of land uses in the Western Canadian Sedimentary Basin: a modeling approach." *Conservation Ecology 7(1)*, 2003: 8.

Semenchuk, G.P. *The atlas of breeding birds of Alberta.* Edmonton: Federation of Alberta Naturalists (FAN), 1992.

Shanley, C.S., and S. Pyare. "Evaluating the road-effect zone on wildlife distribution in a rural landscape." *Ecosphere 2(2)*, 2011: Article 16.

Smith, H.C. *Alberta mammals.* An atlas and guide, Edmonton: Provincial Museum of Alberta, 1993, 239.

Stelfox, J.B., ed. "Relationships between stand age, stand structure, and biodiversity in aspen mixedwood forests in Alberta." 1995: 308.

Stevens, C.E., T. Council, and M.G. Sullivan. "Influences of human stressors on fish-based metrics for assessing river condition in central Alberta." *Water Quality Research Journal of Canada. 45*, 2010: 35-46.

Sullivan, M. (pers. comm., Edmonton).

Sullivan, M. "CEMA INFI indicator criteria." Presentation to CEMA SEWG, 2006.

Sullivan, M. *Conceptual framework for public motorized access management strategies for cumulative effects modelling.* Edmonton: Alberta Sustainable Resource Development, Fish and Wildlife Division, 2009, 24.

Tigner, D.J. *Measuring wildlife response to seismic lines to inform land use planning decisions in northwest Canada.* Master of Science Thesis, Edmonton: Univerity of Alberta, 2012, 118.

Timilsina, G.R., N. LeBlanc, and T. Walden. "Economic impact of Alberta's oil sands. Study No. 110." *Canadian Energy Research Institute.* 2005. http://www.ceri.ca/docs/OilSandsReport-Final.pdf.

Tollefson, C., and K. Wipond. "Cumulative environmental impacts and Aboriginal rights." *Environmental Impact Assessment Review (18)*, 1998: 371-390.

Trombulak, S.C., and C.A. Frissell. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology. 14*, 2000: 18-30.

Vitt, D.H., J.E. Marsh, and R.B. Bovey. *Mosses, lichens and ferns of Northwest North America.* Edmonton: Lone Pine Press, 1988.

Wasel, S. Boyle: Alberta-Pacific Forest Industries Inc., (pers.comm., Boyle).

Willis, K.J., and H.J.B. Birks. "What Is Natural? The need for a long-term perspective in biodiversity conservation." *Science. 314*, 2006: 1261-1265.

Wilson, B., J.B. Stelfox, and M. Patriquin. *SEWG workplan facilitation and modeling project – data inputs and assumptions.* Salmon Arm: Silvatech Consulting Ltd, 2008, 69.

Wong, C., and K. Iverson. "Range of natural variability: applying the concept to forest management in central British Columbia." *BC Journal of Ecosystems and Management. 4*, 2004: 1.

Zwickel, H. *Sport fishing in Alberta 2010: summary report from the eighth survey of recreational fishing in Canada.* Edmonton: Alberta Sustainable Resource Development, 2012, 46.