North Yukon Planning Region
Land Use Scenarios Report

ALCES® Land Use Modelling Results for the North Yukon Planning Region

Prepared for North Yukon Planning Commission by
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Disclaimer

This report was prepared by Shawn Francis and Jeff Hamm for the North Yukon Planning Commission. The authors received assistance and input from numerous individuals—they are listed in the acknowledgements section of this document. While every effort has been made to accurately represent information, results and interpretations, some errors or misrepresentations may have occurred. The primary author, Shawn Francis, takes full responsibility for any errors or omissions contained in this report.

Feedback on this document and the modelling approach is welcome, and should be submitted to the Yukon Land Use Planning Council (www.planyukon.ca) or North Yukon Planning Commission (www.nypc.planyukon.ca).

REPORT SUMMARY

This report presents results of land use scenario modelling for the North Yukon Planning Region. Work on this project was initiated in 2005 in support of the North Yukon Regional Land Use Plan. Modelling results, available in 2007, assisted the North Yukon Planning Commission to make informed land use and conservation recommendations in the Draft North Yukon Regional Land Use Plan (North Yukon Planning Commission 2007a). The North Yukon Regional Land Use Plan was approved in June 2009 by the Yukon and Vuntut Gwitchin Governments.

This project had three major objectives:

- Explore potential outcomes of plausible future land use scenarios in the North Yukon Planning Region;
- Identify and explore natural factors and human land uses and land use practices that act as key drivers of landscape change; and,
- Compare the potential outcomes of different future land use scenarios against a set of socio-economic, land use and ecological indicators.

Modelling results are not intended to be a prediction of future events in the North Yukon Planning Region. Scenario modelling was conducted to facilitate informed discussion about key land use issues and practices, levels of landscape change, and potential land use impacts. The authors fully acknowledge that future events, land uses and biophysical processes may unfold in potentially different and uncertain ways.

This project built upon the experiences and results of Kruse et al. (2004) and Berman et al. (2004) through the Sustainable Arctic Communities Initiative. Funding assistance was provided by the Environment Canada Northern Ecosystems Initiative and Yukon Land Use Planning Council, and is gratefully acknowledged. This project would not have been possible without the support of the North Yukon Planning Commission members, and the participation and contributions of many Yukon and Vuntut Gwitchin government staff, other agencies (e.g., Environment Canada), industry representatives, and Old Crow community members. Meetings, workshops and major consultation events associated with this project are listed in Appendix 1.

1. LAND USE SCENARIOS

The ALCES® landscape computer simulation model was used to explore and better understand potential outcomes of plausible oil and gas, tourism and mining land use scenarios for the North Yukon Planning Region (*Table S-1*). Land use scenarios, and the detailed parameters for each scenario, were developed by domain experts and through research. A number of different scenarios for each sector were not examined, as the range of plausible scenarios was considered to be relatively low.

The results of each land use sector scenario are reported using standardized socio-economic, land use and ecological indicators, where possible (*Table S-2*). These indicators provide a consistent framework for comparison between sector scenarios.

Table S-1. Land use scenarios explored in North Yukon scenario modelling project.

Land Use Sector	Description
Oil and Gas	<u>Study Area</u>: Eagle Plain <u>Information Sources</u>: Yukon Oil and Gas Management Branch, Yukon Geological Survey, Fekete (2006) and Osadetz et al. (2005) <u>Scenario Summary</u>: *Natural Gas Scenario* • Exploration Phase (2010 – 2020) • Pipeline Construction Phase (2020 – 2025) - Demspter Lateral Pipeline to Mackenzie Valley Pipeline - Transportation and distribution infrastructure • Production Phase (2025 – 2055; 2.0 Tcf cumulative production) *Oil Scenario* • Exploration and testing (current – 2012) • Production of local fuel oil (2012 – 2055)
Tourism	<u>Study Area</u>: North Yukon Planning Region <u>Information Sources</u>: Yukon Tourism Branch, Vuntut Gwitchin Government, Vuntut Development Corporation and Yukon Department of Tourism and Culture (2006) <u>Scenario Summary</u>: *4 Tourism Markets*: • Wilderness Travel, primarily river trips on major rivers (60-70 users annually) • Dempster Highway Tourism (7,000 – 8,000 users annually) • Old Crow Visitors (1,200 visitors annually, most are not tourists) • Fishing Branch Grizzly Bear Viewing (maximum 32 users annually)
Mining	<u>Study Area</u>: North Yukon Planning Region <u>Information Sources</u>: Yukon Geological Survey and Yukon Minerals Management Branch <u>Scenario Summary</u>: • Base-level mineral exploration (current – 2030) • Large volume (15 million tonne), low-grade base metal deposit with open pit extraction • 100 km all season access road from Dempster Highway to North Ogilvie Mountains • Infrastructure development and production (2030 – 2045)

Table S-2. North Yukon land use scenario indicators.

Indicator Type	Indicator	Description
Socio-economic	Commodity Production	Amount of commodity produced by a land use activity, expressed as m^3 for Oil and Gas / Mining, and tourism activity days (TADs) for Tourism.
	Revenue	Dollar ($) value of commodity production.
	Employment	Full Time Equivalent (FTE) annual employment.
	Wages	Dollar ($) value of annual wages earned by sector employees.
	Royalties	Dollar ($) value of annual resource sector royalties generated.
	Regional Human Population	Full time resident human population.
Land Use and Ecological	Land Use Infrastructure	Sector specific infrastructure metrics that aid in better understanding surface disturbance and linear density indicators.
	Surface Disturbance	Total amount of direct human-caused surface disturbance (i.e. direct land use footprint) expressed as % of study area or ha.
	Linear Density	Total length of linear features (roads, seismic lines and trails) within a given area, expressed as km/km^2. Linear density may also be referred to as access density.
	Habitat Suitability Index (HSI)	Relative ranking of wildlife habitat quality in the absence of potential human-caused habitat effects. HSI ranges from a value of 0 (no habitat value) to 1 (perfect habitat value). Indicator is used for Range of Natural Variability runs. Two wildlife focal species HSI indicators were examined: • Barren-ground caribou winter HSI • Moose late-fall HSI
	Habitat Effectiveness Index (HEI)	Relative ranking of wildlife habitat quality, with consideration of potential human-caused habitat effects. Like HSI, HEI ranges from a value of 0 (no habitat value) to 1 (perfect habitat value). HEI can be compared against HSI to understand potential land use impacts. Two wildlife focal species HEI indicators were examined: • Barren-ground caribou winter HEI • Moose late-fall HEI

Land use modelling was conducted for two study areas: 1) the entire planning region, and 2) the Eagle Plain oil and gas basin. The Eagle Plain oil and gas basin was considered to have the highest potential to incur significant levels of land use activity in the near future, and was therefore examined in greater detail. Results are interpreted against a backdrop of estimated range of natural variability.

Given the potential importance of, and issues associated with, future oil and gas activity in Eagle Plain, a plausible energy sector scenario was examined in detail. Sensitivity around specific operating practice and reclamation parameters, and their relationship to potential landscape and wildlife habitat impacts, was explored. The relative influence of important natural factors, including habitat conditions and climate change, was also examined.

2. RESULTS

Table S-3 provides a summary and comparison of major sector scenario results. Highlights and major findings are discussed in greater detail, below.

2.1. Sector Scenarios

Eagle Plain Oil and Gas Exploration and Development Scenario
The Eagle Plain oil and gas scenario represents a land use activity with the potential to generate significant economic benefits, but that also poses potentially high ecological risks. Of the three sectors examined, oil and gas activity generates the highest levels of cumulative surface disturbance and linear density, over a 30-50 year time-frame. Development of an all-season access road network within Eagle Plain would be the most significant long-term management issue. Operating practices have the potential to significantly reduce maximum footprint levels, with well aggregation, access road reduction and reduced seismic line width/rapid re-vegetation being the most important factors.

Tourism Scenario
The North Yukon tourism scenario represents a low risk economic development strategy for the region, but also provides relatively low levels of economic benefits (employment and revenue). The tourism scenario investigated in this project does not meaningfully increase regional employment over the 100-year modelling period, but does double in revenue generation. These findings are similar to those reported by Berman et al. (2004)—community-based tourism, while generally desired by northern communities, may not provide expected or desired levels of economic benefits. The ecological impacts of the North Yukon tourism scenario would not be expected to increase beyond current levels, which are very low.

Mineral Exploration and Development Scenario
The North Yukon mining scenario represents a land use activity with potentially significant economic benefits and moderate regional ecological risks. A large-scale, producing open pit mine in northern Yukon would create lower levels of direct surface disturbance than Eagle Plain natural gas production, and more importantly, far fewer access roads. However, it should be recognized that some of the most important long-term impacts resulting from mineral production may be aquatic, and were not directly examined in this project. Examples of large-scale open pit mines and associated access roads being effectively decommissioned are not common, generally leading to long-term, localized impacts and a legacy of increased access into remote areas.

Table S-3. Comparison of North Yukon Planning Region land use sector scenarios.

Indicator	Eagle Plain Oil and Gas Exploration and Development Scenario	Tourism Scenario	Mineral Exploration and Development Scenario
Socio-Economic Indicators			
Commodity Production	Based on 30 year play: • 2.0 trillion cubic feet (Tcf) natural gas • 2.74 million bbls oil	Annual TADs: • 10,820 (current) – 21,450 (100-years future) TADs	Based on 15-year active mine life: • 7.5 million m^3 of base metal ore production
Revenue	Based on $10/McF natural gas: • $500 million - $1.2 billion/yr Based on $60/bbl oil: • $30 million/yr	Based on fixed current TAD spending: • $1.25 million/yr (current) - $2.2 million/yr (end of modelling period)	Based on $60/tonne: • Average $60 million/yr
Employment (Annual)	Exploration: • 120 annual FTE for 20 to 30-year period Production: • 300-350 annual FTE for 30-year period	• 18-20 annual FTE for entire modelling period	Exploration: • 1-12 annual FTE Production: • 350-400 annual FTE for 15-year period
Wages (Annual)	• $36 million at peak production	• Not evaluated	• $35 million for 15-year active mine life
Royalties***	Based on $10/McF natural gas and 10% royalty rate: • $50-$120 million/yr	• None	Based on $60/tonne ore price and 5% royalty rate: • $3 million/yr
Regional Population	• Additional 300-350 full time energy sector works in region (housed in work camps) for 30-year period	• No significant change	• Additional 350-400 mine site workers in region (housed on-site in work camp) for 15-year period
Ecological and Land Use Indicators			
Maximum Surface Disturbance*	• 7,500 - 20,000 ha	No additional surface disturbance or linear density created	300 – 600 ha
Maximum Linear Density*	• 0.7 - 1.3 km/km^2		Not examined in detail, but very low
Barren-ground caribou winter HEI**	• 20 - 40% reduction	Not examined in detail, but no significant reduction in HEI anticipated	Not examined in detail, but approximate total ZOI of 12,0000 -14,000 ha anticipated (including exploration)
Moose late-fall HEI**	• 20 - 40% reduction		

* Note: Surface disturbance and linear density reported as a range of maximum values. Operating practices and reclamation assumptions have a significant influence on potential levels of disturbance, and the life span of those disturbances.

** Focal wildlife species HEI values are presented as a range of maximum and minimum values related to the maximum and minimum surface disturbance and linear density indicator levels. HEI value is reported as percent reduction compared with range of variability results.

*** Royalties. Royalty rates fluctuate in response to price and production. Beyond a certain royalty level, most resource royalties would flow back to the Federal Government and would not be retained by Yukon.

2.2. Potential Outcomes and Impacts

Levels of Landscape Disturbance

- While current estimates of landscape disturbance levels are uncertain (i.e., surface disturbance and linear density indicator levels), this uncertainty does not significantly alter the land use modelling outcomes:
    - At the regional scale, current levels of landscape disturbance are very low (estimated 7,550 ha surface disturbance (0.14% of planning region); 0.14 km/km^2 linear density). 73% of the estimated regional surface disturbance is located within Eagle Plain.
    - In Eagle Plain, current levels of landscape disturbance are moderate (5,520 ha surface disturbance (0.40% Eagle Plain study area); 0.45km/km^2 linear density).
- Without additional land use disturbances, most (80%) of the existing footprint would be re-vegetated after 100-years. After this time, only permanent features such as the Dempster Highway and village of Old Crow would remain.
- Depending on different operating practice and reclamation assumptions, the Eagle Plain oil and gas scenario results in the creation of a maximum level of 7,500 – 20,000 ha of new surface disturbance (0.5% and 1.4% of Eagle Plain, respectively). Linear features associated with the oil and gas scenario result in linear densities of 0.7 – 1.3 km/km^2 for the Eagle Plain study area. Between 60% and 100% of these features would be reclaimed at the end of the 100-year modelling period.
- The tourism scenario does not result in the creation of new surface disturbance.
- The mineral scenario results in 300 – 500 ha of new surface disturbance, considering both the active mine site and potential all-season access road. Surface disturbance and access roads resulting from the mineral scenario would be active for at least 40 years.

Focal Wildlife Species (Barren-ground Caribou and Moose)

- At the regional scale, barren-ground caribou and moose habitat quality are within their range of natural variability.
- In Eagle Plain, historical and current land use impacts have reduced barren-ground caribou winter habitat effectiveness by approximately 20%, compared with the estimated range of natural variability in habitat conditions.
- At the regional scale, snow conditions are currently the most important factor affecting barren-ground caribou winter range habitat quality—fire rate is of secondary importance.
- At the regional scale, both snow and fire conditions have a greater direct effect on barren-ground caribou habitat quality than the Eagle Plain oil and gas scenario examined in this exercise.
- Moose late-fall habitat effectiveness in Eagle Plain is currently within the higher end of the range of natural variability, due to recent large fire events.

Climate Change

- Climate change is a key uncertainty in the ecological scenario outcomes.
- Climate change is anticipated to affect both snow conditions and fire rates, key factors in focal species wildlife habitat effectiveness.
- Climate-induced changes to winter snow conditions may have a larger negative effect on regional barren-ground caribou winter habitat quality than the land use scenarios considered in this exercise.

- Potential climate-induced landscape transitions (e.g., expansion of shrubs into wet tundra/herb communities; encroachment of trees into alpine areas) modelled under the assumptions of this project does not result in significant changes to future wildlife focal species regional habitat quality. The exception to this finding may be wetland-related transitions, for which potential pathways and rates of change are highly uncertain.

Best Management Practices

- In Eagle Plain, different oil and gas operating practices have a measurable effect on reducing the potential level of future landscape disturbance and cumulative impacts to barren-ground caribou winter and moose late-fall habitat effectiveness.
- In the Eagle Plain oil and gas scenario, operating practices may reduce maximum levels of direct surface disturbance by as much as 150%. Adopting 4 wells per pad and 3m or less seismic lines (with an assumed 10 year lifespan), versus using 1 well per pad and 5m seismic lines (with an assumed 30 year lifespan), result in a reduction of 12,000ha of cumulative surface disturbance for the same production scenario.
- In the Eagle Plain oil and gas scenario, the re-vegetation rate of land use features (e.g., 10-year seismic line life span versus 30-year seismic line life span) was found to have a greater effect on cumulative levels of landscape disturbance than the size or width of features.

Cumulative Land Use Impacts

- In Eagle Plain, land uses induced by oil and gas activity (e.g., gravel mining, transportation, and water use) must be considered as part of the Eagle Plain oil and gas scenario. The potential direct surface impacts resulting from these sectors may be nearly as large as those created directly by oil and gas activity, and may have longer-term life spans.
- Within the levels of land use activity investigated in this project, the creation of all-season access roads will be the most significant long-term future impact of industrial land use activity in the North Yukon Planning Region.

3. LIMITATIONS AND IMPORTANT CONSIDERATIONS

The objective of this project was to provide necessary information to make informed land use decisions in support of the North Yukon Regional Land Use Plan. While the best available information was used to complete the modelling exercise, results of the exercise should be interpreted within the context of the following limitations and considerations.

3.1 Future Conditions

Future land use projections have high levels of uncertainty. The land use sector scenarios examined in this exercise are based on specific assumptions about the rate, location and operating practices of the activities. Government policy, global commodity prices, trends in energy supply and transportation infrastructure, and technological innovation all have significant effects on the intensity, location and potentially impacts of future land use activities.

It is highly probable that the land use assumptions upon which this project is based will not be valid 20 or 30-years in the future—economic conditions and policy decisions may result in very different future land use outcomes. For example, it is possible that large increases in oil and gas and mineral activity within the region may not be realized, or that tourism activity may increase substantially.

While changing future conditions are a near certainty, examining plausible futures based on current assumptions allows potential benefits and impacts to be understood and evaluated today, with a focus on risk management. A risk management decision-making framework is critical to developing and implementing sustainable land management strategies that can be re-evaluated as circumstances change. Similar to the precautionary principle, uncertainty about future land use activities should not impede progressive and cautionary approaches to land management.

3.2 Data and Information

Land use scenario modelling requires adequate data and information. While the North Yukon scenario modelling project utilized the 'best available information', it is important to understand the following potential limitations:

Biophysical Description
The ALCES® model requires a description of landscape composition, including landscape types, forest age class structure, plant community dynamics, natural disturbance regimes, and climate. The North Yukon Planning Commission and its many project partners used the best available information to populate the model, but this often required expert opinion and extrapolation based on literature review.

The North Yukon biophysical map used to describe the regional landscape types is based on predictive ecosystem modelling approaches. While it may adequately represent the regional landscape, it cannot be expected to accurately or precisely represent the entire complexity of the northern boreal forest/taiga/alpine interface. All habitat interpretations are based on the biophysical mapping.

Wildlife Focal Species Habitat Quality (Suitability and Effectiveness)
In order to conduct scenario modelling in North Yukon, the relative habitat value of different landscape and footprint types for barren-ground caribou and moose was required. The biophysical map was used as the basis for assigning wildlife habitat value to landscape types. Habitat value was assigned in workshop settings based on the input of community of Old Crow land users, and Yukon Government biologists. Expert opinion and literature was used to quantify habitat value of land use footprints, and potential zones of influence.

Human Land Use Features
The location and amount of anthropogenic footprint is an estimate based on several sources, some of which may be incomplete or inaccurate, but which are currently the best available data for the North Yukon Planning Region. Our assumptions about the rate and extent of historical re-vegetation may not be accurate, resulting in either higher or lower levels of current disturbance on the landscape. Given that linear features represent approximately 80% of the total historical footprint in the region, linear features require special consideration.

3.3 Impact Prediction and Significance

Wildlife Focal Species Populations
A central focus for the modelling exercise was to predict potential impacts of land use activity on wildlife focal species. Land use and habitat-based indicators were used as surrogates for population-level response (i.e., direct mortality), which may not be correct. For barren-ground caribou, impact prediction methods developed for woodland caribou (e.g., Dyer et al. 2001; Anderson et al. 2002; Sorenson et al. 2008) were considered relevant given the barren-ground caribou responses to industrial features observed by Nelleman and Cameron (1998) and Cameron et al. (2005) for the Prudhoe Bay oilfield complex. Linear density and surface disturbance indicator levels were therefore used to represent risk levels for barren-ground caribou. Linear density, as a potential measure of access density, was also used to interpret potential population risks for moose.

While there may be uncertainty associated with focal species population response to land use indictors, in all ecological systems it has been demonstrated that increasing habitat loss/conversion, and increasing linear density/fragmentation result in increased ecological risk to native wildlife species and ecosystems (Holling 1973; Franklin 1993; Forman 1995; Collinge 1996; Forman and Alexander 1998; Spellerberg 1998; Trombulak and Frissell 2000). This finding provides a solid ecological basis for the use of linear density and surface disturbance indicators in northern Yukon, especially in the context of applying land use thresholds in regional planning to achieve long-term ecological sustainability (Environmental Law Institute 2003).

Potential Aquatic Impacts
Aquatic issues were not examined as part of this project. Water flow, water quality, water demand and watershed integrity may be important future issues in the region, but were not addressed directly as part of the current scenario modelling. Some of the most significant long-term mineral exploration and development-related impacts may be on aquatic systems.

Socio-cultural Perspectives on Impact Significance
The significance of potential land use impacts in this project was examined from a quantitative perspective, where land use-induced changes to ecological indicators were examined and compared against their range of natural variability. Regardless of indicator performance, high rates of visual landscape change can be perceived as 'significant negative effects' of land use, especially in a relatively undeveloped landscape like the North Yukon Planning Region. Such perspectives should be considered when discussing and evaluating potential land use impacts, particularly in the context of establishing limits of acceptable change.

4. LESSONS LEARNED

As the first major regional planning exercise in Yukon to be supported by land use scenario modelling, a retrospective evaluation of the project is warranted. If such an approach is used in future Yukon land use planning initiatives, applying the lessons learned from this exercise is recommended. The following points summarize the major lessons learned from the use of the ALCES® model to support the North Yukon Regional Land Use Plan.

4.1 Objective Planning Support

The ALCES® model facilitated an objective discussion about land use activities and potential impacts. Such a discussion between planners, governments and stakeholders would have been challenging without use of the model. The ALCES® model leads participants through a logical planning process in a step-wise manner, where sector specialists are required to explicitly state assumptions, rates of change, and potential significance of impacts, and governments and stakeholders must explicitly state goals and desired outcomes. Such clarity leads to an objective discussion of land use benefits and impacts, and increases understanding between sectors and participants.

4.2 Research and Information Collection

The ALCES® model requires biophysical, ecological, resource potential and economic information. For the North Yukon exercise, significant effort was required to initially populate the model. Current climate and future potential climate and natural disturbance regimes had to be researched and quantified. Landscape and footprint types required definition, and needed to be mapped. Focal wildlife species habitat quality relationships had to be derived. Land use scenarios had to be defined for the different sectors, and operating practices parameterized. Much of this information was collected in support of the North Yukon Resource Assessment Report (North Yukon Planning Commission 2007b), but it should be recognized that significant effort was required for this exercise.

Future land use modelling initiatives in Yukon will benefit greatly from the North Yukon ALCES® modelling experience. It is recommended that future information collection to support land use planning be driven directly by the modelling questions and regional issues. In North Yukon, the Eagle Plain study area was of primary interest, and most resources in this exercise were directed to this planning issue. Secondarily, future research and information collection should focus more on rates of change and significance of impacts, versus quantitative descriptions.

Many of the sensitivity analysis results, particularly those regarding best management practices and impact assumptions (e.g., zone of influence), provide important information that can be used to focus future research.

4.3 Applying Results Spatially

An important outcome of regional planning is the identification of sub-regional planning units, where specific management strategies may be applied to achieve specific objectives. The approved North Yukon Regional Land Use Plan (Yukon and Vuntut Gwitchin Governments 2009) identifies 13 major landscape management units, and several sub-units.

The ALCES® model uses a ‘spatially-stratified’ approach to project and track landscape and footprint types within a study area (see Section 2.1 of main report). With this method, land use footprints are calculated and tracked based on their proportional representation within landscapes types, across a study area. Without additional tools and approaches, it can be challenging to apply and interpret results for a specific geographic location within a regional study area.

In future exercises it is recommended that the ALCES® model be used in a complimentary manner with other spatial modelling tools, such as Marxan or Zonation, to assist in interpreting regional outcomes within specific geographic sub-units. Such an approach would have been possible in this exercise, but due to time constraints, was not pursued. This approach would have allowed alternative zoning strategies or landscape configurations to be examined and evaluated to determine if regional objectives were still being met. The ALCES® model now also has a companion mapping application, ALCES Mapper™, which is being applied effectively within the Alberta Land Use Framework, and should also be considered for application in future Yukon initiatives.

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- Shel Graupe
- William Josie
- Megan Williams
- Mary Jane Moses
- Melissa Valja

Community of Old Crow

- Over 30 Elders and land users participated in habitat suitability, fish and wildlife, and heritage workshops in 2005 and 2006. Community members provided information which directly supported this exercise. A full list of workshop participants is provided in the North Yukon Resource Assessment Report (NYPC 2007).

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- Amy Leach
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TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

North Yukon Planning Region
Land Use Scenarios Report

ALCES® Land Use Modelling Results
for the North Yukon Planning Region

1. INTRODUCTION

1.1 BACKGROUND

Regional land use plans are collective statements about how to use and manage land and resources within a defined area. Regional land use planning provides an opportunity for governments, land users and stakeholders to consider multiple land use and resource interests over broad geographic areas and meaningful time-scales. Understanding the future potential outcomes of land use decisions and activities is an important consideration. Regional planning should allow participants to explore if our collective land use decisions and practices of today will achieve the type of future we desire. In contrast, sectoral approaches to land and resource planning often emphasize one resource value over another, and have difficulty considering and managing multiple concurrent land uses.

The North Yukon regional land use planning process was initiated under the mandate of Chapter 11 of the Vuntut Gwitchin First Nation Final Agreement (VGFNFA). An important goal of the regional planning exercise is to ensure that social, cultural, economic and environmental policies are applied to the management, protection and use of land, water and resources in an integrated and coordinated manner so as to ensure *Sustainable Development* (VGFNFA 11.1.1.6). As defined in the VGFNFA, *Sustainable Development* is "beneficial socio-economic change that does not undermine the ecological and social systems upon which communities and societies are dependent."

Understanding and managing the potential cumulative effects of multiple land uses was identified as an important planning consideration for the North Yukon Regional Land Use Plan (North Yukon Planning Commission 2007a,b). Limits of acceptable change was suggested to be a relevant and practical approach for managing the cumulative impact of multiple land uses. Understanding and managing the potential cumulative impacts of future oil and gas activity in the Eagle Plain area on the Porcupine Caribou Herd and wetlands was identified as the most important land use issue. Arguably, *Sustainable Development* cannot be achieved without managing cumulative land use impacts.

In regional planning, the development of land use scenarios that can be forecast and examined is an effective method to evaluate alternative land use decisions and strategies. Land use scenarios develop an outline or model of plausible land uses that may occur, including possible time-lines, benefits, and impacts. *The development of land use scenarios differs from discrete options; options require making choices between one value or resource over another.* In contrast, scenarios explore alternative futures where a range of potential outcomes may be possible. The use of land use scenarios is generally considered more appropriate for a consensus-based planning process (Brown 1996), such as the Chapter 11 process in Yukon.

1.2 WHAT THIS REPORT IS ABOUT

This report presents results of land use scenario modeling for the North Yukon Planning Region. This work was initiated in 2005. Modeling results, available in 2007, assisted the North Yukon Planning Commission to make informed recommendations for the Draft North Yukon Regional Land Use Plan (North Yukon Planning Commission 2007a).

The ALCES® landscape computer simulation model was utilized to explore and understand the potential outcomes of plausible oil and gas, tourism and mining land use scenarios for the region. The relative influence of important natural factors, including habitat conditions and climate change, was also examined. Potential socio-economic and ecological outcomes of the different scenarios are reported. This project drew upon the experiences and results of Kruse et al. (2004) and Berman et al. (2004) through the Sustainable Arctic Communities Initiative. Funding assistance was provided by the Northern Ecosystems Initiative.

Results are not intended to be a prediction of future events in the North Yukon Planning Region; scenario modeling was conducted to facilitate informed discussion about key land use issues and practices, levels of landscape change, and potential land use impacts. Future events, land uses and biophysical processes may unfold in potentially different and uncertain ways.

1.3 OBJECTIVES

This report has three major objectives:

- Explore possible outcomes of plausible future land use scenarios in the North Yukon Planning Region;
- Identify and explore natural factors and human land uses and land use practices that act as key drivers of landscape change; and,
- Compare the potential outcomes of different future land use scenarios against a set of socio-economic, land use and ecological indicators.

1.4 REPORT ORGANIZATION

This report describes the methods and results of the North Yukon Planning Region land use modeling exercise. A brief overview of the region and the modeling study areas is provided in Section 2. Methods and results are presented in Sections 3 and 4, respectively. A list of meetings and project contributors is included as Appendix 1. The North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) should be consulted for detailed technical documentation regarding the biophysical, natural disturbance, land use footprint, wildlife and habitat characteristics of the region.

2. METHODS

2.1 ABOUT THE ALCES® MODEL

ALCES® is a landscape computer simulation model that projects and tracks current and future land use footprints and other indicators based on user-defined parameters. ALCES® is not a predictive model; it allows users to define land use scenarios and project their potential outcomes into the future. The model enables users to explore and quantify dynamic landscapes affected by single or multiple human land use practices and various natural disturbance regimes such as fire and flooding[1]. ALCES® assists resource managers and planners by: 1) tracking anthropogenic footprints and economic contributions of different land use practices, 2) identifying environmental and land use issues, and 3) discovering mitigation strategies for issues related to the maintenance of ecological (e.g. wildlife habitat quality), social (e.g. population) and economic (e.g. employment and royalty revenues) goals.

ALCES® utilizes a spatially stratified approach to tracking land use activities and natural disturbance regimes. The model stratifies landscapes based on user-defined 'landscape types' and assigns user-defined 'land use footprints', trajectories and reclamation rates for each land use based on proportions and rates. Land use footprints are tracked based on their proportional representation within landscape types.

Many variables act as 'drivers' of landscape change, with some potentially having a more significant effect than others. In the model, the relative influence of land use activities and practices (e.g. oil and gas, tourism or mining), natural disturbance regimes (e.g. fire or forest insects), and climatic effects (e.g. climate change) may be isolated and examined. In this manner, ALCES® provides a framework for evaluating the significance of different natural and human land use factors. Model outputs are in the form of numeric tables or line charts for selected parameters, and can be represented spatially through the use of geographic information systems (GIS).

2.1.1 Using the ALCES® Model

To prepare for ALCES® scenario modeling, data must be entered that describe the study area, land uses and other parameters such as climate, wildlife-habitat relationships, wildlife response to human features (disturbance coefficients) and footprint reclamation rates and trajectories. Information compiled in support of the North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) provided much of the data required for this project.

Study area composition and land use footprints are discussed in Section 2.2, as they are central to interpreting ALCES® results.

[1] A detailed description of the ALCES© model is provided at the ALCES Group website: www.alces.ca

2.2 STUDY AREAS

Two study areas were used to conduct the ALCES® land use simulations: 1) a Regional Study Area and 2) the Eagle Plain Study Area. Using GIS summaries, the model was initially populated with two key sources of information: 1) landscape types, and 2) footprint types. The North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) provides detailed methods and descriptions of the North Yukon landscape and footprint types.

2.2.1 About the North Yukon Planning Region

Setting

The North Yukon Planning Region is 55,566 km^2 (5,556,627 ha) in size, representing about 12% of Yukon (*Figure 1*). It is the traditional territory of the Vuntut Gwitchin First Nation. There is one major all-season road, the Dempster Highway. Old Crow is the only permanent community, and the only community in Yukon with no all-season road access (Old Crow is serviced on an as-needed basis by a winter road).

The region contains three existing protected areas: 1) Vuntut National Park, 2) Old Crow Flats Special Management Area and 3) Ni'iinlii'njik (Fishing Branch) Wilderness Preserve, Ecological Reserve and a Vuntut Gwitchin land selection (VG R-05A) (*Figure 2*). Combined, these areas account for 32% of the study area. An additional 13% of the region is within the North Yukon Land Withdrawal, an area that has not been available for land disposition or industrial land use since 1978.

Figure 1. North Yukon Planning Region.

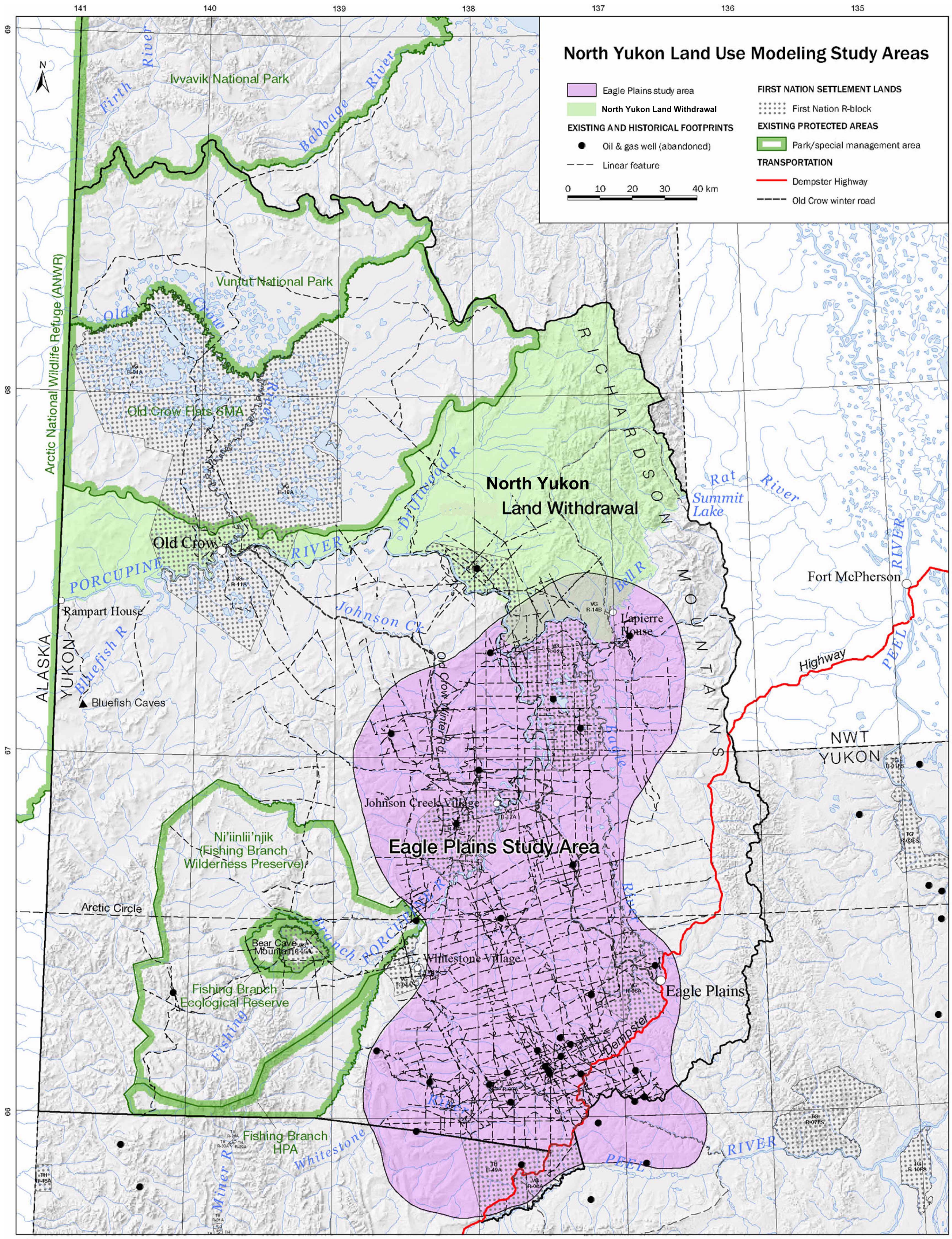

Figure 2. North Yukon Planning Region land use modelling study areas: 1) Regional Study Area and 2) Eagle Plain Study Area.

Environment

The North Yukon Planning Region is part of Beringia, an area spanning from Yukon to Siberia that remained free of continental glaciers for almost two million years. The area has a sub-Arctic climate, and is one of the most extreme climate regions in Yukon. Continuous permafrost underlies most of the area.

The planning region contains portions of six distinct ecoregions, including Old Crow Flats, Old Crow Basin, Eagle Plains, North Ogilvie Mountains, British Richardson Mountains and Davidson Mountains (Smith et al. 2004). The six ecoregions represent a diverse assemblage of landscapes including rolling forested plateaus, large wetland complexes, significant riparian corridors along major rivers, and rugged mountainous areas with expanses of shrub and tundra-like vegetation. Arctic tundra occurs in the northern portion of the region. Elevation ranges from 325m in Old Crow Flats to 1,800m in the North Ogilvie Mountains.

Most of the region is within the Porcupine River watershed, with the Old Crow, Eagle, Bell, Whitestone and Fishing Branch rivers forming major tributaries. Rivers experience very low winter flows and dramatic variations in the summer.

The region is occupied seasonally or annually by approximately 40 species of mammals, 150 species of birds and 18 species of fish, including three species of salmon. The barren-ground Porcupine Caribou Herd is the most significant wildlife resource in the planning region, and is a vital cultural and economic resource for the community of Old Crow and neighbouring Gwich'in communities.

People

The total regional population is about 300. All live in the community of Old Crow and almost all (90%) are Vuntut Gwitchin First Nation beneficiaries. Since 1985, the Old Crow population has remained relatively stable. Population growth trends are currently less than 1%.

Economy

The regional economy is a 'mixed economy' where both traditional subsistence harvesting and wage-based activities co-exist. Subsistence hunting, gathering and trapping are still very important economic and cultural activities in Old Crow. The region currently has one of the lowest levels of wage-based economic activity in Yukon. The planning and delivery of Government services and transfer payments are the primary economic inputs.

Transportation is currently the largest land use sector. Activity levels in all other sectors are currently low, but are increasing. Most tourism, oil and gas and mining interests and activity are focused on the Dempster Highway corridor. The Eagle Plain oil and gas basin received a high level of exploration in the 1960s-70s. Eagle Plain contains proven oil and gas reserves, and current resource assessments suggest substantial natural gas potential (mean estimate 7.9 trillion cubic feet), and moderate oil potential (mean estimate 536 million barrels) (Osadetz et al. 2005). Mineral potential remains largely unexplored. Given the glacial history of the region, aggregate resources are scarce, and are generally constrained to modern river valleys and terraces. There is no commercial forestry or agriculture.

Key Planning Issues

Based on best available information, Eagle Plain is anticipated to contain the majority of the North Yukon Planning Region oil and gas potential, and represents a significant portion of Yukon's total oil and gas potential (Osadetz et al. 2005). Potential impacts of future oil and gas exploration and development in the Eagle Plains region was identified as the major planning issue by most community members and stakeholders (North Yukon Planning Commission 2007a,b). Of special concern were potential impacts to the Porcupine Caribou Herd, wetlands and riparian habitats. Transportation, providing opportunities to access land and resources, and considering the potential effects of climate change were also important planning issues.

2.2.2 Regional Study Area

The Regional Study Area is the entire North Yukon Planning Region (*Figure 2*). Current landscape composition of the Regional Study Area is summarized in *Table 1*.

In the scenario analyses, future potential industrial land use activity was not allowed in either the existing protected areas or the North Yukon Land Withdrawal. These areas were, however, included in the Regional Study Area. Fifty-five percent of the Regional Study Area was considered to be part of the working landscape.

2.2.3 Eagle Plain Study Area

The second study area is a sub-region of the Regional Study Area. The Eagle Plain Study Area is a generalized representation of the Eagle Plain oil and gas basin (*Figure 2*)[2]. The Eagle Plain Study Area is 13,851 km^2 (1,385,116 ha) and was used to examine the oil and gas scenario. Both existing and future potential oil and gas activities will likely be focused within this area for the foreseeable future (Fekete 2006; North Yukon Planning Commission 2007). The Eagle Plain Study Area represents about 25% of the North Yukon Planning Region. There are no protected areas in Eagle Plains.

This area is primarily within the Eagle Plains ecoregion and is characterized by low elevation, gently rolling terrain with a mosaic of shrub and forest types (Smith et al. 2004; *Figure 3*). Forest pattern and age-class is strongly influenced by wildfire; in 2004 over 400,000 ha of area was burned. A large wetland complex, the Whitefish Wetlands, is in central Eagle Plains (*Figure 4*). Current landscape composition of the Eagle Plain Study Area is summarized in *Table 1*.

[2] Note: only the portion of Eagle Plain oil and gas basin within the North Yukon Planning Region boundary was examined in this exercise.

Figure 3. Characteristic Eagle Plain landscape—gently rolling terrain with a mosaic of shrub and forest types. Photo: M. Hoefs.

Figure 4. Whitefish Wetlands complex in central Eagle Plain. Photo: C.Eckert.

2.2.4 Landscape Composition (Landscape Types)

Landscape types describe the biophysical characteristics of the planning region. *Table 1* lists the different landscape types and their extent within the Regional and Eagle Plain study areas. The North Yukon biophysical map describes 18 distinct landscape types; five forested landscape types contain successional stages for a total of 28 potential landscape types (North Yukon Planning Commission 2007b). For this modeling exercise, the amount of lotic (flowing water) landscape types was also estimated, resulting in 20 distinct landscape types. Based on empirically-derived fire history information, forest age-class distributions were also estimated for successional forest landscape types.

Table 1. Study area landscape type composition.

LANDSCAPE TYPE (LT)		NORTH YUKON STUDY AREA		EAGLE PLAIN STUDY AREA	
LT Name	LT Code	Area (ha)	Area (%)	Area (ha)	Area (%)
SUCCESSIONAL FOREST LANDSCAPE TYPES					
High Elevation Conifer Forest	High_CFor	116,672	2.100	2,082	0.150
Wet Coniferous Forest	Cfor_wet	265,215	4.773	56,680	4.092
Moist Coniferous Forest	Cfor_mst	1,294,642	23.299	408,811	29.515
Mesic Coniferous Forest	Cfor_mes	1,191,443	21.442	484,596	34.986
Riparian Coniferous Forest	Rip_Cfor	313,884	5.649	95,869	6.921
NON-SUCCESSIONAL (META-STABLE) LANDSCAPE TYPES					
High Elevation Rock/Exposed	High_Rock	275,594	4.960	662	0.048
High Elevation Sparsely Veg.	High_Sparse	262,794	4.729	8,466	0.611
High Elevation Herb	High_Herb	178,507	3.213	2,047	0.148
Low Elevation Exposed	Low_Exposed	34,273	0.617	3,097	0.224
Wet Herb	Herb_wet	467,419	8.412	99,317	7.170
Wet Shrub	Shrub_wet	702,816	12.648	108,240	7.815
Riparian – Exposed	Rip_Exposed	13,163	0.237	2,942	0.212
Riparian – Herb	Rip_Herb	107,277	1.931	54,665	3.947
Riparian – Wetlands	Rip_Wetland	43,644	0.785	15,480	1.118
Wetland – Herb	Wetland_Herb	4,762	0.086	1,243	0.090
Wetland – Shrub	Wetland_Shrub	35,272	0.635	5,891	0.425
Wetland – Forest	Wetland_For	82,307	1.481	6,799	0.491
Small River (lotic)	River_small	8,165	0.147	2,414	0.174
Large River (lotic)	River_large	20,641	0.371	17,887	1.291
Open Water (lentic)	Waterbody	138,136	2.486	7,927	0.572
TOTAL		**5,556,627**	**100 %**	**1,385,116**	**100 %**

2.2.5 Land Use Footprints (Feature Types)

Land use footprint is the area directly disturbed by a road, gravel pit, seismic line, or any other physical land use feature. Land use footprints create direct habitat impacts. Fifteen land use feature types were used to categorize potential human land uses (*Table 2*). Existing and historical human land use footprints were compiled and summarized from available feature mapping (North Yukon Planning Commission 2007b). Some feature types do not currently exist within the region but may exist in the future (e.g. pipelines). The proportion of each feature type occurring on each landscape type was summarized by an overlay process using GIS.

Regionally, the amount of land use footprint is very low. The Dempter Highway is the only major, all-season road. The Eagle Plain Study Area contains most (about 75%) of the total land use footprint. It is estimated that a maximum of 0.5% of the Eagle Plain Study Area was directly impacted by historical oil and gas exploration, mineral exploration, and associated transportation infrastructure (i.e. Dempster Highway and Old Crow winter road). The maximum level of historical linear density (the total length of all linear features, measured in km, divided by the size of the Eagle Plain Study Area, measured in km^2) in Eagle Plain was approximately 0.56 km/km^2.

Levels for both of these metrics, total footprint and linear density, are currently lower due to natural re-vegetation of some feature types. North Yukon Planning Commission (2007b) estimated that at least 20% of the non-permanent linear features have been re-vegetated through natural processes, with wildfire playing an important role[3].

Table 2. Study area land use footprints. *

FEATURE TYPE (FT)		NORTH YUKON STUDY AREA		EAGLE PLAIN STUDY AREA	
FT Name	FT Code	Area (ha)	Length/ Perimeter (km) **	Area (ha)	Length/ Perimeter (km) **
LINEAR FEATURES					
Major Road (Dempster Hwy)	Major Rd	1,191	198	675	115
Access Road	Access Rd	11	11	5	5
Winter Road (Old Crow W. R.)	Winter Rd	266	266	191	191
Community Use Trail	Comm Trail	154	515	17	56
Trail	Trail	4,563	5,708	3,557	4,444
Seismic Line	Seismic	2,589	3,249	2,398	2,901
Pipeline	Pipeline	0	0	0	0
NON-LINEAR FEATURES					
Airstrip	Airstrip	156	55	114	40
Well Site	Well Site	28	11	25	10
Gravel Pit	Gravel Pit	191	21	60	16
Mine Site	HR Mine	4	1	0	0
Settlement	Settlement	210	8	0	0
Traditional Camp	Trad Camp	12	9	1	1
Tourism / Visitor Facility	Tourism Fac	188	12	10	2
Work Camp	Work Camp	0	0	0	0
TOTAL		**9,564**	**10,065**	**7,054**	**7,782**

* Area and length of footprint types, as reported, is the initial or 'historical' study area footprint; it does not account for potential reclamation of non-permanent features. Footprint reduction resulting from natural re-vegetation is factored during modeling runs and is further discussed in Section 3.1.

** Length is calculated for linear features types. Perimeter is calculated for non-linear feature types. A summary of both length and perimeter represents the total amount of human-caused 'edge' within the study area.

[3] In forested landscapes, land use features are considered re-vegetated when woody vegetation of approximate 1.5m stature has returned to the site.

2.3 LAND USE SCENARIOS

2.3.1 Defining the Scenarios

Conducting land use simulations with ALCES® requires dialogue with and input from stakeholders and sector specialists. In this manner, land use modeling assists in facilitating discussion between planners and land use sectors, and among land use sectors.

A number of workshops and technical meetings were held in support of this modeling exercise. In June 2005 a multi-stakeholder workshop introduced the model, provided an overview of the general modeling approach, and discussed potential land use scenarios to be examined. Sector specialist and technical meetings occurred throughout 2005 – 2007. Meetings and participants are documented in Appendix 1 of this report.

In the North Yukon Planning Region, three land use sectors were determined to warrant simulation:

- **Oil and gas exploration and development**;
- **Tourism**; and,
- **Mineral exploration and development**.

Additional scenarios and sensitivity analyses were examined to explore:

- The range of variability of the study area in absence of new land use;
- Potential climate change effects on landscape composition and habitat value;
- Oil and gas best management practices; and,
- The influence of specific parameters on model results.

Sensitivity analyses methods are further discussed in Section 2.5. The land use scenarios were created based on plausible patterns and levels of activity for each land use sector, using the best available information regarding resource and market potentials. Operating practices and land use assumptions were contributed directly by sector specialists. Of the three land use sector scenarios, the oil and gas scenario is most detailed and received the greatest focus. Energy sector activity in Eagle Plain received previous consideration (Fekete 2006), and development of the North Yukon natural gas resource has the highest potential to result in significant human-caused landscape change (North Yukon Planning Commission 2007a,b).

Table 3 provides an overview of the three land use sector scenarios examined in this exercise. Land use sector scenarios are further described in Section 3. Resource and market potentials and assessments are discussed in detail in North Yukon Planning Commission (2007b).

2.3.3.1 Range of Variability

Range of variability refers to the range of variation or fluctuation that can be expected within a system. As an example, wildfire sizes may range from small to very large, with very large events generally occurring more infrequently than small fires. The variation in fire size and frequency plays a large role in determining habitat conditions of forested landscapes. The relative 'effect' of this natural variation on habitat conditions should be understood prior to land use scenarios being examined.

Scenario analyses were initially conducted in isolation from new human land use to better understand the natural dynamics of wildfire, habitat conditions and potential climate change effects. The relative effect of snow condition on caribou habitat quality was also examined. **These model runs provide a baseline of landscape variability against which new land use activity can be compared and evaluated**.

Two types of variability were examined:

- **Range of natural variability (RNV)**. The range of landscape variability that could be expected in a natural system without the effects of any historic or current human land use influences. Understanding the potential range of natural variability is required to determine if the current landscape has moved outside of its natural range as a result of historic and current land use influences.
- **Range of variability, current landscape composition**. The range of variability of the current landscape, including historical and current land use influences. Examining the range of variability of the current landscape is required to compare against new, future potential land use. The current landscape is the baseline against which new land use activity is compared and evaluated.

2.3.3.2 Oil and Gas Exploration and Development

With input from the Yukon Oil and Gas Management Branch and Yukon Geological Survey, the oil and gas scenario was modeled closely after the analysis of Fekete (2006), based on the oil and gas resource estimates of Osadetz et al. (2005). The Eagle Plain Study Area was the focus of the oil and gas scenario, with natural gas production the primary activity (*Table 3*).

2.3.3.3 Tourism

The tourism scenario, developed with input from the Yukon Tourism Branch, Vuntut Gwitchin Government and Vuntut Development Corporation, was generally based on the North Yukon Tourism Strategy (Yukon Department of Tourism and Culture 2006), with a wilderness and Dempster Highway tourism activity focus (*Table 3*). Tourism was examined within the Regional Study Area.

2.3.3.4 Mineral Exploration and Development

With input from the Yukon Geological Survey and Yukon Minerals Management Branch, a mining scenario was created to illustrate the relative effect of a hypothetical base metal open pit mine development, based on 'typical' infrastructure requirements and deposit characteristics (*Table 3*). The mining scenario is assumed to occur in the Ogilvie Mountains, in the south western portion of the Regional Study Area.

Table 3. Land use scenario summary table.

Land Use Sector	Description
Oil and Gas	Study Area: Eagle Plain Information Sources: Yukon Oil and Gas Management Branch, Yukon Geological Survey, Fekete (2006) and Osadetz et al. (2005) Scenario Summary: *Natural Gas Scenario* • Exploration Phase (2010 – 2020) • Pipeline Construction Phase (2020 – 2025) - Demspter Lateral Pipeline to Mackenzie Valley Pipeline - Transportation and distribution infrastructure • Production Phase (2025 – 2055; 2.0 Tcf cumulative production) *Oil Scenario* • Exploration and testing (current – 2012) • Production of local fuel oil (2012 – 2055)
Tourism	Study Area: North Yukon Planning Region Information Sources: Yukon Tourism Branch, Vuntut Gwitchin Government, Vuntut Development Corporation and Yukon Department of Tourism and Culture (2006) Scenario Summary: *4 Tourism Markets*: • Wilderness Travel, primarily river trips on major rivers (60-70 users annually) • Dempster Highway Tourism (7,000 – 8,000 users annually) • Old Crow Visitors (1,200 visitors annually, most are not tourists) • Fishing Branch Grizzly Bear Viewing (maximum 32 users annually)
Mining	Study Area: North Yukon Planning Region Information Sources: Yukon Geological Survey and Yukon Minerals Management Branch Scenario Summary: • Base-level mineral exploration (current – 2030) • Large volume (15 million tonne), low-grade base metal deposit with open pit extraction • 100 km all season access road from Dempster Highway to North Ogilvie Mountains • Infrastructure development and production (2030 – 2045)

2.3.2 Scenario Modelling

Model scenarios were designed to project the landscape 100 years into the future. This time interval allowed adequate time to examine potential reclamation trajectories. Sector scenarios were conducted by switching ALCES® land use and disturbance switches 'on' for a sector, and adjusting parameters to understand the potential effect of different land use practices on the landscape. Land use scenarios considered alternative options for land use activity or natural disturbance regimes.

Year '0' on all ALCES® output figures in this report represents the year '2005'. A scenario analysis consists of 25 sequential runs of Monte Carlo simulations over a period of 100 years (*Figure 5*). Monte Carlo simulation is a technique for producing more accurate estimates of stochastic process outcomes by running many iterations of the model and averaging the outcomes together. This approach better accommodates the effect of important stochastic landscape processes such as wildfire, which can have large 'random' effects on scenario outcomes, particularly for habitat-related indicators.

Scenario outputs were reviewed to compare the relative contribution of each sector to landscape change and economic activity, and to evaluate key assumptions with respect to surface disturbance estimates, habitat response, and the cumulative impact of land use activity within the study areas.

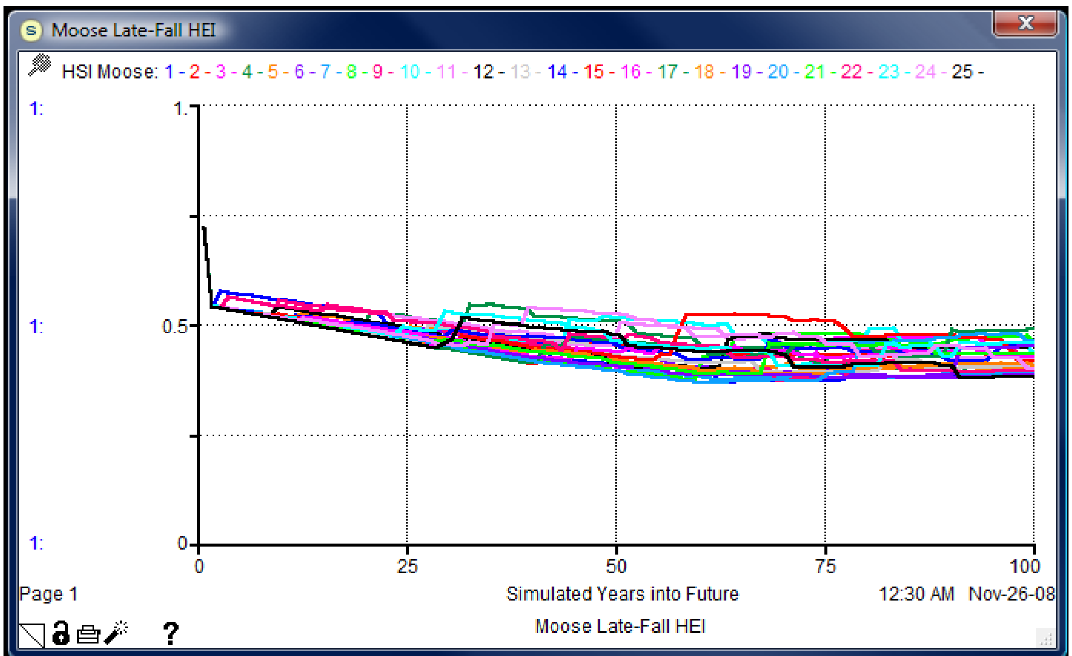

Figure 5. Example ALCES® output graph showing results of 25 Monte Carlo simulations. Year '0' on the x-axis represents the year '2005'. Each line color on the graph represents one simulation run of 100 years. The results of 25 different simulations are shown on the same graph to provide an estimate of natural variation in moose habitat conditions that may result from wildfire or other natural processes. In this example, moose late-fall habitat effectiveness ranges from 0.40 to 0.58.

2.4 INDICATORS

Indicators are measurable signals that can be used to assess the performance of a system. The North Yukon Regional Land Use Plan proposes to use a results-based management framework to determine if land use plan goals and objectives are being met (Yukon and Vuntut Gwitchin Governments 2009). Indicators are a necessary component of the results-based framework.

The ALCES® model tracks potentially hundreds of economic, social and ecological indicators. For this exercise, important indicators included commodity production, revenues and employment, levels of land use footprints, and changes in landscape composition and relative habitat value for focal wildlife species (barren-ground caribou and moose). *Table 4* lists the indicators examined, with more detailed descriptions following. Indicators are organized by sustainable development theme. Not all indicators were examined or relevant for each land use sector.

Indicators were chosen to allow meaningful comparisons between different scenarios, land uses and operating practices. Indicator evaluation allows planners, resource managers, project assessors and regulators to use model results to assess levels of risk to valued resources associated with different policy and operational decisions.

Table 4. North Yukon land use scenario indicators.

Indicator Type	Indicator	Description
Socio-economic	Commodity Production	Amount of commodity produced by a land use activity, expressed as m^3 for Oil and Gas / Mining, and tourism activity days (TADs) for Tourism.
	Revenue	Dollar ($) value of commodity production.
	Employment	Full Time Equivalent (FTE) annual employment.
	Wages	Dollar ($) value of annual wages earned by sector employees.
	Royalties	Dollar ($) value of annual resource sector royalties generated.
	Regional Human Population	Full time resident human population.
Land Use and Ecological	Land Use Infrastructure	Sector specific infrastructure metrics that aid in better understanding surface disturbance and linear density indicators.
	Surface Disturbance	Total amount of direct human-caused surface disturbance (i.e. direct land use footprint) expressed as % of study area or ha.
	Linear Density	Total length of linear features (roads, seismic lines and trails) within a given area, expressed as km/km^2. Linear density may also be referred to as access density.
	Habitat Suitability Index (HSI)	Relative ranking of wildlife habitat quality in the absence of potential human-caused habitat effects. HSI ranges from a value of 0 (no habitat value) to 1 (perfect habitat value). Indicator is used for Range of Natural Variability runs. Two wildlife focal species HSI indicators were examined: • Barren-ground caribou winter HSI • Moose late-fall HSI
	Habitat Effectiveness Index (HEI)	Relative ranking of wildlife habitat quality, with consideration of potential human-caused habitat effects. Like HSI, HEI ranges from a value of 0 (no habitat value) to 1 (perfect habitat value). HEI can be compared against HSI to understand potential land use impacts. Two wildlife focal species HEI indicators were examined: • Barren-ground caribou winter HEI • Moose late-fall HEI

2.4.1 Socio-economic Indicators

Commodity Production
Each land use results in the production of some resource or activity. The units of production are sector specific: cubic metres (m^3) for Oil and Gas and Mining; tourism activity days (TADs) for Tourism. ALCES® utilizes a commodity-based approach to generate revenue and employment metrics (i.e. revenue and employment metrics are derived from units of production through the use of coefficients).

Revenue
Revenue is the dollar ($) value of commodity production for each land use sector. The commodity production of each land use sector contributes to overall economic output, calculated as dollar ($) value per unit of production.

Employment
Land use requires some level of human effort to produce commodities. ALCES® tracks the employment generated directly by a land use activity, as well as indirect jobs providing essential services to those sector employees. Employment is expressed in annual full time equivalent (FTE) jobs.

Wages
Dollar ($) value of wages earned by land use sector employees.

Royalties
Resource royalties represent the proportion of revenue paid by private companies to governments for the right of to produce natural resource commodities. Royalty rates are often not fixed, and may change based on economic conditions. Oil and gas and mineral production result in royalty payments to governments that can then be used for a variety of purposes, including funding health, education and social service programs.

Regional Human Population
A number of potential social indicators were discussed during the initiation of this project, including First Nation resident time on the land and the concept of 'community well-being'. Considering the time and funding available, the modeling team did not pursue these or other potential social indicators at this time. Instead, regional human population was considered to provide a reasonable proxy for representing the potential effects of increasing land use and economic activity on First Nation residents and the community of Old Crow. Other authors (e.g., Berman et al. 2004; Berman and Kofinas 2004; Kruse et al. 2004) have examined possible social responses to different levels of economic activity and land use in northern Yukon.

2.4.2 Land Use and Ecological Indicators

Land Use Infrastructure
Physical land use infrastructure is the 'built features' that support land use activity. Infrastructure includes features such as roads, communities, seismic lines and gravel pits. Physical infrastructure creates land use footprints (i.e. surface disturbance). Understanding the type and amount of infrastructure required to support different levels and types of land use activity contributes to a better understanding of surface disturbance and linear density indicators, and potential mitigation strategies.

Surface Disturbance
Surface disturbance is the visible 'footprint' of human land use; it is the amount of area physically disturbed by human activities. Land use features such as townsites, roads, gravel quarries, seismic lines and airstrips produce physical, visible footprints that create direct habitat impacts. Increasing levels of surface disturbance generally represent increasing risks to the integrity of ecological systems (Holling 1973; Franklin 1993).

Most land uses result in some level of surface disturbance. However, the extent and duration of land use footprints (i.e. the 'footprint lifespan') depends on the type, intensity and scale of the land use activity, and the resilience of the affected landscape type. Total amount of surface disturbance is measured either in hectares (ha) or the proportion of the study area affected (%).

Surface disturbance is a direct measure of habitat loss that does not account for potential 'indirect effects' of the land use features. Indirect effects may include increased mortality risk due to predation, human hunting or vehicle collisions, or habitat avoidance. The total potential 'effect' of land use features, incorporating both direct and indirect effects, can be quantified through an indicator such as Habitat Effectiveness, as described below.

Linear Density
A significant consequence of land use activity is the creation of linear features. Linear density is the total length of all linear features (roads, trails, pipelines, seismic lines, etc.) within a given area; it is expressed as km's of linear features per km^2 of study area (km/km^2). Linear density is an indicator of habitat fragmentation—the division of larger areas of habitat into smaller areas. Habitat fragmentation leads to a reduction in core habitat area, and in some ecosystems has been correlated with a range of species shifts, where non-native wildlife and plant species replace native species (e.g. white tailed deer replacing woodland caribou in southern boreal forests).

Linear features can also facilitate human access into previously inaccessible areas—for this reason linear density is sometimes referred to as 'access density'. Increasing levels of human access may result in increased harvesting of wildlife and fish, and a change in how people and wildlife use the land. Higher rates of natural predation for species like woodland caribou have been recorded in proximity to linear features.

Linear density is an important indicator of cumulative land use impacts. Generally, as linear density increases, so does the level of risk to overall ecological integrity (Forman and Alexander 1998; Trombulak and Frissell 2000).

Habitat Suitability Index (HSI)

Habitat suitability provides a relative measure of the amount and value of habitat available to wildlife in the absence of human land use impacts[4]. Habitat suitability ranges from 0 (no habitat value) to 1 (perfect habitat value). No regional landscape receives 'perfect' habitat suitability scores for any given wildlife species.

In this project HSI was only examined for the range of variability model runs, and serves to provide a baseline against which HEI can be compared. Habitat suitability was examined for two focal wildlife species during relevant biological time-periods:

1. **Barren-ground caribou, winter period (December 1 to March 31)**
   - The largest numbers of Porcupine caribou occupy the region during winter
   - Winter, and in particular late winter, is an energetically demanding season for barren-ground caribou
   - Most industrial land use activities will occur in winter
2. **Moose, late-fall period (rut to late fall/freeze-up, September 16 – October 31)**
   - Moose utilize upland forested habitats during the fall rut, similar habitats as would be impacted by potential oil and gas activities in Eagle Plain
   - Most moose harvesting occurs during this period; managing harvest access is a relevant management issue

Habitat Effectiveness Index (HEI)

The total effect of human features on ecological resources is a result of 'direct' (footprint) effects, and 'indirect' effects that result from avoidance or use of the features. Direct measures of land use footprints only account for the direct physical disturbance to wildlife and fish habitats—they do not account for 'indirect' effects. The indirect effects of human footprints on wildlife may include habitat-related impacts such as zones of avoidance or reduced-use, or population related effects such as increased predation and mortality.

Indirect effects depend on the type of feature and the intensity of use of that feature. While a land use feature may physically disturb a small area, the indirect effect of that feature may extend far beyond the physical footprint. For example, a major highway with high levels of vehicle traffic generally has a much greater 'effect' on wildlife than a low impact seismic line with limited human use.

Habitat effectiveness attempts to quantify both the direct and indirect effects of human land use features on wildlife. Habitat effectiveness measures the value and amount of habitat available to wildlife after taking into account the potential disturbance effects of human development and activities. It is the percentage of suitable habitat after taking into account the potential displacement effects of human land use.

Habitat effectiveness calculations require three data inputs: 1) habitat suitability value (i.e. habitat value in the absence of human effects), 2) zone of influence (ZOI), and 3) disturbance

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[4] Habitat Suitability: North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) contains detailed methods and results of barren-ground caribou, moose and marten wildlife habitat suitability mapping for the planning region.

coefficients (habitat suitability reduction within the ZOI). ALCES® calculates habitat effectiveness by applying a table of user-defined disturbance coefficients within user-defined zones of influence to habitat suitability values. Like habitat suitability, habitat effectiveness ranges from 0 (no habitat value) to 1 (perfect habitat value). No regional landscape receives 'perfect' habitat effectiveness scores for any given wildlife species.

In order to quantify potential habitat-related impacts, habitat effectiveness was compared against habitat suitability for the same focal species during their relevant biological periods: 1) **barren-ground caribou, winter period**; and 2) **moose, late-fall period**.

2.5 SENSITIVITY ANALYSIS

Some variables act as 'drivers' of landscape change, with some potentially having a more significant effect than others. In the ALCES® model, the relative influence of potential land use activities and practices, natural disturbance regimes, and climatic effects can be isolated, modified, and examined. Conducting sensitivity analyses is important to examine the relative effect of different parameters, and assists in establishing confidence estimates for those parameters. With a view to important regional planning issues, sensitivity analysis was conducted on the following five key parameters.

2.5.1 Snow Condition and Barren-ground Caribou Habitat Quality

The Porcupine Caribou Herd is considered to be the most important ecological and cultural resource in the North Yukon Planning Region (North Yukon Planning Commission 2007a,b). The distribution, depth and hardness of snow cover are important factors influencing barren-ground caribou winter habitat quality, and caribou movements. Snow characteristics are particularly important for the Porcupine Caribou Herd (Russell et al. 1992 and 1993) and have important energetic implications for individuals and the overall population (Russell et al. 2005). Under poor snow conditions, additional energy is required to travel and forage for terrestrial lichens, the caribou's primary winter food source. In winters with high snow depth or high snow hardness, access to lichens may be limited, causing caribou to utilize marginal habitats with limited lichen resources but that have more favourable snow conditions. In this manner, caribou winter range use may be determined as much by snow condition as by habitat quality (i.e. caribou may select less lichen rich areas if snow conditions are favourable).

In the North Yukon Planning Region ALCES® model, barren-ground caribou winter habitat suitability under different snow conditions is controlled using a coefficient representing snow pack resistance. Model runs were conducted with and without the application of the snow resistance coefficients, representing 'poor' and 'normal' snow conditions for barren-ground caribou, respectively. In this manner, the relative effect of snow condition on regional barren-ground caribou winter habitat quality was examined. The version of the ALCES® model used for this project did not model annual variability in snow resistance or patterns, so this approach only provided a general method to examine the relative effect of snow condition on habitat quality across the planning region for the entire 100-year run.

2.5.2 Climate Change

Climate change is anticipated to have large effects on biophysical and wildlife habitat conditions at high northern latitudes. Some of the highest rates of global climatic change are expected in northern Yukon. Understanding the potential effects of climate change was therefore considered to be an important regional planning issue (North Yukon Planning Commission 2007a,b). In this modeling exercise, the ALCES® climate change scenario is based on an average 0.5°C warming trend per decade with the following general effects:

- Doubling of average area burned by wildfire at 100 years
- Landscape type transitions:
  - gradual conversion of Wet Herb (i.e., tussock tundra) to Wet Shrub
  - gradual conversion of High Elevation Herb to High Elevation Shrub and High Elevation Forest
- Increasing variability in temperature and precipitation
- Increasing winter snow depths (i.e. more years with poor snow conditions for barren-ground caribou)

ALCES® represents climate change through the application of a 'drought index'. The drought index reflects the combined effect of changes in precipitation and evaporation regimes. Under the 0.5°C climate warming scenario, the drought index is anticipated to increase. While overall levels of annual precipitation may increase, particularly in winter, evapotranspiration is expected to increase at a faster rate than potential increases in precipitation, resulting in an overall 'droughtier' climate regime. Recent reported changes in Arctic lakes and stream flow characteristics in northern unglaciated hydrologic basins support this hypothesis (e.g. Hinzman et al. 2005; Smith et al. 2005; Fleming and Clark 2002).

The version of ALCES® used for this project allows increasing annual variability in temperature and precipitation to be modelled, but intra-annual variation in precipitation could not be represented (i.e. ALCES® models precipitation in annual increments and was not able to isolate summer from winter precipitation). The use of snow resistance coefficients to model high and low snow depth conditions, as described in 2.5.1, above, provided a method to overcome this situation. With increasing winter snow depths predicted under the 0.5°C per decade warming scenario, the snow resistance index should therefore be considered part of the climate change scenario. High snow depth conditions, modeled through the application of the snow resistance coefficients, may be interpreted as potential future winter climate conditions with an increasing frequency of high depth snow years.

The drought index does not explicitly account for climatic-induced changes in soil moisture or permafrost depth that may result from climate change, but these have been partially accounted for through projected landscape type transitions.

2.5.3 Oil and Gas Best Management Practices

Best management practices (BMP's) are management activities or operational practices that can reduce the time, intensity or duration of industrial activities or footprints on the landscape. BMP's are generally not prescriptive, but a general suite of operating practices is well established for different land use sectors.

In the North Yukon Planning Region, potential future energy sector operating practices may have a major effect on the scale and intensity of potential landscape impacts, particularly in the Eagle Plain Study Area. BMP's were therefore considered to be important considerations for the regional land use plan and this modeling exercise. In order to quantify the relative effect of different plausible operating practices, three different BMP scenarios were examined for the Eagle Plain Study Area (*Table 5*). Due to the preliminary nature of tourism and mineral scenarios, different BMP parameters were not examined for those sectors.

The 'base case' oil and gas scenario for Eagle Plain Study Area assumes BMP Scenario #3 operating practices and seismic line lifespan.

By adopting specific operating practices, it is possible for the oil and gas sector to operate in a manner that reduces direct impacts on the landscape. For example, reducing the width of seismic lines reduces the overall area of seismic lines (less direct footprint). Smaller and lighter equipment used to create narrow lines may result in reduced soil impacts, potentially leading to faster regeneration rates. Similarly, an increase in the number of gas or oil wells per well pad reduces the overall number of well pads on the landscape (less direct footprint). Fewer well pads also result in reduced access road construction (less direct footprint and fewer linear features), which has associated effects on aggregate requirements (reduced aggregate production results in less direct footprint).

Table 5. Eagle Plain Study Area oil and gas best management practice scenarios. *

Parameter	BMP Scenario #1	BMP Scenario #2	BMP Scenario #3
Average Seismic Line Width	5m	3m or less	3m or less
Seismic Line Lifespan	30 years	10 years	10 years
Number of Wells per Pad	1	1	4

* Note: BMP Scenario #3 represented the 'base case' operating practices and assumptions for the Eagle Plain Study Area oil and gas scenario.

2.5.4 Seismic Line Regeneration

Seismic lines are a type of linear feature that result from oil and gas exploration. The length of time required for a seismic line to regenerate back to a condition when it is no longer considered a 'functional disturbance' is an important management question. Seismic line regeneration rates are variable and may be influenced by the method of creation, seismic line width, landscape type, fire history, and level of use.

The North Yukon Land Use Plan uses the following definition for determining when a land use disturbance, such as a seismic line, may be considered re-vegetated (reclaimed):

> *"a linear feature or other human-caused surface disturbance that in its current state, does not facilitate increased access or travel. In forested areas, a feature can be considered reclaimed when it contains woody vegetation (trees and / or shrubs) approximately 1.5m in height"*

Lifespan assumptions for other land use features are listed in *Table 6*. For the purpose of this project, seismic line disturbances were assumed to be width-modified, with wider features having a longer residence time than narrow features. The rationale for this decision is that larger, heavier equipment has a higher likelihood of creating soil disturbance, leading to longer recovery times.

Table 6. Estimated base case footprint lifespan for North Yukon feature types.

Feature Type	Lifespan (years)
Major Road (Dempster Highway)	100
Access Road	50
Winter Road (Old Crow Winter Road)	100
Community Use Trail	30
Trail (unclassified historical linear feature – winter access route)	60
Airstrip	100
Gravel Pit	75
Well Site	60
Seismic Line	Width-modified (see *Figure 6*)
Pipeline	60
Hard Rock Mine	40
Settlement	100
Traditional Camp	100
Tourism / Visitor Facility	100
Work Camp	100

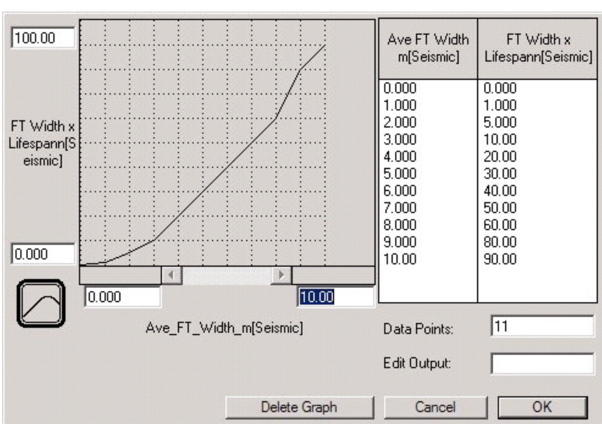


Figure 6. Width-modified seismic line lifespan for Eagle Plain oil and gas scenario base case (<3m seismic lifespan is 10 years; 5m seismic is 30 years).

The residence time of linear features such as seismic lines can have a large effect on ecological indicators such as linear density and habitat effectiveness. As part of the sensitivity analysis, three seismic line regeneration rates (5, 10 and 20 years) were examined for the oil and gas exploration and development scenario. Different regeneration rates were also included as part of the oil and best management practices analysis (*Table 5*, above).

2.5.5 Linear Feature Zone of Influence

Roads, seismic lines, winter trails and similar land use features are considered linear features. Access management refers to the management and control of human activities on linear features. Linear features are currently the largest source of human-caused footprint in the planning region. Given the nature of anticipated industrial land uses, linear features may also be a significant source of future footprint. Understanding the potential habitat impacts of linear features is therefore important.

As discussed in Section 2.4.2, calculating habitat effectiveness requires three variables: 1) habitat quality (i.e. suitability), 2) the zone of influence (ZOI) around land use features (i.e. the area around land use features in which wildlife are affected), and 3) disturbance coefficients (i.e. the intensity of habitat quality reduction within the ZOI). While it is generally agreed that barren-ground caribou and moose are negatively affected by high levels of linear features, there is considerable disagreement regarding feature ZOI's, and the intensity of wildlife response to those features.

Mechanisms for population decline are not well understood, but likely include habitat-related effects such as avoidance or reduced-use, or population related effects such as increased predation, human harvest, and mortality. Numerous studies have suggested zones of influence or reduced-use ranging from 100m to several kilometres around different land use features. Regardless of the ZOI distances, most studies agree that linear density is a key indicator of ecological integrity.

Barren-ground Caribou
Land use feature ZOI values for different feature types were estimated for barren-ground caribou based on existing literature and professional opinion (*Table 7*). The land use scenarios were modeled with these ZOI values.

To better understand the potential effect of linear feature ZOI on barren-ground caribou winter habitat effectiveness, two additional combinations of linear feature buffers were examined:

- 5,000m ZOI on Dempster Highway; and,
- 250m on seismic lines.

Disturbance coefficients for barren-ground caribou were estimated to result in 50% habitat suitability reduction within the feature ZOI's; different disturbance coefficients were not examined as part of the sensitivity analysis.

Table 7. Estimated barren-ground caribou land use footprint zones of influence (ZOI).

FOOTPRINT TYPE		ZONE OF INFLUENCE	SOURCES *
FT Name	FT Code	Buffer in metres	
Major Road (Dempster Hwy)	Major Rd	1000	UNEP (2001)
Access Road	Access Rd	500	UNEP (2001)
Winter Road (Old Crow W. R.)	Winter Rd	500	Professional opinion
Community Use Trail	Comm Trail	500	WCACSC
Trail	Trail	100	Professional opinion (given low human use, assumed less than 250m ZOI typically referenced)
Seismic Line	Seismic	100	Professional opinion (given low use, assumed less than 250m ZOI typically referenced)
Pipeline	Pipeline	250	WCACSC. Pipeline rights of way typically have higher levels of human and predator use than seismic lines.
Airstrip	Airstrip	1000	UNEP (2001)
Well Site	Well Site	500	WCACSC. Stated ZOI is more reflective of active well sites than abandoned well sites.
Gravel Pit	Gravel Pit	500	Professional opinion
Mine Site	HR Mine	1000	WCACSC. ZOI developed for open pit coal mines in west-central Alberta.
Settlement	Settlement	1000	UNEP (2001)
Traditional Camp	Trad Camp	250	Professional opinion (assumed less than permanent Settlements)
Tourism / Visitor Facility	Tourism Fac	500	UNEP (2001)
Work Camp	Work Camp	1000	Professional opinion (assumed same as permanent Settlement)

* Sources:

United Nations Environment Programme (UNEP). 2001. C. Nelleman, L. Kullerud, I. Vistnes, B.C. Forbes, E. Husby, G.P. Kofinas, B.P. Kaltenborn, J. Rouaud, M. Magomedova, R. Bobiwash, C. Lambrechts, P.J. Schei, S. Tveitdal, O. Grøn, and T.S. Larsen. GLOBIO: Global methodology for mapping human impacts on the biosphere. UNEP/DEWA/TR. 01-3.

West Central Alberta Caribou Standing Committee (WCACSC). 1996. 1996/97 operating guidelines for industrial activity in west central Alberta. Unpublished report. WCACSC, Grand Prairie, AB.

Moose

Some human footprint types create suitable moose habitat. However, these footprints, especially linear features, may also create access to moose populations that can result in increased harvest pressures.

Our base scenario assumed that increased human harvesting may occur around accessible all season features during the fall hunting season. To simulate this effect, a 2000m buffer was applied to the following features:

- Major Road (Dempster Highway);
- Access Road (all-season access roads);
- Airstrips;

- Gravel pits;
- Traditional Camps; and,
- Permanent Settlements.

This 2000m buffer simulates potentially increasing mortality risk in proximity to accessible land use features. Outside of the major river corridors, the majority of future late-fall hunting pressure is anticipated to occur around these features—moose mortality risk increases in proximity to all-season infrastructure. Access management is therefore an important issue for moose.

To examine the potential effect of increasing harvest risk around land use features, a 2000m buffer was applied to all linear features (i.e. seismic lines, winter roads, trails and community trails and pipelines) during sensitivity runs.

2.5.6 Access Management

As discussed previously, access management is often referenced as being an important management strategy for minimizing the potential indirect effects of all-season infrastructure on barren-ground caribou and moose. Specifically, access management can, if implemented adequately, effectively reduce or remove potential human harvest pressures along land use features.

To explore the potential effects of access management on barren-ground caribou and moose HEI, buffers were removed from all linear features during sensitivity runs.

3. RESULTS

3.1 RANGE OF VARIABILITY

In the absence of new land use activity, landscape change in the North Yukon Planning Region will be driven by natural processes. Over time, most existing, non-permanent land use footprints will re-vegetate. Prior to considering new land use activity, gaining an understanding of how natural processes affect the condition of key indicators is required. Such an understanding provides a baseline to compare against new potential land use. Results for RNV and range of variability under the current landscape composition are discussed for the Regional and Eagle Plain study areas.

3.1.1 Regional Study Area

3.1.1.1 Range of Natural Variability

Focal Species Wildlife Habitat Suitability

Barren-ground Caribou Winter HSI
A large proportion of the North Yukon Planning Region is high or moderate quality winter barren-ground caribou habitat. The RNV for the barren-ground caribou winter habitat suitability fluctuates between a narrow range of 0.62 and 0.70 (*Figure 7a*). All values are very close to the potential 'optimum' value of 0.70, suggesting that at the planning region scale, wildfire does not appear to be a major driver of winter habitat suitability for barren-ground caribou.

The mix of high and low elevation, forested and non-forested habitats within the region creates a diverse landscape composition that, regionally, buffers the effects of stochastic events such as large wildfires on habitat conditions. Habitat suitability under low or normal snow conditions is therefore maintained within this relatively narrow range throughout the model runs.

This RNV for winter HSI was modeled under the assumption of low or normal snow conditions. The relative effect of snow condition on barren-ground caribou winter habitat suitability is discussed in Section 3.1.3.1, below.

Moose Late-Fall HSI
A large proportion of the North Yukon Planning Region is moderate quality late-fall moose habitat. The RNV for moose late-fall HSI naturally ranges between 0.42 and 0.53 (*Figure 7b*). The moose late-fall HSI index is below its potential maximum HSI of 0.63 due to the ongoing effects of wildfire on forest age-class, and the relatively large proportion of moderate quality habitat types.

High quality late-fall moose habitats generally occur within low elevation forested landscapes similar to Eagle Plain. These landscapes are strongly affected by wildfire, and forest seral stage is a significant factor influencing moose habitat quality. Moose are generally described as preferring younger seral stages for most life stages. However, in the late-fall period, a range of seral stages, including older forests, are considered to have high habitat value.

The RNV in habitat suitability is higher for moose than barren-ground caribou due to the influence of wildfire and its effect on habitat quality. However, similar to barren-ground caribou, the planning region is large and there is a sufficient diversity in habitat types and forest age-classes that the range in RNV is relatively low throughout the 100-year modeling period.

a)

b)

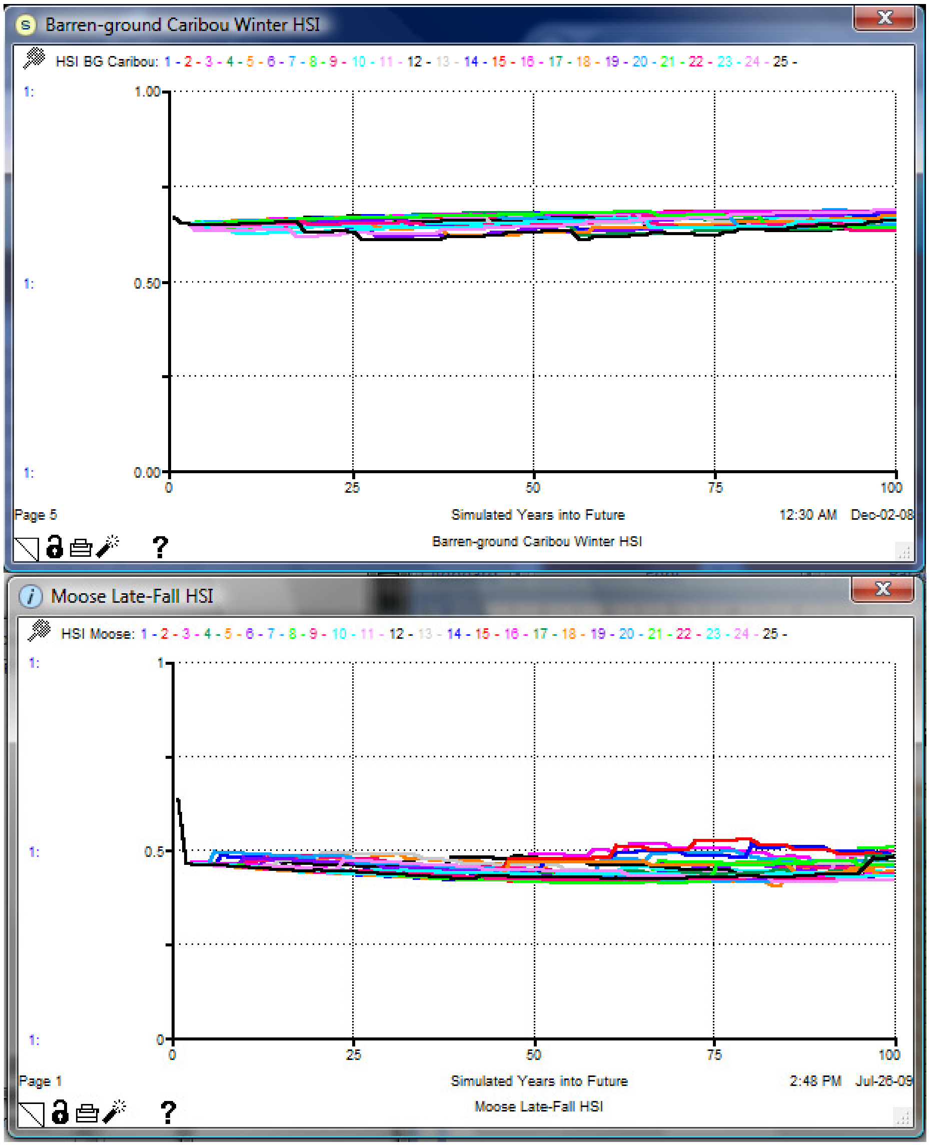


Figure 7. Regional Study Area range of natural variability (RNV): a) barren-ground caribou winter HSI; b) moose late-fall HSI.

3.1.1.2 Range of Variability, Current Landscape Composition

Land Use Footprints

Surface Disturbance

The amount of surface disturbance in the North Yukon Planning Region, not factoring current reclamation status, was initially estimated to be 9,500ha (0.18% of region) (*Figure 8a*). As described in Section 2.2.5, at least 20% of the historical footprint is considered to be reclaimed. This 20% reduction (1,950ha) is reflected in the notable decrease observed in year 2 [5], for a current estimated level of 7,550ha. After the 100 year model run, the amount of surface disturbance is reduced to approximately 2,500ha (0.05% of region).

The initial rate of feature removal is relatively rapid, as small, non-permanent linear features (i.e. seismic lines) are naturally re-vegetated. Some land use features, such as winter roads and gravel pits have longer reclamation times, and persist on the landscape for many years. Some features, such as major roads and settlements, are considered permanent; these features account for all remaining footprint at year 100.

Linear Density

Linear density (*Figure 8b*) follows a similar pattern, decreasing from an initial value of 0.14km/km^2 in year 2 to 0.03 km/km^2 over the 100 year model run. The natural re-vegetation of seismic lines is responsible for the relatively rapid decrease in linear density during the first 50 years. At the end of 100 years, only relatively permanent footprints remain.

There is limited variation around the rate of footprint reclamation. The only major factor affecting surface disturbance and linear density indicator levels is the occurrence of wildfire—model runs with large fire years result in higher rates of natural seismic line regeneration on upland sites, speeding the removal of these features from the landscape. These regeneration ‘pulses’ affect the long-term trajectory of feature removal.

[5] Note: ALCES© builds all land use footprints in year 1 of the model run, and then adjusts for specified reclamation status in year 2, resulting in the large decrease observed in that year.

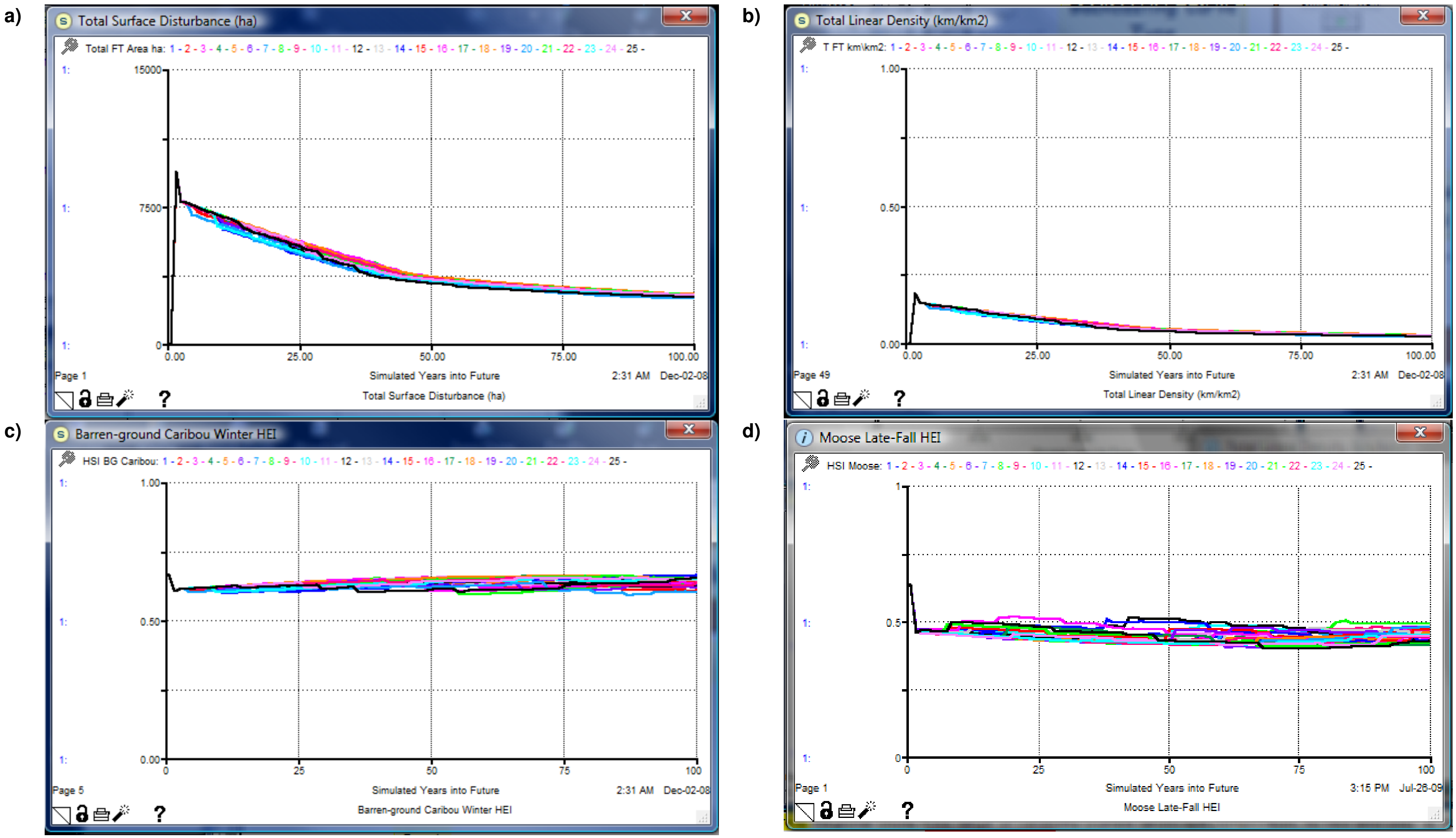


Figure 8. Regional Study Area range of variability (current landscape composition, no new land use): a) surface disturbance, b) linear density, c) barren-ground caribou winter HEI, and d) moose late-fall HEI.

Focal Species Wildlife Habitat Effectiveness

Barren-ground Caribou Winter HEI
The current winter HEI value for barren-ground caribou is approximately 0.65 (*Figure 8c*), well within the range of RNV reported in *Figure 7a* (range of 0.62 to 0.70). As non-permanent land use features (e.g. seismic lines and winter trails) re-vegetate over the course of the 100-year modeling period, winter HEI increases only marginally, returning to near its maximum HSI value of 0.70.

These findings suggest that regionally, the level of existing habitat impacts resulting from historic and current land use activity is low, and that winter habitat quality has not been shifted to a state outside of the expected RNV. In the absence of new land use activities, the occurrence of large fires in any given model run is the largest factor affecting regional variation in HEI.

While the re-vegetation of non-permanent land use features increases barren-ground caribou winter HEI over the 100-year period, the HEI value does not fully recover to its maximum level of 0.70, as some features are permanent and do not reclaim (e.g. community of Old Crow, Dempster Highway).

This RNV for winter HEI was modeled under the assumption of low or normal snow conditions. The relative effect of snow depth on barren-ground caribou winter habitat quality is discussed in Section 3.1.3.1, below.

Moose Late-fall HEI
The current late-fall HEI value for moose is approximately 0.46 (*Figure 8d*), well within the RNV for regional habitat suitability reported in Figure 7b (range of 0.42 to 0.53). The re-vegetation of non-permanent land use features (e.g. seismic lines and winter trails) over the 100-year model run does not result in a notable improvement in late-fall HEI.

This finding suggests that regionally, the level of existing habitat impacts on moose resulting from historic and current land use activity is very low, and that forest age-class is the most significant factor affecting moose late-fall HEI.

3.1.2 Eagle Plain Study Area

3.1.2.1 Range of Natural Variability (RNV)

Focal Wildlife Species Habitat Suitability

Barren-ground Caribou Winter HSI
Without factoring the potential habitat impacts of historical land use, the current winter HSI value for barren-ground caribou is approximately 0.60, versus a maximum potential value of 0.75 (*Figure 9a*). This reduction in the current HSI is due to the forest age-class distribution that has resulted from wildfires over the past 30 years. Most notably, the large wildfires of 2004 burned about 500,000ha of Eagle Plain in a single season; much of the landscape is therefore in

a young seral condition and does not yet support terrestrial lichens, the preferred winter forage of barren-ground caribou.

With a potential HSI of 0.75, the Eagle Plain Study Area has a higher potential habitat suitability index than the Regional Study Area (*Figure 7a*). Mature spruce forests in Eagle Plain contain the highest abundance of terrestrial lichens in the planning region (Russell et al. 1993).

Over the 100-year model runs, HSI increases from its initial state of 0.60. After 100 years, the RNV for winter habitat suitability ranges from a low of 0.64 to a maximum of 0.72. The effect of major wildfires is clearly evident in the HSI graphs for individual model runs. Given the vigorous fire regime of Eagle Plain, there is a larger amount of natural variation in barren-ground winter HSI values than observed across the Regional Study Area (*Figure 7a*).

The RNV results for Eagle Plain also suggest that for barren-ground caribou, the current landscape composition may be outside of the historical RNV, primarily as a result of the 2004 wildfires. The first 50-years of modeling runs demonstrate a landscape that is recovering from a large perturbation. The RNV around year 100 (range of 0.64 to 0.72) may therefore be more reflective of the historical natural range in habitat quality.

While a large portion of the Eagle Plain Study Area contains potential high quality winter caribou habitat (i.e. mature spruce forest with lichen ground cover), the value of this habitat is strongly influenced by snow conditions. The Eagle Plain Study Area typically receives the highest accumulation of late winter snow in the planning region, making much of this habitat energetically costly to utilize. These RNV results are modeled under low or normal snow conditions—the relative effect of snow depth on barren-ground caribou winter HSI in Eagle Plains is discussed in Section 3.1.3.1, below.

<u>Moose Late-Fall HSI</u>

Without factoring the potential habitat impacts of historical land use, the current moose late-fall HSI value is approximately 0.54, compared to a maximum potential value of 0.73 (*Figure 9b*). As with barren-ground caribou winter HSI for Eagle Plain, this reduction in the current HSI is due primarily to the forest age-class distribution that has resulted from wildfire, with the 2004 fire season being of particular importance.

A large proportion of the Eagle Plain Study Area is high quality potential late-fall moose habitat. During this fall period, moose prefer low and mid-elevation, upland forested ecosystems. With a potential HSI of 0.73, the Eagle Plain Study Area has a higher late-fall potential habitat suitability index than the Regional Study Area (*Figure 7b*).

In Eagle Plain, the RNV for moose late-fall HSI naturally ranges between 0.39 and 0.58. Over the 100-year model runs, late-fall HSI gradually decreases from its initial value of 0.54 to approximately 0.42 in year 60, and then stabilizes or slightly increases for the remaining 40 years. At 100-years, the RNV for late-fall HSI ranges from 0.40 to 0.49. The last 50 years of the simulations may be more representative of the historical RNV—the first 50 years represents a period of recovery from (i.e. aging forests) from the large 2004 fire events.

The effect of major wildfires, and vegetation recovery from wildfire, is visible in both the barren-ground caribou and moose HSI graphs for individual model runs. Given the vigorous fire regime of Eagle Plain, there is a larger range of natural variation in moose late-fall HSI values than observed across the Regional Study Area.

a)

b)

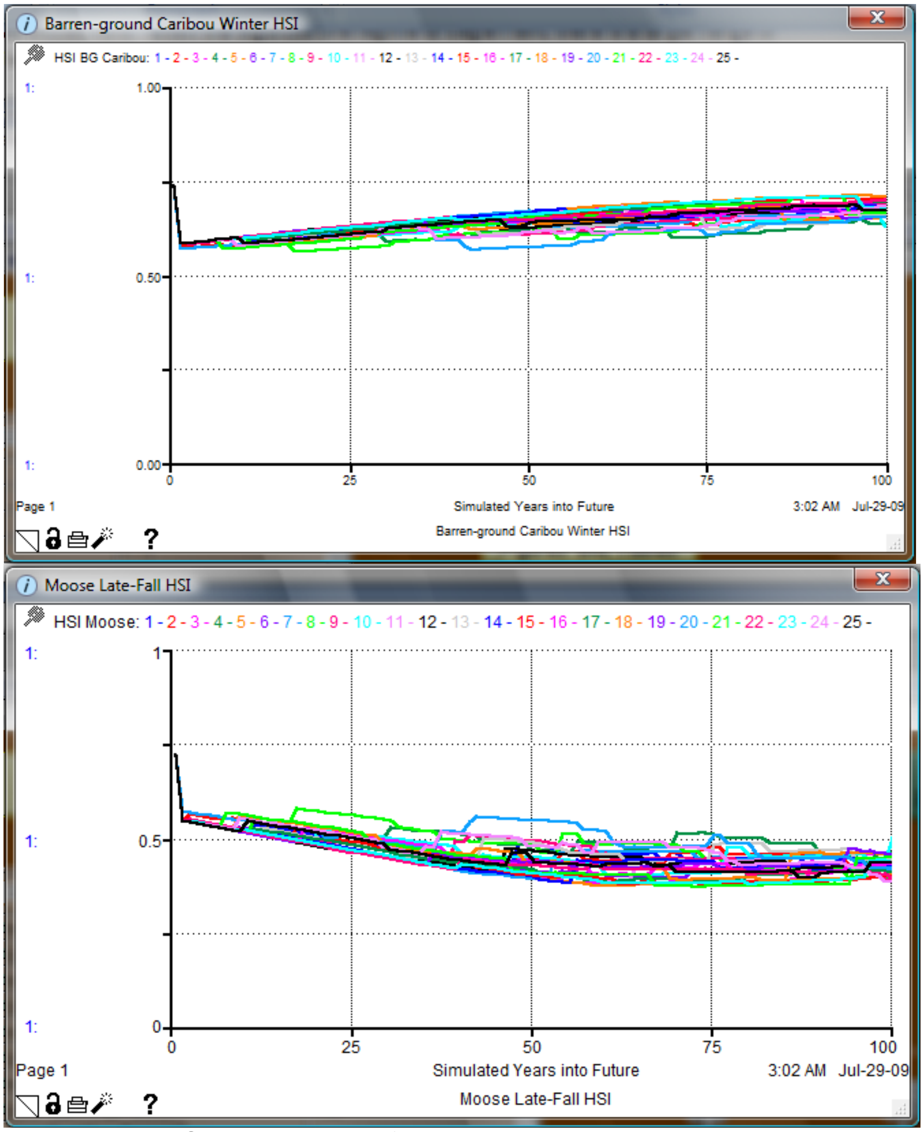


Figure 9. Eagle Plain Study Area range of natural variability (RNV): a) barren-ground caribou winter HSI; b) moose late-fall HSI.

3.1.2.2 Range of Variability, Current Landscape Composition

Land Use Footprints

Surface Disturbance

For the Eagle Plain Study Area, surface disturbance shows an initial cumulative footprint of approximately 6,900ha (0.50% of study area) (*Figure 10a*). As with the Regional Study Area, this initial historical footprint is considered 20% reclaimed in year 2, and is eventually reduced to approximately 1,400ha (0.10% of study area) after the 100-year model run.

The higher initial footprint reflects the concentration of historical land use surface disturbances, mainly seismic lines and winter trails, within the Eagle Plain oil and gas basin. The rate of feature removal over the first 50-years is relatively rapid, as small, non-permanent linear features (i.e. seismic lines) are naturally reclaimed. Permanent features such as the Dempster Highway account for all remaining footprint at year 100.

Linear Density

Linear density (*Figure 10b*) follows a similar pattern, decreasing from the current level of 0.45km/km^2 to 0.07 km/km^2 over the 100-year model run. The natural re-vegetation of seismic lines and winter trails is responsible for the relatively rapid decrease in linear density during the first 50 years. At the end of 100 years, only permanent footprints remain.

As with the Regional Study Area, there is limited variation around the rate of footprint reclamation. The only major factor affecting surface disturbance and linear density indicator levels is the occurrence of wildfire—model runs with large fire years result in higher rates of natural seismic line reclamation on upland sites, speeding the removal of these features from the landscape.

Focal Species Wildlife Habitat Effectiveness

Barren-ground Caribou Winter HEI

Factoring historical land use impacts, the current barren-ground caribou winter HEI value for Eagle Plain is 0.50 (*Figure 10c*), an approximate 20% reduction from the initial RNV value of 0.60. This initial value is below the lower range of RNV reported in *Figure 9a* (range of 0.60 to 0.73). However, as described in Section 3.1.2.1, the current landscape composition may be naturally outside of the RNV as a result of the very large areas burned during the 2004 fire season.

The re-vegetation of non-permanent land use features (e.g. seismic lines and winter trails) over the course of the 100-year modeling period does not contribute significantly to the increase in winter HEI; forest recovery from the 2004 wildfires accounts for the majority of habitat quality increase.

These findings suggest that the level of existing habitat impacts resulting from historic and current land use activity has reduced the natural habitat quality in Eagle Plain by approximately 20%. In the absence of new land use activities, the occurrence of large fires in any given model run is the largest factor affecting regional variation in HEI.

While the re-vegetation of non-permanent land use features marginally increases barren-ground caribou winter HEI over the 100-year period, HEI cannot fully recover to its potential value of 0.75, as some features are permanent and do not reclaim (e.g., Dempster Highway).

This range of variation for Eagle Plain winter HEI was modelled under the assumption of low or normal snow conditions. The relative effect of snow depth on barren-ground caribou winter habitat quality is discussed in Section 3.1.3.1, below.

Moose Late Fall HEI

Factoring historical land use impacts, the current moose late-fall HEI value for Eagle Plain is 0.53 (*Figure 10d*), the same as the initial RNV value. In the absence of new land use, and as historical land use footprints re-vegetate, late-fall HEI decreases until year 55, with a minimum value of 0.38 reached. From years 56 to 100, HEI stabilizes around 0.45, but with a large range of variability (range from 0.39 to 0.53) as a result of stochastic wildfire events.

These results suggest that the historical level of land use impacts has not significantly decreased moose late-fall habitat quality in the Eagle Plain Study Area. In any given simulation year, fire history is the major determinant of moose late-fall HEI.

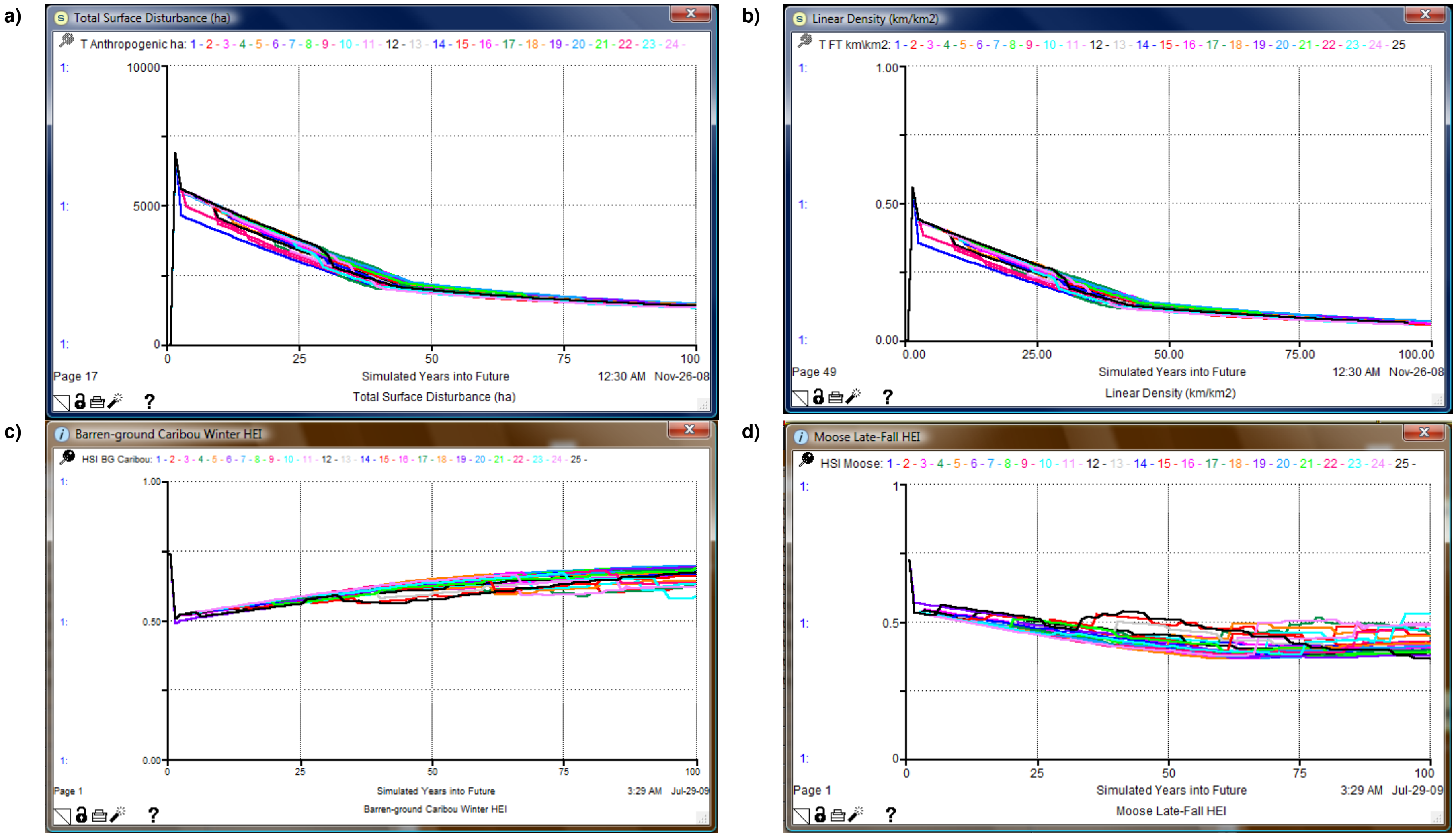


Figure 10. Range of variability (current landscape composition, no new land use) for Eagle Plain Study Area: a) surface disturbance, b) linear density, c) barren-ground caribou winter HEI, and d) moose late-fall HEI.

3.1.3 Sensitivity Analysis

3.1.3.1 Snow Condition and Regional Barren-ground Caribou Habitat Suitability

In low or normal snow years, some low elevation coniferous forested landscape types are high quality winter habitat. These landscape types contain abundant terrestrial lichens, a key winter food source for caribou. Many of these landscape types are found in Eagle Plain. Under adverse snow conditions (e.g., high snow depth), these forested landscape types become less suitable as caribou have difficulty accessing lichen under the deep snow. Large amounts of energy must be expended by caribou to move through the snow and crater to their forage.

In these high-depth snow years, the High Elevation Herb and High Elevation Sparsely Vegetated landscape types become more important for barren-ground caribou. These landscape types are concentrated in portions of the Richardson and North Ogilvie mountains. Through GPS collar analysis and local knowledge, these areas are known to receive high levels of winter use during high snow years. *Figure 11* shows the relative effect of snow conditions on the spatial distribution of winter habitat suitability classes. *Table 8* reports the area of the habitat suitability classes under low and high depth snow conditions.

The relative effect of adverse snow conditions on regional barren-ground caribou winter habitat suitability is illustrated in *Figure 12*. Regionally, there is a substantial reduction in the amount of high quality winter habitat under adverse snow conditions, and the remaining high quality habitats are concentrated in specific mountainous areas. Of special significance, high snow years result in a large reduction of winter habitat value in Eagle Plain.

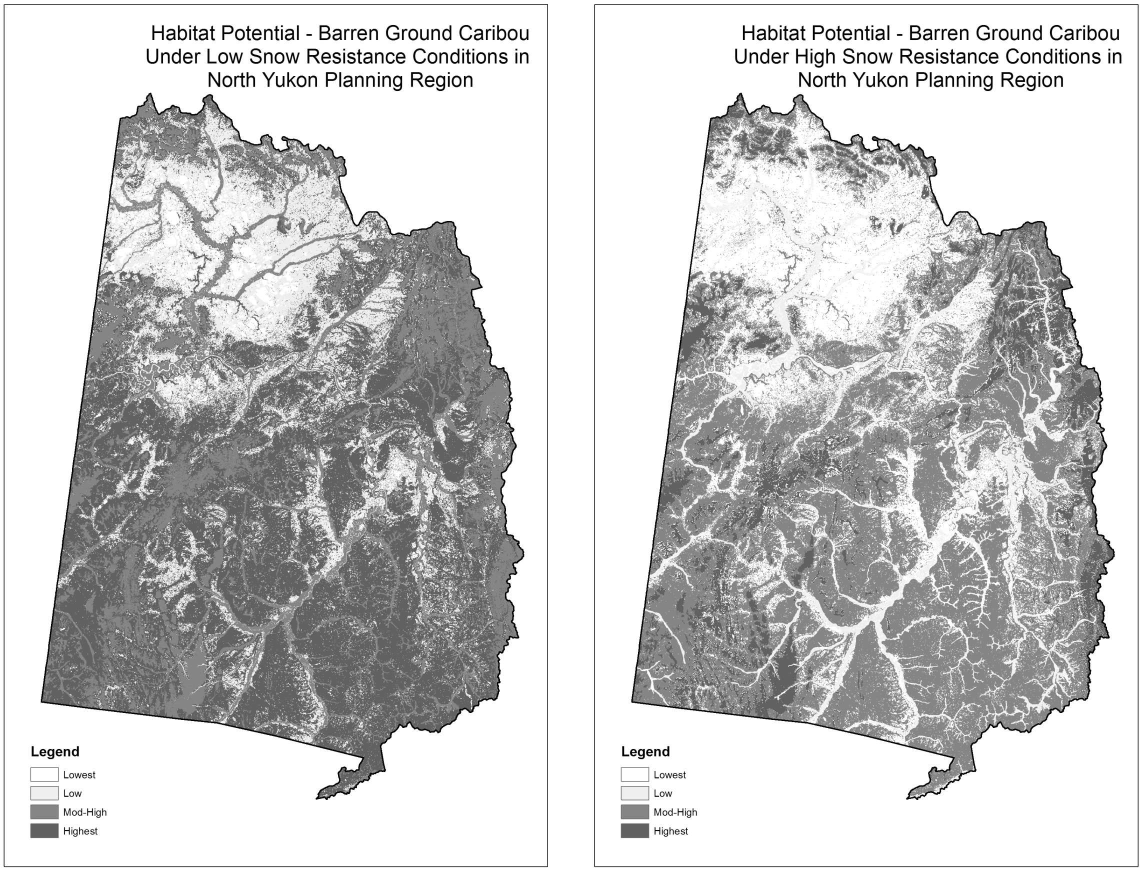


Figure 11. Relative influence of snow conditions on the spatial distribution of barren-ground caribou winter habitat suitability classes.

Table 8. Relative influence of snow conditions on regional barren-ground caribou winter habitat suitability classes.

Suitability Class	% of Region in Normal (Low Snow) Years	% of Region in High Snow Years
0 – Lowest	5 %	32 %
1 – Low	21 %	6 %
2 – Mod-High	22 %	50 %
3 – Highest	52 %	12 %

a)

b)

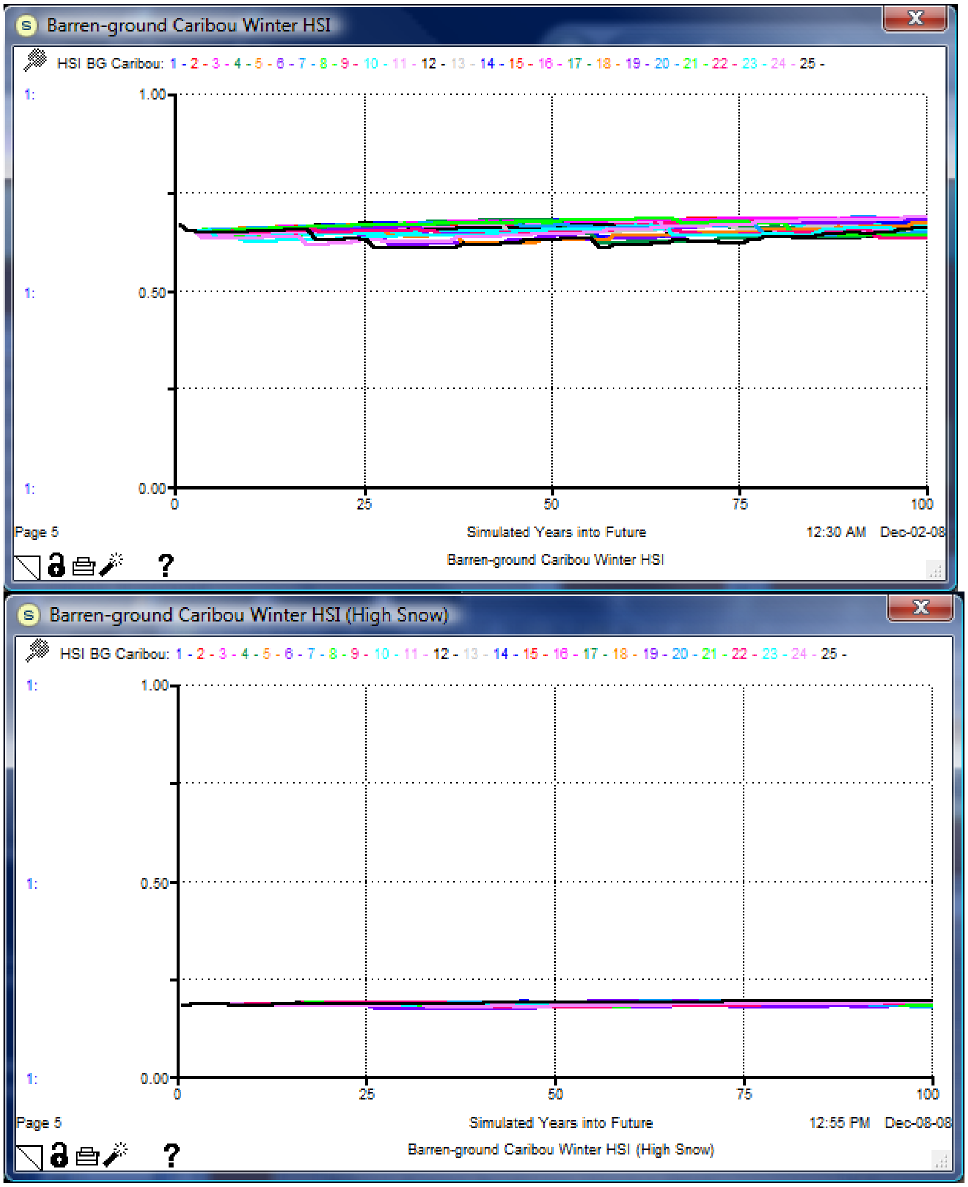


Figure 12. Regional barren-ground caribou winter habitat suitability under: a) low snow conditions and b) high snow conditions.

3.1.3.2 Climate Change and Wildlife Habitat Effectiveness

The potential effect of climate change on focal species wildlife habitat effectiveness is shown in *Figure 13*. In general, direct habitat-related change resulting from climate-induced landscape type transitions and increasing fire rates does not result in substantially altered regional HEI values for barren-ground caribou or moose.

While the direct habitat changes caused by climate-induced landscape type transitions and fire rates appear to be relatively minor under these modeling assumptions, this finding does not consider the potential effect of changing winter precipitation patterns or other biological changes (e.g., insect harassment, changing dates of vegetation green up).

Climate change results were modeled under low or normal snow conditions. As illustrated in *Figure 11* and *Figure 12*, above, snow conditions play a significant role in determining winter HSI for barren-ground caribou. Most northern Canada climate models predict that winter precipitation levels (i.e., snow) will increase, resulting in a higher frequency of years with difficult snow conditions for caribou. The significantly reduced winter HSI values caused by high depth snow conditions (*Table 8* and *Figure 12*) should therefore be considered a potential climate change effect on barren-ground caribou winter habitat quality.

In general, moose are better adapted to deep snow conditions; increasing snow depths are not anticipated to have as significant effects on moose as on caribou.

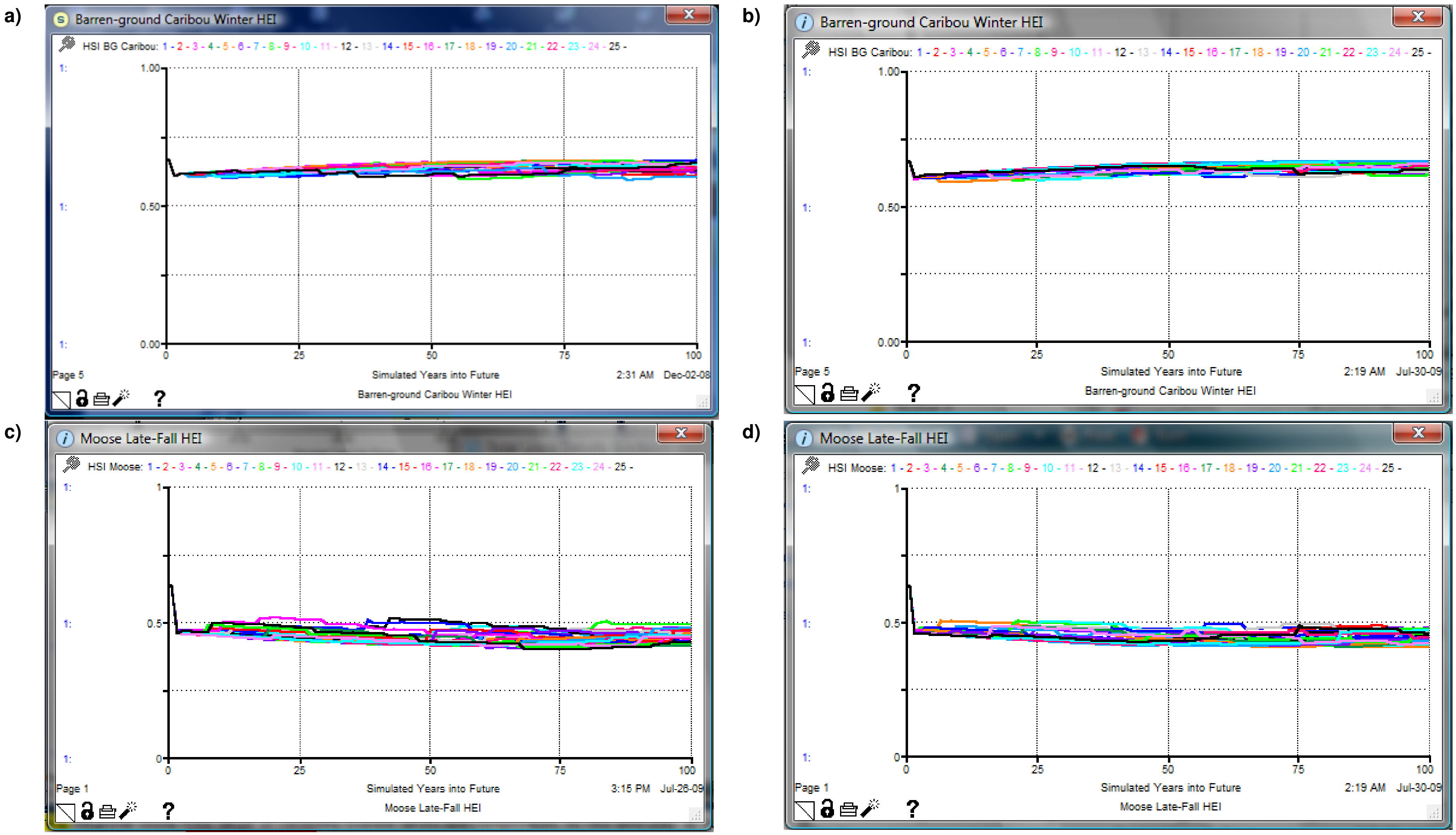


Figure 13. Regional Study Area focal species wildlife habitat effectiveness under climate change scenario (current landscape composition, no new land use): a) barren-ground winter HEI, no climate change, b) barren-ground winter HEI, with climate change, c) moose late-fall HEI, no climate change, and d) moose late-fall HEI, with climate change.

3.2 EAGLE PLAIN OIL AND GAS EXPLORATION AND DEVELOPMENT SCENARIO

3.2.1 Scenario Description

3.2.1.1 Background

The Eagle Plain basin contains significant natural gas potential, and moderate oil potential. The mean estimate of total natural gas potential for the Eagle Plain basin is 6,055 Bcf (6.1 Tcf) of in-place gas, and 437 MMbbls of in-place oil (Osadetz et al. 2005). Of the 35 wells drilled in the Eagle Plain basin from 1957-2004, ten wells flowed gas to surface, and numerous others had gas and oil shows. Discovered resources contain 83.7 Bcf gas and 11.1 MMbbls oil.

The area received a large amount of historical exploration activity. Between the late 1950s and 2005, approximately 10,000km of seismic lines and winter trails were constructed in the Eagle Plain Study Area. Concerns regarding these historical impacts, and potential future energy sector activity, were focal issues for the North Yukon Regional Land Use Plan (North Yukon Planning Commission 2007a,b; Yukon and Vuntut Gwitchin Governments 2009).

In 2005, Yukon Government Oil and Gas Branch contracted Fekete Associates Inc. And Vector Research to present a plausible scenario for oil and gas development in the North Yukon oil and gas basins, with emphasis on Eagle Plain (Fekete 2006). Their report estimated the level of infrastructure that would be required to discover, develop, produce and transport gas and oil resources from the Eagle Plain basin. The Eagle Plain oil and gas scenario developed for this project was modelled closely after the results of Fekete (2006).

The ALCES® model utilizes the Hubbert-Naill (Naill 1972)[6] basin life-cycle approach to simulate full exploitation of the finite hydrocarbon resource. Based on a series of coefficients, the ALCES® model then 'builds' sufficient seismic lines, wells, access roads and gathering pipelines to explore for, develop and transport the hydrocarbon resource. The amount of infrastructure built is based on industry estimates of exploration and development facilities required per unit of hydrocarbon production. The Hubbert-Naill coefficients used by ALCES® were modified to simulate development consistent with the Fekete report estimates of exploration and development activity, pipeline capacity, and minimum economic production. The Yukon Oil and Gas Management Branch contributed significantly to this exercise.

Section 4.1.2 of the North Yukon Resource Assessment Report (NYPC 2007b) provides a detailed description of the oil and gas resources of the region, and a potential Eagle Plain oil and gas scenario. Key aspects and assumptions of the Eagle Plain scenario are described below.

[6] (see also http://www.systemdynamics.org/DL-IntroSysDyn/energy.htm#hubbert)

3.2.1.2 Scenario Overview

Land Use Sector	Description
Oil and Gas	Information Sources: Yukon Oil and Gas Management Branch, Yukon Geological Survey, Fekete (2006) and Osadetz et al. (2005) Scenario Summary: *Natural Gas Scenario* • Exploration Phase (2010 – 2020) • Pipeline Construction Phase (2020 – 2025) - Demspter Lateral Pipeline to Mackenzie Valley Pipeline - Transportation and distribution infrastructure • Production Phase (2025 – 2055; 2.0 Tcf cumulative production) *Oil Scenario* • Exploration and testing (current – 2012) • Production of local fuel oil (2012 – 2055)

3.2.1.3 Important Assumptions and Considerations

Economic Context for the Scenario

- Future natural gas and oil activity in the North Yukon Planning Region is only anticipated to occur in the Eagle Plain basin.
- Natural gas is the major commodity of interest in Eagle Plain. Resource estimates (Osadetz et al. 2005) identify a potential natural gas resource adequate to supply a medium diameter (20 inch, or 508 mm) pipeline for approximately 20-years (Fekete, 2006). The total economically recoverable natural gas extracted over this 20-year period is estimated to be approximately 2,000 Bcf (2.0 Tcf).
- The results of Osadetz et al. (2005) suggest an expected mean volume of 5 Tcf of natural gas remain to be discovered in Eagle Plain basin. **The natural gas scenario explored in this report is therefore potentially conservative.**
- Three major conditions must be met prior to natural gas development in Eagle Plain: 1) a major pipeline must be built along the Mackenzie Valley or Alaska highway, 2) capacity must exist in that pipeline to accept Eagle Plain natural gas, and 3) Eagle Plain natural gas must be accepted for delivery into that pipeline at reasonable toll rates.
- The most likely and cost effective route to transport Eagle Plain natural gas would be via a pipeline constructed along the Dempster Highway to the Mackenzie Valley pipeline near Inuvik (hereafter called the North Yukon Gas Pipeline, or NYGP).
- The timing of the Mackenzie Valley pipeline is important to the Eagle Plain natural scenario. Assuming the Mackenzie Valley pipeline is operational by 2014 and has capacity to transport Yukon natural gas, Eagle Plain gas production could begin between 2020-2025, preceded by 10-15 years of exploration, infrastructure development, and pipeline planning and construction.

- Pipeline capacity is a major consideration for the Eagle Plain natural gas scenario. Pipeline transportation capacity is considered to be the major ‘cap’ that would regulate the pace of exploration, production and associated infrastructure levels in Eagle Plain.
- As described by Fekete (2006), the NYGP pipeline modelled in our scenario is 20” diameter, with a base capacity of 256 million cubic feet per day (MMcf/d) and a maximum capacity of 410 MMcf/d.
- Economic oil reserves are not anticipated to be in large enough quantity to justify the development of a liquids pipeline associated with a NYGP. Oil exploration and development in Eagle Plains is not dependent on the construction of a Mackenzie Valley pipeline; probable markets are anticipated to be small-scale and local.

Operating Practices

- Best management practices will be utilized throughout the entire exploration and development cycle. Specifically:
    - All seismic lines will be <3m in width, and have a lifespan of 10 years (i.e. will be naturally re-vegetated after 10 years)
    - A minimum of four production wells per well pad will be utilized for natural gas development activities
    - Well pads will require all-season gravel access roads
    - Gathering and mainline pipelines will have significant overlap with well pad access roads
- Exploration activities using current northern best practices techniques are not anticipated to result in significant levels of permanent transportation infrastructure, but will result in significant levels of low impact seismic, exploration wells, winter access roads, and associated features being constructed.

Regional Population

- Predicting future regional population trends is challenging. The permanent human population of Old Crow is projected to grow at 1% per year, resulting in a doubling of the permanent regional population in 100 years.
- Under this assumption, the resident population growth rate is not tied to levels of resource production, which may not be an accurate assumption.

3.2.2 Scenario Results

3.2.2.1 Socio-economic Indicators

Commodity Production

The natural gas scenario assumes that natural gas production will be adequate to supply the maximum capacity of the 20" NYGP. The NYGP is assumed to deliver natural gas at the base rate of 256 MMcf/d into the Mackenzie Valley Pipeline in 2020, and that the rate will increase to the maximum NYGP capacity of 410 MMcf/d in 2025. The base capacity of the 20" pipeline is reached in the second year of production, and maximum pipeline capacity is achieved after 5 years.

The Hubbert-Naill life-cycle model produces the minimum economic level of production indicated by Fekete (2006) of 1.9 Tcf within 16 years. Fifty percent of the total natural gas reserves are proven within 20 years from start of production. *Figure 14* shows the cumulative natural gas production of the Eagle Plain scenario.

An important assumption to the economics of the Eagle Plain scenario is that annual gas volumes will meet or exceed base pipeline capacity for at least 20 years (*Figure 15*). Additional exploration and gas discoveries would be required to extend the period of maximum pipeline transportation capacity.

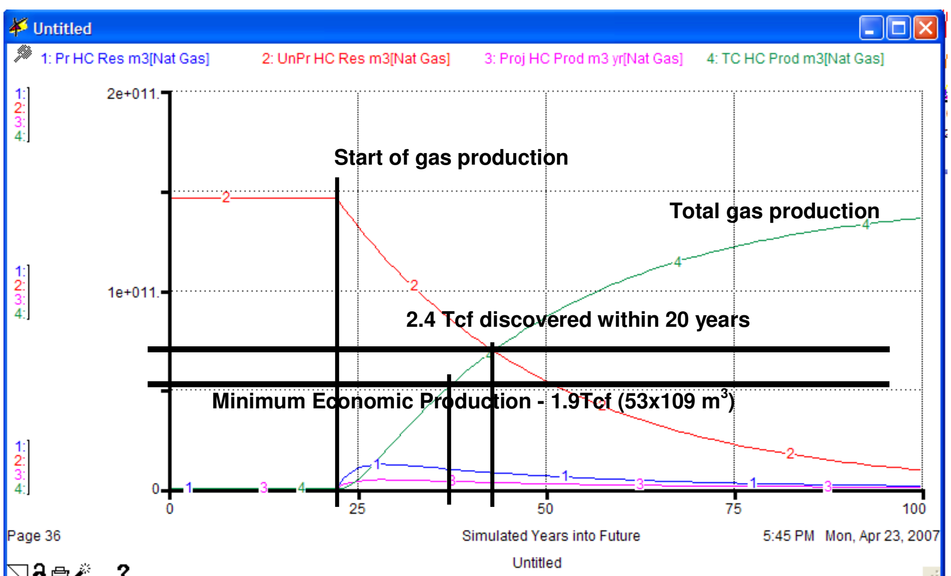


Figure 14. Eagle Plain natural gas reserves and cumulative production (m^3).

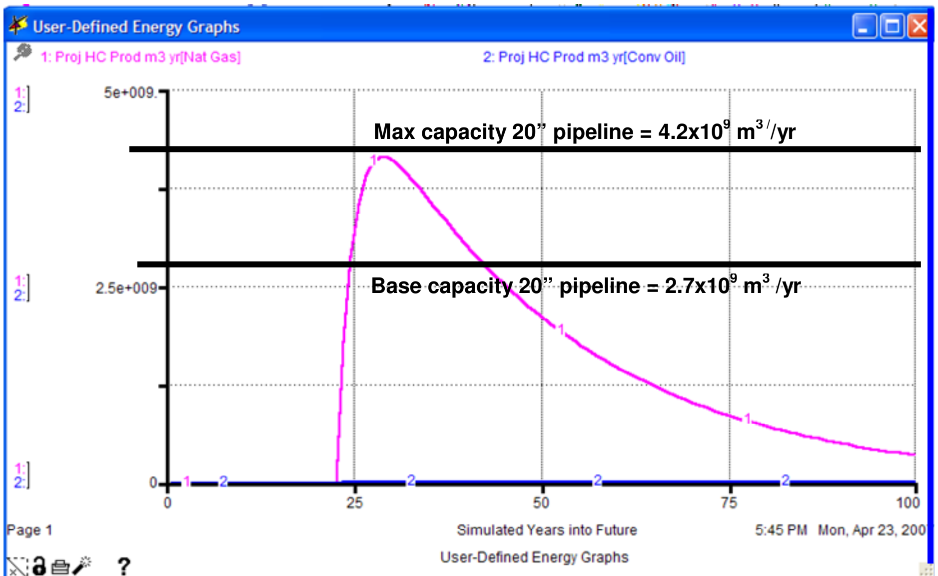


Figure 15. Eagle Plain projected annual natural gas production (m^3/year) and NYGP capacity.

Revenue and Royalties

Fekete (2006) provides a detailed analysis of potential revenue and resource royalty generation from the Eagle Plain natural gas scenario. Assuming an average natural gas price of $10 per million cubic feet (Mcf), annual resource revenue would peak in year 6 of the play at approximately $1.2 billion per year, after the maximum pipeline capacity of 410 MMcf/d is reached in year 5.

Assuming an average royalty rate of 10%, peak natural gas revenue generation in year 6 will create approximately $120 million annually in resource royalties (*Figure 16*). Changing commodity prices for natural gas has significant effects on potential revenue and royalty generation.[7]

As illustrated in *Figure 15* and *Figure 16*, resource royalties and revenues are tied directly to natural gas production levels. Assuming that a similar production profile is realized, and that the total amount of recoverable natural gas in Eagle Plain is between 2 and 4 trillion cubic feet, revenues and royalties decline to about 50% their peak level 30 years after initial production begins in 2020.

Figures for the oil scenario are not presented, but are discussed in detail by Fekete (2006). Assuming an average production rate of 2,500 barrels/day, and an average commodity price of $60/barrel, the oil scenario would generate approximately $30 million in annual revenue and contribute $3 million annually to resource royalties.

[7] Note: As of summer 2009, natural gas prices were fluctuating between $3-4 per Mcf.

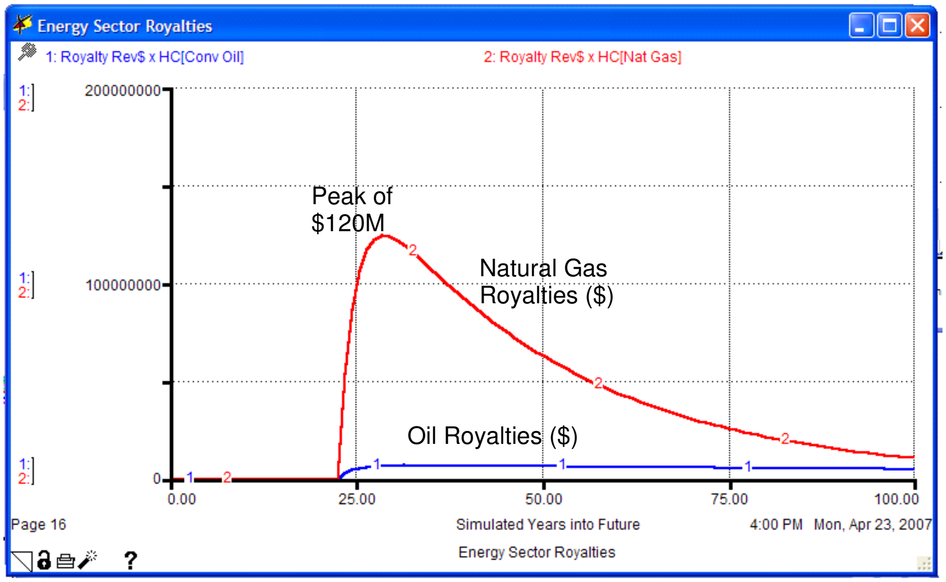


Figure 16. Projected annual royalty revenue generated by Eagle Plain natural gas and oil production.

Employment, Wages and Regional Human Population

In the ALCES® model, employment indicators are related to commodity production, so only the workforce requirement for the period of production is reported. The peak direct energy sector workforce of 305 full time equivalent (FTEs) jobs is reached in the 11th year of production (*Figure 17*). Based on a general index of 2.4 indirect jobs being created for every direct energy sector position, the Eagle Plain oil and gas scenario would be expected to generate an additional 800 non-resource workforce (i.e. indirect) jobs. The estimated annual payroll for the direct energy sector workforce during peak production is $36 million.

These figures do not include construction of the NYGP or workers required during the exploration phase of the oil and gas scenario from 2010 – 2020. Fekete (2006) estimates approximately 1,500 FTEs during the two years of peak NYGP construction. Estimates for other positions and tasks related to the oil and gas scenario, including transportation and gravel, are provided in Fekete (2006).

The maximum direct energy sector workforce would equal the entire current population of Old Crow. However, it is currently assumed that all workers would be accommodated in one or more major work camps in the vicinity of the Dempster Highway, near the production facilities.

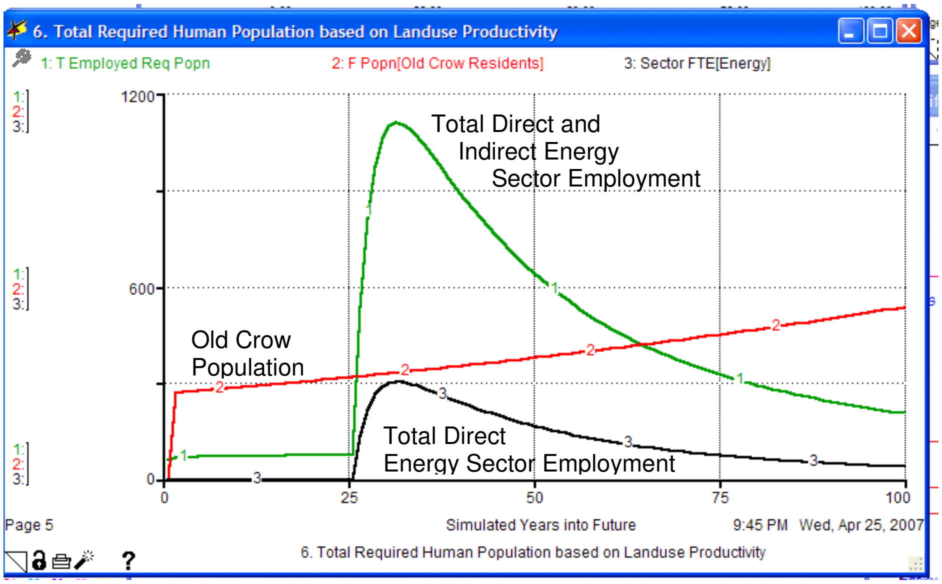


Figure 17. Old Crow population and projected Eagle Plain employment resulting from natural gas and oil production.

3.2.2.2 Land Use and Ecological Indicators

3.2.2.2.1 Infrastructure and Surface Disturbance

Total Amount of Seismic Lines

In order to discover the required natural gas reserves and support the level of anticipated drilling activity required to deliver adequate volumes of gas to the NYGP, approximately 5,000km of initial seismic, and an additional 4,600km of detailed (3-D) seismic will be required over a 20 year period. This level of activity would average 400km annually (Fekete 2006), resulting in 7,500 to 9,600km of total new seismic depending on the amount of overlap of initial and detailed seismic, and historical linear features.

The cumulative length of seismic lines projected by the ALCES model, based on the Hubbert-Naill approach, is shown in *Figure 18*. After 40-years, 9,500km of new seismic is projected, closely matching the Fekete and Government of Yukon estimates. As a result of natural re-vegetation few seismic lines would be functional disturbances after this time, assuming a 10-year re-vegetation period is realistic.

In *Figure 18*, the initial amount of seismic lines is estimated to be 2,900km, as generated from available GIS feature mapping data. The accuracy of this initial amount is uncertain, but is likely an underestimate based on the much higher levels of historical seismic reported by Osadetz et al. (2005). The result may be a higher cumulative level of disturbance than projected, but given uncertainties around current re-vegetation status, 2,900km is considered to be a reasonable estimate.

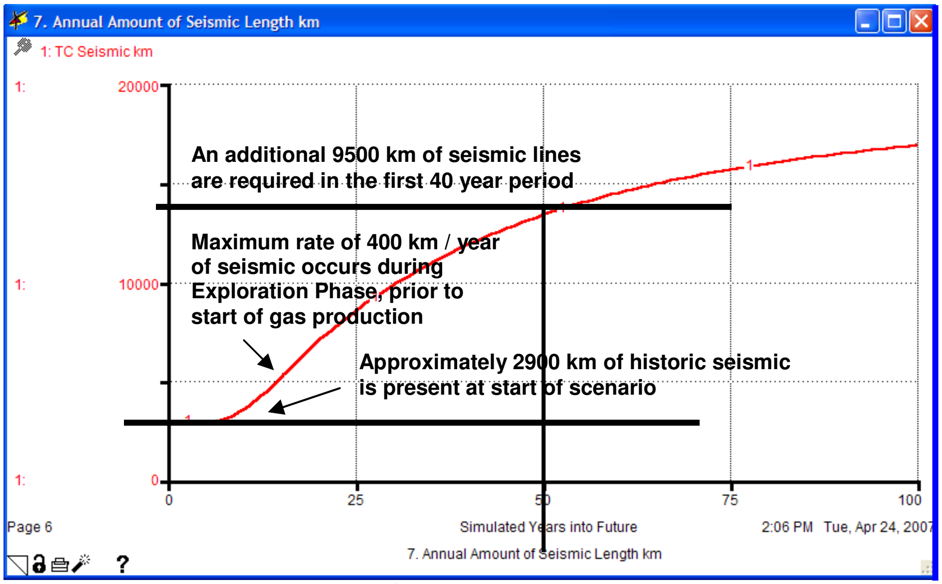


Figure 18. Projected total amount of seismic lines (km) required to support Eagle Plain oil and natural gas scenario. See description above for additional interpretation regarding initial 2900km of seismic.

Number of Exploration and Production Wells

Fekete (2006) estimates that in order to produce the required volumes of natural gas, approximately 900 wells (both exploration and production) would need to be drilled over a 30-year period. At 30-years, approximately half those wells would be active.

The number of wells projected by the Hubbert-Naill model is shown in *Figure 19*. The model projects 1026 wells being drilled over a 30 year period, with 612 being active 30-years into the scenario.

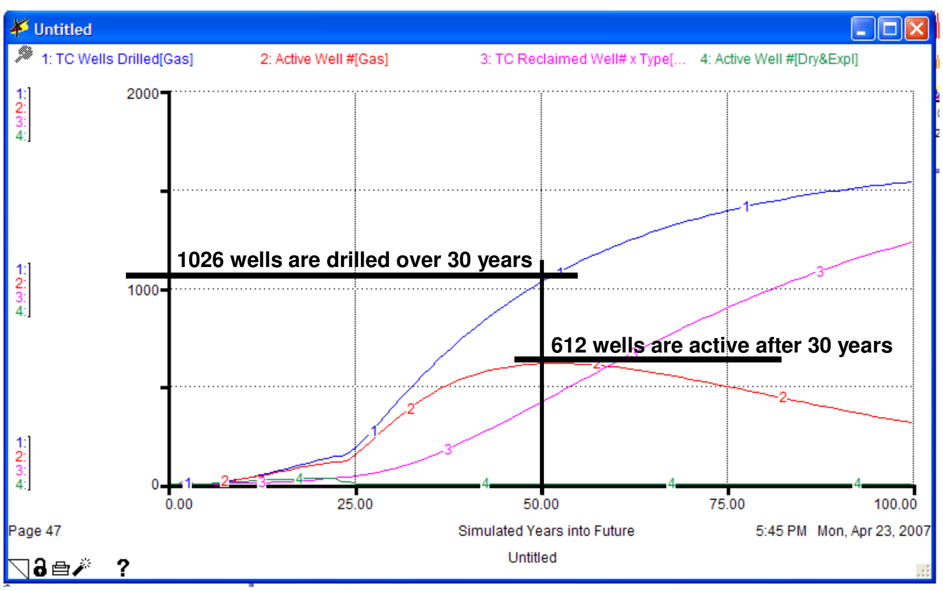


Figure 19. Projected number of exploration and product wells for Eagle Plain natural gas scenario.

Area of Access Roads and Well Sites

ALCES® 'builds' the necessary level of infrastructure required to support drilling and production levels based on user-defined coefficients. This includes developing gravel pits to support access road, well pad and pipeline construction. An estimate of the total required amount of access roads and well pad area is shown in *Figure 20*. After 30 years into the scenario, approximately 1,400 km of access roads, covering 1,500 ha, will be required. Well pads cover approximately 500 ha. These projections are based on the assumption of four wells per pad, and each pad being serviced by an all-season gravel access road.

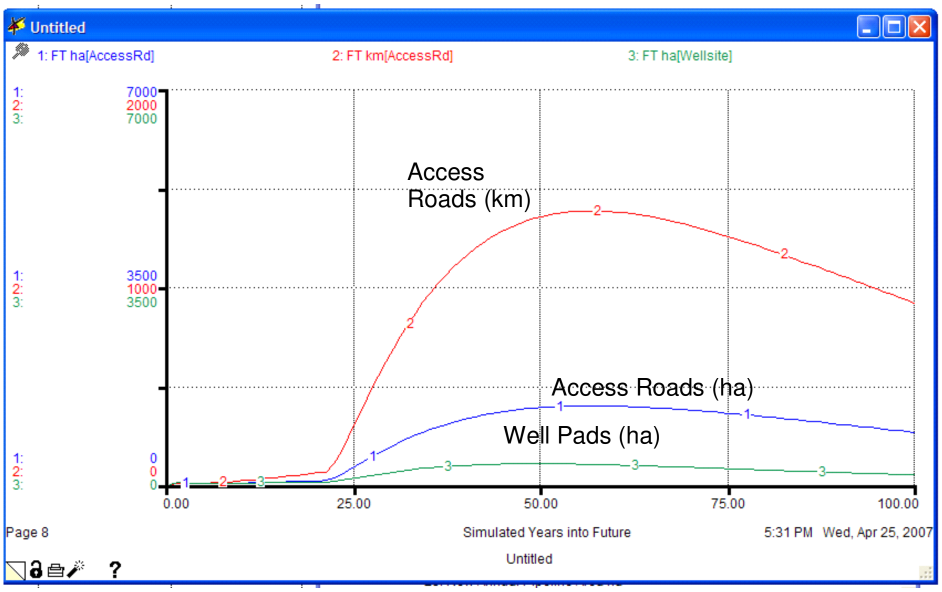


Figure 20. Projected area (ha) and length (km) of access roads and well pads required to produce the oil and natural gas resource in Eagle Plain basin.

Aggregate (Gravel) Production and Quarry Footprints

An estimate of the total required gravel production and area disturbed by gravel quarries is shown in *Figure 21*. Over the life of the natural gas play, approximately 42 million cubic metres of aggregate may be required, with a significant increase near the start of production in year 20. This large increase coincides with the production infrastructure 'build' phase of the scenario, but may occur earlier if stockpiling of aggregate is required. The maximum area of active gravel quarries would occur around year 40, affecting approximately 1,500ha, three times the area of active well pads.

Averaged over a period of 50 years, 840,000m^3 of aggregate may be required annually (this estimate does not include major reconstruction projects for the Dempster Highway). For comparison, total annual gravel requirements for the entire North Yukon Planning Region are currently estimated at 50,000m^3, with less than 150 ha of quarries being actively mined (North Yukon Planning Commission 2007b). Typical aggregate requirements for a variety of feature types are reported in Section 4.1.4 of the North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b).

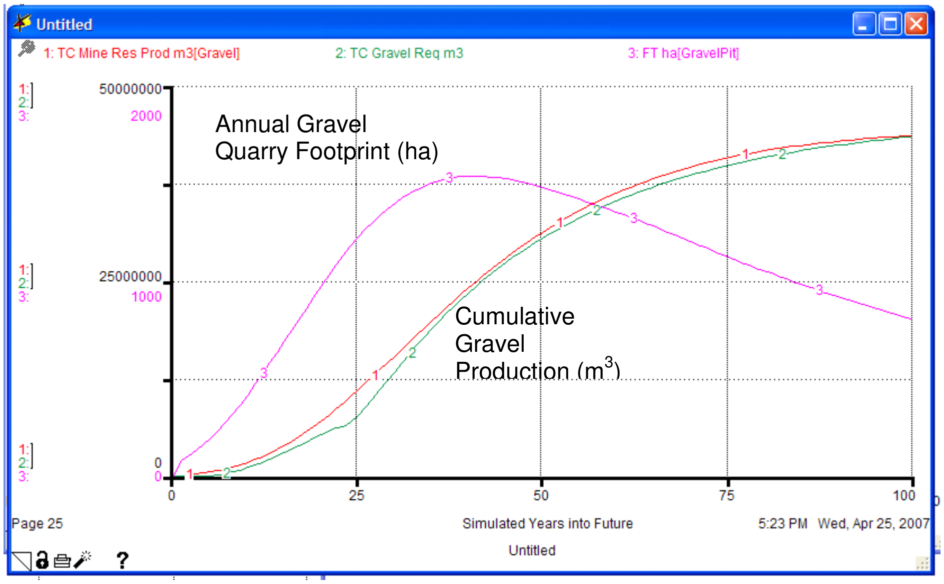


Figure 21. Projected gravel requirements (m^3) and associated gravel quarry footprint (ha) required for access road, well pad and pipeline construction in Eagle Plain basin.

Surface Disturbance by Industrial Land Use Sector

In *Figure 22*, surface disturbance metrics are shown by industrial land use sector. Gravel pits and access roads are attributed to the Mining and Transportation sectors, respectively. Energy sector footprint includes seismic lines, well pads and pipelines. Minor contributions to footprint from human settlement and visitor facilities are not included in this figure, but they are included in total surface disturbance calculations.

Early in the scenario, direct energy sector footprint is the largest contribution to total surface disturbance, with a maximum level of 4,200 ha near the start of natural gas production in year 2020. However, many of the footprints created during this early phase of the play are non-permanent seismic lines and temporary exploration well sites, which are assumed to reclaim relatively quickly.

By year 40, the area disturbed by transportation features (i.e. access roads) has surpassed the direct energy sector footprint. By year 50, the area disturbed by gravel quarries equals the total direct energy sector footprint. All-season transportation features and gravel quarries are persistent features on the landscape, and take many years to reclaim.

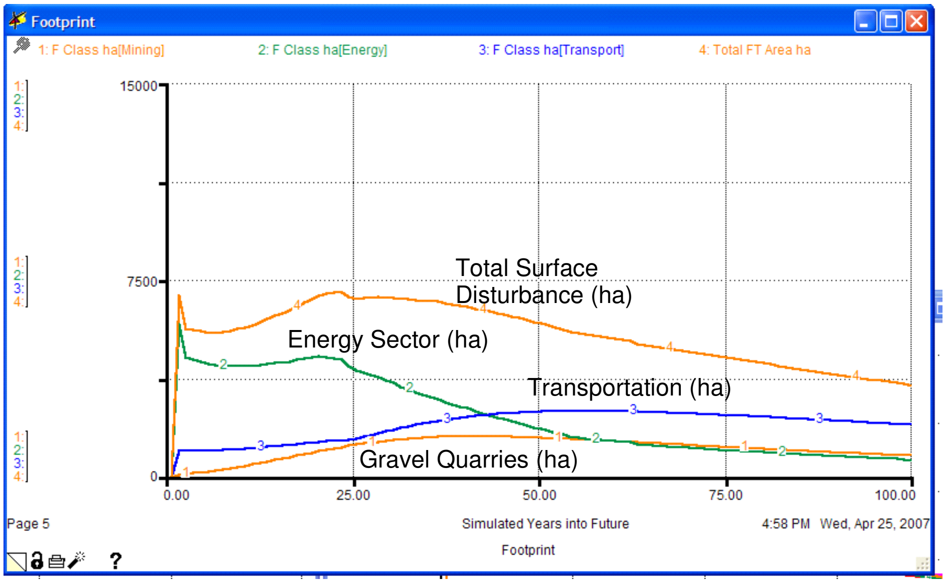


Figure 22. Projected total and industrial land use sector surface disturbance (ha) associated with Eagle Plain oil and natural gas scenario.

Total Surface Disturbance

Under the best management practice oil and gas scenario, total surface disturbance is similar to the maximum historic level of 7,100 ha, or approximately 0.5% of the Eagle Plain Study Area (*Figure 23*). The peak level of surface disturbance is projected to occur around year 25, coinciding with the spike in energy sector activity at that time. However, unlike historical exploration activity, the production scenario results in the creation of many persistent surface disturbances (e.g. access roads and gravel quarries), some of which would not be expected to reclaim by the end of the modelling period.

After 100 years, total surface disturbance decreases to about 3,600ha, approximately 60% more than the 1,400ha of total surface disturbance projected under the Range of Variability Scenario described in Section 3.1.1.1). Transportation features (i.e., access roads) contribute the majority of this additional, un-reclaimed footprint.

Wildfire may accelerate the re-vegetation of non-permanent anthropogenic disturbances such as seismic lines. In *Figure 23*, total surface disturbance is therefore displayed as a range of probable estimates, factoring the possible stochastic effects of wildfire on footprint removal.

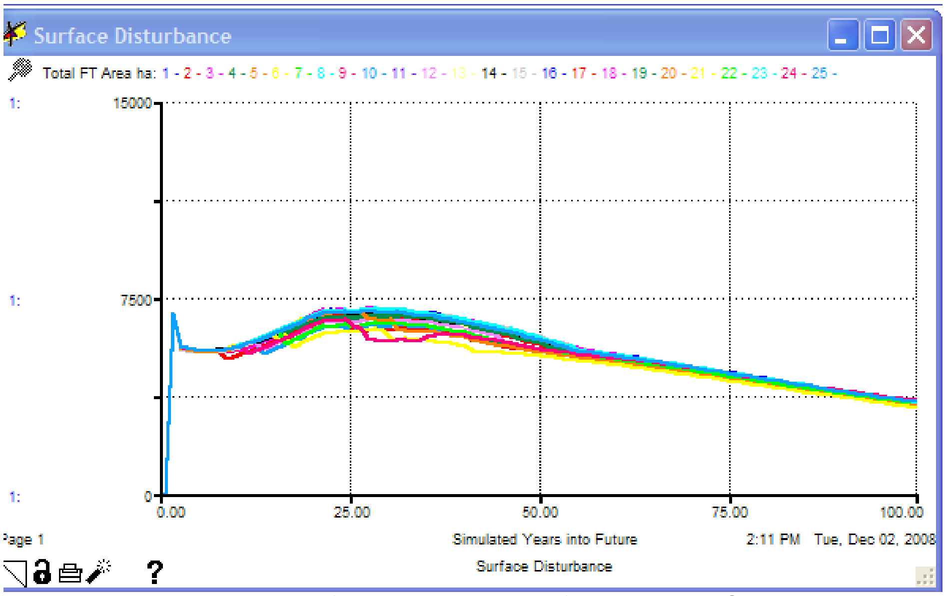


Figure 23. Total projected surface disturbance (ha) for Eagle Plain Study Area. 7,500ha of surface disturbance represents approximately 0.5% of the Eagle Plain study area.

Linear Density

Linear density increases sharply with initial seismic exploration activity in advance of natural gas production (*Figure 24*). The low impact seismic lines (<3m in width) are assumed to have a brief lifespan, naturally re-vegetating within 10-years. Features like access roads, abandoned well pads and pipelines are removed more slowly. Permanent features such as major roads remain as footprints throughout the 100-year period.

Linear density is projected to increase well above the maximum estimated historic level of 0.55 km/km^2 to a peak of 0.70 km/km^2 immediately prior to the start of natural gas production (*Figure 24*). Wildfire may reduce this by as much as 0.10 km/km^2 during this initial exploration period, which reduces overall linear density for the balance of that model run. After 100-years, linear density decreases to approximately 0.16km/km^2, or to about twice the level in the Range of Variability scenario (Section 3.1.1.1).

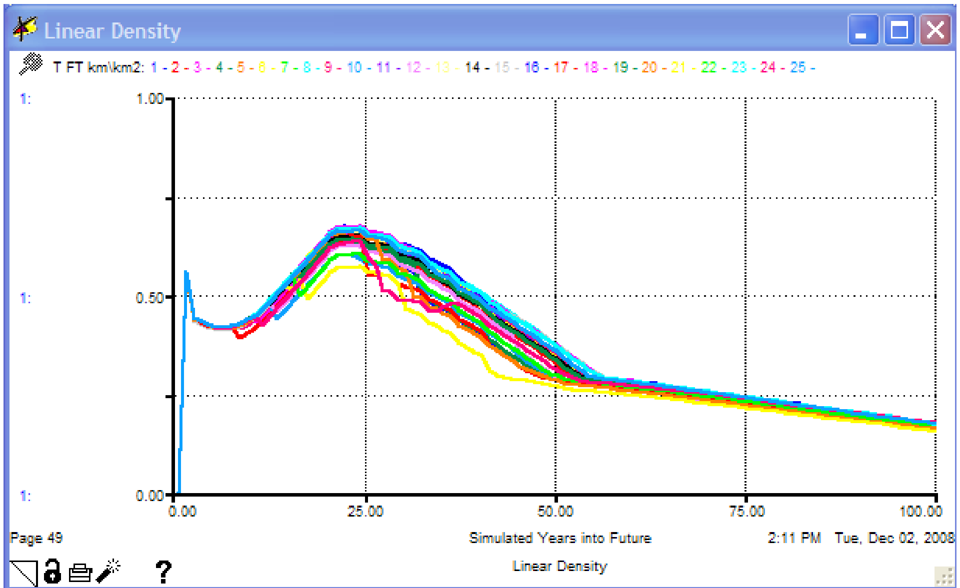


Figure 24. Total projected linear density (km/km^2) resulting from industrial land use activity in Eagle Plain Study Area.

3.2.2.2.2 Focal Wildlife Species Habitat Effectiveness

Barren-ground Caribou Winter HEI

Barren-ground caribou winter HEI initially improves as a result of natural re-vegetation of historical land use features and forest recovery from wildfire events. Beginning in year 2020, barren-ground caribou winter HEI declines in response to the onset of natural gas production (*Figure 25*). Compared with the range of variability results (current landscape composition, no new land use) displayed in *Figure 10c*, a maximum HEI reduction of 10% is experienced in year 2030, around the time of peak natural gas production and infrastructure development. A minimum HEI value of 0.52 in year 30 resulting from natural gas production represents an approximate 20% reduction compared with the RNV results displayed in *Figure 9a*.

Once natural gas infrastructure development slows, and non-permanent features begin to reclaim, HEI increases to within 10-20% of the HEI levels reported by the range of variability and RNV and runs, respectively, after year 70. However, HEI does not completely recover to the historical RNV levels due to the persistence of some land use features (e.g., roads and gravel pits).

This moderate level of long-term HEI reduction is predicated on natural gas extraction ending around year 50, after 2.0 Tcf of cumulative gas production has been achieved. Given that an additional 5.0 Tcf of natural gas may be present in Eagle Plain (Osadetz et al. 2005), this assumption may not be realistic, and could have major implications for long-term barren-ground caribou winter HEI in the Eagle Plain study area.

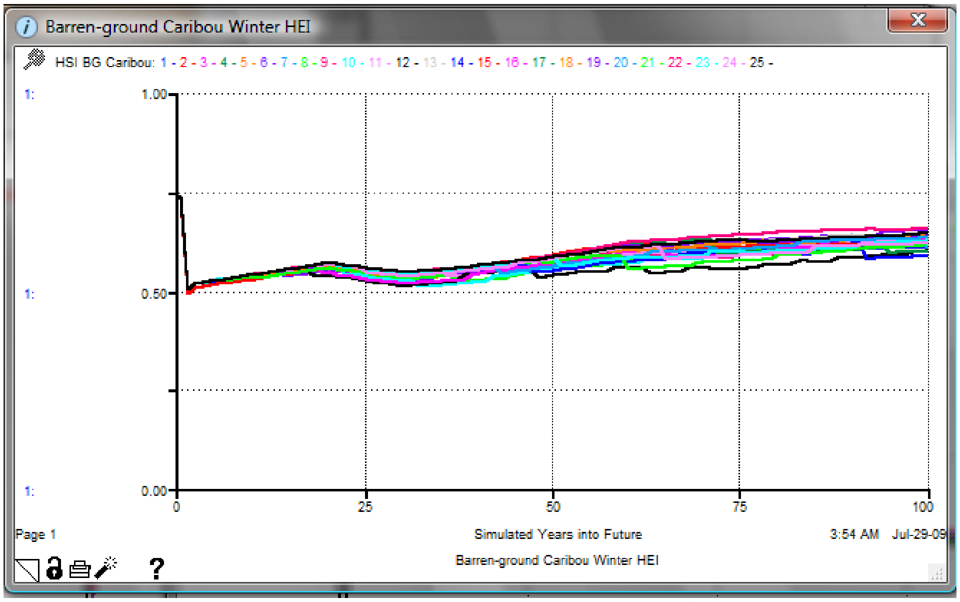


Figure 25. Potential barren-ground caribou winter HEI resulting from industrial land use activity in Eagle Plain Study Area.

<u>Moose Late-Fall HEI</u>

As a result of forest recovery from the 2004 fire events, moose late-fall HEI slowly decreases from present to around year 20. At this time, similar to barren-ground caribou, moose late-fall HEI decreases notably as infrastructure development and natural gas production activities begin (*Figure 26*). Moose HEI has a larger range of variability than barren-ground caribou, as it is more sensitive to forest seral stage.

Similar to the results for barren-ground caribou winter HEI, the natural gas scenario results in a 10-20% reduction in HEI value compared with the range of variability (*Figure 10d*) and RNV (*Figure 9b*) results for moose late-fall HEI, respectively. In any given year, wildfire events have a larger effect on the HEI value than levels of land use.

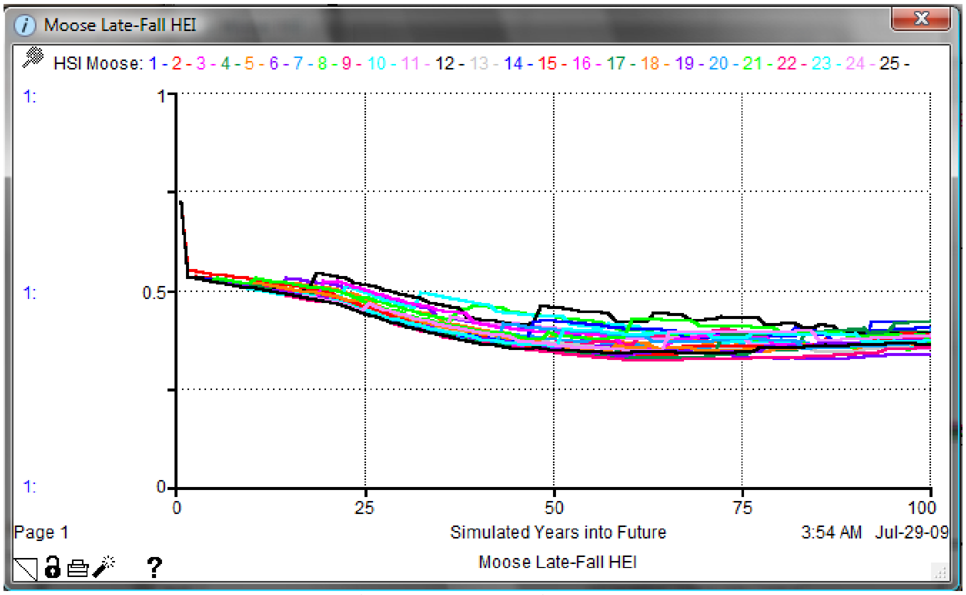


Figure 26. Potential moose late-fall HEI resulting from industrial land use activity in Eagle Plain Study Area.

3.2.3 Sensitivity Analysis

3.2.3.1 Oil and Gas Best Management Practices

Land Use Footprints

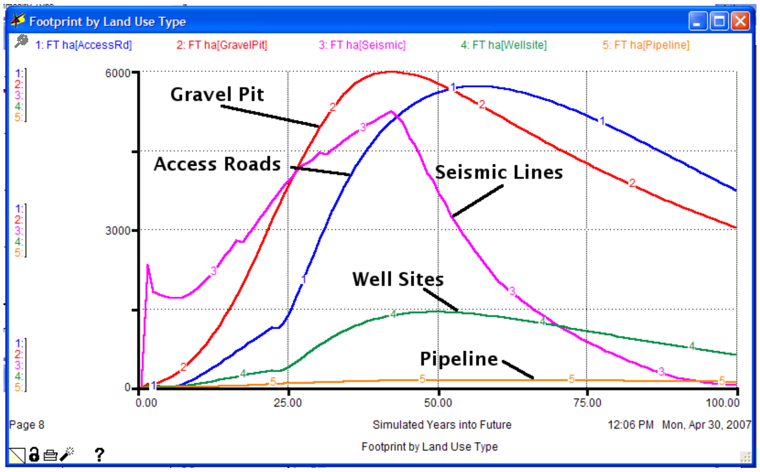
The adoption of low impact operating practices by the energy sector may result in a 60% reduction in maximum levels of surface disturbance and a 50% reduction in linear density. Best management practice scenarios are summarized in *Table 9*. A comparison of different operating practices and seismic line re-vegetation assumptions is shown in *Figure 27*. *Figure 28* and *Figure 29* illustrate results for total surface disturbance and linear density, respectively. Best management practice scenario #3 was used as the basis for the modelling results reported in Section 3.2.1, above.

Table 9. Comparison of different oil and gas operating practices (best management practice) scenarios.

Parameter	BMP Scenario #1	BMP Scenario #2	BMP Scenario #3
Average Seismic Line Width	5m	3m or less	3m or less
Seismic Line Lifespan	30 years	10 years	10 years
Number of Wells per Pad	1	1	4
Maximum Surface Disturbance	20,000 ha (1.4%)	15,000 ha (1.1%)	7,500 ha (0.5%)
Maximum Linear Density	1.3 km/km^2	0.9 km/km^2	0.7 km/km^2

BMP Scenario #1

5m seismic
1 well/pad



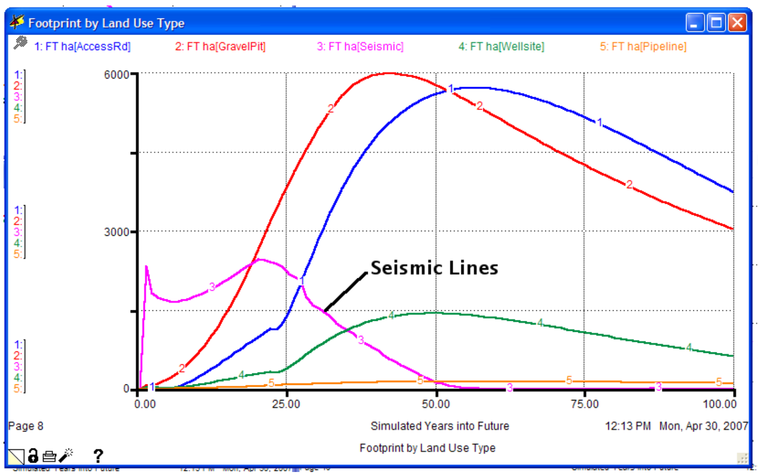
Wider seismic lines have a larger footprint and potentially a longer lifespan. One well per pad requires more access roads and gravel production.

Maximum surface disturbance levels:

- Seismic lines = 5,300ha
- Access roads = 5,730ha
- Gravel Pits = 6,000ha

BMP Scenario #2

<3m seismic
1 well/pad



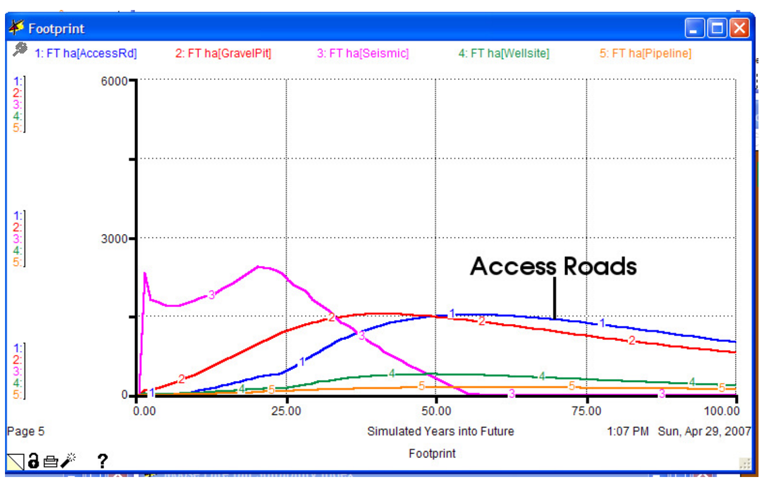
Reduced seismic line widths and shorter lifespan result in less seismic surface disturbance (2,200ha).

Maximum surface disturbance from Access Roads, Gravel Pits and Well Pads is same as BMP Scenario #1.

Access Roads and Gravel Pits are largest source of footprint.

BMP Scenario #3

<3m seismic
4 wells/pad



Seismic line surface disturbance is same as BMP Scenario #2.

Four wells per pad results in a substantial reduction in Access Road requirements (maximum 1,525 ha) and associated Gravel Pit surface disturbance (maximum 1,540 ha).

Seismic lines are largest source of footprint, but they reclaim quickly.

Figure 27. Relationship between different oil and gas operating practices and seismic line re-vegetation rates on potential levels of surface disturbance within Eagle Plain Study Area.

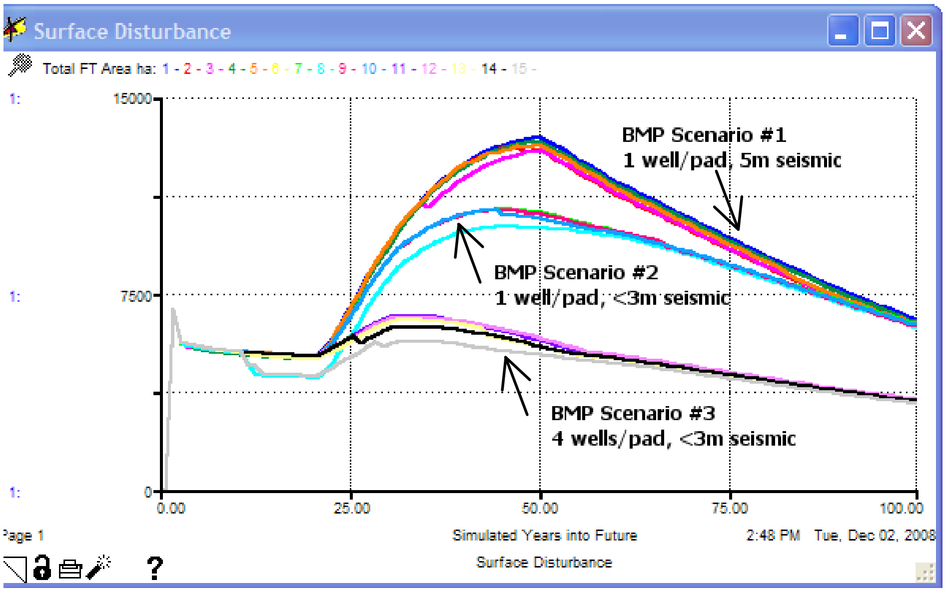


Figure 28. Potential levels of surface disturbance (ha) resulting from different oil and gas operating practices in Eagle Plain Study Area.

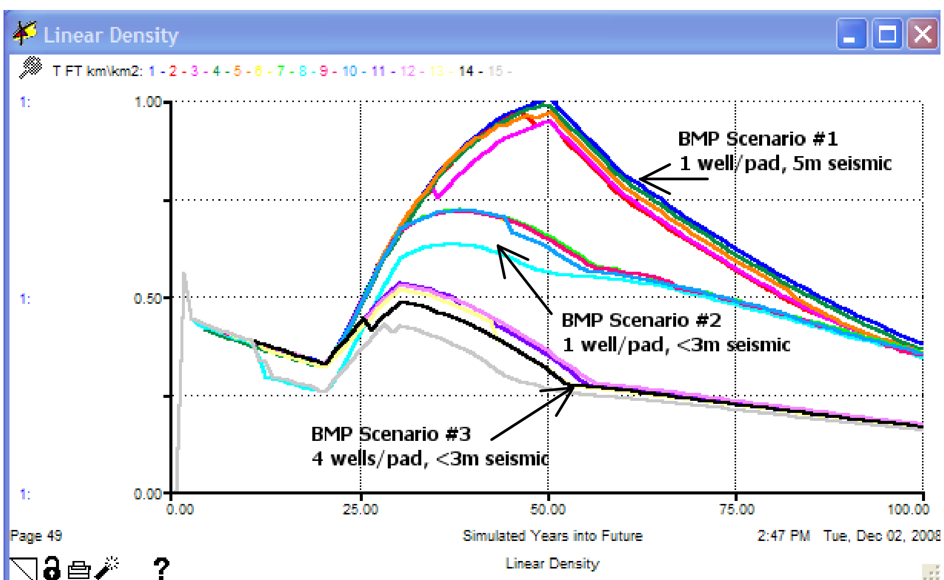


Figure 29. Potential levels of linear density (km/km^2) resulting from different oil and gas operating practices in Eagle Plain Study Area.

Focal Wildlife Species Habitat Effectiveness

Barren-ground Caribou Winter HEI

Energy sector operating practices have a notable effect on potential barren-ground caribou winter HEI and moose late-fall HEI values. As illustrated by *Figure 30*, at year 50 BMP Scenario #1 results in a 20% reduction in HEI value compared with BMP Scenario #3. This represents an approximate 40% reduction versus the RNV results shown in Figure 9a.

BMP Scenario #2 results in marginal HEI improvement versus BMP Scenario #1, but over the long-term, does not represent a significant improvement. This result suggests that the aggregation of multiple natural gas wells on a single well pad represents a more important mitigation strategy than reduced seismic line width. The most significant reductions in footprint, and their associated positive effects on HEI, are realized by a four-fold decrease in access road construction. Correspondingly, gravel requirements decrease dramatically as a result of access road reduction.

Due to the gradual accumulation of land use features with long life-spans, the maximum HEI reduction in BMP Scenario #1 occurs around year 50. After year 50, the long-term winter HEI value for barren-ground caribou remains approximately 20% below BMP Scenario #1.

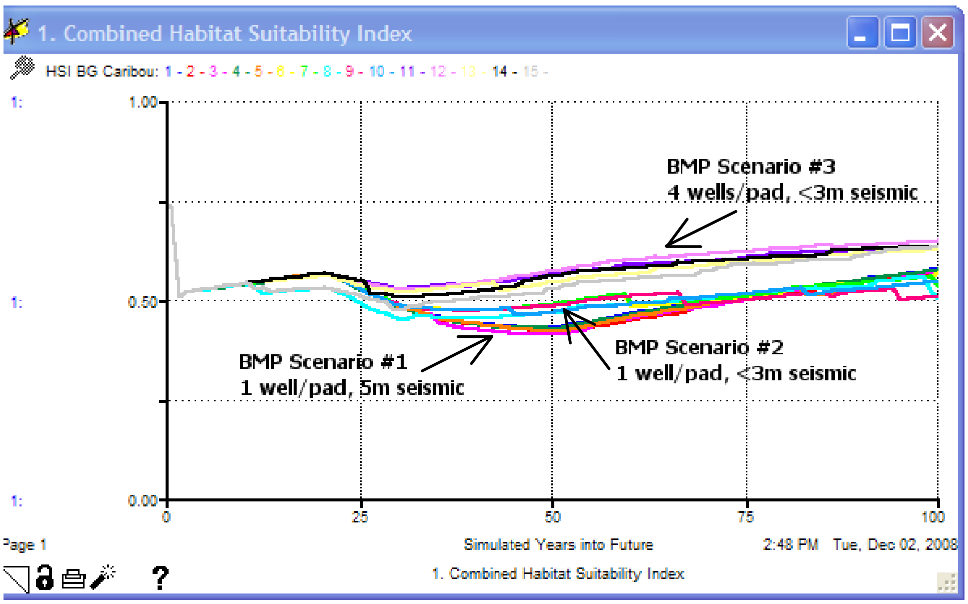


Figure 30. Potential barren-ground caribou winter HEI resulting from different oil and gas operating practices in Eagle Plain Study Area.

Moose Late-fall HEI

The effect of energy sector operating practices on potential moose late-fall HEI follows a similar pattern as observed for barren-ground caribou winter HEI (*Figure 31*). After natural gas production begins in year 20, BMP Scenario #1 results in a rapid 20-30% reduction in late-fall HEI for moose. This value represents an approximate 40% reduction versus the RNV results displayed in *Figure 9b*.

The rapid reduction of HEI observed at the onset of year 20 is predominantly the result of access road construction. Access roads, and their potential direct and indirect effects on moose, are a key variable in the moose late-fall HEI model. BMP Scenario #3 greatly reduces the amount of access road construction required, by aggregating multiple wells on a single well pad. This result reinforces the importance of access road reduction in maintaining focal wildlife species habitat integrity in the Eagle Plain area.

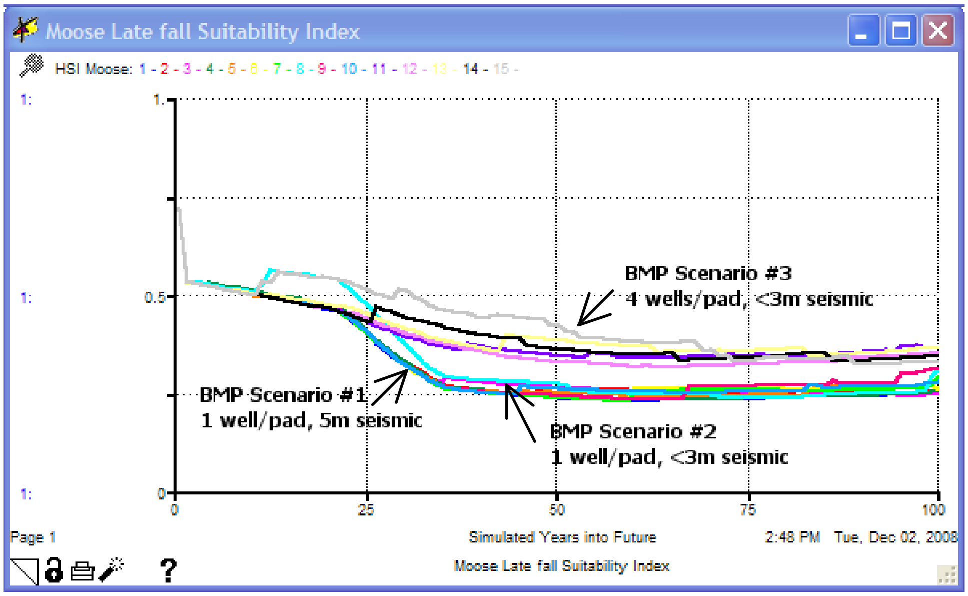


Figure 31. Potential moose late-fall HEI resulting from different oil and gas operating practices in Eagle Plain Study Area.

3.2.3.2 Seismic Line Regeneration

The effect of 5, 10 and 20-year re-vegetation times for seismic lines of 3m or less in width on surface disturbance and linear density is shown in *Figure 32*. In this sensitivity analysis, all runs were completed assuming 4 wells per well pad (i.e., BMP Scenario #3).

The purpose of this sensitivity analysis is to illustrate the relative influence of seismic line re-vegetation rate on land use footprint metrics. The exploration phase of the Eagle Plain natural gas scenario is not shown on *Figure 32*, which affects the maximum footprint levels reported. However, the proportional comparisons between sensitivity runs are relevant, and instructive.

Compared with the 20-year seismic line regeneration times, a 5-year seismic line regeneration period represents an approximate 50% reduction in the maximum level of surface disturbance and a 70% reduction of linear density. A 5-year regeneration period also results in substantial footprint reductions versus the 10-year regeneration period.

These results suggest that seismic line life-span is potentially more important than seismic line width as a surface disturbance reduction strategy. However, seismic line width and lifespan are arguably related, as wider seismic lines are generally created with larger equipment, which have a higher likelihood of creating soil disturbances versus low impact, hand cut techniques. Wider seismic lines may also receive higher levels of wildlife and human use, making them more persistent on the landscape.

With the exception of aggregated natural gas wells, and its associated effect to reduce access road and gravel requirements, seismic line regeneration is the single-most important operational consideration in reducing both short and long-term habitat impacts.

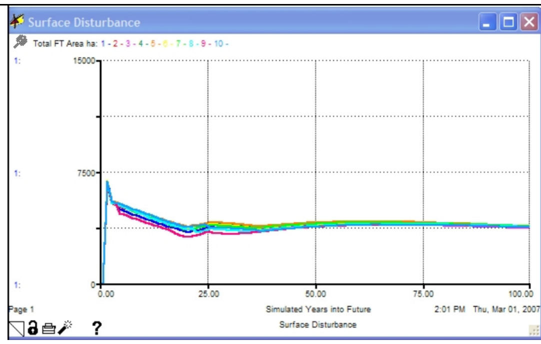
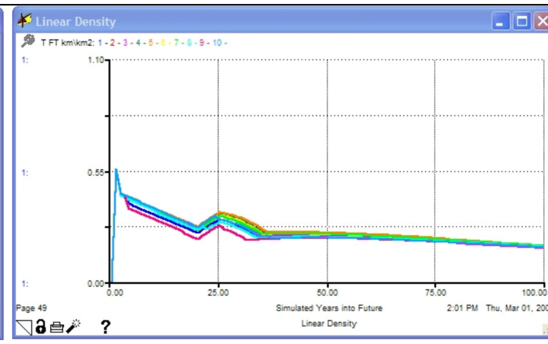
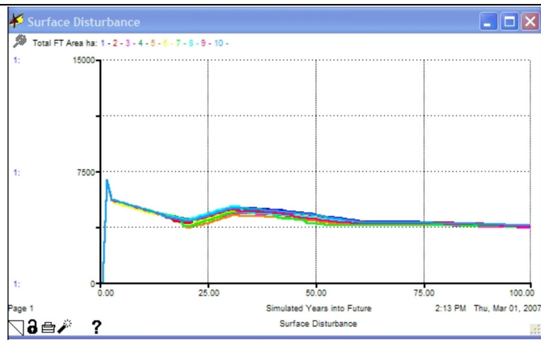
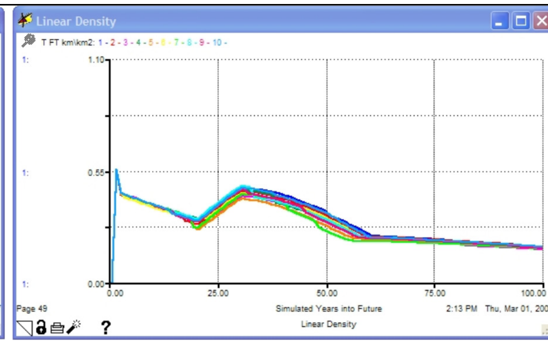
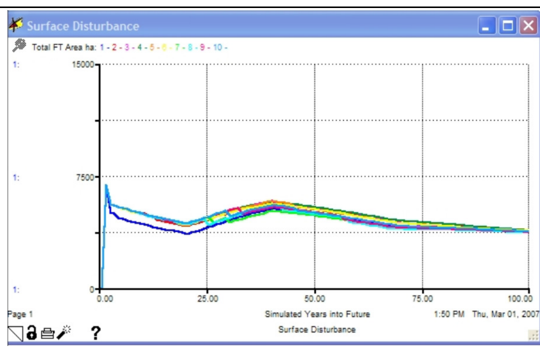
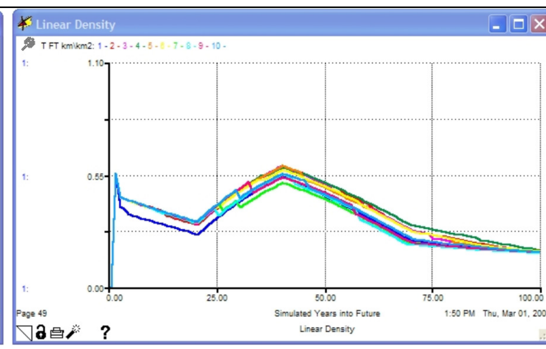
<table>
<tr><td rowspan="3">Faster
5 years</td><td>
</td><td>
</td></tr>
<tr><td>Max. Surface Disturbance = 4,125 ha (0.30%)</td><td>Max. Linear Density = 0.35 km/km²</td></tr>
<tr><td colspan="2">• 30% less total footprint than 10-year Base Case Re-generation Scenario
• Maximum footprint at year 26; return to range of variability at year 35</td></tr>
<tr><td rowspan="3">Base Case
10 years</td><td>
</td><td>
</td></tr>
<tr><td>Max. Surface Disturbance = 5,625 ha (0.40%)</td><td>Max. Linear Density = 0.50 km/km²</td></tr>
<tr><td colspan="2">• Maximum footprint at year 30; return to range of variability at year 60</td></tr>
<tr><td rowspan="3">Slower
20 yrs</td><td>
</td><td>
</td></tr>
<tr><td>Max. Surface Disturbance = 6,375 ha (0.50%)</td><td>Max. Linear Density = 0.60 km/km²</td></tr>
<tr><td colspan="2">• 20% more total footprint than 10-year Base Case Re-generation Scenario
• Maximum footprint at year 40; return to range of variability at year 75</td></tr>
</table>

Figure 32. Relationship between seismic line regeneration rates and potential levels of cumulative surface disturbance (ha) and linear density (km/km^2) in Eagle Plain Study Area.

3.2.3.3 Linear Feature Zone of Influence

The potential influence of different ZOI values on barren-ground caribou winter HEI and moose late-fall HEI are reported in *Figure 33* and *Figure 34*, respectively. The purpose of this sensitivity analysis is to illustrate the relative influence of different ZOI values on HEI trends. The exploration phase of the Eagle Plain natural gas scenario is not shown on *Figures 33* and *34*, which may affect maximum levels of HEI reduction. However, the proportional comparisons are relevant and instructive.

Barren-ground Caribou Winter HEI
The base case for HEI calculations assumed a 1,000m ZOI around the Dempter Highway and 100m around seismic lines. As shown in *Figure 33*, barren-ground caribou winter HEI is only marginally responsive to increased ZOI values for the Dempster Highway (5,000m) and seismic lines (250m). Increasing ZOI values around these features results in a nominal reduction of overall winter HEI in the Eagle Plain study area.

These results suggest that for the purpose of barren-ground caribou management in the Eagle Plain study, establishing precise estimates of ZOI around different land use features may not be required, as the HEI is not sensitive to this parameter given the anticipated level of land use activity. Other factors, such as direct human and predator-caused mortality, may be more important.

Moose Late-fall HEI
The base case for HEI calculations assumed a 2,000m ZOI around the Dempter Highway and future all-season access roads. As shown in *Figure 34*, applying a 2,000m ZOI buffer to all linear features results in a dramatic reduction in late-fall HEI for moose. This large reduction near the onset of natural gas production corresponds to the large increase in linear feature creation. The onset of this large reduction would be earlier if the exploration phase of the natural gas scenario was displayed.

Most seismic lines in the Eagle Plain study area would initially be located far from all-season access roads. This situation may appear to challenge the assumption of increased harvest mortality around seismic lines. However, over time, as the all-season access road network expands into central Eagle Plain, many seismic lines would become accessible to off-road vehicles, if they are sufficiently wide and existed in an active state (i.e., have not re-vegetated).

These results suggest that access management will be a key issue for moose, and potentially barren-ground caribou harvest management, in the Eagle Plain study area. The majority of hunting pressures will occur from accessible linear features, as occurs presently. This analysis also reinforces the importance of creating narrow seismic lines, and ensuring that those seismic lines re-vegetate quickly, to maintain habitat integrity within the oil and gas area of interest.

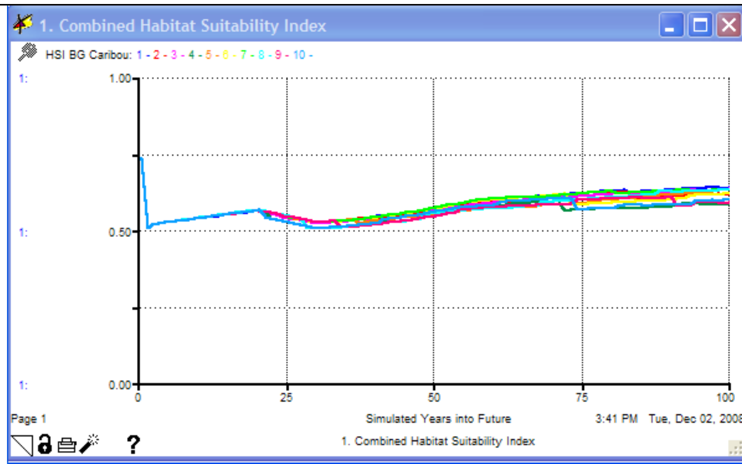
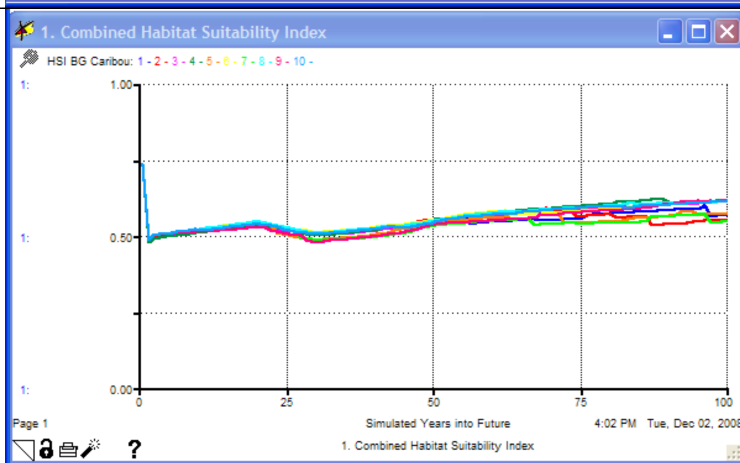
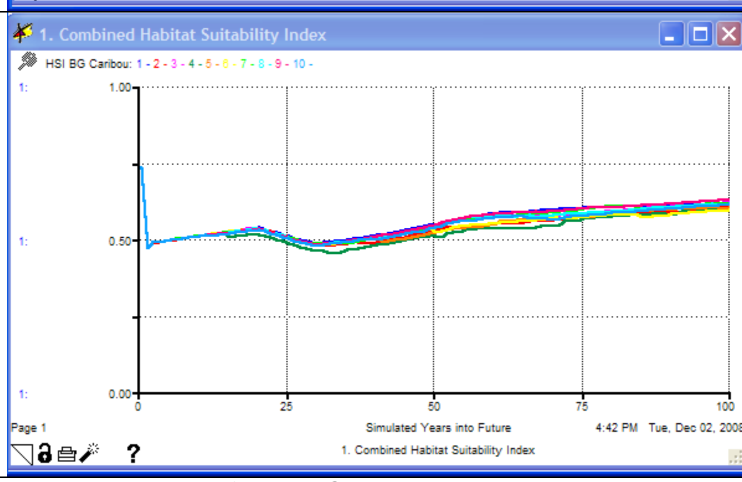
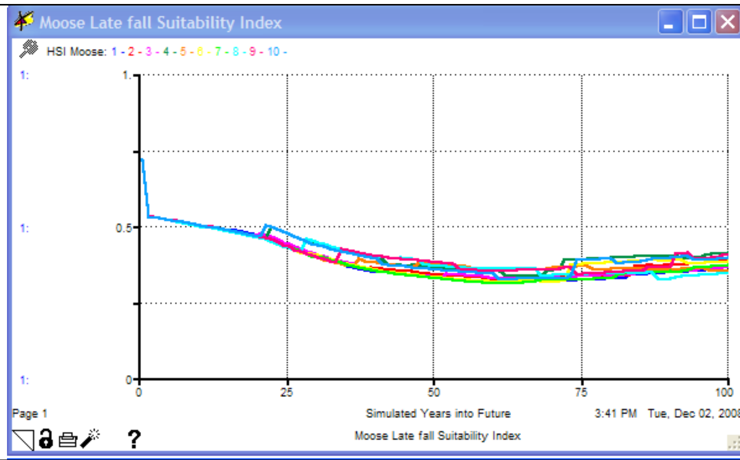
Base Case • 1,000m ZOI on Dempster Highway • 100m ZOI on Seismic Lines		ZOI Base Case assumes 1,000m ZOI for Dempster Highway, and 100m for Seismic Lines.
Dempster Highway • 5,000m ZOI on Dempster Highway • 100m ZOI on Seismic Lines		Extending the ZOI of the Dempster Highway to 5,000m results in a nominal reduction in barren-ground caribou winter HEI for the Eagle Plain Study Area[8].
Dempster Highway and Seismic Lines • 5,000m ZOI on Dempster Highway • 250m ZOI on Seismic Lines		In addition to the 5,000m ZOI for Dempster Highway, increasing the ZOI around Seismic Lines to 250m results in a further slight reduction of winter HEI.

Figure 33. Relationship between linear feature ZOI and barren-ground caribou winter HEI.

[8] Avoidance and reduced use of the Dempster Highway corridor by Porcupine caribou herd has been documented out to 5 km either side of highway (Yukon Department of Environment, 2001)

<table>
<tr>
<td>Base Case
2,000m ZOI on all-season roads (Dempster Highway and Access Roads)</td>
<td>
</td>
<td>Application of a 2,000m ZOI on all-season roads is the base case for the Eagle Plain oil and gas scenario.

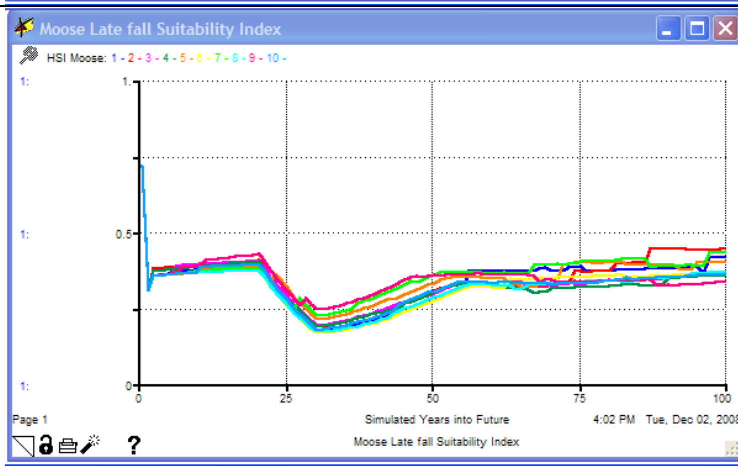
This ZOI assumes that mortality risk resulting from human harvesting only increases around all-season roads.</td>
</tr>
<tr>
<td>All Linear Features
2,000m ZOI on all linear features (seismic and all-season roads)</td>
<td>
</td>
<td>Application of a 2,000m ZOI to all linear features, including Seismic Lines, results in a significant reduction in moose late-fall HEI.</td>
</tr>
</table>

Figure 34. Relationship between linear feature ZOI and moose late-fall HEI.

3.2.3.4 Access Management

In the ALCES® model, the potential influence of access management on HEI value is applied by removing ZOI buffers around land use features. The ZOI buffers simulate potential harvest mortality within a specified distance of a land use feature, causing a reduction of HEI within that area. Removal of the buffer simulates removal of potential harvest effects on HEI value. Access management is therefore directly related to the discussion of ZOI distance, and in many respects, may be considered part of the ZOI sensitivity analysis, as discussed above.

Access management was modelled assuming base case ZOI values and BMP Scenario #3 operating practices, described previously.

Barren-ground Caribou Winter HEI

Figure 35 shows the potential influence of access management (i.e, buffer removal around linear features) on barren-ground caribou winter HEI in Eagle Plain. Access management, as modelled in this manner, does not result in a significant improvement in winter HEI value. Given the relative insensitivity of winter HEI to linear feature buffer distance, as reported in Section 3.2.3.3, this result should not be unexpected.

This finding suggests that the potential effects of harvest mortality on barren-ground caribou, resulting from increased access and harvest opportunities, may not be represented accurately by the HEI approach. In conjunction with a habitat-based model approach such as HEI, a population/ harvest model may also be required to better reflect the potential direct mortality impacts resulting from increased access and harvesting pressures, and the removal or control of those activities.

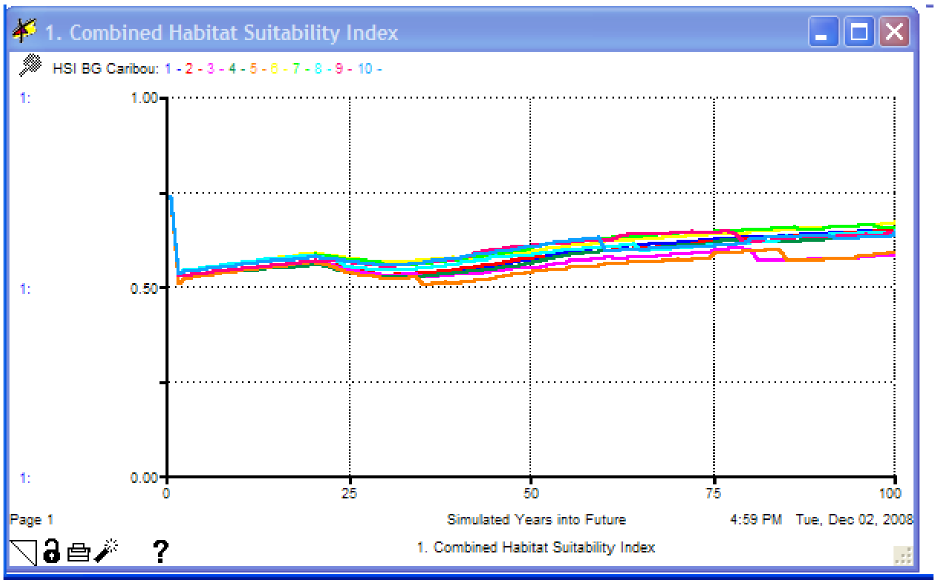


Figure 35. Relationship between barren-ground caribou winter HEI and access management.

Moose Late-Fall HEI

Figure 36 shows the potential influence of access management (i.e, buffer removal around linear features) on moose late-fall HEI in Eagle Plain. Similar to barren-ground caribou, access management, as modelled in this manner, does not result in a significant improvement in late-fall HEI value. Use of a 2,000m buffer on seismic lines illustrates the potential HEI reduction if harvesting occurred along all linear features (*Figure 34*). However, a population/harvest model may be required to provide better insight into possible harvesting-related impacts resulting from increasing access.

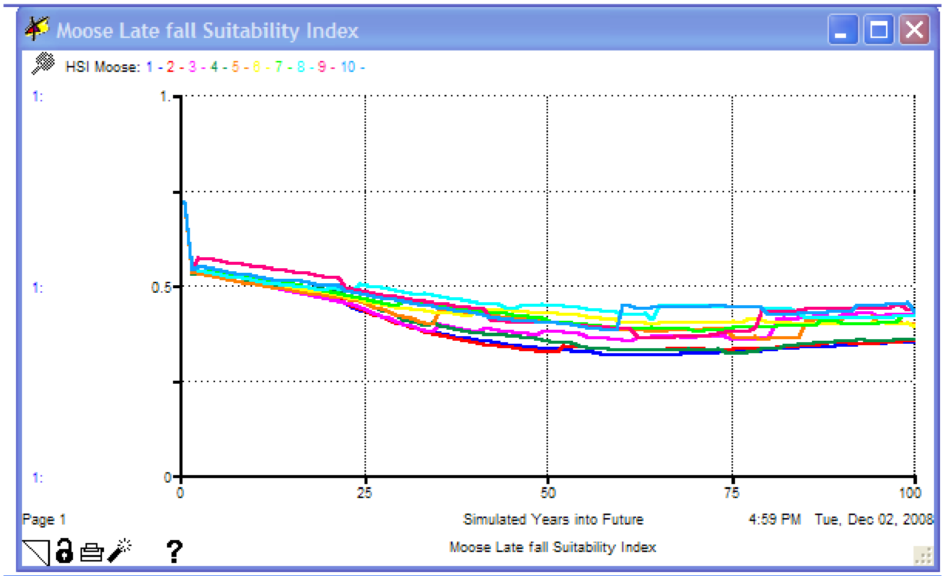


Figure 36. Relationship between moose late-fall HEI and access management.

3.3 TOURISM SCENARIO

3.3.1 Scenario Description

3.3.1.1 Background

Northern Yukon offers both challenges and opportunities for tourism development. Although the region holds impressive natural and cultural features, North Yukon will likely continue to appeal to a small and specialized market. Outside of the Dempster Highway corridor, tourism activity is currently low, tourism products and services are modest and the tourism market is not well developed. Most visitors to the community of Old Crow are not currently tourists. Improvements to Old Crow tourism infrastructure will be required if tourism is to grow in the community.

Most tourists to the region are drawn by the intact wilderness landscapes, significant wildlife resources, and the Vuntut Gwitchin culture and history. Beringia is an important theme. Important areas for tourism activity include the community of Old Crow and adjacent Protected Areas (Vuntut National Park), Ni'iinlii'njik (Fishing Branch), the Dempster Highway and surrounding Richardson Mountains and foothills, and some major river corridors (Porcupine, Eagle and Bell rivers). Approximately 7,000 tourists travel the Dempster Highway annually.

The Vuntut Gwitchin Government is interested in developing a tourism industry but minimizing potential negative impacts of this activity on the people, culture and land is very important. Old Crow residents do not desire mass tourism.

The purpose of this tourism scenario is to investigate potential socio-economic outcomes of plausible levels of tourism and potential interactions with other land use sectors. Potential effects on land use and ecological indicators have not been examined, as very low levels of activity and infrastructure development are expected. Section 4.1.1 of the North Yukon Resource Assessment Report (North Yukon Planning Commission 2007b) provides a detailed description of the tourism resources of the North Yukon Planning Region, and a potential tourism scenario. Key aspects and assumptions of the tourism scenario are described below.

3.3.1.2 Scenario Overview

The tourism scenario is modeled closely after the Draft North Yukon Tourism Strategy (Yukon Department of Tourism and Culture, 2006), with the following the following characteristics:

Land Use Sector	Description
Tourism	Study Area: North Yukon Planning Region Information Sources: Yukon Tourism Branch, Vuntut Gwitchin Government, Vuntut Development Corporation and Yukon Department of Tourism and Culture (2006) Scenario Summary: *4 Tourism Markets*: • Wilderness Travel, primarily river trips on major rivers (60-70 users annually) • Dempster Highway Tourism (7,000 – 8,000 users annually) • Old Crow Visitors (1,200 visitors annually, most are not tourists) • Fishing Branch Grizzly Bear Viewing (maximum 32 users annually)

Tourism Markets
Four tourism markets are included in the North Yukon Tourism scenario:

Adventure (Wilderness) Travelers
Most of the 60-70 adventure travelers to North Yukon each year participate in 10-14 day self-guided canoe trips on the Eagle, Bell or Porcupine rivers. Most are tourists, although a small number of Yukon or NWT recreational canoeists also visit the region. Major river corridors are the focus for this tourism segment.

Dempster Highway
About 7000-8000 people travel the Dempster Highway annually during the summer months. They include independent motorists and guided groups in vans and buses. Approximately 10 tour companies, serving some 500 clients, operate on the Dempster Highway. Most travel in vans and camp as they go. Tours emphasize themes such as wildlife, birding and natural history, and most include hiking, especially in the vicinity of the Richardson Mountains. Tombstone Campground (outside of the region) and Eagle Plains Lodge are the two focal points for most commercial tourism activities. Based on 1999 visitor exit surveys, Dempster Highway travellers spend on average $41 per user night in the region.

Community Visitors
About 1,200 business travelers (government, UFA boards and committees, consultants, construction contractors, etc.) come to North Yukon each year. Most fly to Old Crow and stay in company housing or one of two privately owned bed and breakfasts. Their work usually takes place in or near Old Crow, and they do little in the community apart from business. Not including accommodation, most visitors are estimated to spend about $25/day while in Old Crow (NYPC 2007). In 2005, about 30 tourists stayed in Old Crow bed and breakfasts; data is not available on what they did while in the community.

A portion of this segment can be considered 'Specialty Travel', such as media, researchers and film crews, often associated with the Porcupine caribou – Arctic National Wildlife Reserve issue, or Vuntut National Park/Old Crow Flats Special Management Area.

Bear Cave Mountain Grizzly Bear Viewing

The heart of Ni'iinlii'njik (Fishing Branch) Wilderness Preserve and Ecological Reserve includes a reach of the Fishing Branch River where grizzly bears feed on spawning salmon in late autumn. The karst-salmon-grizzly bear ecological setting of Bear Cave Mountains and the Fishing Branch River offers a unique, remote northern interior grizzly bear viewing opportunity.

In 2006, the Vuntut Development Corporation, Yukon Department of Environment (Parks) and Bear Cave Mountain Eco Adventures partnered to offer guided bear viewing tours. Four visitors plus one guide are permitted to access the site at any one time over a 6-8 week period. Small cabins and a helicopter landing pad have been constructed at the site.

3.3.1.3 Important Assumptions and Considerations

Tourism Growth and Markets

- Tourism growth is anticipated to be modest:
  - All tourism segments are projected to grow at 1% annually; Dempster Highway activity is expected to increase more slowly than highway-based tourism elsewhere in Yukon.
  - No significant new tourism or recreation facilities outside of existing centres (i.e. Old Crow and Eagle Plains Lodge) are constructed as part of this scenario.
- All tourism activity is considered to be generated by non-resident visitors.
- The Community Visits and Grizzly Bear Viewing market segments have culturally sensitive or management limits to growth:
  - The North Yukon Tourism Strategy suggests that Old Crow residents consider a doubling of Community Visits to the community to be acceptable, reaching a maximum at 2,400 tourism activity days (TADs) annually. Further growth is not desired.
  - Under the current Fishing Branch management plan (Yukon Department of Environment and Vuntut Gwitchin Government 2004) Bear Cave Mountain Grizzly Bear Viewing has a maximum visitor limit of 250 TADs.
- All tourism segments, with the exception of Community Visits, are dependent on natural landscapes but are not sensitive to human density within the range of anticipated tourism levels within the region.
- Wilderness tourism (primarily river travel) is moderately sensitive to human density, or anthropogenic features within 500m of river corridors, for reasons of "solitude experience".

3.3.2 Scenario Results

3.3.2.1 Socio-economic Indicators

Tourist activity days (TADs), employment, and revenue ($) are key socio-economic indicators for the tourism scenario. Each is described below[9].

Tourism Activity Days (TADs)
Table 10 indicates initial TADs for each tourism market segment used in the model. Projected future TADs for each tourism market segment are shown in *Figure 37*. Consistent with moderate growth projections, all segments have been modelled to grow at 1% per year, with the exception of Community Visits and Grizzly Bear Viewing. Wilderness travel and Dempster Highway travel doubles to 1,600 and 17,200, respectively. Community Visits reach a maximum culturally acceptable limit of 2,400 visitor days by year 82. Grizzly Bear Viewing begins at 220 TADs, and is then limited to a constant level of 250 TADs for the remaining modelling period, as currently established by the Fishing Branch Management Plan (Yukon Department of Environment and Vuntut Gwitchin Government 2004).

Table 10. Initial tourism activity days (TADs) by tourism market segment.

Market Segment	Initial Annual TADs
Wilderness Travellers	800
Dempster Highway Visitors	8,600
Grizzly Bear Viewing at Fishing Branch	220
Community Visits to Old Crow *	1,200

* Note: As described above, very few visitors to Old Crow can be considered 'tourists'; most are business travellers.

Employment
Growth rates in all market segments are not sufficient to generate a change in total direct tourism employment levels, which vary slightly between 18 – 20 FTEs throughout the 100 year model period (*Figure 38*). On this figure, potential direct energy sector employment is shown for comparison.

Revenue
Under this North Yukon tourism scenario, increased revenue generation occurs as a result of increasing tourism activity, and not spending (*Figure 39*). Throughout the modelling period, spending was fixed at current levels: $100 per Dempster Highway TAD, $135 per Community Visit TAD, $1,000 per Grizzly Bear Viewing TAD, and $10 per Wilderness Travel TAD. Increased spending per TAD was not investigated.

Initial tourism-related revenue in the region is approximately $1.25 million annually, with the Dempster Highway contributing the majority ($860,000). Community visits are estimated to

[9] In all tourism-related graphs: CV = Community Visits; DH = Dempster Highway; GB = Grizzly Bear Viewing; and WT = Wilderness Travel

represent approximately $162,000 in revenue to Old Crow businesses. Grizzly Bear viewing represents $220,000, while Wilderness Travel contributes $8,000.

Future potential revenue for each segment increases in relation to its rate of growth, so proportional contributions remain similar throughout the modelling period. At the end of 100-years, total tourism-related revenue increases to approximately $2.2 million annually, with the Dempster Highway segment maintaining the largest contribution.

Figure 37. Potential growth in North Yukon Planning Region tourism activity days (TADs), by market segment.

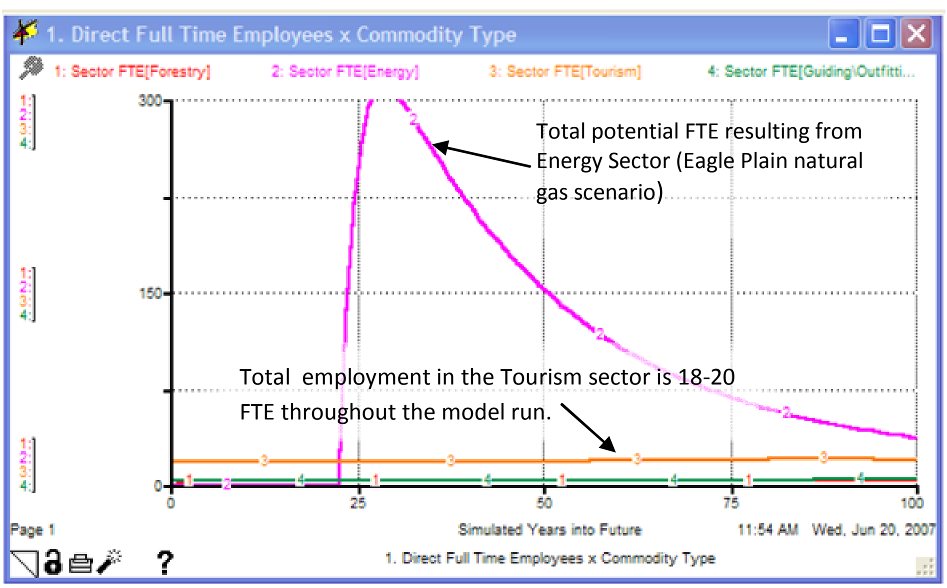


Figure 38. Potential direct employment in North Yukon Planning Region land use sectors (Tourism and Energy), represented by full time equivalent (FTE) jobs.

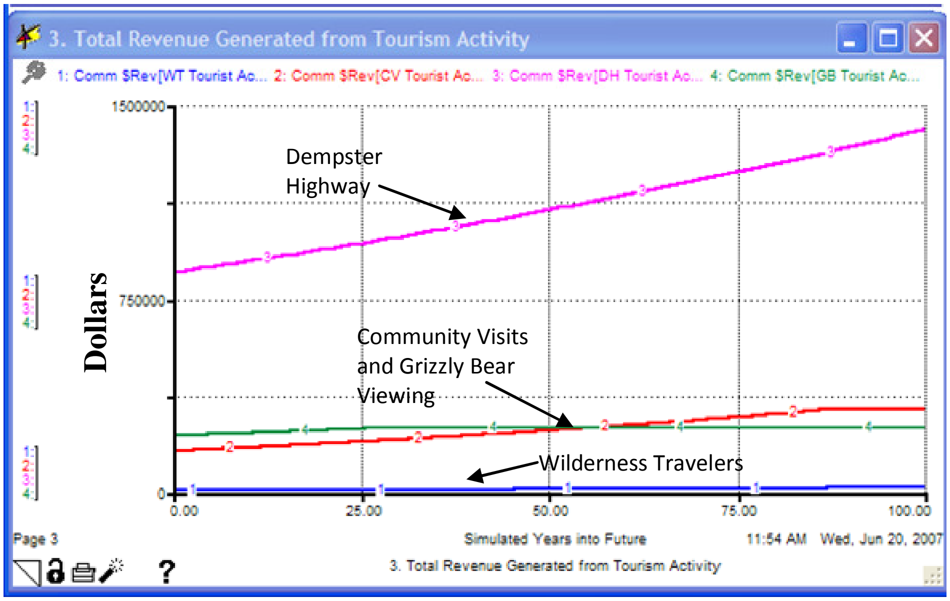


Figure 39. Potential revenue generated by the North Yukon tourism scenario, by tourism market segment.

Tourism-related Infrastructure

Major new tourism infrastructure development was not considered as part of our scenario. It is possible that wilderness lodges or other types of facilities could be built in the future, but major developments in the near future are unlikely, and would be situated near existing transportation access.

It is important to note, however, that in order to accommodate the potentially increasing numbers of visitors to Old Crow under the 1% growth scenario, two additional bed and breakfast/visitor accommodation facilities of similar size to current would be required. Depending on visitor profiles, these new accommodations may be required seasonally and not year-round.

3.3.2.2 Land Use and Ecological Indicators

Given the anticipated level of tourism activity and low infrastructure growth assumed by the tourism scenario, land use and ecological indicators were not a major focus of the tourism analysis. Similar levels of tourism footprints and transportation intensity are expected to exist into the future, as described by the range of variability, current landscape composition (see Section 3.1.1.2 – Regional Study Area, and Section 3.1.2.2 – Eagle Plain Study Area).

Surface disturbance and land use activity associated with the Eagle Plain oil and gas scenario may result in a slight decrease (7%) in wilderness travel along major river corridors in the Eagle Plain basin (*Figure 40*). This finding is based on the assumption that wilderness river travel is only moderately sensitive to potential 'solitude experience' reduction along the Eagle, Porcupine and lower Bell rivers. These river corridors are not high profile wilderness river corridors, and potential 'entry level' river travellers may have a higher tolerance for visual disturbances, while still delivering a satisfying wilderness experience. This may not be the same for all rivers or river travel tourists.

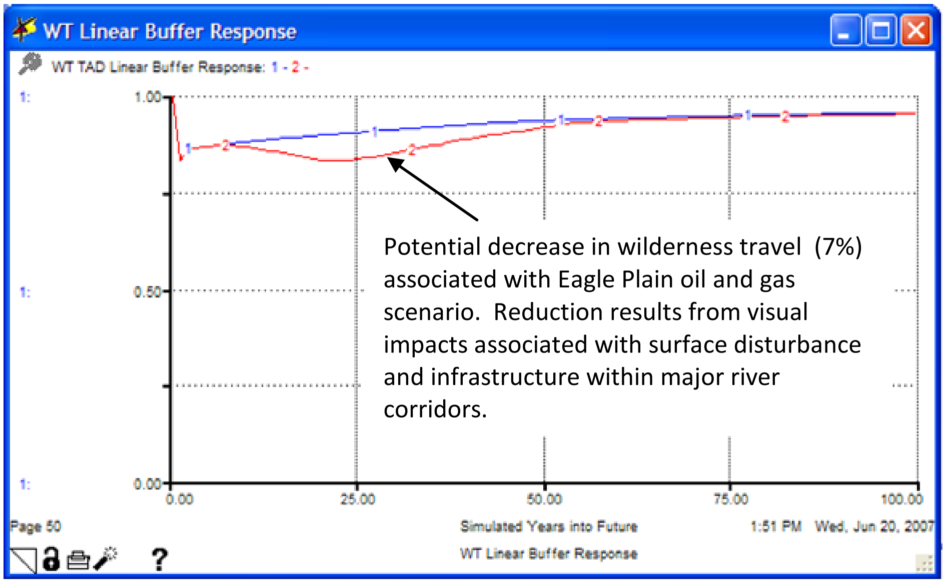


Figure 40. Potential Wilderness Tourism response to development impacts within major river corridors of the Eagle Plain basin.

3.4 MINERAL EXPLORATION AND DEVELOPMENT SCENARIO

3.4.1 Scenario Description

3.4.1.1 Background

The level of direct mineral industry interest and activity in the North Yukon Planning Region is currently low, but is increasing. Relative to other areas of Yukon, the region has historically experienced low levels of mineral exploration. As of 2008, the region contained about 500 active quartz mineral claims; most were staked in 2007. The region has never hosted a producing mine.

The increase in mineral exploration activity experienced in adjacent areas of Yukon and NWT in the past five has also been realized in the North Yukon Planning Region, but to a lesser extent. Poorly understood geology, remoteness and the relative lack of road access have been identified as important factors contributing to the low level of mineral exploration; uncertainty regarding land status and land withdrawals associated with land claim negotiations was also a contributing factor.

In late 1960s and 1970s, the level of geological and mineral exploration activity in North Yukon Planning region was much higher than present. The Geological Survey of Canada conducted Operation Porcupine in the early 1960s, resulting in the currently available bedrock geology mapping for the area. Many of the original mineral occurrences were also recorded and existing mineral claims staked and investigated during this period.

Mineral exploration activity in the 1960s and 1970s was often associated with oil and gas exploration that was also taking place during that time. Similar to oil and gas exploration, the level of mineral exploration interest in North Yukon Planning Region decreased following the Mackenzie Valley Pipeline hearings and the Berger Inquiry of the 1970s.

Section 4.1.3 of North Yukon Resource Assessment Report (North Yukon Planning Commission 2007b) contains a full description of geology and mineral potential of the North Yukon Planning Region.

The purpose of this mineral development scenario is not to predict when or where a mine will occur, which is not possible, but to explore the potential regional effects of a producing mine should it occur.

3.4.1.2 Scenario Overview

The North Yukon mineral scenario examines employment and land use metrics associated with future potential mineral activity in the North Yukon Planning Region. Key parameters of the mineral scenario are as follows:

Land Use Sector	Description
Mining	Study Area: North Yukon Planning Region Information Sources: Yukon Geological Survey and Yukon Minerals Management Branch Scenario Summary: • Base-level mineral exploration (current – 2030) • Large volume (15 million tonne), low-grade base metal deposit with open pit extraction • 100 km all season access road from Dempster Highway to North Ogilvie Mountains • Infrastructure development and production (2030 – 2045)

The mineral scenario was modelled in ALCES® using the following approach and parameters:

- The development of a mine is considered to be based on a probability of occurrence, with the probability of occurrence being influenced by two key factors:
  1) Level of exploration activity; and;
  2) Cost.
- In the North Yukon Planning Region, the level of exploration activity is anticipated to remain relatively low, with exploration and development costs being high.
- Given this situation, and considering the regional geology, the probability of a mineral discovery leading to a producing mine is considered to be lower than other areas of Yukon. In North Yukon, this ratio was estimated to be 500:1; for other areas of Yukon this occurrence ratio has historically been about 250:1.
- Based on this low estimated occurrence rate, ALCES® was unable to probabilistically create a mine within the 100-year modelling period.
- To overcome this situation, a producing mine was arbitrarily generated in year 20 of the modelling period.
- Given the remoteness of the region, and considering potential deposit types, it is assumed that to be economically viable, a very large mineral deposit would be required, and such a deposit would be mined using open pit methods.
- All mine site workers would be housed on site in a work camp setting.
- A single 100km all-season gravel access road would be required from the Dempster Highway to the mine site location.
- In this scenario, an arbitrary deposit of 15 million tonnes (Mt) is worked for a 15 year mine life, resulting in a 150 ha mine site footprint.

- The total mine site footprint remains active for 15-years, followed by a 5-year phase of active reclamation. Footprint removal requires a further 20 years of regeneration, for a total footprint lifespan of 40 years.
- The 15 Mt deposit is equivalent to 7.5 million m^3, and is extracted at a rate of 3333m^3/ha/yr, or roughly 500,000 m^3/yr for the mine.
- The mineral deposit is valued at \$120/m^3 or \$60/tonne.

3.4.1.3 Important Assumptions and Considerations

- The geology of the North Yukon Planning region is poorly understood and other smaller scale, high value mineral production opportunities may exist.
- Mineral exploration and development is highly sensitive to commodity price, which is cyclical and difficult to predict.
- Transportation infrastructure development (e.g., new roads or rail lines) or land policy changes (e.g., lifting of the North Yukon Land Withdrawal) may result in higher levels of mineral exploration investment and effort than currently anticipated.
- Water and aquatic issues vary on a case-by-case situation, and were not examined as part of this project. These topics receive major attention during mine site impact assessments, and are generally considered to represent some of the most important long-term impacts associated with active and abandoned mine sites.
- Potential access road location, and access management and decommissioning strategies, are major considerations that may affect the severity of potential mine impacts on wildlife populations. Given the scope of this project, these issues were not examined, but could be addressed through the use of wildlife population models. A detailed analysis of road footprint and reclamation factors was examined for the Eagle Plain oil and gas scenario; those results are also applicable to the mineral scenario interpretations.

3.4.2 Scenario Results

3.4.2.1 Socio-economic Indicators

Employment
The mineral production scenario generates significant direct and indirect employment during the active life span (15 years) of the mine. At peak production, approximately 400 full time equivalent jobs would be generated (*Figure 41*). Based on a ratio of 2.2 indirect to 1 direct jobs, 880 indirect jobs would also be created for the 15 year period, resulting in total employment of 1280. The annual full time employment payroll generated by the mine site is estimated to be \$35 million.

Upon mine closure, the workforce employment drops back to zero. In comparison, the Eagle Plain natural gas scenario generates a lower level of direct employment, but activity is sustained over a longer period (*Figure 42*).

Revenue

Assuming a constant commodity price of $60/tonne, and a total volume of ore extraction of 7.5 million m^3, the total commodity production value would be $900M (*Figure 42*) over the 15 year mine production life. Revenue generation and mine profitability would be very sensitive to commodity price.

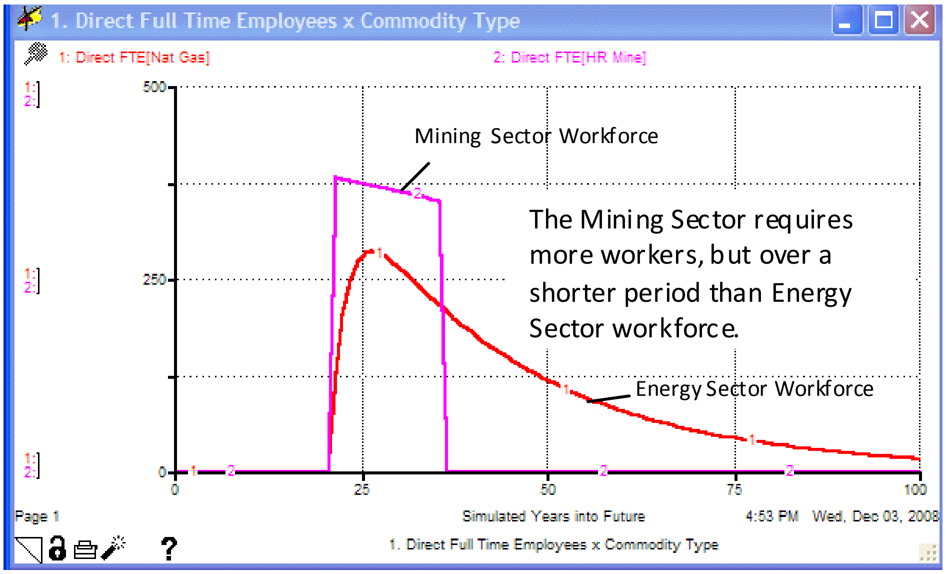


Figure 41. Possible full time employment associated with large-scale producing mine in North Yukon Planning Region. Projected full time energy sector employment resulting from Eagle Plain natural gas scenario is shown for comparison.

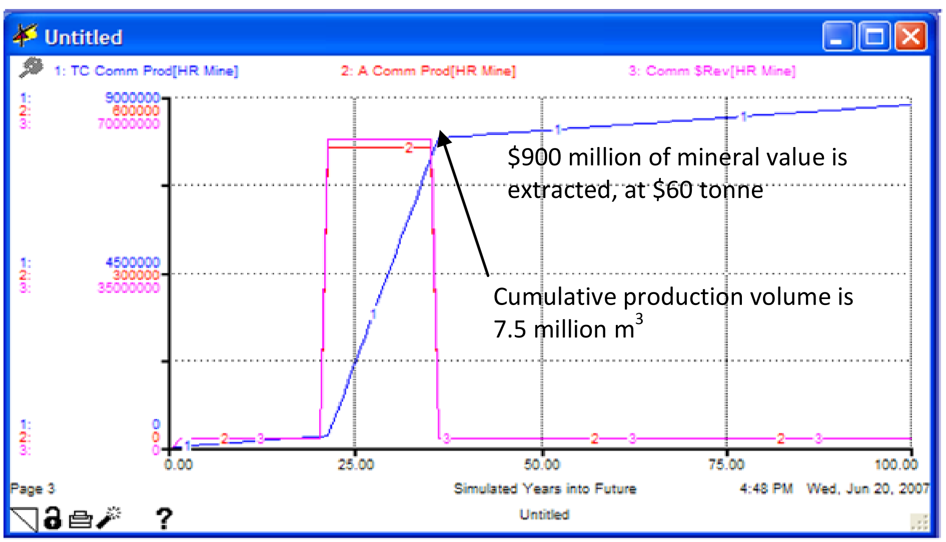


Figure 42. Potential commodity production and revenues for North Yukon Planning Region mining scenario.

Royalties
Under the current Yukon mineral royalty regime, royalty rates are capped at $3 million and are dependent on the profitability of mineral being extracted, not the volume. Royalty revenue contributions generated by the mine site would therefore be marginal. The majority of economic benefits from mineral production would result from payroll wages and secondary service industry employment and spending, and the resultant taxes paid on those incomes and services.

3.4.2.2 Land Use and Ecological Indicators

Surface Disturbance
The North Yukon mineral scenario examined in this exercise does not result in significant surface disturbance at a regional scale. The total direct surface disturbance resulting from the mine site and access road would be approximately 300 ha.

Additional land use footprints, such as gravel quarries, would be required for road construction and maintenance, and may result in an additional 100 ha of disturbed area. Upgrades to the Dempster Highway may also be required to handle increased mine site traffic and heavy equipment, which may also require large volumes of aggregate.

Ongoing mineral exploration activity may lead to additional surface disturbances (e.g., work camps, trails and trenching), but total levels are difficult to estimate. Existing mineral exploration footprints in the North Yukon Planning Region, including airstrips and related features, are estimated to be less than 50 ha.

Linear Density
Assuming a single all-season access road is constructed to the mine site, the mine development would not appreciably increase linear density. However, entry roads into frontier areas have a history of 'opening up the country' for other activities. It should be anticipated that other roads and trails may be developed off of the mine access road, or that the road could be used by people for other purposes, including access points for off-road vehicle use and wildlife harvesting. Increasing linear density increases the likelihood of such activities occurring. Access management on mine access roads is therefore an important management consideration, both during and after the active mine period.

Habitat Effectiveness
Without a specific location for the mine site and access road, it is not possible to calculate barren-ground caribou winter and moose late-fall HEI reduction resulting from the mineral development scenario. However, possible zones of influence as shown in *Table 7* of the mine site and access road features (1000m and 500m, respectively) could expand the total area affected to 11,200 ha. This area represents approximately 0.2 % of the North Yukon Planning Region, or 0.8% of the Eagle Plain study area.

It is important to recognize that the ZOI does not represent a zone of total exclusion for focal wildlife species, but an area where the habitat quality may be reduced, or where risk of mortality increases. Most (10,150 ha, or 90%) of the area within the total ZOI would be created by the access road. This finding illustrates the importance of roads and other linear features in affecting landscape composition and potential ecological impacts.

4. DISCUSSION

4.1 COMPARISON OF LAND USE SCENARIOS

This project examined three plausible future land uses in the North Yukon Planning Region: 1) oil and gas exploration and development in Eagle Plain, 2) tourism, and 3) mineral exploration and development. All activities occur now, but at low levels. The Eagle Plain oil and gas scenario and the mineral exploration and development scenario represent significant increases in activity for those sectors—whether such increases occur is not possible to predict.

Examining the different scenarios assists in developing an understanding of potential benefits and impacts of future land use activity, and provides an objective framework to discuss potential trade-offs, particularly in the context of regional land use planning. *Table 11* compares the three land use sector scenarios examined in this project.

The Eagle Plain oil and gas scenario represents a land use activity with the potential to generate significant economic benefits, but that also poses potentially high ecological risks. Of the three sectors examined, oil and gas activity generates the highest levels of cumulative surface disturbance and linear density, over a 30-50 year time-frame. Development of an all-season access road network within Eagle Plain would be the most significant long-term management issue. Operating practices have the potential to significantly reduce maximum footprint levels, with well aggregation, access road reduction and reduced seismic line width/rapid re-vegetation being the most important factors.

The North Yukon tourism scenario represents a low risk economic development strategy for the region, but also provides relatively low levels of economic benefits (employment and revenue). The tourism scenario investigated in this project does not meaningfully increase regional employment over the 100-year modelling period, but does double in revenue generation. These findings are similar to those reported by Berman et al. (2005)—community-based tourism, while generally desired by northern communities, may not provide expected or desired levels of economic benefits. The ecological impacts of the North Yukon tourism scenario would not be expected to increase beyond current levels, which are very low.

The North Yukon mining scenario represents a land use activity with potentially significant economic benefits and moderate regional ecological risks. A large-scale, producing open pit mine in northern Yukon would create lower levels of direct surface disturbance than Eagle Plain natural production, and perhaps more importantly, far fewer access roads. However, it should be recognized that some of the most important long-term impacts resulting from mineral production may be aquatic, and were not directly examined in this project. Examples of large-scale open pit mines and associated access roads being effectively decommissioned are not common, generally leading to long-term, localized impacts and a legacy of increased access into remote areas.

Table 11. Comparison of North Yukon Planning Region land use sector scenarios.

Indicator	Eagle Plain Oil and Gas Exploration and Development Scenario	Tourism Scenario	Mineral Exploration and Development Scenario
Socio-Economic Indicators			
Commodity Production	Based on 30 year play: • 2.0 trillion cubic feet (Tcf) natural gas • 2.74 million bbls oil	Annual TADs: • 10,820 (current) – 21,450 (100-years future) TADs	Based on 15-year active mine life: • 7.5 million m^3 of base metal ore production
Revenue	Based on $10/McF natural gas: • $500 million - $1.2 billion/yr Based on $60/bbl oil: • $30 million/yr	Based on fixed current TAD spending: • $1.25 million/yr (current) - $2.2 million/yr (end of modelling period)	Based on $60/tonne: • Average $60 million/yr
Employment (Annual)	Exploration: • 120 annual FTE for 20 to 30-year period Production: • 300-350 annual FTE for 30-year period	• 18-20 annual FTE for entire modelling period	Exploration: • 1-12 annual FTE Production: • 350-400 annual FTE for 15-year period
Wages (Annual)	• $36 million at peak production	• Not evaluated	• $35 million for 15-year active mine life
Royalties***	Based on $10/McF natural gas and 10% royalty rate: • $50-$120 million/yr	• None	Based on $60/tonne ore price and 5% royalty rate: • $3 million/yr
Regional Population	• Additional 300-350 full time energy sector works in region (housed in work camps) for 30-year period	• No significant change	• Additional 350-400 mine site workers in region (housed on-site in work camp) for 15-year period
Ecological and Land Use Indicators			
Maximum Surface Disturbance*	• 7,500 - 20,000 ha	No additional surface disturbance or linear density created	300 – 600 ha
Maximum Linear Density*	• 0.7 - 1.3 km/km^2		Not examined in detail, but very low
Barren-ground caribou winter HEI**	• 20 - 40% reduction	Not examined in detail, but no significant reduction in HEI anticipated	Not examined in detail, but approximate total ZOI of 12,0000 -14,000 ha anticipated (including exploration)
Moose late-fall HEI**	• 20 - 40% reduction		

* Note: Surface disturbance and linear density reported as a range of maximum values. Operating practices and reclamation assumptions have a significant influence on potential levels of disturbance, and the life span of those disturbances.

** Focal wildlife species HEI values are presented as a range of maximum and minimum values related to the maximum and minimum surface disturbance and linear density indicator levels. HEI value is reported as percent reduction compared with range of variability results.

*** Royalties. Royalty rates fluctuate in response to price and production. Beyond a certain royalty level, most resource royalties would flow back to the Federal Government and would not be retained by Yukon.

Potential social implications of the different land use sector scenarios were not directly examined in this project, but should be considered. The total workforce associated with large-scale resource development would be equal to or greater than the total regional population. Managing this workforce then becomes a very important land use and social issue. The use of well planned and located work camps, formalized impact and benefit agreements between governments (First Nations and territorial) and industry, employment training programs, and similar approaches can assist in mitigating potentially negative social consequences of wage-based economic development in northern communities like Old Crow.

4.2 LIMITATIONS AND IMPORTANT CONSIDERATIONS

4.2.1 Future Conditions

Future land use projections have high levels of uncertainty. The land use sector scenarios examined in this exercise are based on specific assumptions about the rate, location and operating practices of the activities. Government policy, global commodity prices, trends in energy supply and transportation infrastructure, and technological innovation all have significant effects on the intensity and location of future land use activities. It is highly probable that the land use assumptions upon which this project is based will not be valid 20 or 30-years in the future—economic conditions and policy decisions may result in very different future land use outcomes. For example, it is possible that large increases in oil and gas and mineral activity within the region may not be realized, or that tourism activity may increase substantially.

While changing future conditions are a near certainty, examining plausible futures based on current assumptions allows potential benefits and impacts to be understood and evaluated today, with a focus on risk management. A risk management decision-making framework is critical to developing and implementing sustainable land management strategies that can be re-evaluated as circumstances change. Similar to the precautionary principle, uncertainty about future land use activities should not impede progressive and cautionary approaches to land management.

4.2.2 Data and Information

Land use scenario modelling requires adequate data and information. Predicting the plausible effects of land use activity on ecological indicators requires accurate information, based on testable impact hypothesis pathways. While the North Yukon scenario modelling project utilized the 'best available information', it is important to understand the following potential limitations.

Biophysical Description

The ALCES® model requires a description of landscape composition, including landscape types, forest age class structure, plant community dynamics, natural disturbance regimes, and climate. The North Yukon Planning Commission and its many project partners used the best available information to populate the model, but this often required expert opinion and extrapolation based on literature review.

The North Yukon biophysical map used to describe the regional landscape types is based on predictive modelling approaches. While it may adequately represent the regional landscape, it cannot be expected to accurately or precisely represent the entire complexity of the northern boreal forest/taiga/alpine interface. All habitat interpretations are based on the biophysical mapping.

Wildlife Focal Species Habitat Quality (Suitability and Effectiveness)
Barren-ground caribou and moose were chosen as the wildlife focal species for this project, and were key species for the North Yukon Regional Land Use Plan (North Yukon Planning Commission 2007a,b). In order to conduct scenario modelling, the relative habitat value of different landscape and footprint types for these species was required. The biophysical map was used as the basis for assigning wildlife habitat value to landscape types. Habitat value was assigned in workshop settings based on the input of community of Old Crow land users, and Yukon Government biologists. Expert opinion was used to quantify habitat value of land use footprints, and potential zones of influence.

Quantifying habitat quality is complex, and is influenced by many factors. The resulting habitat quality classification used in this project may not properly account for the effects of snow depth and hardness, or sub-regional snowfall patterns, or other factors influencing wildlife habitat quality and habitat selection (e.g., patch size, adjacency, etc.).

Human Land Use Features
The location and amount of anthropogenic footprint is an estimate based on several sources, some of which may be incomplete or inaccurate, but which are currently the best available data for the North Yukon Planning Region. For example, a seismic line or well site may be represented by existing mapped, but the size or reclamation status of the feature may not be known, and require estimation.

A key question in establishing disturbance estimates is documenting the current status of historical human footprints. The length of time required for natural re-vegetation processes to reclaim historical disturbances is variable, and may be affected by the method of creation, size of the feature, intensity of use, geographic location and landscape type.

Our assumptions about the rate and extent of historical re-vegetation may not be correct, resulting in either higher or lower levels of current disturbance on the landscape. Given that linear features represent approximately 80% of the total historical footprint in the region, linear features are of particular significance. The effect of seismic line width and re-vegetation rate on levels of cumulative anthropogenic disturbance was investigated as a part of the Eagle Plain oil and gas scenario sensitivity analysis (Section 3.2.3).

4.2.3 Impact Prediction and Significance

Wildlife Focal Species Populations
A central focus for the modelling exercise was to predict potential impacts of land use activity on wildlife focal species. Land use and habitat-based indicators were used as surrogates for population-level response (i.e. direct mortality), which may not be correct. For barren-ground caribou, impact prediction methods developed for woodland caribou (e.g., Dyer et al. 2001; Anderson et al. 2002; Sorenson et al. 2008) were considered relevant, given the barren-ground

caribou responses to industrial features observed by Nelleman and Cameron (1998) and Cameron et al. (2005) for the Prudhoe Bay oilfield complex. Levels of linear density and surface disturbance were therefore used to represent risk levels for barren-ground caribou.

Impacts on moose populations resulting from increasing levels of roads and hunting access has been well documented in boreal systems (e.g., Eason et al. 1981; Eason 1989; McMillan et al. 1995). Moose populations in some areas of southern Yukon are currently being over-harvested, due to ease of accessibility (R. Ward, personal communication). Therefore, access and harvest management will be important considerations for moose management for northern Yukon, should road access increase as a result of industrial land use activity. For this reason, in this project increasing linear density was considered to represent increased harvest mortality risk for moose, a pattern that is well documented by wildlife managers.

The potential effect of anthropogenic features and habitat change on barren-ground caribou requires further investigation, as it is currently challenging to relate population-level response to levels of land use. The direct and indirect effects of linear features and other land use disturbances on barren-ground caribou is also uncertain, particularly for in-active features (i.e. abandoned features that receive no human use).

However, in all ecological systems, it has been demonstrated that increasing habitat loss/conversion, and increasing linear density/fragmentation result in increased ecological risk to native wildlife species and ecosystems (Holling 1973; Franklin 1993; Forman 1995; Collinge 1996; Forman and Alexander 1998; Spellerberg 1998; Trombulak and Frissell 2000). This finding provides a solid ecological basis for the use of linear density and surface disturbance indicators in northern Yukon, especially in the context of applying land use thresholds in regional planning to achieve long-term ecological sustainability (Environmental Law Institute 2003).

Potential Aquatic Impacts

Aquatic issues were not examined as part of this project. Water flow, water quality, water demand and watershed integrity may be important future issues in the region, but were not addressed directly as part of the current scenario modelling. Some of the most significant mineral exploration and development-related impacts may be on aquatic systems.

Socio-cultural Perspectives on Impact Significance

The significance of potential land use impacts in this project was examined from a quantitative perspective, where land use-induced changes to ecological indicators were examined and compared against their range of natural variability. Regardless of indicator performance, high rates of visual landscape change can be perceived as ‘significant negative effects’ of land use, particularly in a relatively undeveloped landscape like the North Yukon Planning Region. Such perspectives should be considered when discussing and evaluating potential land use impacts, particularly in the context of establishing limits of acceptable change.

4.3 LESSONS LEARNED

As the first major regional planning exercise in Yukon to be supported by land use scenario modelling, a retrospective evaluation of the project is warranted. If such an approach is used in future Yukon land use planning initiatives, applying the lessons learned from this exercise is recommended. The following points summarize the major lessons learned from the use of the ALCES® model to support the North Yukon Regional Land Use Plan.

4.3.1 Objective Planning Support

The ALCES® model facilitated an objective discussion about land use activities and potential impacts. Such a discussion between planners, governments and stakeholders would have been challenging without use of the model. The ALCES® model leads participants through a logical planning process in a step-wise manner, where sector specialists are required to explicitly state assumptions, rates of change, and potential significance of impacts, and governments and stakeholders must explicitly state goals and desired outcomes. Such clarity leads to an objective discussion of land use benefits and impacts, and increases understanding between sectors and participants.

4.3.2 Research and Information Collection

The ALCES® model requires biophysical, ecological, resource potential and economic information. For the North Yukon exercise, significant effort was required to initially populate the model. Current climate and future potential climate and natural disturbance regimes had to be researched and quantified. Landscape and footprint types required definition, and needed to be mapped. Focal wildlife species habitat quality relationships had to be derived. Land use scenarios had to be defined for the different sectors, and operating practices parameterized. Much of this information was collected in support of the North Yukon Resource Assessment Report (North Yukon Planning Commission 2007b), but it should be recognized that significant effort was required for this exercise.

However, future land use modelling initiatives in Yukon will benefit greatly from the North Yukon ALCES® modelling experience. It is recommended that future information collection to support land use modelling be driven by the modelling questions and regional issues. In North Yukon, the Eagle Plain study area was of primary interest, and most resources were directed to this planning issue. Secondarily, future research and information collection should focus more on rates of change and significance of impacts, versus quantitative descriptions.

Many of the sensitivity analysis results, particularly those regarding best management practices and impact assumptions (e.g., zone of influence), provide important information that can be used to focus future research.

4.3.3 Applying Results Spatially

An important outcome of regional planning is the identification of sub-regional planning units, where specific management strategies may be applied to achieve specific objectives. The approved North Yukon Regional Land Use Plan (Yukon and Vuntut Gwitchin Governments 2009) identifies 13 major landscape management units, and several sub-units.

The ALCES® model uses a 'spatially-stratified' approach to project and track landscape and footprint types within a study area (see Section 2.1). Spatially-stratified means that land use footprints are calculated and tracked based on their proportional representation within landscapes types, across a study area. While a spatially-stratified approach is computationally efficient, it can be challenging to apply and interpret results for a specific geographic area within a regional study area.

For example, in this project two separate study areas were required to adequately represent land use activities spatially within the North Yukon Planning Region. Eagle Plain was the only portion of the region where significant oil and gas activity was considered plausible, so those activities were constrained within this area. However, interpreting the Eagle Plain results in the context of the regional study area can be challenging. Similarly, attempting to apply regional results to a specific sub-region can also be problematic.

In future exercises it is recommended that the ALCES® model be used in a complimentary manner with other spatial modelling tools, such as Marxan or Zonation, to assist in interpreting regional outcomes within specific geographic sub-units. Such an approach would have been possible in this exercise, but due to time constraints, was not pursued. This approach would have allowed alternative zoning strategies or landscape configurations to be examined and evaluated to determine if regional objectives were still being met. The ALCES® model now also has a companion mapping application, ALCES Mapper™, which is being applied effectively within the Alberta Land Use Framework, and should also be considered for application in future Yukon initiatives.

5. SUMMARY

This project utilized the ALCES® landscape computer simulation model to explore three potential future land use sector scenarios for the North Yukon Planning Region—Eagle Plain oil and gas exploration and development, tourism, and mineral exploration and development. Modelling results, available in 2007, assisted the North Yukon Planning Commission to make informed land use and conservation recommendations for the Draft North Yukon Regional Land Use Plan (North Yukon Planning Commission 2007a).

Modelling results are not intended to be a prediction of future events in the North Yukon Planning Region. Scenario modelling was conducted to facilitate informed discussion about key land use issues and practices, levels of landscape change, and potential land use impacts. The ALCES® model was found to be an effective tool for facilitating an objective discussion about land use activities and their potential impacts and benefits between planners, governments and stakeholders.

While the inherent uncertainty of future events must be recognized, examining plausible futures based on current assumptions and conditions allows potential benefits and impacts to be understood and evaluated today, with a focus on managing social and ecological risk. A risk management decision-making framework is critical to developing and implementing sustainable land management strategies that can be re-evaluated as circumstances or objectives change. Similar to the precautionary principle, uncertainty about future land use activities should not impede progressive and cautionary approaches to land use management and decision-making. Scenario modelling approaches, as applied in this project, can assist in facilitating this process.

Please refer to the Report Summary at the front of this document for an overview of major results.

6. REFERENCES

Anderson, R.B., Dyer, S.J., Francis, S.R., and Anderson, E.M. 2002. Development of a threshold approach for assessing industrial impacts on woodland caribou in Yukon. Report prepared by Applied Ecosystem Management Ltd. for Environment Directorate, Northern Affairs Program. Whitehorse, Yukon, Canada. 64 pp.

Berman, M. and Kofinas, G. 2004. Hunting for models: grounded and rational choice approaches to analysing climate effects on subsistence hunting in an Arctic community. *Ecological Economics* (49): 31-46.

Berman, M., Nicolson, C., Kofinas, G., Tetlichi, J. and Martin, S. 2004. Adaptation and sustainability in a small Arctic community: Results of an agent-based simulation model. *Arctic* 57(4): 401-414.

Brown, D.W. 1996. Strategic Land Use Planning Source Book. Commission on Resources and Environment. Victoria, British Columbia, March 1996.

Cameron, R.D., Smith, W.T., White, R.G., and Griffith, B. 2005. Central Arctic caribou and petroleum development: distributional, nutritional, and reproductive implications. *Arctic* 58: 1-9.

Collinge, S.K. 1996. Ecological consequences of habitat fragmentation: implications for landscape architecture and planning. Landscape and Urban Planning 36: 59-77.

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

Eason, G. 1989. Moose response to hunting and 1-km^2 block cutting. *Alces* 25: 63-74.

Eason, G., E. Thomas, R. Jerrard, and K. Oswald. 1981. Moose hunting closure in a recently logged area. *Alces* 17: 111-125.

Environmental Law Institute. 2003. Conservation thresholds for land use planners. Environmental Law Institute, Washington, D.C. 64 pp. Online [URL]: http://www.elistore.org/reports_detail.asp?ID=10839&topic=Land_Use

Fekete and Associates Inc. and Vector Research (Fekete). 2006. North Yukon conceptual oil and gas development scenario and local benefits assessment. Unpublished report prepared for North Yukon Oil and Gas Working Group. Whitehorse, YT, Canada. March, 2006.

Fleming, S.W., and Clark, G.K.C. 2002. Glacial control of water resource and related environmental responses to climatic warming: empirical analysis using historical streamflow data from Northwestern Canada. *Canadian Water Resources Journal* (28): 69-86.

Forman, R. 1995. Land mosaics: The ecology of landscapes and regions. Cambridge University Press, Cambridge.

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

Franklin, J. 1993. Preserving biodiversity: Species, ecosystems or landscapes? *Ecological Applications* 3: 202-205.

Hinzman, L.D., N.D. Bettez, W.R. Bolton, F.S. Chapin, M.B. Dyurgerov, C.L. Fastie, B. Griffith, R.D. Hollister, A. Hope, H.P. Huntington, A.M. Jensen, G.J. Jia, T. Jorgenson, D.L. Kane, D.R. Klein, G. Kofinas, A.H. Lynch, A.H. Lloyd, A.D. McGuire, F.E. Nelson, W.C. Oechel, T.E. Osterkamp, C.H. Racine, V.E. Romanovsky, R.S. Stone, D.A. Stow, M. Sturm, C.E. Tweedie, G.L. Vourlitis, M.D. Walker, D.A. Walker, P.J. Webber, J.M. Welker, K.S. Winker, and J. Yoshikawa. 2005. Evidence and implications of recent climate change in Northern Alaska and other Arctic regions. *Climatic Change* 72: 251-298.

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

Kruse, J.A., White, R.G., Epstein, H.E., Archie, B., Berman, M., Braund, S.R., Chapin III, F.S., Charlie Sr., J., Daniel, C.J., Eamer, J., Flanders, N., Griffith, B., Haley, S., Huskey, L., Joseph, B., Klein, D.R., Kofinas, G.P., Martin, S.M., Murphy, S.M., Nebesky, W., Nicolson, C., Russell, D.E., Tetlichi, J., Tussing, A., Walker, M.D., and Young, O.R. 2004. Modeling sustainability of Arctic communities: an interdisciplinary collaboration of researchers and local knowledge holders. *Ecosystems* 7: 815-828.

McMillan, L.M., G.D. Racey, J.R. Timmermann, and R. Gollat. 1995. Effects of hunting closures and timber harvest on local moose densities and hunting opportunities in Northwestern Ontario: a case study. Ontario Ministry of Natural Resources, Northwest Region, Science and Technology, Thunder Bay, ON. *Tech. Rep. 85*. 53 pp.

Naill, R.F. 1972. Managing the Discovery Life Cycle of a Finite Resource: A Case Study of U.S. Natural Gas. Masters thesis, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, 1972.

Nellemann, C., and Cameron, R.D. 1998. Cumulative impacts of an evolving oil-field complex on the distribution of calving caribou. *Canadian Journal of Zoology* 76(8): 1425-1430.

North Yukon Planning Commission. 2007a. Draft North Yukon Regional Land Use Plan. *Nichih Gwanał'in*—Looking Forward. October, 2007. 294 pp and 7 maps.

North Yukon Planning Commission. 2007b. North Yukon Planning Region Resource Assessment Report (Draft). October, 2007. 420 pp and 54 maps.

Osadetz, K.G., Chen, Z. and Bird, T.D., 2005. Petroleum Resource Assessment, Eagle Plain Basin and Environs, Yukon Territory, Canada. Yukon Geological Survey Open File 2005-2, Geological Survey of Canada Open File 4922, 88 pp.

Russell, D.E., Whitten, K.R., Farnell, R., and van de Wetering, D. 1992. Movements and distribution of the Porcupine caribou herd, 1970-1990. Technical Report Series No. 138. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia. 139 pp.

Russell, D.E., Martell, A.M., and Nixon, W.A.C. 1993. Range ecology of the Porcupine caribou herd in Canada. Rangifer Special Issue No. 8. 168 pp.

Russell, D.E., R.G. White, and C.J. Daniel. 2005. Energetics of the Porcupine caribou herd: A computer simulation model. Technical Report Series No. 431. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia. 64 pp.

Smith, C.A.S., J.C. Meikle, and C.F. Roots. (editors). 2004. Ecoregions of the Yukon Territory: Biophysical properties of Yukon landscapes. Agriculture and Agri-Food Canada, PARC Technical Bulletin No. 04-01, Summerland, British Columbia, 313 pp.

Smith, L.C., Y. Sheng, G.M. MacDonald, and L.D. Hinzman. 2005. Disappearing Arctic Lakes. *Science* 308: 1429.

Sorenson, T., Mcloughlin, P.D., Hervieux, D., Dzus, E., Nolan, J., Wynes, B., and Boutin, S. 2008. Determining sustainable levels of cumulative effects for boreal caribou. The Journal of Wildlife Management 72(4): 900-905.

Spellerberg, I. 1998. Ecological effects of roads and traffic: A literature review. *Global Ecology and Biogeography Letters* 7: 317-333.

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

Yukon Department of Environment and Vuntut Gwitchin Government. 2004. Ni'iinlii'Njik (Fishing Branch) Ecological Reserve and Settlement Land R-5A & S- 3A1 Management Plan. Fishing Branch Local Planning Team. 42 pp.

Yukon Department of Tourism and Culture. 2006. Draft North Yukon Tourism Strategy. Prepared by Yukon Department of Tourism and Culture and TransNorthern Management Consulting with assistance and guidance from Vuntut Gwitchin Government and Vuntut Development Corporation. Whitehorse, YT. July 2006. 46 pp.

Yukon and Vuntut Gwitchin Governments. 2009. North Yukon Regional Land Use Plan. *Nichih Gwanał'in*—Looking Forward. June, 2009. 113 pp and 4 maps.

APPENDIX 1:
List of North Yukon Land Use Scenario and ALCES® Modelling Workshops and Meetings

1. WORKSHOPS AND GENERAL MEETINGS

Date	Meeting Purpose	Participants
June 22-23, 2005	Plan Scenarios Workshop – initial stakeholder workshop, project introduction, discussion of possible scenarios. Whitehorse.	North Yukon Land Use Plan stakeholders (government agencies, UFA boards and committees, industry)
September 7, 2005	Introduce project and discuss methods and stakeholders	Environment Canada, Northern Ecosystem Initiative
October 25, 2005	Detailed work planning and technical discussion	YLUPC and commission staff
November 15, 2005	Presentation to NWT Geoscience Forum, Yellowknife.	Geoscience exploration and regulatory community. Presentation sponsored by Environment Canada NEI program.
January 13, 2006	Project update	Environment Canada, Northern Ecosystem Initiative
February 27, 2006	Project update and status of land use plan	Porcupine Caribou Management Board
February 28, 2005	Presentation to NEI Thresholds Workshop, Whitehorse	FN's, government and researchers
March 13, 2006	Presentation to NWT Thresholds Workshop, Yellowknife	FN's, government and researchers
April 11, 2006	Discussion of threshold concepts, and linkage between modelling and land use plan	Yukon Oil and Gas Management Branch
May 9, 2006	Project update and information review	Vuntut Gwitchin Government
May 16, 2006	Project update and review	NYPC Senior Liaison Committee
May 18, 2006	Project update and review	Yukon Government Internal Working Group
July 24, 2006	Project and land use plan update	Yukon Government Internal Working Group and Vuntut Gwitchin Government staff
September 23, 2006	Presentation on project and update on land use plan status	Community of Old Crow
October 27, 2006	Project and land use plan update	Yukon Government Internal Working Group
February 4, 2007	Project and land use plan update	Porcupine Caribou Management Board
March 31, 2007	Project and land use plan update, Old Crow	Community of Old Crow

April 2, 2007	Project and land use plan update, Old Crow	Vuntut Gwitchin Government
April 3, 2007	Presentation on ALCES scenario modelling approaches	Peel Watershed Technical Working Group
April 12, 2007	Presentation to *Project Approvals North of 60* Conference, Edmonton	Government, industry and regulatory agencies
September 24, 2007	Presentation of modelling results and land use plan update	Porcupine Caribou Management Board
November 27 – December 3, 2007	Draft Land Use Plan consultation and discussion of modelling results	Old Crow, Inuvik, Ft. McPherson (governments and community open houses)
December 6, 2007	Draft Land Use Plan Stakeholder Workshop	North Yukon stakeholders and governments
December 10-12, 2007	Draft Land Use Plan consultation and discussion of modelling results	Whitehorse, Mayo and Dawson
January 18, 2008	Presentation to *'Truths from the North'* Conference, Edmonton	Researchers, students, government
January 24, 2008	Cumulative effects management and scenario modelling, Old Crow	Porcupine Caribou Management Board

2. LAND USE SECTOR TECHNICAL MEETINGS

2.1 Eagle Plain Oil and Gas Scenario

Date	Participants	Description
June 15, 2005	Yukon Oil and Gas Management Branch	Project introduction
June 24, 2005	Yukon Oil and Gas Management Branch	Introduce project and begin dialogue on BMPs used for Eagle Plain oil and gas scenario
October 25, 2005	Yukon Oil and Gas Management Branch	Detailed technical discussion of Eagle Plain oil and gas scenario parameters and assumptions
November 3, 2005	Yukon Oil and Gas Management Branch	Project update
November 8, 2005	Yukon Oil and Gas Management Branch	Discussion of Fekete (2005) report, and potential use in North Yukon Eagle Plain oil and gas scenario.
November 25, 2005	Canadian Association of Petroleum Producers (CAPP) and Yukon Oil and Gas Management Branch, Calgary	Presentation of project to CAPP, Northern Working Group
December 14, 2005	CAPP and Yukon Oil and Gas Management Branch	Follow-up from November 25 meeting
December 15, 2005	Geomatics Yukon	Updates to Yukon seismic line database

December 22, 2005	Yukon Oil and Gas Management Branch	Updates to Yukon seismic line database, and assumptions regarding re-vegetation status
January 12, 2005	Northern Cross Ltd and Yukon Oil and Gas Management Branch	Overview of scenario project and linkage to land use plan
March 15-17, 2005	Yukon Oil and Gas Management Branch, CAPP and modelling team, Calgary	Three-day technical modelling session with focus on Eagle Plain oil and gas scenario
July 31, 2006	Yukon Oil and Gas Management Branch	Seismic line photo, imagery and data updates
August 1, 2006	Yukon Oil and Gas Management Branch	Updates on preliminary modelling results and assumptions
March 15, 2007	Yukon Oil and Gas Management Branch	Results of Eagle Plain oil and gas modelling
January 30, 2008	Yukon Oil and Gas Management Branch	Results of Eagle Plain seismic line re-vegetation study and potential relationship to scenario modelling results

2.2 Tourism Scenario

Date	Participants	Description
June 21, 2005	VGFN Heritage and Land and Resources Departments; Vuntut Development Corporation	Introduce project and begin dialogue on NY Tourism scenarios and markets
June 24, 2005	YG Tourism Branch	Begin in-depth discussion of tourism scenarios and markets to be modelled in ALCES.
October 27, 2005	YG Tourism Branch	Detailed discussion of North Yukon tourism scenario and assumptions
February 27, 2007	YG Tourism Branch	Results of tourism modelling

2.3 Mineral Scenario

Date	Participants	Description
October 27, 2005	Yukon Minerals Management Branch, and Yukon Geological Survey	Technical discussion of North Yukon mineral scenario and assumptions
March, 2006	Yukon Minerals Management Branch, and Yukon Geological Survey	Specific mineral exploration and development metrics were revised and finalized in March 2006

2.4 Ecological Indicators

2.4.1 Wildlife Habitat Suitability Workshops, Whitehorse and Old Crow

Section 2.7.4.2 of the North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) provides a full description of habitat suitability workshops and methods. To support the creation of focal wildlife species habitat suitability maps for use in this project and the North Yukon Regional Land Use Plan, a series of workshops were held in Whitehorse and Old Crow.

In January 2005, Yukon Environment hosted a habitat suitability mapping workshop in Whitehorse, Yukon. Biologists were asked to rate the seasonal value of various habitat types occupied by caribou (Porcupine herd) and moose within the region. Each biologist had expert knowledge of the habitat use for each species. Colour reference photos of the various habitat types identified on the North Yukon biophysical map were shown to participants, and the photos were rated for their relative value to these species, by season.

A subsequent habitat suitability mapping workshop was held with Vuntut Gwitchin First Nation residents in Old Crow, Yukon, from January 27-28, 2005. The workshop was hosted by the North Yukon Planning Commission, in partnership with the Yukon Department of Environment and the North Yukon Renewable Resource Council. Land users who participated in the workshop were shown the same habitat reference photos as provided at the biologist workshop. The participants were asked to rate the habitats for their relative value to caribou and moose, by season. Marten observed habitat use was also rated by community members.

A follow-up workshop in Old Crow in April 2005 brought the January results back to the Old Crow land users for final review and discussion.

2.4.2 Barren-ground Caribou

Section 2.7.4 of the North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) describes barren-ground caribou habitat suitability methods and habitat ranks.

Date	Participants	Description
June 15, 2005	Environment Canada, Canadian Wildlife Service	Introduce project and discuss PCH habitat ranks and biophysical map
October 25, 2005	Environment Canada, Canadian Wildlife Service	Technical discussion of barren-ground caribou modelling approaches using ALCES
February 19, 2007	Environment Canada, Canadian Wildlife Service	Results of PCH modelling

2.4.3 Moose

Section 2.7.4 of the North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) describes moose habitat suitability methods and habitat ranks.

Date	Participants	Description
August 29, 2005	Yukon Environment, Fish and Wildlife	Discuss moose habitat ranks and biophysical map
October 27, 2005	Yukon Environment, Fish and Wildlife	Technical discussion of moose modelling approaches using ALCES.
March 15, 2007	Yukon Environment, Fish and Wildlife	Results of moose modelling

2.4.4 Climate Change and Landscape Transitions

Specific technical meetings were not used to discuss possible climate change and landscape transition scenarios. Instead, a literature review was performed by Dr. J. Johnstone, formerly of Yukon College, to guide the climate change scenario modelling in this project. Landscape transitions were estimated based on empirical information and then applying this information to the North Yukon biophysical map. Detailed methods are discussed in Section 2.6.3 of the North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b).[1]

[1] Note: Table 2.6.8 of North Yukon Planning Region Resource Assessment Report (North Yukon Planning Commission 2007b) is in errata. **High Elevation Forest** should also be included as landscape type with high susceptibility to climate change in the next five decades.