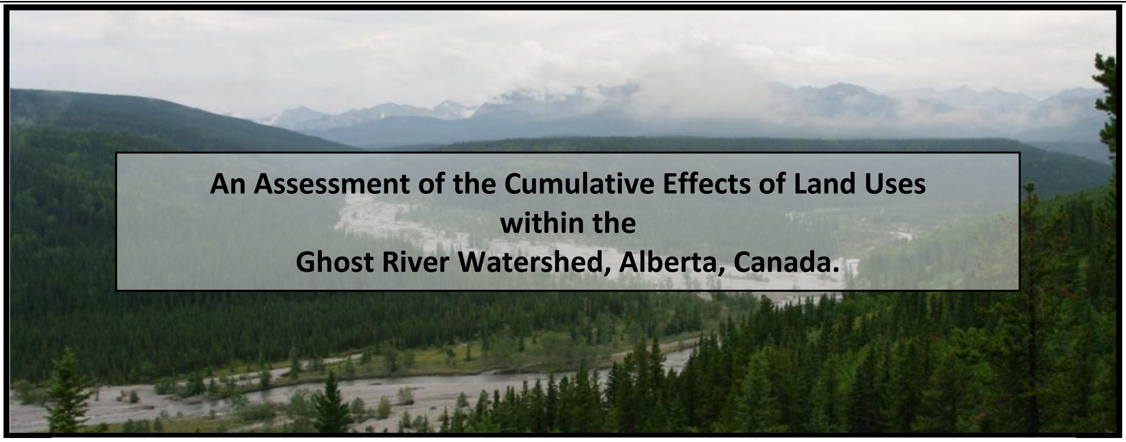
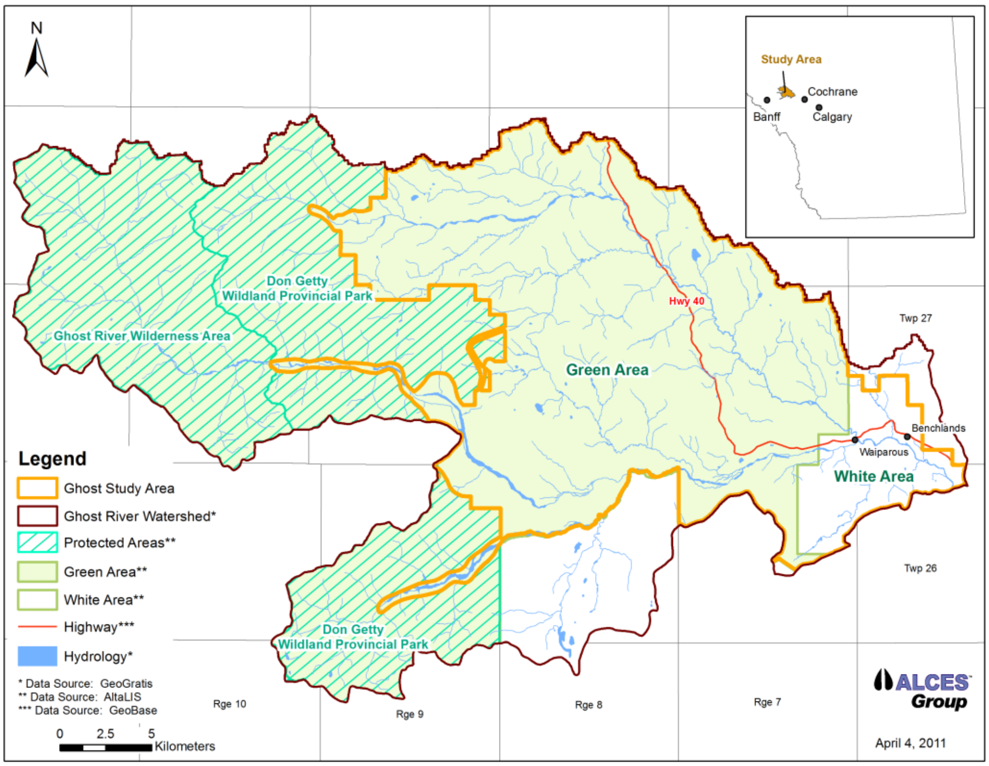
An Assessment of the Cumulative Effects of Land Uses within the Ghost River Watershed, Alberta, Canada.





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The Ghost Watershed Alliance Society (GWAS) is a group of residents with the vision to preserve and enhance the integrity of the ecosystem in the Ghost Watershed in order to secure the optimum quality and yield of the area's surface and groundwater resources.

The GWAS has set its mission to identify ecosystem and environmental issues affecting the watershed of the Ghost-Waiparous, raise public awareness, and work towards resolving these issues.

This report was prepared under contract to GWAS by Cornel Yarmoloy, M.E.Des. and Brad Stelfox, Ph.D., ALCES Landscape and Land-use Ltd.. Ghost Watershed Alliance Society gratefully acknowledges Alberta Ecotrust Foundation for their support of this project.

Disclaimer

ALCES modeling was conducted by Cornel Yarmoloy and Brad Stelfox. ALCES model customization was performed by Brad Stelfox. Any questions concerning the information or its interpretation should be directed to Cornel Yarmoloy or Brad Stelfox.

EXECUTIVE SUMMARY

The Ghost River basin of Alberta's East Slopes supplies approximately ten percent of the water flowing into the Bow River upstream of Calgary, Alberta[1], making it a vital link in the supply of abundant clean water to Calgarians and other downstream users. "Much of the area is of high scenic value and is heavily used for recreation and tourism."[2]

Society is increasingly aware of how our rivers, and the landscapes that support them, deliver not only water, but a suite of societal and ecosystem services which are needed to sustain our quality of life. Eastern Slope watersheds, such as the Ghost, supply diverse recreational needs, timber products, energy resources, support biological diversity and provide ecosystem services such as carbon storage, drinking water and flood control. Human land use development and recreational activities can potentially reduce the effectiveness of these valued services through incremental negative impacts on natural processes. Reductions in the ability of natural systems to provide clean water to downstream communities, such as Calgary, results in an increasing need for water treatment infrastructure and associated monies. Such costs are passed onto consumers through increasing taxes and metered water costs. As demonstrated in other geographies, the significant burden on downstream tax payers for potable drinking water can be reduced through the effective management of headwater areas rather than building and maintaining increasingly larger and more costly water treatment facilities.[3]

To support their vision of preserving and enhancing the integrity of the ecosystem functions in the Ghost watershed, the Ghost Watershed Alliance Society (GWAS; www.ghostwatershed.ca) sponsored a quantitative assessment of how past, current and future cumulative impacts of land use on multiple-use forest reserve and private lands within the Ghost-Waiparous watershed could potentially affect sustainability of forests, water, wildlife and recreational resources (Phase 1). The GWAS engaged ALCES Landscape and Land-use Ltd. (ALCES© Group; www.alces.ca) to conduct this initial assessment. A second phase is planned which will assess the impact of best management practises and alternate planning, alternative economic instruments and policy regimes on ecological and recreational metrics reviewed in the Phase 1 report.

The Ghost Watershed Cumulative Effects Assessment used the ALCES© computer simulation model, field research and review of the best available data and literature sources to complete this assessment. Major land uses such as forestry, recreation, energy, residential and agricultural development were analyzed to determine their impact on selected watershed indicators including; an index of relative water quality, forest age, forest fragmentation, grizzly bear mortality index, index of native fish integrity, recreational opportunity, and timber harvest. The analysis was accomplished by exploring two scenarios:

1. **Range of Natural Variation** (RNV): ALCES© computer simulations demonstrated the natural variation of selected indicators on a simulated Ghost River watershed without modern human activity or infrastructure. In this project, RNV values provide a plausible theoretical

range of natural variation against which current and future simulated indicator performance can be assessed.

2. **Business as Usual**" **Forecast**: Human population, recreational visitation, and land use development were simulated 50 years into the future to explore likely consequences in the performance of selected environmental indicators, recreational opportunity metrics, and timber harvest using conservative estimates of future land use growth rates and impacts.

Compared to RNV, past and current land use activities have caused a significant reduction in simulated and recorded performance of selected ecological indicators, including grizzly bear mortality index, relative water quality, integrity of native fish communities and recreational value of the landscape for non-motorized users. This declining trend is simulated to continue into the future assuming current management regimes and recreational activities characterize future practices. Off-highway recreational vehicle use, forest harvest and a high density of linear features were found to have the greatest potential negative effects on the selected indicators.

A water quality study of Waiparous Creek, Fallentimber Creek and the Ghost River attributed a 10-fold increase in sediment loading in Waiparous Creek to off-highway recreational vehicle (OHRV) activity.[4] Our simulation modelling identified transportation networks, multiple use recreation trails (mostly used by OHRVs) and forestry operations as the largest potential contributing causes of current and future decreases in relative water quality. For the purpose of this study, relative water quality is an index that includes relative loading of sediment, nitrogen and phosphorus.

Based on GIS analysis of 2007, SPOT5 satellite images, the study area has approximately 2,780 km of linear features with an average landscape edge density of ~5 km/km^2 (extrapolated values).[5] During field assessments in 2010, 27 of 29 (93%) of linear features and trails examined showed recent OHRV use.[6] Only 2 of 29 (7%) of the trails and linear features examined were posted with signs indicating they were open for motorized recreation. High density of linear features combined with active motorized use may negatively impact sensitive wildlife species such as grizzly bear and native fish.[7,8] The simulated elevated grizzly bear mortality index for the study area[9] suggests that grizzly bear populations may be challenged to persist given the levels of current and future projected activities relating to resource extraction and motorized recreation (Figure 25).

The health of native fish communities, as modelled using the simulated indicator "Index of Native Fish Integrity,"[10] has declined significantly below RNV over the past several decades. This model result suggests that fish community structure and fish age class distribution may have changed significantly and sustaining a healthy native fish community in this basin may be challenging.[11] The key land use elements affecting the fish index in the Ghost River Basin include human density, road density, and motorized trail density.

The forest age class structure of Ghost River basin is most influenced by the additive effects of fire, insects and logging; the higher the rate of logging, insect infestation and fire, the younger the forest. Current and future forestry practices will likely continue to transform the age class of the commercial forest toward younger trees. If current background fire, insect, and forest harvest rates continue, young forests under 40 years old, and clearcuts, forests under 20 years old, are simulated to become the dominant features of the forest mosaic. Old growth forests, defined as greater than 100 years old, will therefore become a progressively smaller component of the forest landscape.

The transformation of the forest landscape toward younger forests stands may adversely affect wildlife species that require old-growth forests[12,13,14,15] and may potentially erode the recreational value of the region for hikers, equestrian users, motorized off-highway enthusiasts, and others.[16,17,18,19,20]

Using simple economic relationships, recreational use of the landscape was modelled and estimated to have higher dollar value potential than timber harvest.

The combined results of ALCES© simulations, as well as field observations, and literature reviews, were used to identify possible environmental and sustainability concerns, potential areas of conflict between resource users, and to highlight potential strategies for mitigation and priorities for change. For example, literature review and data from field visits combined with simulation results suggest the need for more effective enforcement of OHRV regulations as a strategy to help maintain or restore key environmental indicators and recreational opportunities for non-motorized users.

This cumulative effects assessment evaluated the implications of business-as-usual land use practices on selected biodiversity indicators, landscape metrics, recreational resources and relative water quality on a regional scale, applicable to the entire study area. As such, these analyses are not intended to provide local-scale, tactical-level simulation results. Our model simulations suggest that basin-scale monitoring of biodiversity, hydrology, water quality and recreation may be necessary to enhance the understanding of potential trade-offs related to land use in the Ghost watershed, and to evaluate specific management strategies and best practices.

Many of the environmental, social and economic challenges detailed in this report are not unique to the Ghost Watershed in Alberta. Many Albertans and government officials recognise that current and past land-use management activities are not meeting societal needs with taxpayers often unnecessarily paying the price for inadequate land-use practises and management. "If we want our children to enjoy the same quality of life that current generations have, we need a new land-use system."[21] Concern by current visionaries has prompted the passing of progressive legislation (the Alberta Land Stewardship Act) and the creation of the Alberta Land-use framework to begin addressing these challenges.[22]

Additionally, "In 1992, at the United Nations Earth Summit in Rio, consumers, environmentalists, labour unions, industry representatives and First Nations came together to encourage tougher government regulations for forests. When this was not achieved, they conceived of voluntary forest certification as a market-based mechanism for ensuring healthy forests and strong communities."[23] This resulted in the creation of such organizations as the Forest Stewardship Council (FSC) and others which have effectively used market driven economic instruments to reward forest companies for sound timber management.[24]

"Consumers are increasingly concerned about the impact of their decisions on the environment and communities. Progressive companies are addressing this concern by verifying that the forest products they purchase carry the FSC logo, demonstrating that they come from healthy forests and strong communities. Thousands of companies specify and buy FSC certified wood and paper products."[25]

Currently forty five companies operating on over forty three million hectares of Canadian forests are FSC certified. However, Alberta Pacific Forest Industry is the only forest company in Alberta at this time which holds FSC certification.

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1. SETTING THE STAGE

Magnificent forests, mountains, clear sparkling rivers, and foothills west of Calgary provide area residents and tourists with a wealth of natural goods and services, aesthetics, and recreational opportunities (Figure 1). Past visionaries placed much of this landscape into Forest Reserve, National, Provincial, Wildland, and Wilderness Parks for the long term ecological, economic and recreational benefit of society.

Figure 1. Looking west (upstream) into the Ghost River basin.

However, rapidly growing, affluent regional populations and multiple human land uses have increased pressure on many of these valued landscapes, especially within forest reserve lands where many, often conflicting, land uses occur. "Multiple industrial use, increasing access intensity, and business practices of different sectors often result in a damaging fragmentation of the forest."[26]

Our study area lies within the Ghost River watershed, a sub-basin of the Bow River basin, situated approximately 40 to 70 km north-west of Calgary. This area is composed of both public forest reserve and private lands which support a diversity of overlapping land uses, including oil and gas exploration and extraction, agriculture, livestock grazing, forest harvest, residential, protected environmental areas, and diverse recreational activities.

Several organizations, including the Ghost Watershed Alliance Society[27], Alberta Wilderness Association[28] and the Canadian Parks and Wilderness Society[29] are concerned that multiple use activities within the Ghost River basin forestry lands could be reducing water quality, fish and wildlife habitat, landscape aesthetics and recreation opportunities. In 1999, the M.D. of

Bighorn, which encompasses the Ghost watershed, submitted a report to the Alberta Minister of Environment, "Forest Reserve Multi–Use Dialogue." The report drew attention to widespread ecosystem degradation caused by random camping and off-highway vehicle use in the Ghost River Forest Reserve.[30] The Ghost-Waiparous Operational Access Management Plan found that surveyed Albertan's believe Off-highway recreation vehicles (OHRVs) and random camping are the greatest threats to the environment in the Ghost-Waiparous area[31] (Figure 2).

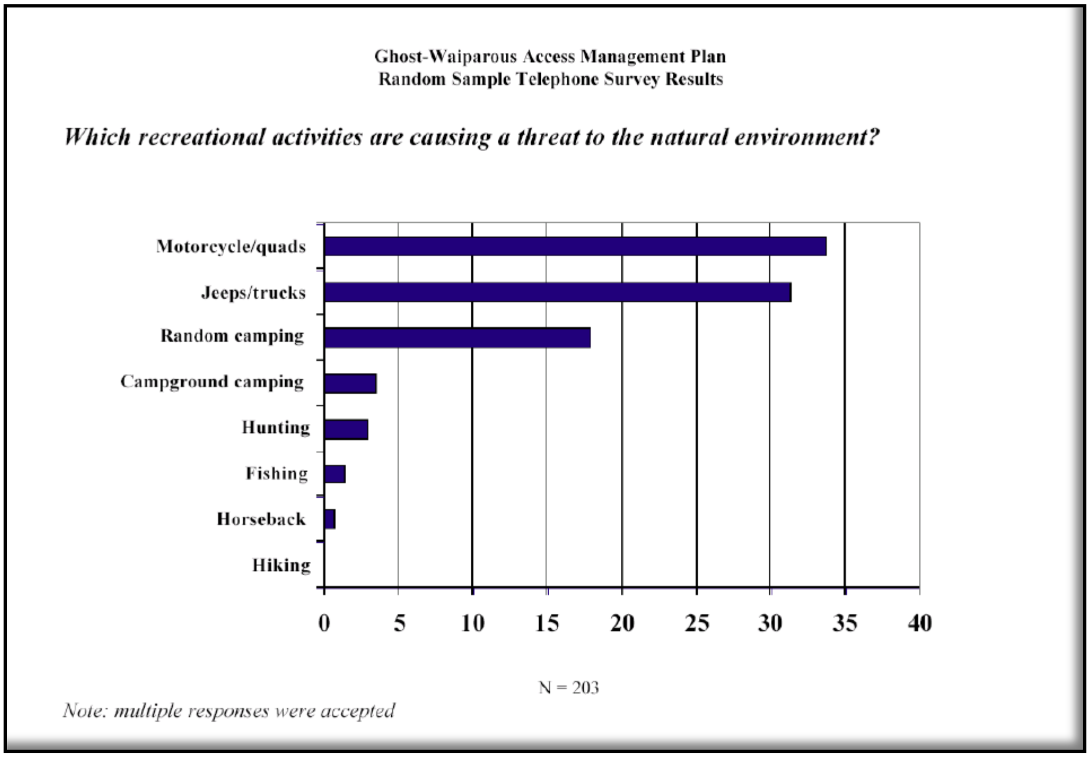


Figure 2. Ghost-Waiparous Access Management Plan, Random Sample Telephone Survey Results.

The Report of the Southern East Slope Task Force also identified inappropriate OHRV use and random camping adversely affecting environmental indicators on Alberta's southern East Slopes.[32]

This project focused on the following question: With current management practices and policy, will the Ghost-Waiparous landscape sustainably support ecological services, aesthetic, recreational, agricultural and industrial demands for the future needs of our children and grandchildren?

More specifically:

- Will the landscape provide clean water supply for downstream users?
- Will there be healthy natural areas providing quality wildlife habitat?
- Will the landscape satisfy motorized and non-motorized recreationalists seeking quality non-urban experiences?

- Will natural resource extraction such as forestry remain sustainable?

To help understand the impacts of the multitude of land use activities occurring in the watershed, and to assist in developing sustainable management plans to manage these impacts, the Ghost Watershed Alliance Society engaged ALCES Landscape and Land-use Ltd. (ALCES Group[33]) to assess the cumulative effects of human activities on selected water, forest, wildlife, and recreational metrics.

To assist with this task, the ALCES© simulation model[34] was used to quantify the "range of natural variation" for water, wildlife, and forest indicators in the Ghost River study area when modern human activities and infrastructure are absent. ALCES© was then used to model indicator trends from 1900 to present day ("backcasting"), as well as project future changes, using conservative estimates of land-use development, for the next 50 years ("forecasting"). Backcasting and forecasting[35] results were compared to the simulated range of natural variability to assess areas of concern and opportunity.

An analysis of recreation activity levels and some economic metrics were also completed. All findings presented in this report are from ALCES© model simulations, except where noted.

1.1 NATURAL CHANGE

The effect of past, current and future human-caused changes to the Ghost watershed can only be understood relative to changes that happen naturally. Since the retreat of the last ice age 10,000 years ago, the Ghost has been shaped and altered by natural disturbances such as weather, erosion, fire, insects, and grazing by wildlife such as elk and bison. While year to year variation would have existed, this natural system was generally characterized by clean rivers, lakes, and groundwater, a mix of forests and grasslands, and diverse wildlife and fish communities.

Water conditions, wildlife populations and plant communities vary naturally over time, affected by precipitation, temperature, fire and other natural phenomena (Figures 3, 4). It is this natural inter-annual variation that is referred to in this report as the "Range of Natural Variability" (RNV). For example, relative water quality in the Ghost River is variable between years (Figure 5). However, overall water quality throughout RNV is high, due to low levels of sediment and nutrients.

Twenty random (Monte Carlo)[36] simulations were performed to assess plausible RNV values for environmental indicators examined. One such run, displaying the average relative water quality index, is shown in Figure 5, below. The green band shows the range in which 95% of all average relative water quality index values existed for all simulations.

Historical and simulated future change in indicator performance can be compared to the theoretical RNV for water, wildlife and forest indicators to understand if there are reasons for concern today and into the future.

Figure 3. The major natural disturbance regimes in the Ghost River basin include wild fire (left), insect outbreaks (middle) and precipitation induced events such as flooding (right).

Figure 4. Bison (left) and elk (right) were important natural herbivores that shaped plant community structure in the foothills of west Alberta.

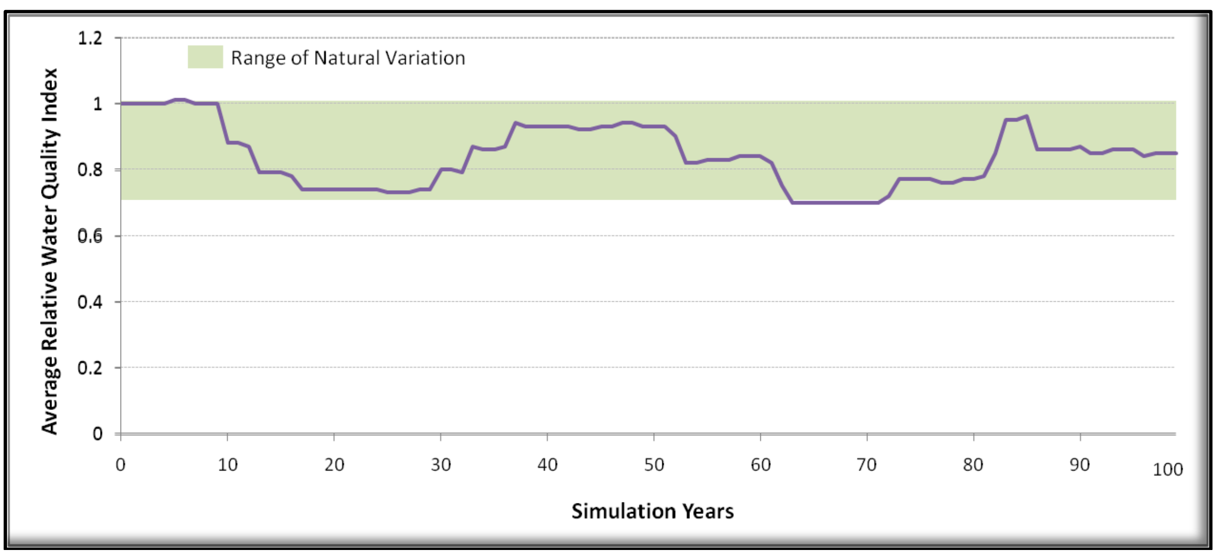


Figure 5. Natural year-to-year variability of relative water quality caused by inter-annual variation in precipitation and fire.

1.2 THE GHOST-WAIPAROUS

The study area includes the non-park portions of the south and north branches of the Ghost River and the Waiparous Creek drainage. This 53,000 hectare region includes portions of the Ghost River Forest Land Use Zone[37] (Green Area/public lands) and a smaller area of agricultural and residential lands (White Area/private lands) along the south-eastern border of the study area (Figure 6).

The area is best defined as a "foothills" topography comprised of a matrix of mixed lodgepole/aspen, lodgepole pine, Douglas fir, and grasslands. There are ~6,400 hectares of wetlands with a river and stream network of ~805 km.

Approximately 400 permanent residents live in the communities of Benchlands and Waiparous Creek and on acreage and agricultural residences on the eastern side of the study area.[38]

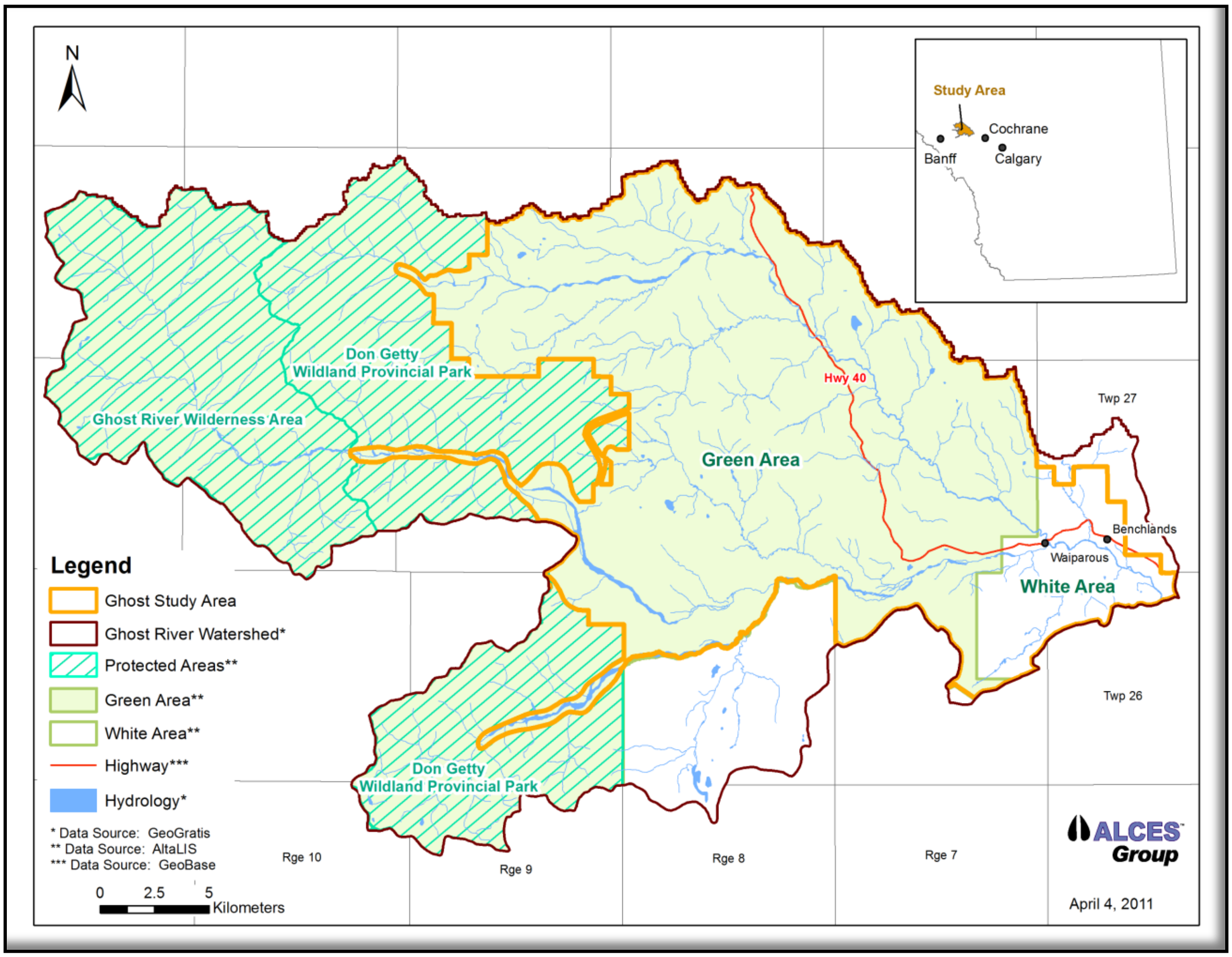


Figure 6. Ghost River watershed. Study area outlined in orange.

1.3 RESOURCE MANAGEMENT RESPONSIBILITIES

Alberta's Department of Sustainable Resources Development manages the Green Area's diverse activities, guided by the Alberta government's Ghost River Sub-Regional Integrated Resource Plan and the Ghost-Waiparous Operational Access Management Plan.[39] The Integrated Resource Plan has defined land use zones which specify acceptable activities within the watershed (Figure 7).[40]

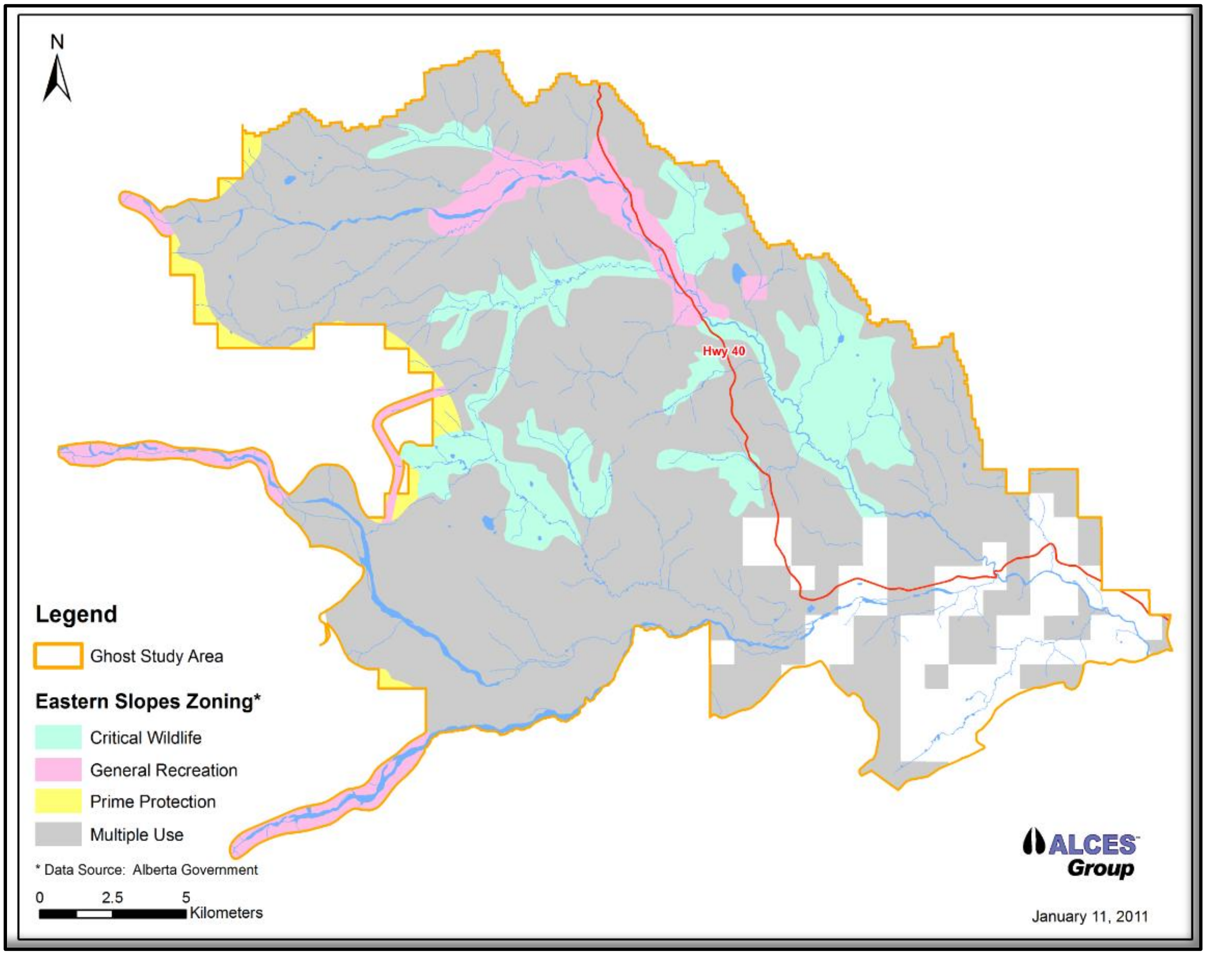


Figure 7. Land use zones within the study area.

The Zones applicable to the study include: Multiple Use (5), Prime Protection (1), Critical Wildlife (2), and General Recreation (4). The majority of the study area is located within the Multiple Use Zone and secondarily, the Critical Wildlife Zone (Table 1).

Table 1. Appropriate activities within each zone are listed below.

Zone	1	2	4	5
Activity	**Prime Protection**	**Critical Wildlife**	**General Recreation**	**Multiple Use**
Non-motorized Recreation				
Fishing				
Hunting				
Scientific Study				
Trapping				
Trails, non-motorized				
Transportation and utility corridors				
Primitive camping				
Intensive recreation				
Off-highway Vehicle activity				
Logging				
Domestic grazing				
Petroleum and natural gas exploration & development				
Coal/mineral exploration and development				
Service Camping				
Commercial development				
Industrial Development				
Residential subdivision				
Cultivation				

Compatible Use
Permitted Use
Not Permitted

The stated principle goal for the Integrated Resource Plan is to protect water resources and to provide for land uses in a manner consistent with the principles of conservation and environmental protection.[41]

The Ghost-Waiparous Operational Access Plan has been designed to "recommend on-the-ground solutions to motorized Off-Highway Vehicle (OHRV) and other related recreational access issues, while at the same time ensuring the sustainability of public land and resources. Key priorities have included the protection of the watershed, fisheries and wildlife."[42]

Under direction of the Ghost-Waiparous Operational Access Plan, the Ghost Stewardship Monitoring Group (GSMG) has been created: *"The Ghost Stewardship Monitoring Group is an assembly of committed stakeholders of the Ghost-Waiparous FLUZ (Forest Land Use Zone) that will deliberate and recommend GAMP implementation decisions that ensure reasonable area access by all users while using its best efforts to ensure that the character of the region is maintained."*[43]

2. ANALYSIS: LOOKING BACK (THE LAST CENTURY) AND LOOKING FORWARD

2.1 LINEAR FEATURES

Human-caused linear features are a defining landscape driver for many biodiversity indicators.[44] This is due to direct and indirect disturbance caused by humans, animals, and plants that move along, or expand from, the linear network. In some cases, linear features can improve habitat for species such as moose and grizzly bear, by providing access to preferred younger plant communities and increased forage. These positive effects however, can be over-whelmed by increased direct and indirect mortality from motorists, hunters, fisherman, trappers, and animal predators. Vehicle-wildlife collisions, intentional and unintentional disturbance or harassment, harvest, poaching, avoidance of habitat along linear features, increased erosion, and changes in predator-prey dynamics all contribute to the cumulative effects that define the interface between linear features and performance of wildlife indicators. [45]

An accurate assessment of linear features is essential to understanding the impacts of land uses and recreational activities. Field assessments, by the authors, found many existing linear features were not readily visible on GIS satellite imagery and were not part of the digitized database being used by the Government of Alberta in assessments of edge density (Figure 8). Field assessment of linear features by Alberta Forestry, Parks and Fish and Wildlife staff in 1997 identified approximately 2,000 km of trails in the Ghost area compared to 189 kilometres of officially designated trails.[46] Spray Lake Sawmills' detailed forest management plan assessed linear densities, in the study area, ranging from approximately 3 to 4 km/km^2.[47]

Figure 8. Example of an OHRV trail not identified in the original data set.

To more precisely quantify linear feature density, we randomly distributed twenty five, 1 km^2 polygons over the study area (Figure 9, top) and had a GIS analyst manually digitize all visible linear features within each polygon (Figure 9, bottom left and right).[48] This dataset allowed for the construction of a linear feature correction coefficient which was applied across the full study area.

The analysis showed that linear features were under-estimated by ~72%. For the study area, the original Government of Alberta data set indicated an average linear density of 1.42 km/km^2, whereas the corrected dataset suggested a linear density of 5.12 km/km^2.[49]

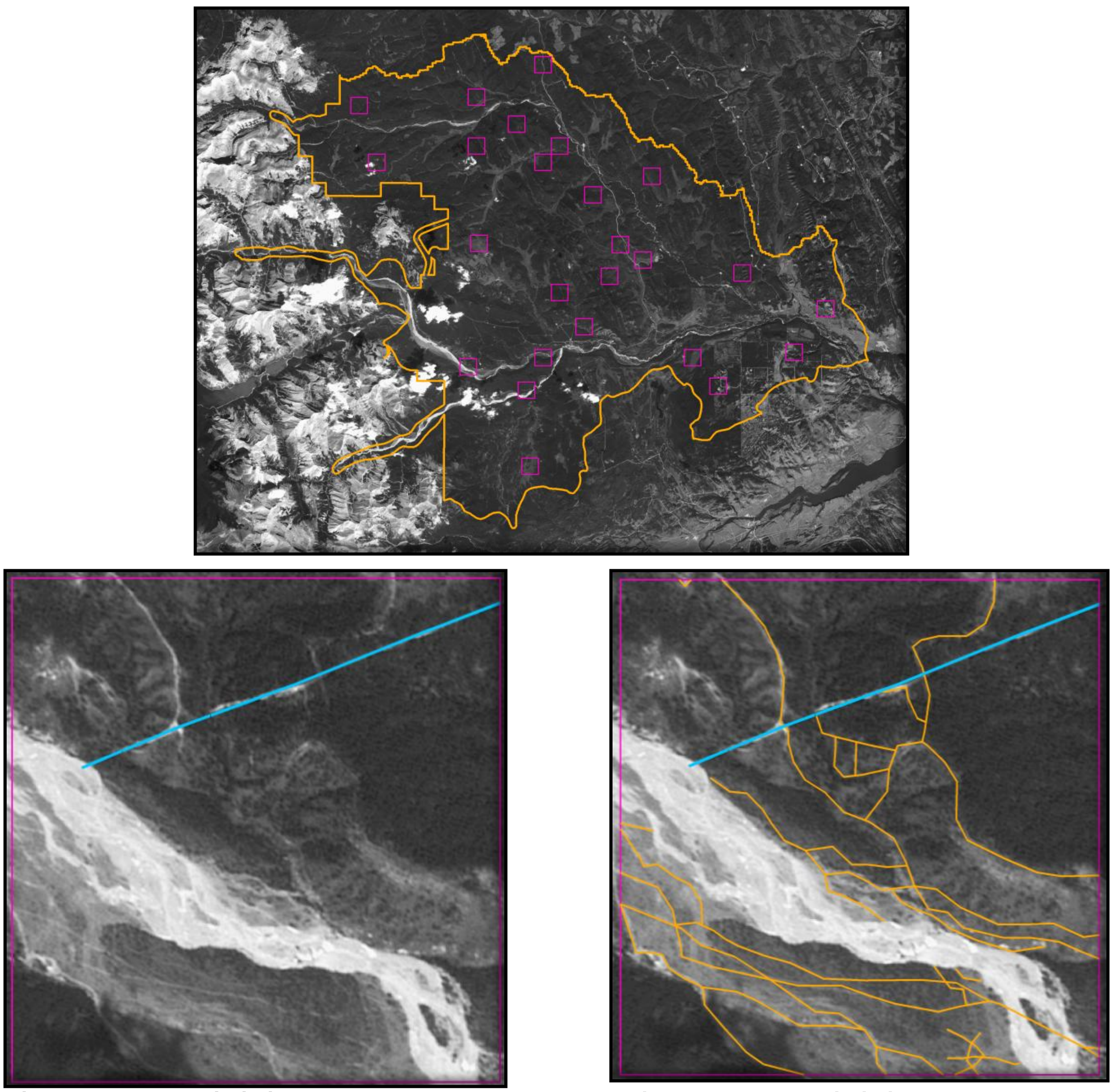


Figure 9. Methodology for quantifying linear feature density in the Ghost River Watershed.

Linear feature density is modelled to increase from current levels of ~5 km/km^2 to ~10 km/km^2 during the next several decades. Two 1 km^2 squares displaying these densities are provided below (Figure 10). At an edge density of 10 km/km^2, any given location is, on average, no greater than 50 m from a road, pipeline, recreational trail or seismic line.

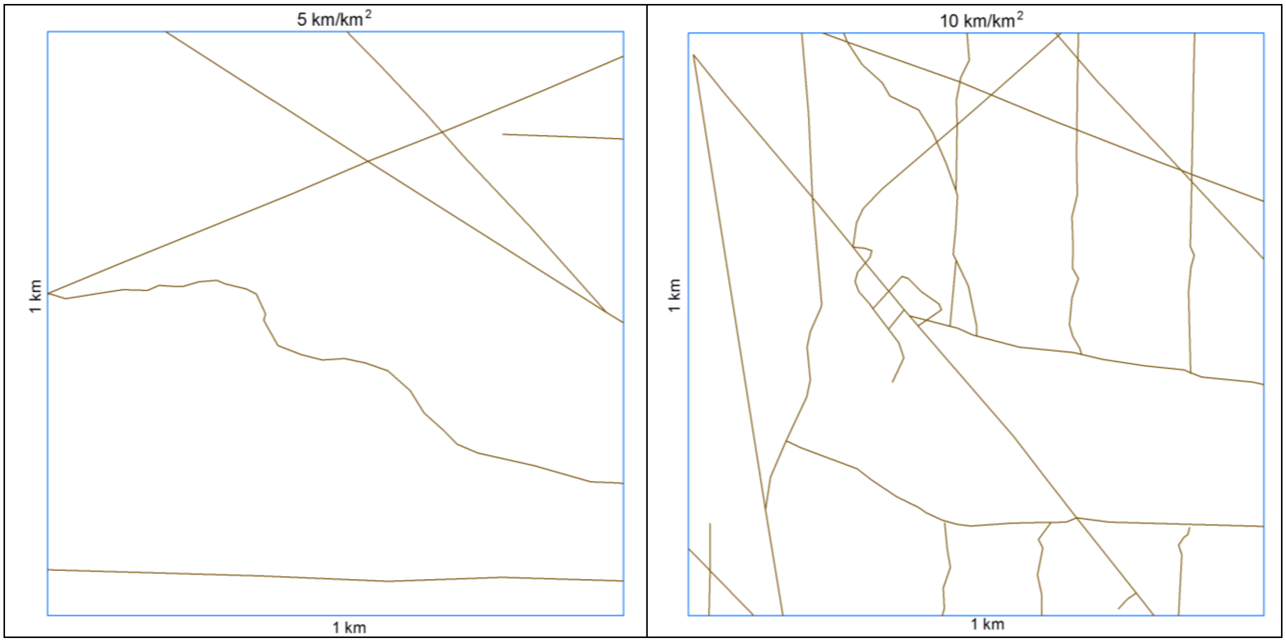


Figure 10. Maps indicating 5 km/km^2 and 10 km/km^2 of linear features.

With 804 km of stream/rivers and ~2,780 km of linear features in the study area, roads, seismic lines, inblock forestry roads and recreational trails will frequently intersect streams, rivers, or wetlands. ALCES© scenarios assumed that bridges would be constructed where streams are intersected by major roads and major forestry haul roads, and culverts would be installed for stream crossings by minor roads, inblock roads, well site access roads and identified official OHRV trails.[50]

Culverts fragment aquatic ecosystems because of their tendency to become “hung” during flood events. A hung culvert occurs when the downstream end of a culvert hangs above the downstream water level as a result of scouring of the stream bed caused by high volumes of water exiting the culvert during snowmelt or storm runoff (Figure 11).[51] These hung culverts create barriers to the upstream movement of fish.

Figure 11. An example of a hung culvert that interferes with fish movement. Photo courtesy of Dr. Michael Sullivan (Government of Alberta).

Hanging culverts that fragment fish habitat can compromise population viability by preventing fish passage, potentially decreasing access of fish to spawning and rearing areas.[52,53]

Livestock, equestrian and vehicular crossings or activity in wetlands (Figures 12, 13) and streams can contribute to significant increases in sediment loading and pollution into standing and moving water.[54,55,56,57,58,59] Livestock grazing has potential to negatively impact riparian health and decrease water quality by causing streambank erosion, vegetative cover loss and increased loading of nutrients and pathogens into waterways.[60,61,62] "Pathogens that are deposited in water bodies will attach to fine sediments and settle to the bottom. These pathogens are mobilized and can move downstream if the sediment is disturbed by vehicles, people, or animals travelling in or across the water body."[63]

Riparian regions often support comparatively high levels of biodiversity, biomass and higher frequencies of seeps and springs.[64] Although overland sediment transport and bedload sediment movement are natural components of foothill stream basins, the additive sediment load contributed from roads, trails and devegetated strea10mbanks, can significantly increase total sediment load and impact both water quality and stream ecosystem processes.[65,66]

Figure 12. Livestock grazing riparian habitat.

Figure 13. Motorized vehicle crossing of wetland causing increased sediment movement (Ghost study area).

2.2 WATER QUALITY

A water quality study of Waiparous Creek, Fallentimber Creek and Ghost River, prepared for Alberta Environment in 2006, found sediment loading of Waiparous Creek and the Ghost River was much greater than would be expected in rivers draining similarly forested environments in the upper foothills of southern Alberta.[67] Sediment loading in Waiparous Creek was up to ten times higher in areas downstream of OHRV use than in upstream areas without OHRV use (Figure 14).[68] Off-road vehicle activity was identified as the factor causing increased erosion and sediment loading into waterways, thereby reducing water quality.[69] Increase in nutrients, bacteria and certain metals (aluminum, iron) are often associated with high sediment loads.[70]

Figure 14. Confluence of Ghost River and Waiparous Creek at Waiparous Village on 21 June 2007. Depicting increased sediment loading in Waiparous Creek identified as related to upstream OHRV use. [71]

Numerous multiple use trails, used predominately by OHRVs, in the study area, cross directly through streams, rivers and wetlands (Figure 15, 16). Such travel corridors can contribute large sources of sediment and pollution to water bodies.[72] During rainfall and snowmelt events sediment is transported directly from trails into watercourses.[73] Erosion and water quality issues due to off-highway vehicles are the most conspicuous and consistently observed impacts by researchers examining OHRV use.[74,75,76]

There is extensive use by OHRVs of closed trails within the study area (Figure 16).[77] During field assessments, 93% of linear features and trails examined showed recent OHRV use.[78] Similar use of closed OHRV trails was documented in a recent study of the Castle Forest Land Use Zone in southern Alberta.[79] The chronic and illegal use of trails and seismic lines by OHRVs also impairs the reclamation of many linear features in the region.

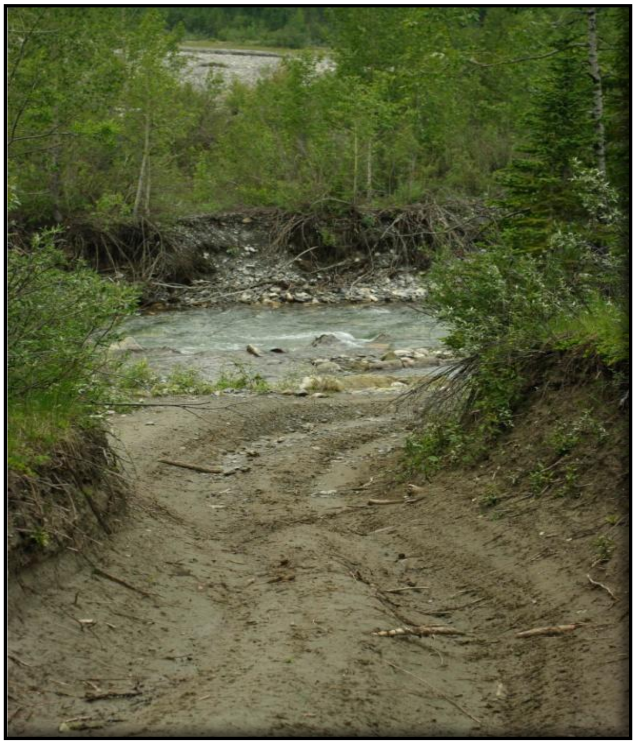


Figure 15. Example of un-vegetated motorized trail contributing sediment to Waiparous Creek.

Figure 16. Meadow and wetland damage by OHRV use, Meadow Creek, Critical Wildlife Zone Ghost Study Area.[80]

Natural disturbances such as fire and avalanches, and human land uses including; forestry, agriculture, energy development and transportation that permanently or temporarily remove vegetative ground cover can contribute to loss of soil and increase sediment loading to streams and rivers.[81],[82],[83],[84] Periodic sediment movement into surface water is a natural phenomenon.[85] The concern, however, is that the additive effects of the various land uses (cutblocks, inblock roads, access roads to cutblocks, camping, livestock grazing and un-vegetated OHV trails) can significantly increase the cumulative amount of sediment loading to that expected from natural processes (Figure 17).

Figure 17. (Left) image showing water turbidity in Waiparous Creek upstream of significant landuses (forestry, inblock roads, OHRV activity, grazing, campgrounds and recreational facilities) - (Right) image showing water turbidity in Waiparous Creek downstream of landuses. Images taken on 29 May 2011, two days after a significant spring storm event.

A recent riparian health assessment of the Waiparous Creek watershed states that, "... most riparian areas within the Waiparous Creek watershed appear to be in proper functioning (healthy) condition." However, "Degraded water quality may also indicate that land uses in the Waiparous Basin may be overtaxing the buffering ability of riparian areas, even those in a healthy condition. If the health and condition of adjacent uplands is degraded, erosion and loss of upland vegetation cover (e.g. logging) can overburden the ability of riparian areas to absorb and filter sediment from overland runoff."[86]

The majority of sediment movement arising from land use footprints and natural processes occurs during and immediately following major precipitation or snow melt events.[87],[88] Figure 18 illustrates an example of sediment movement associated with clear-cut logging, in the study area, during a precipitation event.

Figure 18. Sediment erosion from inblock road, Meadow Creek area cutblock, Ghost River study area, 27 May 2011.

The total contribution of sediment loading to rivers from each land use sector within the study area is variable. Greatest contributions are from the transportation sector (major roads, minor roads), multi-use recreation trails, and forestry cutblock roads (Figure 19). The forest sector is an important contributor of new minor roads accessing cutblocks in the region and can be significant sources of sediment loading (Figure 18). Within the model, energy sector footprints are defined as well pads and pipelines. Additional sediment loading related to the energy industry is created by seismic lines and access roads, however these are collectively grouped under transportation, as are major and minor forestry access roads.

Runoff coefficients for sediment, nitrogen and phosphorus, used for this analysis, were based on information developed for southern Alberta landscapes.[89]

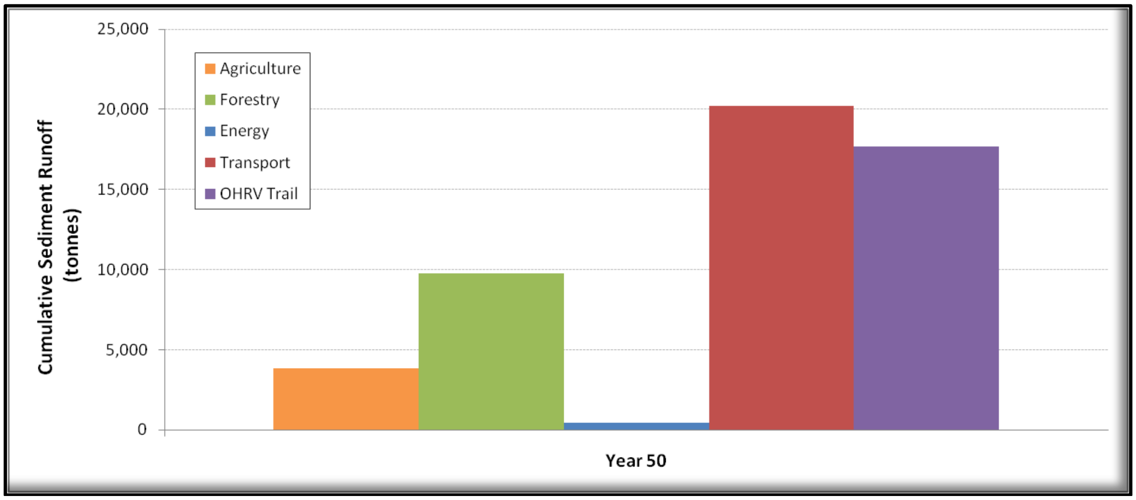


Figure 19. Relative land use sector contributions of sediment runoff.

Random vehicle camping is a popular activity within the watershed with limited or no facilities (outhouses, food poles, garbage containers) associated with this use. While brochures recommend random campers "camp at least 30 meters away from watercourses,"[90] many camp sites are located very close to streams (Figure 20).[91]

Figure 20. Random camping adjacent to Lesueur Creek showing loss of streambank vegetation.

The Ghost River Access Management Plan recommends posting "signs that identify areas available for motorized random camping (on highway vehicles) at sites deemed appropriate for that purpose. Areas that are not specifically signed would not be available for motorized random camping."[92] During field visits to the study area such signage was not noted. Random camping sites can be found directly adjacent to waterways where vegetation loss and proximity to waterways greatly increase the likelihood of transportation of sediment and human wastes into streams during spring snowmelt and rain events.[93] Uncontained human feces are not only an aesthetic concern but pose threats of water contamination and potential for disease transmission.[94,95]

Based on simulated recreational visitation rates and (non) availability of outhouses, the estimated fresh weight of human manure[96] deposited in the watershed but not contained in sanitary facilities is currently estimated to range from 62 to 125 tonne/yr, this value is expected to increase to a range of 135 to 270 tonne/yr within four decades (Figure 21). Possible bacterial and pathogenic contamination of water supplies from uncontained human manure should be of concern to downstream users both in terms of health implications and increased water treatment costs.

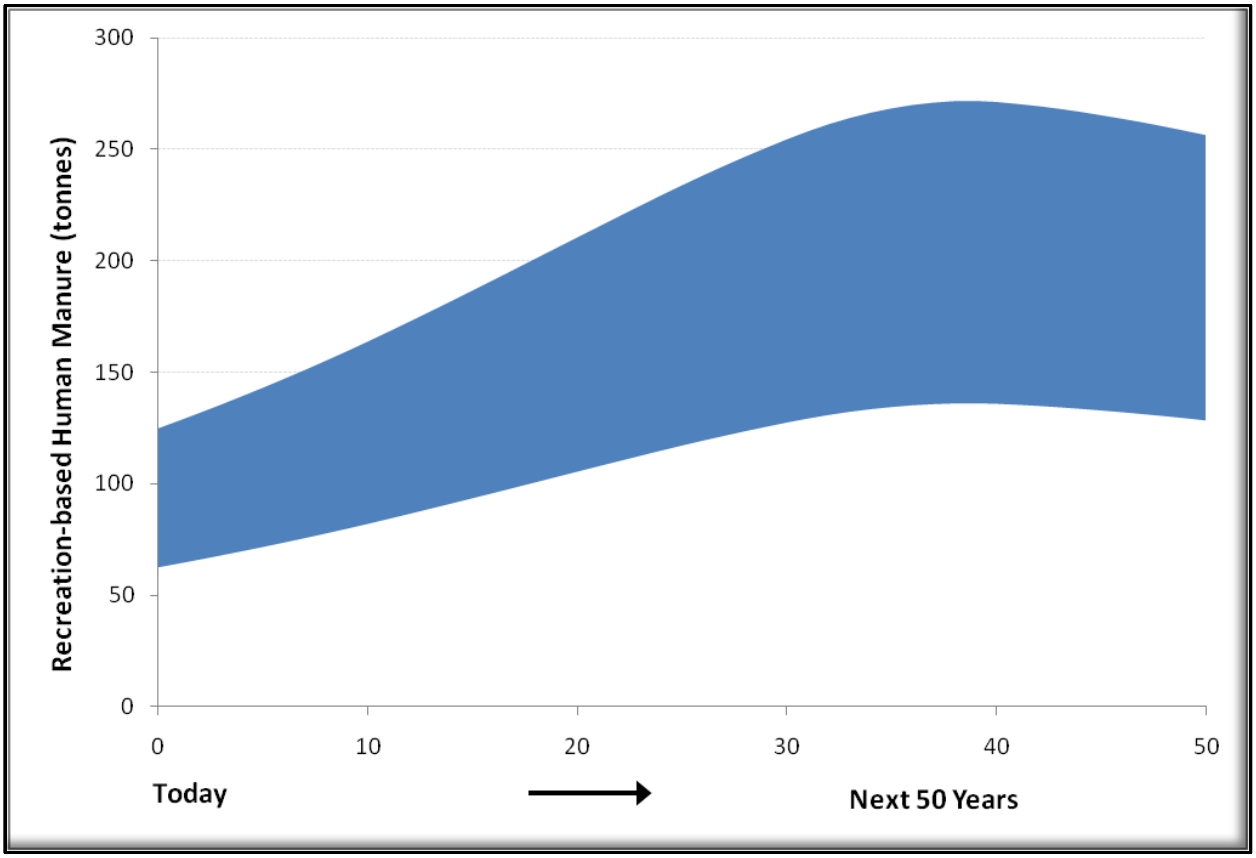


Figure 21. Range of annual "uncontained" human manure deposited in study area.

Agricultural activity in the study area is focussed on the livestock industry with cattle and horses grazing on private lands and forestry grazing allotments. Grazing allotments issued by the Alberta government have been in existence within the Forest Reserve portion of the study area for more than 50 years.[97]

Livestock grazing has potential to decrease water quality by causing streambank erosion and increase nutrient loading into waterways from manure.[98,99] Forest harvest cutblocks and associated transportation features are also sources of increased sediment and nutrient loading.[100,101] Significant areas of the study area are projected to be harvested over the next 50 years.

Increases in sediment, phosphorus and nitrogen loading are projected, leading to further declines in relative water quality within the watershed (Figure 22). The index of relative water quality shows sediment, nitrogen and phosphorus loading may be close to three times natural in 50 years, with the index of relative water quality declining from excellent to fair. For a detailed description of relative water quality, as modelled in this report, see Appendix C.

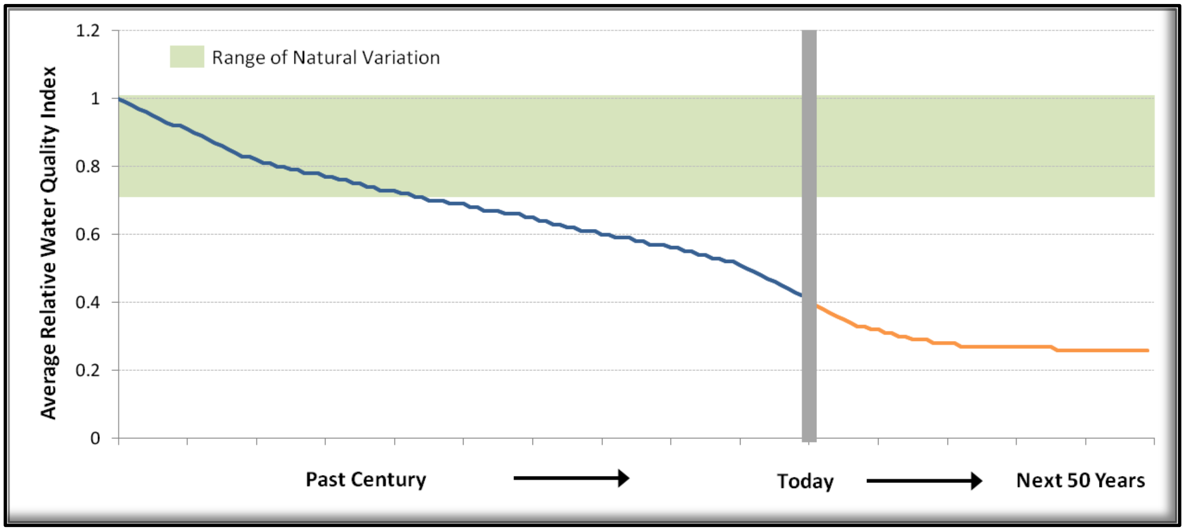


Figure 22. Change in relative river water quality index.

2.3 NATIVE FISH

The cumulative effects of recreation, agricultural, forestry, transportation and industrial activity have resulted in decreased relative water quality, watercourse fragmentation, streambank erosion and increased fish catch/harvest due to high human access levels. Ongoing development and activity will likely lead to a further decline in native fish habitat and populations (Figure 23).

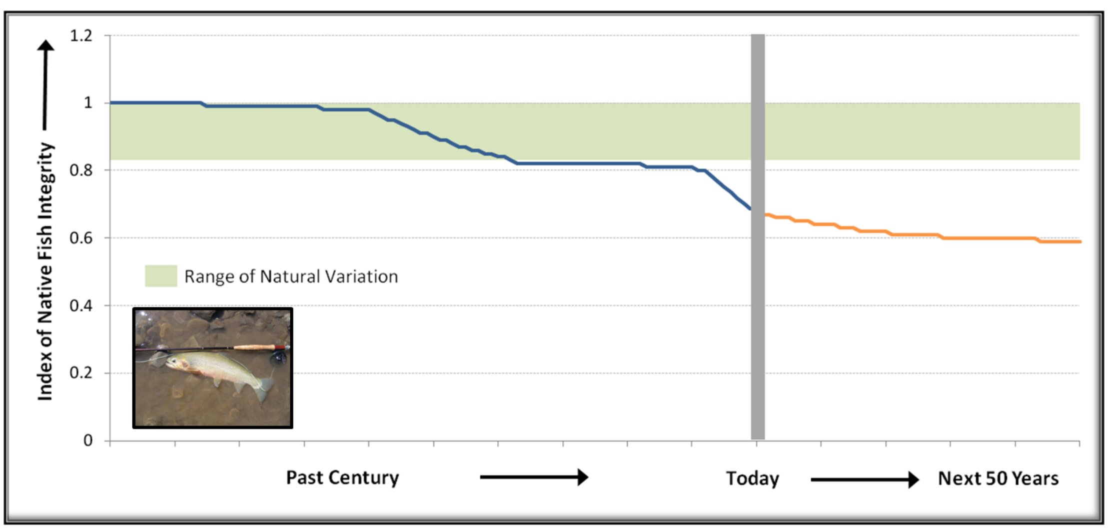


Figure 23. Projected changes in Index of Native Fish Integrity.

A high native fish integrity index (INFI) value, (0.8 to 1.0), indicates a fish community comprised of sensitive fish species, rare fish, top predators and long-lived individuals. These species would include bull trout, cutthroat trout and rocky mountain whitefish. Most people would interpret this fish community condition as one that provides “good fishing”.[102]

The modelled current INFI value (~0.68) indicates that the health of the native fish community is below what would be expected under natural conditions. Future simulations predict a further decrease to ~0.59, in fifty years. This future index level suggests native fish populations will be mostly self sustaining, but with threats of serious declines possible.[103] Angling experiences for native fish species will remain sub-optimal.

An assessment of trout abundance and distribution in the Waiparous Creek drainage showed non-native brook trout outnumbered native cutthroat and bull trout. Depending on the stream section sampled, brook trout outnumbered bull trout by a range of 15-33 to one. Cutthroat trout were outnumbered by brook trout by a range of 7-14 to one.[104]

Native fish species such as westslope cutthroat trout are considered an indicator species for watershed quality.[105] Increased sediment releases into fish bearing watercourses can have detrimental effects on spawning areas and food production for cutthroat and bull trout,[106] “... it is likely that catchments subject to higher densities of landscape disturbance (i.e. clear-cuts, roads/OHV trail and stream-crossings) will be associated with lower westslope cutthroat densities and factors of condition.”[107]

A cumulative effects analysis of the Carbondale River watershed, in south western Alberta, found higher clear-cut densities were generally associated with lower westslope cutthroat trout relative abundance, biomass density and average relative weight.[108] The abundance of bull trout in Alberta`s Kakwa River watershed was negatively related to the percentage of fine sediment substrate and sub-basin forest harvest. Local extirpation of bull trout from 24% to 43% of stream reaches was predicted as a result of forest harvesting.[109] “Roads are the principal source of fine sediments to streams in forestry operations, typically being much greater than that from all other land management activities combined.”[110] “Even small increases in fine sediment loading to spawning areas can cause dramatic losses of early life-history stages of salmonids.”[111]

For forest harvest operations, “The primary strategy of maintenance and protection of aquatic environment and fish habitat values is to maintain treed buffers along watercourses and water bodies and adopt rigorous watercourse crossing and erosion control measures.”[112]

An assessment of forestry related disturbance in south-eastern B.C. found that ... logging of non-fish bearing perennial and ephemeral streams is a major limiting factor to the conservation of cutthroat trout.[113] Logged ephemeral streams were observed on cutblocks in the Meadow Creek area during May 2011, as illustrated in Figure 24.

Figure 24. Logging of ephemeral streams, Meadow Creek cutblocks, Ghost River study area, 27 May 2011.

Conservation risk for bull trout in the Ghost Watershed has been rated as high risk of extirpation.[114] In a presentation to the Endangered Species Conservation Committee, December 2010, Dr. M. Sullivan stated, "A few bull trout (populations) in our protected areas (e.g., Banff, Jasper, parts of Kananaskis Country) are recovering, but areas with continued habitat degradation and development pressure show continued declines and lack of recovery. Our failure to recover bull trout is clear evidence of the link between the cumulative effects of land use and fish population health."[115]

2.4 GRIZZLY BEAR

Grizzly bear numbers are relatively low outside mountains and foothills parks and protected areas because they are likely to be killed near roads, trails, residences, and facilities.[116,117,118] The current high density of linear features (5 km/km^2),[119] being used by motorized recreationalists exceeds the management target of 1.2 km/km^2 or below, recommended by the Alberta Grizzly Bear Recovery Plan.[120] Foothill and mountain ecosystems with high linear feature densities, such as currently found in the study area, may be avoided by grizzly bears resulting in a potential net loss of habitat[121,122,123] and potential negative impacts on populations.

There are many features of the Ghost-Waiparous region that define its limited potential capacity to maintain grizzly bear populations, including high densities and motorized use of linear features, forestry clearcuts, poor management of attractant foods by random campers[124] and lack of food storage and garbage facilities (Figure 25).[125] Recent research in Alberta suggests that although bears may find more food in clearcuts, the associated high level of human access leads to apparently unsustainable mortality.[126]

Figure 25. An example of bagged attractant organic garbage left behind at a random campsite, 2 August 2010.

Under "business as usual" assumptions of future land use, the index of grizzly bear mortality in the study area is expected to increase in the future (Figure 26). The mortality index in the area is currently twice what would be expected under natural conditions. Simulation modelling indicates the mortality index will rise to approximately five times natural rates as forestry and recreational developments increase human access throughout the study area (Figure 26). Such potentially high mortality rates suggest that maintaining viable populations of grizzly bear within the study area will be challenging.

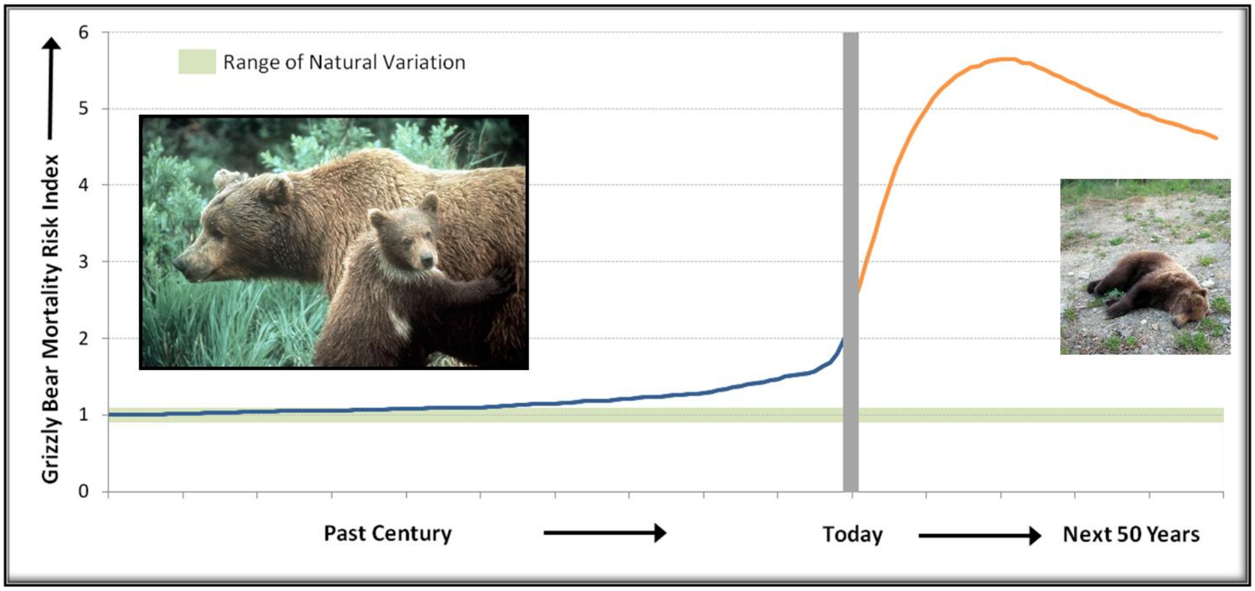


Figure 26. Projected changes in grizzly bear mortality index.

"The persistence of grizzly bears in Alberta hinges directly on reducing human-caused mortality. That reduction can best be achieved through limiting motorized access to grizzly bear habitat, including road closures and disallowing off-road vehicles."[127] "Management of access, in particular open roads, and human food and garbage, and educating hunters are critical issues with respect to managing grizzly bear mortality…"[128]

2.5 FORESTRY

2.5.1 Forest age and structure

Currently, forest harvest operations in the study area are conducted mainly by Spray Lake Sawmills of Cochrane, under the license of a Forest Management Agreement (FMA). As stated in Spray Lake Sawmills Detailed Forest Management Plan, "The primary use to the FMA is to establish, grow, harvest and remove timber."[129] Annual harvest volumes and area can vary between years (because of fire salvage or insect abatement programs) but were calculated to be approximately 52,000 m^3 per year within the study area.[130] Computation of subjective deletions and merchantable landbase in ALCES were based on information extracted from the Detailed Forest Management Plan of SLS and the timber growth and yield curves were those provided to the ALCES Group by the Timber Supply Analysts of Sustainable Resources Development for the Southern Foothills Study.

The general forest harvest strategy of Spray Lake Sawmills is to approximate an even-flow harvest based on at regulated forest age class structure within the merchantable landbase of their FMA (Spray Lake Sawmills Detailed Forest Management Plan 2001-2026). This theoretical strategy would create approximately equal areas of all forest ages of stands from 0 to 100 years of age in the future. Stands older than 100 years would be of lower occurrence and largely restricted to forests that are non-merchantable, located close to streams, or on excessively steep slopes. This generalized harvest strategy of even-flow harvest has been adjusted by SLS to accommodate a surge cut to mitigate risk to timber harvest from regional mountain pine beetle outbreaks (Spray Lake Sawmills Detailed Forest Management Plan, 2001-2006).

From a forest landscape management perspective, it is important to remember that forest age structure is being influenced by logging, insects and fire. Collectively, these disturbance regimes, each of which is additive to the other, will generate a future forest landscape that is much younger than exists today (Figure 27). A key outcome of these natural and man-made disturbances is the significant reduction or loss of old forests and the ecological processes that are dependent on old forests.[131]

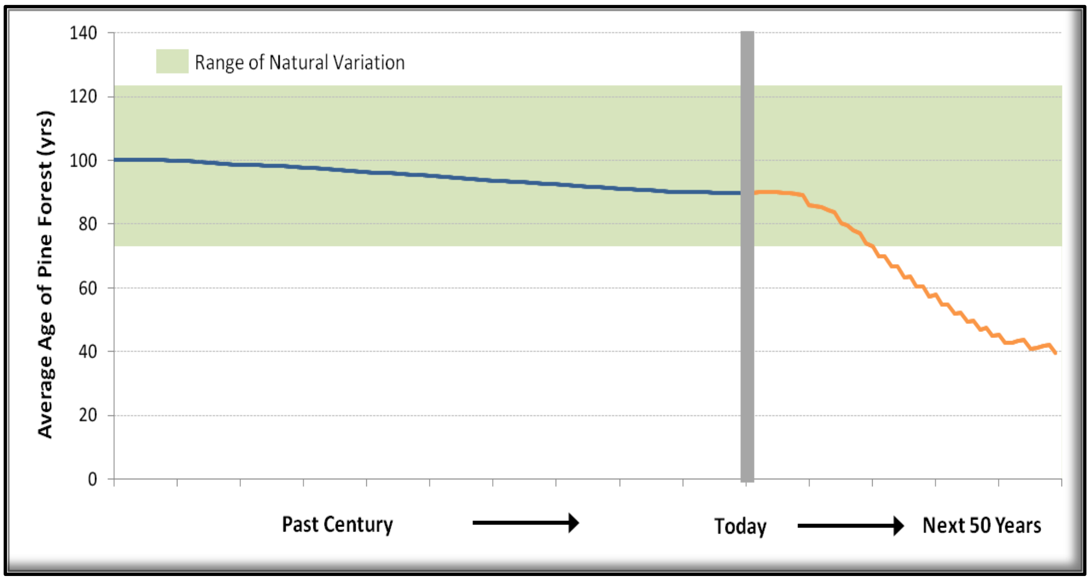


Figure 27. Changes in average age of pine forest in the study area.

The possible pattern and intensity of forest harvest occurring within the Spray Lake FMA is demonstrated in Figure 28,[132] this image is from an area situated north of the study area.

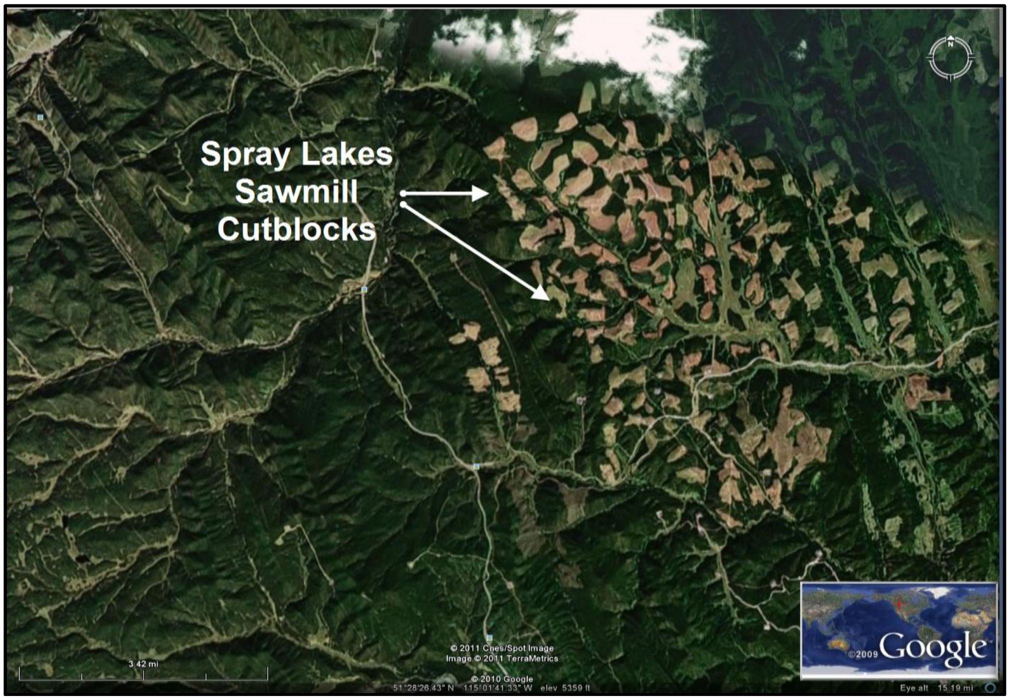


Figure 28. Example of Spray Lake Sawmill's forest harvest activities, adjacent to the Ghost River watershed, depicting possible future harvest patterns in study area.

The "average" forest age structure of the study area experiencing a natural fire and insect regime and no logging, is shown in Figure 29. This pattern approximates a negative exponential distribution whereby older forest age class become progressively less common than the next younger forest age class.[133] The oldest forest age class (nominally 160-200 years) is actually a combination of all seral stages older than 160 years and likely includes some stands as old as 300 years. In reality, however, there is no such thing as an "average" insect and fire-induced forest age class structure because insect infestations and fire are highly episodic in nature. The "average" presented here represents a common pattern when comparing many different simulation scenarios.

In contrast to the forest age class structure created under natural conditions, a regulated forest age class distribution created by logging, with no fire or insect perturbations will contain approximately equal amounts of area for each seral stage younger than "rotation age". Rotation age refers to that age when forests are optimal for harvest. Younger stands are not generally harvested because they are still adding incremental volume whereas older stands are suboptimal because of less desirable growth form or because of increased rates of tree mortality, (Figure 30).

In practice, the forests of the Ghost River watershed will be shaped by logging, insects and fire.[134] These disturbance regimes exist today. Current policies regarding logging and practical constraints regarding insect control and fire suppression indicate that this pattern is likely to persist in the future. Unsurprisingly, the forest age class structure created by logging, insects and fire is a hybrid between the two patterns described above, (Figure 31).

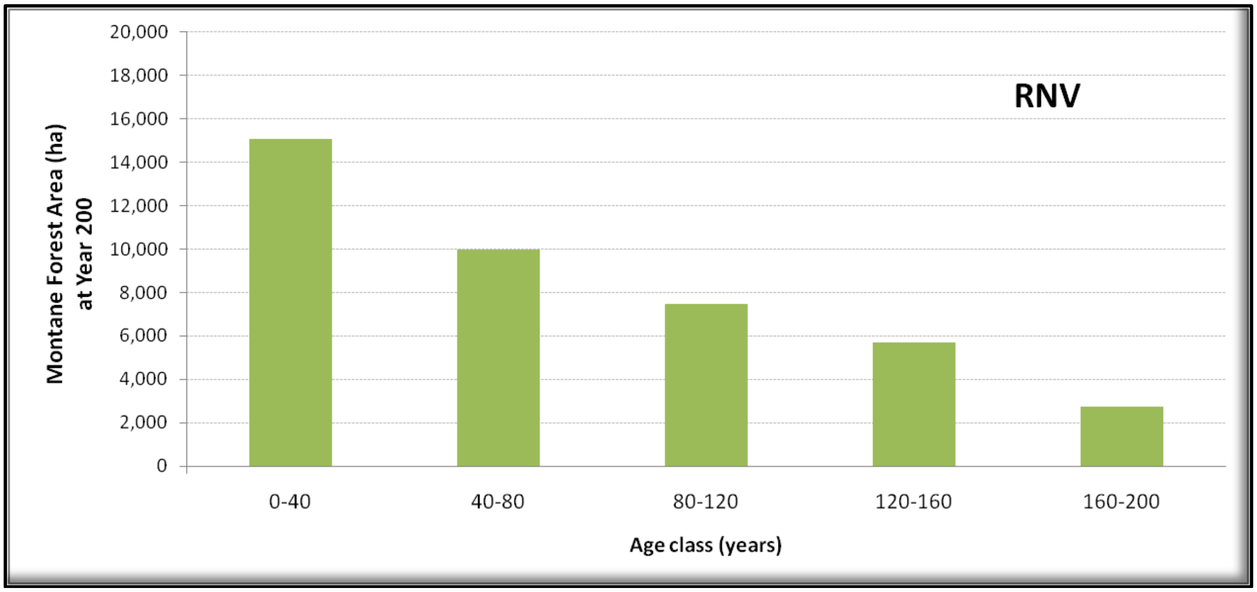


Figure 29. **Generalized average forest age structure generated by a constant fire regime in a "range of natural variation" scenario (simulation period of 200 years).**

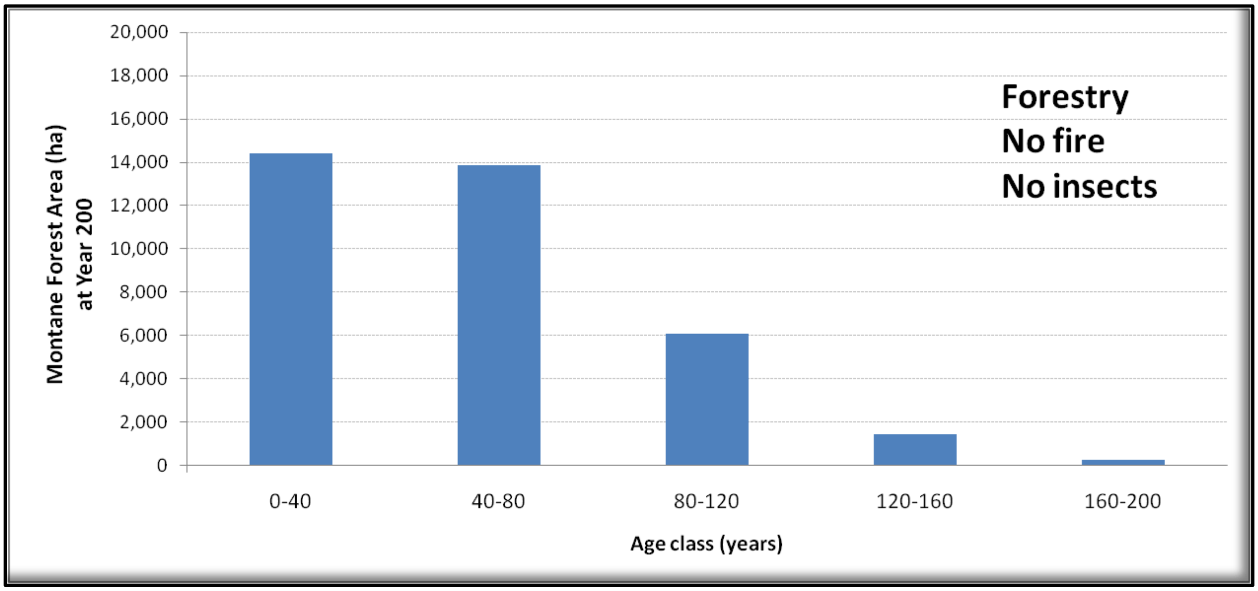


Figure 30. **Probable forest age structure generated by simulations including forest harvest practises but without fire or insect perturbations (simulation period of 200 years).**

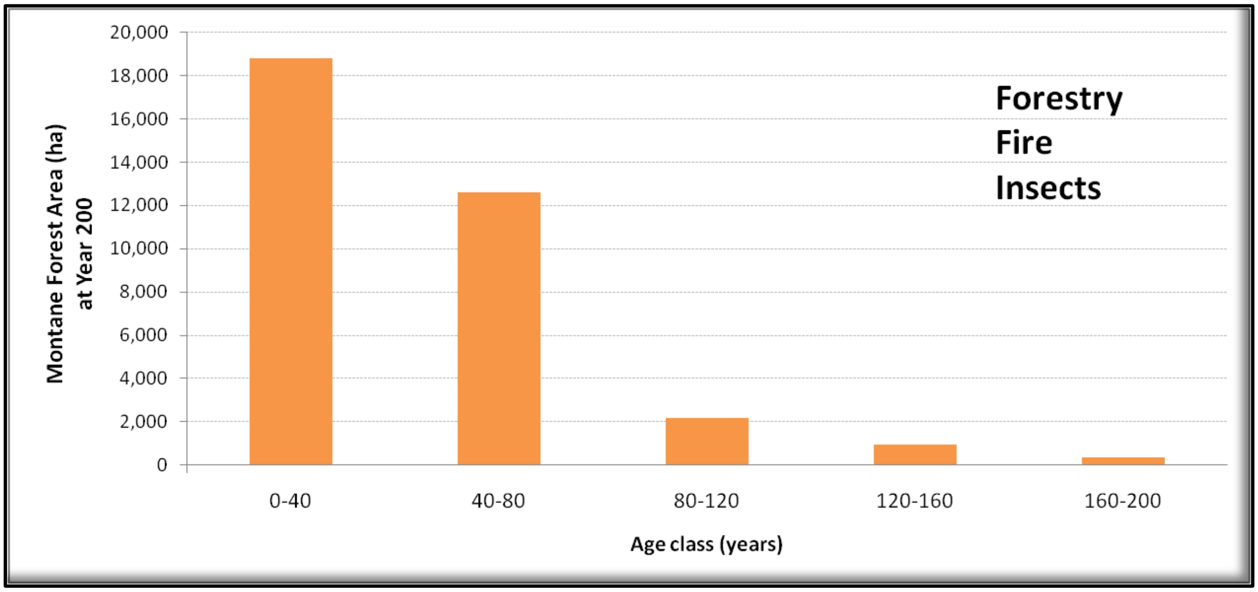


Figure 31. Probable forest age structure generated by simulations including forest harvest, fire and insects perturbations (simulation period of 200 years).

Forest landscapes characterized by extensive young stands, such as shown in Figure 31 above, will likely experience reduced biodiversity[135] and increased sediment and nutrient loading to surface water as older forests generally release less sediment and nutrients than do clearcuts and young forests. [136,137,138] Maintenance of largely intact forest cover in source water areas is a key principle for production of clean and inexpensive water supply for downstream users.[139,140,141] "Headwater and source water protection and the need to manage land use to sustain water production and water quality are critically important."[142]

2.5.2 Ecological Goods and Services and Recreation Value

Lumber and wood fibre production is important to Alberta's economy and quality of life.[143] However, forests also provide society with a host of ecological goods and services that include carbon storage, climate regulation, water treatment, and provision of wildlife habitat and biodiversity. Non-timber values for forests have been estimated to be up to ten times the value of timber revenues.[144] Given the proximity of the Ghost-Waiparous watershed to Calgary, Cochrane and Canmore, this basin helps satisfy the significant and growing recreational demand of the surrounding regional population.

Recreational activities, in the form of camping, hiking, skiing, horse-back riding, and OHRV activity, have a significant economic value to Albertans. Based on conservative estimates, ~141,000 people currently visit the study area annually,[145,146] generating ~$33 Million (M) in direct spending.[147,148] These expenditures are forecast to increase to over $70 M in the future.[149] In comparison, forest harvest direct revenues are estimated at approximately $21 M[150] (Figure 32).[151] The key point here is that forest harvest practices should be conducted in a fashion that does not erode important potentially higher value recreational opportunity.

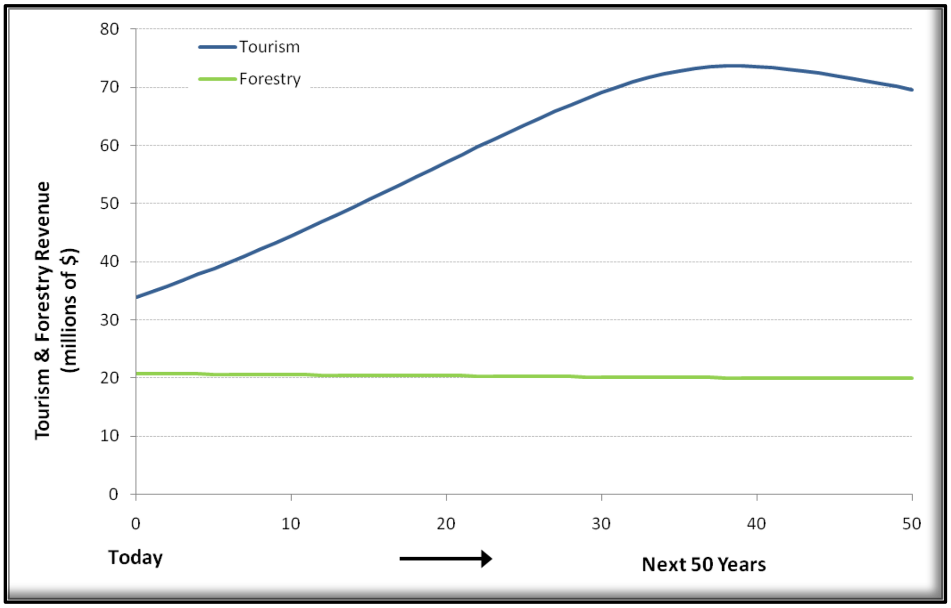


Figure 32. Projected Tourism Expenditure and Forestry Revenue. Reduction in tourism based expenditure at year 37 reflects the discounted value of the landscape due to the prevalence of clearcuts and forest under 40 years of age which are perceived as less desirable recreational landscapes than mature forests. Dollar values were held constant and not adjusted for inflation.

Similar relative values of tourism and forestry, in Alberta, have been calculated using gross domestic product (GDP) as an index of value. The Alberta Southern East Slopes Integrated Land Management Pilot Project estimated forestry GDP value per hectare of $12.63, recreation GDP value $59.58 per hectare, non-resource sector GDP $1,700.70 per hectare.[152]

Outdoor recreationalists generally prefer older forests (Figure 33) and avoid clearcuts (Figure 34) for recreational activities.[153,154,155] In Sweden and Australia, research has demonstrated selective cutting of forests creates a forest landscape with the highest perceived recreation value and clearcutting generates the lowest value.[156,157] Forestry practices in the Ghost selectively target mature timber stands, using clearcut harvest methods (Figure 34). Although this traditional harvest strategy may be preferred for maximizing wood fiber production, it may create a landscape of lowered recreational value.

The B.C. government`s Forest Practices Branch states:

> *"One of the clearest messages is that most people do not like the appearance of clearcuts or the effects clearcutting has on tourism and recreational experiences such as hiking and fishing. One of the challenges for the Forest Service is to further integrate the objectives of aesthetics, recreation and timber harvesting creatively using a variety of silvicultural systems."*[158]

Figure 33. Old growth lodgepole pine forest, Ghost River watershed, photo courtesy of Herb Hammond, Silva Ecosystem Consultants Ltd.

Figure 34. Clearcut on the western edge of the study area, 1 August 2010, picture taken from a well-site access road, demonstrating lack of vegetative screen, along roadway margins, for aesthetics or wildlife vulnerability.

Reducing the average age of forests and creating forests with a potential large proportion of clearcuts (Figure 35) may adversely impact future tourism revenue as the forest becomes potentially less desirable for many recreationalists.[159] Clearcuts, by their very nature, create an industrial landscape with vegetation removal, slash debris such as limbs and stumps and rough uneven ground created by heavy machinery making them visually unappealing and difficult to traverse.

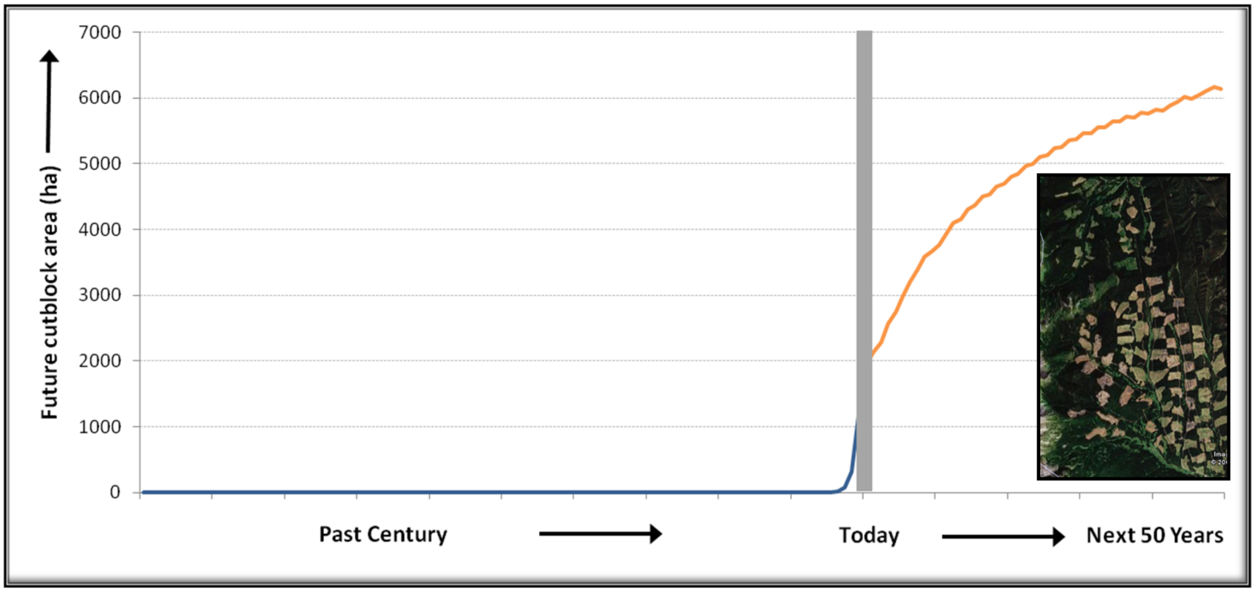


Figure 35. Future cutblock area.

Spray Lake Sawmills' detailed forest management plan and timber harvest planning and operating ground rules[160] recognize the possible impact of timber harvesting on aesthetics and recreation potential. The detailed forest management plan states, "Scenic values can be addressed through varied block sizes, avoidance of geometric shapes, irregular edges, retention of trees or other structure, block positions and distribution on the landscape, use of visual screens and harvest system."[161] Recreational demand and direct expenditure opportunities in the Ghost River basin associated with recreation are projected to increase in proportion to the expanding regional population (Figure 36).

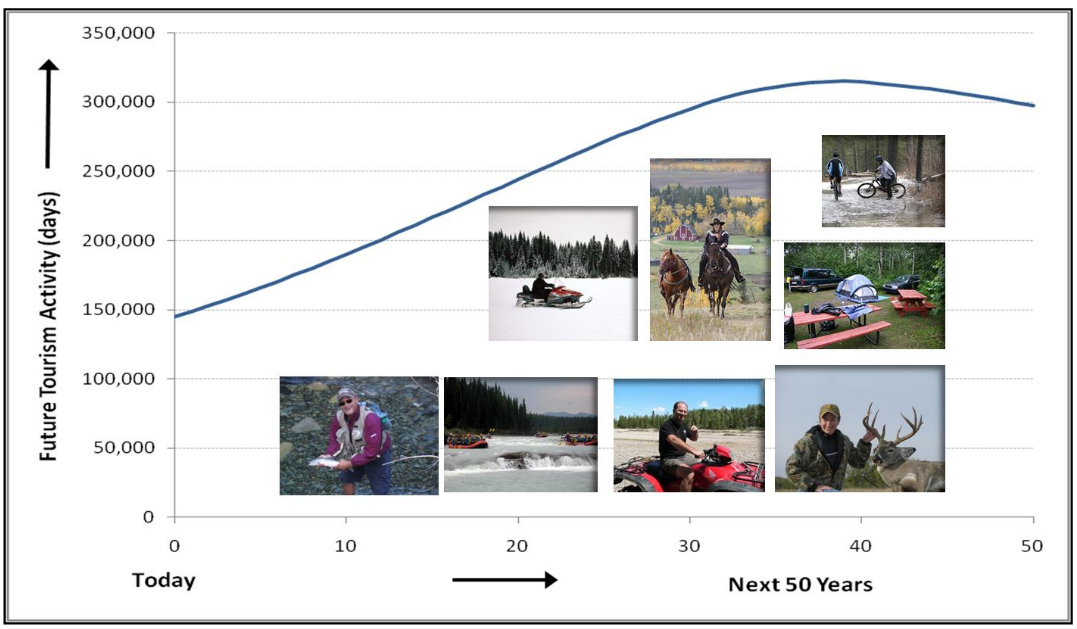


Figure 36. Future tourism activity days.

However, as younger forests and clearcuts become more prevalent in the Ghost River basin, simulation modelling suggests the landscape will become less desirable for recreationalists with visitations and associated expenditures beginning to decline approximately 37 years in the future, as younger forests and clearcuts begin to dominate the landscape (Figures 35,36).

2.5.3 Forest Harvest Sustainability

Our analysis of the Ghost River study area indicates that current harvest volumes by Spray Lake are likely to be sustainable over the next eight decades. This pattern appears robust with or without the existence of a co-incidental fire regime. Following eight decades, however, the additive effects of logging and fire are likely to generate the need for a harvest adjustment to values that are lower than are currently being harvested. There are two reasons for this conclusion. The first is that current calculations of Annual Allowable Cut (AAC) generally ignore the existence of fire from a planning perspective. The effects of fire on AAC are only handled "after the fact". Since this basin has not received a large number of fires in recent decades this region contains a high proportion of merchantable age forest stands. If one or more large fire events occur within this merchantable forest landbase, then the AAC will need to be adjusted accordingly.

If the forest operator or management agencies were to ignore the effects of fire on timber supply, a fall-down in harvest may be expected (Figure 37). In practice however, the government would likely adjust AAC "on the fly" following fire events. The conclusion remains the same: current harvest rates will eventually require downward adjustment as the cumulative effects of logging, fire and insects manifest themselves.

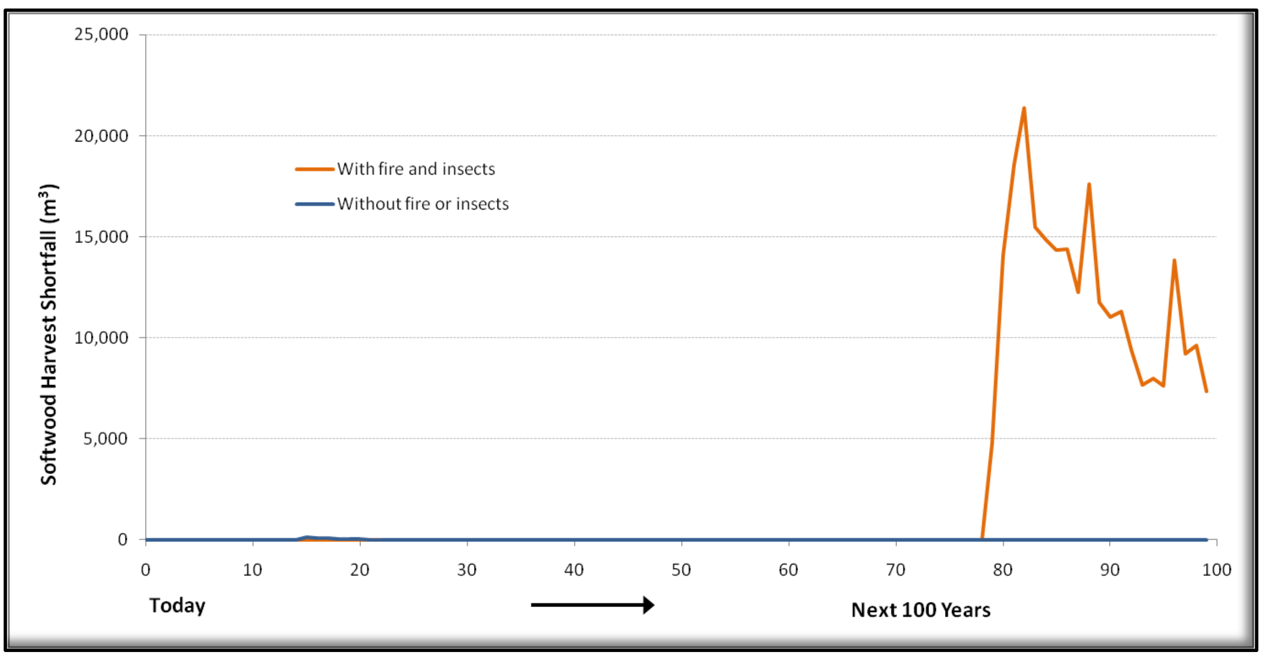


Figure 37. Softwood harvest shortfall.

Simulations of timber supply in the study area indicate that current harvest volumes are sustainable if there are no future forests fires. The combined effects of logging, fire, and insect outbreaks on future forest age class structure will likely require adjustments in future forest harvest volumes (Figure 37).

"While threats for forest sustainability may not be immediately apparent, the ongoing risk of fire and the cumulative impact of oil, gas and other forest land development throughout the province (Alberta) do point to the potential for risk to the long-term economic viability (i.e., sustained timber supplies) of some forestry operations."[162] The work of the Ghost Watershed Alliance Society presented here should prompt forest managers and public policy decision makers to assess and mitigate risk. It points to the need to consider the potential impact of forestry on the economics of recreation and the cumulative impact of both natural and human related disturbances when developing long-term timber supply strategies.[163]

3. RECREATION CONFLICTS

The majority of recreational activity within the study area is by motorized recreationalists (Figure 38, 39).[164] This activity has been approved as appropriate for this landscape as part of a mix of multi-use recreational activities. Hikers, mountain bikers, equestrian users and other non-motorized recreationalist also use the landscape but in lower numbers than motorized users.[165] This may be partly due to management focus on motorized recreation. An example of this focus would be that brochures and signage are provided for motorized trails and activities with minimal identification of hiking, biking or equestrian trails or other non-motorized recreational opportunities.[166]

Figure 38. Motorized recreation, random camping.

Figure 39. Multiple use trail open and signed as open to motorized use, July 2010, Ghost River Forest Land Use Zone.

As noted previously and described further below, many linear features within the study area are used by motorized vehicles, even though they are signed as closed or not signed as open.[167] Research in Utah and Colorado suggests that most riders knowingly ride off designated routes.[168,169] Widespread motorized recreational activity within the study area may lead to perceptions of user conflict, as found in the user survey (Figure 40), or displace other legitimate non-motorized activities.[170,171,172,173,174]

Motorized recreationalists can geographically displace non-motorized users, and the two activities are largely seen as incompatible by non-motorized users.[175,176,177,178] This pattern of conflict is underscored in a survey by the American Hiking Society, where hikers indicated "a strong preference for separated areas for motorized and non-motorized use, given the significant disturbance, noise, pollution, resource impacts, and safety and health threats."[179] A survey conducted by the American Hiking Society of member organizations with a combined membership of over half a million people, found that off-road vehicle use was displacing hikers in all regions of the country.[180]

There are many citations in the literature of non-motorized recreationalists being displaced or leaving areas altogether where motorized use is frequent.[181,182,183,184,185,186]

Similarly, in an Alberta Government survey, respondents identified motorized recreationalists as having the greatest adverse impact on enjoyment of the Ghost-Waiparous by other users (Figure 40).[187]

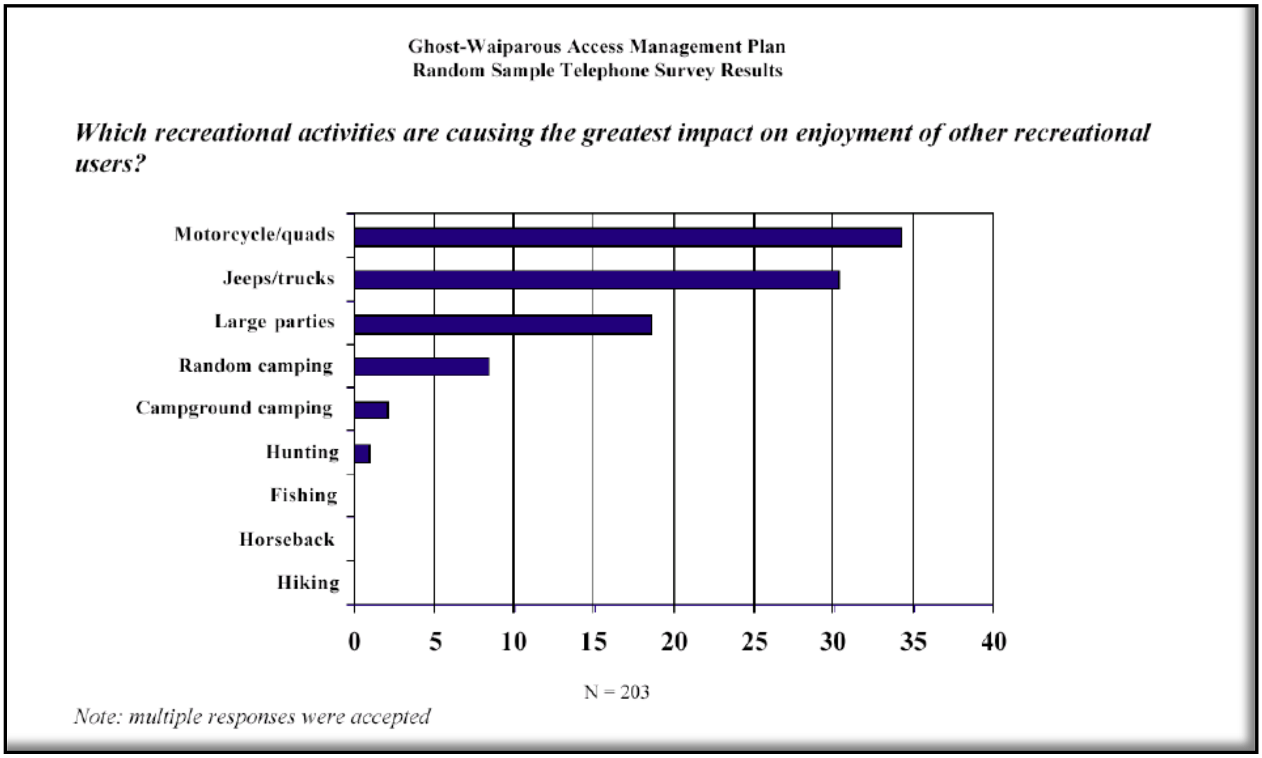


Figure 40. Public perception of recreational activities responsible for negatively impacting recreational enjoyment of the Ghost-Waiparous region.

Equestrian outfitters within the study area identify OHRV use as negatively affecting their business due to a high incidence of “non-repeat” customers who indicated that OHRVs detracted from their hoped for wilderness experience.[188]

Throughout the study area, any random location is likely no further than 100 to 200 m from the closest linear feature. Field visits during the 2010 non-snow season showed OHRV use of 93% of linear features assessed.[189] Based on evidence in the literature, that motorized recreation displaces many non-motorized users through both direct physical presence and noise,[190,191,192] we simulated the theoretical percentage of the study area that would likely be suitable for non-motorized users. This was done by assuming that areas adjacent to linear features would be functionally avoided by 90% of non-motorized users due to physical presence, noise or visual detection of vehicles by non-motorized recreationalists (Figure 41). We assumed an avoidance range of 50 m to 75 m on either side of linear features. We recognise that further analysis would be required to quantify more precisely avoidance range and percentage of non motorized uses that would avoid roadways and trails used by motorized recreationalists. Some non-motorized uses may be more or less tolerant of motorized vehicle use and the avoidance metric may average higher or lower. However, it is instructive to calculate what percentage of area would be suitable for non-motorized recreation if these avoidance metrics are utilized under the assumption that 93% of linear features in the study area are used by motorized vehicles.

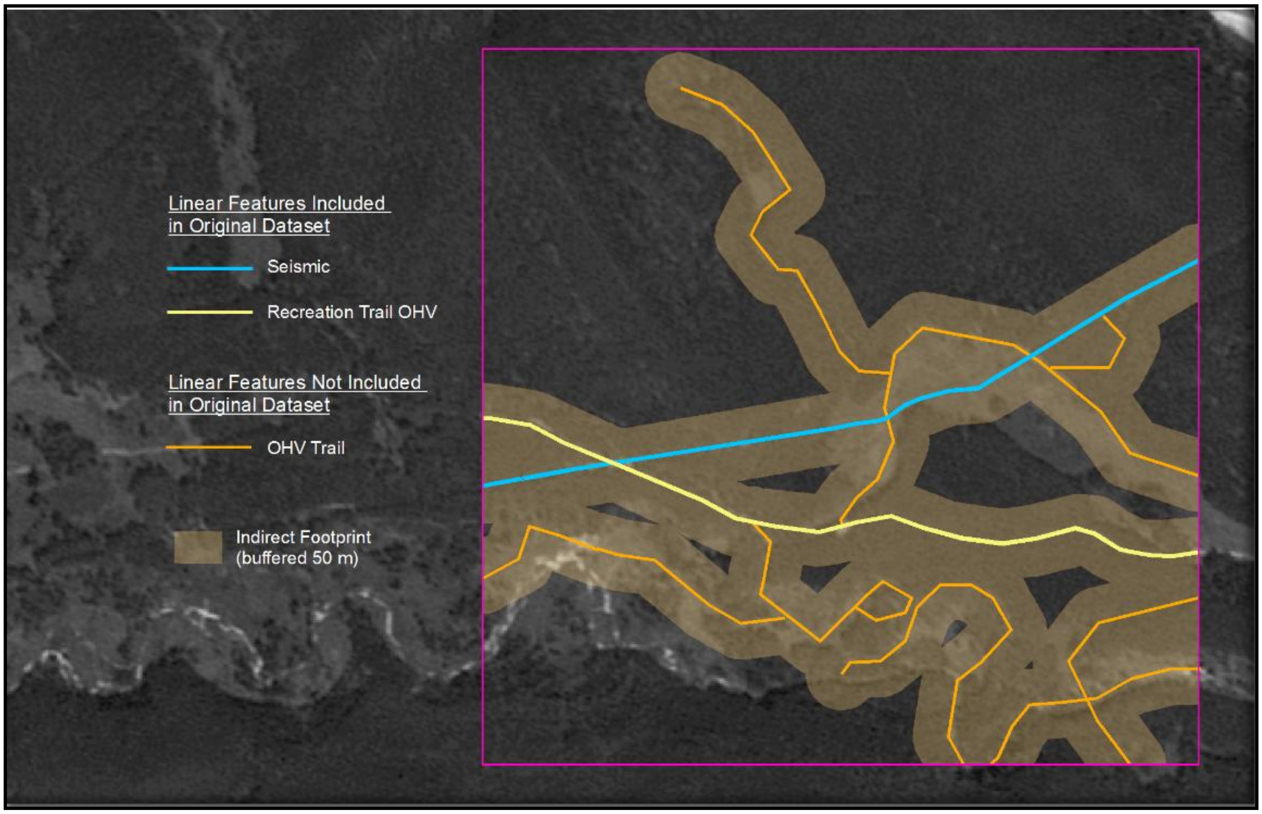


Figure 41. Showing 50 meter theoretical area of avoidance by non-motorized recreationalist along linear features used by vehicles.

Under these assumptions, simulation results demonstrate that approximately 27 to 50% of the area is currently suitable for non-motorized users in the study area. The fraction of the landscape eligible for non-motorized recreational users would continue to decrease to approximately 7 to 29% by year 50 (Figure 42). Without significant improvements in the enforcement of existing OHRV regulations, which stipulate motorized recreation on designated roads and trails only, the potential use of the study area by hikers, mountain bikers, and equestrian users will likely remain low and continue to decline into the future. The multiple-use legislation that applies to this study area legitimizes use for many outdoor recreational activities. However, this theoretical exercise demonstrates widespread motorized use of undesignated trails may result in a loss of recreational potential for other user groups.

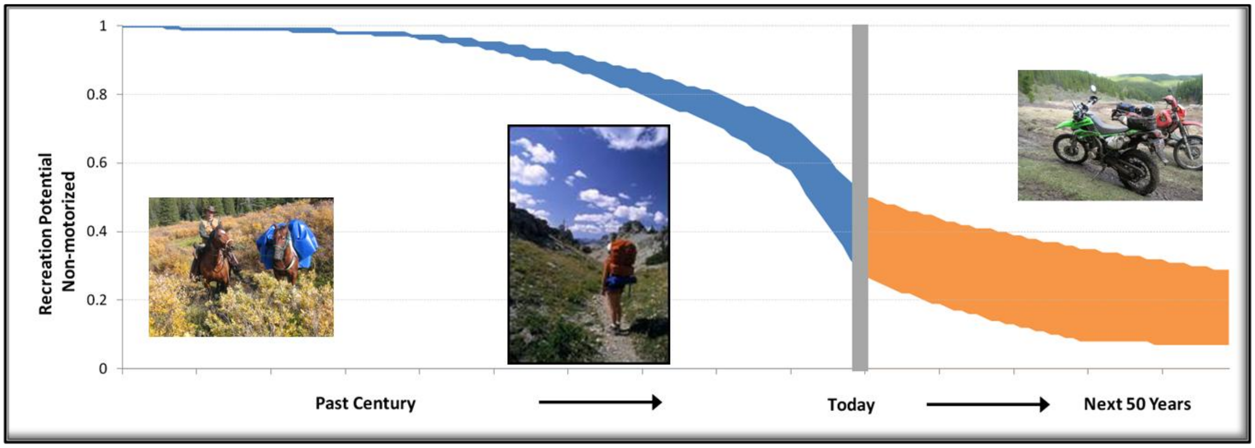


Figure 42. Fraction of study area preferred for use by recreational non-motorized users.

4. CONCLUSIONS

The Ghost-Waiparous watershed is typical of many Eastern Slopes forest lands where increasing land use pressures by a large regional population and ongoing resource extraction activities challenge current management regimes and policy. Our future population, footprint, and resource demands are likely to increase as affluent regional populations and industrial and recreational land use continues to expand. The reality of increasing environmental degradation and future potential loss of economic prosperity has prompted discussions regarding the inability of current land use planning to deliver the social, economic and environmental services which Albertan's expect.[193] Current forward looking legislation such as the Alberta Land Stewardship Act and the Alberta Land-use Framework may help to address regional issues associated with land-use planning. Market instruments such as the Forest Stewardship Council certification may also encourage forest companies to manage forests to the highest possible standard.

However, without significant changes in how lands are managed within the Ghost watershed, what will the future hold for the Ghost-Waiparous and those who depend on the landscape for recreation, water, and livelihoods?

- **Will the landscape contribute clean water supply for downstream communities such as Cochrane and Calgary?**

Measured water quality in the Ghost-Waiparous has been significantly affected by motorized recreational vehicle use.[194] Simulation modeling conducted for this study indicates that sediment and nutrient loading has increased significantly above natural conditions over the last century and is likely to increase further in the future with increased logging and ongoing agricultural, energy and recreational uses. By adopting best practices and adopting limits on activities, a reduction in sediment and nutrient loading in source watersheds like the Ghost-Waiparous can potentially decrease downstream water treatment costs[195,196] and benefit fish, wildlife, and recreational users.

- **Will there be healthy natural areas providing quality fish and wildlife habitat?**

The current high density of linear features such as roads, seismic lines, forestry access and off-road vehicle trails in the study area is projected to increase in the future. Both official and unofficial off-highway vehicle trails cross directly through watercourses and critical wildlife habitat zones in the study area; in contravention of existing zoning.[197] Logging also appears to be occurring in critical wildlife zones which are not zoned for timber harvest (Figure 43).

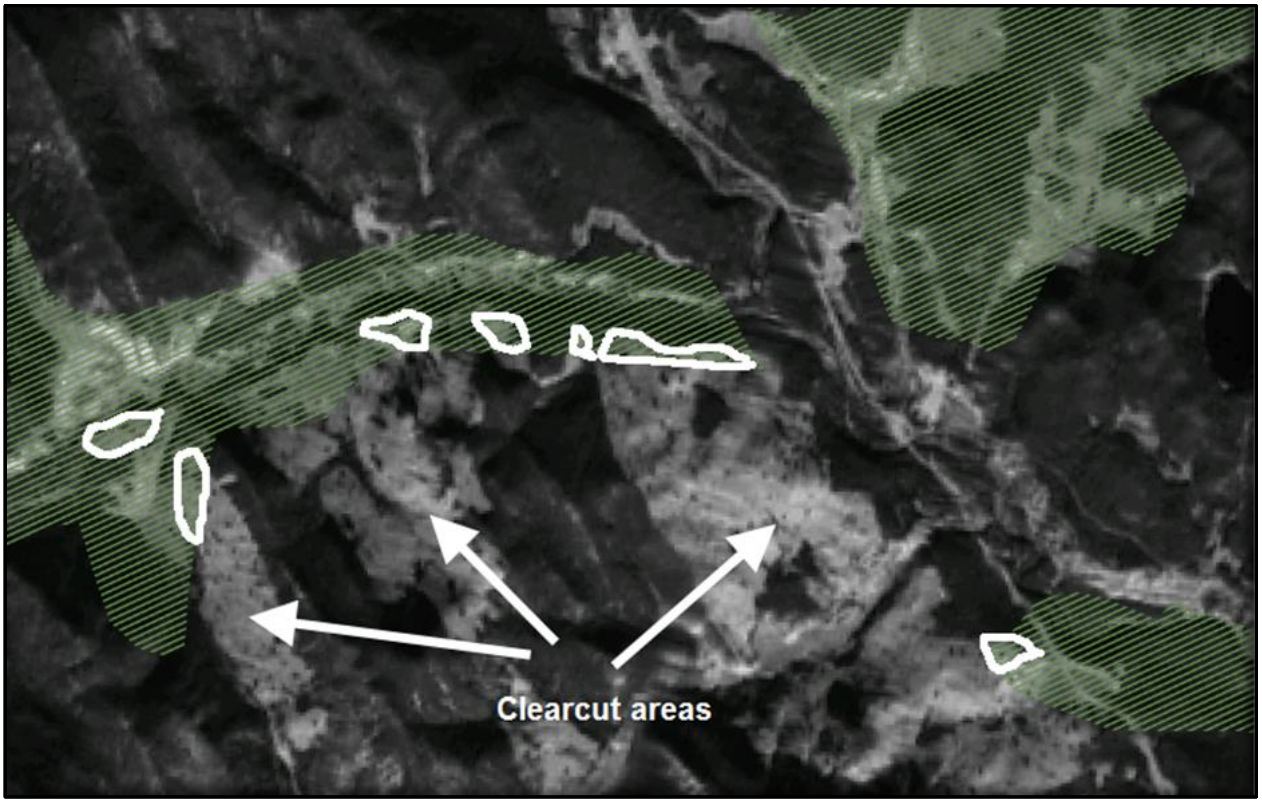


Figure 43. Green cross hatched areas identify critical wildlife zones. White highlighted areas indicate clearcut logging activity within the critical wildlife zones.

Future increased densities of linear features and timber harvest may further fragment fish wildlife habitat and increase exposure of many species to human disturbance, with potential detrimental effects. Sensitive species such as grizzly bear and bull trout may not be able to maintain viable populations in the study area.

Over time, forestry operations will shift the merchantable land base to a younger, more homogenous forest which may benefit some species but likely reduce biodiversity and adversely impact species that depend on old forests. Energy development, forestry clearcuts and associated access roads and trails will also increase sediment loading in the watershed.

Native fish communities have declined and several species have experienced reduced population levels, relative to natural conditions.[198] Further decreases are projected with likely losses in opportunity for high-quality recreational fishing for native species such cutthroat and bull trout. Bull trout are identified as being at high risk of extirpation.[199]

“Alberta's Endangered Species Conservation Committee has identified the bull trout as a Species of Special Concern—a species that without human intervention may soon become threatened with extinction.”[200] Native westslope cutthroat have “... been identified as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). ... It is currently being considered for listing under the federal *Species at Risk Act* (SARA).”[201]

The study area will be challenged to provide quality fish and wildlife habitat without concerted management action.

- **Will the landscape satisfy motorized and non-motorized recreationalists seeking quality non-urban experiences?**

Opportunity exists for the region to satisfy both motorized and non-motorized recreational needs. However, current low enforcement levels and resultant widespread OHRV use of trails and linear features not open to OHRV use reduces recreational opportunities for non-motorized users throughout much of the study area.

A large proportion of the future landscape will be comprised of forestry clearcuts and young forests which are less desirable for visitors and may reduce recreational visitation and associated tourism expenditures.

- **Will natural resource extraction such as forestry remain sustainable?**

The current harvest rate of forests in the study area is unlikely to be sustained. Current harvest volumes are predicated on the absence of fire and insect perturbations, a highly unlikely assumption, and no change in the size of the merchantable forest landbase. The reality is that fires and insect infestations will occur, footprints of the energy and recreational sector will expand, and that adjustments to forest harvest will be inevitable. The greatest effects to future forest harvest levels is not the footprint of other land uses, but the future fire rate and perhaps the extent to which the recreational community influences the type of logging that is permissible on this high-profile landscape.

4.1 RECOMMENDATIONS

Several “best management practices” (BMP) are available to resource managers in the Ghost-Waiparous watershed to help mitigate the relatively poor performance of key indicators forecasted in this study.

4.1.1 Access Management

Despite efforts by the Ghost Stewardship Monitoring Group (GSMG), and sound government policy and legislation regarding access management, widespread illegal and undesirable use of trail-ways by off road vehicles is occurring (Figure 44). Portions of the official OHRV trail network are in critical wildlife zones, much of them adjacent to or crossing riparian or wetland habitat, where this activity has been zoned as inappropriate.[202] These conditions are projected to continue to increase sediment loading, impair the recreational value of the area for non-motorized recreational users, and increase negative impacts on ecological indicators such as grizzly bear and native fish communities.

Figure 44. Non-designated OHRV trail – Waiparous Creek.

Increasing levels of OHRV traffic are raising concerns about the general viability of aquatic and terrestrial habitats in the Ghost River Forest Land Use Zone.[203] The South Saskatchewan Regional Advisory Council recommends that; "Motorized activities should not be permitted in riparian areas or wetlands, mud bogging should be prohibited on public land, and motorized activity should not be permitted off of designated trails, routes or areas."[204]

Effective enforcement of current access legislation is a necessity to protect recreational and water resources in the Ghost-Waiparous. In the recent past, large staffing reductions in Forest Officers have taken place, reducing enforcement presence and effectiveness, which is likely a primary contributing factor to the widespread illegal off road vehicle activity in the study area.

"Between 1992 and 1998 staffing decreased from 28 full time seasonal personnel to none with the closing of the ranger station and the result being removal of a physical presence at the ranger station and a gross reduction in the governmental presence in the area."[205] "In 2010, SRD, Southern Rockies Area, had one Forest Guardian patrolling the Ghost FLUZ as part of his regular duties."[206] During high use weekends, such as the May long weekend, several, regularly office based forestry staff, Fish and Wildlife officers and RCMP may be used to temporarily augment the regular field officer.

The literature is clear on the need for effective enforcement being required for the sustainable management of off highway recreational use.[207,208,209,210] "Good rules have no tangible effect if not enforced."[211]

Monitoring the success of management actions, enforcement, policy and legislation is also key to successful management of non-motorized and motorized recreational activities in the Ghost-Waiparous. However, the 2009 GSMG Annual Report notes there is no progress to date regarding implementation of monitoring activities.[212]

The National Off-Highway Vehicle Conservation Council is a well known organization dedicated to ensuring off-highway motorized vehicle access to public lands in the United States through a program designed to minimize environmental impacts and user conflicts. They detail what they identify as the four E`s of OHRV management keys to success:

• **Engineering –** Designing the facilities to address issues.

• **Education –** Telling participants what is expected, important, and interesting.

• **Enforcement –** Identifying and dealing with problems.

• **Evaluation –** Making sure your actions are accomplishing your goals."[213]

Without effective success in all four of these E's, OHRV programs are not likely to be successful.[214]

According to the GSMG 2009 Annual Report,[215] some progress has been made in the first two E`s, Engineering and Education. However, effective enforcement and monitoring programs are still required.

Another organization, Wildlands CPR, states that without effective enforcement sustainable OHRV use is not achievable. They suggest a combination of six strategies for effective enforcement which have been successfully deployed for OHRV management on five case study areas in the United States. Implementation of these strategies would be recommended.

1) Make a commitment—Engage in serious enforcement efforts.
- Expand enforcement capacity;
- Target and intensify patrol efforts;
- Look for new funding sources; and

- Do not tolerate damage from off-road vehicles.

2) Lay the groundwork—Create enforceable routes and regulations.
- Create off-road vehicle route systems with an eye toward enforceability;
- Make the route systems clear on maps and on the ground; and
- Implement a system that identifies off-road vehicles or limits their numbers.

3) See and be seen—Engage in visible action and meaningful collaboration.
- Organize and publicize volunteer labor;
- Form broad coalitions for public support;
- Formalize law enforcement collaborations;
- Create opportunities for citizen reporting;
- Use nonprofit status to gather money; and
- Publicize progress.

4) Make riders responsible—Promote a culture shift among peers.
- Use mass media campaigns to educate riders and cultivate support;
- Work with off-road community leadership;
- Focus on common values; and
- Promote rider responsibility.

5) Use the force—Incorporate technologies that work.
- Use remote electronic monitoring;
- Track noise violations; and
- Track recurring problems and repeat offenders.

6) Fit the punishment to the crime—Make penalties meaningful.
- Toughen penalties; (penalties for violations in Alberta are low)[216,217]
- Consider natural resource damage in determining fines;
- Add community service as a penalty; and
- Link off-road violations with other recreational privileges; and
- Impound vehicles."[218]

During field surveys, it was noted that many off road vehicles especially motorbikes did not display licence plates which makes enforcement difficult.[219] All operating off road vehicles within the Ghost Forest Land Use Zone are required to be legally registered and display licence plates. For ease of enforcement this should be extended to OHRVs being transported, operated or parked within the study area. Existing information kiosks, websites and printed brochures should detail this information and enforcement effectively implemented. Where metal license plates are impractical to attach to vehicles a registration decal may me an appropriate solution.[220]

It was also observed during field visits that many motorbikes and some quads were excessively loud. Excessive noise has been identified as a source of conflict with non-motorized users,[221,222] and may negatively affect wildlife. Noise regulations should be enforced to minimize user conflicts and disturbance of wildlife.[223]

User access charges for motorized operation within the forest reserve have been proposed in the past by researchers, off highway recreational organizations and local municipal governments, to fund environmental protection, reclamation, increased trail signage, additional trail networks and enforcement.[224,225,226,227] Implementation of such fees in other jurisdictions of Canada and the United States has successfully generated secure funding to help ensure successful regional recreational plans.[228] In the Ghost, the lack of effective enforcement needs to be addressed and user fees would be a logical approach to generate funding for that purpose.[229,230] The South Saskatchewan Regional Advisory Council also recommends the development and implementation of "...a user-pay system(s) to assist with funding the development and management of necessary recreation planning, management and infrastructure."[231]

Bob Reed, Vice President of the "The Alberta Society of Off-Road Motorcyclists", states the need "... to build a sustainable trail system that the users are happy with and therefore will use and respect, close any of the current legal trails that are not sustainable. The key is to develop, manage, maintain and enforce a realistic sized sustainable trails system to support the motorized users group for the Calgary area."[232]

4.1.2 Resource Extraction

Managing forests for sustainable use requires that both the biological diversity of the forests and a viable forest industry be maintained through appropriate harvest strategies. Whereas a network of dispersed small cutblocks with high edge to area ratio may be optimal for hunted big game species such as deer and elk,[233] this configuration may not be optimal for the broader suite of biodiversity found within this region. As recommended by the Alberta Forest Conservation Strategy,[234] the adoption of a broader range of cutblock sizes, shapes, and inblock residual patches better approximates the RNV of disturbances created by natural fire regimes. The Canadian Forest Stewardship Council further recommends retention of significant levels of both living and dead residual trees at a retention level ranging from 10 to 50%, based on pre-industrial condition.[235] Currently a one percent inblock retention strategy is identified for timber harvest in the study area.[236]

Larger cutblocks, with irregular shapes (as illustrated in Figure 45) should be an important component of the cutblock matrix, but it is important that the amount of inblock residual green trees also approximate the patches not burned in natural fire regimes along the east slopes. Given the management issues relating to increasing road density and legal or illegal harvest of ungulates and grizzly bears, careful attention to unharvested residual stands along roadways and within cutblocks is an important consideration in cutblock layout to reduce wildlife vulnerability. Ground rules 7.2.5 and 7.2.7 of Spray Lake Sawmills timber harvest planning and operating ground rules state that roadside vegetation should be protected in harvest areas to limit the line-of sight distance across the harvest area and distance to wildlife hiding cover should not exceed 200 meters.[237]

Bull trout and cutthroat trout have been shown to be potentially negatively impacted by forest harvest. Logging should avoid both fish bearing and non-fish bearing perennial and ephemeral streams and wetlands to minimize potential increases in sediment loading. Ephemeral streams should be identified prior to harvest, ideally during spring melt conditions or significant rainfall events. Careful attention should be paid to stream road crossings to minimize erosion and possible barriers to fish movement.

Figure 45. Example of cutblocks, by Spray Lake Sawmills, on the western edge of the study area, east of the north fork of the Ghost River. The larger cutblock illustrates a low cover to forage ratio that is likely to reduce habitat potential for species such as elk, moose and deer.[238] The smaller cutblock in the bottom right of the image illustrates potentially better forage

to cover ratio for elk and deer. To ensure the use of forage areas such as meadows, clearcuts and other openings by elk and deer, main roads should be effectively screened by vegetation.[239] Note the lack of effective vegetation screening along portions of the main Calgary Power access road which may decrease aesthetic potential and increase wildlife vulnerability.

Forest harvest is projected to create a landscape of younger, fragmented forests and clearcuts. Some authors feel "... the fragmentation of the forest, loss of species diversity and effective wildlife habitat as well as the liquidation of old growth ("over mature") trees is seen as a real threat to ecological health."[240]

The Ghost-Waiparous, in addition to providing valuable forest products, is an important recreational area that has the potential for long term sustainable motorized and non-motorized recreational use and associated economic benefits for Albertans. Resource extraction activities, especially in prime Eastern Slope recreation areas, close to large regional populations, should be managed to minimize negative impacts on recreation potential and tourism. Cost benefit analysis of tourism and timber harvest methods should be conducted to determine how to maximize benefits and minimize liabilities. For forestry, the benefits of selective cutting, optimal combinations of cutblock sizes and shapes, maintenance of significant areas of old growth forest, irregular cutblock edges (Figure 46) and setbacks of cutblocks from roadways and trails should be evaluated to minimize impact on environmental and recreational/aesthetic resources.

Working partnerships with recreational and community based user groups should be required in harvest planning activities. The South Saskatchewan Regional Advisory council further recommends, **"**Implement(ing) an integrated planning process that reduces redundancy and incorporates the management of forestry with water production, biodiversity, recreation and tourism and energy production."[241]

Figure 46. Example of cutblock layout designed to approximate the spatial pattern of a fire and to optimize distribution of inblock residual patches for maintenance of ecological processes and aesthetics.[242]

High densities of linear features associated with industrial activities such as energy exploration and development, occur throughout the study area. To minimize disturbance and vehicle access, new seismic lines are much narrower and many new roadways are reclaimed effectively by rolling back logs and debris over them. However, an aggressive program of reclamation, gating and signage of existing linear features, supplemented with increased enforcement would likely benefit sensitive species such as grizzly bears and native fish as well as other wildlife species and provide benefits for both motorized and non-motorized recreational users.

New drilling activities should be directed, where possible, to existing pads using directional technology to minimize both well site infrastructure and new roads.

The study area provides important secondary habitat for grizzly bear and as such a reasonable target for linear features would be the 1.2 km/km^2 maximum recommended in the Alberta Grizzly Bear Recovery Plan.[243]

4.1.3 Livestock Grazing

Agricultural activity in the study area is focussed on the livestock industry with cattle and horses grazed extensively on private lands and grazing allotments. Grazing allotments issued by the Alberta government have been in existence within the Forest Reserve for more than 50 years.[244]

The Forest Reserve Multi-Use Dialogue states that allotment holders feel damage to grassland areas and the widespread use of OHRVs are making some areas unusable for grazing livestock and that the ability to manage livestock grazing is also made difficult by OHRV users allegedly damaging fences to gain access to unauthorized areas and by vehicle noise and activity causing disturbed cattle to move to areas where they are not desired.[245] OHRV use in British Columbia has been identified as creating similar issues with fencing, and disturbance which can disrupt livestock movements and patterns.[246]

"A Range Health Assessment Audit conducted by ASRD, in 2007, found a high number of upland sites in an *unhealthy* or *healthy, with problems* condition in the Ghost River Grazing Allotment. Degraded range health was attributed to a combination of factors including OHV use, overgrazing by livestock, feral horse use, and encroachment of non-native plant species."[247]

Livestock grazing has potential to negatively impact riparian health and decrease water quality by causing streambank erosion, vegetative cover loss and increased nutrient loading of nutrients and pathogens into waterways.[248,249,250,251] Much of this impact can be mitigated through proper range management which minimizes use of riparian areas by livestock.[252,253] Figure 14, illustrates the relative contribution of agricultural activities, largely livestock grazing, on sediment loading within the study area.

It appears that without effective management of OHRVs, management of livestock in the area may be compromised. However, salting away from watercourses, fencing of riparian areas, off stream watering programs, exclusion of livestock from critical wildlife zones through fencing and effective rotational grazing of appropriate areas to minimize impacts are required. A recent publication by the B.C. government titled "Water quality and livestock grazing on Crown rangeland in British Columbia" provides an excellent up to date summary of best practices for livestock management that would be applicable to the Ghost watershed.[254]

4.1.4 Random Camping

Management of random camping needs to be improved. Currently there is no signage directing random campers to sites that minimize environmental impacts. "Unmanaged camping should not be permitted on public lands unless authorized in designated areas."[255] Random camping areas should minimally provide toilet facilities and bear proof garbage containers.

Current recommended random camping setbacks from watercourses should be enforced to reduce sediment or waste movement from campsites into waterways.[256]

Staging areas for both non-motorized users and motorized users should have toilet facilities and bear proof garbage containers.

4.1.5 Non-Motorized Recreation

Non-motorized use of the study area is a designated activity but is not well identified. Brochures should more clearly acknowledge opportunities for non-motorized pursuits. Hiking, biking and equestrian trails should be identified on maps and brochures and signage posted. Proper trails and facilities for non-motorized pursuits should be designed and developed to minimize environmental impacts. Education materials should inform recreationalists of best practises in relation to their activity to help minimize impacts.[257] Effective enforcement of rules and regulations is important. Such actions would help to fulfill the goals and stated objectives of sustainable recreational multiple use within the study area.

The Ghost Stewardship Monitoring Group should ensure that they seek to provide a balance of motorized and non-motorized management and opportunities within the Ghost-Waiparous Forest Land Use Zone. Simply providing "reasonable access" for all users does not ensure effective multiple uses as intended by the Alberta Government's Ghost River Sub-Regional Integrated Resource Plan.

5. SUMMARY

Current land use trends, as conservatively modelled in this report, will have to change if the study landscape is to provide a healthy suite of ecological and societal services such as quality water production, healthy fish and wildlife habitat, quality recreation and sustainable forestry. Similar to other areas on Alberta's Eastern Slopes, the study area does not appear to be achieving goals established in government mandates, policy and legislation.[258,259,260] Significant aspects of the Ghost River Sub-Regional Integrated Resource Plan and the Ghost-Waiparous Operational Access Management Plan appear to be under implemented, with resultant negative impacts on both natural and recreational resources.

Albertans are concerned about their water, forests and biodiversity. In a survey sample of 2881 Albertans, conducted for the Alberta Forest Products Association, 90% of respondents were either somewhat or extremely concerned about the management of Alberta's forests; only 10% were not very or not at all concerned. Eighty three percent of Albertans felt, "Access and use of forests should be based firstly on preserving and protecting the environment and sustaining wildlife habitat at the expense of sustained economic benefits and jobs."[261] In response to the question of which environment-related issues will have the greatest impact on Alberta's future economic prosperity, the top three issues identified were: rivers and watershed management (21.43%), water quality (18.9%) and maintaining biodiversity (14.33%).[262]

In response to such concerns, the Ghost Watershed Alliance Society's goal is to create an ecosystem-based conservation plan which fits people into ecosystems, such as the Ghost watershed, in ways that protect the land, water, plants, animals, soil and all the other parts and processes of a fully functioning ecosystem while providing for diverse, community-based economies.[263]

Phase 2 of the Ghost River Cumulative Effects study will assess the positive benefits of best management practices on ecological indicators, and human activities in the Ghost-Waiparous watershed while working together with the Ghost Watershed Alliance Society, partner organizations and stakeholders to create an ecosystem-based land-use plan for today and future generations of Albertans.

6. APPENDIX A: ALCES® III LANDSCAPE SIMULATION MODEL

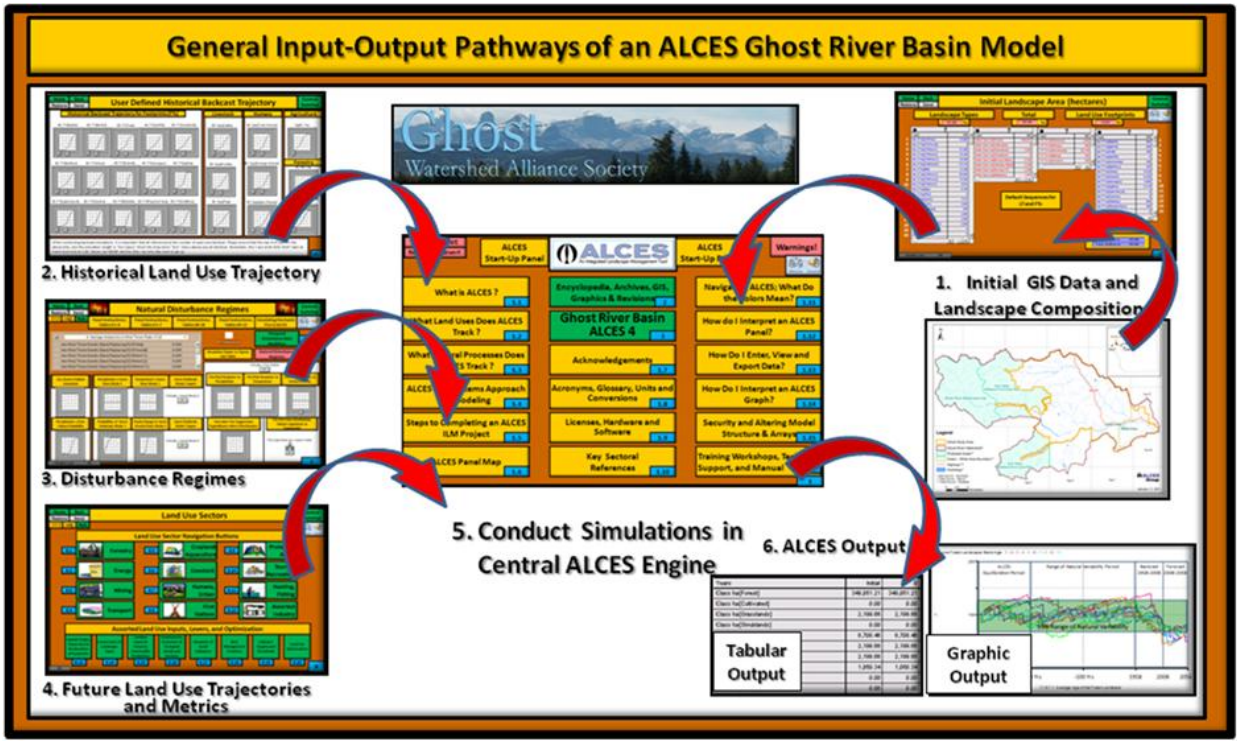
ALCES® is a landscape cumulative effects simulation model that projects and tracks current and future land use footprints and other indicators based on user-defined parameters. ALCES® is not a predictive model; it allows users to define land use scenarios and project their potential outcomes into the 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. ALCES® assists resource managers and planners by:

1. Tracking land use 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 each landscape type.

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. residential, agricultural, forestry, or recreation), natural disturbance regimes (e.g. fire or floods), 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 ecological, social, and economic indicators.

To prepare for ALCES® scenario modelling, data must be entered that describe the study area, land uses and other parameters such as climate, water balance and use coefficients, and footprint reclamation rates and trajectories. For this project, assumptions were drawn from previous work conducted by the Upper Bow Basin Cumulative Effects Study, Alberta Environment Southern Alberta Sustainability Strategy, South Saskatchewan Regional Plan, Southern Foothills Study, and Alberta Environment/Alberta Sustainable Resource Development Southern East Slopes Study.


General Input-Output Pathways of an ALCES Ghost River Basin Model
1. Initial GIS Data and Landscape Composition
2. Historical Land Use Trajectory
3. Disturbance Regimes
4. Future Land Use Trajectories and Metrics
5. Conduct Simulations in Central ALCES Engine
6. ALCES Output
Tabular Output
Graphic Output

7. APPENDIX B: PHASE 1 (BUSINESS AS USUAL-FORECAST) ASSUMPTIONS

GIS Inputs

ALCES® requires three basic GIS data inputs:

- **Landscape Type (LT) classification** – these are the natural, non-anthropogenic landscape classes that characterize the earth surface. The classification is user-defined, and can be derived from any type of spatial information, either raster (classified satellite imagery) or vector (forest cover mapping, etc). ALCES® can utilize a maximum of 20 LTs.
- **Footprint Type (FT) classification** – these are the anthropogenic features/disturbances on the earth surface. The classification is user-defined, and can be derived from any type of spatial information, either raster or vector. Vector GIS data (e.g. .shp, .e00, etc) usually works best for the FT mapping, as linear features and feature geometry are better represented. ALCES® can utilize a maximum of 15 FTs.
- **Landscape Type age** – the time since disturbance age-class of LTs is required to understand age-class related plant community dynamics. This is more critical for Forested LTs, but ALCES® also has the ability to model succession in non-forested LTs.

GIS information developed for the South Saskatchewan Regional Plan area was provided by Alberta Sustainable Resource Development for use by the Upper Bow Basin Cumulative Effects Study /Ghost River. The South Saskatchewan Regional Plan also used the ALCES® model for scenario simulations, so GIS information was already divided into ALCES® - compatible LTs and FTs.

Table 1. Initial landscape and footprint type composition of the Ghost River Study Area.

Landscape Type	Area (ha)	Area (%)
Forest Types		
Hardwood	514	1
Mixedwood	180	.3
Spruce	1,976	3.9
Pine	10,536	20.6
Montane	26,095	52
Other Landscape Types		
Pr Riparian		
Wetlands	6,412	12.6
Foothills Fescue	3,024	5.9
Badlands		
Rock/Ice	210	.4
Reservoir	1	
Lakes	232	.5
River/Stream	1,356	2.7
Annual		
Specialty		
Pasture/Forage	529	.1
TOTAL	51,065	100

Footprint Type	Area (ha)	Length (km)
Major Road	203	48
Minor Road	299	203
Rec Trail OHRV	646	2059
Inblock Road		
Transmission Line Wind		
Coal Gravel	11	
Feedlot		
Industrial Plant / Rec	226	
Ag Res	9	
Town City	1	
Rural Res	89	
Seismic	217	382
Wellsite	59	
Pipeline	115	87
Canal	8	4
TOTAL	1,883	2,783

8. APPENDIX C: RELATIVE WATER QUALITY INDEX – USED FOR UPPER BOW BASIN AND GHOST RIVER CUMULATIVE EFFECTS STUDIES

Aquatic health can be measured using chemical, physical, and biological criteria (North/South 2007). One measure – water quality – was identified as a high priority issue by the Upper Bow Basin Cumulative Effects Study (UBBCES) Steering Committee and the Ghost Watershed Alliance Society. A survey commissioned for the Southern Foothills Study found that maintaining high water quality was the most important issue for both rural and urban residents of the region (SALTS 2007).

One of the challenges of any discussion about water quality is that it means different things to different people:

- most residents are concerned about the quality and safety of water that comes out of their taps or wells;
- recreational users and acreage owners are concerned that water in lakes and streams looks clean, is safe to touch and drink with minimal treatment, and supports healthy plant, fish, and wildlife communities;
- water and wastewater managers are concerned that regulated 'point source' discharge quality (e.g., sewage treatment plants or industrial plant outfalls, Figure 1) complies with drinking, recreational, or aquatic life water quality guidelines and that upstream activities do not inadvertently increase their treatment costs;

Figure 1. Bonnybrook sewage treatment plan, a water pollution point source.

- ranchers and farmers are concerned about the safety of stock water in dugouts, ponds, and streams; and
- fish and wildlife managers and others are concerned about chronic (long-term low dose) effects of unregulated 'non-point' sources (e.g., runoff from urban areas and agricultural lands, Figure 2) that gradually alter habitat quality, even where short-term water quality guidelines have been exceeded infrequently.

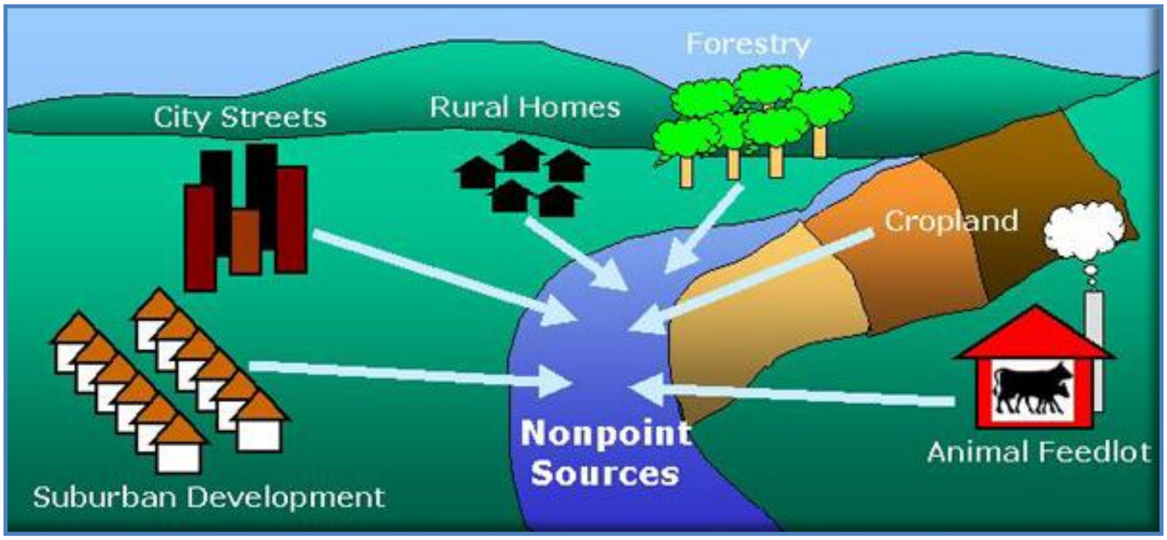


Figure 2. Non-point sources of water pollution (from LCEA nd).

Most definitions of water quality involve the instantaneous or average measurements of physical elements (e.g., sediment, temperature), biological inputs (e.g., organic carbon), nutrients, metals, and ions (e.g., nitrogen, phosphorus, chloride), and chemicals (e.g., pesticides, trace organics) in a waterbody (river, lake, pond). Instantaneous or average water quality may be affected by both point sources and non-point sources (Figures 1 and 2).

The concept of a "Relative Water Quality Index" index' focuses on non-point sources and is based on the well understood phenomenon that each hectare of the landscape releases nutrients and sediment that could ultimately reach waterbodies. As nutrient and sediment emitting landscape types (e.g., roads) become more common, and absorbing landscape (e.g., riparian vegetation) become less common, loading to surface waters increases. The approach was developed for Alberta Environment (AENV) Southern Alberta Sustainability Strategy (SASS) initiative to evaluate the long-term influence of unregulated non-point sources at a workshop held in June 2003, with participants from AENV (Al Sosiak, Wendell Koning, Pat Kinnear), academia (Dr. David Schindler and Dr. Bill Donahue, University of Alberta), and the ALCES Group (Dr. Brad Stelfox, Dr. Dan Farr).

The 'Relative Water Quality Index' reflects the relative landscape loading rate of three water quality parameters. The chosen parameters include two nutrients (total nitrogen and total phosphorus) and sediment (non-filterable residue or total suspended solids), that are, in a general sense, negatively linearly related, to overall water quality. Water quality deterioration has been shown to result from changes in landscape and land use features such as forest area/type, fire history, road density, percent of landscape that is agricultural or urban, livestock density; and OHRV use (e.g., Anderson et al. 1998a; Carpenter et al. 1998; Cooke and Prepas 1998; Carignan et al. 2000; Beaudry 2004; Burke et al., 2004; Croke and Hairsine 2006; Clearwater 2006; Ouren et al. 2007; Cows and Fish nd). Although consistent trends have been documented, it is important to note that forecast changes in the Relative Water Quality Index do not provide empirical information on anticipated changes in instantaneous or short-term water quality.

Sediment and nutrients were also used as aquatic health indicators in a recent provincial Water for Life assessment (North/South 2007). As stated in this assessment, "These indices are not intended to replace the conventional process of analyzing and interpreting water quality data in detail; rather, they should be utilized as qualitative and complementary assessment tools."

When considered alone, or combined into a Relative Water Quality Index, total nitrogen, total phosphorus and sediment releases provide a measure of relative changes in the regional export of these parameters from the study area over time. The ALCES® model provides the user with the option to adopt one of two approaches:

1. Calculate total nitrogen, total phosphorus and sediment loads or combined loads of the three parameters in the study area relative to average natural loads to forecast relative change in nutrient and sediment release; or
2. Estimate the portion of total nitrogen, total phosphorus and sediment loading that reaches waterbodies by including a 'discount' coefficient that reduces total load to account for attenuation of these exports prior to reaching waterbodies (e.g., not all sediment lost from fields reaches lakes or streams because the distance to the nearest waterbody varies and vegetation filtering results in nutrient uptake and sediment deposition; Corley et al. 1999), or for physical and chemical processes that occur within waterbodies (Wetzel 1975). With this approach, forecast loads can be calibrated against annual average water quality values to ensure that they reflect historical or current landscape composition.

Option 1 was selected for the UBBCES study because AENV and City of Calgary water managers were concerned that results could be misinterpreted by a non-technical audience. With this option, the Relative Water Quality Index (RWQI) is reported as a value between 1 and 0, where 1 reflects average natural conditions, and 0 represents extremely high loading (very poor water quality). In other words, relative water quality is considered to degrade from excellent to poor as values become smaller.

Regional sediment, nitrogen, and phosphorus inputs and outputs were calculated based on water quantity simulations and coefficients defining the rates (tonnes/ha/yr) at which nitrogen, phosphorus, and sediment are exported from various landscape and footprint types. Coefficients used here were derived for SASS based on the most representative values available in the literature (Jeje 2003). Road nitrogen export coefficients from Davidson et al. (2010) were used because these values were not provided in Jeje (2003). Table 1 summarizes the inferred water quality coefficients used and their origin.

Nutrient and sediment coefficients derived for South Saskatchewan Regional Plan modeling and results of the CAESAA water quality monitoring program (Anderson et al. 1998a,b; Casson et al., 2008; Jedrych 2008; Lorenz et al., 2008), were also considered at the request of AENV and Alberta Agriculture and Rural Development. Small watershed nutrient export rates documented by the CAESAA water quality monitoring program were lower than those provided in Jeje (2003), and were shown to be correlated with surface runoff rate and landscape characteristics; sediment export rates were not provided. In general, higher agricultural intensity watersheds (based on census data rather than land use metrics) had the highest concentrations of nutrients (Lorenz et al. 2008).

CAESAA/SSRP coefficients were not used for the UBBCES nor Ghost River Cumulative Effects Study because they suggest that natural forested lands contribute more than fifty times as much sediment as crop lands and natural grasslands contribute more than eight times as much sediment as crop lands. This means that we should expect to see better water quality and healthier waterbodies in areas that are dominated by agriculture, although the scientific literature consistently documents the reverse. Put another way, CAESAA/SSRP coefficients suggest that the best thing to do to reduce sediment input in the Upper Bow watershed would be to convert all the forest in national and provincial parks to crops and pasture.

Table 1. Relative water quality loading coefficients used for the Upper Bow Basin and Ghost River Cumulative Effects Studies.

Landscape or Footprint Type	Nitrogen Runoff (tonnes/ ha/yr	Source	Phosphorus Runoff (tonnes/ ha/yr)	Source	Sediment Runoff (tonnes/ ha/yr)	Source
Hardwood Forest	0.00051	foothills parkland from Jeje 2003	0.0000575	foothills parkland from Jeje 2003	0.3049	foothills parkland from Jeje 2003
Mixedwood Forest	0.00051	foothills parkland from Jeje 2003	0.0000575	foothills parkland from Jeje 2003	0.3049	foothills parkland from Jeje 2003
Spruce Forest	0.00275	subalpine from Jeje 2003	0.0002	subalpine from Jeje 2000	0.251	avg forest from Jeje 2003
Pine Forest	0.00275	subalpine from Jeje 2003	0.0002	subalpine from Jeje 2001	0.251	avg forest from Jeje 2003
Montane Forest	0.00275	subalpine from Jeje 2003	0.0002	subalpine from Jeje 2002	0.251	avg forest from Jeje 2003
Prairie Treed / Riparian	0.00051	foothills parkland from Jeje 2003	0.0000575	foothills parkland from Jeje 2003	0.3049	foothills parkland from Jeje 2003
Wetlands	0.00055	from Jeje 2003	0.00001	from Jeje 2003	0.251	avg forest from Jeje 2003
Foothills Fescue	0.00061	from Jeje 2003	0.00011	median from Jeje 2003	0.0621	median from Jeje 2003
Badlands	0.0018	1/2 montane; per Jeje 2003	0.00009	median alpine from Jeje 2003	0.502	twice forest
Rock Ice	0.0018	1/2 montane; per Jeje 2003	0.00009	median alpine from Jeje 2003	0.251	avg forest from Jeje 2003
Reservoir	0		0		0	
Lentic (lakes and ponds)	0		0		0	
Lotic	0		0		0	
Annual Crop	0.0012	from crowfoot crk median, Jeje 2003	0.00032	from crowfoot crk median, Jeje 2003	1.44	S AB, from Jeje
Specialty Crop	0.0012	from crowfoot crk median, Jeje 2003	0.00032	from crowfoot crk median, Jeje 2004	1.44	S AB, from Jeje
Pasture, Forage, Tame Grass	0.0051	avg from Jeje 2003	0.0007525	avg from Jeje 2003	0.457	avg from Jeje 2003
MajorRoad and Rail	0.01	Davidson et al. 2010, water air soil polln	0.0035	from Jeje 2003	2	SASS - urban from Jeje 2003

Table 1 Relative water quality loading coefficients used for the Upper Bow Basin and Ghost River Cumulative Effects Study (cont).

Landscape or Footprint Type	Nitrogen Runoff (tonnes/ ha/yr	Source	Phosphorus Runoff (tonnes/ ha/yr)	Source	Sediment Runoff (tonnes/ ha/yr)	Source
MinorRoad	0.01	Davidson et al. 2010, water air soil polln	0.0035	from Jeje 2003	2	SASS - urban from Jeje 2003
Rec Trail OHV	0.01	Davidson et al. 2010, water air soil polln	0.0035	from Jeje 2002	1	half major and minor roads
Inblock Roads	0.01	Davidson et al. 2010, water air soil polln	0.0035	from Jeje 2003	1	half major and minor roads
Transmission Lines and Wind Farms	0.01	Davidson et al. 2010, water air soil polln	0.0035	from Jeje 2003	1	half major and minor roads
Mines	0.0086	from Jeje 2003	0.0015	from Jeje 2003	0.869	industrial from Jeje 2003
Feedlot	1.95	from Jeje 2003	0.255	median from Jeje 2003	2	SASS - urban from Jeje 2003
Industrial Plant\Recreational	0.00225	from Jeje 2003	0.00795	from Jeje 2003	0.869	industrial from Jeje 2003
Ag Res	0.00152	lawns from Jeje 2003	0.0005	mixed ag from Jeje 2003	0.209	residential from Jeje 2003
Town City	0.00525	avg from Jeje 2003	0.00123	avg from Jeje 2003	2	urban from Jeje 2003
Rural Res	0.00152	lawns from Jeje 2003	0.0005	mixed ag from Jeje 2003	0.209	residential from Jeje 2003
Seismic	0.00152	lawns from Jeje 2003	0.00019	lawns from Jeje 2003	0.209	residential from Jeje 2004
Wellsite	0.00152	lawns from Jeje 2003	0.00019	lawns from Jeje 2003	0.209	residential from Jeje 2005
Pipeline	0.00152	lawns from Jeje 2004	0.00019	lawns from Jeje 2004	0.209	residential from Jeje 2006
Canal	0		0		1.44	S AB, from Jeje

Note: Please refer to the Upper Bow River Basin Cumulative Effects Study – Phase 1 & 2 Technical Report for citations.[264]

9. APPENDIX D: LINEAR FEATURE EXERCISE METHODOLOGY

Linear Feature Exercise Methodology:

Purpose

Determine the amount of trails and linear features that were not included in the GIS dataset being used for the Ghost project - essentially to determine the amount of linear footprint being underestimated.

Methods

1	Randomly located twenty five 1 km x 1 km polygons (approx 5% of area) throughout the study area.
2	Polygons are random. Karen Manual created a 1 km x 1km grid of the study area, numbered the polygons. Using a random number generator, generated a list of 25 polygons (25 polygons is approximately 5% of the study area. Random numbers generated Jul 13 2010 at 12:52:15 by www.psychicscience.org. Free educational resources for psychical research.
3	Overlaid the Upper Bow Basin Cumulative Effects Study / South Saskatchewan Regional Plan GIS dataset - linear features only - over a 2007 sat image (2.5 m resolution) of the study area.
4	Digitized the linear features that were evident in the imagery and also included in the GIS dataset, per polygon.
5	Digitized the linear features that were evident in the imagery and NOT included in the GIS dataset, per polygon - these were almost exclusively multi-use OHRV trails 1 to 3m wide.
6	The tab 'linear feature counts' provides the results of the digitization
7	the tabs ' pivot' and summary' summarize the data.
8	Calculated the total km of OHRV trails apparent in the imagery but not included in the GIS dataset, per polygon.
9	The average km per km2 of linear features and trails under represented is 3.7 km per km2.
10	This number was applied to the study area for a combined linear density calculation of 5.12km/km$^{2.}$

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- Habitat selection coefficient for used landscape and footprint types;
- Mortality coefficient for each used landscape and footprint types;
- Combined exposure coefficient for used landscape and footprint types;

Individual coefficients express the probability of grizzly bear use (or death) for each landscape type, based on analysis of actual bear telemetry locations. Exposure reflects overall mortality risk when habitat is considered (i.e., exposure is reduced in habitat types that have lower selection probability, and increased in habitat types that have higher selection probability [attractive sinks]).

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