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Calculating Net Present Values for Grassland Conservation Activities within Saskatchewan's Milk River Watershed

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Growing Forward

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Abstract

This report is the first of two reports that outline the creation of several MARXAN mathematical programming models for species at risk conservation within Saskatchewan's Milk River Watershed. The mathematical programming models were used to investigate cost-effective conservation planning for the region's multiple species at risk. This report presents the calculation of net present values – direct and opportunity costs – for the conservation activities used as inputs within the mathematical programming models. The conservation activities for which net present values were calculated include restrictions to oil and gas activity in the region, the removal of agricultural production, the re-vegetation of modified landscapes to native grassland species, the planting/retention of buffer strips and shelterbelts, the implementation of conservation easements, and the reduction of livestock stocking rates. The methods used to calculate the net present values of the conservation activities are largely straightforward; however, the clear presentation of the data and assumptions used within the calculations improves both the transparency of the final mathematical programming models as well as the interpretation of their results. Final products presented within this report include a final cost summary as well as net present value maps for the study region at a quarter section (160 acre, 65 hectare) resolution for all 21 532 quarter sections (13 871 km^2) considered within the net present value analysis and subsequent mathematical programming models.

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1 Introduction

As of January 2013, a multiple species at risk (MULTI-SAR) conservation planning initiative – The South of the Divide Action Plan – is being undertaken within Saskatchewan's Milk River Watershed. One question that arose with the progression of the planning process is the magnitude of the economic costs associated with potential conservation actions. This document is the first of two documents in a project that details the economic costs of several conservation scenarios that could potentially be implemented by the MULTI-SAR conservation planning initiative. The project is intended to highlight the economic trade-offs necessary to achieve native grassland protection – and, thereby, the survival and recovery of grassland species at risk – within the watershed. This first document is dedicated to the calculation of conservation activity costs, while the second report (Entem *et al.* 2013) is dedicated to outlining the economic trade-offs for the region via a cost-effectiveness analysis of four different conservation scenarios.

The goal of this paper is to provide clear information on the methods used to calculate the economic cost (opportunity and direct) of conservation activities that strive to maintain and/or improve the quantity and/or quality of native grasslands within the study region. There are many actions, including research, communication and extension with landowners and managers, captive breeding and translocation programs, disease control measures, among others, that will be implemented within the Milk River Watershed. However, this document, as stated above, focuses on the actions that result in the provision of native grassland habitat. As a result, the net present value analyses conducted in this document focus on the economic costs of modifications to the region's two largest economic sectors – oil and natural gas, and agriculture – that will improve the region's grassland habitat provision. The conservation activities for which net present values were calculated include modifications of oil and gas activity in the region, the removal of agricultural production, the re-vegetation of modified landscapes to native species, the planting/retention of buffer strips and shelterbelts, the implementation of conservation easements, and the reduction of stocking rates.

This report presents a brief introduction to the Milk River Watershed region (interchangeably referred to as the South of the Divide study area) and then systematically outlines the native grassland conservation actions considered within this document and finally goes into a thorough presentation of the net present value calculations carried out for the conservation activities. Final products presented within this report include a final conservation cost summary as well as net present value maps for the study region at a quarter section (160 acre, 65 hectare) resolution for all 21 532 quarter sections (13 871 km^2) considered within the net present value analysis.

2 Study Area

Saskatchewan's Milk River Watershed is located in the only portion of Saskatchewan south of the continental divide (all water in the region flows to the Mississippi River and ultimately the Gulf of Mexico) and is delineated to the south by Montana and the west by Alberta (Figure 2.1). The watershed is located within the mixed grassland and Cypress upland ecoregions of the Canadian prairie ecozone. The study area for this project used the planning region already selected for the South of the Divide Action Plan taking place within the Milk River Watershed. As a result, the Nekaneet Cree Nation Indian Reserve, Birch and Maple Grazing Co-op Ltd., Piapot and Bear Grazing Co-op Ltd., Black Hills Grazing Co-op Association, Scotsguard Grazing Co-op Ltd, Beaver Valley Community Pasture, Auvergne-Wise Creek Community Pasture, Mankota Community Pasture and any bordering quarter sections with partial inclusion in the basin were encompassed within the study area (Kirk and Pearce 2009). The result is a total study area of 14,923 square kilometers of dry mixed grass, mixed grass and Cypress upland prairie. A total of 21,532 quarter sections were included within the final analysis (13,871 square kilometers).[1]

Figure 2.1. The geographic location of the Saskatchewan's Milk River Watershed and the South of the Divide conservation planning area.

[1] Net present value calculations for conservation activities were all completed at the quarter section level. Since land is generally bought, sold and managed at the quarter section level within this primarily agricultural landscape, the quarter section (160 acres or 65 hectares) was the obvious resolution for the conservation planning models presented in Entem *et al.* (2013), and, therefore, also for the calculation of conservation costs within this document.

The current allocation of land within the region to each agricultural land-use, soil classification, and range ecosite was determined using spatial information provided by the Canadian Wildlife Service and the Saskatchewan Ministry of Environment. Within the region, approximately 42% of the area is privately owned farmland, 30% is provincial crown lease land, 17% is federal and provincial community pastures, 4% comprises Grasslands National Park, 3% is grazing cooperatives, and the remaining 4% is divided up amongst 'other' land uses including wildlife areas, irrigation project land, Indian reserve land, conservation easements and town sites (Figure 2.2). Annual cropland, hay fields/tame pastures, and native grasslands cover 23%, 13% and 53% of the region, respectively (Figure 2.3).

2.1 The Species at Risk

As many as 24 species[2] currently listed on the federal species at risk public registry have all or part of their historic range located within the watershed. Species endemic to the prairies, including permanent residents and migratory species, use the Milk River Watershed as their breeding grounds (Kirk and Pearce 2009) and the success of these species is tied to the continued provision of healthy, well-managed native grasslands.

The large number of species at risk located in the Milk River Watershed resulted in the multi-species approach implemented in the South of the Divide Action Plan. Managing multiple species at risk adds an additional layer of complexity to the design of an economically and biologically efficient conservation area plan (Kirk and Pearce 2009); species at risk have different habitat and management requirements, and particular actions on the landscape may aid one species while hindering another.

While managing multiple species may be difficult, the common grassland habitat requirement of many of the species at risk included within the South of the Divide Action Plan may make management easier in this region. All of the species at risk considered within this document, at the broadest level, require the native grasslands located on unmodified areas within the Milk River Watershed (Kirk and Pearce 2009).[3] More specifically, Canadian prairie species at risk are found in native grasslands, riparian areas, wetlands, tame pastures and haylands (Environment Canada 2011). Only a few species at risk are found in summerfallow, winter crops and shelterbelts, and the presence of species at risk is generally an indicator of healthy biological communities and responsible agricultural management (Environment Canada 2011).

[2] See Appendix A of Entem (2012) for a complete list of species including discussions of their habitat requirements, historic ranges and locations for proposed critical habitat.

[3] The only potential exceptions are Loggerhead Shrike and Greater Sage-Grouse that require shrubland for nesting and foraging. However, if it is assumed that conserved and restored grasslands will undergo a certain level of natural linear succession, those areas that historically supported shrubland will ultimately once again provide shrubland plant communities.

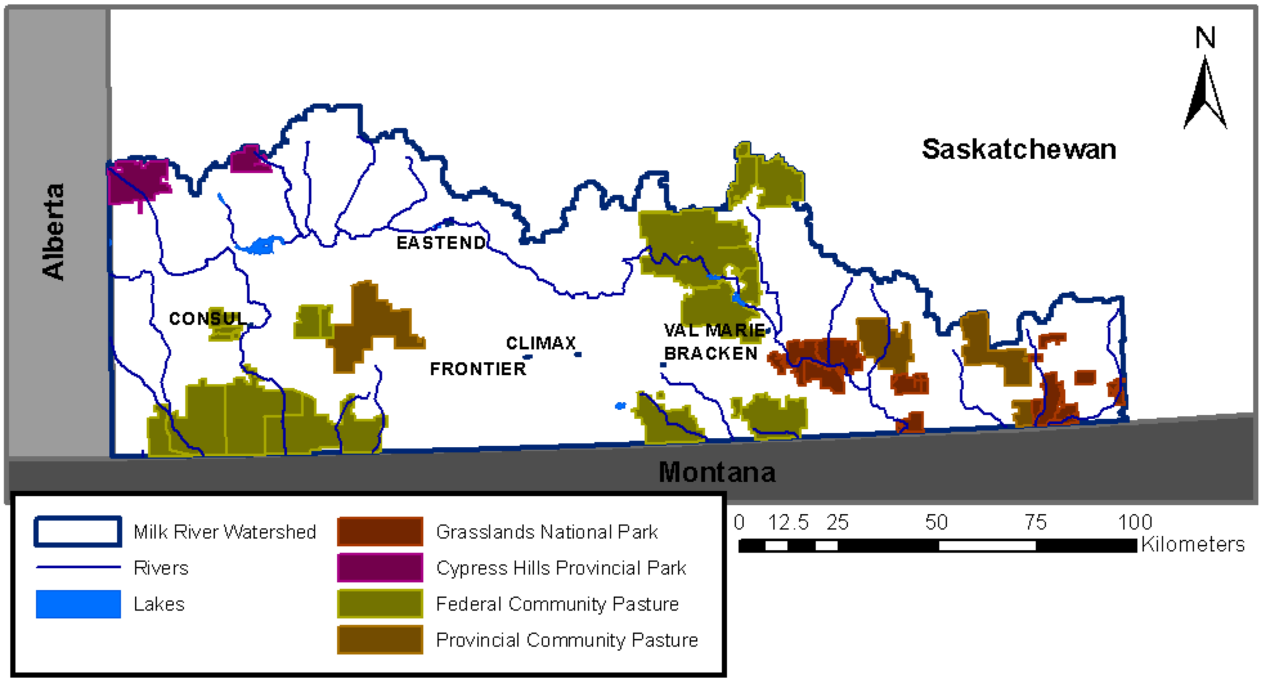

Figure 2.2 The distribution of government parks and community pastures within the Milk River Watershed.

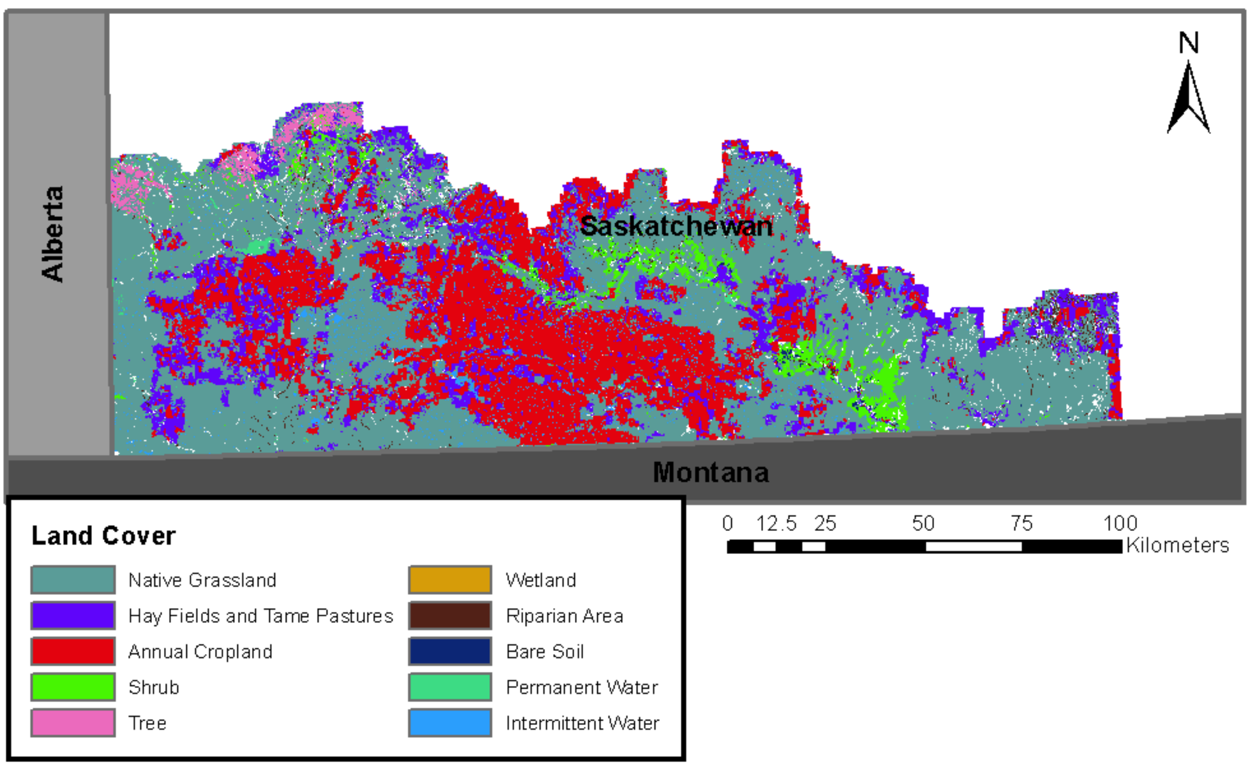

Figure 2.3 The distribution of landcover types within the Milk River Watershed.

A total of eight species were included within the conservation planning models created for the Milk River Watershed. The eight species included Burrowing Owl (*Athene cunicularia*), Loggerhead Shrike (*Lanius ludovicianus excubitorides*), Sprague's Pipit (*Anthus spragueii*), Swift Fox (*Vulpes velox*), Greater Sage-Grouse (*Centrocercus urophasianus urophasianus*), Eastern Yellow-bellied Racer (*Coluber constrictor flaviventris*), Black-footed Ferret (*Mustela nigripes*), and Mountain Plover (*Charadrius montanus*). The habitat requirements and historical ranges for these eight species influenced the conservation activities analyzed within this conservation cost report.

These species were chosen because they had either a detailed assessment report or recovery strategy posted on the Species at Risk Act (SARA) registry. These reports were used to select appropriate conservation actions that would aid the species at risk. They all also have legally designated or proposed critical habitat polygons that are partially or entirely located within the Milk River Watershed.

2.2 Geographic Distributions of the Species at Risk within the Watershed

Historic ranges of the grassland species were provided by the Saskatchewan Ministry of the Environment. Of the eight species considered in the conservation planning models, three historically covered the entire study region: Burrowing Owl, Loggerhead Shrike and Sprague's Pipit (Figure 2.4). Swift Fox historically covered a large portion of the region and only the north-central portion of the study area would originally have lacked the small cat-sized foxes (Figure 2.4). Eastern Yellow-bellied Racers, Black-footed Ferrets and Mountain Plovers were all historically found in similar locations near what is now Grasslands National Park. Greater Sage-Grouse had pockets and stretches of habitat scattered throughout the entire region (Figure 2.4).

Proposed or legally designated critical habitat polygons (as of October, 2011) for the grassland species at risk were provided by Parks Canada and Environment Canada (Canadian Wildlife Service Division) [4]. Parks Canada and the Canadian Wildlife Service are responsible (along with the Department of Fisheries and Oceans) for the identification and designation of critical habitat for all species listed in Schedule 1 under SARA. Legally, critical habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species" (Subsection 2(1) of the Species at Risk Act). Commonly critical habitat is associated with a species' high quality habitat (Hall *et al.* 1997). For some species, the critical habitat polygons have been published in the species' recovery strategies, for others, the newly proposed critical habitat designations have been expanded, updated or created for the Milk River Watershed and the South of the Divide Action Plan. Figure 2.5 shows the locations of the proposed/designated critical habitat for all eight species within the Milk River Watershed.

[4] Stephen K. Davis, of the Canadian Wildlife Service's Prairie and Northern Region office in Regina Saskatchewan is the head of the Critical Habitat task group for the South of the Divide Action Plan. All legally designated and proposed critical habitat polygons (as of October, 2011) were supplied by Stephen Davis out of the Canadian Wildlife Service office in Regina, SK.

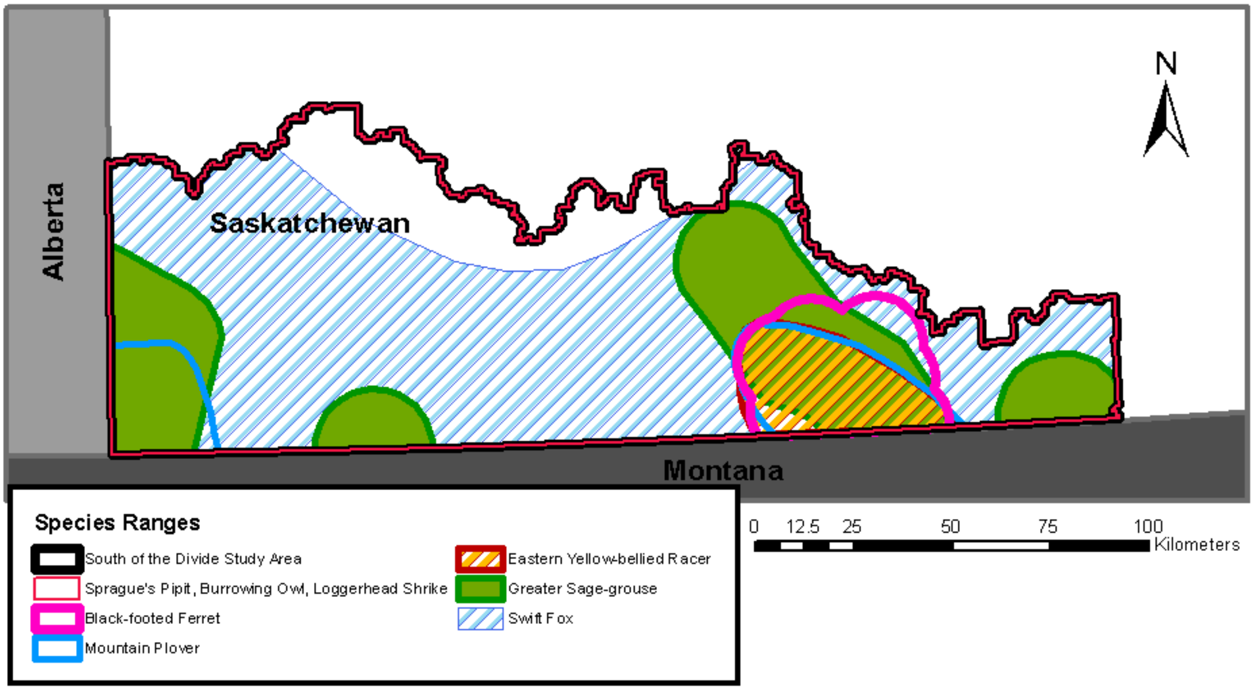

Figure 2.4 The historical ranges of species at risk within the Milk River Watershed (i.e. the South of the Divide conservation planning area).

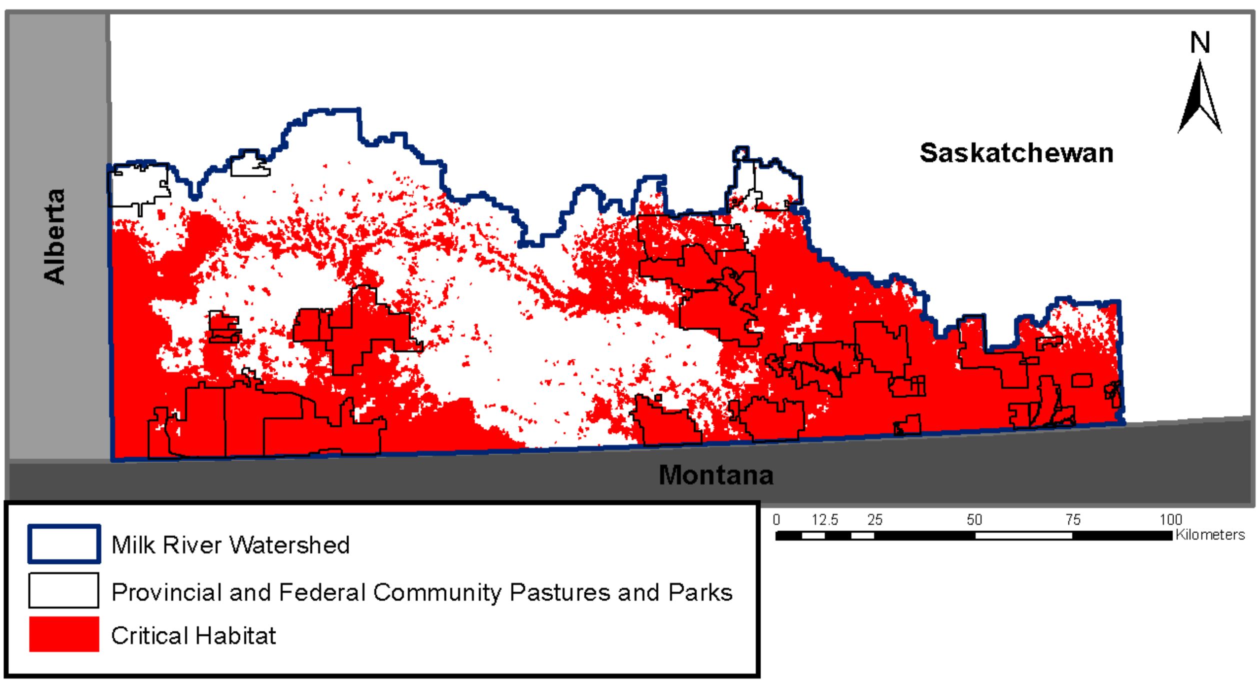

Figure 2.5. The critical habitat boundaries for all eight species considered together.

2.3 Causes of Species Declines

Habitat loss is often considered the primary cause of species declines (Brooks *et al.* 2002; Pimm and Raven 2000; Ceballos and Ehrlich 2002). Within the Milk River Watershed, loss of habitat, habitat fragmentation and habitat degradation are the primary threats to species at risk (Kirk and Pearce 2009; Kerr and Cihlar 2004; Kerr and Deguise 2004). Other threats – environmental stochasticity, invasive species, increased predation, direct human-caused mortality, etc. – often result from (directly or indirectly), or are exacerbated by, the activities that have caused habitat loss, fragmentation and degradation.

Land use changes that continue to threaten Saskatchewan's native prairie habitat include cultivation, invasive species, woody species encroachment, resource development, and poor grazing management (Riemer *et al.*1997; Kirk and Pearce 2009). Many of these changes are related to agricultural and oil and gas production. Agricultural production and subsurface resource extraction both result in numerous issues: increases in invasive species due to the seeding of lease sites, tame pastures and roadways; altered hydrologic patterns due to the digging of dugouts and roadways (especially with improper culvert installation); increased predation due to the introduction of fences and buildings that provide avian predator roosts and also the creation of roadways and other linear features that assist predator movement; as well as direct human caused mortality on roadways, lease sites, and in crops and pastures as a result of heavy machinery operation.

2.4 Native Grassland Conservation Actions

Slowing, halting, or even, optimistically, reversing the trend of species declines within the southwest corner of Saskatchewan will be achieved through the implementation of a multitude of different conservation tools. This document focuses on conservation actions that address the issues of habitat loss, fragmentation and degradation. As a result, all conservation actions were selected due to their ability to prevent future native grassland degradation/loss, or restore/improve already-modified landscapes. The activities considered were influenced by an Environment Canada (2011) publication on beneficial management practices (BMPs) as well as the species assessments or recovery strategies for each of the species at risk (Environment Canada 2006; Environment Canada 2008; Environment Canada 2010; Parks Canada Agency 2010; Pruss *et al.* 2008; Tuckwell and Everest 2009; Lungle and Pruss 2008; COSEWIC 2004).

The list of possible activities that could be implemented by land owners and land managers within the Milk River Watershed in an attempt to promote the survival and recovery of grassland species at risk include:

1) Protecting existing native grasslands
    a. Public purchase of native grasslands from private land owners
    b. Prevent or modify future oil and gas extraction activities
    c. Promote sustainable grazing practices on current native grasslands
2) Restoring modified landscapes to native grasslands
    a. Convert cultivated land to native perennial cover
    b. Public purchase of restored grasslands from private land owners
    c. Remove current oil and gas extraction activities
3) Creating habitat patches within modified landscapes
    a. Leave uncut vegetation in hay fields
    b. Plant strips of perennial cover around the perimeters of cropland
    c. Plant shelterbelts within cropland or tame hay fields or pastures.[5]

The following sections provide step-by-step information on how the cost, i.e. net present value, of each conservation action was calculated for all 21,532 quarter sections within the Milk River Watershed.

3 Oil and Natural Gas Extraction

The net present value of discovered and undiscovered future oil and natural gas reserves were calculated using a net present value model that accounts for profits, royalties and taxes under four extraction scenarios. These four scenarios are: (1) all current and future petroleum extraction is halted, (2) current extraction proceeds but future extraction is prohibited, (3) current extraction proceeds and future extraction occurs only on pre-existing well sites at a maximum density of 4 well per section (640 acres or 259 hectares), and (4) current extraction proceeds and future extraction also proceeds but never at a well density in excess of 4 wells per section. The following sections outline the data used within the analysis, the net present value model used to calculate the oil and natural gas values, and finally present the results of the oil and natural gas net present value analysis.

3.1 Summary of Data and Method Sources

The Saskatchewan Ministry of Economy manages information on reserves, wells (depth, location, numbers, etc.), tax formulas, and royalty formulas for the oil and gas sector in Saskatchewan. As a result, much of the data used in the oil and natural gas analysis were collected from reports, publications, information sheets, and InfoMaps that are publicly

[5] Shelterbelts were used in the management of only one of the eight species at risk: Loggerhead Shrike. For all other species, shelterbelts can provide perching areas for avian predators and may be detrimental to the survival of the species.

available and provided on the Ministry of Economy's[6] website: http://www.er.gov.sk.ca/. In the case of natural gas, additional reserve information was collected from a 2008 report published by the National Energy Board and the Saskatchewan Ministry of Energy and Resources (ER/NEB 2008).

Several key documents provided necessary information on relevant costs, well production profiles, and price forecasts. Information on costs associated with exploration, drilling and extraction came from Hauer *at al.* (2010b), Alberta Department of Energy (2007), and the Petroleum Services Association of Canada (2007).[7] The Alberta Department of Energy (2007) document also provided well production profiles for the Petroleum Services Association of Canada (PSAC) regions located within Alberta (Figure 3.1).[8] Natural gas and crude oil price forecasts were obtained from GLJ Petroleum Consultants on April 1st, 2011 (GLJ Petroleum Consultants 2011).

The calculation of oil and natural gas net present values for the Milk River Watershed (the South of the Divide study area) follows the methods of the 2010 Project Report 'A Net Present Value Model of Natural Gas Exploitation in Northern Alberta: An Analysis of Land Values in Woodland Caribou Ranges' by Hauer *et al.* (2010b). Hauer *et al.* (2010b) created a model that accounts for remaining resource reserves, exploration and drilling costs and the probability of successful exploration and drilling.

There are sufficient differences between the model of Hauer *et al.* (2010b) and the net present value model used for southwest Saskatchewan to warrant a thorough discussion of the modified Milk River Watershed model within this report. Differences in the two models were driven by differences data availability. For example, while Hauer *et al.* (2010b) used tracts – the intersection of a delineated land surface area and its subsurface, resource-producing stratigraphic interval – as the unit for which net present values were calculated, the Milk River Watershed natural gas net present value model uses land surface area, i.e. quarter sections, as the unit of delineation. The use of land surface area was necessary because the publicly available information on gas reserves (ER/NEB 2008) was not broken down by stratigraphic level. The presence of oil pool information allows oil net present value calculations to be based on tracts; however, the majority of the Milk River Watershed only has one stratigraphic interval

[6] The Ministry has recently had its name changed from the Ministry of Energy and Resources to the Ministry of Economy. At the time of analysis, it was known as the Ministry of Energy and Resources; as such, hereinafter, any reference to data sources provided by the ministry, or references to the ministry itself, will use the name that applied at the time of analysis: the Ministry of Energy and Resources.

[7] The Petroleum Services Association of Canada (2007) publication is the only information source used within the analysis that is not freely publicly available. The publication is available for purchase on the organization's website.

[8] Some information required for the net present value calculations was unavailable for the PSAC region – PSAC region SK2 – in which the Milk River Watershed is located. However, PSAC region AB3 is adjacent to PSAC region SK2 and both share several natural gas formations. Therefore, information for PSAC region AB3 was used when information specific to the Milk River Watershed was not available.

of interest. Thus, oil net present value calculations can largely be delineated simply through the use of land surface units (i.e., quarter sections) – analogous to the gas analysis.

A complete discussion of the methods used within the Milk River Watershed follows. Oil and natural gas are discussed together in each section with natural gas discussed first followed by a discussion on oil.

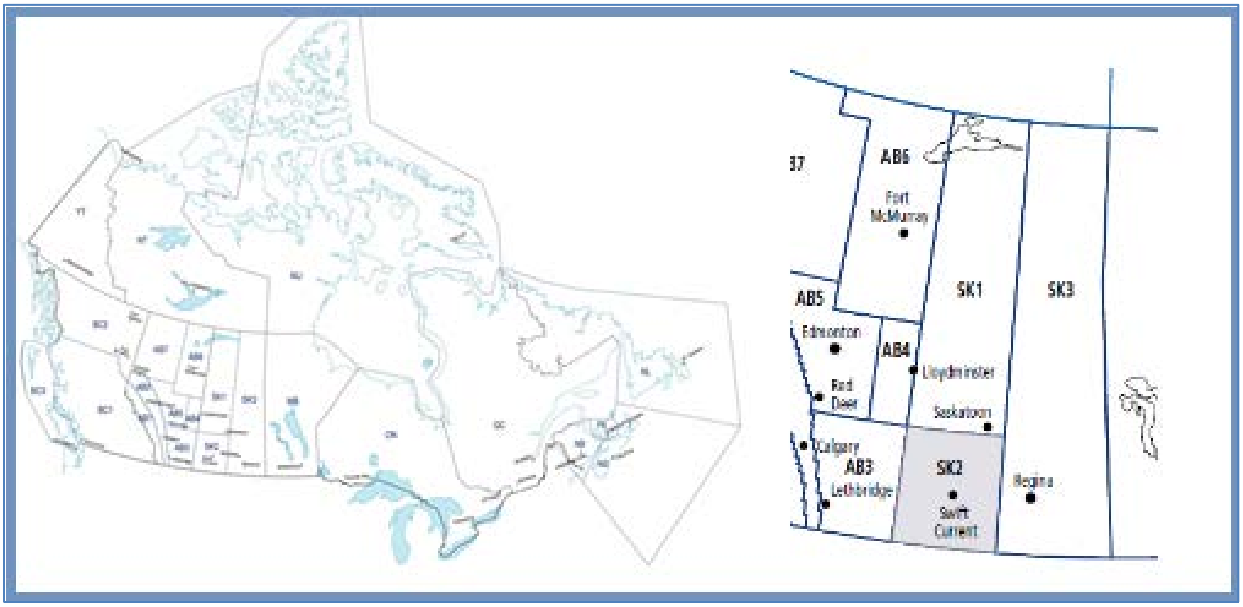

Figure 3.1.The location of PSAC regions within Canada (Petroleum Services Association of Canada 2011), and the location of PSAC region SK2 in relation to PSAC region AB3 (Petroleum Services Association of Canada 2007).

3.1.1 Reserve Data

The following sections highlight the methods used to calculate the remaining natural gas and oil reserves within Saskatchewan's Milk River Watershed.

3.1.1.1 Natural Gas

Spatial information on Saskatchewan's remaining ultimate potential for marketable natural gas was collected from a 2008 report published by the National Energy Board and the Saskatchewan Ministry of Energy and Resources (ER/NEB 2008). Very little gas in Saskatchewan is produced in association with crude oil reserves (ER/NEB 2008); as a result, the gas reserve estimates for the Milk River Watershed are non-associated, conventional natural gas estimates. This analysis made use of the report's medium probability estimates for undiscovered reserves since this estimate was termed the 'most realistic estimate' within the report (ER/NEB 2008).

Reserves can be classified in several different ways. Within Saskatchewan's gas reserve reports, reserves are broken down into discovered and undiscovered resources (Figure 3.2). Ultimate potential is defined as the sum of discovered and undiscovered (future) resources; remaining ultimate potential is an estimate of total remaining natural gas reserves (ultimate potential minus cumulative production) and it represents the volume that is assumed to be available to meet future market demands (ER/NEB 2008). Gas reserves can also be classified to indicate the amount of gas available at different processing stages: gas in place (GIP) is the initial volume of gas in the reservoir (the total available reserve), recoverable gas is the volume of gas that can be extracted (GIP multiplied by current recovery factors – an average of 73% in Saskatchewan) and marketable gas is the volume that remains after processing and is the amount of gas that is available to the market (recoverable gas minus surface losses – an average of 5% in Saskatchewan). The reserves used in this study were marketable remaining ultimate potential reserves.

Terminology used for Study of Saskatchewan's Ultimate Potential for Conventional Natural Gas

Terms			Level of Uncertainty
Ultimate Potential	Discovered	Cumulative Production	None
		Reserves	Low
	Undiscovered	Future	High

Figure 3.2. Chart taken from the ER/NEB (2008) report on Saskatchewan's Natural Gas Potential. The chart highlights the classification system used to distinguish between discovered and undiscovered gas resources within Saskatchewan.

Within the ER/NEB (2008) report, gas reserves were displayed in ranges of million cubic meters per township (~100 km^2 or 36 land sections). All reserves were aggregated into a total reserve value allocated to each surface area unit.[9] The ranges of gas reserves that were present within the watershed were 1 – 25, 25 – 50, 50 – 100 and 100 – 250 million cubic meters of natural gas per township. These were the lowest ranges within the province's gas producing areas. Estimates of marketable remaining ultimate potential within Saskatchewan's gas producing areas[10] ranged from 1-25 million cubic meters to as much as 2 500 – 5 000 million cubic meters. The gas hotspots in Saskatchewan are found just north of the Milk River Watershed.

Natural gas reserves were scaled down to quarter sections in order to calculate net present values at the appropriate spatial scale for analysis. There are 36 sections in a township and 4 quarter sections in 1 section; therefore, natural gas reserves divided by 144 (36 x 4) to have the gas reserves presented on a quarter section scale. This division relies on the assumption that within townships of the Milk River Watershed, gas reserves are equally distributed across quarter sections. The final result was a spatial map of natural gas reserves (cubic meters) per quarter section.

[9] The ER/NEB (2008) report did not provide any spatial information on individual gas pools or play formations; as a result, gas reserves were not able to be separated by pools or play (subsurface geological) formations.

[10] Many areas of Saskatchewan have no current or future natural gas reserves. Natural gas reserves are primarily located in the western half of the province.

3.1.1.2 Oil

Information on the spatial location of oil pools within the Milk River Watershed was obtained from the Saskatchewan Ministry of Energy and Resources' interactive oil and gas InfoMap (Saskatchewan Industry and Resource 2011). The area of each pool (acres) was calculated within ArcMap 10.0 and the oil pool layer was clipped to the study area.

Remaining reserve information for each of the 16 oil pools within the study region was collected from a Reserve Summary Report located on the Saskatchewan Ministry of Energy and Resources' website (ER 2008). This summary report provided information on each formation's remaining oil reserves (in million cubic meters); the reserves located within this region are medium density conventional crude oil reserves. Within the region, the only 2 oil pools that spatially overlapped had identical boundaries and differed only by depth.[11]

Total remaining reserves within a pool were divided by the total area (acres) of that pool and then multiplied by 160 (160 acres/quarter section) to get the total reserves that would be found under each quarter section. This, like the gas reserve discussion above, assumes an equal spatial distribution of the oil reserves. Quarter sections and pools perfectly aligned, so all quarter sections were either completely included within the oil pools or were completely excluded (i.e. no quarters were partially included within a pool), and, thus, every quarter section overlaying a particular oil pool would receive the same calculated amount of remaining oil reserves. Finally, joining information on Saskatchewan's remaining oil reserves (calculated at a quarter section scale) and information on the spatial location of oil pools created a spatial map of discovered remaining oil reserves for the watershed.

3.1.2 Well Data

Net present value calculations required information on current extraction, probability of successful future exploration and extraction, and depth-dependent exploration and extraction costs. Current and historic well data provided the data necessary to fill these information gaps.

The Saskatchewan Ministry of Energy and Resources' website provided information on oil and natural gas wells for the study region. The Ministry's website provides a link to an interactive oil and gas InfoMap (Saskatchewan Industry and Resources 2011). The InfoMap provides information on oil and gas wells that is updated daily by the provincial government, and well information was downloaded on the 3rd of May, 2011. The information downloaded included well location (UTM coordinates and legal land description), well type (oil, natural gas, water), well status (abandoned, active), well depth (meters), well age (license date), and many additional characteristics. The information layers were extracted into a format usable by ESRI's

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[11] Unfortunately, information on future reserves was not available. Predicted future reserve information was available for conventional oil reserves in the southeast part of the province and oil sand reserves within the northwest part of the province; however, no reports or other information could be found to indicate the presence of future reserves within southwest Saskatchewan. As a result, only discovered reserves were used within the oil analysis.

ArcGIS platform. All the oil and natural gas wells for the province were extracted, designated as abandoned or active, and clipped to the study region using ArcMap 10.0. Within ArcMap 10.0, the wells were all spatially linked to their respective subsurface reserves using the data discussed in the previous subsection (Subsection 3.1.1).

3.1.2.1 Number of Wells

There are many factors that determine the number of wells drilled to exploit resources, and modelling the number of wells drilled is a complex issue (Hauer *et al.* 2010b). As a result, within this study, the best method for determining the number of wells drilled per quarter section was by using past data on wells drilled in the study area. Using the logic of Hauer *et al.* (2010b), there are three potential scenarios that can result on a quarter section that has had drilling occur on it: (1) drilling resulted in all successful (i.e. resource producing at a profitable level) wells, (2) drilling resulted in no successful wells, or (3) drilling resulted in a combination of successful and unsuccessful wells. Consequently, well numbers were broken down into three categories: W^s, W^{sa}, and W^a. W^s is the average number of successful wells drilled on a quarter section that had at least 1 successfully drilled well (i.e. a 'successful' quarter). W^{sa} is the average number of unsuccessful wells drilled on a quarter section that had at least 1 successfully drilled well (i.e. a 'successful' quarter). W^a is the average number of unsuccessful wells drilled on a quarter section that has never had a successful well drilled (i.e. an 'unsuccessful' quarter). These values were calculated using the well data provided by the Saskatchewan Ministry of Energy and Resources' InfoMap (Saskatchewan Industry and Resources 2011). The calculation method was slightly different between the natural gas and oil analyses, thus each will be discussed in turn below.

3.1.2.1.1 Natural Gas

W^s, W^{sa}, and W^a were calculated for each natural gas remaining ultimate potential reserve level (Table 3.1). Values were calculated using townships rather than quarter sections because the use of information on quarter sections would result in inflated parameter values for two reasons: 1) reserve information was provided at the township level not at the quarter section level, and 2) there is a low proportion of quarter sections that have been drilled.

The number of successfully and unsuccessfully drilled wells was calculated for both successful and unsuccessful townships. W^s, W^{sa}, and W^a were calculated as the average number of successful wells on successful townships, the average number of unsuccessful wells on successful townships, and the average number of unsuccessful wells on unsuccessful townships, respectively. These numbers were then divided by 144 (144 quarter sections per township) to provide the values at a quarter section level (Table 3.1).

Table 3.1. The average number of natural gas wells drilled on a quarter section in the Milk River Watershed.

Remaining Ultimate Potential (000 m^3)	Average # of Successful Wells on Successful Quarter Sections	Average # of Unsuccessful Wells on Successful Quarter Sections	Average # of Unsuccessful Wells on Unsuccessful Quarter Sections
1 – 174	0.007	0.322	0.000
175 – 347	0.019	0.021	0.004
348 – 694	0.088	0.024	0.000
695 – 1736	0.109	0.040	0.010

3.1.2.1.2 Oil

The use of oil pool spatial information in the oil analysis, allowed each oil pool to have its own average number of wells calculated. The number of successful and unsuccessful wells and quarter sections were both calculated. Those values were then used to find the average number of wells per quarter section conditional upon both the well's success and the quarter section's success (Table 3.2).

Table 3.2. The average number of oil wells drilled per quarter section in the Milk River Watershed study region categorized by oil pools.

	Average # of Successful Wells on Successful Quarter Section	Average # of Unsuccessful Wells on Successful Quarter Sections	Average # of Unsuccessful Wells on Unsuccessful Quarter Sections
Battle Creek Upper Shaunavon Pool	1.500	0.500	1.000
Whitemud Shaunavon Pool	1.707	0.122	1.200
Battle Creek West Madison Pool	3.200	0.500	1.000
Rapdan West Shaunavon Pool	1.188	0.313	1.077
Rangeview Madison Pool	1.500	0.000	0.000
Battle Creek Madison Pool	2.250	0.250	1.000
Rangeview East Madison Pool	1.500	0.000	1.000
Eastend Shaunavon Pool	1.458	0.167	1.000
Rapdan Upper Shaunavon Pool	2.053	0.197	1.048
Rapdan South Upper Shaunavon Pool	1.429	0.143	0.000
Divide Madison Pool	3.667	0.000	0.000
Battle Creek South Upper Shaunavon Pool	2.500	0.000	0.000
Eastbrook Shaunavon Pool	1.500	0.308	1.000
Chambery Upper Shaunavon Pool	1.000	0.429	1.000
Rapdan North Lower Shaunavon Pool	1.200	0.000	1.000
Dollard Upper Shaunavon Pool	2.231	0.231	1.000

3.1.2.2 Probability of Success

Net present value calculations for future subsurface resource extraction – especially on quarter sections that have not yet been drilled – inherently contain uncertainty related to the probability of successful exploration and drilling on an area of land. As such, net present values were adjusted to reflect this uncertainty by using expected probabilities of exploration (i.e. seismic) success, P^{seis}, and drilling success, $P^{success}$, using the methods of Hauer *et al.* (2010b). The probability of drilling success was based on historic well data collected from the Saskatchewan oil and gas InfoMap (Saskatchewan Industry and Resources 2011) while the probability of seismic success was derived.

The probability of drilling success for oil and natural gas resources was computed as the total number of successfully drilled quarter sections divided by the total number of quarter sections drilled, as shown in Equation 3-1 below. Each natural gas reserve level has a probability of success calculated, and each oil pool had its own probability of success calculated.

Equation 3-1

$$P^{success} = \frac{Number\ of\ Successfully\ Drilled\ Quarter\ Sections}{Total\ Number\ of\ Quarter\ Sections\ Drilled}.$$

Table 3.3 displays the region's probability of drilling successful for each oil pool and natural gas reserve level. The high probabilities of successful drilling are not unreasonable if one considers Alberta as an appropriate reference. It has been found that the chance of commercial drilling success in Alberta is very high and averages close to 80% (Alberta Department of Energy 2007).

The probability of exploration success was not computed for oil reserves because the reserves were already considered discovered and therefore required no further exploration activities to occur; however, the probability of exploration success, P^{seis}, for natural gas was derived using two data sources. One source, the Saskatchewan InfoMap (Saskatchewan Industry and Resources 2011), suggested a region wide average drilling success rate of 0.57 (method of calculation discussed above). The second source, an appendix to the ER/NEB (2008) report on Saskatchewan's natural gas potential, provided an estimated cumulative success rate of 0.05 over the past 60 years for 5 natural gas plays within the study region. This success rate is much lower than the success rate expected after successful exploration; thus, it was assumed, as it was in Hauer *et al.* (2010b) that these success rates were not adjusted by exploration. As a result, seismic success rates were able to be calculated by comparing these two different reported success rates. To compute P^{seis} Equation 3-2 was used, and P^{seis} was found to be 0.09[12].

Equation 3-2

$$P^{seis} \times P^{Success}_{InfoMap} = P^{Success}_{NEB} \rightarrow P^{seis} = {P^{Success}_{NEB}}\Big/{P^{Success}_{InfoMap}}$$

[12] The calculation uses a region-wide probability of successfully drilling a natural gas well. The probability of success for the region as a whole is 0.57.

Table 3.3. The calculated probability of drilling success for each oil pool and the total natural gas reserve in the Milk River Watershed study region.

	# Successfully Drilled Quarter Sections	Total # of Drilled Quarter Sections	Probability of Success
Gas Reserves 1 000 – 174 000 m^3	2	92	0.02
Gas Reserves 175 000 – 347 000 m^3	98	314	0.31
Gas Reserves 348 000 – 694 000 m^3	115	141	0.79
Gas Reserves 695 000 – 1 736 000 m^3	563	735	0.73
Battle Creek Upper Shaunavon Pool	2	23	0.50
Whitemud Shaunavon Pool	41	79	0.80
Battle Creek West Madison Pool	5	16	0.76
Rapdan West Shaunavon Pool	32	64	0.61
Rangeview Madison Pool	6	6	1.00
Battle Creek Madison Pool	4	23	0.75
Rangeview East Madison Pool	6	10	0.82
Eastend Shaunavon Pool	24	46	0.78
Rapdan Upper Shaunavon Pool	76	129	0.81
Rapdan South Upper Shaunavon Pool	7	9	0.91
Divide Madison Pool	3	3	1.00
Battle Creek South Upper Shaunavon Pool	6	8	1.00
Eastbrook Shaunavon Pool	26	30	0.81
Chambery Upper Shaunavon Pool	7	11	0.58
Rapdan North Lower Shaunavon Pool	10	16	0.92
Dollard Upper Shaunavon Pool	13	20	0.76

3.1.2.3 Depth

The depth to subsurface resources can have a large effect on drilling costs. As such, depth to reserves was estimated for each resource (oil and natural gas) for all quarter sections within the study region.

3.1.2.3.1 Natural Gas

An average natural gas reserve depth was estimated for each township. First, an average was taken of all well depths within a township and that became the township's assigned depth. However, a second step was required in the case that a township did not have a recorded depth for a previously drilled well (which was the case for 48 of the 190 townships). In the case of a township with no recorded well depths, a nearest neighbour principle was used. For each township with adjacent townships with depth data, the adjacent township depths were averaged and assigned to the township lacking the depth data. Thus, townships with no depth data were assigned a depth based on the average depths of their neighbouring townships. This process continued through several passes, as necessary, until all townships were assigned a depth.

3.1.2.3.2 Oil
In the case of depth to oil, each pool had information regarding the depth to the formation and these depths were used to estimate the drilling depth required to extract the resource.

3.1.3 Production Profiles
Net present value calculations explicitly account for time; therefore, production profiles that account for resource volume extraction through time are a fundamental component for any model used to calculate the net present value of oil and natural gas resources. The volume of oil or natural gas extracted from a well over time is dependent upon a number of factors – including prices. For simplicity, this model does not attempt to model changes in volume extraction that result from changes in prices. Instead, volume flow over time is treated as a fixed set of parameters.

A technical background document for Alberta's Royalty Review (Alberta Department of Energy 2007) provided well profiles representative of each oil and gas producing region in Alberta. Production profiles were based on wells drilled between 1998 and 2002 and were developed to create a representative range of production profiles for each PSAC region in Alberta. Each PSAC region has 6 natural gas production curves and 3 conventional oil production curves that represent different production percentiles (Table 3.4). Production profiles for PSAC region AB3 were used to approximate the PSAC region SK2 production profiles.

Table 3.4. Production profiles for PSAC region AB3 showing extraction rates of oil (bbl/year) and natural gas (1000m3/year) for typical wells (Alberta Department of Energy 2007). These production profiles were used to approximate production profiles in the Milk River Watershed study region (PSAC region SK2).

Year	Gas Well 1	Gas Well 2	Gas Well 3	Gas Well 4	Gas Well 5	Gas Well 6	Oil Well 1	Oil Well 2	Oil Well 3
2012	198	510	736	963	2464	3002	1400	18400	57300
2013	170	396	566	736	1727	2152	1000	12000	37400
2014	170	368	481	623	1331	1671	800	8300	25500
2015	113	227	396	510	1104	1388	600	5700	17300
2016	85	142	340	425	934	1133	500	3900	11800
2017	57	113	255	340	736	906	100	2700	8000
2018	142	255	227	255	595	736	0	1800	5500
2019	113	283	170	198	481	595	-	1300	3700
2020	85	170	142	170	396	510	-	900	2500
2021	0	0	113	142	340	425	-	600	1700
2022	-	-	85	142	311	340	-	300	1200
2023	-	-	28	85	255	311	-	0	800
2024	-	-	28	57	227	255	-	-	600
2025	-	-	28	57	170	198	-	-	200
2026	-	-	28	57	142	170	-	-	0
2027	-	-	28	28	142	142	-	-	-
2028	-	-	28	28	142	142	-	-	-
2029	-	-	0	0	113	113	-	-	-
2030	-	-	-	-	113	113	-	-	-
2031	-	-	-	-	113	113	-	-	-
2032	-	-	-	-	57	85	-	-	-
2033	-	-	-	-	28	57	-	-	-
2034	-	-	-	-	28	57	-	-	-
2035	-	-	-	-	28	57	-	-	-
2036	-	-	-	-	28	57	-	-	-
2037	-	-	-	-	28	57	-	-	-
2038	-	-	-	-	28	57	-	-	-
2039	-	-	-	-	28	57	-	-	-
2040	-	-	-	-	28	28	-	-	-
2041	-	-	-	-	0	0	-	-	-
TOTAL	**1133**	**2464**	**3681**	**4814**	**12091**	**14895**	**4300**	**55700**	**173600**

Following the approach of Hauer *et al.* (2010b), production profiles were calculated for each quarter section based on the resource's remaining reserves, the total flow over a well's life, and an assumption about the number of wells that would be used to extract the resource from the quarter section. The following equations highlight the method used to derive the production profiles for natural gas and oil, respectively.

Equation 3-3

$$V_t^{R/W^s} = \begin{cases} \dfrac{R/W^w}{P_1} \times V_t^{P_1} \; when \; \dfrac{R}{W^s} \le P_1 \\ \left(1 - \dfrac{(R/W^s - P_l)}{(P_{l+1} - P_l)}\right) \times V_t^{P_l} + \dfrac{(R/W^s - P_l)}{(P_{l+1} - P_l)} \times V_t^{P_{l+1}} \; when\ there\ is\ a\ P_l\ and\ P_{l+1}\ such\ that\ P_l \le \dfrac{R}{W^s} \le P_{l+1} \\ \dfrac{R/W^s}{P_6} \times V_t^{P_6} \; when \; \dfrac{R}{W^s} > P_6 \end{cases}$$

Equation 3-4

$$V_t^{R/W^s} = \begin{cases} \dfrac{R/W^w}{P_1} \times V_t^{P_1} \; when \; \dfrac{R}{W^s} \le P_1 \\ \left(1 - \dfrac{(R/W^s - P_l)}{(P_{l+1} - P_l)}\right) \times V_t^{P_l} + \dfrac{(R/W^s - P_l)}{(P_{l+1} - P_l)} \times V_t^{P_{l+1}} \; when\ there\ is\ a\ P_l\ and\ P_{l+1}\ such\ that\ P_l \le \dfrac{R}{W^s} \le P_{l+1} \\ \dfrac{R/W^s}{P_3} \times V_t^{P_3} \; when \; \dfrac{R}{W^s} > P_3 \end{cases}$$

Where

- R is the quantity of reserves in the tract in 000 m^3 (natural gas) or bbl (medium oil);
- W^s is the number of wells extracting the quarter section's resources (natural gas, medium oil);
- V_t^{R/W^s} is the volume extracted from a quarter section's well in year t given that the well has R reserves (000 m^3 or bbl) and a total of W^s wells extracting its reserves;
- $P_1, \dots, P_l, P_{l+1}, \dots, P_6$ $for\ natural\ gas\ reserves$; and $P_1, \dots, P_l, P_{l+1}, \dots, P_3$ $for\ oil\ reserves$ are lists of all the production levels over well life for each resource, ordered smallest to largest.
- P_l is the total well production level which is the greatest of all production levels less than or equal to $R/_{W^s}$ and P_{l+1} is the well in the list with the smallest total production of all wells with greater production than $R/_{W^s}$ – essentially, $P_l \le \frac{R}{W^s} \le P_{l+1}$.

Figure 3.3 is an illustrative example of a production profile derived for a natural gas well in the study region. The production profile was created for a gas well located on a quarter section with an estimated $R/W^s = 6887\ thousand\ cubic\ meter$ (natural gas reserve of 521 thousand cubic meters (R) and an estimated well density of 0.065 (W^s)). As a result, the estimated production profile makes use of the 4th and 5th reference natural gas wells (Table 3.4). Since natural gas volumes were provided in ranges (ER/NEB 2008), a range of production volumes was created: low, mid and high. Figure 3.4 displays how this worked for a natural gas well found on a quarter section with a predicted reserve range of 7 to 174 thousand cubic meters of gas (R), an estimated well density of 0.065 wells per quarter section (W^s), and a calculated R/W^s equal to 2627 (low), 3694 (mid) and 4789 (high) thousand meters cubed. The low volume estimation is found using reference gas wells 2 and 3 (Table 3.4), the mid volume estimation is found using gas wells 3 and 4, and the high volume estimation uses gas wells 4 and 5.

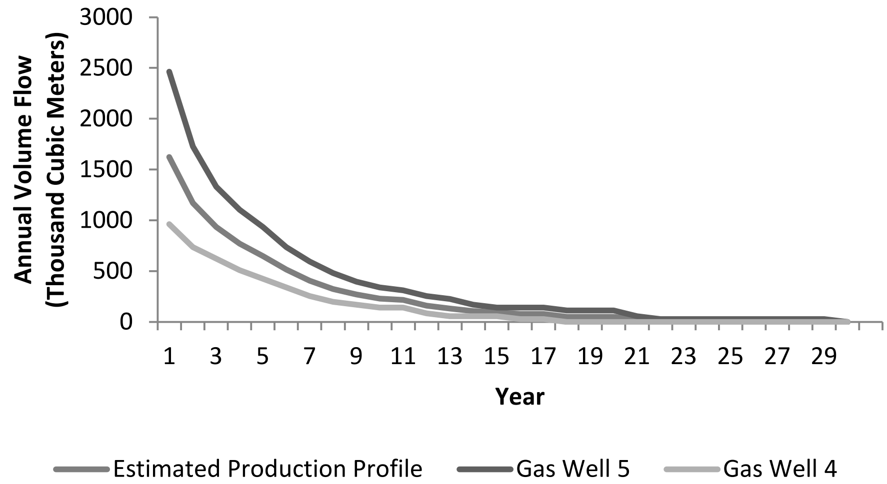

Figure 3.3. Production profile for an example natural gas well with a calculated expected lifetime production of 6887 thousand cubic meters of natural gas.

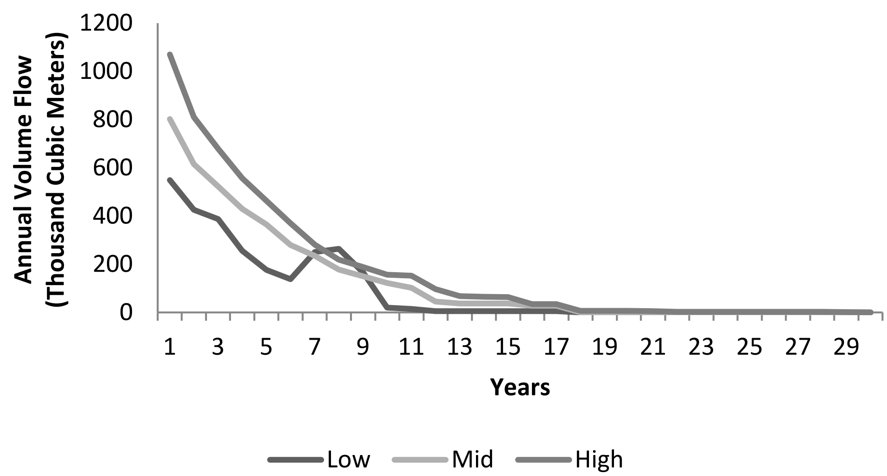

Figure 3.4. Production profiles for a natural gas well with an estimated total production range of 2627 (low), 3694 (mid) and 4789 (high) thousand cubic meters of natural gas. The difference in the shapes of the production profiles are due to differences in the reference wells used to estimate each of the production profiles.

3.1.4 Costs

Costs can be divided into fixed costs (seismic, drilling, equipment and tie in costs) and variable costs (operating costs). Drilling costs were collected from a PSAC well cost study (Petroleum Services Association of Canada 2007) and costs were assigned to a quarter section based on whether its resources would require a drilling depth less than, or more than, 1000 meters. Seismic, equipment, tie-in, and operating costs were all collected from an Alberta Department of Energy (2007) technical report (Table 3.5). The costs collected from the report are for PSAC region AB3, but were used approximate the costs of PSAC region SK2.

Table 3.5. The costs used in the NPV model for natural gas and medium oil wells.

	Seismic Costs ($/well)	Drill and Complete Costs ($/well) Depth ≤ 1000m	Drill and Complete Costs ($/well) Depth > 1000m	Drill and Abandon Costs ($/well) Depth ≤ 1000m	Drill and Abandon Costs ($/well) Depth > 1000m	Equipment Costs ($/well)	Tie-In Costs ($/well)	Variable Operating Costs Gas Well ($/ 000m^3)	Variable Operating Costs Oil Well ($/bbl)
Gas	9,000	412,124	690,666	187,204	331,240	39,000	53,000	11.30	-
Oil	9,000	412,124	690,666	187,204	331,240	57,000	-	-	4.79

*Seismic, equipment, tie-in, and variable operating costs taken from Alberta Department of Energy (2007); Drilling costs taken from Petroleum Services Association of Canada (2007).

3.1.5 Price Forecasts

Price forecasts for natural gas (methane) were obtained from GLJ Petroleum Consultants on April 1st, 2011 (GLJ Petroleum Consultants 2011). This analysis makes use of the SaskEnergy Price forecast presented within their report since this is the provincial gas price used to calculate royalties. Price forecasts for crude oil were also obtained from GLJ Petroleum Consultants on April 1st, 2011 (GLJ Petroleum Consultants 2011). This analysis makes use of the Medium Crude Oil forecast presented in their report since the oil pools in the Milk River Watershed predominantly produce a medium density crude oil.

Prices were reported in current dollars; however, prices were deflated to 2008 dollars using the consumer price index. This calibration allowed the net present value model to be inflation adjusted to reflect 2008 dollars. The price forecast only went up to 2020, however, prices after 2020 were predicted to increase at 2%/year (GLJ Petroleum Consultants 2011). These prices were adjusted by an estimated 2 point increase in CPI/year[13]. Future price predictions are smooth projections into the future (Figure 3.5 and Figure 3.6).

The natural gas prices were reported in \$/mmbtu and therefore required a couple simple conversions to move prices into \$/1000m^3. The first conversion factor is that there are 1.055 GJ/1 mmbtu; and the second conversion is that there are 37 GJ/1000m^3 of methane. Thus, simply multiplying $\frac{\$}{mmbtu} \times \frac{1\ mmbtu}{1.055\ GJ} \times \frac{37\ GJ}{1000m^3}$ yields the appropriate pricing units of $\frac{\$}{1000m^3}$.

[13] If a higher inflation rate of 2% were used instead, resource prices past 2020 would remain constant at the 2020 real price.

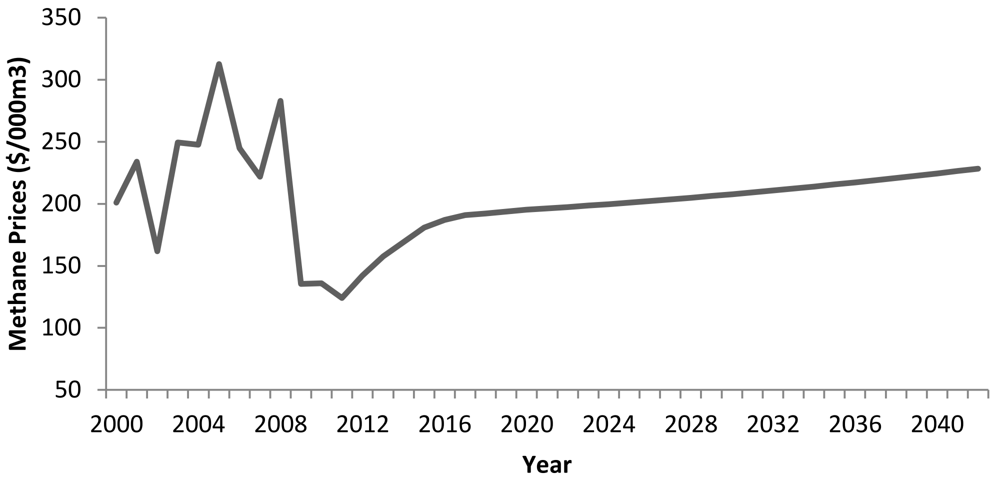

Figure 3.5. SaskEnergy prices (constant 2008 prices) for methane gas from 2000 to 2011 and predicted into 2042 (information from GLJ Petroleum Consultants 2011).

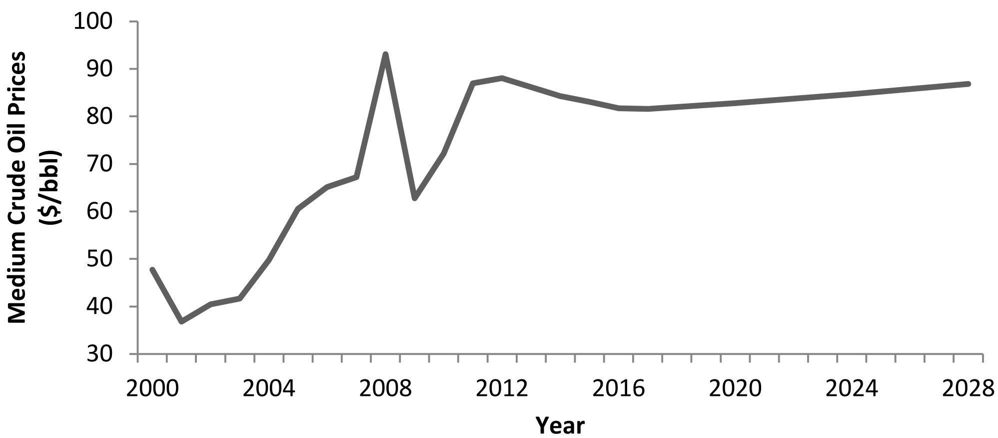

Figure 3.6. Medium crude oil prices (constant 2008 prices) from 2000 to 2011 and predicted into 2028 (information from GLJ Petroleum Consultants 2011).

3.1.6 Royalty Formulas

Royalties on future natural gas and medium crude oil extraction were computed using the Saskatchewan oil and gas formulas information circular (ER 2011) and the Alberta Department of Energy (2006) report on Oil and Gas Fiscal Regimes of the Western Canadian Provinces and Territories. Computations were simplified by excluding special rates and incentive programs (for example, horizontal well drilling incentives, waterflood project incentives, oil well reactivation incentives, etc.).[14]

[14] Associated gas (natural gas produced from oil wells) was not included in the net present value calculations as a result of inadequate data. However, Saskatchewan has very little associated gas (ER/NEB 2008), so the exclusion of associated gas from the analysis is not expected to have a large impact on the accuracy of the results.

3.1.6.1 Natural Gas

The crown royalty rates (R%) paid on natural gas producing wells are dependent upon the age of the well, the productivity of the well, and the provincial average gas price ($/1000m^3). The annual royalty value can be computed using Equation 3-5. While monthly royalties are calculated by the province, annual royalties were calculated within our model for simplicity. In order to alter the calculations to reflect annual royalty rates, annual volume flows replaced monthly flows, and an average annual price replaced monthly natural gas prices.

Equation 3-5

$$Royalty\ Value = V_t C_t^{roy} = V_t R_t^{\%}(P_t - 10)$$

Where

- V_t is the well's annual volume flow in thousand cubic meters;
- $R_t^{\%}$ is the natural gas royalty rate for year t;
- $(P_t - 10)$ is the annual wellhead value of the gas;[15]
- C_t^{roy} is the percentage of the natural gas wellhead value collected as royalties for each thousand cubic meters of natural gas produced (also known as the royalty cost; $/1000m^3).

The calculation used to determine the natural gas royalty rate, $R_t^{\%}$, are outlined in Table 3.6 (Alberta Department of Energy 2006). Kg, Xg, Cg and Dg are constants calculated from the formulas outlined in Table 3.7.

Table 3.6. The formulas used to calculate crown royalty rates based on natural gas well volumes and age (Alberta Department of Energy 2006).

	MGP* ≤ 25 000 (m^3/month)	**25 000 < MGP ≤ 115 400 (m^3/month)**	**MGP > 115 400 (m^3/month)**
Old, New and Third Tier Gas[16]	R%[†] = (Cg[‡] x MGP) – SRC[¥]	R% = (Cg x MGP) – SRC	R% = (Kg – (Xg/MPG)) – SRC
Fourth Tier Gas	R% = 0	R% = (Cg x MGP) – Dg	R% = (Kg – (Xg/MGP))

*MGP = Monthly Gas Production (m^3/month)[17]
[†]R% = Crown royalty rate (to a minimum of 0%)
[‡]Kg, Xg, Cg and Dg are constants calculated from the formulas outlined in Table C.6
[¥]SRC = Saskatchewan Resource Credit of 2.5% for third tier gas and 1% for old gas and new gas. The SRC does not apply to fourth tier gas.

[15] The annual wellhead value of gas is the annual provincial price of gas ($/1000m^3) minus the fixed gas cost allowance of $10/1000m^3 set by the province of Saskatchewan.

[16] Old Gas is produced from wells drilled prior to October 1st 1976; New Gas is produced from gas wells drilled on or after October 1st 1976; Third Tier Gas is produced from gas wells drilled on or after February 9th 1998; and Fourth Tier Gas which is produced from gas wells drilled on or after October 1st 2002.

[17] Volumes from the production profiles are in yearly flows, thus the appropriate royalty rates were determined by multiplying the MGP values by 12. This assumes that flow is evenly distributed throughout the year and the royalty rate is equal in every month throughout the year.

Table 3.7. The formulas used to calculate the constants used within the natural gas Crown royalty calculations Alberta Department of Energy 2006).

	Kg	Xg	Cg	Dg
Old Gas	26 + (32.5 x (PGP* – 35)/PGP)	Kg x 57.69	Kg/230.76	-
New Gas	19.5 + (26 x (PGP – 35)/PGP)	Kg x 57.69	Kg/230.76	-
Third Tier Gas	19.5 + (26 x (PGP – 50)/PGP)	Kg x 57.69	Kg/230.76	-
Fourth Tier Gas	6.75 + (33.73 x (PGP – 50)/PGP)	Kg x 64.7	Kg/205.76	Kg/8.23

*PGP is the provincial average gas price ($/1000m^3) set each month.[18]

3.1.6.2 Oil

Crown royalty rate calculations for oil closely parallel the calculations used for natural gas. As in the case of natural gas, oil royalty rates are sensitive to a well's production, the age of the well, the current provincial oil price ($/m^3), but now in addition, royalty rates are sensitive to the type of oil produced (Alberta Department of Energy 2006). Oil production is divided into 3 types of oil – Heavy Oil, Southwest-Designated Oil, and Non-Heavy Oil. The Milk River Watershed is encompassed within the Southwest-Designated Oil zone.

Southwest-Designated Oil has its own unique royalty calculation procedures. The annual royalty value can be computed using Equation 3-6. While monthly royalties are calculated by the province, annual royalties were calculated in our model for simplicity. In order to alter the calculations to reflect annual royalty rates, annual volume flows replaced monthly flows, and an average annual price replaced monthly medium oil prices.

Equation 3-6

$$Royalty\ Value = V_t C_t^{roy} = V_t R_t^{\%} P_t$$

Where

- V_t is the well's annual volume flow in cubic meters;
- $R_t^{\%}$ is the oil royalty rate for year t;
- P_t is the annual wellhead value of the oil;
- C_t^{roy} is the percentage of the oil wellhead value that is collected as royalties for each cubic meters of medium oil collected from a well (also known as the royalty cost).

Table 3.8 outlines the gas royalty formulas and rates (Alberta Department of Energy 2006) used to calculate royalties within the oil net present value model. K, X, C and D are constants derived from the formulas outlined in Table 3.9.

[18] While PGP varies monthly, the price forecast model includes only annual average price, and it is this price that is used to calculate the constants necessary to determine the crown royalty rates.

Table 3.8. The formulas used to calculate Crown royalty rates based on oil well volumes and age (Alberta Department of Energy 2006).

	MOP* ≤ 25 (m^3/month)	25 < MOP ≤ 136.2 (m^3/month)	MOP > 136.2 (m^3/month)
New and Third Tier Oil[19]	†R% = (K‡ – (X/MOP)) – SRC¥	R% = (K – (X/MOP)) – SRC	R% = (K – (X/MOP)) – SRC
Fourth Tier Oil	R% = 0	R% = (C x MOP) – D	R% = (K – (X/MOP))

*MOP = Monthly Oil Production (m^3/month)
†R% = Crown royalty rate (to a minimum of 0%)
‡ K, X, C and D are constants derived from the formulas outlined in Table C.8.
¥SRC = Saskatchewan Resource Credit of 2.5% for third tier oil and 1% for new gas. The SRC does not apply to fourth tier oil.

Table 3.9. The formulas used to calculate the constants used within the oil Crown royalty calculations (Alberta Department of Energy 2006).

	K	X	C	D
New Oil	16.25 + 29.25 x (SOP* – 50)/SOP	Kg x 23.08	-	-
Third Tier Oil	16.25 + 29.25 x (SOP – 100)/SOP	Kg x 23.08	-	-
Fourth Tier Oil	7.14 + 35.71 x (SOP – 100)/SOP	Kg x 75	Kg/247.48	Kg/9.9

*SOP is the average southwest designated oil wellhead price (\$/m^3)[20]

3.1.7 Tax Rate Formulas

Hauer *et al.* (2010b) developed a simple model to estimate taxes. Their model allows the calculation of corporate taxes – generally paid at a corporate level – to be calculated for an individual oil or natural gas well, thereby allowing tax calculations to be included in our net present value models for oil and natural gas.

Taxes for every year of a well's producing life were calculated by multiplying the corporate sales tax percentage rates by the well's net revenue and the net revenue calculations accounted for operating costs, royalty payments and depreciation (Hauer *et al.* 2010b). A federal corporate tax rate of 15% and a provincial corporate sales tax of 12% were used. A depreciation rate of 20% was used in the model. Taxes are computed for both natural gas and oil wells using formula Equation 3-7.

[19] New Oil is produced from oil wells drilled prior to February 9th, 1998; Third Tier Oil is produced from wells drilled on or after February 9th, 1998; and Fourth Tier Oil is produced from wells drilled on or after October 1st, 2002.

[20] Future SOP values were estimated using the GLJ Petroleum Consultants (2011) price forecast for medium oil. While SOP varies monthly, the price forecast model includes only annual average price, and it is this price that is used to calculate the constants necessary to determine the Crown royalty rates.

Equation 3-7

$$T_t^{ax} = 0.27\left[V_t\left(P_t - C^{oper} - C_t^{roy}\right) - \delta K_t\right]$$

Where

- T_t^{ax} = corporate taxes collected in year *t*;
- V_t = volume of resource (natural gas, medium oil) extracted per well in year *t;*
- P_t = price of resource (natural gas, medium oil) in year *t*;
- C^{oper} = unit cost of operating a well;
- C_t^{roy} = royalties collected on the resource (natural gas, medium oil) in year *t*;
- K_t is the capital balance in real dollars at the beginning of period t;
- δ is the depreciation rate.

The capital balance is updated annually using Equation 3-8.

Equation 3-8

$$K_t = K_{t-1}(1-\delta)$$

In the case of wells that have yet to be drilled in the model, K_1 would equal the sum of equipment, drilling and tie-in costs (if applicable). If instead, wells currently exist, K_1 would instead equal the initial capital costs multiplied by $(1-\delta)^{M-1}$ where M is the number of years the well has already been in production. Capital balance would be calculated as normal in subsequent years. It is possible that the tax formula could yield a negative result, and in that case, taxes for that year were set to zero.

3.2 Net Present Value (NPV) Model of Oil and Natural Gas Reserves

Following the methods of Hauer *et al.* (2010b), a model that accounts for remaining resources, costs of exploration and drilling, and the probability of successful exploration and drilling was created to calculate the net present value (NPV) of subsurface resources on all quarter sections (160 acres, 65 ha) within the study region. The method used to calculate net present values for each quarter section was dependent upon the current classification of resource reserves – discovered or undiscovered – on that quarter section and by whether or not resource extraction – as indicated by the presence of an active well – was currently proceeding on the quarter section. The following sections outline the NPV models as well as the process used to assign each quarter section to the appropriate NPV model.

3.2.1 Profits

A total of three different NPV equations were used to calculate oil and natural gas values within the study region. Equation 3-9 was used for confirmed resources – as indicated through the presence of an active well on their associated quarter sections. Resources values on quarter sections without active wells were calculated using expected NPV Equation 3-10 if the resources are classified as discovered and expected NPV Equation 3-11 if the resources are classified as undiscovered.

For resources currently being extracted by active wells, the NPV model is as follows:

Equation 3-9

$$\boldsymbol{NPV} = \boldsymbol{W^s}\left(\sum_{t=1}^{L}\boldsymbol{\beta}_t\left[\boldsymbol{V}_t\left(\boldsymbol{P}_t - \boldsymbol{C}^{oper} - \boldsymbol{C}_t^{roy}\right) - \boldsymbol{T}_t^{ax}\right]\right)$$

Where

- $\beta_t = \left[\frac{1}{1+r}\right]$ = a discount factor set to 0.96 which is equivalent to a 4% interest/discount rate;
- V_t = volume of resource (natural gas, medium oil) extracted per well in year *t;*
- P_t = price of resource (natural gas, medium oil) in year *t*;
- T_t^{ax} = corporate taxes collected in year *t*;
- C_t^{roy} = royalties collected on the resource (natural gas, medium oil) in year *t*;
- C^{oper} = unit cost of operating a well;
- W^s= the number of successful wells on the quarter section (known);
- L = lifespan of a well.

In this equation, initial fixed capital costs (drilling, equipment and tie in costs if applicable) are considered sunk and are not included in the equation; however, variable operating costs (Table 3.5) remain included. Royalties and taxes are computed as discussed in Sections 3.1.6 and 3.1.7, and the volume of gas extracted per well per year V_t is calculated as shown in Section 3.1.3. In the case of quarter sections with active wells, W^s is known and it is not necessary to use the average values calculated for the region (Table 3.1 and Table 3.2 in Section 3.1.2.1).

The length of time the well operates is implicit in the volume extraction profile and varies from 7 – 12 years for oil resources and 9 – 29 for natural gas resources (Table 3.4). Since cumulative production was not available for the wells in the study area, it was not possible to appropriately adjust their volume extraction profiles according to the volume already extracted during their time in production. Thus, it was assumed that the existing wells were capable of extracting all remaining resources beneath their quarter section and volume extraction began at year 1 of the production profile appropriate for the quarter section's resource reserve. In this model, year 1 is assumed to be 2012, and, as such, prices and tax rates have been used in the calculation so that the starting year would reflect conditions in 2012.

For discovered resources not currently being extracted, the NPV model is adjusted to account for the probability of successful drilling and is as follows:

Equation 3-10

$$\boldsymbol{ENPV} = \boldsymbol{P^{success}W^{s}}\left(\boldsymbol{C^{drillcomp}} + \boldsymbol{C^{tiein}} + \boldsymbol{C^{equip}} + \sum_{t=1}^{L}\boldsymbol{\beta_t}\left[\boldsymbol{V_t}\left(\boldsymbol{P_t} - \boldsymbol{C^{oper}} - \boldsymbol{C_t^{roy}}\right) - \boldsymbol{T_t^{ax}}\right]\right) + \boldsymbol{P^{success}W^{sa}C^{drillabandon}} + (\boldsymbol{1} - \boldsymbol{P^{success}})\boldsymbol{W^{a}C^{drillabandon}}$$

Where

- $\beta_t = \left[\frac{1}{1+r}\right]$ = a discount factor set to 0.96 which is equivalent to a 4% interest/discount rate;
- V_t = volume of resource (natural gas, medium oil) extracted per well in year *t;*
- P_t = price of resource (natural gas, medium oil) in year t;
- T_t^{ax} = corporate taxes collected in year t;
- C_t^{roy} = royalties collected on the resource (natural gas, medium oil) in year t;
- C^{oper} = unit cost of operating a well;
- $C^{drillcomp}$ = cost of drilling and completing a well;
- C^{tiein} = the cost of tying in the gas well to the pipeline gathering and processing system (not included in medium oil NPV equations)
- C^{equip}= the cost of equipment used to extract the natural gas or medium oil;
- $C^{drillabandon}$ = the cost of drilling and abandoning a well;
- $P^{success}$ = probability that drilling activity on the section will result in discovery of oil and/or gas;
- W^{s}= the number of successful wells required to extract gas given successfully drilled quarter section (estimated);
- W^{sa} = the number of unsuccessful wells given that the quarter section has been successfully drilled;
- W^{a} = the number of wells abandoned on a quarter section given that drilling has been unsuccessful;
- L = lifespan of a well.

Equation 3-10 suggests a 2 stage process (the last 2 stages of Figure 3.7). In stage one, drilling is completed which triggers its associated costs (Table 3.5). Drilling is successful with probability $P^{success}$ (Table 3.3) and unsuccessful with probability $(1 - P^{success})$. A successfully drilled and completed well incurs cost $C^{drillcomp}$ and an unsuccessfully drilled well incurs cost $C^{drillabandon}$. The method used to calculate average number of successful and unsuccessful wells on a quarter section (W^{s}, W^{sa}, and W^{a}) is discussed in Section 3.1.2.1 and the results are presented in Table 3.1 and Table 3.2. In the second stage, the successful wells are completed and set up to extract gas which adds additional tie in and equipment costs (Table 3.5). Royalties and taxes are also collected and subtracted from revenues (Sections 3.1.6 and 3.1.7).

For undiscovered future resources, the NPV model was altered to consider the probabilities of successful exploration and drilling and is as follows:

Equation 3-11

$$\boldsymbol{ENPV} = \boldsymbol{C^{seis}}[\boldsymbol{P^{success}}(\boldsymbol{W^{s}} + \boldsymbol{W^{sa}}) + (\boldsymbol{1} - \boldsymbol{P^{success}})\boldsymbol{W^{a}}] + \boldsymbol{P^{seis}}\Big[\boldsymbol{P^{success}}\boldsymbol{W^{s}}\big(\boldsymbol{C^{drillcomp}} + \boldsymbol{C^{tiein}} + \boldsymbol{C^{equip}} + \sum_{t=1}^{L}\boldsymbol{\beta_t}\big[\boldsymbol{V_t}\big(\boldsymbol{P_t} - \boldsymbol{C^{oper}} - \boldsymbol{C_t^{roy}}\big) - \boldsymbol{T_t^{ax}}\big]\big) + \boldsymbol{P^{success}}\boldsymbol{W^{sa}}\boldsymbol{C^{drillabandon}} + (\boldsymbol{1} - \boldsymbol{P^{success}})\boldsymbol{W^{a}}\boldsymbol{C^{drillabandon}}\Big]$$

Where

- $\beta_t = \left[\frac{1}{1+r}\right]$ = a discount factor set to 0.96 which is equivalent to a 4% interest/discount rate;
- V_t = volume of resource (natural gas, medium oil) extracted per well in year *t;*
- P_t = price of resource (natural gas, medium oil) in year *t*;
- T_t^{ax} = corporate taxes collected in year *t*;
- C_t^{roy} = royalties collected on the resource (natural gas, medium oil) in year *t*;
- C^{oper} = unit cost of operating a well;
- C^{seis}= cost of seismic activities per well;
- $C^{drillcomp}$ = cost of drilling and completing a well;
- C^{tiein} = the cost of tying in the gas well to the pipeline gathering and processing system (not included in medium oil NPV equations)
- C^{equip}= the cost of equipment used to extract the natural gas or medium oil;
- $C^{drillabandon}$ = the cost of drilling and abandoning a well;
- P^{seis} = the probability that seismic and/or other information indicate that resources are present in the quarter section;
- $P^{success}$ = probability that drilling activity on the section will result in discovery of oil and/or gas;
- W^{s}= the number of successful wells required to extract gas given successfully drilled quarter section (this is estimated);
- W^{sa} = the number of unsuccessful wells given that the quarter section has been successfully drilled;
- W^{a} = the number of wells abandoned on a quarter section given that drilling has been unsuccessful;
- L = lifespan of a well.

Equation 3-11 is similar to Equation 3-10 except for the additional cost and uncertainty associated with exploration. This equation models a 3 stage process (Figure 3.7). In the first stage, quarter sections with undiscovered reserves are tested using seismic exploration or some other exploration method. Resources are found with a probability of P^{seis}(Section 3.1.2.2), and exploration incurs a cost of C^{seis} (Table 3.5). Seismic costs are often reported on a per-well basis (Hauer *et al.* 2010b), however, seismic costs were adjusted to reflect quarter section costs by multiplying the costs by the expected number of wells for the quarter section. The second and third stages of the process are the same drilling and completion stages modeled in Equation 3-10 and explained in detail above.

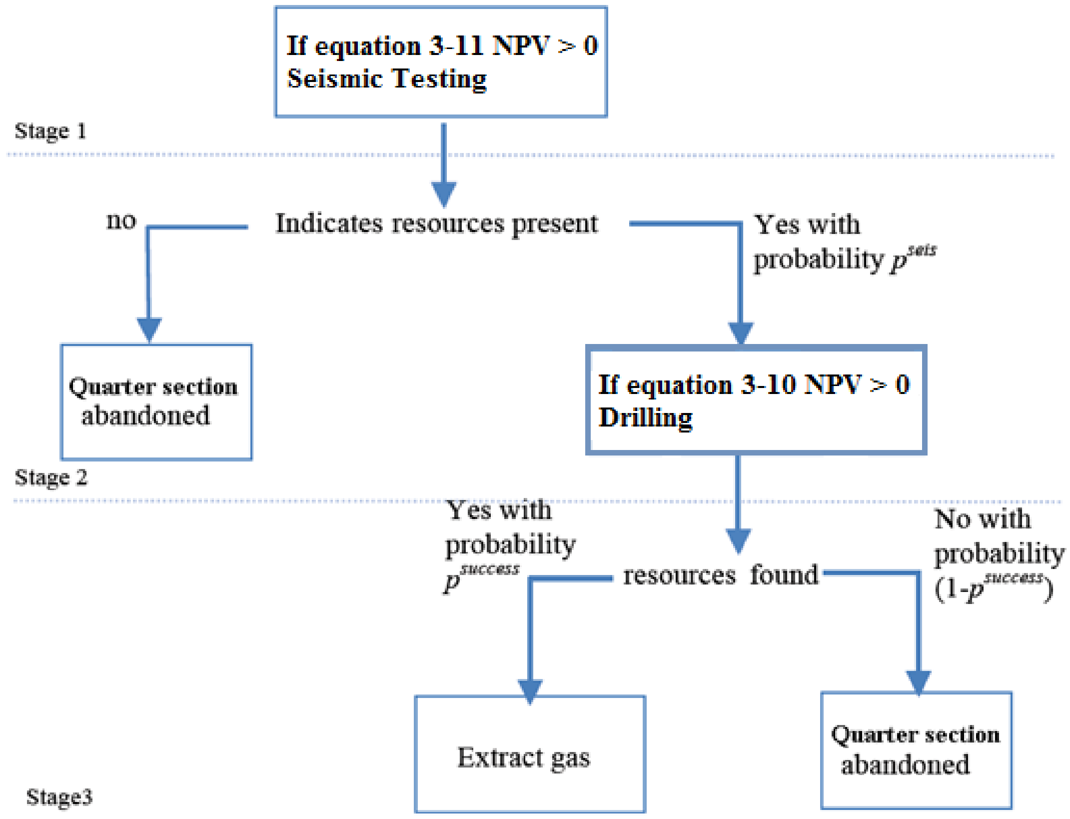

Figure 3.7. Showing the 3-stage process – exploration, discovery and extraction – used by expected NPV Equation 3-11. Nested within the 3-stage process is the 2-stage process – discovery and extraction – used by expected NPV Equation 3-10. Flow chart is adapted from Hauer *et al.* (2010b).

Figure 3.8 shows the classification process used to determine the appropriate NPV equation for each quarter section's resource reserves within the study region. In the case of gas resources, there are 4 possible categories that quarter sections with gas resources can be placed into: 1) Existing active wells present, 2) Discovered reserves only (no active wells), 3) Undiscovered reserves only (no active wells) and 4) Both discovered and undiscovered reserves present (no active wells). The quarters that fall within category 4 have their total reserves divided between those reserves that are discovered and those that are classified as undiscovered. With respect to oil resources, all the quarter sections have discovered reserves (due to a lack of available information on future reserves in the area) and consequently there are only 2 possible categories that quarter sections can fall within: 1) Existing active wells present and 2) Discovered reserves only (no active wells).

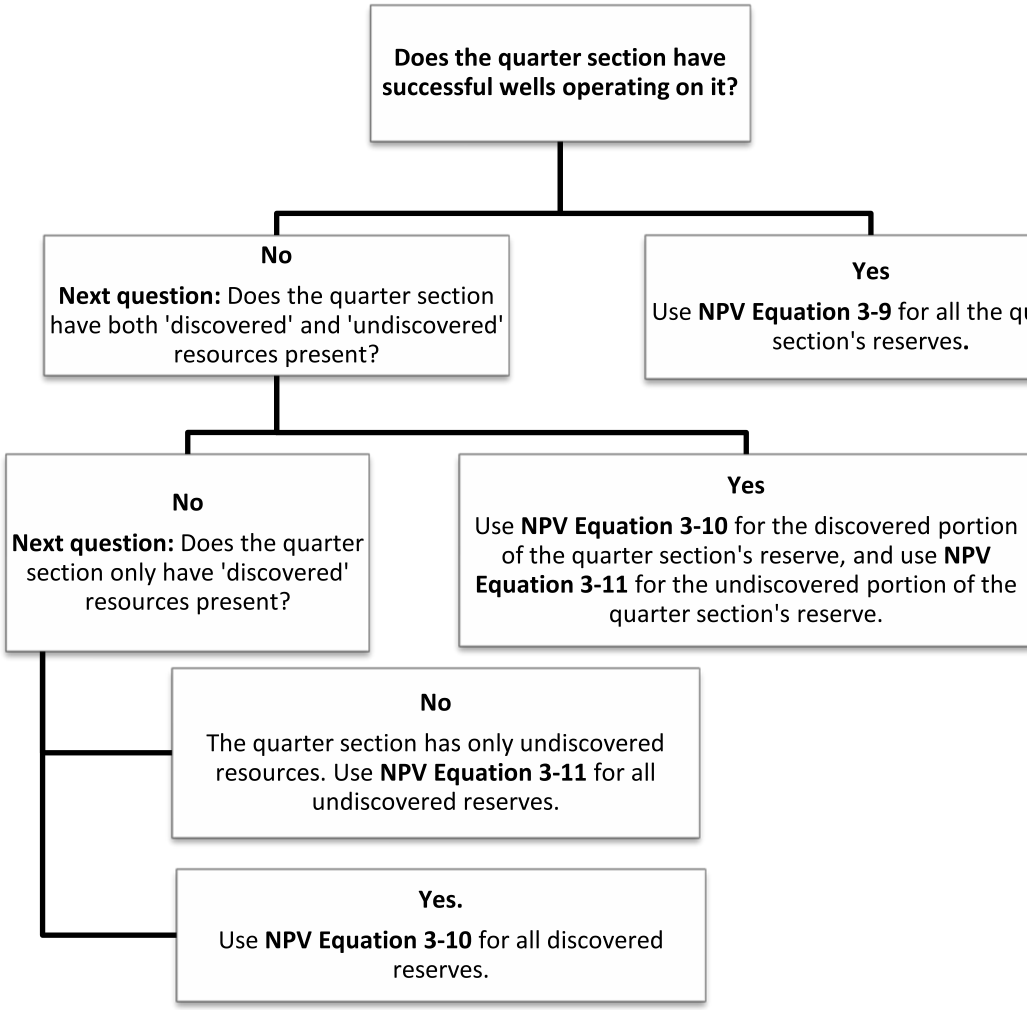

Figure 3.8. Decision process used to select the appropriate NPV equation to calculate the value of each quarter section's resources. This chart is applicable for both the natural gas and oil analysis; however, only a portion of the chart pertains to quarter sections with oil resources. **Note: Some quarter sections would use this process for their natural gas resources, and then again for their oil resources.

3.2.2 Royalties and Taxes

While the net present value of profits is the primary concern of oil and gas companies, there is a public interest in the net present values of royalties and taxes associated with oil and natural gas extraction. Each of the equations used to calculate the net present value of subsurface extraction profits has its own associated tax and royalty equations. Each equation, like its associated profit equation, is distinguished by its level of uncertainty with respect to successful resource extraction. The following equations would permit the calculation of royalties and taxes:

Associated with Equation 3-9, the net present value of royalties associated with oil and natural gas reserves that have existing wells would be calculated using Equation 3-4 while taxes would be calculated using Equation 3-13.

Equation 3-12

$$NPV^{roy} = W^{s}\left(\sum_{t=1}^{L} \beta_t V_t C_t^{Roy}\right)$$

Equation 3-13

$$NPV^{tax} = W^{s}\left(\sum_{t=1}^{L} \beta_t T_t^{ax}\right)$$

Associated with Equation 3-10, the net present value of royalties associated with discovered but currently undrilled oil and natural gas reserves would be calculated using Equation 3-14 while taxes would be calculated using Equation 3-15.

Equation 3-14

$$ENPV^{roy} = P^{success} W^{s}\left(\sum_{t=1}^{L} \beta_t V_t C_t^{Roy}\right)$$

Equation 3-15

$$ENPV^{tax} = P^{success} W^{s}\left(\sum_{t=1}^{L} \beta_t T_t^{ax}\right)$$

Associated with Equation 3-11, the net present value of royalties for undiscovered natural gas reserves would be calculated using Equation 3-16 while taxes would be calculated using Equation 3-17.

Equation 3-16

$$ENPV^{roy} = P^{seis} P^{success} W^{s}\left(\sum_{t=1}^{L} \beta_t V_t C_t^{Roy}\right)$$

Equation 3-17

$$ENPV^{tax} = P^{seis} P^{success} W^{s}\left(\sum_{t=1}^{L} \beta_t T_t^{ax}\right)$$

3.2.3 The Oil and Natural Gas Conservation Actions

The previous sections outline the data and procedures used to calculate the net present values of the natural gas and oil reserves located with the Milk River Watershed. Those net present values can ultimately be used to answer questions regarding the cost of removing, restricting or reducing subsurface resource extraction from the watershed. Four management scenarios were considered including (1) all current and future petroleum extraction is halted, (2) current extraction proceeds but future extraction is prohibited, (3) current extraction proceeds and future extraction occurs only on pre-existing well sites at a density of 4 well per section (640 acres or 259 hectares), and (4) current extraction proceeds and future extraction also proceeds but never at a well density in excess of 4 wells per section. The results section (Section 3.2.4) presents the net present value information required to calculate the costs associated with each of the four conservation scenarios outlined.

3.2.4 Results

Net present values (NPV) of profits were calculated for each quarter section using Equation 3-9, Equation 3-10, and Equation 3-11 for natural gas resources, and Equation 3-9 and Equation 3-10 for oil resources. Setting the discount rate at 0.04 reflects a risk free real return on capital (Hauer *et al.* 2010b). The result is that investing in oil and gas development has a higher return (i.e. higher net present values) than if risk was included through the use of a higher discount rate. It is possible that a higher discount rate may be more representative of the rate used by oil and gas development companies. The result is that oil and gas companies would have slightly lower estimates of NPV.

The NPVs in this model are calculated under the assumption that initial investment proceeds immediately for all quarter sections in the area. This is not a realistic assumption – due to the capacity and time constraints faced by energy producers. Two quarter sections with identical reserves and estimated NPVs would have different realized NPVs if they are developed at different times. The quarter section that is developed later would have a lower NPV due to discounting. In fact, Hauer *et al.* (2011) extend the work done in Hauer *et al.* (2010b) to include a 50 year planning horizon for oil and gas development with capacity constraints which resulted in reduced estimates of oil and gas net present value[21]. Adamowicz *et al.* (2009) found that oil and natural gas NPVs were 8 – 30% lower when capacity constraints were included.

Consequently, the oil and gas values provided here are an upper bound on the oil and gas NPVs within Saskatchewan's Milk River Watershed. However, the inclusion of low, mid and high estimates of gas values provides a sensitivity analysis which presents a range of values possible for the region. The oil and gas land values here, while an upper bound, still provide information on relative values of areas and can provide valuable information on the selection and conservation of priority areas (Hauer *et al.* 2010b).

Each quarter section had its total NPV (profits, taxes and royalties) summed to get the total oil and natural gas value. In the case of oil, only two oil pools overlapped which required their individual NPVs to be summed. In the case of natural gas, only quarter sections that contained discovered and undiscovered reserves without any active wells required their NPVs from

[21] The areas of Alberta that had lower natural gas net present values were developed later in the 50 year planning horizon. The idea is that the wealthier deposits are exploited first and poorer reserves are developed after the wealthier reserves have been depleted. Interestingly, the regions with natural gas values similar to those found in Saskatchewan's Milk River Watershed region were not exploited at all during the 50 year time horizon as a result of their very low values.

Equation 3-10 and Equation 3-11 (profits); Equation 3-14 and Equation 3-16 (royalties); and Equation 3-15 and Equation 3-17 (taxes) to be summed to get their total NPVs. Land values for natural gas were calculated for the low, mid and high natural gas reserve scenarios. Figure 3.9 is a map showing the total land values for oil reserves in the region. Total land values for the low, mid and high remaining ultimate potential reserves are shown in Figure 3.10, Figure 3.11, and Figure 3.12 respectively. The relatively homogeneous total land values for natural gas are due to the homogeneous natural gas reserves in the region[22].

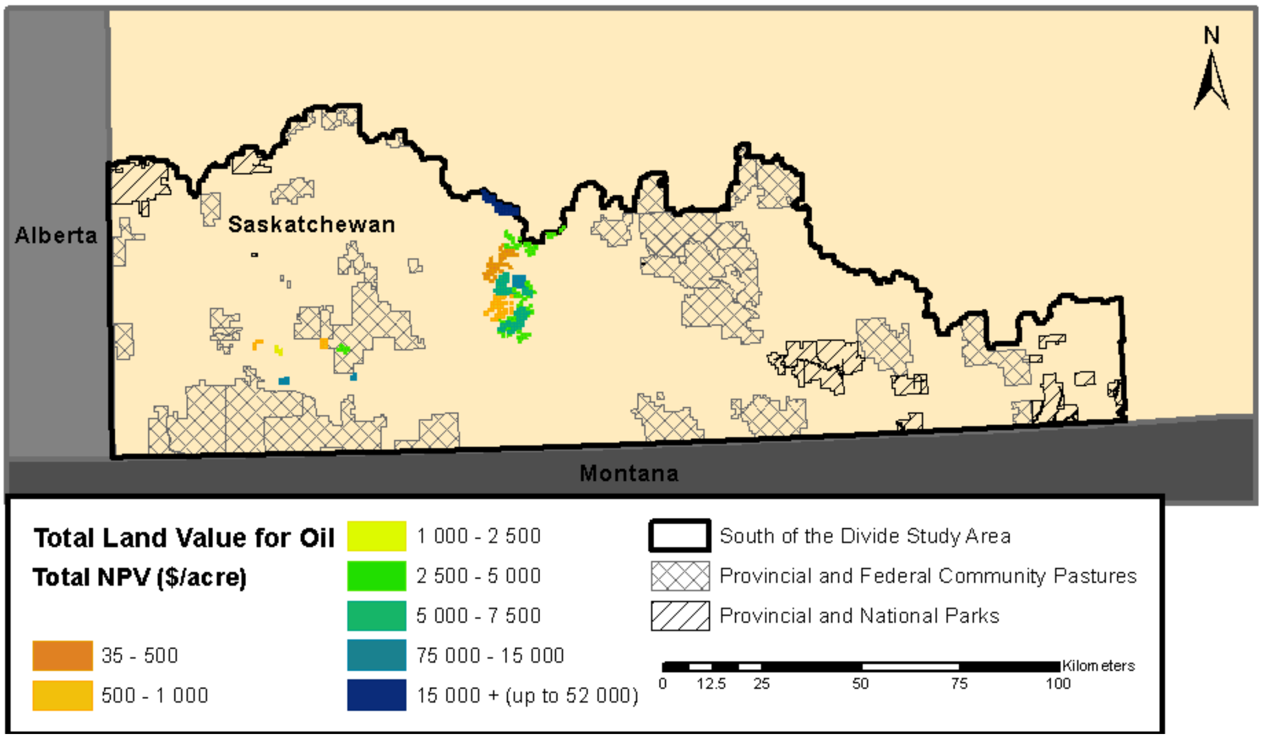

Figure 3.9. The Milk River Watershed oil land values shown for all oil pools in dollars per acre.

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[22] The natural gas values calculated for the Milk River Watershed can be put to test against the natural gas values calculated by Hauer *et al.* (2010b) for Alberta. The reserves in the watershed are similar to reserves in northwest Alberta. They are low (in general <4 000 000 m^3/section or equivalently <1 000 000 m^3/quarter section) and primarily undiscovered. The resulting natural gas values are similar between the two regions and range from $2.5/acre to $500/acre. The values greater than $500/acre in the watershed are due to one of three reasons: the quarter section has a higher natural gas reserve potential (as much as 6 400 000 m^3/section in the western part of the region), the quarter section has 'discovered' reserves with a higher probability of success, or the quarter section already has active wells that no longer have to account for drilling and exploration costs. Natural gas values for southeast Alberta may not be the best indicator of gas values for southwest Saskatchewan because in general, natural gas formations are less developed in Saskatchewan than similar formations in Alberta (ER/NEB 2008). As a result, gas reserves are less explored in Saskatchewan and natural gas net present values may be lower than Alberta values because of greater levels of undiscovered reserves and higher levels of uncertainty.

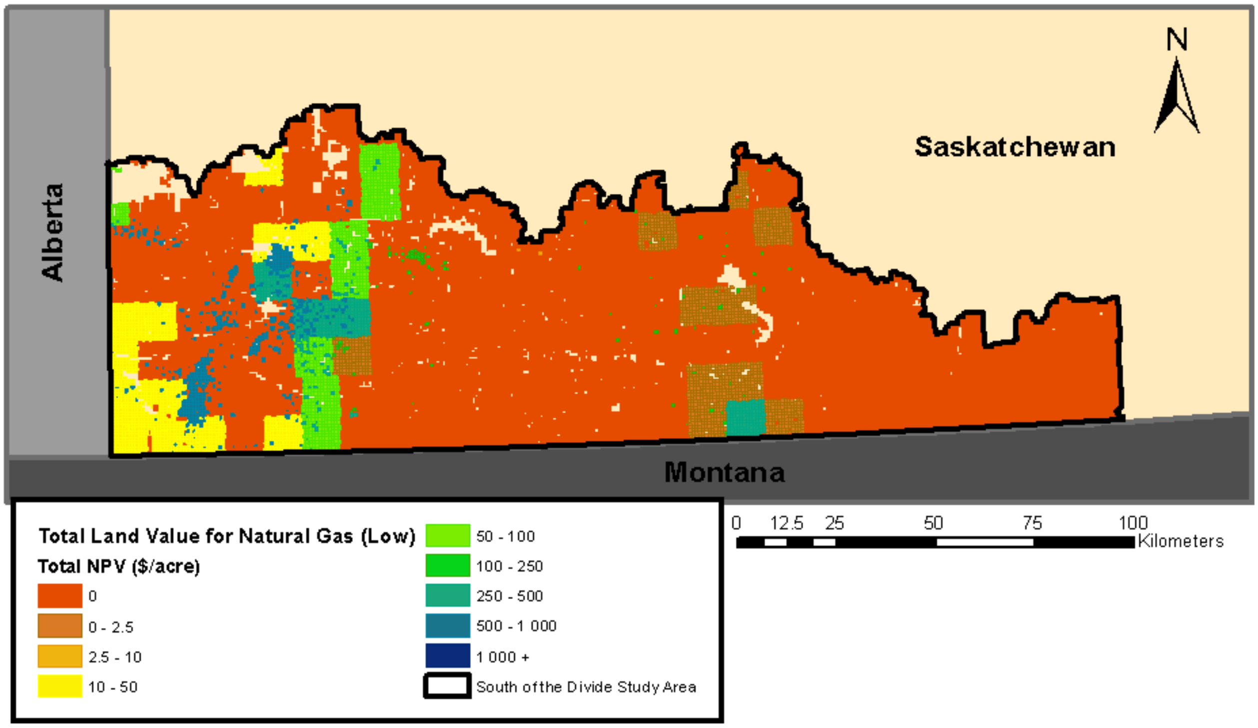

Figure 3.10. The Milk River Watershed natural gas land values for the lower bound of the estimated remaining ultimate potential reserves.

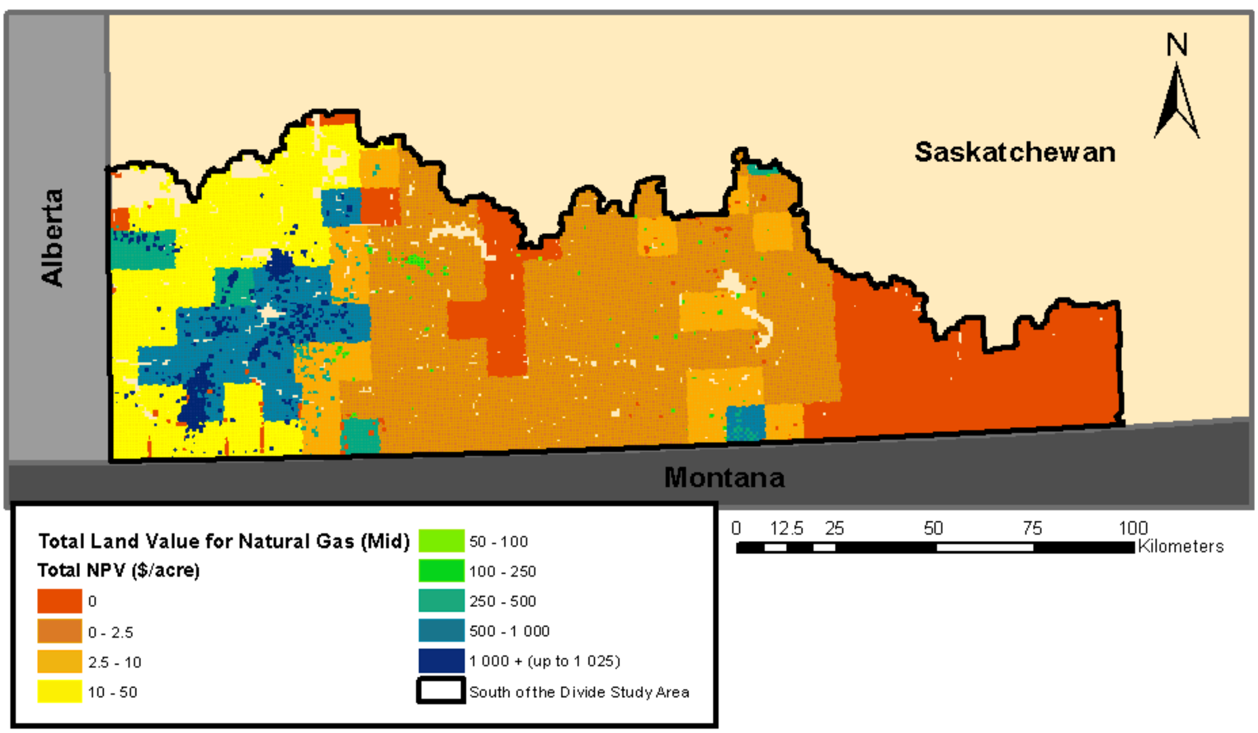

Figure 3.11. The Milk River Watershed natural gas land values for the midpoint of the estimated remaining ultimate potential reserves.

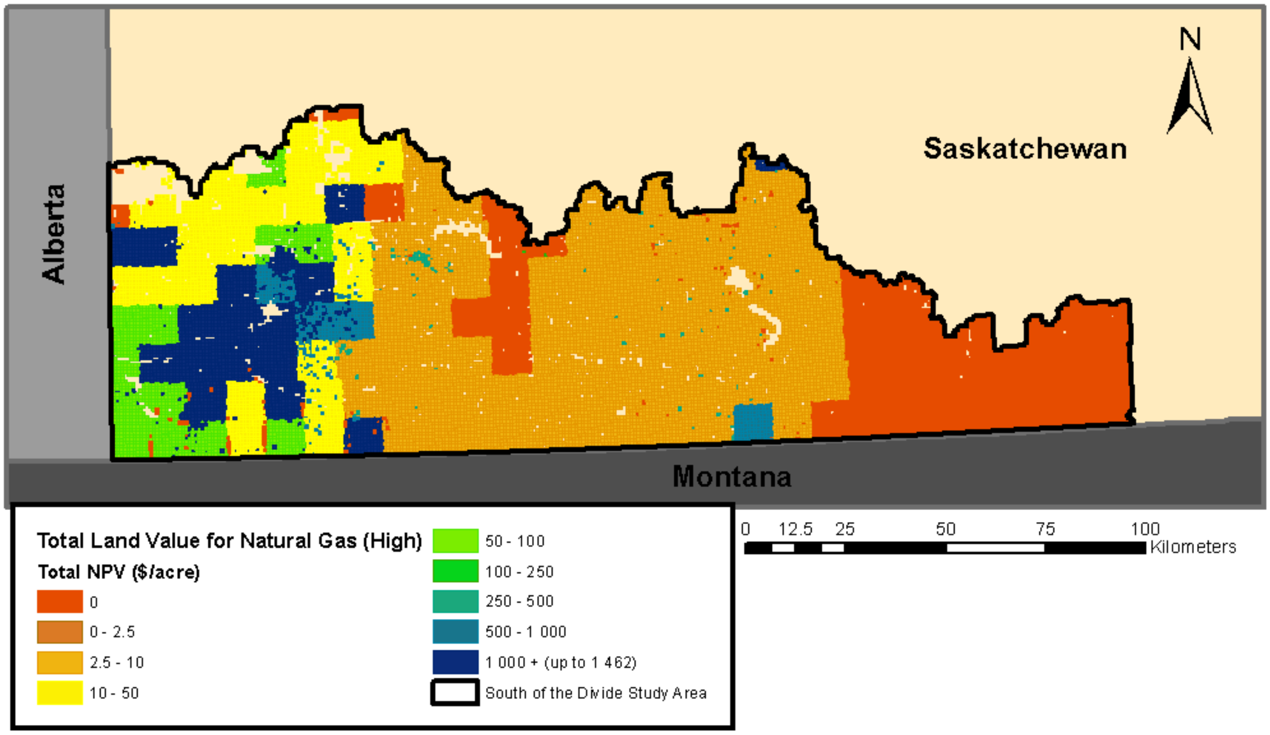

Figure 3.12. The Milk River Watershed natural gas values for the upper bound of the estimated remaining ultimate potential reserves.

Table 3.10. The net present values of the direct and opportunity costs (2008$) associated with various prohibitions on current and future oil and natural gas development within the Milk River Watershed study region. Costs are reported as totals for the region.

Development Type	Action	Direct Costs (million$)	Opportunity Cost (million$)	Total Cost (million$)
Future Natural Gas[1]	Prohibit all development in the watershed	-	193	193
Future Oil	Prohibit all development in the watershed	-	157	157
Future Oil and Natural Gas	Prohibit future development except on pre-existing well sites and prohibit development that exceeds 4 wells per section	43	74	117
Future Oil and Natural Gas	Prohibit development that exceeds 4 wells per section[3]	-	0	0
Current Natural Gas	Remove all development	-	95	95
Current Oil	Remove all development	-	248	248

[1] Mid-level natural gas reserve estimates were used to calculate all net present values (profits, taxes and royalties) within this table

[2] Assumed that horizontal drilling could be used at a price of $25,000/well (MacFarlane 2007) to reach resources up to 800 meters from the well head. This works out to a cost of $16 813.13/quarter section for natural gas and $75 000/quarter section for oil.

[3] The oil and natural gas reserves within the region and the production profiles created by Alberta Energy (2007) suggest that a well density greater than 4 wells per section is not a requirement to fully extract the subsurface resources within the Milk River Watershed (the lone exception may be the Dollard Upper Shaunavon Pool which covers only 93 quarter sections in the region). As such, this conservation action was applied a cost of zero.

4 Agricultural Land

Within this section, net present value maps for the agricultural lands within the Milk River Watershed were created using two different methods. The first method used historic land sale transactions (available for land bought and sold in the region between 1993 and 2010) and agricultural land assessments (available for all agricultural land in the region). The second method also used historic land sale transactions, but combined this information with spatial land characteristics – as determined using geospatial analysis – to create a hedonic land value model for the watershed.

The productive capacity of agricultural land as well as the the spatial distribution of agricultural land capacity were incorporated within both land valuation methods. However, each method was best suited to provide a particular piece of information regarding the cost of implementing conservation activities in the region. The first method was used to generate a map of agricultural land net present values within the watershed while the second method (the hedonic land value model) provided information on the net present value associated with converting land from one agricultural usage to another (e.g., annual cropland to native grassland).[23] The following sections outline the data and methods used to calculate the spatial land values and present the results of the agricultural land value analysis.

4.1 Summary of Data

Three key pieces of data were used to calculate the net present values of agricultural land and land-use conversions within the watershed. These three pieces included land sale data, land assessment data and spatial land data (land cover, soil capability, etc.) for the region. The land sale data were purchased for a nominal fee from the Saskatchewan Farm Land Security Board. The assessment data were provided free of charge by the Saskatchewan Assessment Management Agency. The majority of the spatial land data were provided under a data sharing agreement by Saskatchewan's Ministry of Environment, but relevant oil and natural gas information was also collected from the publicly available oil and gas information map on the Ministry of Energy and Resource website (http://www.er.gov.sk.ca/infomap), and an invaluable land ownership file was provided by the Canadian Wildlife Service.

4.1.1 Land Transaction Data

Transaction data were purchased for the Milk River Watershed from the Saskatchewan Farmland Security Board (FLSB). Data were able to be purchased based on Rural Municipalities, and as such, information was purchased for the 15 Rural Municipalities (RMs) included within the watershed (Table 4.1). A total of 26 725 land transactions were made in the 15 RMs between the years of 1993 and 2011.

[23] Government-owned land (crown grazing land, Grasslands National Park, Federal and Provincial community pastures) makes up approximately 58% of the Milk River Watershed, and this government-owned land has a high spatial overlap with the 53% of the watershed that remains as native grasslands. Since government lands rarely, if ever, come up for sale, the hedonic land value model is biased by the lack of data representative of the entire region's agricultural land (i.e., the model is unable to accurately assess the value of government-owned grasslands as a result of an inadequate number of government land sale data points in the data set).

Table 4.1.The rural municipalities (RMs) included within Milk River Watershed study region and their 2001 and 2006 rural populations (Saskatchewan Bureau of Statistics 2001).

#	RM Name	RM No.	2006 (2001) Population[24]	#	RM Name	RM No.	2006 (2001) Population
1	Reno	51	462 (457)	9	Lone Tree	18	105 (190)
2	Maple Creek	111	1167 (1156)	10	Wise Creek	77	222 (257)
3	Piapot	110	392 (424)	11	Auvergne	76	329 (355)
4	White Valley	49	418 (470)	12	Glen McPherson	46	112 (126)
5	Frontier	19	323 (319)	13	Mankota	45	382 (430)
6	Arlington	79	413 (371)	14	Waverly	44	422 (444)
7	Grassy Creek	78	305 (401)	15	Old Post	43	394 (475)
8	Val Marie	17	479 (481)				

The information provided by the FLSB included legal land location, RM name and number, acres, price, sale date, purchaser, vendor, and whether the transaction was a family sale or arm's length transaction. A series of steps was taken to clean the data and ensure that only parcels of land larger than 100 acres, valued at a price equal to or greater than $31.25/acre (the lowest assessed land value in the region), not part of a debt settlement transaction, and located within the Milk River Watershed remained for inclusion within the net present value analyses (Entem, 2012). All market sale prices were converted into 2008 dollars using the consumer price index, and as a final step, all family land transactions were separated out of the data.

A total of 3600 arm's length land transactions met the requirements for inclusion within the net present value analyses. The following descriptive statistics provide a snapshot of the arm's length transaction data available (Table 4.2). Figure 4.1 shows the spatial distribution of land sales throughout the Milk River Watershed classified by family and arm's length transactions. The lack of transactions within several key areas of the region is noteworthy. These transaction information gaps include government holdings – parks, community pastures, crown grazing leases, etc. – which are key native grassland areas for the region's species at risk.

[24] These population numbers do not include populations of towns or villages within the RM and instead reflect the rural population within the study area; the total rural population in these 15 RMs is 5 925. The rural population would be the population most impacted by land-use changes required to protect species at risk. Data source is the 2001 and 2006 Canadian census: http://www.stats.gov.sk.ca/stats/population/SaskCensusPopulation.pdf.

Table 4.2. Summary of the arm's length transactions data (n = 3600) used to calculate the market value of agricultural land in the Milk River Watershed.

	Arm's Length Land Transactions			
	Min	**Mean (St. Deviation)**	**Max**	**Number of Transactions (%)**
Price/parcel* ($)	6 662	38 959 (21 102)	442 460	-
Size (Acres)	102	158.80 (3.92)	176	-
Price/Acre	42.44	245.50 (133.97)	2 765.40	-
Year	1993	2001 (4.99)	2011	-
Family Transactions	-	-	-	0 (0%)
Arm's Length Transactions	-	-	-	3600 (100%)
1993	-	-	-	11 (0.31%)
1994	-	-	-	172 (4.78%)
1995	-	-	-	301 (8.36%)
1996	-	-	-	315 (8.75%)
1997	-	-	-	205 (5.69%)
1998	-	-	-	315 (8.75%)
1999	-	-	-	201 (5.58%)
2000	-	-	-	229 (6.36%)
2001	-	-	-	228 (6.33%)
2002	-	-	-	123 (3.42%)
2003	-	-	-	195 (5.42%)
2004	-	-	-	134 (3.72%)
2005	-	-	-	151 (4.19%)
2006	-	-	-	215 (5.97%)
2007	-	-	-	211 (5.86%)
2008	-	-	-	234 (6.50%)
2009	-	-	-	170 (4.72%)
2010	-	-	-	189 (5.25%)
2011	-	-	-	1 (0.03%)

* Prices are adjusted for inflation into 2008 dollars.

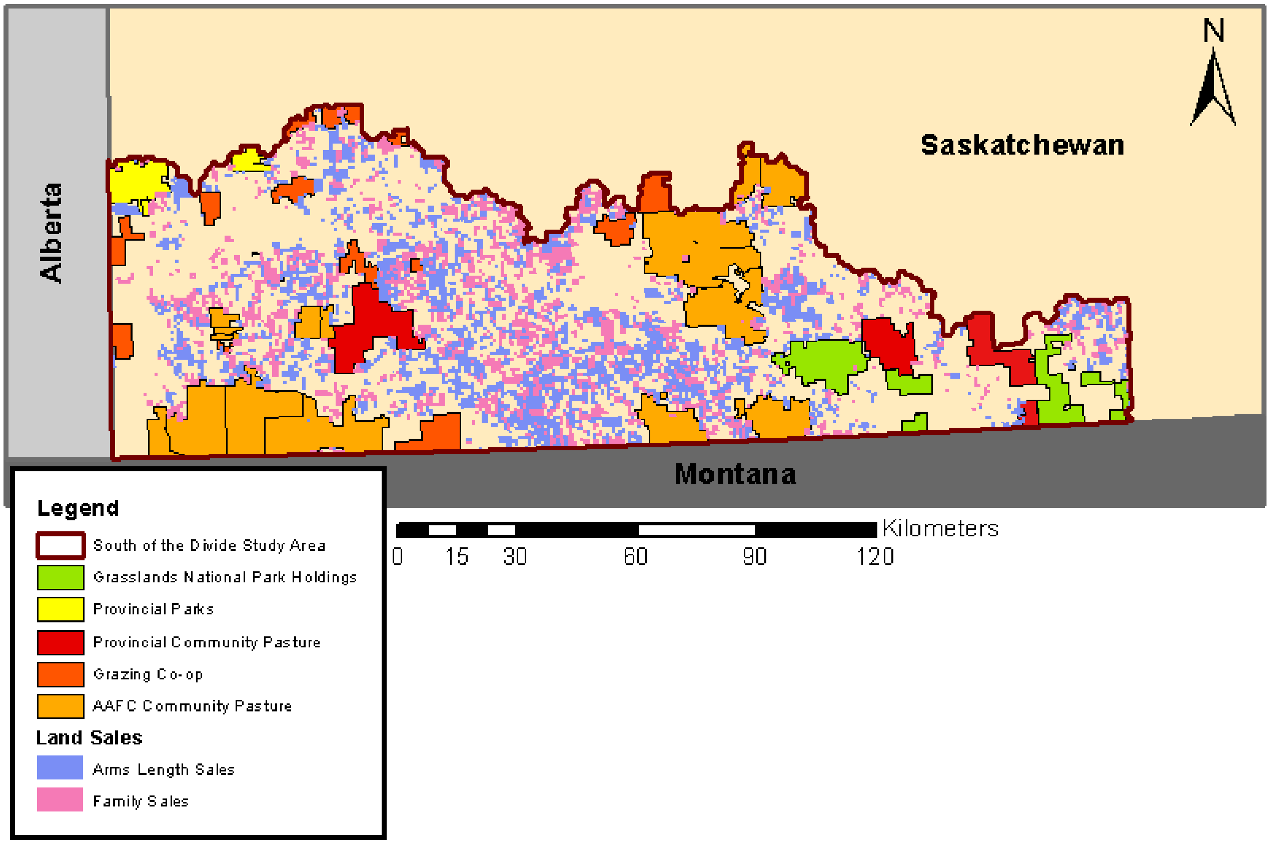

Figure 4.1. The spatial distribution of family and arm's length transactions within the Milk River Watershed.

4.1.2 Land Assessment Data

Land assessments in Saskatchewan are handled by the Saskatchewan Assessment Management Agency (SAMA). The data were provided by SAMA to Ed Beveridge at the Saskatchewan Ministry of Environment who had a GIS technician, Barry Otterson, join the data to the Milk River Watershed Cadastral spatial layer. As a result of the join, a total of 21 532 quarter sections within the study region had assessed values assigned to them.

In 2009, residential and commercial properties were valued using a market value standard for the first time; however, the agricultural property assessments used within this analysis do not reflect market values. The assessment process for agricultural land only accounts for the productive capability of the land and does not account for any subsurface resources, or the value of the land for any other competing uses. Arable and pasture land have separate assessment procedures, but both use a regulated property assessment valuation standard. The following sections outline the assessment process for arable and non-arable land, and finally present summary statistics of assessed land values in the Milk River Watershed. A more in-depth coverage of the land assessment calculations is presented in Entem (2012).

4.1.2.1 Arable land

The assessed value of arable agricultural land is determined by the application of the formula $LV = PR \times E \times PF \times U$ where LV is the assessed value of land, PR is productivity rating (an index out of 100 based on largely on soil capability and climate), E are economic factors that influence costs of production (distance from markets, topography, stones), PF is the provincial factor ($6.60/index point) and U is the number of land units (acres) (SAMA 2007). Thus, the land assessment process for arable land first calculates the land's production capacity (maximum of 100 index points per acre), and then adjusts the productivity by using physical and economic factors that may reduce productivity. It then convents the index points into a usable $/acre format and calculates the value of a quarter section.

4.1.2.2 Non-arable land (pasture and hay land)

Calculating the assessed value for non-arable land closely resembles the calculation for arable land. The assessed value of non-arable (pasture and hay land) is determined by the application of the formula $LV = R \times PF \times U$ where LV is assessed value of land, R is a land rating factor (based on carrying capacity in the case of pasture land and forage yield in the case of hay land), PF is provincial factor (a conversion of land rate/acre to $/acre using a value of $5.75/land rate for both pasture and hay land) and U is the number of land units (acres) (SAMA 2007).

The process for calculating the assessed value of pasture land requires first the calculation of the parcel's carrying (or grazing) capacity and then a two-step conversion of this carrying capacity into a $/acre value. Calculating assessed land values for hay land is also relatively straightforward. A land rate is assigned to a parcel of land based on its forage yield and its frequency of harvest. In turn, that land rate is converted to a $/acre value. Each parcel of land can have its assessed value calculated by multiplying its size (acres) by its unit price ($/acre).

4.1.2.3 Summary of Land Assessment Data

Table 4.3 displays the breakdown of land assessment categories within the region and some simple descriptive statistics of the assessed values assigned to each category. Figure 4.2 is a map of the spatial distribution of appraised land values in the region.

Table 4.3. Summary statistics of assessed land values (2008 dollars) in the Milk River Watershed broken down by land use.

	Arable Land	Hay and Pasture Land	Other Lands*	All Land Uses
Number of Quarters	7 613	13 906	13	21 532
Minimum Assessed Value	941	105	16 625	105
Mean Assessed Value (Std. Deviation)	390929.85 (7 573.26)	20 495.32 (6 794.19)	121 666.85 (145 142.16)	27 427.81 (12 389.37)
Maximum Assessed Value	194 062	166 249	463 825	463 825

*Commercial and Industrial land (n = 9) and mixed agricultural land (n = 4) make up the other category

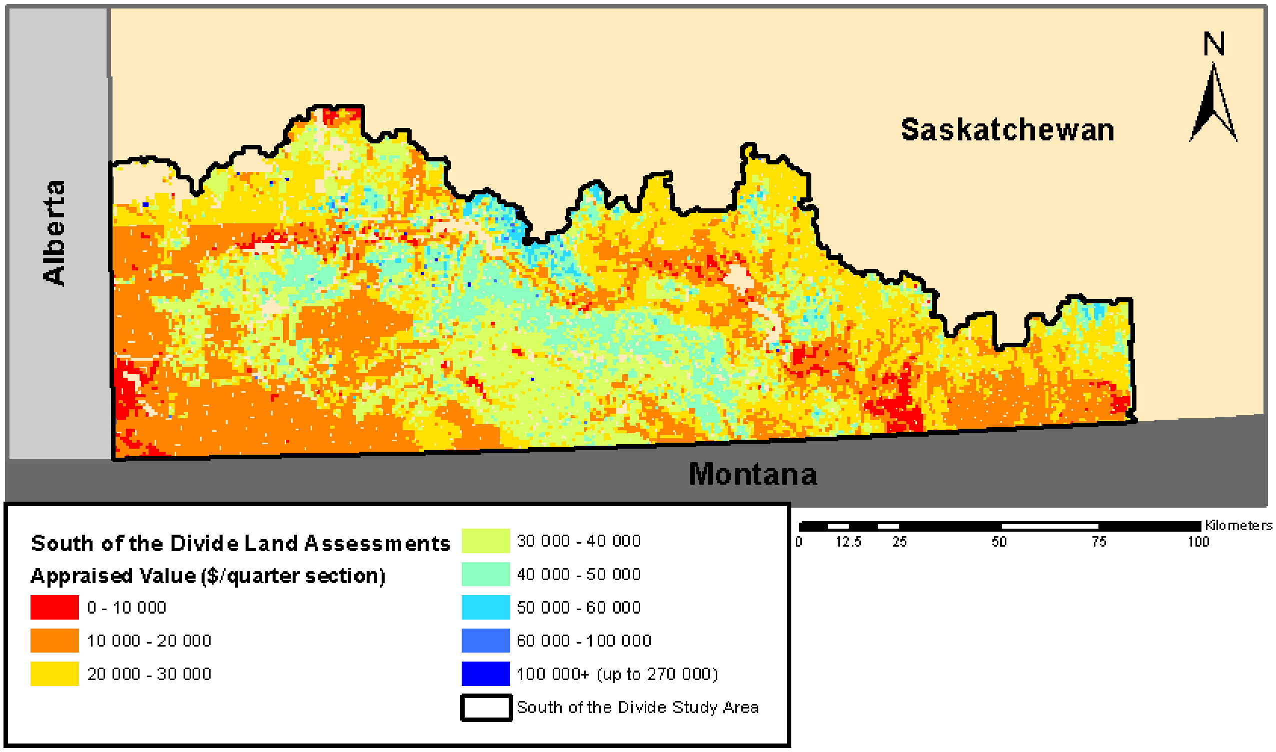

Figure 4.2. Appraised land values (2008 dollars) for 21534 quarter sections in the Milk River Watershed.

4.1.3 Spatial Land Characteristics

Additional land characteristics required in the net present value analysis of land-use conversions were collected from GIS layers provided by the Saskatchewan Ministry of Environment, Saskatchewan Ministry of Energy and Resources, and the Canadian Wildlife Service. The information collected included spatial layers showing all quarter sections in the study region, the location of all oil and natural gas development/infrastructure, land ownership type, land cover/use, and land quality. The land sale data was spatially joined to the landownership layer in order to create a spatial layer containing all the land transaction data. Table 4.4 contains a summary of the spatial layer and land transaction data, as well as a description of how the data was organized in order to facilitate the creation of descriptive statistics, and ultimately the use of the data in a hedonic land value model (see Section 4.3).

Table 4.4. The spatial land characteristics and the variables created to summarize and describe the characteristics.

Characteristic	Variable Name	Description	Source
Sale type	FAM	Dummy variable indicating that the sale of the quarter section was between family members	Farmland Security Board (Transaction Quarters)
Legal land location	LLD	Legal land location of all quarter sections in the area	Farmland Security Board (Transaction Quarters) SOD_Land_Ownership GIS Layer SK Ministry of Environment (All Quarters)
Price per acre	PRICEAC	Unit price of land ($/acre) for all quarter sections with sale data available	Farmland Security Board (Transaction Quarters)
Parcel size	ACRE	The size of the land parcel in acres	Farmland Security Board (Transaction Quarters) SOD_Land_Ownership GIS Layer SK Ministry of Environment (All Quarters)
Year of sale	YEAR1, YEAR2, … YEAR 18, YEAR19	Dummy variables representing year of sale (Year1 = 1993, Year2 = 1994, …Year18 = 2010, Year19 = 2011)	Farmland Security Board (Transaction Quarters)
Location (north – south and east – west)	TWN, RNG	Twn is the township in which a quarter section is located; acts as a north – south control Rng is the range in which a quarter section is located; acts as an east – west control	Farmland Security Board (Transaction Quarters) SOD_Land_Ownership GIS Layer SK Ministry of Environment (All Quarters)
Oil and gas development	GWELL, OWELL	A count of the number of active wells on a quarter section GWell = active gas wells, Owell = active oil wells	Saskatchewan Ministry of Energy and Resources InfoMap
Rural municipality (RM) population	POSGWTH	A dummy variable that equals 1 if there was positive rural population growth (2001 to 2006) in the RM in which the quarter section is located	Rural_Municipality GIS Layer SK Ministry of Environment SK Bureau of Statistics Saskatchewan
Land ownership	AC, NP, IP, IR, CE, PF	Dummy variables indicating land ownership (AC = agricultural crown land, NP = national park, IP = irrigation project, IR = Indian reserve, CE = conservation easement, PF = private farmland and all other minor categories)	SOD_Land_Ownership GIS Layer SK Ministry of Environment (All Quarters)
Land cover and use	HP, CRP, NG	Dummy variables indicating the quarter sections predominant land use (HP = hay and tame pasture, CRP = annual crops, NG = native grasslands)	Land_Cover GIS Layer from the Canadian Wildlife Service
Land cover and use	WTRPCNT, WDPCNT, HPPCNT, CRPPCNT, NGPCNT	Variables representing the percentage of the quarter sections surface area that is made up of different land covers (WtrPcnt = % water, WdPcnt = % woody vegetation, HpPcnt = % hay or tame pasture, CrpPcnt = % annual crops, NgPcnt = % native grass)	Land_Cover GIS Layer from the Canadian Wildlife Service
Land capability	MS, S, VS, NC	Dummy variables indicating the predominant land capability classifications of each quarter section (MS = moderately severe or 3, S = severe or 4, VS = very severe or 5, NC = no annual crop capability or 6)	Land_Capability GIS Layer from the Canadian Wildlife Service
Ecosite classification	SALTY, HILLY, WET, OVERFLOW, LOAMY, OTHER	Dummy variables indicating the predominant ecosite of each quarter section (Salty = all solonetzic and saline ecosites, Hilly = thin and badland ecosites, Wet = marsh, dry meadow and wet meadow ecosites, Overflow = overflow ecosite, Loamy = loam and sandy loam ecosites, Other = clay and gravel ecosites)	Rangeland_Ecosite GIS Layer from the Canadian Wildlife Service

Within the study region, the average quarter section is 154.61 with an average of 0.020 and 0.033 oil and natural gas wells, respectively (Table 4.5). Within the entire study area, cropland, hay and tame pasture lands, and native grasslands make up 26%, 15% and 61% of the quarter sections respectively. The highest quality land in the region (land capability class 3) makes up 54% of the land in the study area. Class 4 land makes up 36% of the study area. Class 5 land makes up a very small portion of the land in the study area 0.07%), and, finally, class 6 land (not capable of supporting annual cropland and limited to the production of native or tame perennial species) makes up 10% of the study region's land base.

Loam and overflow ecosites cover the majority of Saskatchewan's Milk River Watershed (66%). Saline and solonetzic ecosites cover the second largest portion of land in the study area (13% and 15% respectively). Bandlands and thin soils make up 10% of the quarter sections in the Milk River Watershed, and very small portions of the landscape are made up of clay, gravel, wet and dry meadow, and marsh ecosites.

Table 4.5. Summary of the spatial land characteristics across the region as well as the subset of quarter section for which arm's length land sale transaction data are available.

	All Quarter Sections within the Study Region					Quarter Sections with Arm's Length Land Sale Transaction Data between 1993 and 2011				
Name	**N**	**Mean**	**St. Dev**	**Min**	**Max**	**N**	**Mean**	**St. Dev**	**Min**	**Max**
ACRES	23934	154.610	32.320	0	329	3600	158.800	3.924	102	176
GWELL	23989	0.033	0.189	0	5	3600	0.036	0.190	0	2
OWELL	23989	0.020	0.215	0	7	3600	0.022	0.201	0	4
POSGWTH	20948	0.410	0.492	0	1	3593	0.403	0.491	0	1
PF	23908	0.424	0.494	0	1	3600	0.903	0.297	0	1
AC	23908	0.293	0.455	0	1	3600	0.040	0.196	0	1
NP	23908	0.036	0.186	0	1	3600	0.002	0.044	0	1
IP	23908	0.004	0.061	0	1	3600	0.004	0.060	0	1
IR	23908	0.005	0.073	0	1	3600	0.028	0.164	0	1
CE	23908	0.005	0.074	0	1	3600	0.016	0.125	0	1
WDPCNT	23963	4.904	16.822	0	101	3588	1.841	8.551	0	93
WTRPCNT	23963	3.412	9.005	0	101	3588	3.154	6.420	0	90
NGPCNT	23963	52.865	42.244	0	105	3588	23.080	32.933	0	100
HPPCNT	23963	13.275	26.784	0	106	3588	21.783	33.012	0	100
CRPPCNT	23963	23.244	38.138	0	101	3588	48.526	43.697	0	100
NG	23963	0.611	0.488	0	1	3588	0.249	0.433	0	1
HP	23963	0.146	0.353	0	1	3588	0.229	0.420	0	1
CRP	23963	0.262	0.440	0	1	3588	0.524	0.499	0	1
MS	22260	0.541	0.498	0	1	3360	0.751	0.433	0	1
S	22260	0.357	0.479	0	1	3360	0.204	0.403	0	1
SALTY	23908	0.149	0.356	0	1	3594	0.133	0.340	0	1
HILLY	23908	0.104	0.305	0	1	3594	0.047	0.212	0	1
WET	23908	0.000	0.006	0	1	3594	0.001	0.029	0	1
OTHER	23908	0.011	0.106	0	1	3594	0.003	0.053	0	1

Within the study area, 42% of the quarter sections are classified as private farmland by the Canadian Wildlife Service. Agricultural crown land makes up 30% of the study area, and Grasslands National Park makes up approximately 4% of the area. The remaining 24% of the study area is divided amongst irrigation projects (0.4%), conservation easements (0.5%), Indian reserves (0.5%), community pastures (17%), grazing cooperatives (3%), provincial parks (1%), and small contributions by town sites (0.03%), fish and wildlife lands (0.07%), historic parks, properties and sites (0.05%), regional parks and recreational areas (0.01%), and migratory bird sanctuaries (0.02%).

In general, higher quality agronomic quarter sections make up the bulk of the quarter sections sold in arm's length transactions between 1993 and early 2011.This subset of the region's quarter sections over represent private farmland by 48% (90% vs. 42%), annual cropland cover by 26% (49% vs. 23%) cover and perennial hay and tame pasture lands by 9% (22% vs. 13%). As a result, native grasslands are underrepresented with a calculated land cover that is 30% lower than the regional average (23% vs. 53%). Higher quality land is also overrepresented in the land transaction data. Seventy-five percent of the quarter sections that were sold between 1993 and 2011 were class 3 (the highest land capability classification in the region), which only 54% of the entire study region has a class 3 rating. However, non-agronomic characteristics such as oil and natural gas development, parcel size, and population growth were all consistent between the entire study region and the subset of quarter sections with sale data.

4.2 Net Present Value Model of Agricultural Land

The sale price of a parcel land is equal to the discounted sum of expected net returns obtained from the use of that land in its most profitable form (Plantinga *et al.* 2002), and in the case of southwest Saskatchewan, the most profitable use of land is largely agriculture. As such, the market value of a parcel of agricultural land is able to reflect the net present value of all future agricultural production that will occur on the land, or equivalently, it can be though to reflect the net present value of all foregone production opportunities if it were the case that a parcel of land was removed permanently from agricultural production (Polasky *et al.* 2001). Using this logic, agricultural market values were used to represent the net present value of agricultural land in the Milk River Watershed.

Agricultural land market values were calculated by taking a ratio of sale prices and assessed values and applying these ratios to the assessed values of all the quarter sections in the region. First a spatial layer was created that related sale transactions to assessed values by creating a ratio of sale price/acre to assessed price/acre[25] $(sale\ price/acre \div assessed\ value/acre)$ for the 3314 quarter sections that had both land assessment data and land transaction data that were suitable for inclusion in the land value analysis. These ratios were then applied to all quarter sections within the study region such that any quarter section that was not one of the 3314 quarter sections with a calculated ratio, would receive a ratio from whichever of the 3314 quarter sections with ratios was located spatially nearest to it. The result was that all 21 532 quarter sections received a land value ratio that best represented the market surrounding the quarter section. Finally, agricultural market values were calculated for all quarter sections using the formula $[(ratio \times assessed\ value/acre) \times acres]$.

4.2.1 Results

The average land value ratio was 1.15 suggesting that, on average, agricultural land in the region sells for 1.15 times its assessed value. On average, the ratios were highest for 'other' lands (1.20), and lowest for cultivated lands (1.10; Table 4.6). The average land value in the region is $30 836.91 for all 21 532 quarter sections considered. Arable lands had a higher

[25] Both land values were brought into 2008 dollars using the consumer price index (CPI).

average market value than hay and pasture lands at $43 519.85 ($271.99/acre) and $23 783.21 ($148.64/acre), respectively. Land values are displayed in Figure 4.3.

Table 4.6. A summary of the land value ratios and the resulting land market values (2008 dollars) for parcels of land within each land-use type in the watershed.

	Arable Land	Hay and Pasture Land	Other Lands*	All Land Uses
Number of Quarter Sections	7 613	13 906	13	21 532
Mean Ratio (Std. Deviation)	1.10 (0.46)	1.18 (0.85)	1.20 (0.40)	1.15 (0.74)
Mean Market Value ($/quarter section)	43 519.85	23 783.21	148 789.47	30 836.91
Mean Market Value ($/acre)	271.99	148.68	929.93	192.73

*Commercial and Industrial land (n = 9) and mixed agricultural land (n = 4) make up the other category

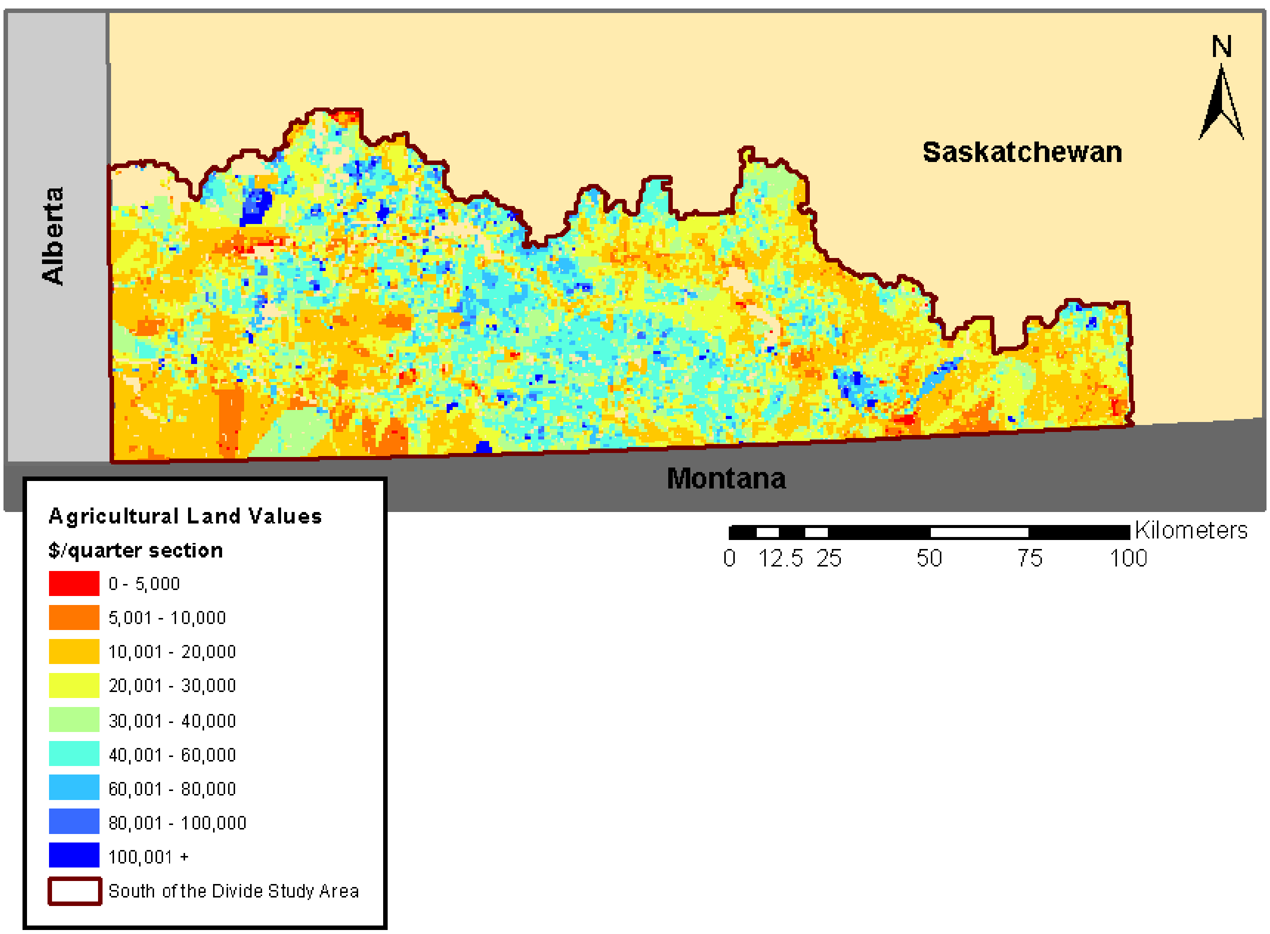

Figure 4.3. Agricultural land values calculated using sales transaction and assessment data.

4.3 Net Present Value Model of Land-Use Conversion

Using the same logic presented in Section 4.2, if the sale price of a parcel of agricultural land represents the net present value of all future agricultural production, a difference in land-use (i.e., agricultural production) will be reflected in the sale prices of agricultural land. This measurable difference in sale price can, in turn, provide information on the difference in the net present value associated with each land use. The difference in net present values between land uses ultimately provides information on the opportunity costs associated with land-use conversion.

In order to calculate the systematic differences in land market values that result from differences in land-use (holding all other land characteristics constant), a hedonic land value model was designed and run for Saskatchewan's Milk River Watershed using the data discussed in Sections 4.1.1 and 4.1.3. A hedonic model works by breaking a 'whole' (in this case, a parcel of agricultural land) into individual attributes (such as the size, location, soil classification, land use, etc. of a parcel of agricultural land) and assigning values to each attribute. For example, heterogeneity in land sale prices are attributed to heterogeneity in land attributes, such as soil capability classification or current land use, and each attribute is assigned a value that reflects its contribution to the overall value of the land parcel. The hedonic land value model can also be used to calculate the value of changes in land characteristics (Palmquist and Danielson 1989). Of particular interest in this study is the change from one land-use to another land-use, more specifically, the change from annual cropland and perennial forage production into native grasslands. This section outlines the model, the results and the interpretation of the hedonic land value analysis.

Equation 4-1 outlines the functional form and variables, as defined in Table 4.4, used within the hedonic model. The model includes a constant, time dummies (years 2010 and 2011 together act as the base case since 2011 had only 1 observation), a gas well count variable, an oil well count variable, township and range variables, a positive growth dummy (negative growth as the basecase), land ownership dummies (private farmland as the basecase), variables indicating the percentage of the quarter section made up of water or woodlands (shrubs and trees), land use dummies (annual cropland and hay/tame pasture) to indicate the quarter sections' predominant land use (native grasslands as the basecase), ecosite dummies (using loam and overflow ecosites as the basecase), and land capability variables (using land capabilities of 5 and 6 as the basecase).

Equation 4-1

$$\begin{aligned} PRICEAC = {} & CONSTANT + YEAR1 + \cdots + YEAR17 + GWELL + OWELL + TWN + RNG \\ & + POSGWTH + AC + NP + IP + IR + CE + WTRPCNT + WDPCNT + HP \\ & + CRP + SALTY + HILLY + WET + OTHER + MS + S \end{aligned}$$

The model was designed to facilitate the valuation of a land-use change within the region. The opportunity cost of land-use conversion can be calculated in this model as the change in land value that results from a change in land use. The model results in a constant $/acre opportunity cost (i.e., a constant marginal opportunity cost) for the conversion of land between uses. While marginal costs are constant, total opportunity costs would still increase linearly with the number of acres converted and would, therefore, vary spatially. The constant marginal opportunity costs of converting land from cropland to native grassland can be calculated using Equation 4-2 while the costs of converting land from hay or tame pasture to native grassland can be calculated using Equation 4-3.

Equation 4-2

$$\Delta PRICEAC = \hat{\beta}_{CRP} * (CROP_2 - CROP_1) = \hat{\beta}_{CRP} * (1)$$

Equation 4-3

$$\Delta PRICEAC = \hat{\beta}_{HP} * (HAY\ or\ TAME\ PASTURE_2 - HAY\ or\ TAME\ PASTURE_1) = \hat{\beta}_{HP} * (1)$$

The hedonic models were run in SHAZAM Professional Edition. A multiple linear regression was run that made use of the Ordinary Least Squares (OLS) estimator. The model included a large number of dummy variables which restricts the functional form that can be used because it is impossible to take the log of 0. Thus, a linear functional form has been selected because of 1) the inability to take the logarithmic of many of the variables, and 2) the variables and interpretation are best suited to a linear form. The model was run with all arm's length transaction data (N = 3360). The lower number of observations (compared to 3600 arm's length transactions) is due to the removal of any observations with missing data.

The model was tested for heteroskedasticity using two tests (Whistler *et al.* 2004). Both models were found to have significant heteroskedasticity using the Lagrange Multiplier (LM) and Breusch-Pagan-Godfrey (B-P-G) tests (see Table D.8 and Table D.9). Despite the presence of heteroskedasticity, OLS remains an unbiased estimator. However, the OLS estimator is not efficient (Whistler *et al.* 2004) and the coefficients' variances are biased. Therefore, the initially estimated standard errors are incorrect for the models and hypothesis tests cannot be conducted. Biased standard errors can be corrected by computing White's heteroskedasticity-consistent covariance matrix and recalculating the standard errors. The model was estimated using an OLS estimator that made use of White's heteroskedasticity-consistent covariance matrix. As such, conclusion can be made regarding the significance of the estimated coefficients.

4.3.1 Results

Table 4.7. Summary of results from hedonic land value models run using arm's length transaction data.

Variable	Estimated Coefficient	Standard Error	P-Value
ACRE	-1.38	0.73	0.06*
YEAR1	-63.22	74.40	0.40
YEAR2	-123.94	20.55	0.00***
YEAR3	-103.91	20.27	0.00***
YEAR4	-92.39	20.47	0.00***
YEAR5	-74.57	20.30	0.00***
YEAR6	-36.00	22.06	0.10*
YEAR7	-91.82	21.09	0.00***
YEAR8	-58.53	20.49	0.00***
YEAR9	-38.57	21.26	0.07*
YEAR10	-67.81	21.20	0.00***
YEAR11	-88.56	20.37	0.00***
YEAR12	-59.83	21.54	0.01***
YEAR13	-54.92	22.91	0.02**
YEAR14	-64.61	21.24	0.00***
YEAR15	-57.80	20.06	0.00***
YEAR16	-57.30	18.93	0.00***
YEAR17	-33.24	19.42	0.09*
GWELL	-10.28	6.55	0.12
OWELL	38.84	13.44	0.00***
TWN	3.32	1.56	0.03**
RNG	-0.81	0.55	0.14
POSGWTH	8.14	5.94	0.17
AC	-56.44	9.87	0.00***
NP	-36.44	9.25	0.00***
IP	-14.05	50.01	0.78
IR	6.83	16.25	0.67
CE	-11.25	18.11	0.54
WTRPCNT	-0.27	0.33	0.42
WDPCNT	0.16	0.40	0.70
HP	50.29	7.38	0.00***
CRP	71.03	6.71	0.00***
SALTY	-19.61	7.48	0.01***
HILLY	-17.83	9.48	0.06*
WET	-117.71	47.83	0.01***
OTHER	23.50	56.37	0.68
MS	39.67	8.96	0.00***
S	9.26	9.99	0.35
CONSTANT	453.95	125.50	0.00***
N		3360	
R^2		0.15	
ADJUSTED R^2		0.14	
LOG LIKELIHOOD		-20814.80	
HET TESTS	**Test Stat**	**DF**	**P-Value**
LM	6.61	1	0.01***
BPG	2361.46	38	0.00***

Note: * significant at 10% level; ** significant at the 5% level; *** significant at the 1% level

Quarter sections that are currently cropland would calculate their marginal opportunity cost of converting to native grasslands using Equation 4-2 $\Delta \text{PRICEAC} = -\hat{\beta}_{\text{CRP}} * (1) = -71.03$. As a result, the conversion cost is $71.03/acre. Quarter sections that are currently hay or tame pasture would calculate their marginal opportunity cost of converting to native grasslands using Equation E-2 where $\Delta \text{PRICEAC} = -\hat{\beta}_{\text{HP}} * (1) = -50.29$. The conversion cost would as a result be $50.29/acre. It is also worth noting that if the goal were to turn annual cropland into tame hay or pasture lands, the opportunity cost of conversion would be $20.74/acre.

Opportunity costs of land conversion were calculated for all quarter sections in the study area. Each quarter section's acres of cropland were multiplied by $71.03/acre to calculate the total opportunity cost of converting cropland to native grassland, and the same was done for hay and tame pastures using their opportunity costs of $50.29/acre. The total opportunity cost of converting a quarter section to native grass is the sum of the opportunity cost of converting both cropland and hay and tame pastures to native grassland. Figure 4.4 shows the total opportunity cost of conversion to native grassland for all quarter sections in the study area.

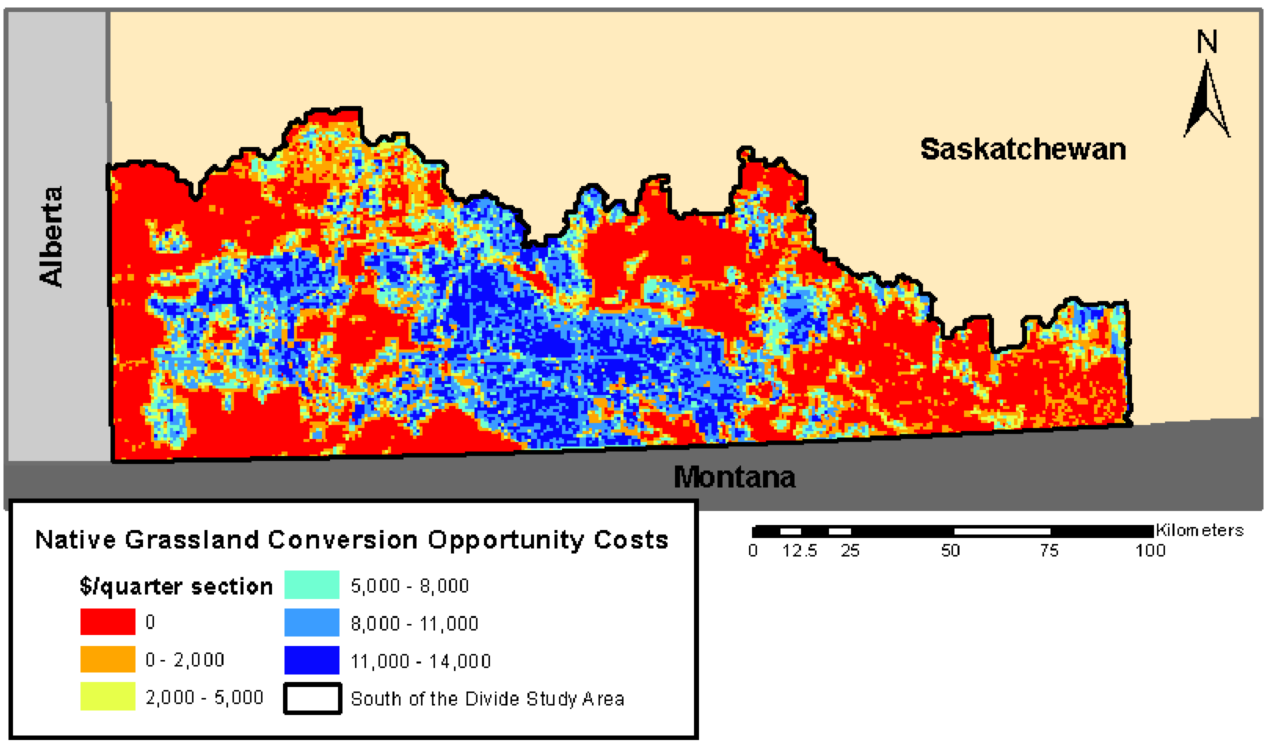

Figure 4.4. The opportunity cost of converting land from annual cropland and perennial forages (tame pasture or hay land) into native grasslands.

The following table (Table 4.8) highlights the potential direct cost per acre to return cropland into perennial cover. The total cost of conversion (Table 4.9) used within the final reserve network model is the sum of direct costs and opportunity costs. The total costs of converting cropland or hay land into native grasslands closely correspond to the $421/acre value found by Dollevoet (2010) when farms in southeastern Saskatchewan convert cropland into tame hay.

Table 4.8. Direct costs of converting cropland into perennial cover.

	Cost ($/acre)	Cost (2008$/acre)	Source
Cropland to Hay or Tame Pasture	$53.09/acre*	$54.34/acre	Saskatchewan Ministry of Agriculture 2006
Cropland to Native Pasture	$375/acre	$373.88/acre	Tannas 2009 (in Dollevoet 2010)
Hay or Tame Pasture to Native Pasture	$400/acre	$391.84/acre	Pat Fargey pers. comm. 2011

* Assumes breaking and glyphosate application not required since converting cropland into tame pasture, and not breaking tame pasture in order to reseed.

Table 4.9. Total costs (2008$) of converting between land uses within the Milk River Watershed.

	Direct Cost ($/acre)	Opportunity Cost ($/acre)	Total Cost ($/acre)*
Cropland to Hay or Tame Pasture	$54.34/acre	$20.74/acre	$75.08/acre
Cropland to Native Pasture	$373.88/acre	$71.03/acre	$444.91/acre
Hay or Tame Pasture to Native Pasture	$391.84/acre	$50.29/acre	$442.13/acre

*Total cost is in 2008 dollars

5 Grazing Management

Approximately 60% of the quarter sections within the Milk River Watershed are made up of a majority of native grasslands, and about 50% of the area in total is native grasslands (Table 4.5). These native grasslands are owned and managed several different ways. There are community pastures (provincially and federally owned and managed), grazing cooperatives (provincially owned and privately managed), crown lease land (provincially owned and privately managed), and private land (privately owned and managed). Recommended stocking rates are provided to land managers, but there is no monitoring or enforcement conducted by the provincial government to ensure management of the provincially owned and privately managed land aligns with the recommendations of the province (Jessica Williams, pers. comm.).

There is no single grazing strategy that benefits all of the species at risk included within the Milk River Watershed's South of the Divide Action Plan. It's likely that the optimal scenario for grazing management on the Milk River Watershed would be the provision of a heterogeneous grassland landscape that is sustainably grazed over the long run. Within this analysis, it is assumed that a heterogeneous grassland structure and composition can be achieved by following the provincial stocking guidelines and allowing topography, climate, soils, and livestock grazing preferences to result in a natural provision of heterogeneity.

Grazing management adjustments will undoubtedly come at a cost to land managers. If grazing strategies that are optimal for species at risk provided the greatest return from the land, managers would already manage their land in such a manner. The fact that grazing changes are required is evidence that optimal grazing for species at risk is not also optimal for ranch revenues.

This section will attempt to measure the cost of moving from current stocking rates within the region to the recommended stocking rates provided by the province (Thorpe 2007). The following sections outline the data and methods used to calculate the net present value that results from grazing management changes within the region. Finally, the results of the net present value calculations are presented. Of course, some land managers will already stock at the recommended rates, some will stock below, and some will stock above. However, spatial information on rangeland health and stocking rates is not available; therefore, simplifying assumptions about average stocking rates will be used in the analysis.

5.1 Summary of Data

Recommended and realized grazing management strategies and stocking rates varying by ecosite and ecoregion. As a result, the information required for this net present value analysis included spatial information on rangeland ecoregions and ecosite provided by the Saskatchewan Ministry of Environment, recommended stocking rates for the region (Thorpe 2007), estimates of actual stocking rates within the region (Tara Davidson pers. comm.), and information linking grazing capacity to assessed land values (SAMA 2007). The following sections discuss the data in greater detail.

5.1.1 Spatial Data

The southwest corner of Saskatchewan is often divided into two ecoregions: the Cypress Upland and the Mixed Grassland. However, the stocking rate guidelines for Saskatchewan uses an additional ecoregion – the Dry Mixed Grasslands (Thorpe 2007). While we only use two ecoregions within this analysis (Mixed Grassland and Cypress Upland), the Mixed Grasslands stocking rates were calculated as an evenly weighted average of the stocking rates for the Dry Mixed Grasslands and the Mixed Grasslands since each ecoregion is equally represented in the watershed.

Within the Milk River Watershed, there are 16 ecosites. The primary ecosite of the region by far, is the loam ecosite (Figure 5.1). The reference grassland communities that grow on the loam soils include Northern Wheat Grass – Needle-and-thread communities on the driest areas, Northern Wheat Grass – Western Porcupine Grass or Western Porcupine Grass – Northern Wheat Grass communities on moister sites, and Plains Rough Fescue grasslands on the Cypress Uplands. These are the key grassland communities of the region. Other major ecosites include the solonetzic ecosite. This ecosite is found in the extreme southwest corner of the province and has lower grazing tolerances and capacities than loam ecosites. Other ecosites with unique management needs include gravelly sites, clay sites, thin sites, and badland sites. These sites often have recommended stocking rates much lower than the loam ecosites.

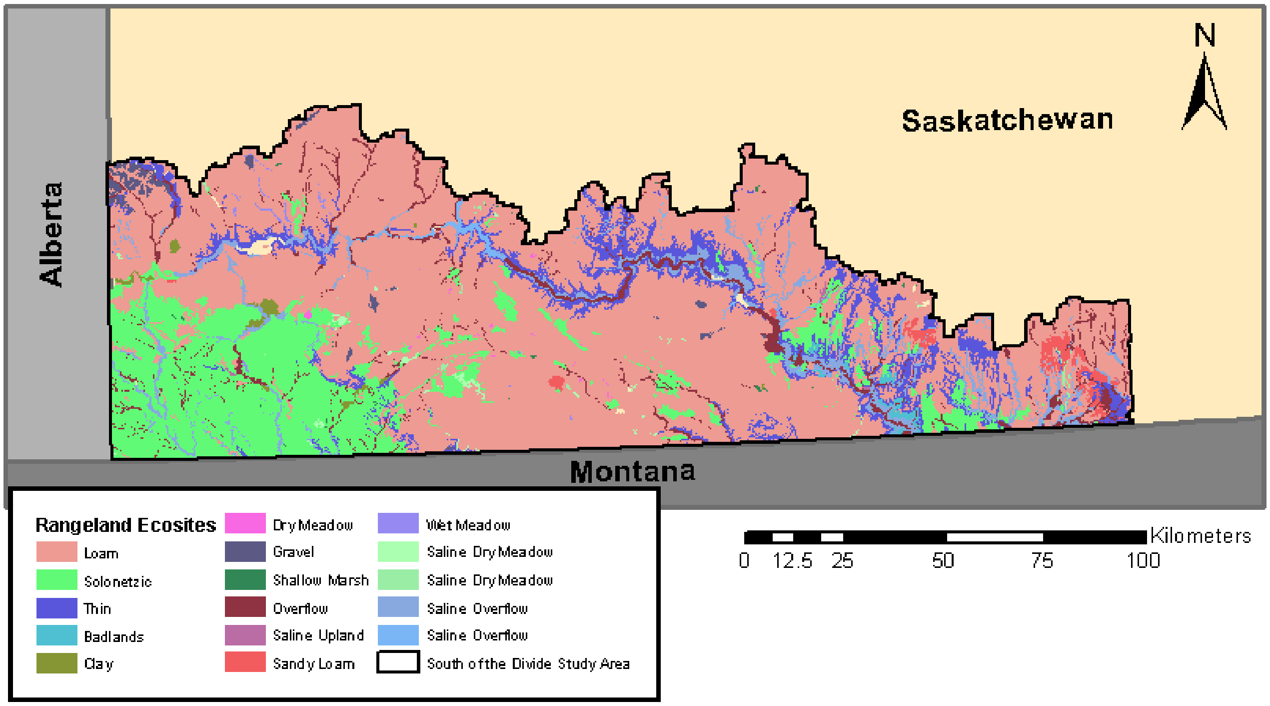

Figure 5.1. The sixteen rangeland ecosites making up Saskatchewan's Milk River Watershed region.

5.1.2 Grazing Management within the Milk River Watershed

As mentioned above, there is no single grazing strategy that benefits all of the species at risk within the Milk River Watershed. However, it's possible that one way to achieve grassland structure and composition heterogeneity is to follow the provincial stocking rate guidelines and permit topography, climate, soils, and livestock grazing preferences to create a natural provision of heterogeneity while ensuring a sustainable level of grazing.

5.1.2.1 Recommended Grazing Management

Recommended stocking rates are calculated using loam ecosites as the reference communities. The loam ecosite recommendations for the Dry Mixed Grasslands, Mixed Grasslands and Cypress Uplands are 0.20 AUM/acre, 0.29 AUM/acre, and 0.56 AUM/acre, respectively. The complete list of recommended stocking rates for reference communities (communities in excellent to good condition) is calculated and displayed in Table 5.1 below. These are the maximum grazing capacities possible on these ecosites. However, historic mismanagement of rangelands can reduce grazing capacities.[26]

[26] For example, a moderately altered community would provide 0.8 times the grazing capacity as the reference communities and a significantly altered community would provide only 0.6 times the grazing capacity of the reference community.

Table 5.1. Recommended stocking rates for the Mixed Grassland Ecoregion and the Cypress Upland Ecoregion within the Milk River Watershed study area.

Ecosite	Ratio to Loam	Mixed Grassland Ecoregion Stocking Rate (AUM/acre)* (Loam = 0.245 AUM/acre)	Cypress Upland Ecoregion Stocking Rate (AUM/acre) (Loam = 0.56 AUM/acre)
Shallow Marsh	2.69	0.66	1.51
Wet Meadow	2.59	0.64	1.45
Dry Meadow	2.34	0.57	1.31
Overflow	1.54	0.38	0.86
Saline Overflow	1.37	0.34	0.77
Saline Dry Meadow	1.11	0.27	0.62
Loam	1.00	0.25	0.56
Sandy Loam	0.97	0.24	0.54
Clay	0.96	0.24	0.54
Sand	0.94	0.23	0.53
Dunes	0.73	0.18	0.41
Thin	0.73	0.18	0.41
Solonetzic	0.66	0.16	0.37
Gravelly	0.60	0.15	0.34
Saline Upland	0.52	0.13	0.29
Badlands	0.29	0.07	0.16

* The Mixed Grassland numbers in this table are an average of the Dry Mixed Grassland grazing capacity (Loam = 0.20 AUM/acre) and the Mixed Grassland grazing capacities (Loam = 0.29 AUM/acre) found in Thorpe 2007.

5.1.2.2 Realized Grazing Management

Tara Davidson (pers. comm.), the Range Management Specialist for Agriculture and Agri-Food Canada in southwest Saskatchewan, provided detailed information on historic federal community pasture stocking rates, and was also able to provide some insight into private land management in the area. [27]

Federal community pastures in the regions are largely concentrated in the southern half of the study area, with the exception of the Auvergne-Wise Creek, Beaver Valley and Val Marie pastures (Figure 2.2). The average loam stocking rates for each of the federal community pastures is listed in Table 5.2. All of the community pastures are stocked at or below the recommended stocking rates except for Auvergne – Wise Creek. The higher rate in the Auvergne – Wise Creek pasture is because this pasture has higher elevations (more akin to the Cypress Uplands), good production potential, no major slope issues, and fairly good precipitation (Tara Davidson pers. comm.). While detailed information on the stocking rates of

[27] Tara Davidson provided professional and personal insight into stocking rates in the region. Tara manages the federal community pastures in the region and owns and manages a ranch just north of the Milk River Watershed.

the provincial community pastures was not obtained, it is assumed that they – like the federal pastures – are stocked according to the recommended stocking rates for the region. As such, the loam ecosites of the provincial community pastures of Arena, Dixon and Mankota are assumed to be stocked at or below 0.25 AUM/acre on average, and all other ecosites are also assumed to be stocked at or below their recommended rates.

Table 5.2. The loam ecosite stocking rates used for the federal community pastures of the Milk River Watershed region.

Community Pasture	Actual Loam Stocking Rate (AUM/acre)	Recommended Loam Stocking Rate (AUM/acre)
Auvergne – Wise Creek	0.36	0.25
Beaver Valley	0.20	0.25
Val Marie	0.25	0.25
Lonetree	0.16	0.25
Masefield	0.20	0.25
Battle Creek*	0.18	0.25
Govenlock	0.14	0.25
Nashlyn	0.16	0.25
Reno 1	0.16	0.25
Reno2**	-	0.25
Overall Long Term Average	0.20	0.25

* Battle Creek, Govenlock, and Nashlyn in the southwest corner of the study area do not have pure loam ecosites, but instead have areas of solonetzic-loam mixed soils. It is from these areas that the loam stocking rates in this table come from. The long term average stocking rate for these areas is 0.15 AUM/acre (Tara Davidson pers. comm.) which is a conservative stocking rate below the recommended solonetzic stocking rate of 0.16 AUM/acre.
** Reno 2 does not have any loam ecosites, but its solonetzic sites are stocked at 0.10 AUM/acre – much below that of the recommended stocking rate of 0.16 AUM/acre.

Communications with Jessica Williams, a Resource Agrologist with the Saskatchewan Ministry of Agriculture in southwest Saskatchewan, provided the information that lessees of crown lease land are provided with recommended stocking rates, but at no time during the duration of their lease does the provincial government monitor or enforce those stocking rates. Thus, crown lease land is managed essentially as if it is privately owned and the lessees have the opportunity to manage and stock the land using their own management philosophies.

There are management differences between publicly managed and privately managed grazing lands in the Milk River Watershed. While the community pastures have similar goals to private operations there is not the same pressure to be able to make land or lease payments at the end of the year (Tara Davidson pers. comm.). As a result, the Agriculture and Agri-Food Canada (AAFC) community pastures have quite conservative stocking rates and carrying capacities relative to private ranches in the area on average (Tara Davidson pers. comm.).

Privately managed land within the Milk River Watershed includes privately owned land and crown lease land. Estimates of private stocking rates are found in Table 5.3. In personal communications with Tara Davidson, it was found that private loam stocking rates in the Mixed

Grassland region ranged from 0.27 AUM/acre on the low end, to 0.35 AUM/acre on the high end, with 0.30 AUM/acre being a moderate stocking rate for private ranches. Thus, compared to the recommended stocking rate for a reference (i.e., excellent to good condition) loam ecosite, the high stocking rate is 43% higher, the moderate stocking rate is 22% higher, and the low stocking rate for private ranches is still 10% higher. Tara Davidson's estimate of heavy stocking rates being 43% higher than the recommended rates is similar to the 33% higher estimate that is commonly cited in the literature for heavy grazing in the Mixed Grasslands of the United States (Lecain *et al.* 2000; Reeder and Schuman 2002; Abdel-Magid *et al.* 1987; Schuman *et al.* 1999). Tara Davidson also estimated that the more fragile ecosites (gravel, bandland, thin, solonetzic etc.) which have an average recommended stocking rate of 0.14 AUM/acre are likely stocked at 0.20 AUM/acre on the high end (43% higher than recommended), 0.15 AUM/acre on the low end (7% higher than recommended), and around 0.18 AUM/acre as a moderate stocking rate (29% higher than recommended).

The estimated stocking rates used on private ranches in southwest Saskatchewan are displayed in Table 5.3. Calculations of the estimated stocking rates are based on the information discussed in the previous paragraph. The stocking rates of the first nine ecosites for each ecoregion were calculated by multiplying the recommended stocking rate for their reference community by 110% (low stocking rate), 122% (moderate stocking rate), and 143% (high stocking rate). The last six ecosites (the more fragile ecosites) listed for each ecoregion had their actual stocking rates calculated by multiplying the recommended stocking rate for their reference community by 107% (low stocking rate), 129% (moderate stocking rate), and 143% (high stocking rate). These calculations make several simplifying assumptions. The first major assumption is that private land managers stock all ecosites (divided only into two groups: productive ecosites and fragile ecosites) at the same relative rates (i.e., the percentages calculated from communications with Tara Davidson). The second major assumption is that the relative stocking rates hold not only across ecosites, but also across ecoregions (Mixed Grassland and Cypress Upland). While these assumptions may seem restrictive, detailed information on stocking rates is not available. Ideally detailed spatial information on stocking rates and rangeland health would exist for the entire study area.

Finally, grazing cooperatives are an interesting grazing management design. Most grazing cooperatives are leased from the provincial government and adhere closely to the provincial recommended stocking rates in order to not risk losing the rights to continue to graze their cattle. The larger area of the grazing cooperatives and their ability to limit grazing permits allows the cooperative the ability to better manage the variability in production that comes with good and bad growing years (Randy Currence[28] pers. comm.)

[28] Randy Currence is a lifelong rancher and member on the board of the Scottsguard Grazing Cooperative. The Scottsguard Grazing Cooperative is located along the northern border of the study area.

Table 5.3. Comparison of the recommended stocking rates for the region (for reference communities in excellent to good condition, communities with moderate alterations in fair condition, and communities with significant alteration in poor condition) and the actual stocking rates observed on privately managed land.

		Recommended Stocking Rates (AUM/acre)			Actual Stocking Rates (AUM/acre)		
Ecoregion	**Ecosite**	**Reference Community**	**Moderate Alterations**	**Significant Alterations**	**Low**	**Moderate**	**High**
Mixed Grassland	Shallow Marsh	0.66	0.53	0.40	0.73	0.81	0.94
	Wet Meadow	0.63	0.51	0.38	0.70	0.78	0.91
	Dry Meadow	0.57	0.46	0.34	0.63	0.70	0.82
	Overflow	0.38	0.30	0.23	0.42	0.46	0.54
	Saline Overflow	0.34	0.27	0.20	0.37	0.41	0.48
	Saline Dry Meadow	0.27	0.22	0.16	0.30	0.33	0.39
	Loam	0.25	0.20	0.15	0.27	0.30	0.35
	Sandy Loam	0.24	0.19	0.14	0.26	0.29	0.34
	Clay	0.24	0.19	0.14	0.26	0.29	0.34
	Sand	0.23	0.18	0.14	0.25	0.28	0.33
	Dunes	0.18	0.14	0.11	0.19	0.23	0.26
	Thin	0.18	0.14	0.11	0.19	0.23	0.26
	Solonetzic	0.16	0.13	0.10	0.17	0.21	0.23
	Gravelly	0.15	0.12	0.09	0.16	0.19	0.21
	Saline Upland	0.13	0.10	0.08	0.14	0.16	0.18
	Badlands	0.07	0.06	0.04	0.08	0.09	0.10
Cypress Upland	Shallow Marsh	1.51	1.21	0.90	1.66	1.84	2.15
	Wet Meadow	1.45	1.16	0.87	1.60	1.78	2.07
	Dry Meadow	1.31	1.05	0.79	1.44	1.60	1.87
	Overflow	0.86	0.69	0.52	0.95	1.06	1.23
	Saline Overflow	0.77	0.61	0.46	0.85	0.94	1.10
	Saline Dry Meadow	0.62	0.50	0.37	0.69	0.76	0.89
	Loam	0.56	0.45	0.34	0.62	0.69	0.80
	Sandy Loam	0.54	0.43	0.33	0.60	0.67	0.78
	Clay	0.54	0.43	0.32	0.59	0.66	0.77
	Sand	0.53	0.42	0.32	0.58	0.64	0.75
	Dunes	0.41	0.33	0.25	0.44	0.53	0.58
	Thin	0.41	0.33	0.25	0.44	0.53	0.58
	Solonetzic	0.37	0.30	0.22	0.40	0.48	0.53
	Gravelly	0.34	0.27	0.20	0.36	0.43	0.48
	Saline Upland	0.29	0.23	0.17	0.31	0.37	0.42
	Badlands	0.16	0.13	0.10	0.17	0.21	0.23

5.1.3 Grazing Land Rating Valuation

The Saskatchewan Assessment Management Agency (SAMA) calculates the assessed land value of pasture land using carrying capacities (AUM/acre). Carrying capacities are a measure of the productive capacity of a pasture and its ability to support grazing herbivores.[29] While carrying capacity can be influenced by historic land management and range improvements, the capacity of the land to support cattle is largely the result of the inherent productive potential of the land (ecoregion, ecosite, soil, etc.). This inherent capability of the land is translated into a land rate which is then multiplied by a conversion factor of $5.75 per land rate and again by the number of acres in the parcel to get the final assessed value of the land parcel. In essence, this process provides each animal unit month (AUM) measure is provided a value that represents its discounted sum of expected returns, or in other words, its net present value.

Stocking rate and carrying capacity are not equivalent; the first indicates the intensity at which a parcel of land is actually stock and the latter indicates the intensity at which a parcel of land should be stocked to maintain sustainable rangelands. However, they are measured in the same units, AUM. As Therefore, the land rating and conversion factor system used by SAMA to provide a value to AUM levels was used to value a reduction in stocking rate analogously to how it would value the difference between two parcels of land with differing carrying capacities. The method used is discussed in greater detail in the next section.

[29] See Section 4.1.2, Entem (2012) or SAMA (2007) for a complete discussion on SAMA's pasture assessment calculations.

Table 5.4. Saskatchewan Assessment Management Agency (SAMA) land rating chart used to determine the $/acre value of grazing lands in Saskatchewan.

	Application Range				
Stocking Rate (AUM/acre)	**Min**	**Max**	**Land Rating**	**$/acre**	**2008$/acre**
0.03	0.00	0.04	5	28.75	30.06
0.05	0.04	0.06	7	40.25	42.09
0.08	0.07	0.09	9	51.75	54.11
0.10	0.09	0.11	11	63.25	66.13
0.13	0.12	0.14	13	74.75	78.16
0.15	0.14	0.16	15	86.25	90.18
0.18	0.17	0.19	17	97.75	102.21
0.20	0.19	0.21	19	109.25	114.23
0.23	0.22	0.24	21	120.75	126.26
0.25	0.24	0.26	23	132.25	138.28
0.28	0.27	0.29	25	143.75	150.30
0.30	0.29	0.31	27	155.25	162.33
0.33	0.32	0.34	29	166.75	174.35
0.35	0.34	0.36	31	178.25	186.38
0.38	0.37	0.39	33	189.75	198.40
0.40	0.39	0.41	34	195.50	204.41
0.43	0.42	0.44	35	201.25	210.43
0.45	0.44	0.46	36	207.00	216.44
0.48	0.47	0.49	37	212.75	222.45
0.50	0.49	0.51	38	218.50	228.46
0.53	0.52	0.54	39	224.25	234.47
0.55	0.54	0.56	40	230.00	240.49
0.58	0.57	0.59	41	235.75	246.50
0.60	0.59	0.61	42	241.50	252.51
0.63	0.62	0.64	43	247.25	258.52
0.65	0.64	0.66	44	253.00	264.54
0.68	0.67	0.69	44	253.00	264.54
0.70	0.69	0.71	45	258.75	270.55
0.73	0.72	0.74	45	258.75	270.55
0.75	0.74	0.76	45	258.75	270.55
0.78	0.77	0.79	46	264.50	276.56
0.80	0.79	0.81	46	264.50	276.56
0.83	0.82	0.84	46	264.50	276.56
0.85	0.84	0.86	46	264.50	276.56
0.88	0.87	0.89	47	270.25	282.57
0.90	0.89	0.91	47	270.25	282.57
0.93	0.92	0.94	47	270.25	282.57
0.95	0.94	0.96	47	270.25	282.57
0.98	0.97	0.99	47	270.25	282.57
1.00	0.99	1.01	48	276.00	288.58
1.03	1.02	1.04	48	276.00	288.58
1.05	1.04	1.06	48	276.00	288.58
1.08	1.07	1.09	48	276.00	288.58
1.10	1.09	1.11	48	276.00	288.58
1.13	1.12	1.14	48	276.00	288.58
1.15	1.14	1.16	49	281.75	294.60
1.18	1.17	1.19	49	281.75	294.60
1.20	1.19	1.21	49	281.75	294.60
1.23	1.22	1.24	49	281.75	294.60
1.25	1.24	1.26	49	281.75	294.60
1.28	1.27	1.29	49	281.75	294.60
1.30	1.29	1.31	49	281.75	294.60
1.33	1.32	1.34	50	287.50	300.61
1.35	1.34	1.36	50	287.50	300.61
1.38	1.37	1.39	50	287.50	300.61
1.40	1.39	1.41	50	287.50	300.61

5.2 Net Present Value Model for Grazing Management

Calculating the opportunity cost of a reduced stocking rate is relatively straightforward if the adjustment is made for just a year. In that case, pasture rental rates can be used to estimate the value of an AUM/acre, and opportunity costs can be calculated. The difficulty of calculating opportunity costs for grazing management changes comes when the opportunity cost is required to portray a change in management that will exist in perpetuity.

If it is assumed that private land managers in the area are able to continually stock their land at a certain level above the recommended stocking rate, the difference in the two stocking rates can be calculated (AUM/acre), and the value of being able to utilize those additional animal unit months can be calculated using SAMA's land rate chart (Table 5.4). These calculations rely on the fact that the actual stocking rates used in the region are in fact sustainable and are, therefore, possible indefinitely[30]. In this case, the actual stocking rates (which are higher than recommended) reflect some sort of hypothetical 'carrying capacity' that is higher than the recommended stocking rates would portray is possible for the pasture. This assumption requires the actual stocking rates of the region to have no measurable detrimental effect on the plant communities and, as a result, the grassland communities under these stocking rates will continue to be in good to excellent condition. Thus, the appropriate stocking rates to compare these higher private stocking rates with are the recommended stocking rates for the reference plant communities. Table 5.5 contains the information on differences in stocking rates (between actual and recommended) for both ecoregions, and all sixteen ecosites. Differences in stocking rates are provided for the low, mid and high stocking rates used in the region by private landowners. The land ratings and opportunity costs associated with the stocking rate differences are also included in the table. The opportunity costs are highest for the most productive ecosites and lowest for the least productive ecosites.

[30] In all likelihood, the higher than recommended stocking rates would have a detrimental impact on the plant communities of the Milk River Watershed. Therefore, even though the stocking rates are currently sustainable, it is unlikely that they would be into the long run. As a result, assuming these higher stocking rates can be maintained will result in an upper bound on the opportunity cost of changing stocking rates to reflect the recommended rates.

Table 5.5. The difference in actual (low, moderate and high) stocking rates, and the recommended references stocking rates for the Milk River Watershed and the associated opportunity costs of moving management in line with the recommended rates.

		Difference between Actual and Recommended Reference Stocking Rates (AUM/acre)			Land Rating Associated with the Differences in Stocking Rate			The Opportunity Cost (2008$/acre) of Changing Stocking Rates to the Recommended Reference Rates		
Ecoregion	**Ecosite**	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**
Mixed Grassland	Shallow Marsh	0.07	0.15	0.28	7	15	25	42.09	90.18	150.30
	Wet Meadow	0.06	0.14	0.27	7	13	25	42.09	78.16	150.30
	Dry Meadow	0.06	0.13	0.25	7	13	23	42.09	78.16	138.28
	Overflow	0.04	0.08	0.16	5	9	15	30.06	54.11	90.18
	Saline Overflow	0.03	0.08	0.14	5	9	15	30.06	54.11	90.18
	Saline Dry Meadow	0.03	0.06	0.12	5	7	11	30.06	42.09	66.13
	Loam	0.03	0.06	0.11	5	7	11	30.06	42.09	66.13
	Sandy Loam	0.02	0.05	0.10	5	7	11	30.06	42.09	66.13
	Clay	0.02	0.05	0.10	5	7	11	30.06	42.09	66.13
	Sand	0.02	0.05	0.10	5	7	11	30.06	42.09	66.13
	Dunes	0.01	0.05	0.08	5	7	9	30.06	42.09	54.11
	Thin	0.01	0.05	0.08	5	7	9	30.06	42.09	54.11
	Solonetzic	0.01	0.05	0.07	5	7	9	30.06	42.09	54.11
	Gravelly	0.01	0.04	0.06	5	5	7	30.06	30.06	42.09
	Saline Upland	0.01	0.04	0.05	5	5	7	30.06	30.06	42.09
	Badlands	0.01	0.02	0.03	5	5	5	30.06	30.06	30.06
Cypress Upland	Shallow Marsh	0.15	0.34	0.65	15	29	44	90.18	174.35	264.54
	Wet Meadow	0.15	0.33	0.62	15	29	43	90.18	174.35	258.52
	Dry Meadow	0.13	0.29	0.56	13	27	40	78.16	162.33	240.49
	Overflow	0.09	0.19	0.37	9	17	33	54.11	102.21	198.40
	Saline Overflow	0.08	0.17	0.33	9	17	29	54.11	102.21	174.35
	Saline Dry Meadow	0.06	0.14	0.27	7	13	23	42.09	78.16	138.28
	Loam	0.06	0.13	0.24	7	13	21	42.09	78.16	126.26
	Sandy Loam	0.06	0.12	0.23	7	13	21	42.09	78.16	126.26
	Clay	0.05	0.12	0.23	7	13	21	42.09	78.16	126.26
	Sand	0.05	0.12	0.23	7	11	21	42.09	66.13	126.26
	Dunes	0.03	0.12	0.18	5	11	17	30.06	66.13	102.21
	Thin	0.03	0.12	0.18	5	11	17	30.06	66.13	102.21
	Solonetzic	0.03	0.11	0.16	5	11	15	30.06	66.13	90.18
	Gravelly	0.02	0.10	0.14	5	11	15	30.06	66.13	90.18
	Saline Upland	0.02	0.08	0.12	5	9	13	30.06	54.11	78.16
	Badlands	0.01	0.05	0.07	5	7	9	30.06	42.09	54.11

Opportunity costs were spatially applied to all grasslands within the Milk River Watershed. Quarter sections predominantly covered by grasslands (calculated using the Tabulate Area command in ArcMap 10.0 and a land cover raster received from the Canadian Wildlife Service) were included in the analysis. Quarter sections were then separated out based on whether they are publicly or privately managed, and which ecoregion they are located. Finally, opportunity costs were calculated for each region by multiplying the area (acres) of a quarter section made up by each ecosite (determined using the Tabulate Area command within ArcMap 10.0 and an rangeland ecosite shapefile provided by the Canadian Wildlife Service) with the corresponding opportunity cost ($/acre) for that ecosite and ecoregion. Figure F.4 is a simple diagram outlining the process.

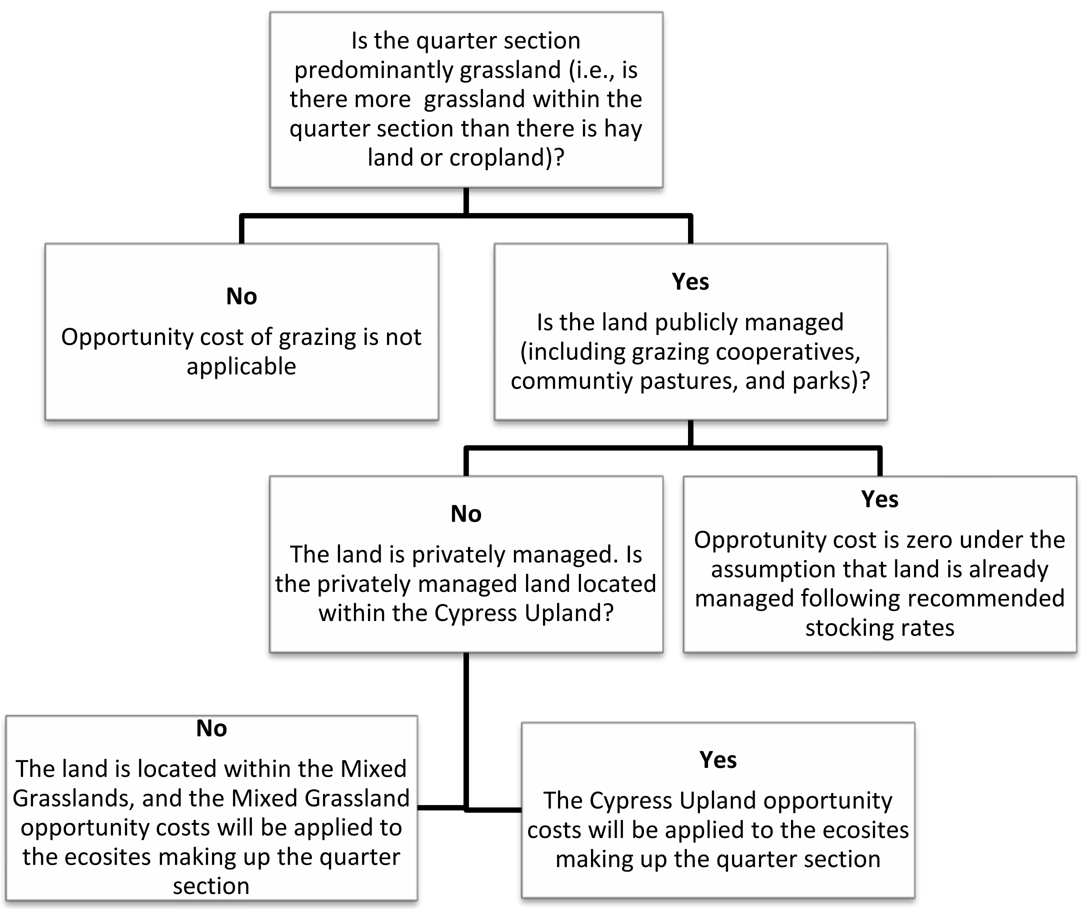

Figure 5.2. Decision tree showing how stocking rates were spatially applied to quarter sections within the Milk River Watershed study region.

5.2.1 Results

Grazing management opportunity costs were only calculated for quarter sections covered predominantly with native grasslands (relative to cropland and hayland). In that way, only land already managed as grazing land would have grazing management opportunity costs calculated. A total of 22 964 quarter sections had sufficient information on ecoregion, ecosite, land cover and land ownership to be included within this analysis. A total of 18 790 quarter sections had some amount of native grassland on them, 14 770 were composed of over 50% native grasslands, and 14 950 had a larger proportion of their area covered by native grasslands than either hayland or cropland. Opportunity costs of grazing were calculated for all 14 950 quarter sections with grassland as their primary land use.

Information in Table 5.6 includes public and private land to provide a complete picture; however, in the final opportunity cost model public land is assumed to have an opportunity cost of zero due to its current management being in line with recommended stocking rates for the region. The average quarter section size is very close to the standard value of 160 acres per quarter section. Within both samples, the minimum cost per acre is set by the lowest producing ecosites in the Mixed Grasslands, and the highest cost per acre is set by the highest producing ecosites in the Cypress Upland. The average costs per quarter section and per acre are lower when public land is included which is likely due to the high proportion of the Mixed Grassland – which has lower values than the more productive Cypress Uplands – that is represented by public grazing lands.

Table 5.6. Summary statistics for grazing management opportunity costs in the Milk River Watershed.

	Private Land	Public and Private Land
Average Number of Acres per Quarter Section	158.85	159.12
Number of Quarter Sections **(% of total quarters in region)**	9228 (40%)	14,950 (65%)
Average Cost per Quarter Section **(Standard Deviation)**	8838.30 (3236.50)	8452.47 (3071.90)
Minimum Cost per Acre	30.06	30.06
Average Cost per Acre **(Standard Deviation)**	55.79 (16.13)	53.24 (14.60)
Maximum Cost per Acre	174.35	174.35

Figure 5.4 displays the spatial distribution of grazing management opportunity costs for privately managed land within Saskatchewan's Milk River Watershed. Higher opportunity costs arise in the Cypress Upland where land is more productive and the potential difference between actual AUM/acre and recommended AUM/acre is higher.

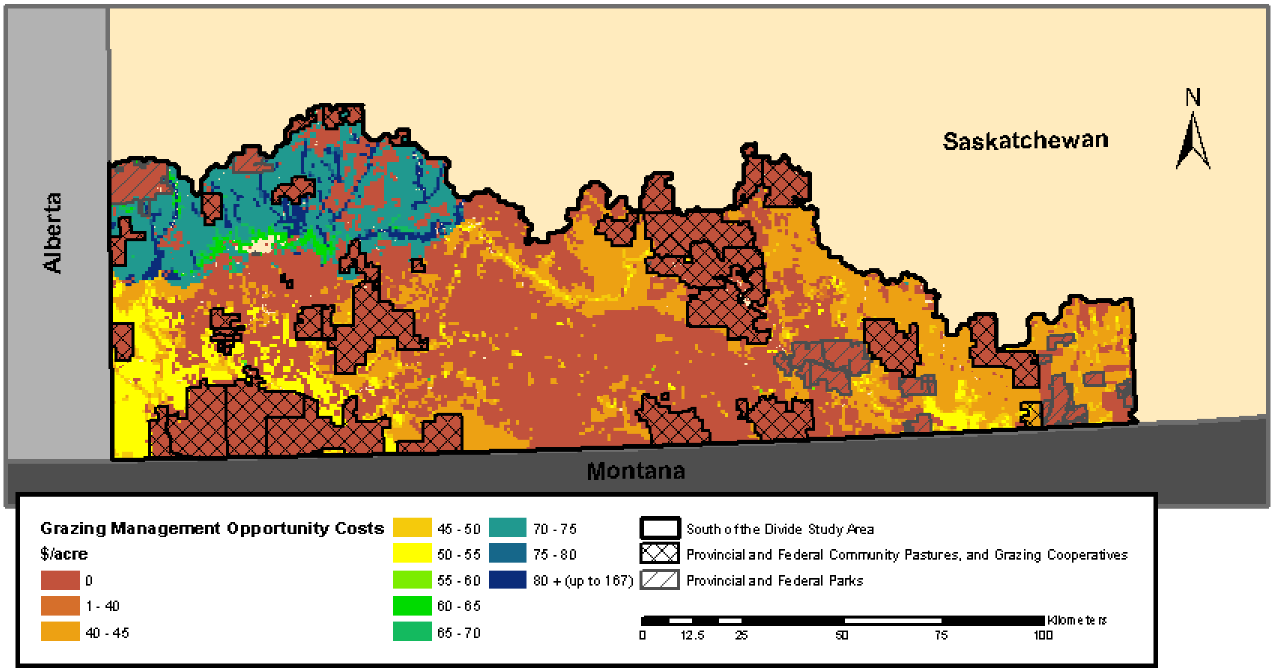

Figure 5.3. The spatial distribution of grazing management opportunity costs in the Milk River Watershed region.

6 Buffer Strips and Shelterbelts

Buffer strips and shelterbelts are a common beneficial management practices (BMP) on already modified agricultural land. Within this report, net present values were calculated for the implementation of buffer strips and shelterbelts within both agricultural annual cropland, and agricultural perennial hay fields. These beneficial management practices are a lower-cost conservation option to land-use conversion.

6.1 Summary of Data

The cost data required to calculate the net present value of the creation and retention of buffer strips, and the establishment and maintenance shelterbelts were collected from several sources. Information on the cost of buffer strips was collected from the agricultural land-use conversion section of this report as well as a reports created by Saskatchewan's Ministry of Agriculture (Saskatchewan Ministry of Agriculture 2007) and Forage Council (Saskatchewan Forage Council 2010). The cost information used to calculate the net present value of shelterbelt establishment was collected from a University of Alberta master's thesis (Trautman 2011). All costs were calculated in 2008 dollars in order to promote consistency with the oil and gas values, agricultural land values, grazing management costs and land conversion costs. Finally, a spatial layer provided by the Saskatchewan Ministry of Environment (Figure 2.3) was used to link buffer strip and shelterbelt costs to the parcels of land on which the beneficial management practices, and therefore costs, would be applicable (i.e., on annual cropland and perennial hay fields).

6.1.1 Buffer Strip

Buffer strips incur two types of costs – the opportunity cost of removing agricultural land from production and creating it into a buffer strip and the direct cost of planting and maintaining a buffer strip. Within cropland, if it is assumed that buffer strips are completely removed from agricultural production (no haying or grazing permitted), the opportunity cost of buffer strips can be estimated using the average price per acre of cropland in the Milk River Watershed which is $271.99/acre (see Section 4.2; Table 4.6). The direct costs of establishing a perennial cover buffer strip composed of vegetation native to the region would cost around $373.88/acre (2008 dollars; see Table 4.8). Therefore, the total per acre cost of converting annual cropland into a native grassland buffer strip is $645.87/acre.

Since hay fields already have perennial cover established, there is no direct cost of establishment and the only relevant costs are opportunity costs, and the opportunity cost is equal to the value of the hay that is left standing. Assuming an average forage yield of 1.5 tonnes/acre within the watershed (Saskatchewan Ministry of Agriculture 2007) and an average value of standing hay equal to $30/tonne (Saskatchewan Forage Council 2010), the opportunity cost of maintaining uncut buffer strips of hay is $45/acre (2010 dollars) or $44.08 (2008 dollars; inflation adjusted using the CPI).

6.1.2 Shelterbelt

Information on the total cost (opportunity and establishment) of shelterbelts in cropland came from a Masters' thesis completed at the University of Alberta's Department of Resource Economics and Environmental Sociology. Trautman (2011) investigated the costs of BMPs, one of which was the planting of shelterbelts, on farms within four soil zones of Alberta – brown, dark brown, black, and dark grey. The brown soil zone model was used to represent the Mixed Grassland ecoregion within the Milk Rivers Watershed, and an average of the dark brown and black soil zone models was used to represent the Cypress Upland ecoregion.

While establishment costs are the same regardless of soil zone, as a result of the varying impact of shelterbelts on annual crop and perennial forage yields, the opportunity cost of a shelterbelt varies across ecoregions and crop types (Trautman 2011). The net present value[31] – including direct[32] and opportunity costs[33] – of shelterbelts on annual cropland is $772.22/acre within the Mixed Grassland ecoregion and $1144.06/acre for the Cypress Upland ecoregion. While Trautman (2011) only considered cropland shelterbelts, a simple conversion was used to adjust these results for hay fields in the study region. If it is assumed that the ratio of opportunity cost to land value is transferable between cropland and hay fields a simple calculation can be done

[31] The net present values were calculated using a discount rate of 0.10.

[32] The tree species considered were Caragana (*Caragana arboescens*) and Green Ash (*Fraxinus pennsylvanica*). The total establishment cost for a shelterbelt is $798/acre ($1972/ha) assuming that the shelterbelt is 12 meters wide and has a 2:1 Caragana to Green Ash planting ratio with all trees planted 60 cm apart.

[33] The opportunity cost of planting shelterbelts is the difference between the total and direct costs of implementing shelterbelts. In the Mixed Grasslands, there is no opportunity cost, but rather a $25.78/acre benefit, from planting shelterbelts. This negative cost is the result of productivity increases as a result of the tree rows. In the Cypress Upland, the opportunity cost of shelterbelts is $346.06/acre.

to find opportunity the cost, and ultimately the total cost, of planting shelterbelts on a quarter section of perennial forages. Since the average value of an acre of hay or pasture land in the watershed is $148.64/acre, the net present value – including direct and opportunity costs – of shelterbelts on perennial hay land is $783.88/acre for the Mixed Grasslands $986.77/acre for the Cypress Uplands.

6.2 Net Present Value Model of Buffer Strips

The buffer strip BMPs were prescribed in two different manners dependent upon whether the current land use was perennial forage or annual cropland. Within cropland, it was determined that a 12 m perimeter of native grassland should be planted around a quarter section. This results in a removal of 9.35 acres of land from production assuming a square, 160 acre quarter section. As a result, the net present value of this BMP (with a 10% discount rate) is $6038.88/quarter section. Within hay fields, the pattern of uncut hay was projected to look similar to the pattern shown in Figure 6.1 below: 2 meters are left uncut around the perimeter of the quarter section and again every 100 meters working toward the centre of the field. The result is 3.94 acres of standing hay remaining in the field which results in a net present value of $1736.80/quarter section (with a 10% discount rate).

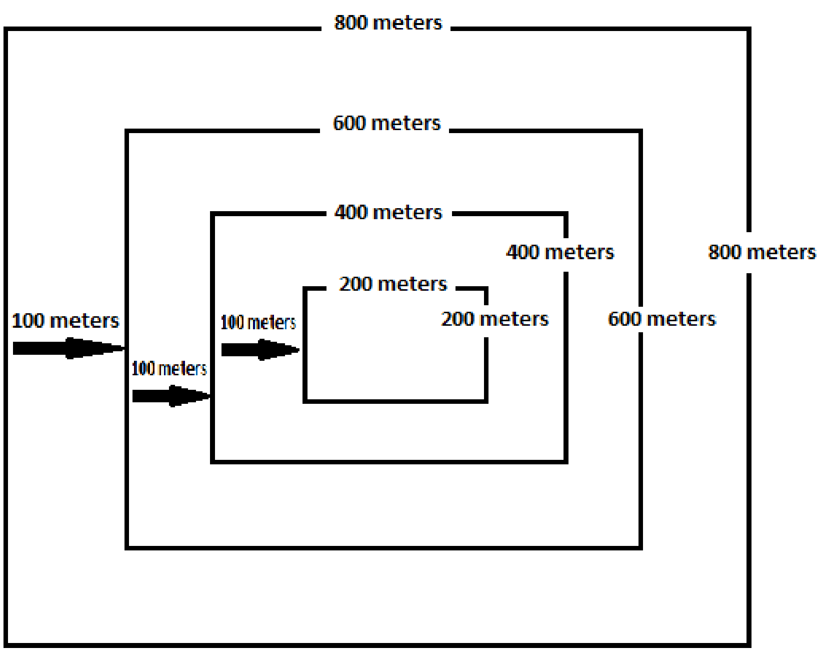

Figure 6.1. Diagram showing the buffer strips of remaining standing hay left on a quarter section.

6.3 Net Present Value Model for Shelterbelts

The shelterbelt BMP specifications were the same regardless of current land-use type. Within both cropland and hay fields, three 12 m wide shelterbelts with a length of 750 meters were specified (~6.67 acres). On cropland, the net present value of the shelterbelt BMP would be $5152.09/quarter section in the Mixed Grassland ecoregion and $7632.79/quarter section in the Cypress Uplands. On hay land, the net present value of the shelterbelt BMP is $5224.81/quarter section of Mixed Grassland and $6581.76/quarter section of Cypress Upland.

7 Net Present Value Summary

The net present values (i.e., costs) associated with conservation activities are summarized in Table 7.1. This table presents information on cost per acre ($/acre) and total cost ($ millions) for the conservation activity. The costs per acre were calculated as an average unit cost for only the quarter sections on which the activity is applicable. As a result, these unit costs are higher than they would be if averaged across the entire Milk River Watershed region. Total cost is presented for two scenarios: (1) protection of the entire Milk River Watershed region and (2) protection of the proposed critical habitat area shown in Figure 2.5.

Table 7.1. Projected unit costs (2012$/acre) and total costs (millions of 2012$) for a subset of conservation activities within the Milk River Watershed. Costs are net present values discounted into perpetuity.[34]

	Unit Costs ($/acre)[a]			Aggregate Costs ($ million)	
Conservation Activity	**Direct**	**Opportunity**	**Total**	**Entire Region**	**Only Critical Habitat**[b]
Prohibit future oil development	-	40,000	40,000	165	1
Prohibit future natural gas development	-	15 - 187	15 - 187	37 – 480	27 – 292
Halt all current oil wells	-	6,300[c]	6,300	260	54
Halt all current natural gas wells	-	505 – 1,225	505 – 1,225	58 – 141	40 – 98
Permit future oil and natural gas wells only on current existing lease sites	129 – 161[d]	6 – 79	135 – 239	50 – 231	26 – 145
Remove privately owned agricultural land from production	-	C: 286[e] H:156	C: 286 H: 156	403	135
Implement conservation easements on privately owned land[f]	C: 57 H: 32	-	C: 57 H: 32	80	26
Re-vegetate hay and crops to native pastureland	C: 392 H: 412	C: 75 H: 53	C: 467 H: 464	496	166
Re-vegetate hay and crops to native grassland and remove from production	C: 393 H: 412	C: 286 H: 156	C: 678 H: 568	1,094	492
Reduce current livestock stocking rates to recommended stocking rates	-	DMG: 32 – 95 CU: 44 – 183	DMG: 32 – 95 CU: 44 – 183	82	59
Re-vegetate a 12 meter (~9 acres) perimeter around crop fields to native grassland species	393	286	678	44	15
Retain strips of uncut hay in hay fields	-	463	463	0.09	0.05
Plant and establish shelterbelts in hay fields	838	DMG: -15[g] CU: 198	DMG: 823 CU: 1,036	0.3	0.2
Plant and establish shelterbelts in crop fields	838	DMG: -27 CU: 363	DMG: 811 CU: 1,201	40	14

a. These costs per acre are calculated for only those acres on which the costs are applicable and not as an overall average across the region. Unit costs would be substantially lower if averaged across the entire study region.
b. The critical habitat costs reflect the cost of protecting all quarter sections, in their entirety, that are intersected by the critical habitat polygons designed and provided by the Canadian Wildlife Service in October, 2011 for the following species: Burrowing Owl, Loggerhead Shrike, Mountain Plover, Sprague's Pipit, Greater Sage-Grouse, Swift Fox, Black-footed Ferret and Eastern Yellow-bellied Racer.
c. The oil and gas opportunity costs do not include the costs of reclaiming current lease roads, well sites, etc. They are the result of a calculation reflecting the potential for foregone profits, royalties and taxes.
d. This number reflects the added cost of directional and/or horizontal drilling ($25,000/well as reported in MacFarlane, 2007) required to cluster wells on lease pads with existing wells (assumes resources can be extracted up to 800 m from the well head).
e. Within this table, the following codes are used: DMG = Dry mixed grassland; CU = Cypress upland, C = Cropland, H = Hayland
f. Conservation easements in the region were valued at 20% of the market value of agricultural land.
g. Negative opportunity costs reflect increases in crop and hay production within the dry mixed grass prairie as a result of the presence of shelterbelts.

[34] Costs calculated in 2008 dollars within this analysis were updated by converting them from 2008 to 2012 dollars using the Canadian consumer price index (CPI) for 2008 (115.8) and July, 2012 (121.5).

8 Conclusions

This paper provided comprehensive information on the methods used to calculate the economic costs (opportunity and direct) of conservation activities that strive to maintain and/or improve the quantity and/or quality of native grasslands within the study region. There are many additional conservation actions that can, and will likely, be implemented in the Milk River Watershed including research, communication and extension with landowners and managers, captive breeding and translocation programs, and disease control measures among many others. This document, however, has focused on the actions that result in the provision of native grassland habitat by focusing on the economic costs of modifying the region's two largest economic sectors – oil and natural gas, and agriculture. The next step was to use these economic costs in a set of mathematical programming models designed to create least-cost conservation plans for species at risk in the Milk River Watershed (Entem *et al.* 2003), and to ultimately create a comprehensive benefit-cost analysis that will inform future conservation endeavors in the Milk River Watershed.

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