MAPPING WILDERNESS CHARACTER IN THE MUSKWA-KECHIKA MANAGEMENT AREA

by

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Abstract

Mapping Wilderness Character in the Muskwa-Kechika Management Area

Wilderness is an abstract concept containing both an ecological component more generally referred to as naturalness, and a social/human component attributed with recreation; it varies geographically, culturally and jurisdictionally. This thesis focuses on a case study of the Muskwa-Kechika Management Area (M-KMA) in northern British Columbia, Canada where maintaining wilderness is central to the vision. Previous mapping within the M-KMA has focused on wildlife and resource values, whereas this thesis aimed to define and map the wilderness character of the M-KMA. This thesis assesses the current state of wilderness to potentially examine changes over time and to spatially compare wilderness with other uses such as resource potential. When wilderness character data are separated into categories (lower, moderate, high and very-high), 55% is represented in the very-high quality category and only 9% by the lower category. In addition, there is 26% overlap between high resource potential values and very-high wilderness values.

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Chapter 1: Introduction

It was a cool autumn day and the sun was shining. As we travelled through different environments, I observed the colors of trees fade from the grey of aspen to the dark blue-green of firs atop my sturdy horse Tony. There were sounds and signs of wildlife all around as we climbed the trail through natural mineral licks, low-lying wetlands, and forest into the mountains. Tony and I climbed higher and higher up, and as the faint laughter of the group faded behind us a cold, heavy breeze passed by bringing autumn smells of wild berries ripening, dew forming, and the slow decay of organic matter. I'll never forget that feeling of tranquility when at that moment, Tony and I trotted through the alpine tree layer into the high mountain range above. Looking back down the valley, it was the first time I was truly feeling the Muskwa-Kechika Management Area; I felt peace, I felt pride, I felt wonder, I felt the enormity of life, and I felt alive. I remember pondering how the mountains formed, what wildlife and adventures could lay beyond each range, whether this land would remain forever a true wilderness area and whether my stewardship to help conserve wilderness could help.

In the past, wilderness narratives commonly refer to the absence of human intervention and influence on the land being integral to the wilderness concept. Today, global threats such as population growth, biodiversity loss, and climate change have unintentionally affected or altered wilderness areas world-wide and will continue to provide added pressures on wilderness areas and land stewards through this century (Wohl, 2013). Thus, human intervention on the land is now an unavoidable circumstance of human influence on the world's resources. The world's finite resources such as viable land, raw materials, and biophysical resources are limited to the number of people that they can support and ultimately maintain over time. Already added pressures are put on terrestrial crops and industrial farms to feed the growing population, as 87% of the world's marine fisheries are fully exploited or depleted (Wohl, 2013). Projections have estimated that the number of people that the Earth's resources can maintain is 7.7 billion people, with each plot of viable land being used agriculturally to sustain the population, and thus leaving no wilderness areas (Van den Bergh & Rietveld, 2004). Subsequently, with all the external pressures on both terrestrial and aquatic wild ecosystems, wilderness areas are currently facing drastic decline.

Watson et al. (2016) reported that there is only 23.2% (30.1 million km^2) of terrestrial wilderness remaining globally. Of which, in the last two decades, there has been an accelerated loss of 9.6% or 3.3 million km^2. Most wilderness lands left are in North America, North Asia, North Africa, and Australia (Watson et al., 2016). In a perfect world, the remaining wilderness lands would have an equal representation of the earth's 14 terrestrial biomes. However, of these biomes, three such biomes located in the tropics already have no wilderness remaining and five biomes only have 10% wilderness remaining (Watson et al., 2016). Of the remaining wilderness area, there are still 350 significantly large wilderness blocks (areas of at least 10,000 km^2), but they are all facing both natural and anthropogenic influences, as 74% of the blocks are experiencing significant erosion and the largest block in the Amazon basin has had a 30% loss of surrounding wilderness since the 1990s (Watson et al., 2016).

With such large-scale ecosystem alterations, it is apparent that global biodiversity loss is adversely affected by both population growth and expansion. Today, the annual loss of animal and plant biota is 1000 times greater than previous historic global extinctions (Gorenflo, Romaine, Mittermeier, & Walker-Painemilla, 2012). Since the 1992 Rio Earth Summit[1], several international agreements have been made to conserve wilderness areas and now new agreements

[1] The Rio Declaration on Environment and Development (1992). Retrieved from: http://www.unesco.org/education/nfsunesco/pdf/RIO_E.PDF

such as the Aichi Targets of The Strategic Plan for Biodiversity 2011-2020[2] have put protected area creation on new ground (Watson et al., 2016). However, the rate of wilderness loss globally is still greater than protected area creation (Watson et al., 2016). Wilderness stewards and managers face difficult tasks in maintaining wilderness characteristics and values as increasing populations and technological advances bring people into more remote areas. Therefore, learning new adaptive approaches on how to manage, monitor and maintain wilderness values through the next century is becoming increasingly important (Ward & Green, 2015; Wohl, 2013).

1.1 The Evaluation of the Wilderness Concept

Historically, in the Western world 'wilderness' has been viewed by two contrasting ideologies – a horrific, desolate space where humans dare not go on their own accord, or a symbol of sublimity, of godly power (Cronon, 1996). The word wilderness originates from the word 'wilderones', which was transformed from the Old English word 'wilderor', meaning 'wild beast' (Semcer & Pozewitz, 2013). In 1949, Aldo Leopold wrote *A Sand Country Almanac* describing wilderness as:

> "To the laborer in the sweat of his labour, the raw stuff on his anvil is an adversary to be conquered. So was wilderness an adversary to the pioneer. But to the laborer in response, able for a moment to case a philosophical eye on his world, that same raw stuff is something to be loved and cherished, because it gives definition and meaning to his life" (Leopold, 1949, 188 *In* Klein, 1994, 1).

This quote sums up the two views of wilderness in North America: the first, the view of colonizers that the land is something to be conquered and transformed into a 'frontier'; the second, a more recent and modernistic view of the land, that it should be preserved and conserved for how it enriches lives (Klein, 1994). These differing Western ideas of wilderness

[2] The Aichi Targets for the Strategic Plan for Biodiversity. Retrieved from: https://www.cbd.int/sp/

vary since the concept of wilderness is complex and interpretation of wilderness varies resulting in different definitions and management techniques.

The term wilderness is often used synonymously with park or protected area, or even more generally to refer to land that is undeveloped or has a relatively minimal human footprint (as per Wohl (2013) and Watson et al. (2016) above). In this thesis, I use the word wilderness to refer to the least developed areas of the planet. Although some wilderness may be designated as parks or protected areas, others are not. Additionally, much of the area within parks and protected areas is more developed than the wilderness ideal discussed here.

The United States (US) pioneered the conservation of wilderness places through the enactment of the *Wilderness Act (1964)*[3] (Wilderness Act of 1964*,* 2017). At its enactment, 54 legislated wilderness areas were created, colloquially referred to as 'big W Wilderness' (as opposed to other land not legislatively designated, referred to as 'small w wilderness'). Today, the US National Wilderness Preservation System (NWPS) is comprised of 796 Wilderness areas (Landres et al., 2015). These Wilderness areas are monitored and managed through an inter-agency monitoring strategy involving several agencies: The Department of the Interior's Bureau of Land Management, the Fish and Wildlife Service, the National Park Service, and the Department of Agriculture's Forest Service. While the National Park Service manages designated Wilderness areas within the National Parks, not all National Parks are considered wilderness areas. Today, participating US agencies work to monitor Wilderness areas guided by a 2008 publication of *Keeping It Wild: An Interagency Strategy for Monitoring Wilderness Character Across the National Wilderness Preservation System*, which outlined a strategy for inter-agency cooperation to assess whether wilderness character is being preserved (Landres et al., 2008).

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[3] The US Wilderness Act. 1964. Retrieved from http://www.wilderness.net/nwps/legisact.

Wilderness is an abstract concept that contains both an ecological component more generally referred to as naturalness or having ecological integrity, and a social/human component attributed closely with recreation. The wilderness idea differs geographically, culturally and jurisdictionally; it contains tangible, intangible, legal, personal, spiritual, societal and national dimensions (Landres et al., 2015). Thus, planning and managing a specific wilderness area necessitates definition, and then ultimately assessment and monitoring, of the associated wilderness characteristics. In northern British Columbia (BC), protection of a wilderness area spanning over 4 million hectares has driven dedicated stewards, traditional Indigenous-rights holders and stakeholders to work with the BC government to maintain the unique wilderness values intrinsic to the area (Muskwa-Kechika Advisory Board, 2015).

1.2 The Muskwa-Kechika Management Area

Written into law in 1998 by the BC government through the Muskwa-Kechika Management Act, the Muskwa-Kechika Management Area (M-KMA) was intended to showcase a world class model for land planning and management (Muskwa-Kechika Advisory Board, 2015). The vision for the M-KMA developed by the Muskwa-Kechika Advisory Board in a strategic planning process states: "the M-KMA is a globally significant area of wilderness, wildlife, and cultures, to be maintained in perpetuity, where world class integrated resource management decision-making is practiced ensuring that resource development and other human activities take place in harmony with wilderness quality, wildlife and the dynamic ecosystems on which they depend."

The objective of this vision was to allow for the M-KMA to be a model of sustainability by protecting large, intact areas of wilderness while allowing for economic activities that would support the surrounding communities (Muskwa-Kechika Advisory Board, 2013). In order to protect important ecosystems and large ecological processes within the wilderness, over 17,000 km^2 in 13 new provincial parks and over 4 million hectares of different Resource Management Zones were created (Crane Management Consultants, 2008; Rutledge & Davis, 2005). At the time, this combination of protected areas, provincial parks and special resource management zones was the most innovative planning process that BC had embarked on (Rutledge & Davis, 2005).

Central to the management ethos of the area, the preamble to the M-KMA Act cites the centrality of wilderness noting:

> "WHEREAS the Muskwa-Kechika Management Area is an area of unique wilderness in northeastern British Columbia …AND WHEREAS the management intent for the Muskwa-Kechika Management Area is to maintain in perpetuity the wilderness quality…AND WHEREAS the long-term maintenance of wilderness characteristics, wildlife and its habitat is critical to the social and cultural well-being of first nations and other people in the area" (Province of British Columbia, 1998).

As defined in the 1998 M-KMA Act, wilderness is referred to by modifiers 'unique' and ascribed non-specific 'qualities' and 'characteristics'. The notion of wilderness within the M-KMA is clearly somewhat different than other definitions of wilderness (e.g., the US Wilderness Act of 1964) because outside of the protected areas resource development is permitted and yet, as per the preamble of the Act, the management intent is to "maintain in perpetuity the wilderness quality… while allowing resource development" (Province of British Columbia, 1998). Therefore, colloquially, the M-KMA has been described as a Working Wilderness.

1.2.1 Managing Wilderness in the Muskwa-Kechika Management Area

To aid in understanding and thus managing for wilderness, the legislatively created M-KMA Advisory Board (M-KAB) has developed a wilderness vision and other supporting documents and studies. The first wilderness definition was developed and ratified by the M-KAB in 2004 and outlines that wilderness in the M-KMA contains two inter-related concepts:

> "I) an ecological system maintaining its ecological integrity, based on best scientific analysis, and
>
> II) a large area perceived by humans to be natural or wild, based on anthropocentric criteria" (Muskwa-Kechika Advisory Board, 2004).

This definition specified characteristics of what wilderness is in the M-KMA more clearly but did not define wilderness in sufficient detail for monitoring and assessment. Given that the concept of wilderness within the M-KMA has spatial and temporal variability and that wilderness conditions are intended to be maintained, monitoring and assessment of wilderness condition over time and space is a key need. In addition, as planning and analysis is conducted for resource use within the M-KMA (e.g., mining, wind, forestry, recreation), understanding the wilderness values within the M-KMA and how they are, or may be, affected by other resource uses is critical. In short, developing an approach to describe and assess wilderness that is compatible with other resources and uses in the M-KMA can help put the abstract concept of wilderness on a level playing field.

1.3 Purpose and Research Questions

The purpose of my research project was to develop an approach to map and monitor wilderness values for the Muskwa-Kechika Management Area and examine the wilderness values relative to other resource values to understand differences in wilderness condition over space and time. More specifically, I was guided by the following research questions:

1) What are the criteria and indicators of wilderness within the M-KMA that adequately represent the unique ecological and social characteristics of the area?

2) What are the data sources that are practical, measurable and meaningful to assess wilderness condition?

3) How can the indicators of ecological and social characteristics of wilderness be mapped and subsequently, the overall wilderness character be mapped?

4) Can the data from these indicators be combined in a meaningful and spatially compatible way to express different kinds of wilderness values/experiences and be compatible and comparable with other resource value mapping?

1.4 Study Significance

Northern British Columbia has economic potential as it contains 70% of BC's land but houses only 7.7% of the population. Since the 1920s, resource development and extraction have been the foundation for the economy when fur trade trails linked northern BC to the international trade network (Northern Health, 2013). Prior to the 1950s the northern BC landscape was vast and open with small rural communities. The 1950s to the 1980s was a period of economic growth in northern BC, as the forest industry expanded in the area making BC timber an international commodity. The boom continued into the end of the 20^{th} century bringing in mining and power generation, as Canadian policies such as the Free Trade Agreement and the North American Free Trade Agreement allowed international companies to deliver the same amount of resources with lower cost (Northern Health, 2013). In addition, through northern development initiatives over $50 million have been spent on over 350 different projects since 2005 (Initiatives Prince George Development Corporation and Northern Development Initiative Trust, 2009).

Within the province at large and the northeast part of the province specifically, developments such as oil and gas exploration, forestry, wind power, and mining outside of the M-KMA have had a significant impact on intact forests and wilderness values (Noss, 2002). Today, the area continues to be a place for resource development to thrive as the forest and oil and gas industries are substantively invested in the area. Currently, new renewable energy sectors are also looking at northern BC for potential; one wind farm is already generating electricity and another large hydro-electric dam is suggested (Larson & Yip, 2013). In addition, large pipeline proposals are proposed to cross large sections of northern BC that would span 4,000 km and transport more than 700,000 barrels of oil, gas or condensate per day (Figure 1) (Levy, 2009).

My research provides a means of not only assessing the current state of wilderness within the M-KMA, but it can also be used to examine changes over time, and can be used in combination with other resource value mapping (see for example Suzuki & Parker, 2016).

1.5 Thesis Structure

My thesis addresses the concept of wilderness through both an ecological and social lens and how to spatially represent these indicators of wilderness to display the extent and variability of wilderness in the Muskwa-Kechika Management Area. Following this introduction to wilderness, Chapter 2 introduces the case study area and provides a description of the M-KMA. I then provide a literature review in Chapter 3 that addresses what wilderness is through a review of previous and current definitions of wilderness. I then address methods used to previously map wilderness globally and nationally and discuss why wilderness mapping has been, and continues to be, important. Chapter 4 provides an overview of the approaches I used to model and map wilderness. It will addresses criteria and indicator development for ecological and social indicators of wilderness, data collection and assessment, and early model review. Following, Chapter 5 will discuss in more detail the spatial model for each indicator and the human footprint maps, as well as the methods used to merge each indicator into the final map. In Chapter 6 I present several results including each individual indicator map, the human footprint maps, and the final map of Wilderness Character in the M-KMA. Next, I compare my final map to other resource values in the M-KMA to address overlap. Lastly, in Chapter 7 I discuss data collection and assess completeness and accuracy, outline benefits of this spatial model and the final maps and provide several recommendations before concluding the thesis.

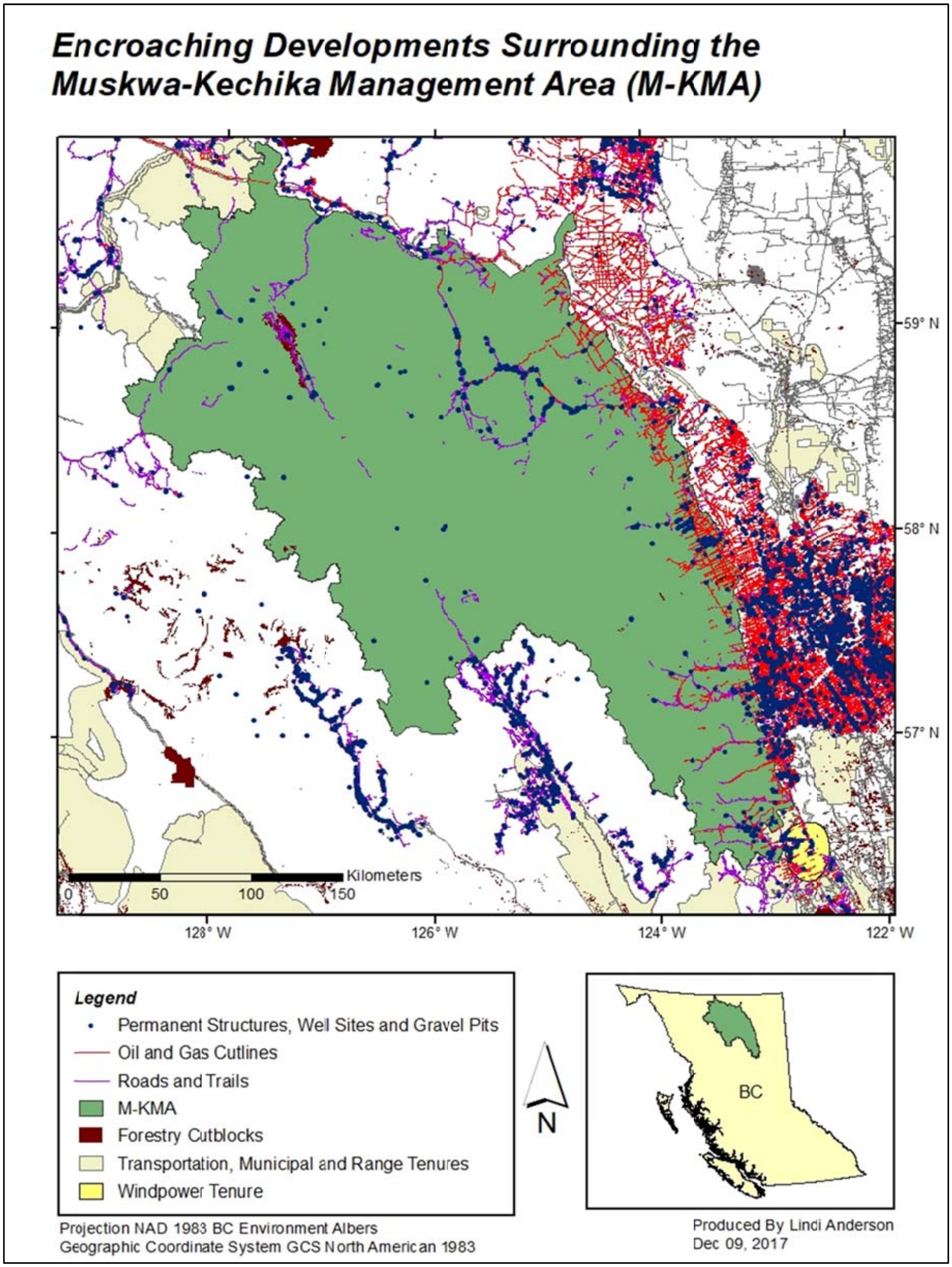

Figure 1. Encroaching Developments Surrounding the Muskwa-Kechika Management Area, Northeastern British Columbia.

Chapter 2: Case Study of the Muskwa-Kechika Management Area

2.1 Physiographic and Ecological Profile of the Case Study Area

The Muskwa-Kechika Management Area (M-KMA) is in northeastern British Columbia in the Cordilleran Region, which lies along the Foreland and Omineca belts where the Northern Rocky Mountains and the Cascades of the west meet the muskeg and boreal plains that continue towards eastern Canada (Figure 2). Glacial processes that shaped the area have created geological formations such as scenic valleys and rugged mountain tops, hoodoos, glaciers, and hot springs (Muskwa-Kechika Advisory Board, 2015). Although the M-KMA was named for two major rivers flowing through the area, the Muskwa River and the Kechika River, it is transected with numerous other large rivers including the Frog, Finlay, Fox, Liard, Prophet, Rabbit, Halfway, Toad, Tuchodi, Turnagain, Chief and Sikanni rivers (Crane Management Consultants, 2008). The high mountain ranges and rich valley bottoms have allowed for the continual support of one of the largest predator-prey systems in North America as low road density, restricted motorized access, and restrictions on industrial development have enabled these large ecosystems to remain in a relatively natural state (Muskwa-Kechika Advisory Board, 2015). Often referred to as the "Serengeti of the North", the M-KMA supports tremendous biodiversity; large mammals include grizzly bears, black bears, moose, northern woodland caribou, mountain goats, Stone's sheep and wolves. In addition, the largest bison herd in North America inhabits the area for part of the year (Crane Management Consultants, 2008). The M-KMA contains several different biogeoclimatic ecosystem classification (BEC) zones including the alpine tundra (AT), boreal white and black spruce (BWBS), Engelmann spruce-subalpine fir (ESSF) and spruce-willow-birch (SWB) (Muskwa-Kechika Advisory Board, 2015).

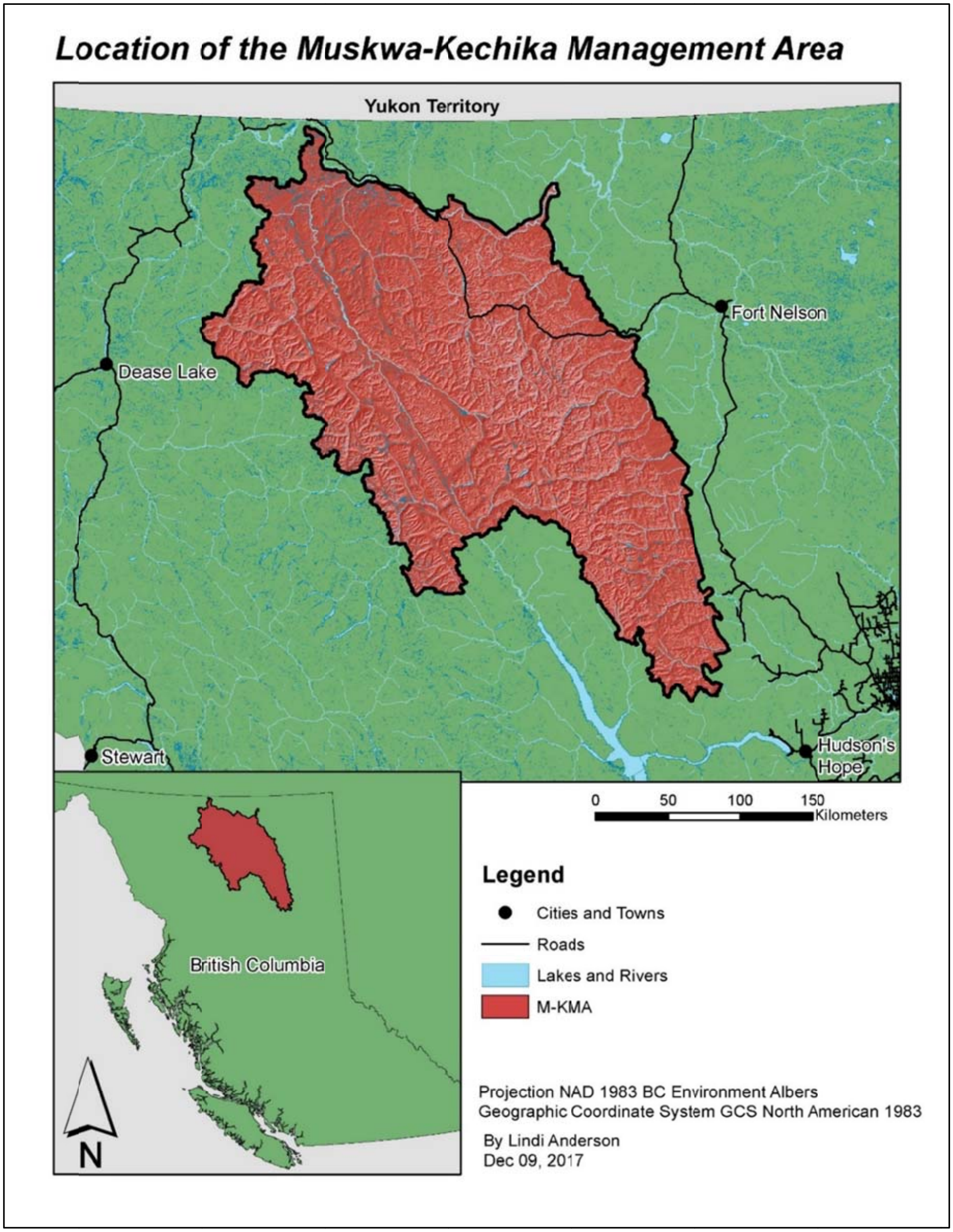

Figure 2. Location of the Muskwa-Kechika Management Area (M-KMA) in Northeastern British Columbia.

2.2 Legislation

Dedicated stakeholders at land and resource management planning (LRMP) tables in Fort Nelson (1997), Fort St. John (1997), and subsequently Mackenzie (2000), worked in collaborative planning processes and arrived at a consensus on how the land was to be managed. After the LRMP process was completed, the area was designated through the *Muskwa-Kechika Management Act* (Bill 37) in 1998 (Province of British Columbia, 1998; Rutledge & Davis, 2005). The M-KMA Act outlined the M-KMA management model and the central wilderness concept integral to its creation, recognized inclusion of First Nations, and emphasized needed scientific research and pre-tenure planning requirements (Crane Management Consultants, 2008). This guided the framework for *The Muskwa-Kechika Management Plan* (M-KMP). In 2001, the completion of the Mackenzie LRMP added an additional million hectares to the M-KMA bringing the size of the management area to over 6.3 million hectares (Rutledge & Davis, 2005).

2.3 Governance

The M-KMA Act acknowledges the traditional territories of the Carrier-Sekani, Kaska Dena First Nations, and Treaty 8 First Nations within the management area. Each traditional territory supports many communities found within or adjacent to the M-KMA (Muskwa-Kechika Advisory Board, 2015). Prior to the creation of the M-KMA, a formal letter of agreement was drafted between the BC Government and the Kaska Dena Council, which acknowledged recognition of the Kaska Dena's rights and obligations to the area, their culture and heritage and their right to fish and hunt for sustenance and profit. Although the Kaska Dena was the first to complete a letter of understanding, the M-KMA Act acknowledges the "long term maintenance of wildlife characteristics, wildlife and its habitat is critical to the social and cultural well-being of

First Nations and other people in the area" (Province of British Columbia, 1998[4] *In* Crane Management Consultants, 2008: 12).

Through the legislation of the *Muskwa-Kechika Management Act* the Muskwa-Kechika Advisory Board (M-KAB) was created and several responsibilities were assigned to the Board. Along with advice to the BC government on planning and management of the area, the M-KAB also makes recommendations on research and expenditures and ensures that all activities taking place within the management area are within compliance of the M-KMA Act (Crane Management Consultants, 2008). Made up of non-governmental representatives, First Nations, local stakeholders and industry stakeholders, the M-KAB created and follows a *Strategic Direction and Operational Plan*, which defines the goals and objectives to be accomplished in each fiscal year (Muskwa-Kechika Advisory Board, 2013). In addition, there are also a number of Advisory Board sub-groups including the Wilderness Working Group and the M-KMA - University of Northern British Columbia (UNBC) research partnership group (Crane Management Consultants, 2008).

2.4 Resource Management Zones

The M-KMA includes a mix of land use designations including parks and protected areas and areas where resource extraction is allowed if wilderness and wildlife values can be maintained. Figure 3 depicts these zones including: Protected Areas, Special Wildland Resource Management Zones, Special Resource Management Zones and Enhanced Resource Management Zones (Muskwa-Kechika Advisory Board, 2013) (descriptions of these land designations in Appendix A and B: Figure B1).

[4] Province of British Columbia. 1998. British Columbia, Bill 37: Muskwa-Kechika Management Area Act, Victoria.

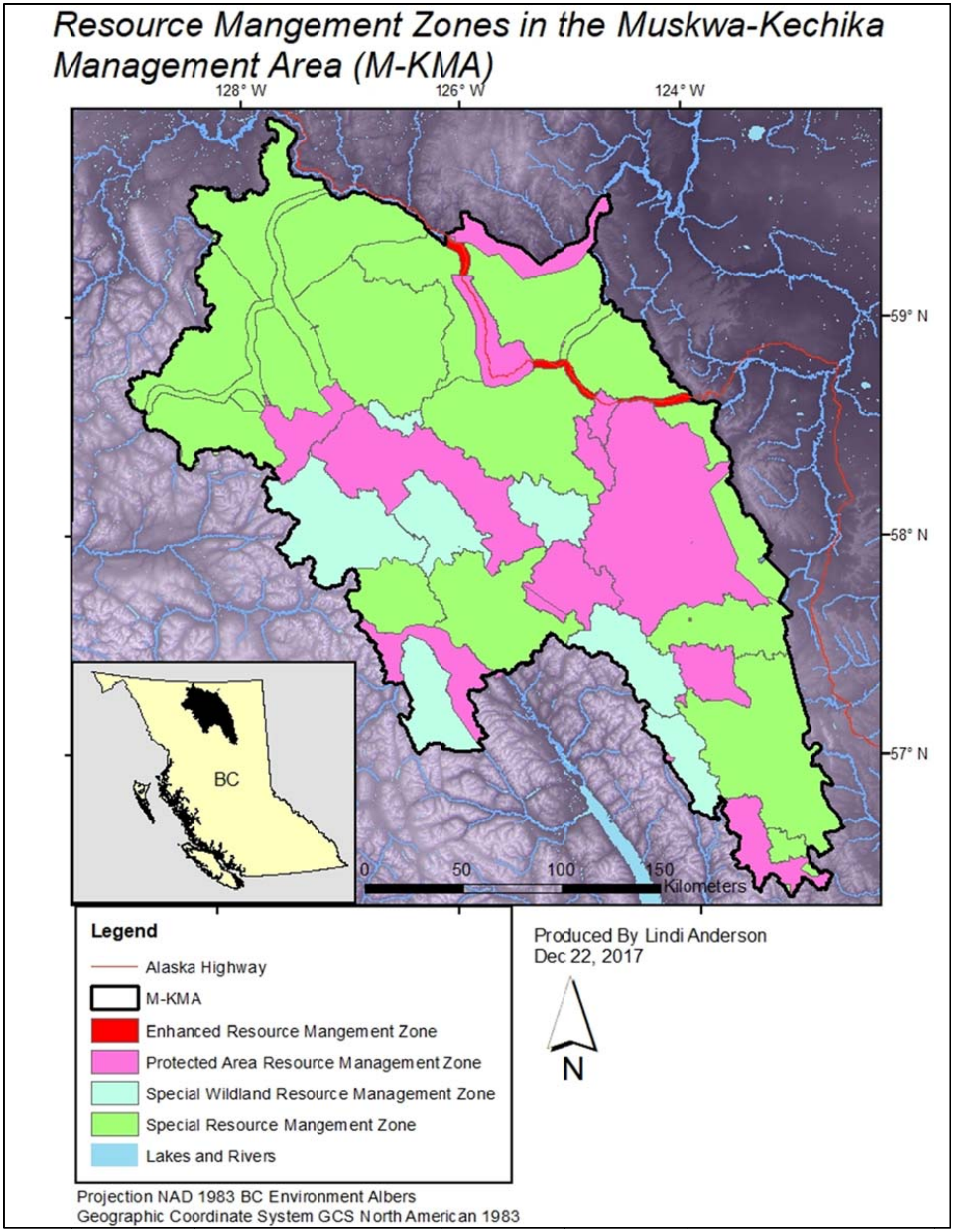

Figure 3. Resource Management Zones in the Muskwa-Kechika Management Area (M-KMA), northeastern British Columbia (BC).

2.5 Wilderness Recreation

The unique physiography and remoteness of the M-KMA allows for spectacular recreational opportunities. Along the eastern edge, the area has numerous campsites and built facilities for 'rubber-tire' travelers camping or stopping along the well-travelled Alaska Highway. Throughout the M-KMA, numerous guide outfitters cater to a range of recreationists by providing different activities such as hunting, camping, fishing and trail riding. Although there are a variety of tourists and tourism, most activities in the M-KMA can generally be characterized as wilderness recreational activities (Rutledge & Davis, 2005).

As a whole, the M-KMA can be described as providing a wilderness setting, but the opportunities available to recreationists vary greatly by remoteness of the location. The vast size of the M-KMA makes it difficult to provide recreational opportunities over the whole area. The *Local Strategic Recreation Management Plan for the Muskwa-Kechika Management Area (2005)* for the Muskwa-Kechika Management Area was developed to provide managers with guidelines for evaluating recreational applications and the appropriateness of different recreation access methods and uses in each of the Resource Management Zones (RMZ) in the M-KMA[5] (Rutledge & Davis, 2005). The Plan outlined the following six different recreation categories for the RMZs that represent one way to differentiate between recreation settings in the M-KMA (Rutledge & Davis, 2005):

1. Small Provincial Park
2. Large Remote Resource Management
3. Major River Corridors
4. Large Resource Management Zones
5. Alaska Highway Corridor

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[5] See Appendix C for a complete table of the Recreation Category appointed to each Resource Management Zone, the First Nations and cultural heritage values, the important features/facilities/trials, estimated current recreation value, current access mode, the estimated current public activities and use levels, estimated current commercial activities/ use levels, the forecasted public and commercial recreation activities/use levels, environmental considerations for the area and also other factors.

6. First Nation Community Core.

Each of these six categories provides different recreational opportunities depending on their recreational supply. The recreation supply is the recreation resources needed to meet the demand for wilderness recreational experiences. Given the remote nature of the M-KMA, much of the recreational needs are facilitated by guides and outfitters. In addition to guided wilderness recreation, the M-KMA is the setting for a variety of organized recreation opportunities from hunting, camping and ATV use to hiking and boating (Garrity, 2013). Table 1 shows the number of Commercial Recreation Park Use Permits in the Muskwa-Kechika (Garrity, 2013).

Table 1. Commercial Recreation Park Use Permits in the M-KMA in 2005

Activity	Number
Trail Riding	1
Fishing, and water activities	2
Guide Outfitter	17
Air Transportation	7
Transporter	3
Total	30

Of the seventeen guide outfitters above, fifteen offer adventure or eco-tourism activities in addition to commercial hunting. In the whole of the M-KMA the province has allotted 32 Adventure Tourism Policy tenures (Garrity, 2013). Of these tenures, twelve are extensive recreational use sites which span 300 hectares or greater and twenty are 10 hectares or less. The majority of the tenures are located in the Peace area, but two are in the Skeena region and two are in the Omineca region of the M-KMA. The number of recreation users per tenure is not known (Garrity, 2013). Guide outfitters offer a wide array of wilderness recreational activities including fish camps, guided rafting, nature viewing, recreation reserve, multiple use, trail riding, and hunting camps (Garrity, 2013). Outside of limited reporting of overnight use numbers in some of the parks, recreation use levels are by and large not being tracked in the M-KMA.

2.6 Wilderness Legislation, Policy and Guidelines

Legislation for the Muskwa-Kechika Management Area highlights wilderness sustainability as a key purpose identifying management goals to maintain the wilderness quality. *The Muskwa-Kechika Management Area Act* and the *Muskwa-Kechika Management Plan Regulation* outline local strategic plans that must comply with the general management intent for the area (Province of British Columbia, 1998; Province of British Columbia, 2002). The General Management Direction for the M-KMA is:

> "The management intent for the Muskwa-Kechika Management Area is to ensure wilderness characteristics, wildlife and its habitat are maintained over time while allowing resource development and use, including recreation, hunting, timber harvesting, mineral exploration and mining, oil and gas exploration and development" (Province of British Columbia, 2002: Section 7(1)).

Tasked with developing a definition and guidance for wilderness management, the Muskwa-Kechika Advisory Board (2004) originally described wilderness as containing two inter-related concepts: I) an ecological system maintaining its ecological integrity, based on best scientific analysis, and II) a large area perceived by humans to be natural or wild, based on anthropocentric criteria. This definition has now been refined and the latest draft of the wilderness definition defines wilderness as, "a large natural landscape where the integrity of the ecological systems is maintained" (Muskwa-Kechika Advisory Board, 2015). The M-KMA Act further clarifies wilderness to include wilderness characteristics. Wilderness characteristics for the M-KMA are outlined in the preamble of the M-KMA Act as,

"(I) a natural appearing landscape where evidence of human is not readily apparent, (II) a high probability of experiencing solitude, and (III) ecological integrity".

Legislation written by the Province of British Columbia outlines the management intent for each RMZ, but with the complexity and diversity of the M-KMA more specific knowledge is needed to effectively define the wilderness nature of those areas, particularly relative to proposed resource development projects. With a more informative knowledge base, the M-KAB as well as government decision-makers could provide proponents with guiding principles and recommendations for maintaining wilderness over time (Muskwa-Kechika Advisory Board, 2015).

Chapter 3: Literature Review

3.1 Introduction

Starting with a brief overview of the concept of wilderness, this literature review focuses on different jurisdictional approaches to defining wilderness. This is followed by a review of the ecological and social components of wilderness. Finally, I examine several different approaches to mapping wilderness condition (Figure 4).

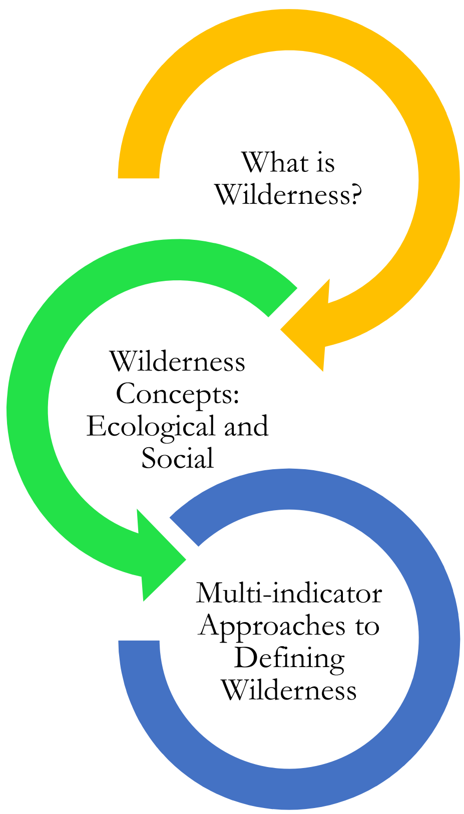


Figure 4. Outline of the Literature Review.

3.2 What is Wilderness?

Wilderness, like justice, is an abstract concept. Individual and cultural perceptions of wilderness vary and thus clarity and definition are needed to proceed to the stage of monitoring and mapping of wilderness character. Throughout the 20th and 21st centuries the concept of wilderness has been viewed both as a "place that is *free* and as a place in which one can be *free*" (Aplet et al., 2000: 90). The juxtaposition of wilderness, both as a place and an experience stems from the varying societal cultures of the world having different perceptions of what 'wilderness' is (Aplet et al., 2000).

The word and concept 'wilderness' is very specifically a term of European origins and it remains generally a Euro-western term. First viewed as a desolate place and something to be conquered, this view of wilderness evolved into a place to be cherished, preserved and explored (Klein, 1994). For the Athabascan peoples of northern British Columbia (BC) who have historically inhabited the study area since time immemorial,[6] "there is no such place as wilderness" (Johnson, 2000: 304). Experience and interaction with the land can alter one's perception of it and the Athabascan people think of the land as a cultural identity (Henderson, 1992). Indigenous peoples view the landscapes as both a part of their history and culture passed down through language and stories. Simply denoting an area as wilderness cannot encompass the cultural and spiritual significance of the land (Cruikshank, 2005). Klein (1994) goes as far as suggesting that creating specific areas of 'wilderness' in territories previously or currently occupied by indigenous peoples, is ignorant and insensitive to those cultures. Although the idea of wilderness as a place is primarily a Euro-western, white-elitist idea, the need to protect a

[6] This thesis uses the Athabascan interpretation of wilderness as their traditional territory spans my study area. The Athabascan people, or Na Dene, arrived in North America after the last Ice Age. Traversing by boats or walking the Bering Strait, these people arrived in the Alaska-Yukon subarctic area where they remained until AD 750 when a volcano eruption dispersed the Athabascan phylum (www.fourdir.com, n.d.). Today, the Athabascan people are also known as the Na-Dene and their languages range from Alaska and northwestern Canada south to the Rio Grande (Encyclopedia Britannica, 2009).

natural place can be mutually agreed upon. The M-KMA was created with the involvement and agreement of First Nations of the area who value the importance of protecting and managing wilderness in their traditional lands. The Treaty 8 First Nations and the Carrier-Sekani were involved in the LRMP process and the Kaska Dena First Nations developed a letter of understanding with the BC government (LRMP; Mackenzie Working Group, 2000; Fort Nelson Working Group, 1997; Fort St. John Working Group, 1997).

Perceptions of wilderness may vary but there are characteristics common to many definitions and writings such as experiencing freedom and the naturalness of a place (Aplet et al., 2000; Carver et al., 2012; Carver & Tin, 2013; Orsi et al., 2013). Common elements associated with a sense of freedom found within a space are the degree of solitude, remoteness from anthropogenic motorized devices and the degree of intact and functioning ecological processes (Aplet et al., 2000). Characteristics related to the naturalness of a place include a natural composition, a degree of unaltered forest structure by anthropogenic structures, and the unpolluted nature of the area (Aplet et al., 2000). Different combinations of wilderness characteristics make up a wide spectrum of wilderness experiences. Cumulatively, they represent a high-quality wilderness experience (Whitney, 1997 *In* Aplet et al., 2000). The many combinations of wilderness characteristics make each wilderness setting relatively different and thus definition of each wilderness setting may vary.

3.3 Defining Wilderness Character

While the M-KMA's wilderness definition has only recently been expanded upon, other jurisdictions have defined wilderness in ways that may suggest potential elements to guide monitoring and mapping.

The United States has an advanced system in place to assess wilderness character. Spearheading the wilderness protection movement, the US passed *The Wilderness Act* in 1964 creating specific designations for nationally recognized tracts of land and thus, from the US legal perspective, wilderness areas are the most remote, pristine, and superlative areas that are designated (Klein, 1994). At a national scale, monitoring of wilderness character can assess national trends in wilderness and set national stewardship actions to maintain the overall national wilderness quality and the quality of the wilderness experiences in addition to linking strategic mandates. Wilderness character includes attributes which when combined can represent a specific wilderness setting and/or experience. Such attributes are ecological characteristics, social characteristics, cultural characteristics, spiritual characteristics, or economic characteristics (Carver & Fritz, 2016). Each wilderness setting varies due to the varying combinations of wilderness characteristics; when characteristics are measured with a criteria and indicator approach, the resulting values provide managers with different measures of wilderness character, which can be assessed over time (Carver & Fritz, 2016). At a local and regional level, monitoring wilderness characteristics allows managers to assess visitor use, degradation, and other threats to wilderness character (Landres et al., 2008).

Within *The Wilderness Act*, federal lands that were already national parks, wildlife refuges or national forests had areas designated within them as 'Wilderness areas' (Klein, 1994; Semcer & Pozewitz, 2013). Between 1964 and 2000, 132 wilderness designation laws were passed by the US Congress and today the US is looked upon as a good example of wilderness conservation and management (Hendee & Dawson, 2004). The Act defined wilderness as:

> *``A wilderness, is hereby recognized as an area where the earth and its community of life are <u>untrammeled</u> by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of <u>undeveloped</u> Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its <u>natural conditions</u> and which (1) generally appears to have been*

affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features (Pub. L88-577 In Carver et al., 2013)." [Emphasis added]

This definition identified four characteristics that are intrinsic to US wilderness legislation, planning and management: (I) untrammeled, (II) undeveloped, (III) natural, and (IV) providing opportunities for solitude or primitive or unconfined recreation. These characteristics have been developed further through an *Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al., 2008) (Table 2) and *Keeping it Wild: Mapping Wilderness Character in the United States* (Carver et al., 2013) where spatial representation of these characteristics was tested in a case study for Death Valley National Park (DEVA).

Table 2: Definition of Wilderness Characteristics from the USWS

Wilderness Characteristic	Definition
I. Untrammeled quality	Wilderness is essentially unhindered and free from modern human control or manipulation.
II. Undeveloped quality	Wilderness retains its primeval character and influence, and is essentially without permanent improvement or modern human occupation.
III. Natural quality	Wilderness ecological systems are substantially free from the effects of modern civilization.
IV. Solitude or Primitive or Unconfined Recreation Quality	Wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation.

The US Wilderness definition and creation of a 'Wilderness' specific area provided land managers with an outline for designating wilderness areas all over the world. The four qualities of the US 'Wilderness' – untrammeled, undeveloped, natural and provides opportunities for solitude or primitive recreation – have been used and adapted by numerous countries and today are used as a basic approach for mapping wilderness quality.

Finland serves as an example of how the US Wilderness System's approach was used and further adapted to include a social characteristic. The Finland model takes into consideration the local indigenous land use and incorporated that social aspect to help guide wilderness legislation. In 1991, Finland passed their *Wilderness Act*, which allotted 12 areas in northern Finland to be preserved as 'wilderness' areas (Hallikainen, 1995). The objective of this *Wilderness Act* is quite different to the "untrammelled" intention written into the US definition. Instead, Finland's wilderness areas were created with the traditional land use and sustenance of reindeer herding and hunting as being an important characteristic to wilderness. The objective for the Finland *Act* was to maintain wilderness areas while preserving the local Sami culture; in turn preserving natural livelihoods and helping develop multiple use areas and benchmarks. This juxtaposition of objectives– to conserve the wilderness and then allow for multiple uses– has resulted in claims and critiques that the legislation is too vague (Tynys, 1995).

In Canada, use of the term wilderness is more conceptual than legislative. Although Canada has a well-established parks and protected area system, wilderness is not legislatively defined, designated or protected. Other than passing mention in the 1930 *Canada National Parks Act,* there is no national act that defines and outlines the concept of wilderness. The *Canada National Parks Act* provides the highest level of government protection with the mechanism to create wilderness areas within already designated national parks (Boyd, 2002). In essence, wilderness is merely a zone and one that is rarely used. According to the 2009 *National Parks of Canada Wilderness Area Declaration Regulation* made under the *Canada National Parks Act,*

> "The regions that exist in a natural state or that are capable of returning to a natural state are declared to be wilderness areas within the national park of Canada" (Canada National Parks Act of 2000, 2017)."

This definition does not explain in detail the Canadian wilderness characteristics, but it is the only attempt to use wilderness on a national scale.

Some provinces and territories in Canada do use provincial legislation to define, plan and manage wilderness areas although the intent varies greatly. Table 3 identifies the legislation at a provincial/territorial level (Boyd, 2002).

The Government of Nova Scotia makes the most prominent use of the term wilderness through the *Provincial Parks Act*, amended in 1992 and 1993, and the creation of the *Wilderness Areas Protection Act*. *The Wilderness Areas Protection Act* prioritized ecological integrity and biodiversity while prohibiting industrial development in protected areas (Boyd, 2002). This *Act* outlines the areas found in Nova Scotia that are designated wilderness areas in Schedule A and then defines wilderness as:

> "(1) the areas of land described in Schedule A to this Act, except any privately-owned land included therein, are hereby designated as wilderness areas, and
>
> (2) the area of land described in Schedule B to this Act, except any privately-owned land included therein, is hereby designated as a wilderness area" (Government of Nova Scotia, 1998).

T*he Wilderness Areas Protection Act* then outlines the purpose of the act to maintain the primary objectives for each wilderness area such as*:*

- *I.* maintain and restore the integrity of natural processes and biodiversity;
- II. protect representative examples of natural landscapes and ecosystems;
- III. protect outstanding, unique, rare and vulnerable natural features and phenomena, and the following secondary objectives:
- IV. provide reference points for determining the effects of human activity on the natural environment;
- V. protect and provide opportunities for scientific research, environmental education and wilderness recreation; and
- VI. promote public consultation and community stewardship in the establishment and management of wilderness areas, while providing opportunities for public access for sport fishing and traditional patterns of hunting and trapping (1998, c. 27, s. 2. In Nova Scotia Government, 1998).

Table 3. Regulations for Each Province and Territory to Protect Land in Canada. Items in bold are specific to Wilderness in Canada.

Province/ Territory	Protected Areas Legislation
British Columbia	*Park Act, R.S.B.C. 1996, c. 344* *Ecological Reserves Act, R.S.B.C. 1996, c. 103* *Environment and Land Use Act, R.S.B.C. 1996, c. 117*
Alberta	*Provincial Parks Act, R.S.A. 2000, c. P-35* ***Wilderness Areas, Ecological Reserves, Natural Areas, and Heritage Rangelands Act,*** *R.S.A. 2000, c. W-9* ***Willmore Wilderness Park Act,*** *R.S.A. 2000, c. W-11*
Saskatchewan	*Parks Act, S.S. 1986, c. P-1.1* *Ecological Reserves Act, S.S. 1979-80, c. E-0.01*
Manitoba	*Provincial Parks Act, C.C.S.M., c. P-20* *Ecological Reserves Act, C.C.S.M., c. E-5*
Ontario	*Provincial Parks Act, R.S.O. 1990, c. P-34* *Public Lands Act, R.S.O. 1990, c. P-43* ***Wilderness Areas Act,*** *R.S.O. 1990, c. W-8*
Quebec	*Parks Act, R.S.Q. 1977, c. P-9* *Ecological Reserves Act, R.S.Q. 1977, c. R-26.1*
New Brunswick	*Parks Act, S.N.B 1982, c. P-2.1* *Ecological Reserves Act, S.N.B. 1975, c. E-1.1*
Nova Scotia	***Wilderness Areas Protection Act,*** *S.N.S. 1998, c. 27* *Provincial Parks Act, R.S.N.S. 1989, c. 367* *Special Places Protection Act, R.S.N.S. 1989, c. 438*
Prince Edward Island	*Natural Areas Protection Act, R.S.P.E.I. 1988, c. N-2* *Recreation Development Act, R.S.P.E.I. 1988, c. R-8*
Newfoundland and Labrador	***Wilderness and Ecological Reserves Act,*** *R.S.N. 1990, c. W-9* *Provincial Parks Act, R.S.N. 1990, c. P-32*
Yukon	*Parks and Land Certainty Act, S.Y. 2001, c. 46*
Northwest Territories	*Territorial Parks Act, R.S.N.W.T. 1988, c. T-4*
Nunavut	*Territorial Parks Act, R.S.N.W.T. 1988, c. T-4, (as duplicated for Nunavut by s. 29 of the Nunavut Act)*

However, by and large the use of the term wilderness in Nova Scotia is merely a semantic variation of other provincial and territorial protected area systems. Across North American and European jurisdictions, the term wilderness refers to something 'more than' a park or protected area, but the terminology used to define wilderness characteristics is not used consistently.

In 2016 the International Union for Conservation of Nature (IUCN) released the *Wilderness Protected Areas: Management Guidelines for IUCN Category 1b Protected Areas*, which announced that the term 'wilderness' will be used to refer to all protected areas at the highest level of protection. In Canada that refers to our National Parks and many Provincial Parks (Casson et al., 2016). The report also emphasized the importance of long-term effective monitoring systems to evaluate values and progress over-time. As little is known about the Muskwa-Kechika Management Area, my study provides a good stepping stone to developing a wilderness monitoring system in the M-KMA.

3.4 Wilderness Characteristics

With the complex concept of wilderness encompassing both ecological components and social/human aspects, it is important to address these components to better understand what wilderness characteristics are and how they can differ in different wilderness settings. Ecologically, having an area with natural environmental qualities such as ecological integrity, high-quality wildlife habitat, unaltered ecosystem functions and processes, and intact watersheds usually indicates strong wilderness quality (Landres et al., 2009; Pissot, 2002; Province of British Columbia, 1998; Watson et al., 2016). As some natural qualities impact human perception of wilderness, there are other social qualities including use and non-use values (Shuster, Tarrant, & Watson, 2003).

3.4.1 Ecological Wilderness Characteristic

From an ecological perspective, the wilderness concept typically refers to an often pristine or natural environment dominated by ecological processes and systems. Most often the ecological value is noticed as residing in the ability of the wilderness to provide for and sustain wildlife (Pissot, 2002). Other ecologically-based characteristics of wilderness include intact natural processes such as predator-prey dynamics, natural disturbance patterns along with natural composition of wildlife and biodiversity, unaltered ecosystem structures, and watershed quality (Aplet et al., 2000; Province of British Columbia, 1998).

The three ecological US Wilderness characteristics (undeveloped, untrammeled, and naturalness) are further outlined and discussed as examples. As these characteristics have been widely used and developed by many nations and jurisdictions, review of the attributes and their measures is helpful. In addition, ecological integrity is discussed as a relatively new characteristic for ecological wilderness character.

Undeveloped

As per the United Stated Wilderness System (USWS), an undeveloped wilderness setting is free from any human manipulation or control and provides the opportunity for one to be completely unhindered (Landres et al., 2009). Indicators to monitor untrammeled wilderness quality in the USWS are measures of the actions used to control and manipulate natural processes, animal populations, soil, water bodies and plant communities. The USWS also describes the undeveloped nature of wilderness as retaining "primeval" character (Landres et al., 2008). Today, however, these terms and concepts are problematic in two primary ways. Many forests today are not in their "primeval" state as large catastrophic events such as large insect outbreaks and large-scale fires force human intervention in order to protect the overall health of forest ecosystems (Stephenson & Millar, 2014). Forest systems are altered through intentional intervention such as building fire guards or through unintentional acts like the transfer of invasive species making it rare to find a "primeval" forest or state. Additionally, the terms define wilderness as the absence of human habituation, denying the indigenous footprint on the land that within many parts of North America has co-evolved with ecological systems for over 10,000 years (Smith, 1999). In a more contemporary sense, the undeveloped characteristic more typically includes a distance or area model that outlines and separates the human footprint on the landscape from undeveloped area. In its simplest form, this metric is often a buffered outline of human roads and developments.

Untrammeled

The 'untrammeled' concept is also a pseudo-ecological characteristic made prominent by the USWS. Untrammeled refers to an area free from human manipulation or control. Thus, an area that has no internal agency actions would have a high untrammeled quality (Landres et al., 2009). Within the *US Wilderness Act* definition, the untrammeled quality of wilderness can be confused with the naturalness characteristic. However, the untrammeled quality is monitored to show intentional human impacts on wilderness, whereas the naturalness quality represents the human impacts *and* external natural impacts to wilderness (Landres et al., 2009). A commonly used proxy version of the untrammeled wilderness characteristic is un-roaded areas or without major access points. This characteristic also does not consider Indigenous populations.

Naturalness

The third of the ecological characteristics from the USWS, naturalness, refers to the natural quality of wilderness that contains a biological community that retains natural composition and function and is free from effects of anthropogenic influences (Landres et al., 2009). The US indicators to measure naturalness are air pollutants, developments, invasive species measures, air quality and the number of threatened and extirpated species (Landres et al., 2009). 'Natural' described by the Muskwa-Kechika Advisory Board (M-KAB) is an area free from human impacts (with particular reference to industrial activities) where natural composition and biodiversity can be found (Muskwa-Kechika Advisory Board, 2004). One of the largest ecological systems in natural areas is the predator-prey system. Predator-prey dynamics are the interactions that native-prey and native-predators have without influence from humans (Berger, 2007).

Ecological Integrity

Although the terms untrammeled, undeveloped and naturalness are all definitionally problematic, they contain individual elements and potential indicators that have value in assessing wilderness quality. The move towards a more ecologically meaningful definition of wilderness means consideration of richer concepts such as "health", "integrity", and "diversity". The concept of ecological integrity (EI) has emerged in the last few decades as a scientifically valid term (Woodley, 2000). "An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes" (Canada Parks Agency, 2000). Monitoring and assessment of EI, however, is an enormous task. Frameworks of indicators for EI monitoring have been developed by the Parks Canada Agency and others (See for example Environment Canada, 2012; Environment and Climate Change Canada, 2015; Vickerman & Kagan, 2014; Woodley, 2000). Figure 5 is one such framework outlining the different concepts that make ecological integrity a sound measurement tool for ecological health and wellness of an area (Vickerman & Kagan, 2014).

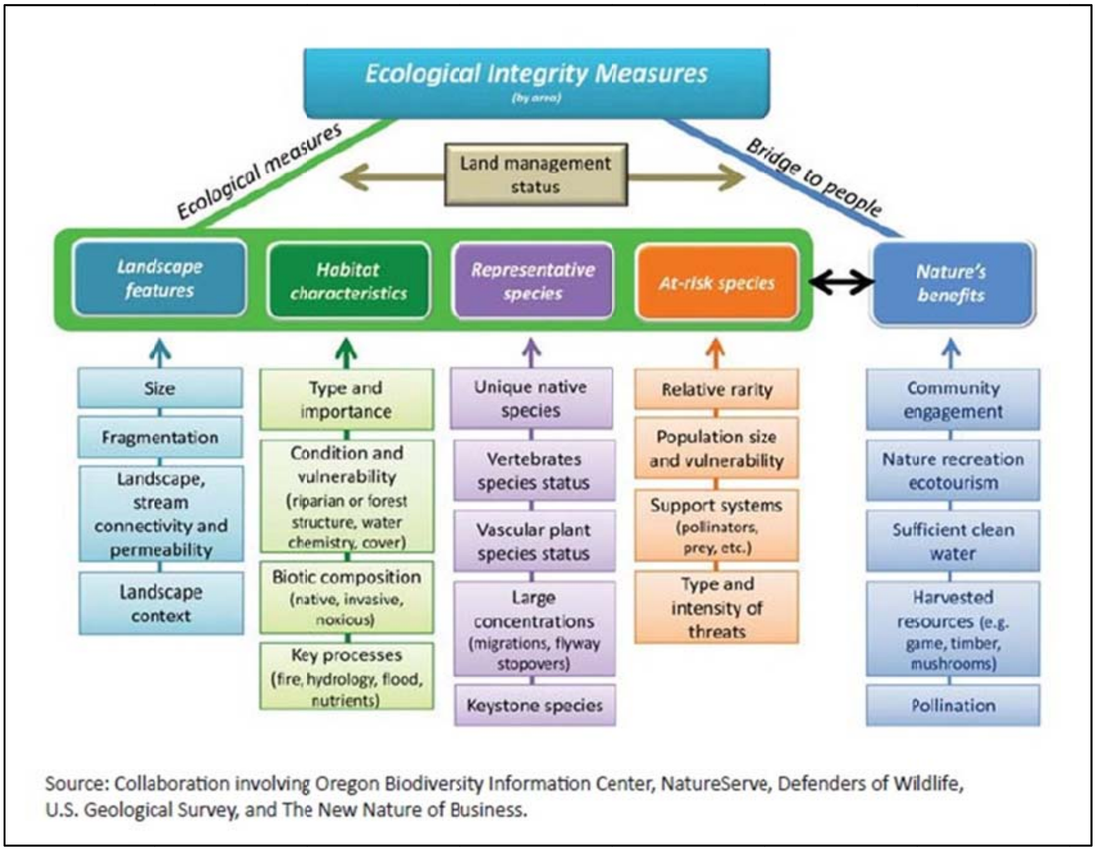


Figure 5. Ecological Integrity Measures.

3.4.2 Social Wilderness Characteristic

The idea of wilderness is often referred to as a Western one – originally where nature was considered an undesirable state from civilization (Klein, 1994; Rolston, 1997). As a social construct, the concept of wilderness varies. Wilderness has value to both users and non-users and wilderness perceptions can alter between individuals depending on their nature, nurture and personal experiences with wild land (Heintzman, 2012). Socially, wilderness values are dependent on the user's perceptions of the wilderness space; therefore, it is important to understand reasons and desires one might have as both a user and non-user of wilderness (Rolston, 1997). Use values consist of direct and indirect values, whereas non-use values are derived from social constructs of preserving land for its intrinsic value (Mountford & Kepler, 1999 *In* Shuster et al., 2003). Hence, the social concept of wilderness use usually resonates around several key dimensions including those associated with individual contact with wilderness and non-use values, which focus on the larger public benefits accrued from wilderness (Shuster et al., 2003).

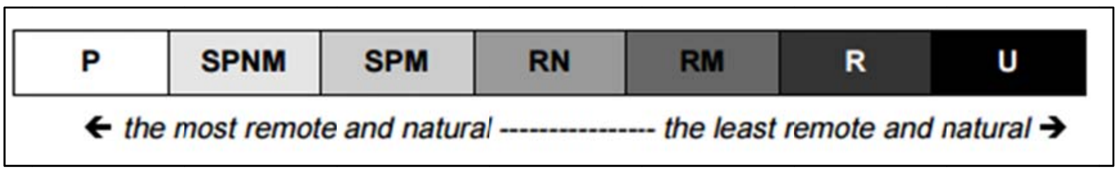
Use values include personal/individual experiences such as self-identity and self-reliance, personal well-being, and many elements of spiritual growth. The most common social values of wilderness are gained through immersion in wilderness areas. These values include solitude, remoteness, physical activity and the aesthetics of the natural environment, although other societal values of wilderness include education, research and cultural values (Shuster et al., 2003; Thornton, 2011). For my thesis, because of a lack of data availability, only a subset of the social characteristics was examined further: solitude and remoteness. These indicators are mappable and measurements for both can be replicated overtime.

Solitude

One of the most prominent characteristics ascribed to wilderness is the opportunity for solitude. Specifically, the US *Wilderness Act of 1964* describes wilderness as, "containing outstanding opportunities to experience solitude, remoteness, and primitive recreation free from the constraints of modern society" (Wilderness Act of 1964, 2017). The distance from other people, lack of signs of human intervention on the land, sheer size and associated time required for wilderness experiences result in opportunities for solitude that are uncommon in other settings. Common indicators and measures of solitude include probability of encounters with others, sight or sound of other users and developments, and travel time. For areas that are not as remote and isolated as the M-KMA, other indicators for solitude can be fly-overs, noisy soundscapes, and the dark sky index (Tricker et al., 2012).

Remoteness

The wilderness environment provides a unique setting for recreation. Wilderness recreation may take many forms (e.g., horse-packing, hiking, boating), but the wilderness setting implies remoteness, self-sufficiency and intense immersion. The physical challenge of surviving in the 'wild' is an ideal reality for many adventure seekers (Shuster et al., 2003). Remoteness from anthropogenic influences and main access points puts one further and deeper into the wilderness. A Recreation Opportunity Spectrum (ROS) was developed to identify a way to classify land according to its potential recreation opportunities; the British Columbia Ministry of Forests has also adopted this strategy. The ROS inventory separates land into 7 recreation designations. Figure 6 presents these designations on a scale from the most remote and natural to the least remote and natural (British Columbia Ministry of Forests, 1998):



1. Primitive (P),
2. Semi-primitive Non-Motorized (SPNM),
3. Semi-primitive Motorized (SPM),
4. Roaded Natural (RN),
5. Roaded Modified (RM),
6. Rural (R), and
7. Urban (U).

Figure 6. Relationship Among Recreation Opportunity Spectrum Classes.

What differentiates these categories is the remoteness (distance from roads and size), naturalness (motorized use and evidence of humans), and the social experience available (solitude/ self-reliance and social encounters) (British Columbia Ministry of Forests, 1998). In terms of wilderness, the Primitive (P) ROS designation would be the closest designation to the highest quality of wilderness areas as it calls for areas farther than 8 km from roads, very high degree of naturalness, very high opportunity to experience solitude and self-reliance and little-to-no interaction with other parties, as well as small party sizes (Table 4) (British Columbia Ministry of Forests, 1998).

Table 4. Recreation Opportunity Spectrum Delineation Factors

Remoteness	Naturalness	Social Experience
Distance from – approximate distance from the nearest road (km)	Motorized use – degree of motorized use within the area (includes off-road, boat and air access vehicles).	Solitude/self-reliance – opportunity to experience solitude, closeness to nature, self-reliance and challenge.
Size – approximate size of the area (ha)	Evidence of humans – on-the-ground evidence of restrictions and controls, facility development, site modifications, and site or trail degradation.	Social encounters – number of interactions with others and expected party size.

The concept of wilderness is both tangible and intangible. It includes both an ecological component and a social/human component, which vary depending on an individual's, societies', or culture's perception of wilderness. In order to identify, manage and maintain wilderness, it must first be defined. To define and spatially represent wilderness specific to an area requires defining the associated wilderness characteristics, which provide a unique wilderness scene and experience relative to that area. Once characteristics are defined and measured, then wilderness may be mapped for management and conservation purposes.

3.5 Why Map Wilderness?

Wilderness has been mapped for centuries unintentionally as early explorers mapped the absence of wilderness throughout global conquests. Maps, as early as the 1800s, have parts labelled as "Parts Unknown", indicating that the cartographer had no knowledge of what lay beyond (Carver & Fritz, 2016: 6). Several maps from this time include wild, imaginary lands inhabited by strange beasts captioned in Latin "HC SVNT DRACONES", meaning "here be dragons" (Carver & Fritz, 2016: 6). Through time the idea of a wild land and wilderness area has been viewed differently depending on the needs and wants of varying civilizations.

Originally, wilderness was an "adversary to the pioneer" as it was feared and exploited (Leopold, 1949: 188 *In* Klein, 1994: 1). At the beginning of the 20th century the land was discovered by explorers commonly dominating the landscape and altering it through developments of settlements and then, subsequently, towns and cities. As the urban sprawl of civilizations expanded, the idea and perceptions of wilderness changed. Originally viewed as a 'frontier' to be conquered, by the end of the 20th century it was evident that the wild lands provided important benefits for the environment and for people such as air, water, oil, gas, minerals, timber, fish, and wildlife (Carver & Fritz, 2016; Klein, 1994).

Part of the past, wilderness now plays an integral role in global biodiversity protection now and into the future (Watson et al., 2016). Recent technological advances and scientific discoveries have now documented that wilderness is the ultimate resource that provides multiple benefits both to humans and the environment. Through advances in modern geographical information systems, satellites, and aerial photography, it is now possible to more accurately map wilderness (Carver & Fritz, 2016). Mapping wilderness globally has provided insight into the spatial coverage of remaining wild lands relative to altered lands, spatial coverage of protected areas, and evaluation of the overlap of wild lands and wildlife (Watson et al., 2016).

The first time that wilderness was mapped intentionally to show the human impact on global wild lands was for the 4th World Wilderness Congress in 1987 by McCloskey and Spalding (Figure 7). This map was the first to use a single indicator rule-based method to globally map wilderness; it was done completely by hand (Carver & Fritz, 2016).

This first map was based on a simple criterion of unroaded areas that equaled 400,000 hectares or more with no human structures within six kilometers. Since then multiple indicator approaches have been taken to create both small and large-scale maps. Maps made at a local scale tend to have more detailed modelling and analysis whereas global maps of wilderness tend to be focused on mapping simplified indicators such as the presence and absence of humans (Carver & Tin, 2013). Today, global wilderness maps, such as those provided by Watson et al. (2016), have immense detail and can provide projections for conservation efforts.

3.5.1 Single Indicator Approaches to Mapping Wilderness

Single indicator approaches to mapping wilderness revolve around one characteristic of wilderness that is deemed so important that it can spatially depict a wilderness area. For example, areas that have no linear transects typically imply that they are a greater distance away from civilization, thereby creating a 'wild' space (Carver & Fritz, 2016). Global wilderness models based on a single indicator approach tend to have low-quality detail and represent a generalized projection of wilderness (Carver & Tin, 2013).

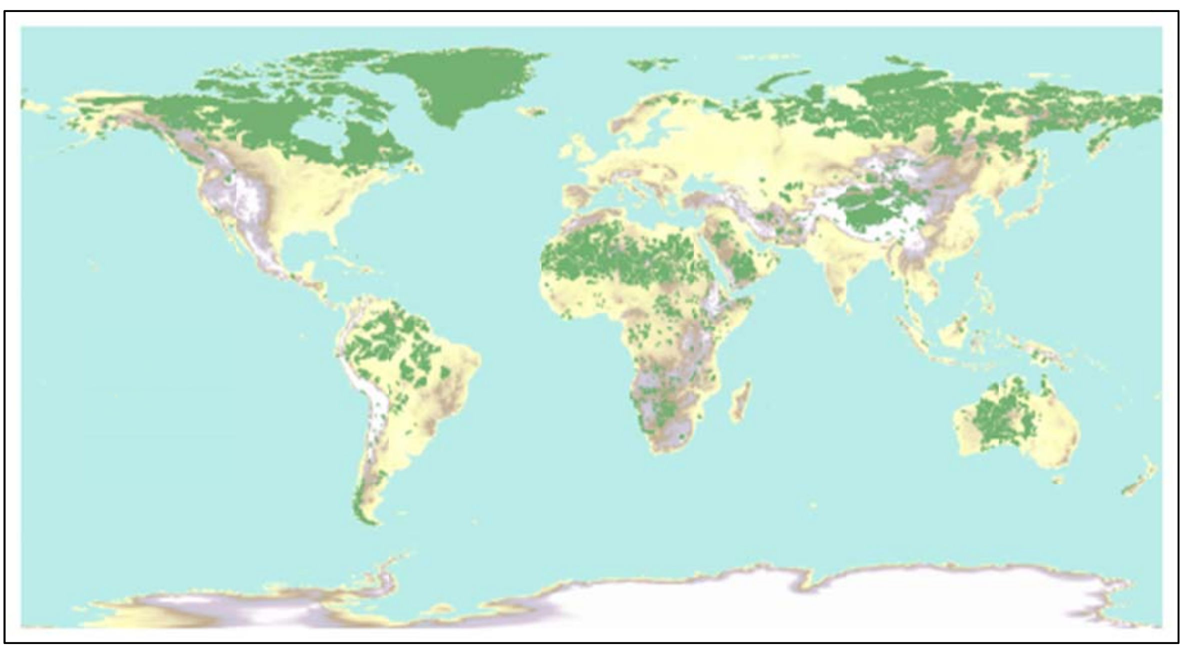


Figure 7. A Global Reconnaissance of Wilderness (McCloskey and Spalding, 1989 *In* Carver & Tin, 2013). Note: Green depicts wilderness areas.

Another global approach to mapping wilderness is the wilderness continuum concept. A basic model based on a singular characteristic, it is often called the environmental modification spectrum and assumes that wilderness character is opposite to human impact (Carver & Fritz, 2016) (Figure 8).

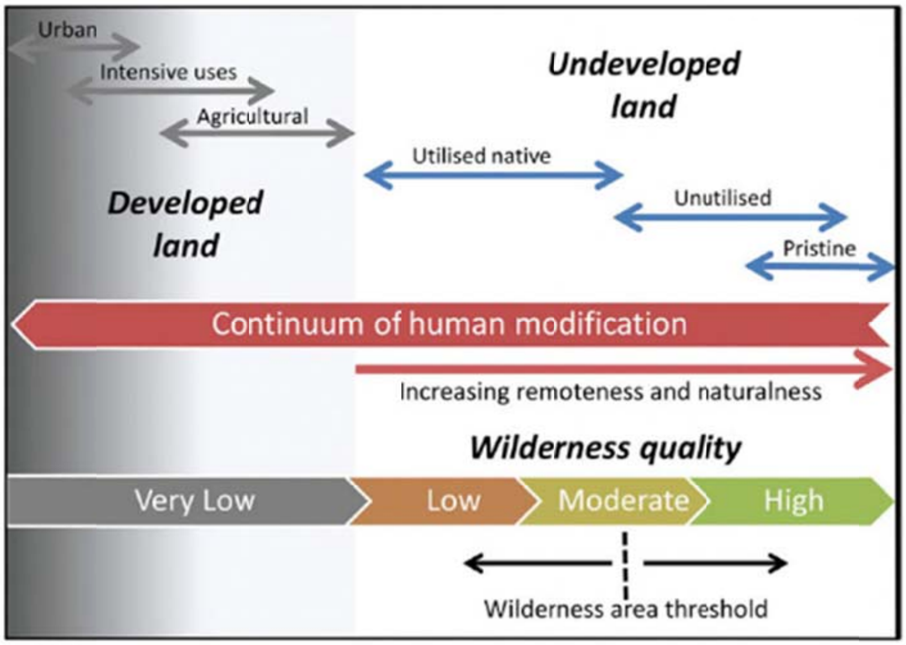


Figure 8. The Wilderness Continuum Concept (Adapted from Leslie and Taylor, 1985 *In* Carver & Fritz, 2016).

Single indicator approaches entail some version of naturalness or the absence of the human footprint as a proxy for wilderness (European Environment Agency, 2014; Machado, 2004; Yellowstone to Yukon Conservation Initiative, 2012). A 2012 assessment of the M-KMA done by the Yellowstone to Yukon Conservation (Y2Y) Initiative used this approach. Wilderness was defined as synonymous with natural or unmodified areas. Any developments (e.g., buildings, energy/transmission lines, harvested areas, industrial areas, and transportation features such as roads, railways and airports) were buffered by a uniform 3.83 km regardless of severity of impact. The study does not indicate why this uniform buffer was used (Yellowstone to Yukon Conservation Initiative (Y2Y), 2012). The resulting map shows areas that are perceived as natural or 'intact'. The naturalness of the area, shown in green, highlights where there is human influence and likely more disturbance on the land, but it does not capture entirely the different gradations of wilderness quality across the land (Figure 9). In addition, this measure is incomplete, omitting more impermanent influences such as recreation use that affect the solitude and natural qualities of wilderness.

Single indicator approaches can be used to quickly identify areas that are remote, using a buffered development layer, which is often viewed as a naturalness layer. Although these approaches are quick with modern geographical information systems (GIS) and can easily be repeated, they do not show the varying types of wilderness available to different wilderness users. It has been said that "one man's wilderness is another's roadside picnic ground" because the perception of wilderness makes it different to different people, allowing for various relationships and experiences one may have with and within wilderness (Nash, 1993: 1 *In* Carver & Fritz, 2016: 1).

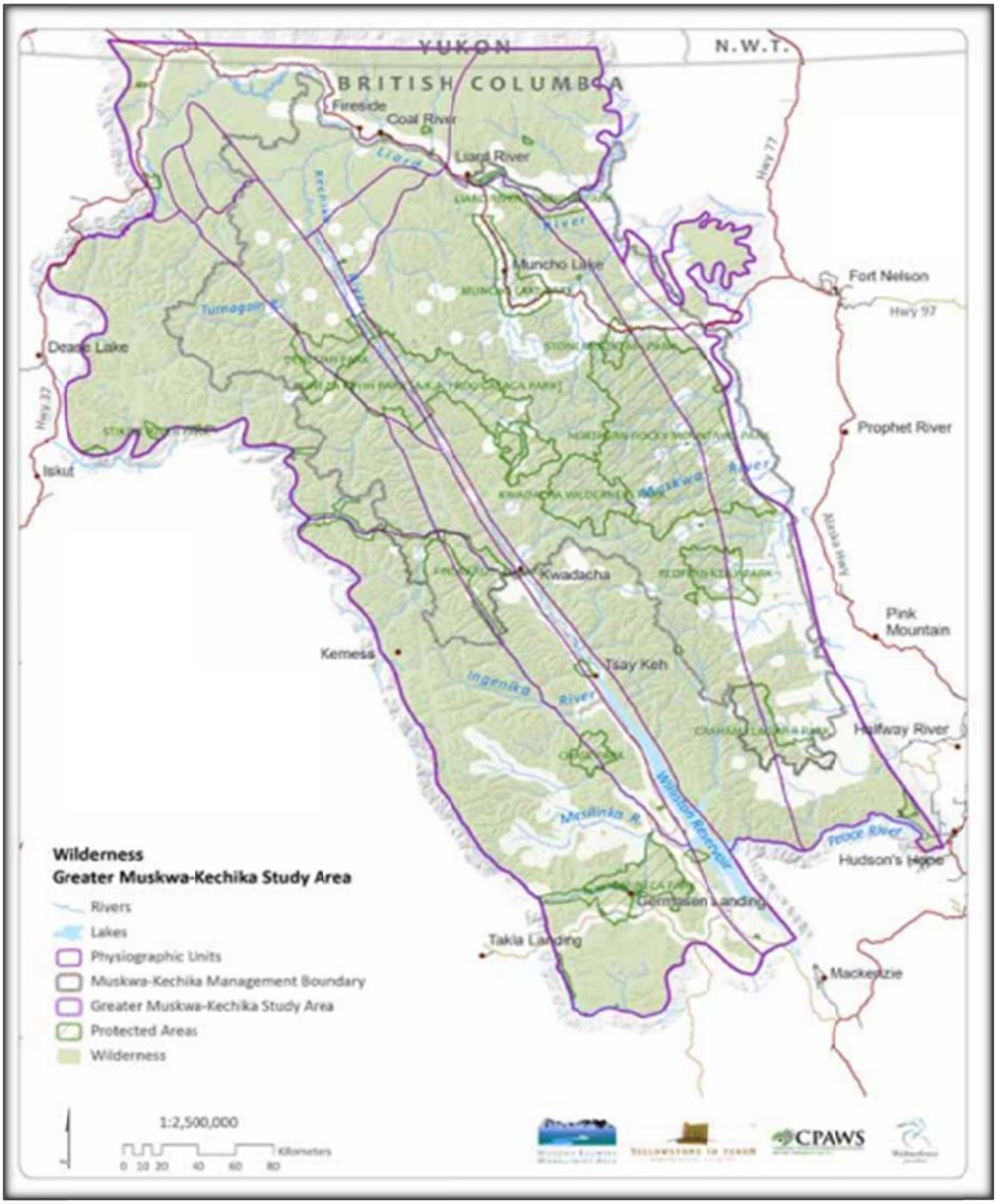


Figure 9. Wilderness in the Greater Muskwa-Kechika Management Area (M-KMA) Study Area (The Yellowstone to Yukon Conservation Initiative, 2012).

To achieve a spatial representation of wilderness that represents multiple wilderness qualities and experiences, a more complex and systematic approach to mapping criteria and indicators is needed and often includes multiple indicators that measure wilderness character.

3.5.2 Multi-indicator Approaches

The first known use of GIS to map wilderness quality was done in Australia through the National Wilderness Inventory Program (NWI) initiated in 1989 after concerns arose regarding the rapidly diminishing remote, natural land in Australia (Carver & Fritz, 2016). The NWI was created to identify wilderness qualities and since its creation has successfully developed a method to survey wilderness quality in Australia, completed a base-line continental wide survey of Australia and applied (GIS) use to planning and management issues (Lesslie & Maslen, 1995). This assessment identified the main characteristics of wilderness to be remoteness from land, remoteness from mechanized access, the natural appearance and the biophysical ecological integrity of the land. These four parameters were given a score from 0 to 5 making the maximum wilderness quality possible 20 (Carver & Tin, 2013; Lesslie & Maslen, 1995; Sawyer, 2015).

Aplet et al. (2000) developed a similar methodology for the US Forest Service to create an overall wilderness quality map for the US (with the exclusion of Hawaii and Alaska). The framework uses characteristics of wilderness derived from the *Wilderness Act* definition of wilderness: solitude, remoteness, uncontrolled processes, natural composition and unaltered structure. To represent solitude, the probability of encountering another person and the likelihood of encountering people at visitor hotspots were taken into account. Ideally, remoteness would exempt all access roads and trails. This type of data was difficult to attain on the national scale and therefore it was assumed that ecological processes that are intact and are larger are therefore under less anthropogenic influence and control (Aplet et al., 2000). Natural composition is a measure of ecosystem composition and supporting data sets included species composition information such as vegetation inventories, forest inventories and wildlife inventories. Unaltered structure was devoid of buildings, dams, roads, agricultural land, and resource development. Lastly, a relative pollution layer was created from light pollution and noise pollution data. These weighted layers were then overlaid using ArcMap Arc GIS (Aplet et al., 2000).

These same techniques were then applied in several US national parks. In accordance with the US national strategy to monitor wilderness character, mapping was done throughout several Wilderness areas to assess whether management techniques were currently fulfilling the mandate. Using consistent and credible data, these procedures can be repeated overtime to evaluate how management actions affect wilderness character in the US Wilderness. For example, Death Valley National Park (DEVA) was mapped through the development and combination of several different GIS databases (Tricker et al., 2012). This regional-scale mapping can be extremely detailed and time-consuming, though it can provide managers with a better quality map, which in turn can guide better management decisions (Steve Carver & Tin, 2013). Figure 10 shows the overall wilderness quality map for Death Valley National Park. This multiple-indicator approach map shows how using multiple indicators for wilderness characteristics allows for a spectrum of wilderness to be portrayed, which adequately depicts the varying qualities of wilderness (ranging from 0-10 % – degraded wilderness to 91-100% – optimal wilderness) and thus different wilderness recreational areas.

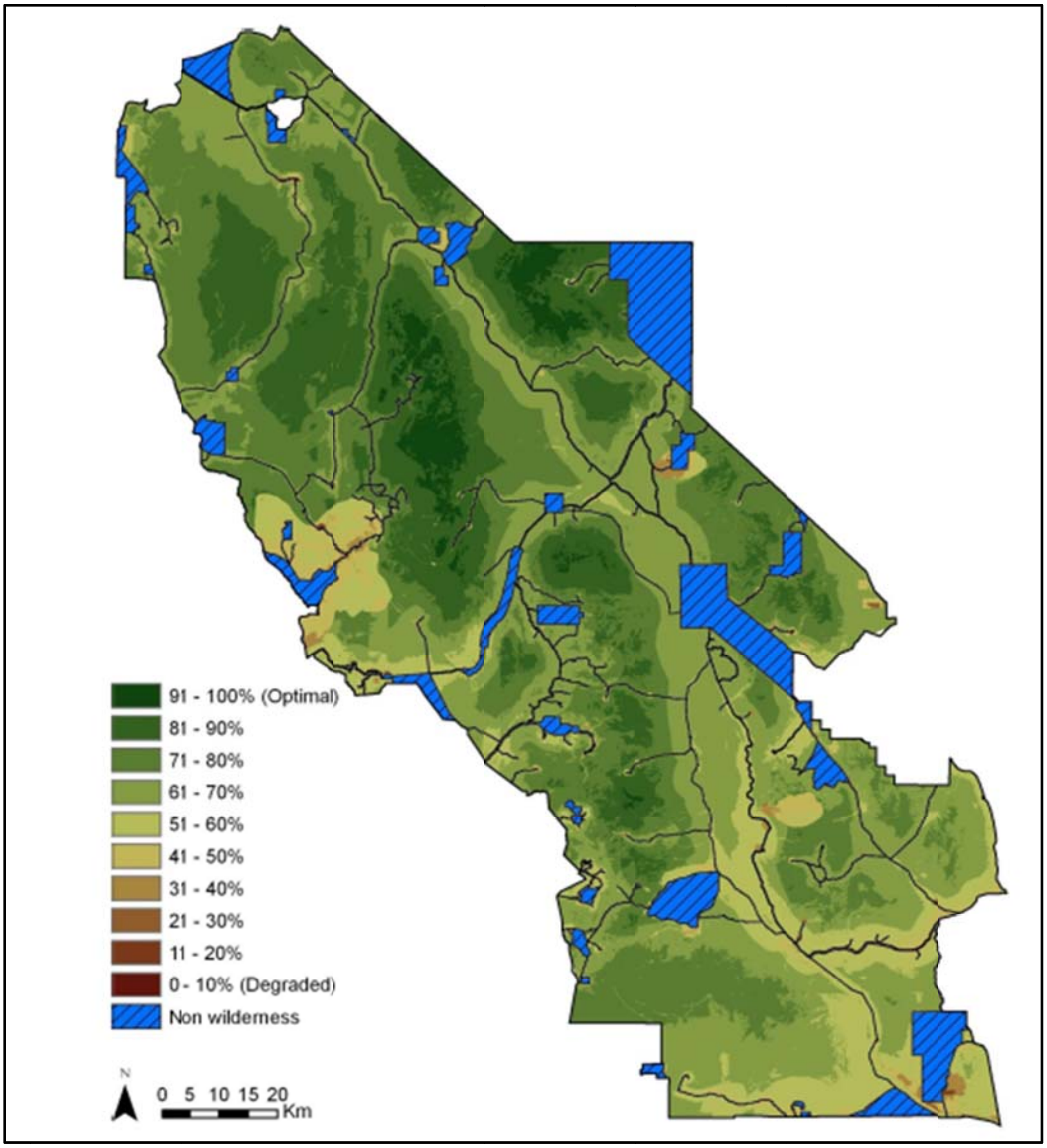


Figure 10. Wilderness Quality in Death Valley National Park (Tricker et al., 2012).

In Canada specifically, *The Peel Watershed: International Significance* report (2008) took a multiple indicator approach to map the wilderness in the Peel Watershed in Yukon. It used overlapping variables of the ecological land classification system, wildlife key areas, the recreation features inventory, and a development layer with roads and access routes, gas, oil, mineral exploration and mines (Green et al., with UNEP-WCMC, 2008). In addition to providing multiple indicators, this report used specific buffers for different types of developments to represent how different developments can have altering affects to wilderness character. For example, the Dempster Highway was given a buffer of 10 kilometers, but seismic lines were only given a buffer of 1 km (Green et al., with UNEP-WCMC, 2008). This change in buffer size provides a more conservative model of development compared to a single buffer size for all developments.

Several other countries and jurisdictions have mapped wild areas in their regions by taking a multiple indicator approach including New Zealand (Kliskey, 1994), Italy (Orsi et al., 2013), Scotland (Carver et al., 2012) and Britain (Carver, Evan, & Fritz, 2002). Whereas New Zealand, Italy and Scotland all used models relatively similar to both Australia's NWI and the US mapping system, Britain mapped their wilderness using public opinion as part of the modelling process.

In contrast, the framework to map wilderness quality in Britain includes wilderness perception (Carver, Evan and Fritz, 2002). Using the wilderness continuum model, which acknowledges that pristine wilderness is one extreme on the scale of environmental quality, the approach mimics and combines the approaches taken by Australia and the US to create six map layers including remoteness from local population, remoteness from national population centers, remoteness from mechanized access, apparent naturalness, biophysical naturalness and altitude (Carver et al., 2002). Next, an internet-based GIS survey was used to solicit public opinion, which allowed the public to weight the wilderness characteristics differently and submit a final wilderness continuum map, which was then used to create consensus maps from the public submissions (Carver et al., 2002). This type of mapping allows for a unique insight from public perceptions and use of a wilderness area. It provides multiple opinions, which can be beneficial although limited to only people with internet access and knowledge of the area.

More recently, the need to map wilderness has become an important issue for global biodiversity and conservation. Global maps of wilderness are used to assess current and future trends in climate, urban sprawl, resource exploitation and over-population. They are guiding documents that visualize the importance of the most irreplaceable resource on the planet – wild land (Watson et al., 2016).

3.5.3 Future Global Wilderness and Biodiversity Mapping

If we do not protect natural areas, which protect most of the world's biodiversity, then eventually there will be a major loss of biodiversity and in turn the ecosystems it supports. Thus, in order to maintain ecosystem functions and biodiversity over time, conservation measures must be taken to preserve remaining wilderness. New wilderness models are addressing these tough choices. Watson et al (2016) reported that not only are we losing wilderness at an astonishing rate, but the conservation measures in place to protect wilderness may not be covering the standard for Key Biodiversity Areas set up by the International Union for Conservation of Nature and Natural Resources (IUCN) (Watson et al., 2016). Therefore, it is crucial to define, map, and analyze wilderness areas to better address management, planning and most importantly, future policy for conservation, whether on a global scale or regional scale like the M-KMA.

Chapter 4: Overview of Approaches to Modelling and Mapping Wilderness in the Muskwa-Kechika Management Area

My research involved geographic information system methods to develop a model of wilderness and map wilderness values within the Muskwa-Kechika Management Area. Mapped values represent both ecological and social values in the M-KMA based on quantitative information. The design of the model and mapping of the wilderness values was informed throughout by an advisory group – the Muskwa-Kechika Advisory Board (M-KAB) Wilderness Working Group. Throughout my study this group of informed, educated and interested stakeholders provided a mix of quantitative and qualitative feedback and input into model development and mapping.

My study represents a combination of research with practice. Given that the focus was on developing an approach to map wilderness, the methods and procedures I used to develop my criteria and indicators and to map wilderness were both research methods in a conventional sense, as well as a result. Thus, in this chapter I focus on giving a broad overview of the approaches used to address the research questions. In the following chapter I provide details on the procedures used in the development of the wilderness mapping model with specific attention to identification of the wilderness indicators used in the model, sources of spatial data, the approaches used to map the indicators including buffers and weights, and the way in which the model indicators were synthesized.

This chapter specifically examines the approach used to identify criteria and indicators of wilderness; methods to assess data sources; overarching approaches to map this information; approaches to synthesize and analyze the results; and the incorporation of perspectives from the M-KAB Wilderness Working Group into the wilderness mapping model.

4.1 Identifying Criteria and Indicators of Wilderness in the M-KMA

Operationalizing the concept of wilderness into a tangible, mappable value layer first required the definition of key attributes of wilderness within the M-KMA and the development of a conceptual model for how these attributes can be applied. To do this, I adapted a criteria and indicator framework, which is used most commonly in developing comprehensive (e.g., state of environment/state of ecological integrity reporting) monitoring programs.

Monitoring and assessment can assist resource managers by creating benchmarks that can be used and compared to a desired state for that area. They can also be used to evaluate the effectiveness of management programs and to build a base understanding of an ecosystem (Wright et al., 2002). Monitoring and assessment of an area or ecological system helps managers communicate about the quality of the resource, supports planning decisions and allows for accountability due to the management system (Wright et al., 2002). Intertwined within a larger management process, the monitoring and assessment process becomes an essential feedback loop in managing for sustainability (Landres, 1995). Spatially-based approaches for monitoring and assessment are particularly applicable where there is spatial variability in the resource condition and/or where planning and management decisions may differentially affect, on a spatial basis, the resource (Wright et al., 2002).

Frequently, however, monitoring activities are designed in isolation such that data collected on one particular topic are not compatible with other monitoring initiatives. As such, these initiatives don't provide a coherent or holistic view of a system. Frameworks such as criteria and indicator (C&I) frameworks can assist in identifying important variables or values to improve the understanding of a whole system. This more inclusive approach creates a model that links together all of the important data (Vickerman & Kagan, 2014; Wright et al., 2002). These frameworks are hierarchical, starting first with larger goals (criteria), such as the social perception of wilderness character, and then breaking that goal down into manageable smaller pieces (indicators), such as wildlife habitat. In practice, these indicators are measured and then assessed against norms, reference values, or standards (Wright et al., 2002). As the terminology and number of layers vary from application to application, the following definitions are used in this thesis.

Criteria are larger or higher order workings of a system, function or part of a system which is to be monitored; they can be social, ecological, or economic. A criterion must be a value that is suitable for setting objectives and managing performance to a satisfactory level (Franc, Laroussinie, & Karjalainen, 2001).

An indicator is "an attribute or feature that can be measured quantitatively, qualitatively or descriptively and will show directional change over time" (Beasley and Wright, 2001). Indicators are helpful for synthesizing large, complex bits of information and making it more approachable and understandable for an audience (Wright et al., 2002). Appropriate indicators and measures for monitoring overall wilderness quality must be chosen to be: (1) relevant, (2) reliable (3) cost-effective, (4) specific, and (5) related to visitor use (Landres, 2009; Manning & Lime, 2000). Relevance guarantees that the indicator will have meaning and value to show change in wilderness quality over time (Landres, 2009). A reliable indicator can be measured accurately with confidence and yield the same result when measured by various managers long-term (Landres, 2009). Specific indicators describe an objective quality instead of allowing for generalization, which can be interpreted differently. Careful thought was put into indicators that are relevant to the broad definition of wilderness and M-KMA specific. Additionally, I focused on indicators that were reliable and cost-effective (for this thesis) and related to resource development and visitor use, which are sensitive to change.

Criteria and indicator approaches to developing a monitoring program provide a structure within which to move beyond a 'single indicator' approach to monitoring and overcomes many of the weaknesses of traditional assessment and monitoring approaches.

To develop criteria and indicators for the wilderness mapping tool, I reviewed wilderness definition literature (e.g., Aplet et al., 2000; Carver et al., 2012; Landres et al., 2008; McCloskey & Spalding, 1989; and Tricker et al., 2012) and wilderness mapping and monitoring approaches from other jurisdictions (e.g., US Forest Service). From these documents, I generated a broad list of tentative criteria and indicators of wilderness. I then reviewed 11 important legislative, policy and planning documents relevant to the M-KMA (See Appendix C). These latter reviews were first used to identify additional possible criteria and indicators. From this broad list of tentative criteria and indicators, I then screened them against the M-KMA legislation and guiding policy documents to make sure they were relevant within the M-KMA context. I looked for wilderness criteria or indicators that were common across multiple approaches and combined similar elements where possible. For example, the concept of 'isolation' was merged with that of 'remoteness'. The indicators were organized into two overarching criteria: ecological wilderness characteristics and social wilderness characteristics. Some indicators and/or measures were relevant for assessment of wilderness for both ecological and social criteria, but the lens and specific interpretation of that information differed.

4.2 Approaches to Assess Data Availability

This initial master list of indicators was reviewed with my graduate supervisory committee to finalize a refined list of wilderness indicators that could represent the unique wilderness values in the M-KMA, as well as be spatially represented with available data or a proxy measure. These indicators were presented to the M-KAB Wilderness Working Group for their review. I asked them to review the indicators to ensure that each was logical and that together as a suite they represented the important elements associated with the M-KMA wilderness definition.

For each indicator, I adapted or developed a definition and a justification for inclusion. I identified data sources noting data availability, completeness, age and accuracy issues. Although this step was completed at the beginning of my study, the indicators continued to be refined throughout the study in an iterative fashion as I began working with the data.

Indicators without available or reliable data sources were not useful for my study. Thus, I screened the master list of indicators for data availability specifically for the M-KMA. This master list included several concepts that were relevant to a wilderness definition (e.g., light pollution), but if there wasn't any readily available data at the current time for the M-KMA, the indicator was moved to a low-priority listing. Indicators lacking data may still be important but were not currently feasible to include. In other situations when data to support direct measurement of the indicator (e.g. noise pollution) were not available, the indicator was still useful to inform the identification of a proxy measure (e.g., motorized use routes in the backcountry were buffered to accommodate not only the direct disturbance on the land/riverscape but also the effects of noise).

4.3 Data Collection and Assessment

For the list of indicators, I sought out reliable and relevant data from two primary data sources: Data BC and Data Basin[7]. Data BC, the government warehouse for spatial data[8], provided the baseline data needed to create a digital elevation model, and shapefiles of topographical layers such as lakes and rivers. Although Data BC was a great source for general data for BC, it proved difficult to get more detailed assessments of the study area (such as a vegetation inventory layer – BC VRI) as there were missing or incomplete data for the M-KMA.

[7] Data Basin can be retrieved from https://databasin.org/
[8] The Data Catalogue at Data BC can be retrieved from https://catalogue.data.gov.bc.ca/dataset?download_audience=Public

Gathering data for the area can be costly and often not economically viable because of its remoteness. Therefore, compared to other more-populated areas of BC, the M-KMA data were scarce and/or incomplete and therefore other sources were sought.

Data Basin is an online data catalogue and scientific mapping tool developed by non-governmental organizations, principally the Conservation Biology Institute, to democratize data availability and conservation planning. Previous research and conservation planning initiatives in the M-KMA area have been made accessible through the Data Basin platform. Data Basin proved a good source of relevant, up-to-date data from recent published works such as the 2004 *Conservation Area Design for the Muskwa-Kechika Management Area* (MKMA) (Heinemeyer et al., 2004) and the *Yellowstone to Yukon M-KMA Biodiversity, Conservation and Climate Change Assessment* (Yellowstone to Yukon Conservation Initiative (Y2Y), 2012). Table 5 summarizes the baseline data.

After data were collected, they were assembled and checked for completeness and coverage. Data were then cleaned and organized. For example, several of the data layers had data elements that were extraneous to the study, study area or needed to be merged with other data (e.g., layers). This process was completed for each indicator individually. Where data were not spatially available, proxy measures and shapefiles were created from relevant and current data. For example, visitor use numbers for the M-KMA would have been ideal to help create an indicator of solitude for the social characteristics of wilderness. However, as use levels are not monitored across the M-KMA, a proxy measure was constructed from use estimates at a broad resource management zone scale contained within the *2005 Draft Recreation Management Plan for the M-KMA* (Rutledge & Davis, 2005).

Table 5. Baseline Data Sources Including Source of Data, Description of Layer and Data Layer Name from Source

Source of Data	Description of Layer	Data Layer Name from Source
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Land tenures- Agricultural, industrial, First Nations, residential, transportation etc.	TA_CRT_SVW_polygon
Discover Catalogue available from Data BC	Biogeoclimatic zones in BC, which was clipped to study boundary.	BEC
Discover Catalogue available from Data BC	BC Protected Areas.	Parks
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Wetlands in the M-KMA.	a_bc_cwb_wetlands_clip
Discover Catalogue available from Data BC	Atlas lakes in the M-KMA.	a_bc_cwb_lakes_clip
Discover Catalogue available from Data BC	Atlas rivers in the M-KMA.	River_FWRVRSPL_polygon
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Man-made structures such as points, buildings, gravel pits, gas wells etc.	tculpt22jan04point
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Access: roads (paved and unpaved), trail, rail, bridge, airstrips, airports.	ttrnln_ama arc
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Cutlines	tmisc22jan04 acr
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Agriculture, Rangeland, and Logging.	btm_impacts polygon
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Designated areas, pits, mines, and buildings (other).	tculln22jan04 arc
Discover Catalogue available from Data BC	The BC Albers Digital Elevation Model map sheets.	Map sheets- All of 94 and A, H, I, P of 104
Discover Catalogue available from Data BC	Alaska highway and main roads off of highway.	TA_MAS_SVW_polyline
Yellowstone to Yukon M-KMA Biodiversity, Conservation and Climate Change Assessment	Wildlife Connectivity for Four Focal Species, Greater Muskwa-Kechika, BC.	Linkage Models- 4 species.lpk
Yellowstone to Yukon M-KMA Biodiversity, Conservation and Climate Change Assessment	Enduring Features of the Greater M-KMA Ecosystem.	MKMA Enduring Features.lpk

Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Resource Management Zones for the M-KMA.	mk_landuse_divisions.shp
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Caribou Habitat Growing Season.	car_grow_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Caribou Habitat Winter Season.	car_wint_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Elk Habitat Growing Season.	elk_grow_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Elk Habitat Winter Season.	elf_wint_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Goat Habitat Growing Season.	got_grow_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Goat Habitat Winter Season.	got_wint_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Grizzly Habitat.	gzz_ge_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Grizzly Habitat.	gzz_gl_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Grizzly Habitat.	gzz_gm_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Sheep Growing Season.	shp_grow_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Sheep Winter Season.	shp_wint_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Wolves Growing Season.	wlf_grow_fin
Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)	Wolves Winter Season.	wlf_wint_fin

4.4 Approaches to Map the Indicators

With the list of indicators refined to a list suitable for spatially representing the M-KMA, the approaches to measure and spatially display wilderness were developed. Through the data assessment process, I looked for approaches to rate and assess indicator values. Some data sources for indicators had an embedded rating scheme. For example, the enduring features indicator had data values categorized into (1) rare, (2) varied, (3) rare and varied etc., groupings. For other indicators, I developed or adapted these values. For example, Watershed Integrity values were created by comparing the amount of development in each watershed and then ranking those values.

Data for each indicator were mapped by converting vector layers, either downloaded from previous sources or created in Arc GIS, into raster format. Each ecological and social indicator was developed into a fluid raster grid with reclassified values ranking from 1 to 10. This 1 to 10 ranking was chosen to be compatible with methodology in *"Potential Conflict Between Future Development of Natural Resources and High-value Wildlife Habitats in Boreal Landscapes"*, where 1 was low value and 10 was high value (Suzuki & Parker, 2016).

4.5 Analysis and Synthesis Approaches

The approaches used in analysis and synthesis of the criteria and indicators occurred in several steps: 1) synthesis of individual indicator results; 2) creation and application of human footprint models; and 3) analysis of a Wilderness Character map compared to other resource values. Figure 11 graphically depicts the elements of the Wilderness Character model for the M-KMA: the Ecological and Social Characteristics of Wilderness based on the five ecological and two social Indicators, as well as Ecological and Social Human Footprint maps.

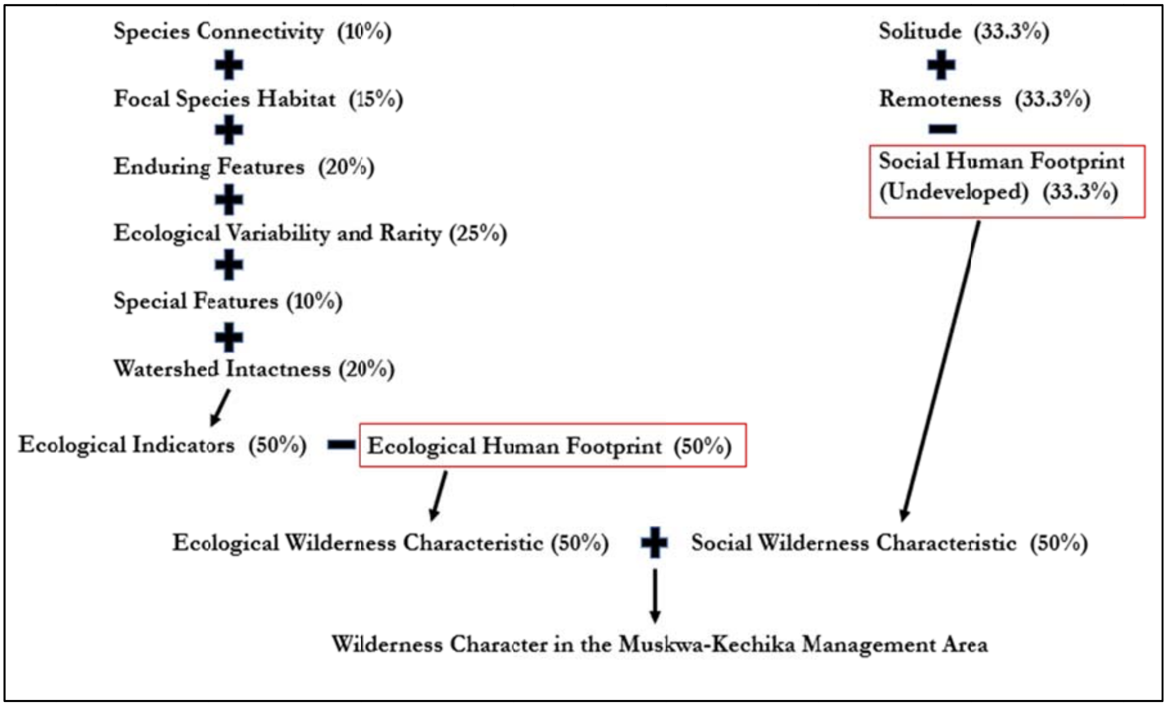


Figure 11. Outline of the Wilderness Modelling Process for the Muskwa-Kechika Management Area Showing the Weight of All Model Components.

4.5.1 Creation and Application of Human Footprint Maps

Following the mapping of individual indicators, the human footprint model, commonly known as the 'development layer' in previous literature, was produced by reviewing common wilderness and human footprint literature. The literature specific to the M-KMA was also reviewed with respect to the type of developments that are acceptable in an M-KMA wilderness setting. Data were sought through various online databases (previously mentioned: Data BC and Data Basin).

With each of the developments represented, I then developed a buffer and weighting scheme for the human footprint layer. This buffer approach was based on a previous mapping document: *The Peel Watershed: International Significance report (2008*), which assigned larger buffers to developments that pose greater harm/affect to the environment over time (Green et al., with

UNEP-WCMC, 2008). Weighting of each development was based on its permanence on the environment, and for the magnitude of the development on the landscape over time, using methodology adapted from the Conservation Area Design (CAD) for the Muskwa-Kechika Management Area (M-KMA), which developed a weighting scheme for human linear, point and area 'footprints' (Heinemeyer et al., 2004).

I developed two human footprints (one ecologically based and one socially based) to merge with the Ecological and Social Wilderness Characteristics. For the Ecological Human Footprint, each development was combined into a raster mosaic using a cumulative function that added each layer together with the result showing where overlapping developments were common or not common in the area. The Social Human Footprint allowed for additional adjustments related to negative effects of development including noise and visual deterrents. The Ecological Human Footprint was equally weighted at 50% and merged with an Ecological Indicators model (the combination of the five ecological indicators; Figure 11) to create the Ecological Wilderness Characteristic map. The Social Human Footprint, which also used the Ecological Indicators' undeveloped layer (with modifications), was equally weighted (at 33.3%) with the two social indicator maps (solitude and remoteness) to create the Social Wilderness Characteristic map. I then evenly combined the Ecological Wilderness Characteristic map and the Social Wilderness Characteristic map to model Wilderness Character in the M-KMA (Figure 11 for review).

In summary, the steps taken to create a finalized mapping model of wilderness in the M-KMA were:

1. An individual analysis was done for each indicator layer.
2. Simultaneously, these indicators were them merged with the human footprints to create the Ecological Wilderness Characteristic and the Social Wilderness Characteristic (the addition of merging a characteristic model with a human footprint model subtracts the values of the characteristic model representing the 'influence' or 'footprint' that humans

have on wild land). For the social model, the Social Human Footprint layer represents the 'undeveloped' indicator of wilderness.

3. The Ecological Wilderness Characteristic Map and the Social Wilderness Characteristic Map were then added together to create the final Map of Wilderness Character for the Muskwa-Kechika Management Area.

4.5.2 Analysis of the Wilderness Map Compared to Other Resources

Once the final wilderness map was developed, I examined how wilderness values compared to other resource values, in particular where the high wilderness values overlapped with other high values of different resources. To do this, I used previously created layers developed by Suzuki & Parker (2016) for mineral, timber, oil and gas, and wind energy potential in the M-KMA. Before this analysis, I eliminated areas that were already classified as a Park or Protected Area, as they would not be subject to resource exploitation. Then, I reclassified all of the layers (wilderness, minerals, timber, oil and gas, and wind energy) into four equal categories of Very-High, High, Moderate and Low to assess overlap of very high-valued resources. I compared and overlapped the highest value category for each layer to assess the overlapping areas of potential conflict.

4.6 Informing Model Development with Advisory Group Input

To assist in the development of the overall approach to map and model Wilderness Character in the M-KMA, I formed an advisory group at project initiation[9]. The first part of the advisory group consisted of my supervisory committee members, who have expertise in GIS, ecological integrity and wilderness character mapping. The second part of the advisory group consisted of members of the M-KAB Wilderness Working Group, consisting of a cross section of individuals representing multiple sectors and expertise. Throughout the years of this project I made several presentations to the M-KAB Wilderness Working Group (or the M-KAB as a whole) to update them on the progress of my research and to encourage their participation. At

[9] Conducted under the authority of the UNBC Research Ethics Board.

specific points in the development of the wilderness mapping procedures I met, either in person as a group or consulted individually (usually by phone/email) with members of the advisory group to obtain input on specific questions or steps.

The most significant source of input from the advisory group revolved around a workshop I conducted with group members at UNBC on October 15th, 2015. At that meeting, I provided an update of the work conducted to date and asked the group to provide specific feedback on final indicator selection, the indicator weighting scheme for the first Human Footprint models, the Ecological Wilderness Characteristics, the Social Wilderness Characteristics and the overall weighting scheme for each indicator and each characteristic for the wilderness model. I solicited feedback in two different ways: the first involved open-ended questions designed to obtain individual and group perspectives on the approach taken and the second entailed more specific quantitative rankings of weighting and buffering schemes for the footprint models. Although I had originally intended to obtain individual feedback from each advisory group member for these items and then compile them, the workshop quickly evolved into a collaborative group discussion producing a more unified result. For example, when presented with a draft list of buffers for the impact of human developments on the ecological values of the M-KMA, the group discussed the items and came to a consensus decision on the result. In another case, advisory group members with specific on-the-ground knowledge of the M-KMA identified potential weaknesses in how data sources regarding seismic lines were identified, which led me to explore potential options for alternative data sources or for clarifying the data.

There was no doubt that the advisory group was integral to the steps I undertook to develop the wilderness mapping model. Members provided continuous feedback into the approach I took to develop the model and guidance on next steps.

Chapter 5: Model Development and Computing

My thesis was designed to model and map both the ecological and social characteristics of wilderness in the Muskwa-Kechika Management Area.

5.1 Phase 1: Criteria and Indicator Development

I chose a multi-indicator approach to mapping wilderness that combined both ecological and social indicators together to develop a more complex map. By considering both the ecological values integral to ecological integrity and the intrinsic social values closely related to the M-KMA wilderness experience, I hoped to provide a fluid representation of the varying wilderness qualities, and ultimately, the varying wilderness experiences available.

The model outlined in Figure 11 is a simplified representation of a complex system of combining layers and layer values to create a finalized mapping model of wilderness in the M-KMA. Five ecological indicators and two social indicators were chosen for this analysis (see section 4.1 and Appendix C).

5.1.1 Ecological Indicators

Species Connectivity and Habitat

In order for biodiversity and healthy wildlife populations to be maintained, core habitats and connectivity between them need to also be maintained. Predator-prey systems are supported by a large array of charismatic species, low-lying valleys and high alpine ridges, which provide connectivity. The connectivity of landscapes used by large species such as caribou, elk, grizzly bears and bison allow for seasonal movements, help maintain genetic diversity, and provide for the needs of other smaller species. As climates shift, species that have connected habitat are more likely to persist (Yellowstone to Yukon Conservation Initiative (Y2Y), 2012). Therefore, to maintain critical 'wild' habitat through time, connectivity must be maintained. Focal species such as caribou, elk, mountain goats, Stone's sheep, grizzly bears, moose and wolf are umbrella species that represent protection of a range of biodiversity if they themselves are protected (Heinemeyer et al., 2004).

Enduring Features

Enduring features on the landscape include physical topography such as elevation, slope and aspect, as well as geology and bedrock, macro landforms and major water elements such as watersheds. The premise supporting enduring features is that while ecological shifts such as climate change may result in significant change to ecosystems (e.g., vegetation), preserving the diversity of enabling conditions that support biodiversity will support diversity in the long run (Yellowstone to Yukon Conservation Initiative, 2012). The *M-KMA Biodiversity and Climate Change Assessment* (Yellowstone to Yukon Conservation Initiative, 2012) mapped enduring features in the M-KMA into nine elevation groups, 10 substrate groups, and 23 macro land forms (Heinemeyer et al., 2004).

Ecological Variability

Ecological variability, much like enduring features, shows the extent of varied landscapes using the Biogeoclimatic Ecosystem Classification (BEC) zone system. When defining environments, vegetation is usually a central feature, but BEC also integrates other ecosystem components including site, soil, and biota. The current BEC maps and BEC site unit classification provide data with baseline information to assess changes in ecosystems and species distribution, and to track the evolution of these zones as climates change (Pojar & Klinka, 1987).

Special Features

Special features on the landscape such as wetlands, large lakes, valley bottoms, karst environments and mineral licks are often keystone habitats, and sometimes biological hotspots, which provide for an abundance of species diversity. Areas that have higher productivity are more likely to have higher biological productivity, such as wetlands, and support focal wildlife species that might not be captured during habitat suitability models. Maintaining higher primary productivity in an area may lead to maintaining a wider range or species (Yellowstone to Yukon Conservation Initiative, 2012).

Watershed Intactness

At a landscape scale, watershed intactness can measure landscape fragmentation and perforation. An *Inventory of Undeveloped Watersheds in British Columbia* (1992) used a 2% fragmentation rule which states that if the fragmentation was less that 2%, then it was considered an intact watershed (British Columbia Ministry of Forests, 1992).

5.1.2 Human Footprint

Undeveloped landscapes are important in retaining ecological conditions of wilderness and the wilderness experience. Areas that are less developed tend to produce healthier, more diverse wildlife populations and are better able to maintain ecosystem systems and functions. Wild and less fragmented areas are better to connect important focal habitats and provide better recreation in terms of the wilderness experience (Yellowstone to Yukon Conservation Initiative, 2012). The intent of this indicator is to show spatially the magnitude and permanence of developments on the land. This includes oil and gas developments on the eastern portion of the M-KMA, logging in the southern portion, houses, cabins, campsites, roads, trails, cut lines, rural developments, and the two primary transportation routes near the M-KMA – the Alaska and Cassiar Highways (Heinemeyer et al., 2004).

5.1.3 Social Indicators

Solitude

Solitude is an important social attribute of the wilderness experience. It is used as an indicator of wilderness because it is often attributed to recreational activities free from the constraints of society. This indicator can be degraded through sight and sound of developments or people, recreational facilities and management restrictions (Landres et al., 2008 *In* Tricker et al., 2012). Solitude provides a chance for self-reliance, closeness to nature, risk and challenge (British Columbia Ministry of Forests, 1998). The Recreation Opportunity Spectrum (ROS) and Wilderness Opportunity Spectrum (WOS) outline expectations for primitive and pristine wilderness areas. Primitive solitude consists of a large area that provides a high opportunity to experience self-reliance and challenge with no, or minimal, interaction with other people; when people are encountered they are smaller party sizes (British Columbia Ministry of Forests, 1998).

Undeveloped (Represented by the Social Human Footprint for this model)

The undeveloped wilderness quality is often also referred to as the 'naturalness' of wilderness. Natural and perceived natural qualities are degraded by developments and by the use of motorized vehicles and motorized equipment (Tricker et al., 2012). In addition, naturalness is affected by the site modification, site degradation, and restrictions on controls and facility developments (British Columbia Ministry of Forests, 1998).

Remoteness

Whereas solitude is measured by the chance or possibility of encountering others, remoteness can be measured by distance from main access routes and settlements, distance from aircraft landing strips, and distance from designated trails or popular routes (Tricker et al. 2012). A primitive wilderness is remote when it is secluded by minimal air access and has no motorized access; it must be at least 8 km from an access route (British Columbia Ministry of Forests, 1998).

With a clear list of wilderness indicators defined and ways to spatially represent them, I developed an approach to represent the human anthropogenic influence on the land. I developed two of these layers, which show separate influences on the land: (1) The Ecological Human Footprint model and (2) The Social Human Footprint model. The Ecological Human Footprint shows the influence, severity and extent of human influence on ecological systems. The Social

Human Footprint shows the influence, severity and extent of human influence on the social wilderness experience values in the M-KMA.

5.2 Development of the Human Footprint Model

The Human Footprint is a model that shows the developments or footprint that humans have on the natural environment. Developments for this model are point, line, and polygon data that vary in severity from a dock or cabin to an open-pit mine. Data for this model were obtained in several layers collected from Data BC: designated areas, pits, mines, (tculln22jan04_arc); agriculture, rangeland, logging (btm_impacts polygon); cutlines (tmisc22jan04 acr); roads, trails, rail, bridge, airstrip, airport (ttrnln_ama_arc); and man-made structures – buildings, gravel pits, gas wells, etc. (tculpt22jan04point). Working in ESRI's ArcGIS v.10.3, the developments were separated into layers, which were then weighted and buffered.

5.2.1 Weighting and Buffers

Each development was weighted from 1-10 with lower numbers representing developments that have a higher degree of influence on wilderness quality (permanent roads have the lowest weight as they have the largest impacts on wilderness quality). Higher weighted developments represent developments that do not have a high degree of influence on the land and therefore are less likely to degrade wilderness quality. This weighting scheme is similar to the Conservation Area Design (CAD) for the Muskwa-Kechika Management Area, which developed a weighting scheme for human linear, point and area 'footprints' which were weighted based on relative potential of human use and relative human influences from that use (Heinemeyer et al., 2004). My research focused specifically on mapping developments that are currently altering the landscape throughout the year, although frequency of use was not available; at different times of the year the M-KMA wilderness use can vary substantially from high alpine snow recreation to low valley river cruises.

Because my study could not solely weight on relative use as there is scarce use and user data for this area (Heinemeyer et al., 2004), I created a permanence and magnitude weighting scheme. In addition, the CAD was missing data information such as cabins, campgrounds, river access and guide camps. The relative use analysis used for the CAD put more emphasis on the potential of use and actual use of developments and not their relative influence on the ecology of the area. Considering that my research sought to map the current extent and variety of wilderness in the M-KMA, a different approach was taken to weighting developments.

Weighting for human footprint indicators incorporated applying both a permanence weight and a weight of magnitude to each disturbance. In this case, I define permanence as, "the state or quality of lasting or remaining unchanged indefinitely" (Permanence *In* English Oxford Living Dictionary, 2018: para 1). This refers to the capacity a development or structure needs to have to last over a long period of time (100 years). Therefore, developments that include creating permanent built-in structures are viewed as having a higher permanence than areas that have quicker ecological rehabilitation time such as trails and logged areas. The scoring for these permanence weights, in order to work mathematically with other current M-KMA mapping models, is reversed: developments that are the most permanent have a low (1) weight and developments that are the least permanent receive a high weight (10). Areas that have potential to be used sporadically such as river boat access and float plane-landing lakes have a higher permanence weight because their use does not have a permanent effect on the surrounding area. Areas with intensive resource developments such as mines and seismic lines have the lowest possible permanence weight as they often create landscape-sized disturbances (Heinemeyer et al., 2004).

The magnitude of a disturbance is defined as, "great size or extent" (Magnitude *In* Merriam-Webster's Collegiate Dictionary, 2018: para 1). Developments have different levels of magnitude and therefore were weighted differently. Developments that have a larger magnitude of development or land disturbance have a low (1) weight and developments that pose a smaller magnitude received a high weight (10). The lower weight implies that a development has a higher magnitude, extent and effect on the surrounding area.

Each development received both a permanence and magnitude value. Both values were then added together and divided by two to get the average value for each development. This ranking scheme ranks each impact from 0 (no impact) to 10 (high impact). The weighting scheme of 1 to 10 was adopted to be compatible with various resource layers already developed for the M-KMA where 1 represents a low value where permanent development has a larger magnitude of influence on the environment and 10 indicates a high value where developments have a lower, less permanent influence on the environment (Table 6).

Buffers

The buffer sizes for the developments were a result of researching different government legislation, research literature, and resource guidelines. Using these resources, a preliminary minimum allowable buffer was established for each development. The Conservation Area and Design (CAD) approach took use frequency into account, separating them into long-term human footprint developments and short-term human footprint developments, and therefore was used as a buffer guide to finalize the human footprint layer buffers. Mimicking their approach on buffering the human footprint layer, as it was the most conservative, buffers were adjusted for seasonal or short-term developments (e.g., air-strips). This was beneficial because the M-KMA has relatively little use in most areas; of that, some is only short term to seasonal use, such as airfields and landing lakes. As the M-KMA is remote, it was important to add popular landing lakes and river boat access use areas to the human footprint model to account for all kinds of ecological and social disturbances.

Table 6. A Weighting of Developments in Human Footprint Models

Data Layer	Permanence	Magnitude	Average Weighting
Trails	9	9	9
Float Plane Lake Access	10	6	8
Motorized trails	8	7.5	7.75
Riverboat Access	10	8	9
Guide Camp	7	8	7.5
Campsite/ campground	6	7	6.5
Cabin/ lodge	5	6	5.5
Dock	9.5	9.5	9.5
Farms/ houses	4	6	5
Buildings	4	6	5
School	4	6	5
Airstrips	8	6	7
Crop Lands	6	9	7.5
Range Land	9	9	9
Tower	1	6	3.5
Communication Station	1	6	3.5
Electrical Substation Complex	1	6	3.5
Logged Areas	9	8	8.5
Cut-blocks	9	8	8.5
Built-up area	1	6	3.5
Gravel Pit	1	5	3
Dump or Sewage	1.5	6	3.75
Burner	1	6	3.5
Rail line	1	4	2.5
Unimproved roads	7	7	7
Gravel Roads	4	4	4
Oil and Gas points	1	4	2.5
Oil and Gas Linear	8	2	4
Mine- abandoned	1	3	2
Mine- underground	1	3	2
Mine- open pit	1	1	1

Tailings Pile/ Pond/ Dump	1	3	2
Paved Roads	1	1	1
Wind Power	1	1	1
Dock/ Fence	0	0	0

A list of landing lakes was supplied by a key informant. While researching river access points, it became clear that river access is on all major rivers in the area. Therefore, only major river routes were selected to be buffered as a development layer. It was assumed that some access points (landing lakes, river access or air strips) are not on the map due to missing or incomplete data.

Revisions were made to the Human Footprint development list after meeting with the MK Wilderness Working Group (see Criteria and Indicator Review section). Some of the layers were again adjusted to fit the parameters needed for GIS analysis. As all the points needed to be integer values, the floating points (values that had .5 or .75) needed to be rounded to an integer value. To err on the side of caution, these values were rounded down with the exception of the dump development layer, which moved from 3.75 to 4 (Table 7).

Table 7. Final Weights, Buffers, and Area for Developments Used in the Ecological Human Footprint Model

Developments	Weight (1-10)	Buffer (km)	Area (ha)
Mine (open pit)	1	10	31416
Paved Roads	1	10	433573
Windpower	1	10	65676
River Boat Access	1	5	25560
Taillings Pond	2	7.5	17671
ATV Trails	2	7.5	822585
Open AMAs	2	7.5	2984812
Oil and Gas Points	2	10	216832
Drill and Well Site	2	10	281091
Gravel Pit	3	2.5	179892
Dump	4	6	11309
Gravel Roads	4	7.5	87163
Air Strips	4	1	13503
Oil and Gas Pipelines	4	5	123991
Seismic Cutlines	4	1	463296
Buildings	5	7.5	1281729
Transmission Tower	5	7.5	35342
Burner	5	7.5	17671
Campground	6	5	42694
Designated Area Lines	7	5	304715
Agriculture	7	2.5	23465
Float Plane Access	8	1	149274
Mine (abandoned)	8	2.5	12281
Logged Areas	8	2.5	25598
Trails	9	2.5	335180
Roads (cut and fill)	9	2.5	65099
Rangeland	9	2.5	118717
Abandoned Airports	9	0	12872m (length)
Fence	9	0	15866m (length)

Dock	9	0	0

SCALE: 1-10
1 is a development with a high relative permanence with a significant magnitude
10 is a development with low relative permanence and a low magnitude

5.2.2 Creating the Social Human Footprint or 'Undeveloped' layer

The Social Human Footprint model was adjusted from the Ecological Human Footprint model with changes made to any developments that make noise, have light pollution, or drastically alter the viewscape such as transmission lines and tailings ponds; for any development that had either of these qualities their weighting was reduced by 1. These included open Access Management Areas (AMA's), ATV trails, a tailings pond, gravel roads, air strips, dumps, transmission towers, campgrounds, float plane access lakes, and logged areas. In addition, to account for the social value of solitude, and to portray isolation, two layers had buffers adjusted. The trail layer had its buffer adjusted from 2.5 to 5 kilometers and the air strips buffer was changed from 1 to 2 kilometers to account for the noise of air traffic. Several of these adjustments came as recommendations from the Muskwa-Kechika Advisory Board during the criteria and indicator review meeting (see below).

5.2.3 Criteria and Indicator Review

An in-person consultation with key informants from the M-KMA Wilderness Working Group took place on October 15th, 2015 (see Section 4.6; Figure 12). After a review of progress, the floor was opened up to comments; one person in attendance commented on how the mapping process was "completely appropriate" as "we don't know – we don't have a great knowledge of the hard and fast mapped wilderness characteristics out there and, it may not be appropriate to map every moose lick or trail" (pers. comm, 2015). They noted how with the scope of the M-KMA and the likelihood of recent large-scale developments, it is important to develop guidelines for mapping wilderness. Another person commented, "the big piece is getting the process right and testing it as best we can on whatever data is there and then having that template that proponents can use to flesh out data at a smaller level. They will have the resources to do the mapping at the scale they need at that point" (pers comm, 2015).

Figure 12. The Wilderness Working Group Consults on the First Draft of the Ecological Human Footprint Map on October 15, 2015.

Several recommendations from the Wilderness Working Group were made. These included:

1. Assess whether seismic cut lines can be distinguished from heli-portable cuts or cat-cuts as there is a big difference in the disturbance and reclamation.
2. Remove dock and fence buffers.
3. Add wind power, pipelines, and exploration camps.
4. Lower weighting for roads, motorized trails, and logged areas.
5. Add in river-boating and weight it like motorized vehicles as it is "intense in some places".
6. Remove gravel pits as they are subsumed by roads.
7. Alter the Social Human Footprint to lower any development that has light pollution or makes noise.

In addition, they noted that the process could be improved if there was a way to reflect the temporal aspect of use with river-boat access and airstrips.

Ground Truthing Criteria and Indicators

From August 23rd to September 2, 2015 I had the good fortune to go deep into the Muskwa-Kechika Management Area to partake in a guided pack trip with Wayne Sawchuk of Muskwa-Kechika Adventures. The vast expanse of the M-KMA was overwhelming and heartening at the same time. The clear goal to adequately represent this area was intensified from working closely with Wayne and his crew, who knew so much about the area and truly loved the land. It was clear from all on the expedition that maintaining the wilderness quality is key to maintaining the wilderness experience; as one person I was on the trip with, stated: "the legislation is only as strong as the people advocating for it" (pers comm, 2015).

5.3 Phase 2. Developing the Mapping Tool

Base map GIS layers were collected and created in ESRI's ArcGIS 10.3 as 12 BC Albers 1:250,000 map-sheets were merged together into a 25-by-25-meter raster grid. I chose to make each raster grid cell 25-by-25-meters to work with previously developed resource layers. A study boundary was created around the M-KMA and all the base map data were clipped to that extent.

A value of 11 was added to any grid cell outside of the M-KMA boundary as some of the shapefiles had diverse extents. A 25-meter by 25-meter grid cell was used for all the ecological and social indicators except for the Ecological Variability layer, which used an overlapping layer consisting of 1500-hectare planning units (PU) or polygons draped over the raster grid cells to assess the variety of BEC units within one PU (the most was eight different BEC units in one PU – more variable – and the least was one BEC unit in one PU – less variable). The manipulation of each indicator varied as some required little-or-no manipulation (e.g., Special Features) while others required the creation of a new dataset (e.g., Watershed Integrity).

5.4 Human Footprint Maps

5.4.1 Ecological Human Footprint

Each development was separated into its own layer and then weighted. In the attribute tables, a new field was added – weight, and each development's weight was added into the layer's attribute table. Each development was then buffered according to the ecological buffers. The value field that was highlighted for each buffer was the 'weight' field so that the weight values were emphasized and remained within the attribute table. Each layer was then turned into a raster grid with the weight value being identified as a value input field. The Raster Calculator tool was used to create a fluid rectangular grid of valued pixels in a dot matrix structure over the study boundary. With all the developments in a raster grid, they were then adjusted so that each layer spanned the extent of the study boundary.

Then the Mosaic-To-New Raster tool was used with the minimum function. This tool merges all raster datasets into one raster dataset. Using the minimum function, this tool computes each value in every grid cell in every raster layer to determine which overlapping cell has the lowest value; for each grid cell, the lowest value is shown on the new raster. The overall result is a more conservative model of developments, presenting a fairly distinct contrast between developed and non-developed areas. As the wilderness scale was 1-10, an 11 value was then only located outside of the M-KMA; the whole of the M-KMA was represented by values of 1-10. The Social Human Footprint was developed the same way the Ecological Human Footprint was developed with the exception of lowering the weight value for some of the developments and adjusting a few of the buffers for seasonal use.

5.5 Ecological Indicator Maps

Species Connectivity and Enduring Features

Fortunately, the species connectivity model and enduring features model had already been mapped (Yellowstone to Yukon Conservation Initiative, 2012) so few adjustments were needed. The connectivity layer was reclassified using the Reclassify tool to 10 classes of natural breaks and valued from 1-10 with 1 being area with lower connectivity and 10 being area with the highest connectivity values. Lastly, as the layer was already a fluid rectangular grid of valued pixels, it was then fixed to the extent of the study boundary using the Raster Calculator tool. The enduring features layer was classified into feature categories: (1) rare, (2) very rare, (3) high variety, (4) very high variety, (5) rare and high variety, (6) rare and very high variety, (7) very rare and high variety, (8) and very rare and very high variety (Table 8). As each layer was already significant to wilderness (having rare and varied features), I adjusted the values as seen below to show that they are all high wilderness values. Since there was no research to suggest how to weight these categories, they were separated into three weights based on whether rare, varied or a combination of both. As this layer was already a fluid rectangular grid, it was fixed to the study boundary.

Table 8. Enduring Feature Categories and Their Assigned Weights

Assigned Weight	Enduring Features
8	Rare and Very Rare
9	High Variety and Very High Variety
10	Rare and High Variety, Rare and Very High Variety, Very Rare and High Variety, and Very Rare and Very High Variety.

Focal Species Habitat Suitability Index

Protecting the growing season and winter season habitats of focal species such as caribou, elk, mountain goats, Stone's sheep, grizzly bears, moose and wolves can help encompass habitat of numerous other species, creating an 'umbrella' effect of natural protection. The growing season habitat characteristic layers and winter season habitat characteristic layers of each species from Heinemeyer et al. (2004) were merged and then each species layer was merged into an All Habitat layer. This layer was then reclassified. As all areas of wildlife habitat were identified as having good ecological wilderness qualities, the values were reclassified into 4 classes from 6-10 with 6 being areas with high habitat quality and 10 being the highest habitat quality. As this layer was already a fluid rectangular grid, it was fixed to the extent of the study boundary using the Raster Calculator tool.

Ecological Variability

Using the biogeoclimatic ecosystem classification (BEC) zone system, ecological variability is spatially represented by the variety and rarity of the four zones and their sub-zones found in the area: Alpine Tundra (AT), Boreal White and Black Spruce (BWBS), Engelmann Spruce Sub-alpine Fir (ESSF), and Spruce-Willow-Birch (SWB).

In order to get the *variety* of the BEC zones, the BEC zone layer was intersected with a 1500-hectare planning unit (PU) layer resulting in 1500-hectare PUs that spanned the M-KMA. The Summarize tool was used to get a count of the number of BEC sub-zones in each PU[10]. The summary table was joined to the BEC layer and the symbology was changed to represent the count numbers. The values were ranked from 1-8 with one representing a PU that only had one BEC sub-zone and eight being a PU with eight sub-zones, indicating an area that could support a larger array of biodiversity. While there are ten BEC sub-zones, eight was the maximum number

[10] For a complete list of sub-zones in the M-KMA view the table below.

of sub-zones observed in one PU. This layer was then turned into a fluid rectangular grid of valued pixels in a dot matrix structure using Polygon to Raster and fixed to the study boundary extent with the Raster Calculator.

The *rarity* of the BEC zones was calculated by comparing the percentage of each sub-zone found in the M-KMA to the total sub-zone percentage of BC. Table 9 shows the BEC sub-zone areas in BC and their areas in the M-KMA as well as their assigned values from 1-10 with 10 being the rarest sub-zone and 1 being the most prominent.

Special Features

Special features have been previously identified as including important landscape features such as wetlands, karst environments, mineral licks and other keystone habitats, which are common hotspots for biological diversity (Yellowstone to Yukon Conservation Initiative, 2012). Unfortunately, there is little publicly available information on karst environments or mineral licks in northern BC and therefore my study used wetlands as the only value within the special features indicator. The wetlands layer was cut to the extent of the study boundary and then weighted 10 to represent having a high wilderness quality. It was turned into a fluid rectangular grid using the Polygon to Raster tool and then fixed to the extent of the study boundary using the Raster Calculator tool.

Table 9. Rating Method for Biogeoclimatic Ecosystem Classification (BEC) Zones to Represent Ecological Rarity in the Muskwa-Kechika Management Area

Zone Name	BEC Sub-Zone	Area of Zone in BC (Ha)	Area of Zone in M-KMA (Ha)	Value
Spruce--Willow--Birch	Moist Cool Scrub	1627353	2516.4	1
Englemann Spruce--Subalpine Fir	Moist Very Cold Parkland	507486	309.9	2
Boreal Altai Fescue Alpine	undifferentiated	6125608	1514	3
Spruce--Willow--Birch	Moist Cool	4197188	507.6	4
Englemann Spruce--Subalpine Fir	Moist Very Cold	2956380	121.9	5
Boreal White and Black Spruce	Wet Cool	833387	11.1	6
Boreal White and Black Spruce	Dry Cool	2064110	7.2	7
Sub-boreal Spruce	Moist Cool	1788496	4.1	8
Boreal White and Black Spruce	Warm Moist	2900649	4.8	9
Boreal White and Black Spruce	Moist Cool	9647455	1.2	10

Note: A value of 10 indicates it is the rarest sub-zone and a value of 1 indicates the most prominent sub-zone in the M-KMA relative to BC.

Watershed Intactness

Watershed intactness is represented by the amount of development within each watershed. I used the already delineated British Columbia Watershed Atlas groupings. Topographic aquatic features such as lakes, rivers and streams used in the mapping process, where all third-order or greater watersheds were defined by a boundary, were identified for all of BC by the government of BC Fisheries division. I used the watershed groupings that were within the M-KMA boundary and ranked each by the amount of area containing developments in order to assess which watersheds had the most and least developed area. Using the same developments as the Ecological Human Footprint model but without any buffering, the point and line shapefiles were then buffered by 0.25 meters to dissolve development lines and create polygons that could be merged and measured. This layer was then intersected with the watershed groupings shapefile of BC. In the attribute table, an Area field was added and the table was exported to Excel to get the percent of intersecting developments in each watershed; this table was then joined to the shapefile again and another Weight field was added to the attribute table (Table 10 below). Lastly, the watershed layer was turned into a fluid rectangular grid using Polygon to Raster and then fixed to the study boundary extent with the Raster Calculator. Watershed intactness in this analysis is specifically relative to the area of development per area of the watershed in the M-KMA. For that reason, some watersheds that only have a small percentage of their reach in the M-KMA are represented with a high value regardless of their 'intactness' outside of the M-KMA boundary. For example, the Stikine, Dease River and Pitman River Watersheds had too small an area represented in BC and after the analysis was done the results indicated that they have a perfectly intact or a '10' area, although this is not a good representation of the whole watershed grouping's actual intactness.

Table 10. Watershed Intactness Weighting Scheme

Watershed Name	Overlap with Developments (in Ha)	Watershed Value
Stikine River	366	10
Peace River	157101	10
Pitman River	489	10
Dease River	333	10
Rabbit River	370533	9
Finlay River	874143	8
Kechika River	1965540	7
Liard River	671987	6
Fort Nelson River	1295040	5
Road River	712012	4
Halfway river	336902	3

5.6 Social Indicator Maps

Solitude

Due to the lack of data on the number of visitors in the M-KMA, a proxy measure for solitude was created. The *Local Strategic Recreation Management Plan for the Muskwa-Kechika Management Area* (2005) outlined estimates of potential use for each Resource Management Zone (RMZ) (Rutledge, & Davis, 2005) (See Appendix D). This table was reviewed by a key informant with intimate knowledge of the M-KMA for accuracy and currency and then the numbers were added into an Excel file into two columns: Estimated Public Use and Estimated Commercial Use. A Total Use column was created from the total of both Estimated Public Use and Estimated Commercial Use. The table was added into Arc GIS and 'joined' to the RMZ layer. Using the Reclassify tool, the values were adjusted to 10 natural breaks (Table 11):

Table 11. Reclassified Values of Total Use for Each Resource Management Zone (RMZ)

Total Use for Each RMZ	Reclassified
0-6	10
7-30	9
31-80	8
81-180	7
181-325	6
326-450	5
451-800	4
801-1400	3
1401-5000	2
5001-140,000	1

Each RMZ was reclassified with values from 1-10 with 1 representing areas that have the highest total visitors per year (5001-140,000) and 10 being areas that have 0-6 visitors per year. This solitude layer was then turned into a fluid rectangular grid and merged with the study boundary extent using the mosaic to raster minimum function.

Remoteness

Remoteness indicates areas that are a set distance from the main access points in the M-KMA as per the Ministry of Forests guideline for *pristine* environment on the Recreation Opportunity Spectrum (British Columbia Ministry of Forests, 1998). The main access points included: the Alaska Highway, trails, open Access Management Areas, jet boat river access, float plane landing lakes, air strips, gravel roads, and campgrounds. A Multiple Ring Buffer was used on each layer. Points or lines were first buffered by 100 meters to account for the range that light and sound may travel from a trail or camping location. Using the Multiple Ring Buffer approach set distances of 2, 4, 6, and 8 kilometers were applied to set a gradient of remoteness across the area. The 'ringed' access layer was then turned into a fluid rectangular grid of valued pixels in a dot matrix structure.

Social Human Footprint or 'Undeveloped' Layer

The undeveloped quality of wilderness is usually represented by area uninhabited by permanent structures. In theory, wilderness can be degraded by the presence of structures, permanent and non-permanent residences, motorized activity, and other non-recreational structures (Landres et al., 2008). In my study, this undeveloped indicator layer was represented by the Social Human Footprint model (as in Section 5.2.2). The Social Human Footprint used the same data for developments as the Ecological Human Footprint layer. It varied from the Ecological Human Footprint in that developments that would have a social effect on the landscape (e.g., made a noise or shone a light) were downgraded by one level. However, the developments retained the same buffers as within the ecological model. In addition, the function used to merge the developments was different. Instead of the cumulative function used for the Ecological Human Footprint, which emphasized areas where developments converge, the Social Human Footprint model used a minimum function as it produces a more conservative representation of the footprint taking into account sights and sounds of developments and access routes.

With each indicator set to the study boundary, the Extract by Mask tool was used to 'cookie-cut' the final indicator maps to the M-KMA boundary (See Results section).

5.7 Merging Indicators and Creating the Wilderness Map

The six ecological indicators were merged together with the Ecological Human Footprint model using the Raster Calculator tool. Each indicator was weighted appropriately in response to its data availability and quality to create the M-KMA ecological wilderness values. The indicators were weighted as follows: Species Connectivity (10%), Focal Species Habitat (15%), Enduring Features (20%), Ecological Variability and Rarity (25%), Special Features (10%), and Watershed Intactness (20%), as in Figure 11. The resulting map titled *Ecological Indicators of Wilderness in the M-*

KMA (Chapter 6) was later reclassified so that the values were scaled from 9.1 to 10. The three social maps were merged together using the Raster Calculator tool. Each indicator was equally weighted at Solitude (33%), Remoteness (33%) and Undeveloped (33%). The resulting map *Social Indicators of Wilderness in the M-KMA* (Chapter 6.2) was later reclassified so the values were scaled from 9.1 to 10. Both these reclassified ecological and social maps were then merged together using the Raster Calculator tool and equally weighted with the Ecological Indicators of Wilderness at (50%) and the Social Indicators of Wilderness at (50%). The final result is the map titled *Wilderness Character in the Muskwa-Kechika Management Area* (Chapter 6.3).

Chapter 6: Wilderness Character Results and Analysis

In this chapter I present the results of mapping Wilderness Character within the M-KMA, organized in four sections:

6.1 Indicators that represent the Ecological Wilderness Characteristic of Wilderness Character, and the Ecological Human Footprint model;

6.2 Indicators that represent the Social Wilderness Characteristic of Wilderness Character, and the Social Human Footprint model;

6.3 Synthesis and analysis of overall Wilderness Character; and

6.4 Relationship of Wilderness Character to other natural resource values.

Readers should bear in mind a few important considerations relative to these results. The maps and associated analysis for the Wilderness Character indicators and overall Wilderness Character use scales of 1-10 (for the human footprint models), or 9.1 to 10 (for indicator and wilderness maps), where 1 represents lower wilderness quality and 10 represents higher wilderness quality. Colour ramps on the legends from light green to dark green are associated with these scales to ensure visibility. However, compared in particular to the landscapes surrounding the M-KMA as well as many other wilderness or protected areas identified worldwide, it is important to remember that the entire M-KMA is currently largely remote and relatively undeveloped. Thus, the lower wilderness quality-to-higher quality displays are a relative ranking scheme. A schematic of green to dark green was chosen to symbolize that while the wilderness qualities within the M-KMA do vary, the entire M-KMA is still considered wilderness.

It is also important to remember that some of the developments that inform the Ecological and Social Human Footprint models are more variable than the model suggests. For example, most motorized recreation in the M-KMA occurs in the ice-free season and sometimes in a much more restricted time period than that. However, as I could not accurately obtain data with a temporal dimension at the scale of the entire M-KMA, the wilderness maps are not temporally differentiated. Therefore, the human use impact of a landing strip, for example, might only have an impact for a few weeks of the year but the data are not weighted for this differential impact. Thus, the resulting wilderness maps are conservative in nature (with social being more conservative than ecological), representing the current baseline human footprint at its maximum level of probable impact.

6.1 The Ecological Wilderness Characteristic Model

I developed an Ecological Human Footprint model to combine with the Ecological Indicators of Wilderness to produce a map of Ecological Wilderness Characteristics and anthropogenic influences in the M-KMA.

6.1.1 The Ecological Human Footprint

The Ecological Human Footprint map (Figure 13) represents all existing developments largely derived from government data sources for which mapped data were available.

It shows a gradient of developments within the M-KMA from 1-10 where 1 (a light green) indicates that there are more developments present in an area. The varying sizes of the elliptical shapes are due to the different buffers on the developments. Areas that have a lighter green are more likely to have been impacted by developments, whereas areas that have a darker green have no measurable developmental impact to the environment at the time of this study. The color gradients of the Ecological Human Footprint Map can be grouped into four classes: lower (values 1, 2 and 3), moderate (values 4 and 5), high (values 6 and 7), and very-high (values 8, 9 and 10).

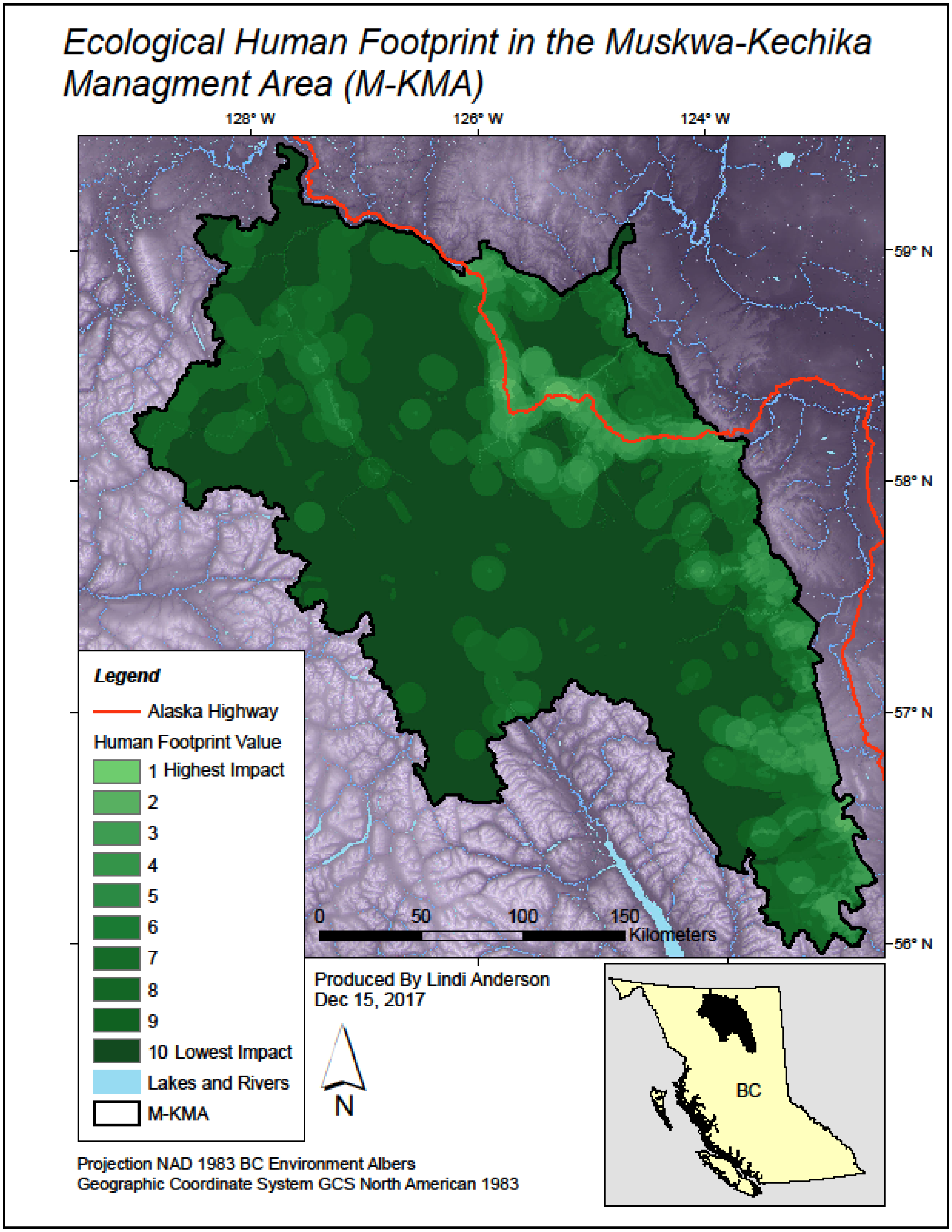


Figure 13. Ecological Human Footprint in the Muskwa-Kechika Management Area (M-KMA).

The final value representation for the Ecological Human Footprint is summarized in Table 12 below:

Table 12. Ecological Human Footprint Values in the Muskwa-Kechika Management Area (M-KMA).

Ecological Human Footprint Value	*% of the M-KMA*
1	0.04%
2	0.52%
3	2.62%
4	3.02%
5	4.98%
6	5.95%
7	10.48%
8	14.24%
9	5.60%
10	52.56%

Note: 1 = the biggest footprint and 10 = the least footprint

The Ecological Human Footprint model shows most of the M-KMA represented within a High or Very-High value (values 6 to 10) representing 88.82% of the area, leaving only 11.18% of values in classes 1 to 5. Nearly three quarters of the area (72.40%) was categorized in the Very-High class while only 3.18% is represented with the lowest values (values 1-3) for areas with the highest impacts of development (Figure 14).

The extent of the Ecological Human Footprint varies across the M-KMA with the lowest values heavily concentrated on the Eastern edge (Figure 13). The lowest value and lightest green color contains the Alaska Highway and the surrounding environment. Other areas of low values contain unbuffered river boat access routes and the open pit mine located in the northeast. Major access routes into the M-KMA are more common along the Eastern edge near the communities of Fort Nelson and Fort St. John, as well as Mackenzie to the southwest, where these areas have more motorized use such as 4x4, dirt biking and boating.

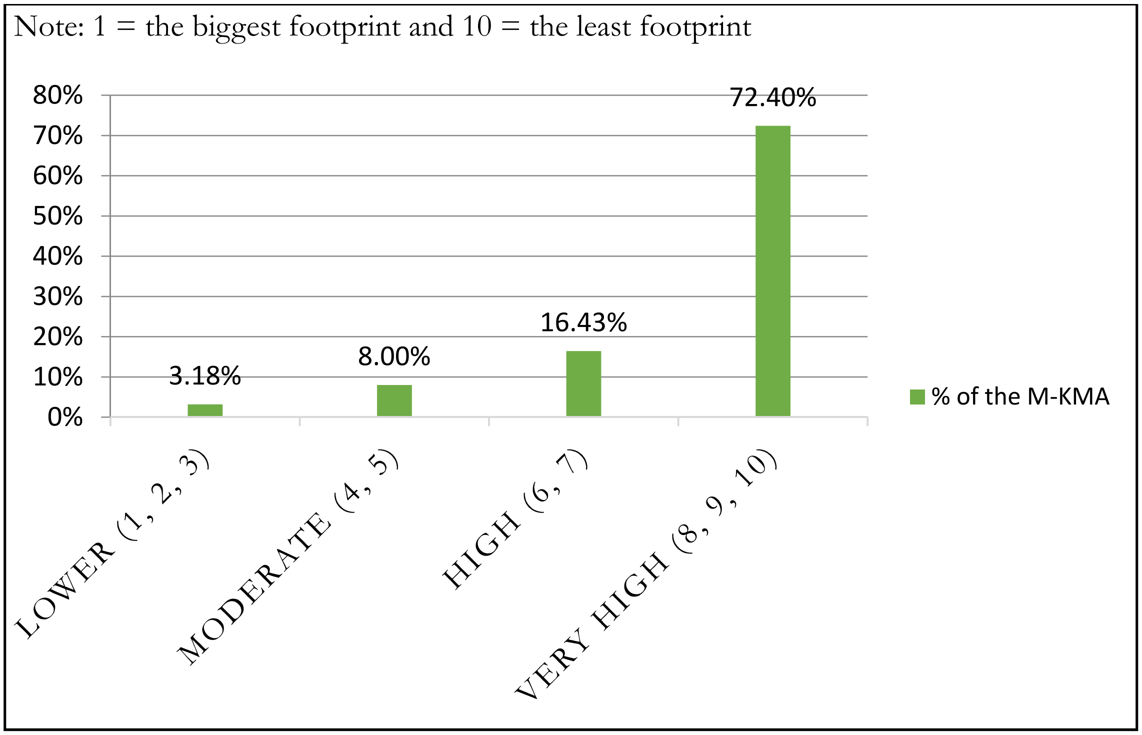


Figure 14. Percent of the Muskwa-Kechika Management Area (M-KMA) in Each of the Ecological Human Footprint Classes from Low Footprint to Very-High Footprint.

To the west, the human footprint is lighter on the more remote western edge of the M-KMA (Figure 13). Throughout the M-KMA, the lighter, cream-coloured circles contain small cabins or buildings encapsulated within 5-km buffers. As there was little known information about these buildings, each was conservatively buffered. The lighter green lines are airstrips and landing lakes, which also get more ephemeral use and therefore would appear different in seasonal variations of this model.

Each ecological indictor within the Ecological Human Footprint model examines human influences separately. Specific reference is made to using the Resource Management Zones to spatially describe the results.

6.1.2 Indicators of Ecological Wilderness Character in the M-KMA

6.1.2.1 Species Movement and Connectivity

Data for the Species Movement and Connectivity model were developed for the *Yellowstone to Yukon Muskwa-Kechika Management Area Biodiversity and Climate Change Assessment* (2012) where the most suitable habitats for four large charismatic species were studied (caribou, moose, mountain goat and Stone's sheep) and then important wildlife corridors between them were mapped (Yellowstone to Yukon Conservation Initiative, 2012). I reclassified the data into values ranging from 9.1 to 10 to match the other map scales and adjusted the color scheme. Figure 15 presents the final map of Wildlife Connectivity in the M-KMA.

Figure 15 shows where one or more species (caribou, moose, mountain goat or Stone's sheep) are likely to move through the landscape. Connectivity, particularly in the northern Rockies is heavily influenced and constricted by mountainous terrain and large rivers. The areas that have high overlap for multiple species are in the darker green colors. The values that range from 9.1 to 9.5 represent 95.76% of the total area with only 3.28% of the M-KMA being represented with a wildlife connectivity value of 9.6 or more. The value of 9.1 has the highest representation as it represents area that is good wildlife habitat but may not possess the features most desirable for movement and connectivity (of potentially multiple species) through the landscape. The breakdown of the values is shown in Figure 16.

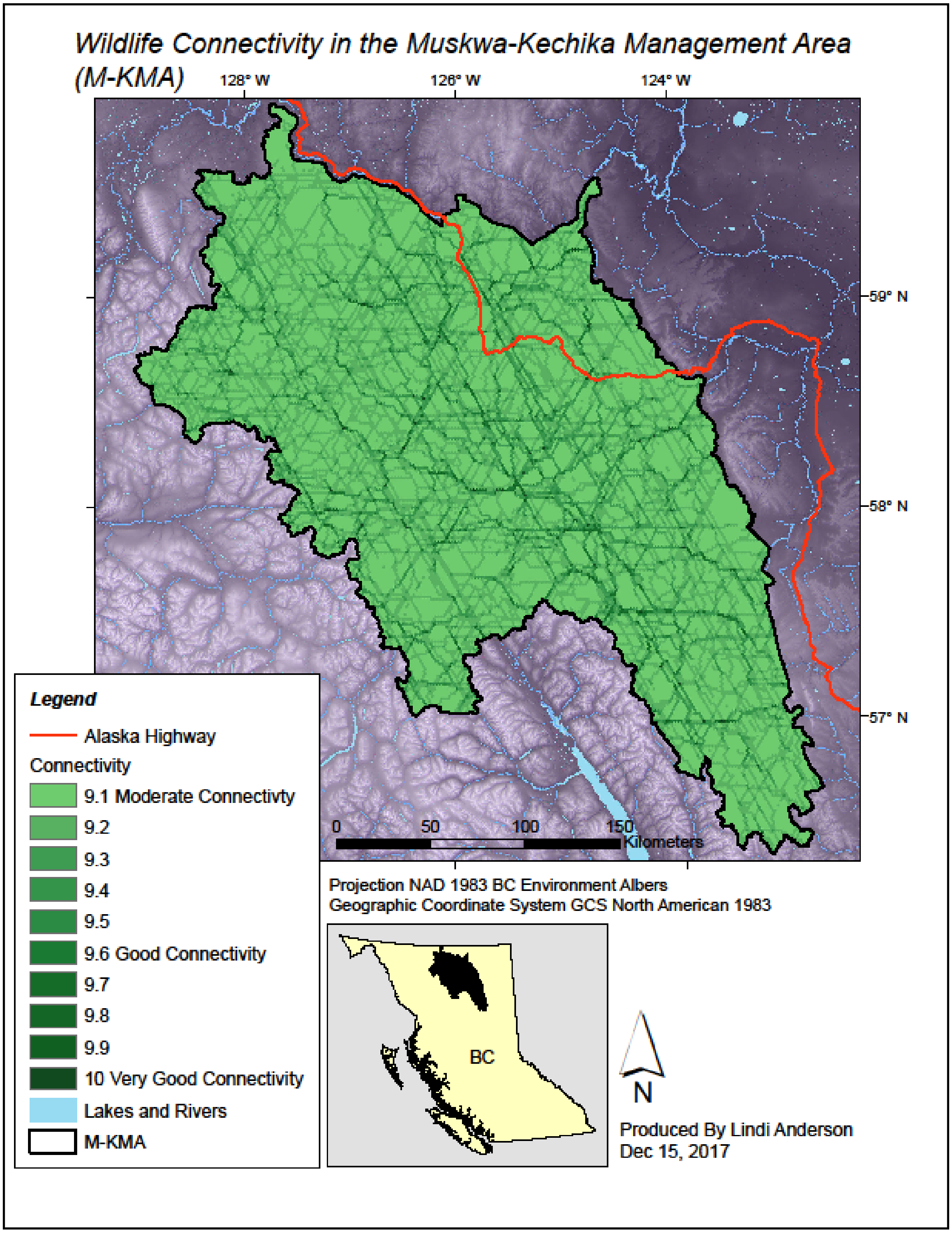


Figure 15. Wildlife Connectivity in the Muskwa-Kechika Management Area (M-KMA).

The whole of the M-KMA is considered to have, at the least, moderate wildlife connectivity. In addition to showing where key species are likely to move, this map represents a gradient of different connectivtiy routes showing areas with good connectivity or very-good connectivity where more than one species is likely to move. In contrast, the lighter green is area that is used less frequently for connectivity purposes and therefore only has a moderate connectivity ranking.

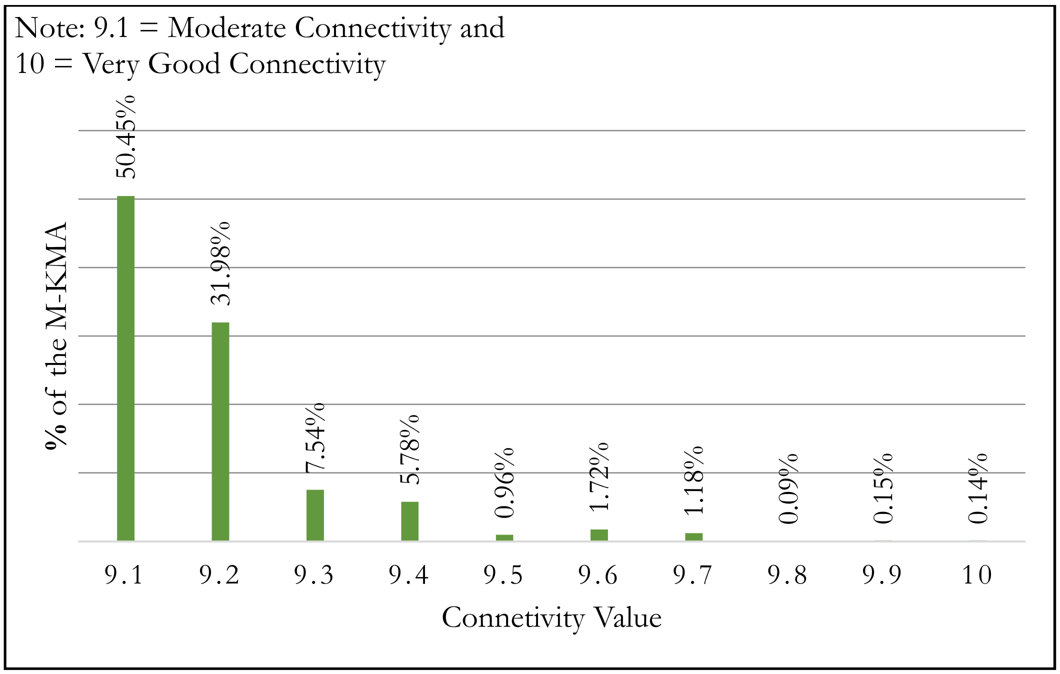


Figure 16. Percent of the Muskwa-Kechika Management Area (M-KMA) with Each of the Connectivity Values.

Theoretically as the human footprint increases, wildlife connectivity will decrease. However, the type of footprint (e.g., seasonal or not), and its permanence and magnitude will have variable effects on the connectivity of individual species. Some species, like caribou are more sensitive to human disturbance, whereas other species such as moose may be more favorably adapted to some kinds of disturbance.

When compared to the Ecological Human Footprint model, wildlife connectivity and movement are not being broadly affected by the development on the eastern edge of the M-KMA. Some areas on this edge are affected by developments and the Alaska Highway, such as the Sulphur/8 Mile Special Management Zone, Muncho Lake Provincial Park, Northern Rocky Mountains Protected Area and the Besa Halfway Chowade Special Management Zone. However, the majority (88.83%) of the mapped wildlife connectivity in the M-KMA does not coincide with areas with highest current human footprint (Figure 17).

6.1.2.2 Focal Species Habitat Suitability

Habitat suitability values for seven focal species (caribou, elk, goat, sheep, grizzly, moose

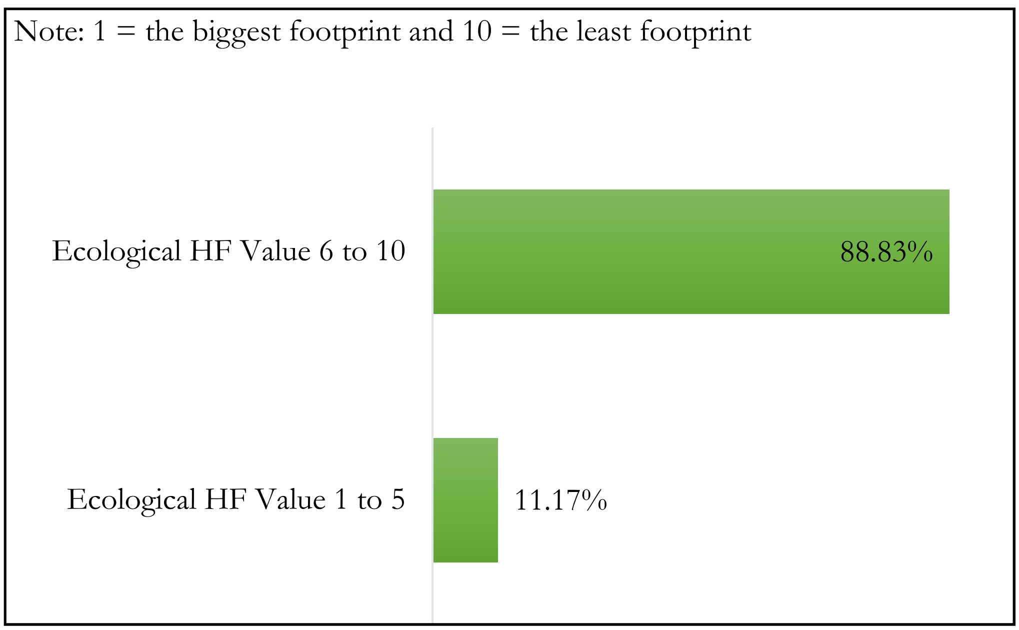


Figure 17. Percent Overlap in the Muskwa-Kechika Management Area (M-KMA) of Wildlife Connectivity and Movement Values with the Ecological Human Footprint (HF) Values 1 to 5 and 6 to 10.

and wolf) based on models developed by Heinemeyer et al. (2004) were merged into an all habitat layer and then reclassified into five classes from high to highest habitat quality. As the whole area is considered good-to-excellent wildlife habitat and wildlife habitat is considered to represent wilderness values, the scale ranges from 9.6 to 10 (Figure 18).

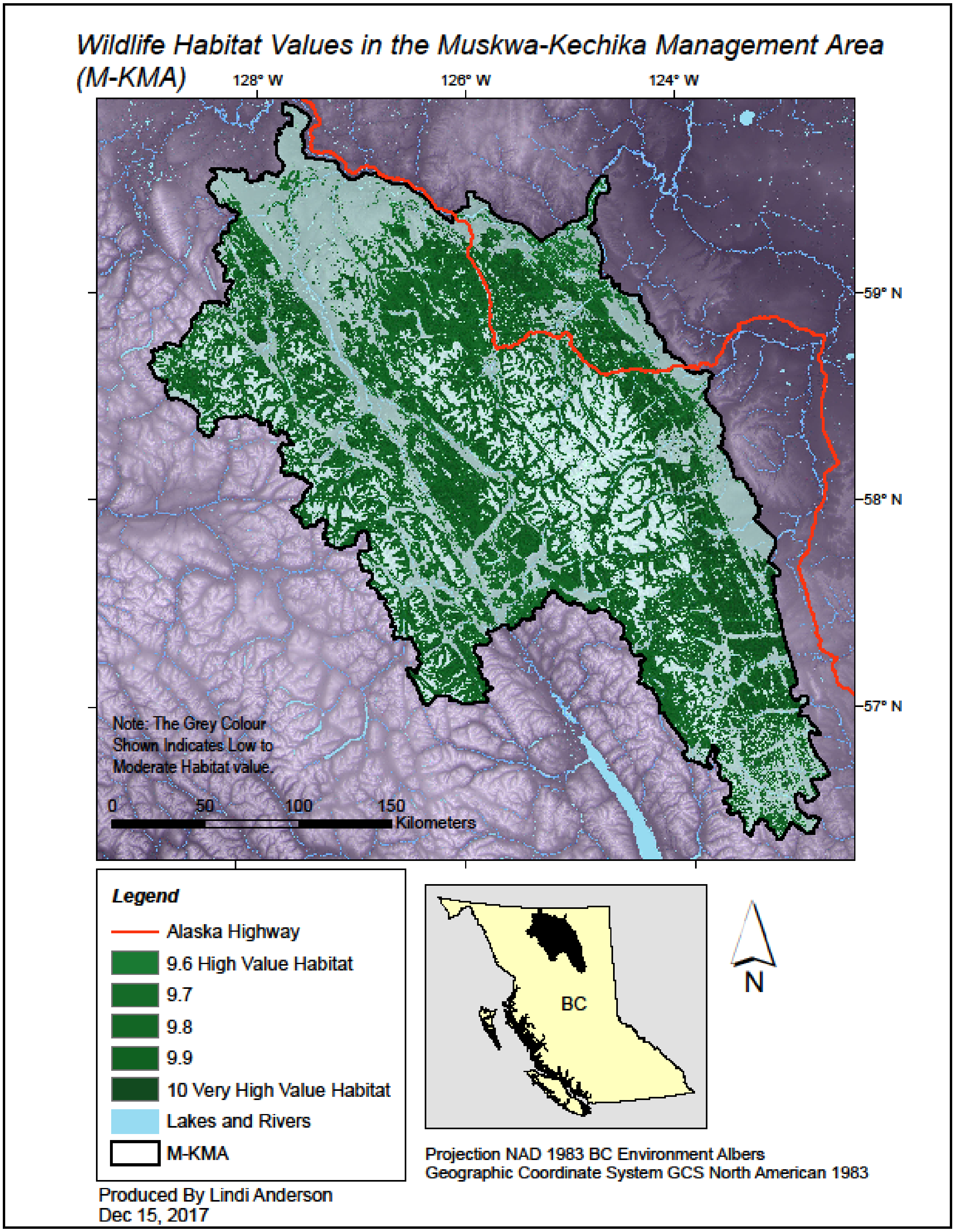


Figure 18. Wildlife Habitat Values in the Muskwa-Kechika Management Area (M-KMA)

White and light-green areas are areas such as high elevation snow/ice or water features that do not have high wildlife values for the seven focal species. The dark-green gradient of values represents the high to very-high value habitat. The representation of these values can be seen below in Figure 19. Independent of the existing Ecological Human Footprint, more than half (54.24%) of the M-KMA contains high to very-high quality habitat for at least one of the focal species.

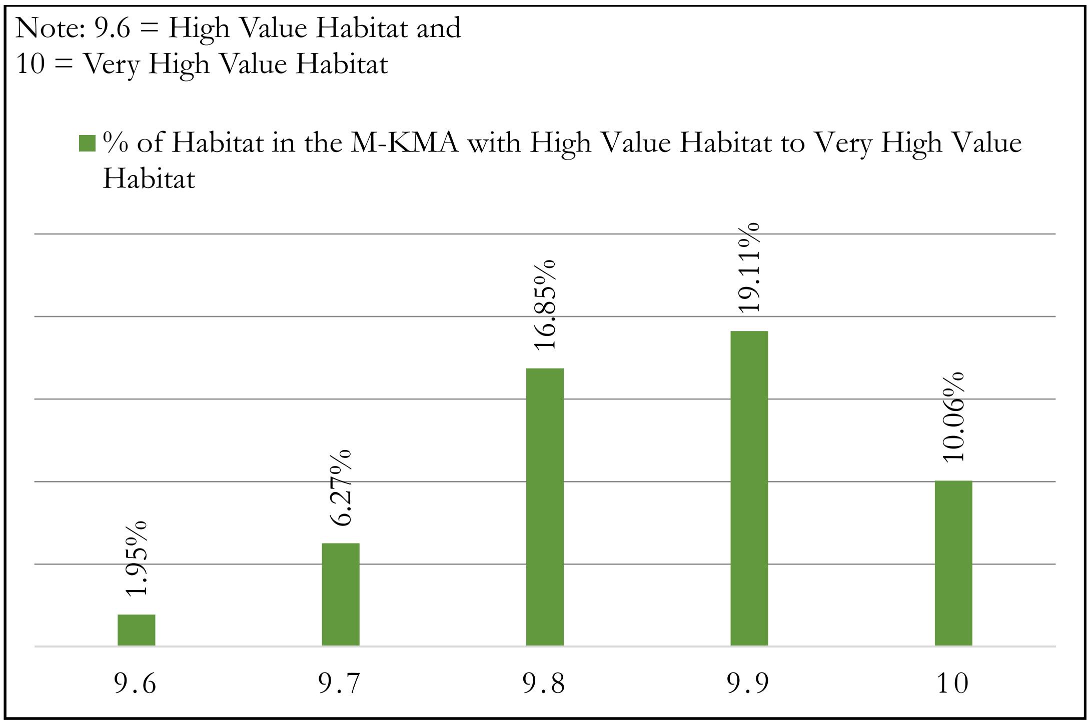


Figure 19. Percent of the Muskwa-Kechika Management Area (M-KMA) in High- and Very High-Value Wildlife Habitats for Focal Species.

When the amalgamated focal species' habitat is examined relative to the existing Ecological Human Footprint, 90.09% of high-value habitat is in areas that contain high Ecological Human Footprint values (6 to 10). The remaining 9.91% of the high-value habitat overlaps with lower Ecological Human Footprint values (more human impacts) (Figure 20).

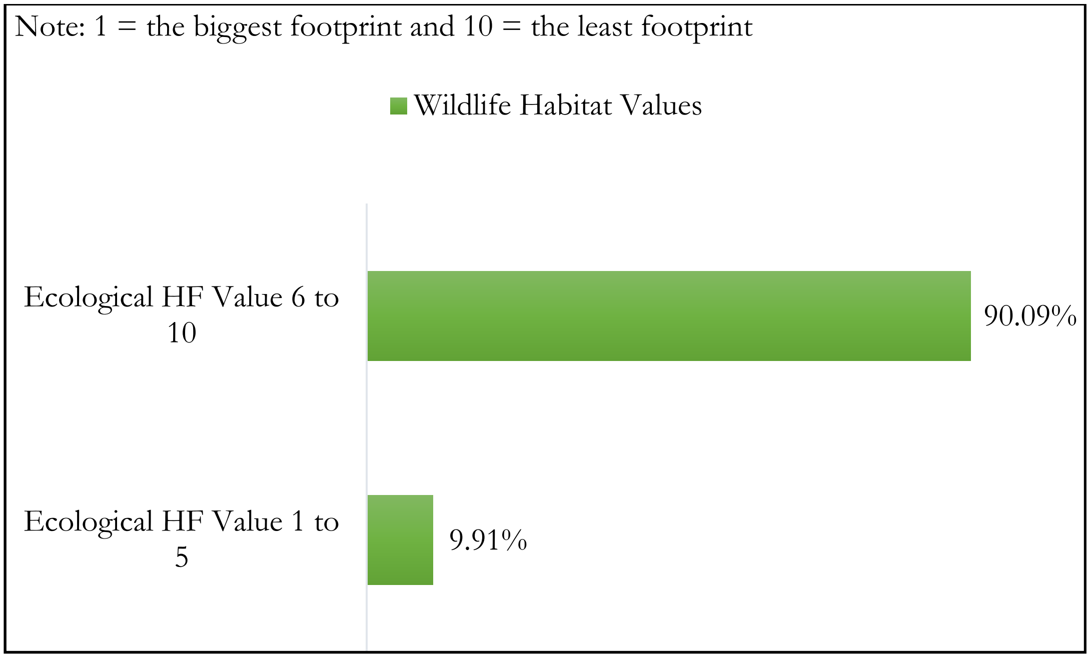


Figure 20. Percent Overlap in the Muskwa-Kechika Management Area (M-KMA) of Wildlife Habitat Values with the Ecological Human Footprint (HF) Values 1 to 5 and 6 to 10.

6.1.2.3 Enduring Features

The data for Enduring Features – landforms, bedrock, and surface geology – from the *Muskwa-Kechika Management Area Biodiversity and Climate Change Assessment* (Yellowstone to Yukon Conservation Initiative, 2012) included rare enduring features, varied enduring features, and combinations of both variations. These were simplified by reclassifying them into three variations ranking from 9.8 to 10: Rare and Very Rare Enduring Features, High Variety and Very High Variety, and Very Rare and Very High Variety of Enduring Features (Figure 21). Less than a third of the M-KMA includes these features. This model is scaled differently (9.8 to 10) as I was only able to sort the values into three categories: rare values, varied values and a combination of both.

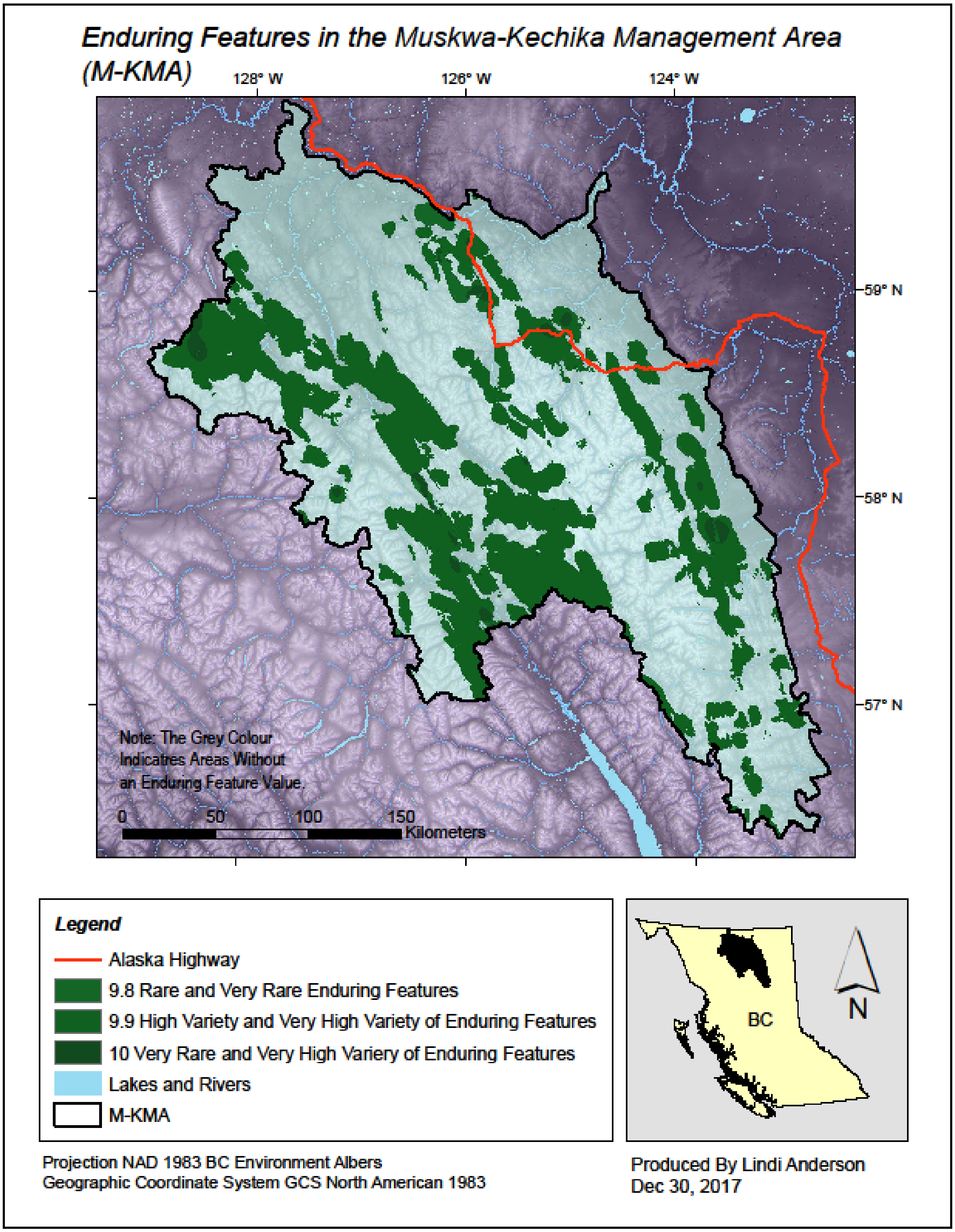


Figure 21. Enduring Features in the Muskwa-Kechika Management Area (M-KMA), reclassified from Yellowstone to Yukon Conservation Initiative (2012).

Not surprisingly, the Rare and Very Rare Enduring Feature class (9.8) had a lower representation across the M-KMA than the other two classes (Figure 22).

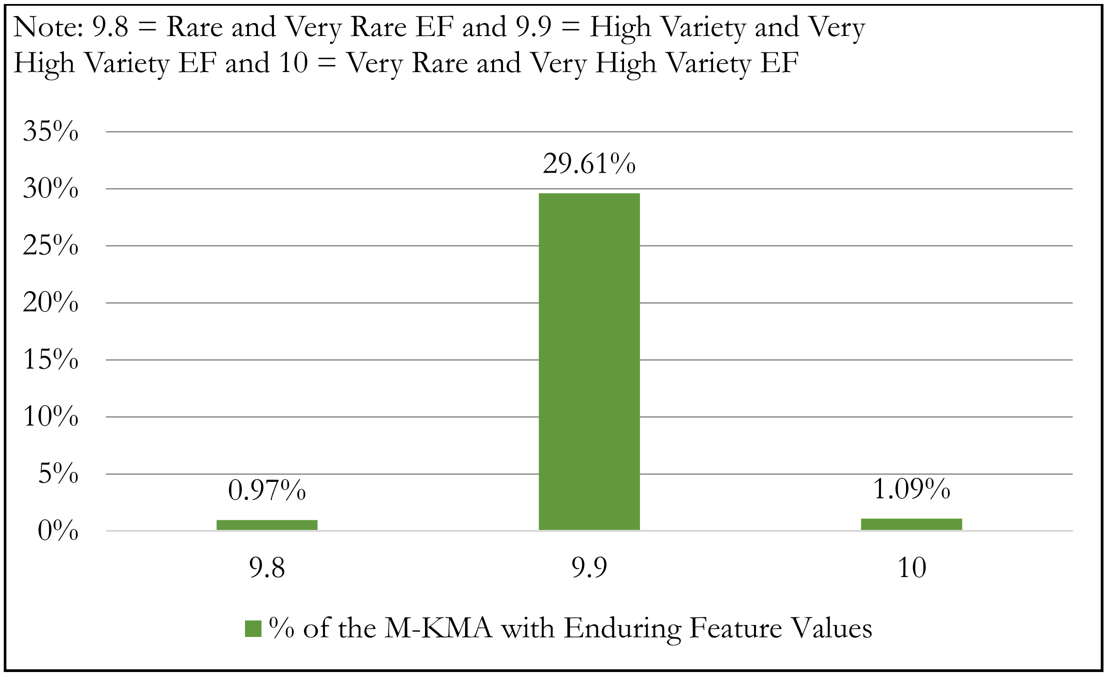


Figure 22. Percent of Muskwa-Kechika Management Area (M-KMA) in Each of the Enduring Feature (EF) Values.

With most of the enduring features located in the southern and western portions of the M-KMA, a high portion of the enduring features (89.08%) do not overlap with high values of the Ecological Human Footprint. There is little disturbance to enduring feature values currently; only 10.92% of enduring features overlap with lower Ecological Human Footprint values (more human impacts, Figure 23). It is important to note that while the data suggest that only approximately 32% of the M-KMA has enduring features, it is likely that the other 77% may as well but there were no spatial data available to suggest otherwise.

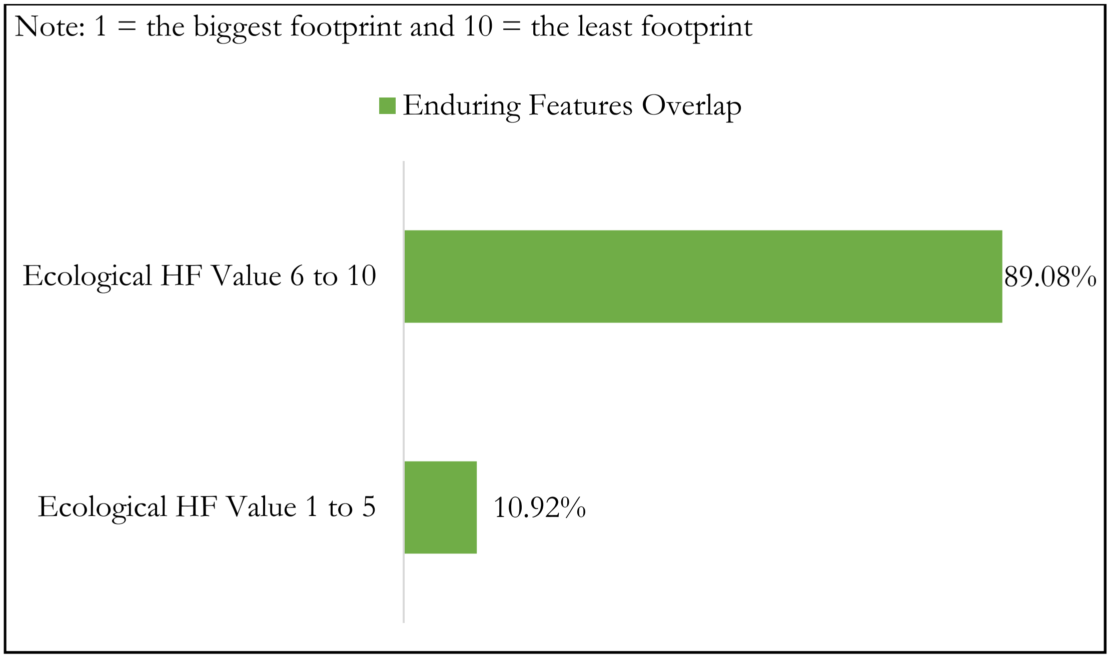


Figure 23. Percent Overlap in the Muskwa-Kechika Management Area (M-KMA) of Enduring Feature Values with the Ecological Human Footprint (HF) Values 1 to 5 and 6 to 10.

6.1.2.4 Ecological Variability

Using the Biogeoclimatic Ecosystem Classification (BEC) system, ecological variability is spatially represented by the variety and rarity related to the four zones found in the study area: Alpine Tundra (AT), Boreal White and Black Spruce (BWBS), Engelmann Spruce Sub-alpine Fir (ESSF), and Spruce-Willow-Birch (SWB). Within the four zones there are 10 sub-zones in the M-KMA[11]. Both a rarity and a variety model were created and then were merged to create the final ecological variability map.

The *rarity* of BEC sub-zones in the M-KMA relative to British Columbia's ecological variability is shown in Figure 24.

[11] For a complete list of sub-zones see Ecological Variability section in Chapter 5: Model Development

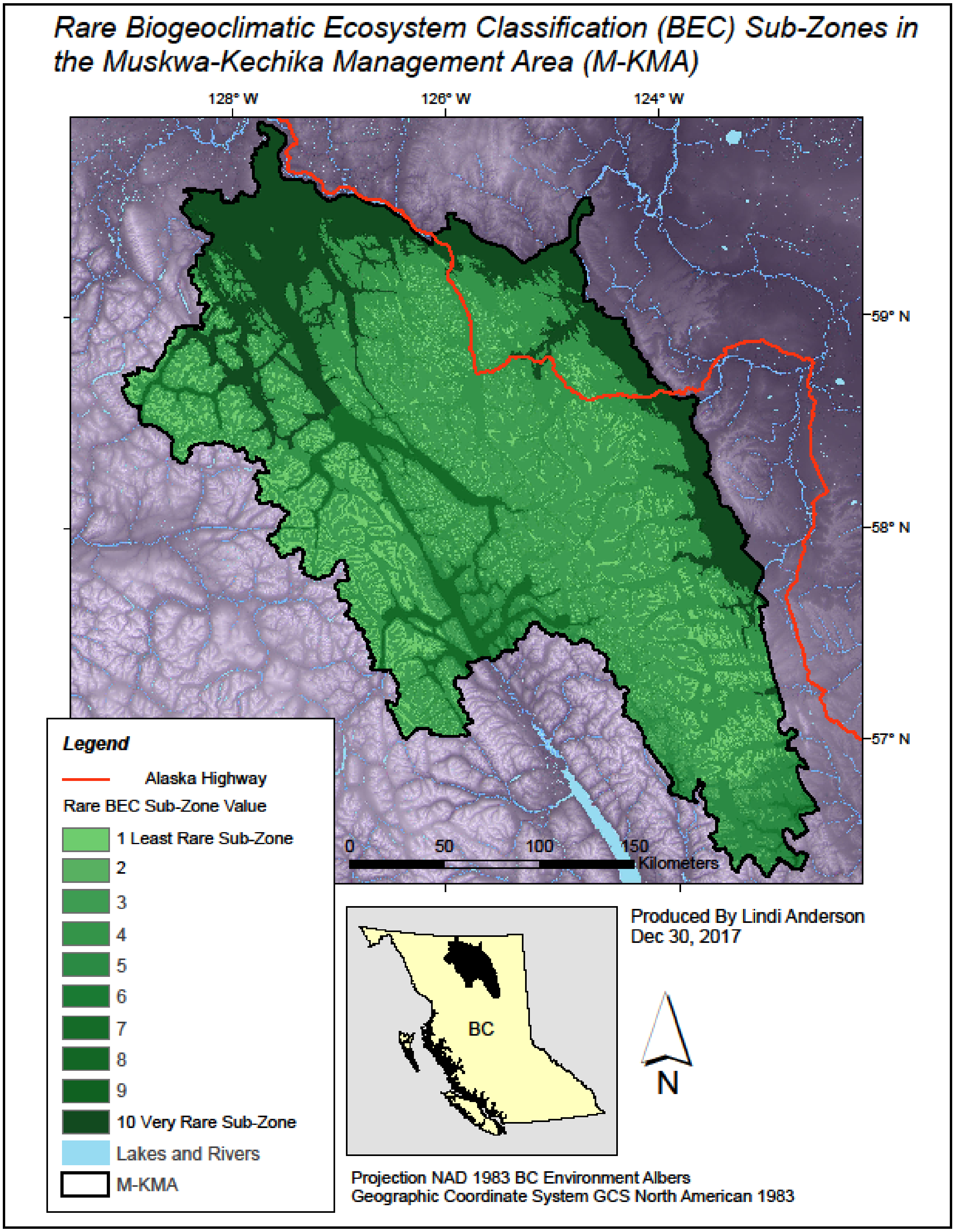


Figure 24. Rare Biogeoclimatic Ecosystem Classification (BEC) Sub-Zones in the Muskwa-Kechika Management Area (M-KMA) Relative to British Columbia.

Compared to the ecological representation of BC, the most rare and diverse ecosystem in the M-KMA is the most northerly BEC sub-zone which is BWBS moist cool (Table 9). Nearly a quarter of the M-KMA (19.2%), value 10 indicating very rare BEC sub-zone clusters covers the northern tip and the eastern edge of the M-KMA. The low-lying valleys and major river routes also are represented as high rarity value, indicating they are rare relative to the rest of BC (Figure 25).

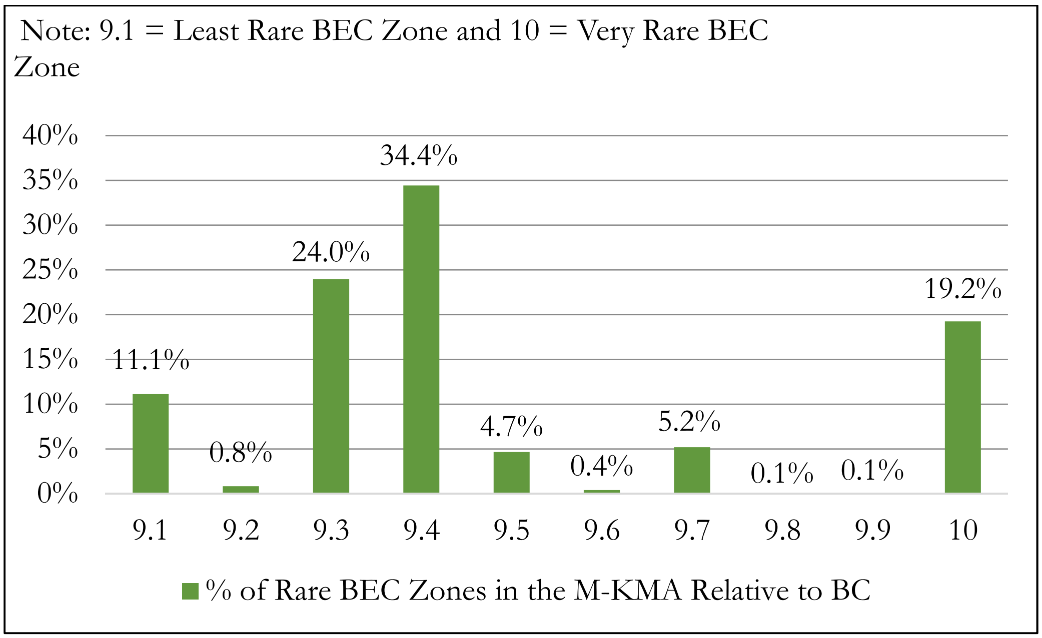


Figure 25. Percent of Rare Biogeoclimatic Ecosystem Classification (BEC) Zones in the Muskwa-Kechika Management Area (M-KMA) Relative to British Columbia (BC).

The *variety* of BEC zones, as a relative count of the number of BEC sub-zones in each 1500-hectare planning unit (PU), as described in Section 5.5, is shown in Figure 26. Ranked from 9.1-9.8, a value of 9.1 represents a PU that only had one BEC sub-zone and 9.8 a PU with the maximum of eight possible sub-zones in a PU. While there are ten BEC sub-zones (Table 9), eight is the maximum number of sub-zones observed in one PU.

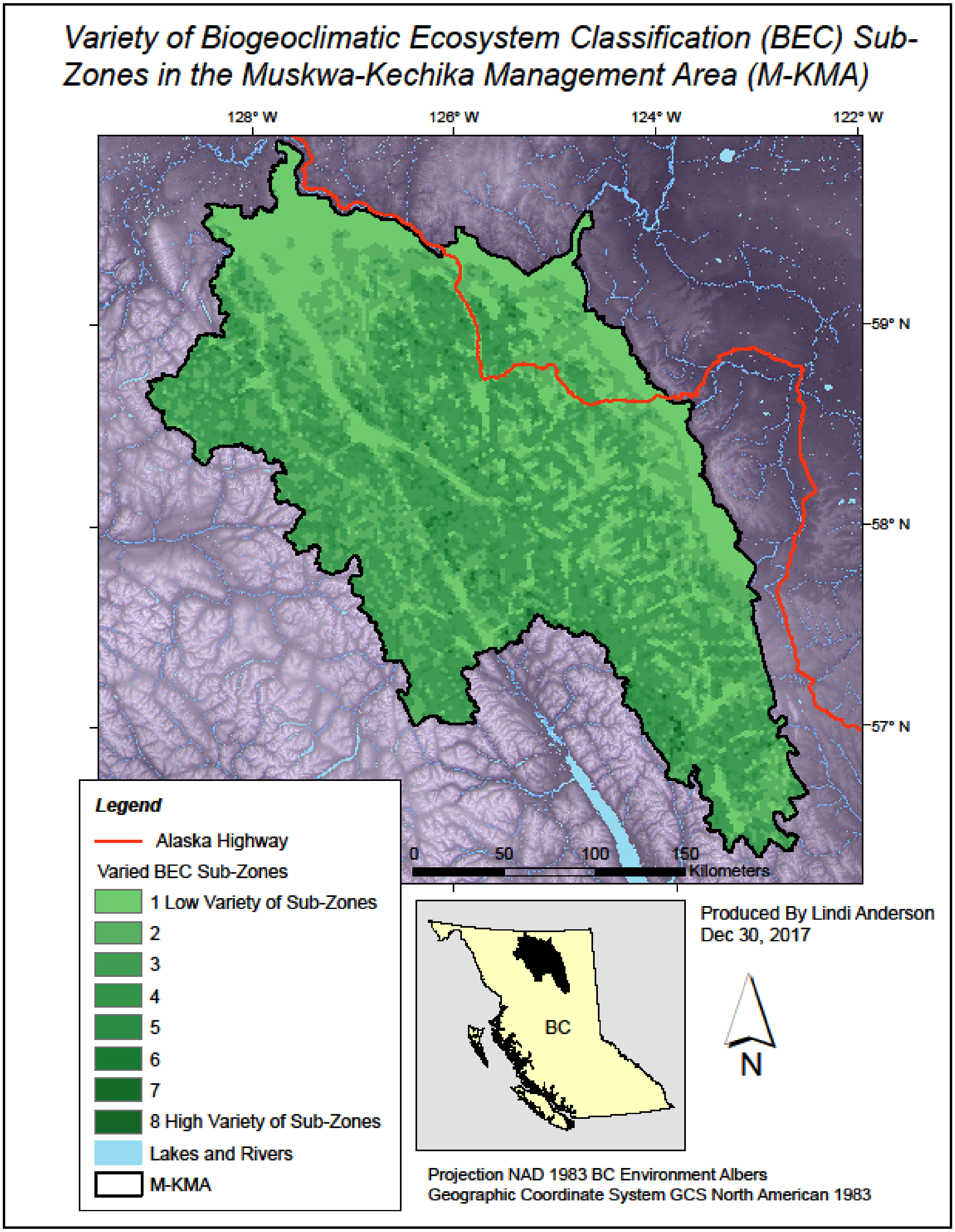


Figure 26. Variety of Biogeoclimatic Ecosystem Classification (BEC) Sub-Zones in the Muskwa-Kechika Management Area (M-KMA).

With respect to variety, not much area in the M-KMA has the highest variety with eight BEC sub-zones within a single 1500-hectare PU (only 0.06%). Most of the area (97.09%) is represented by four or less sub-zones in one PU (Figure 27).

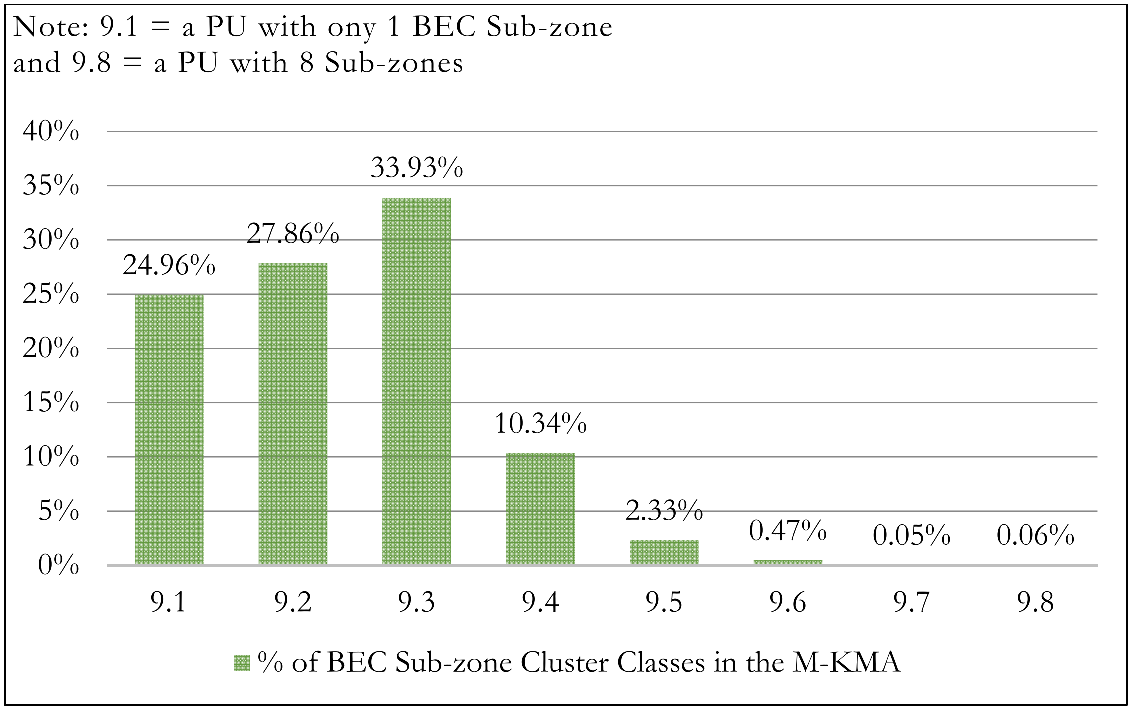


Figure 27. Variety of Biogeoclimatic Ecosystem Classification (BEC) Sub-zones within 1500-hectare Planning Units (PU) in the Muskwa-Kechika Management Area (M-KMA).

To create the final map of Rare and Varied Biogeoclimatic Ecosystem Classification in the M-KMA, both the map of BEC rarity and BEC variety layers were equally weighted at 50% and merged together (Figure 28).

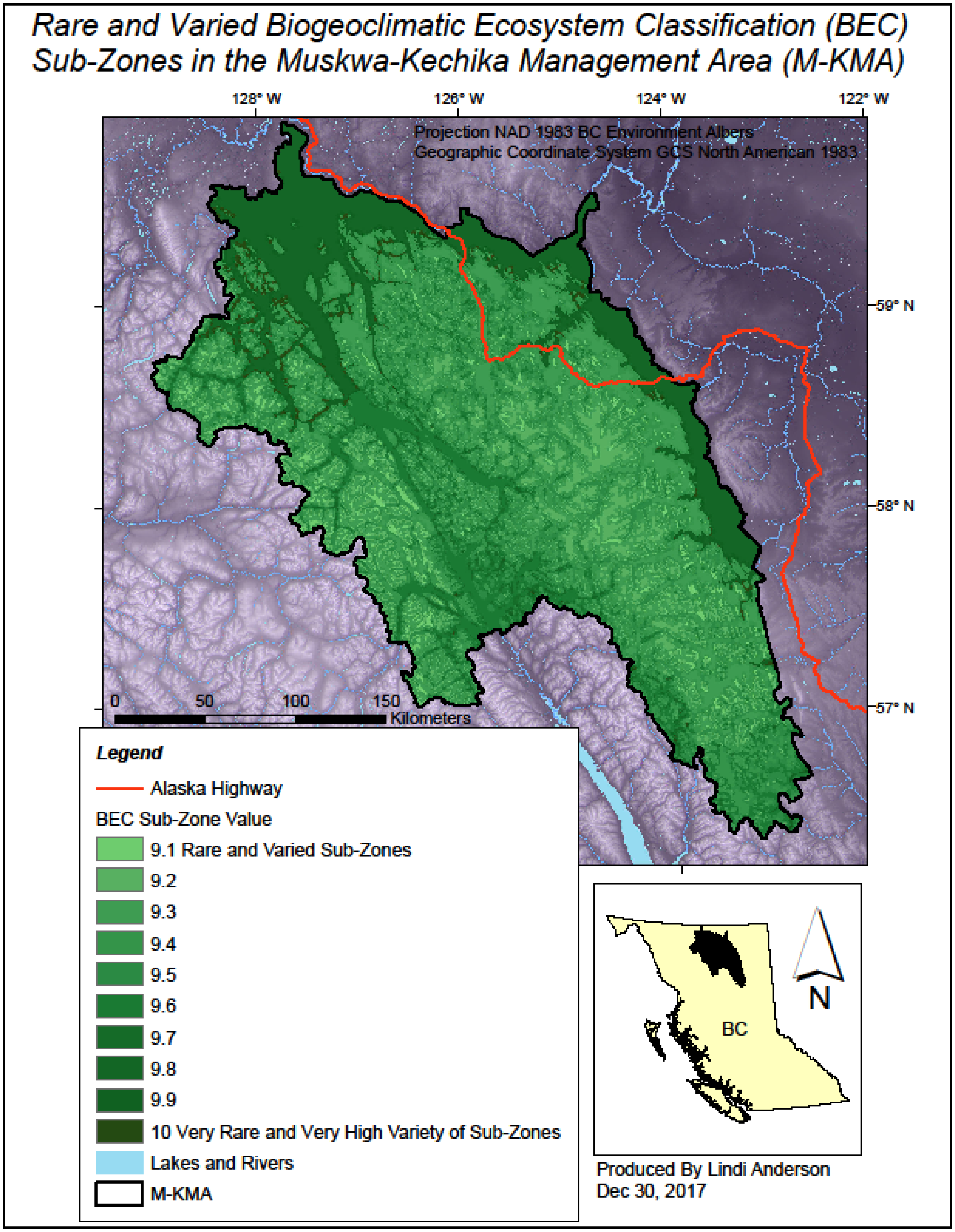


Figure 28. Rare and Varied Biogeoclimatic Ecosystem Classification (BEC) Sub-Zones in the Muskwa-Kechika Management Area (M-KMA).

The finer details of ecological variation can be viewed in a larger scale map (e.g., 1:10,000 scale). From the smaller scale represented here, it is evident that there is perhaps a richer, more diverse ecological variability in the northern and eastern edges of the M-KMA. The darkest colors (in Figure 28) representing the most diverse and rarest areas (9.8, 9.9 and 10) only comprise 6.23% of the M-KMA (Figure 29).

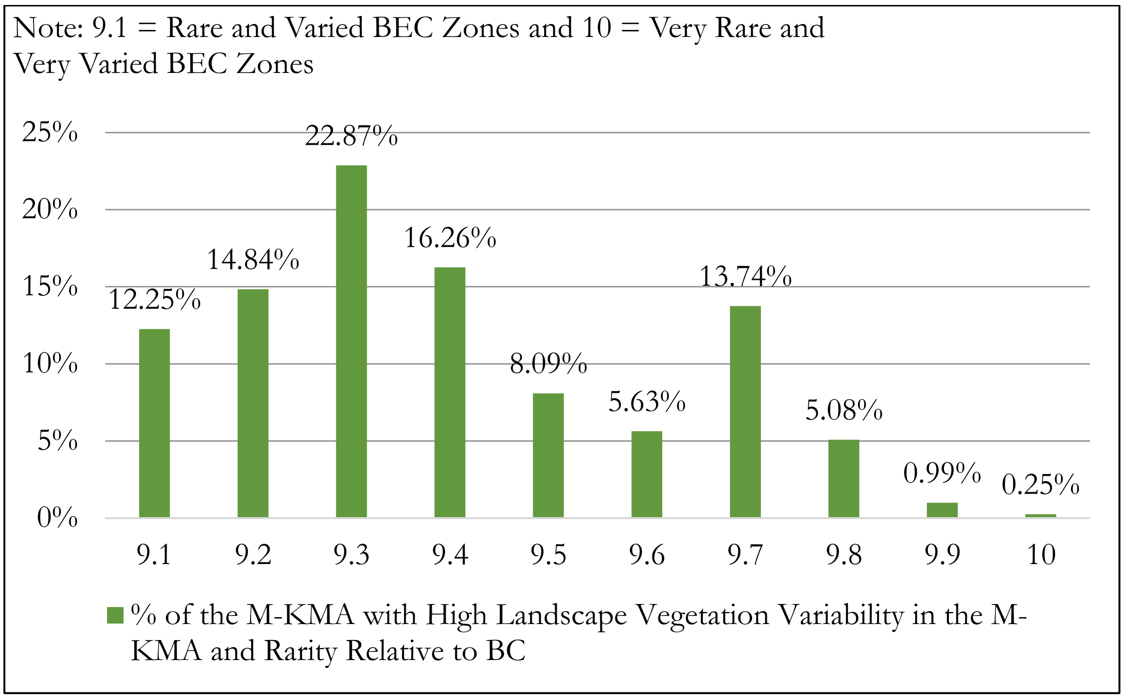


Figure 29. Percent of Rare and Varied Biogeoclimatic Ecosystem Classification (BEC) System Values in the Muskwa-Kechika Management Area (M-KMA).

This richness extends into river and valley bottoms in the Aeroplane Special Management Zone, the Sandpile Special Management Zone, the Rabbit Special Management Zone, the Fishing Special Management Zone, the Turnagain/Dall Rivers Corridor, and the Kechika River Corridor. Slightly lighter green areas follow the river and valley bottoms through Denetiah Protected Area, Frog-Gataga Protected Area, the Brain Special Wildland, and into the Fox Special Management Zone (Appendix A and B: Figure B1). The lower half of the values (9.1-9.5) represents 74.30% of the M-KMA, whereas the upper half (9.6-10) represents 25.70%. When overlapped with the

Ecological Human Footprint, this 25.70% of high-valued ecological variability has a 4.12% overlap with the lower-valued human footprint area (1 to 5), showing some conflict (Figure 30).

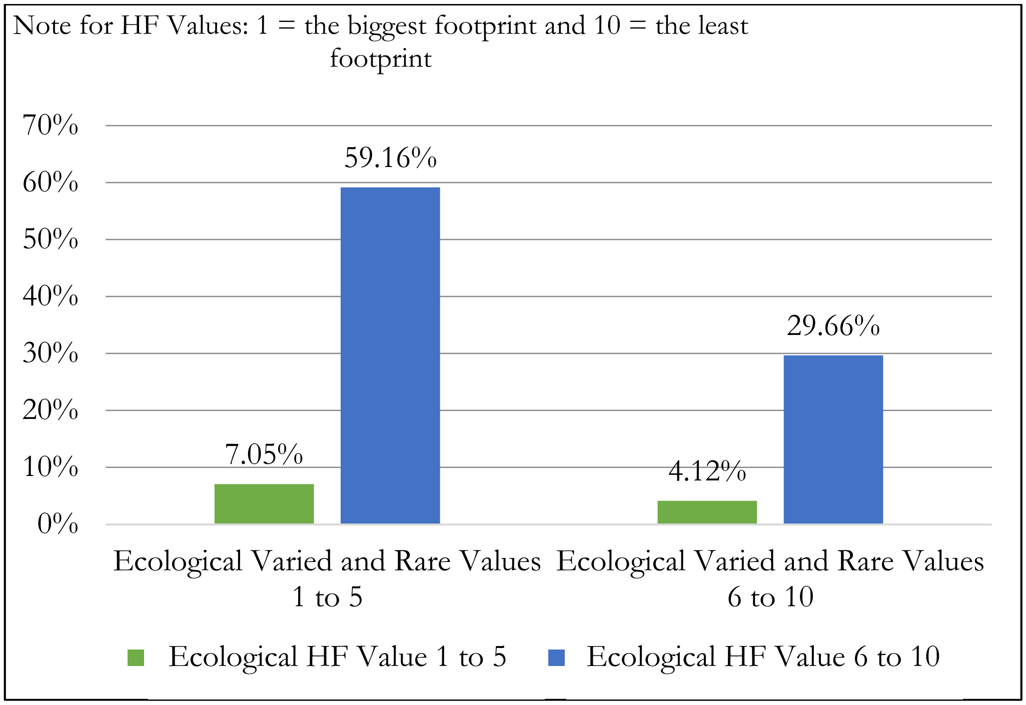


Figure 30. Percent Overlap in the Muskwa-Kechika Management Area (M-KMA) of Rare and Varied Biogeoclimatic Ecosystem Classification (BEC) System with the Ecological Human Footprint (HF) Values.

6.1.2.5 Special Features

Special features were mapped using readily available wetlands data (as the only data currently available). Wetlands cover only 1.22% of the M-KMA.

The majority of the special features (89.36%) are in areas that correspond to higher human footprint values (6 to 10). The remaining 10.63% of the special features in the M-KMA overlap with the lower human footprint values – high impact (1 to 5) (Figure 31).

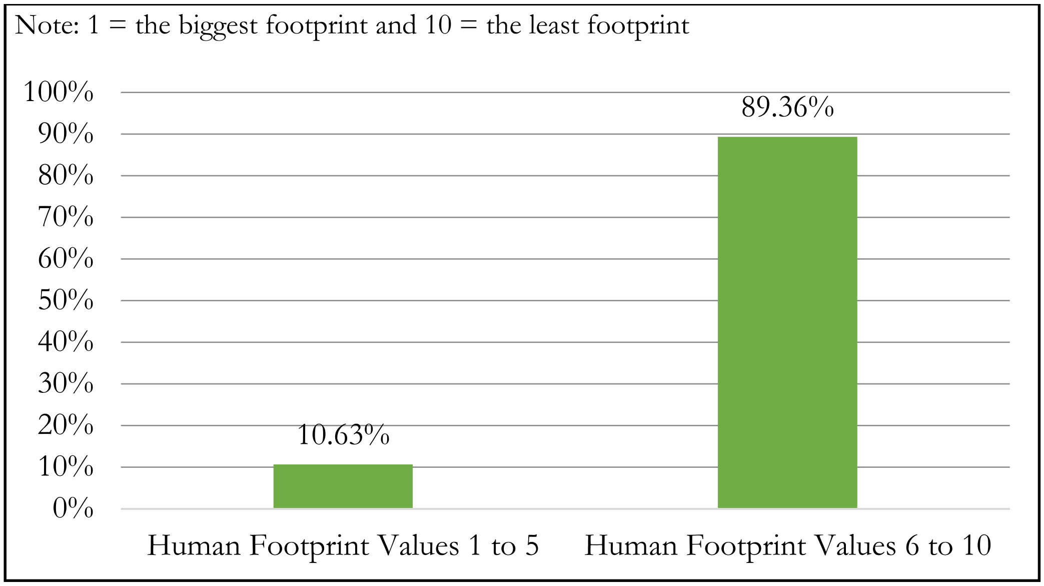


Figure 31. Percent Overlap in the Muskwa-Kechika Management Area (M-KMA) of Special Feature Values with the Ecological Human Footprint (HF) Values 1 to 5 and 6 to 10.

Figure 32 shows that the wetlands used for this special feature model can be found throughout the M-KMA. However, a large portion of the special features are gathered in the western edge, the middle and the northern and southern tip of the M-KMA with very little towards the eastern edge, where human footprint values from development and access areas are likely to have more impact.

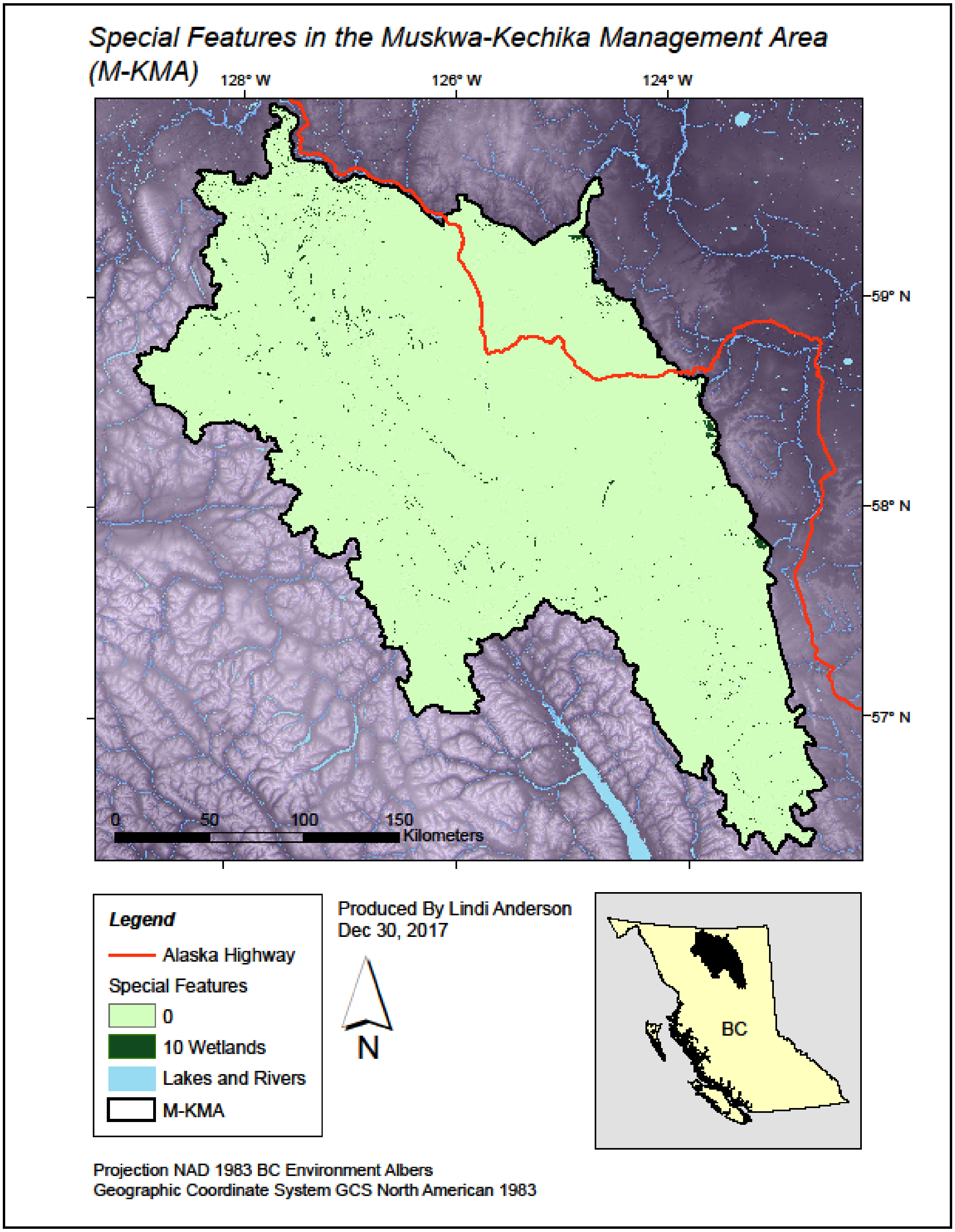


Figure 32. Special Features Measured as Wetlands in the Muskwa-Kechika Management Area (M-KMA).

6.1.2.6 Watershed Intactness

Watershed intactness is a measure of development per watershed group in the M-KMA. A watershed group is a delineated collection area for river drainage basins[12]. For analysis, the watershed layer was changed into a raster layer and reclassified into a 10-class values system for watershed fragmentation to match the other layers (Table 13).

Table 13. List of Watershed Fragmentation Values in the Muskwa-Kechika Management Area

Watershed Name	Final Watershed Value
Stikine River	10
Pitman River	10
Dease River	10
Peace River	9.9
Finlay River	9.8
Rabbit River	9.7
Kechika River	9.6
Fort Nelson River	9.4
Liard River	9.3
Toad River	9.2
Halfway River	9.1

The final values have a relatively equal distribution across the M-KMA. From Figure 33 is it evident that the eastern edge of the M-KMA shows a greater influence from the developments, roads and access routes of the Ecological Human Footprint, and thus, the watershed intactness in that area appears lower – or more fragmented – than the western edge. However, this representation is based on developments and access routes that receive relatively little or no seasonal use and therefore, this is a very conservative representation of watershed fragmentation in the M-KMA. The value scale for Figure 33 ranges from 9.1 to 10, showing the lower values (9.1 to 9.5) as areas that are more fragmented than watersheds with higher values (9.6 to 10). Figure 34 shows the percentage of each watershed value in the M-KMA.

[12] See Table 10 in Section 5.5.

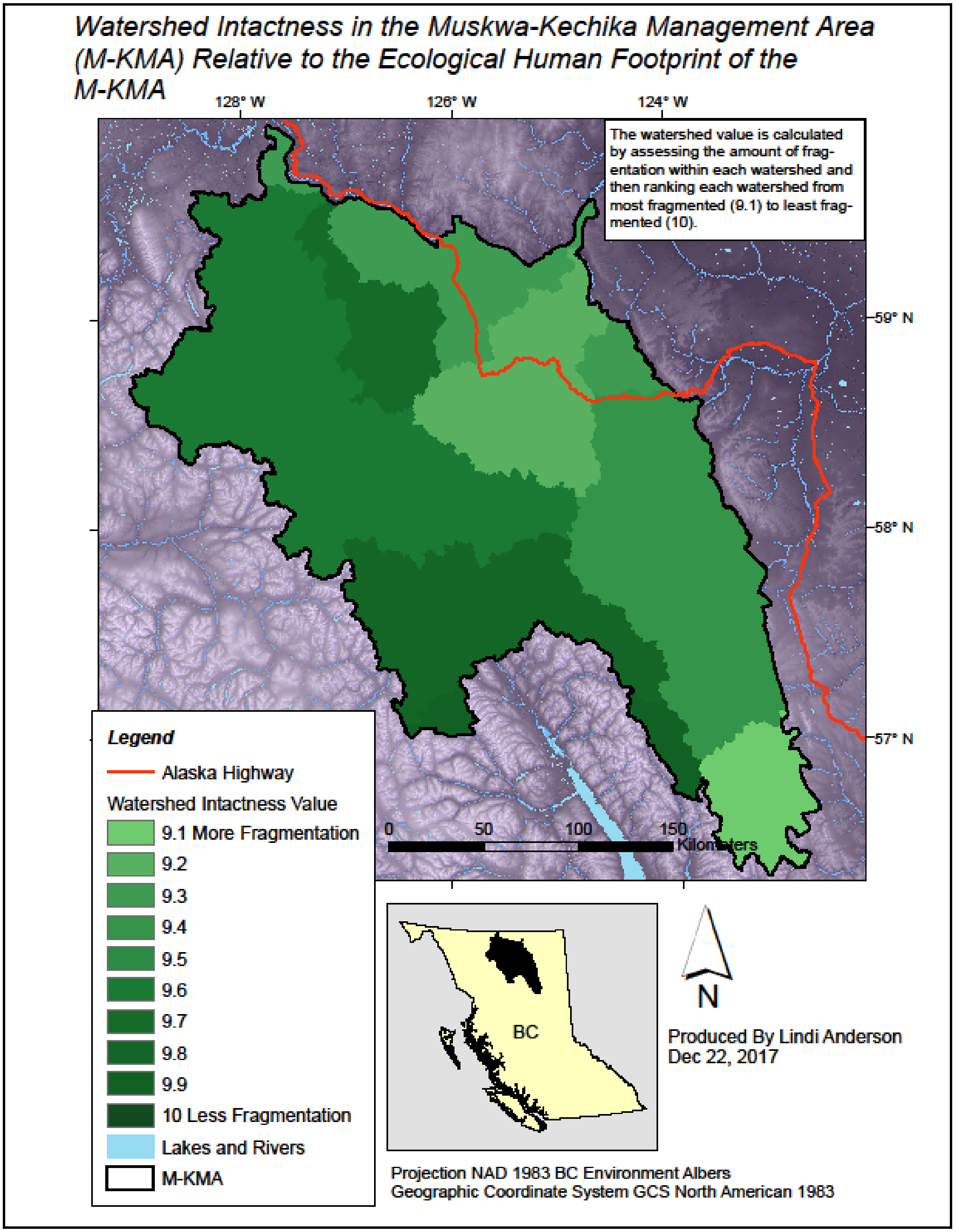


Figure 33. Watershed Intactness in the Muskwa-Kechika Management Area (M-KMA).

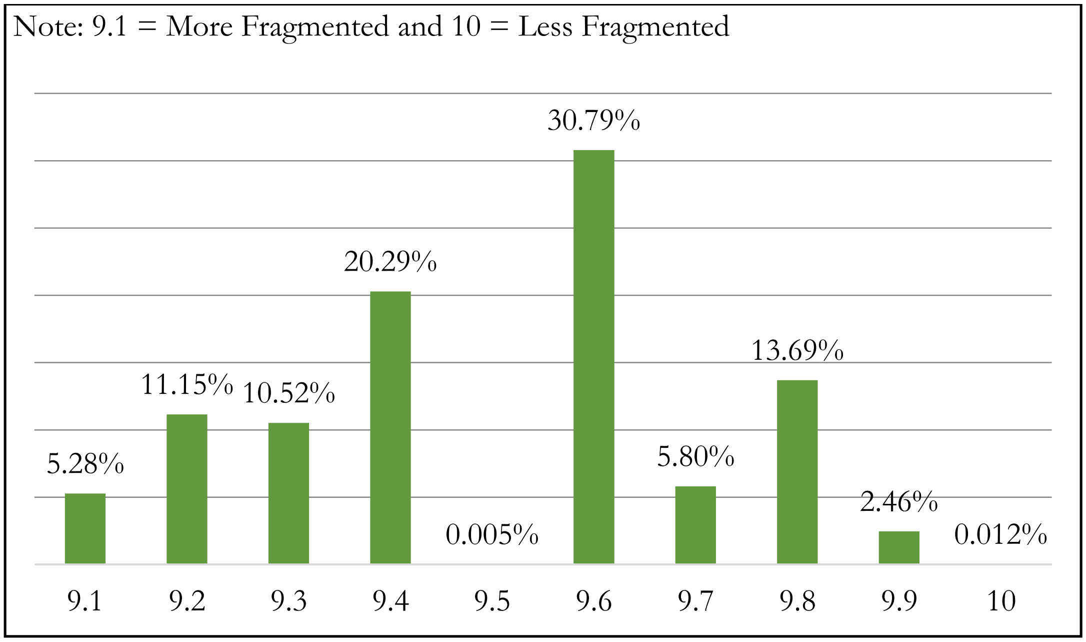


Figure 34. Percent of Watershed Intactness Values in the Muskwa-Kechika Management Area (M-KMA).

The roads, motorized access and tourism due to the Alaska Highway result in a higher degree of fragmentation on the eastern edge in the Liard River Watershed, the Toad River Watershed, the Fort Nelson River Watershed, and the Halfway River watershed. However, when compared to the Ecological Human Footprint model, a large majority (88.83%) of watershed intactness is in areas relatively unaffected by human influence, indicating that the majority of the watersheds in the M-KMA are relatively intact and will remain that way into the near future without any major urban sprawl or resource development boom in the area (Figure 35).

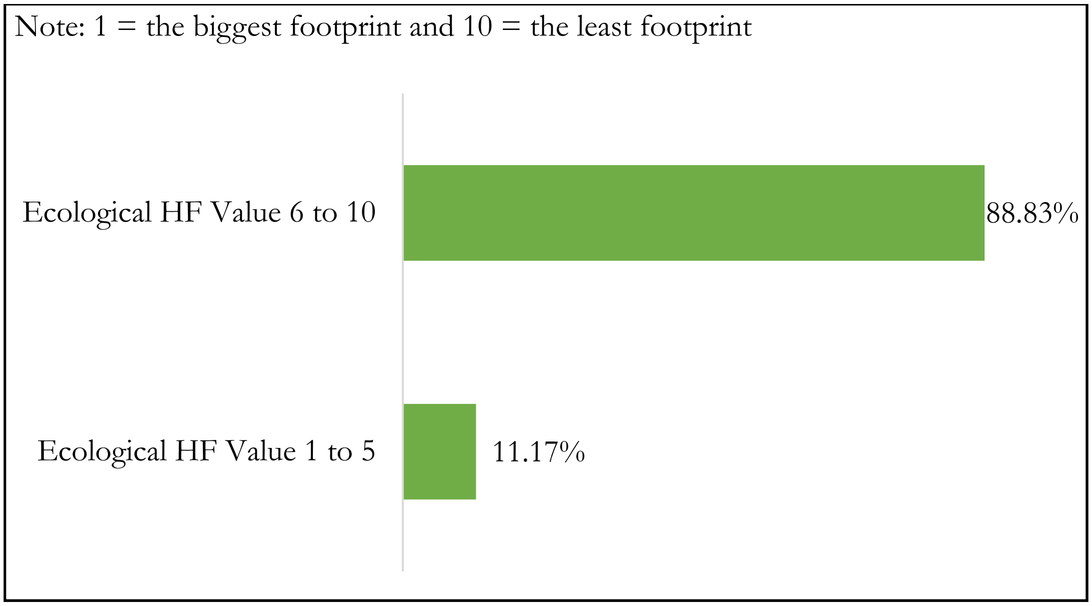


Figure 35. Percent Overlap in the Muskwa-Kechika Management Area (M-KMA) of Watershed Fragmentation Values with the Ecological Human Footprint (HF) Values.

6.1.3 Ecological Wilderness Characteristic Model

Each layer for the ecological indicators was weighted and merged to create a final map of the M-KMA Ecological Wilderness Characteristic. The indicators were weighted (as per Figure 11) as follows: Species Connectivity (10%), Focal Species Habitat (15%), Enduring Features (20%), Ecological Variability and Rarity (25%), Special Features (10%), and Watershed Intactness (20%). Once all the ecological indicators were merged together, they were subsequently merged with the Ecological Human Footprint model. The resulting map titled *Ecological Wilderness Characteristic in the M-KMA* was then reclassified so the values were represented by 9.1 to 10 (Figure 36).

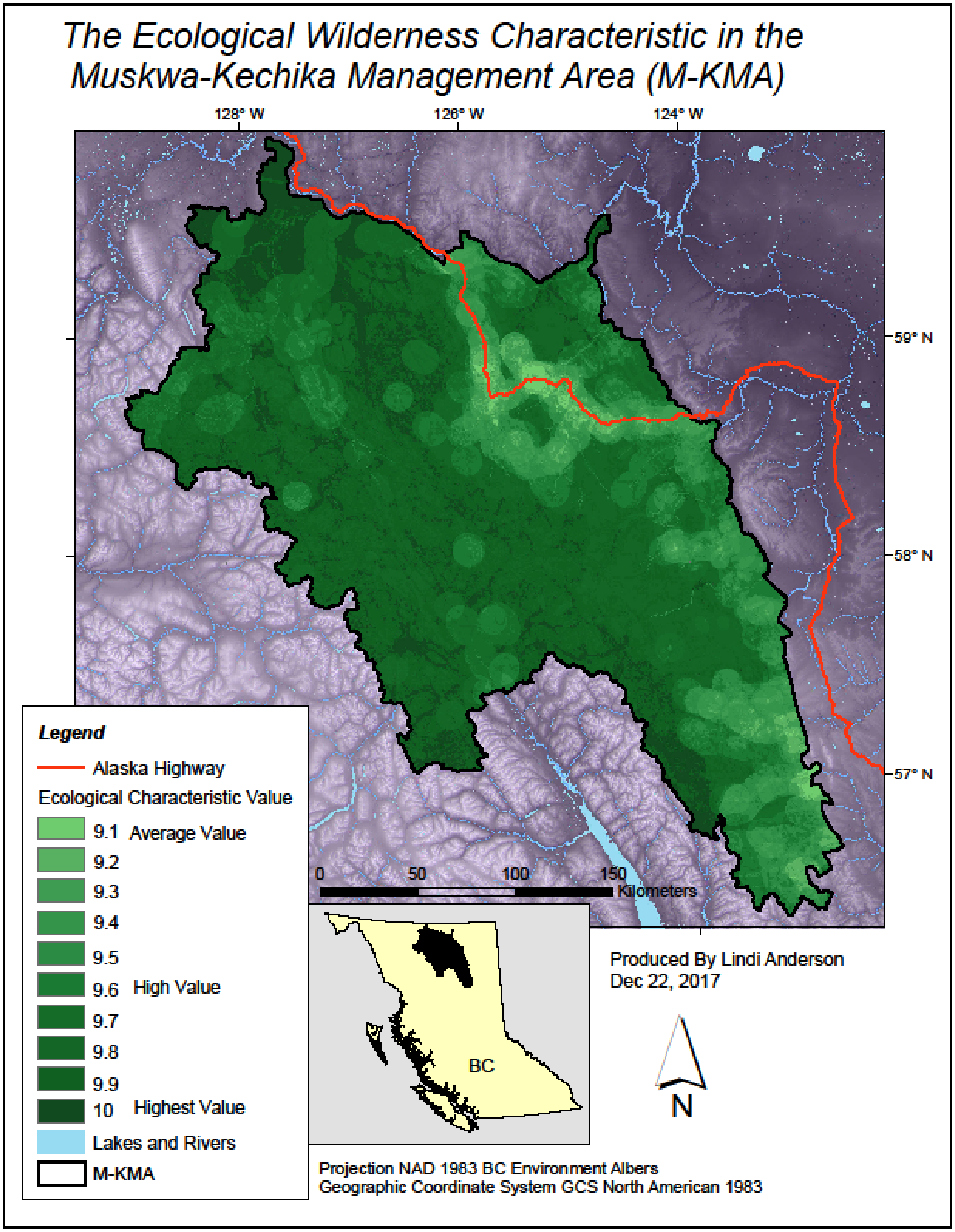


Figure 36. Ecological Wilderness Characteristic in the Muskwa-Kechika Management Area (M-KMA).

The Ecological Wilderness Characteristic map displays a large portion of the M-KMA (81.53%) as being ecologically rich with values of 9.6 to 10 (Table 14). The other 18.47% of values are affected to some degree by the existing human footprint. The darker greens of the Aeroplane Special Management Zone, the Kechika River Corridor, the Fishing Special Management Zone (Appendix A and B: Figure B1) and descending into the eastern, central and southern M-KMA highlight areas that have a high degree of ecological variation, enduring features, wildlife suitability, and watershed intactness. Areas in a lighter-green have more developments and access for motorized activities. The circular lighter areas throughout the middle of the M-KMA represent small buildings, landing lakes and/or airstrips, which likely only see temporal use. Therefore, this offers a conservative, year-round model of Ecological Wilderness Characteristic.

Table 14. Percent of Ecological Wilderness Characteristic Values in the Muskwa-Kechika Management Area (M-KMA)

Wilderness Value	% of the M-KMA
9.1	0.71%
9.2	2.16%
9.3	3.46%
9.4	5.18%
9.5	6.97%
9.6	11.58%
9.7	10.21%
9.8	21.57%
9.9	26.22%
10	11.95%

Note: 9.1 = Lower Valued Wilderness and 10 = Very High Valued Wilderness

When separated into the four categories used to synthesize wilderness values, the Ecological Wilderness Characteristic model shows that 59.73% of the M-KMA has a very-high Ecological Wilderness value (Table 15).

Table 15. Breakdown of Ecological Wilderness Characteristic by Wilderness Category in the Muskwa-Kechika Management Area (M-KMA)

	Wilderness Category	% of the M-KMA
lower	1,2,3	6.32%
moderate	4,5	12.15%
high	6,7	21.79%
very-high	8,9,10	59.73%

When examined by Resource Management Zones, a large percentage of the lower-valued wilderness is in the enhanced RMZ (e.g., highway corridors) and the higher-valued wilderness is largely represented in the Special Wildland RMZ, the Special RMZ and the Existing Protected areas (Figure 37).

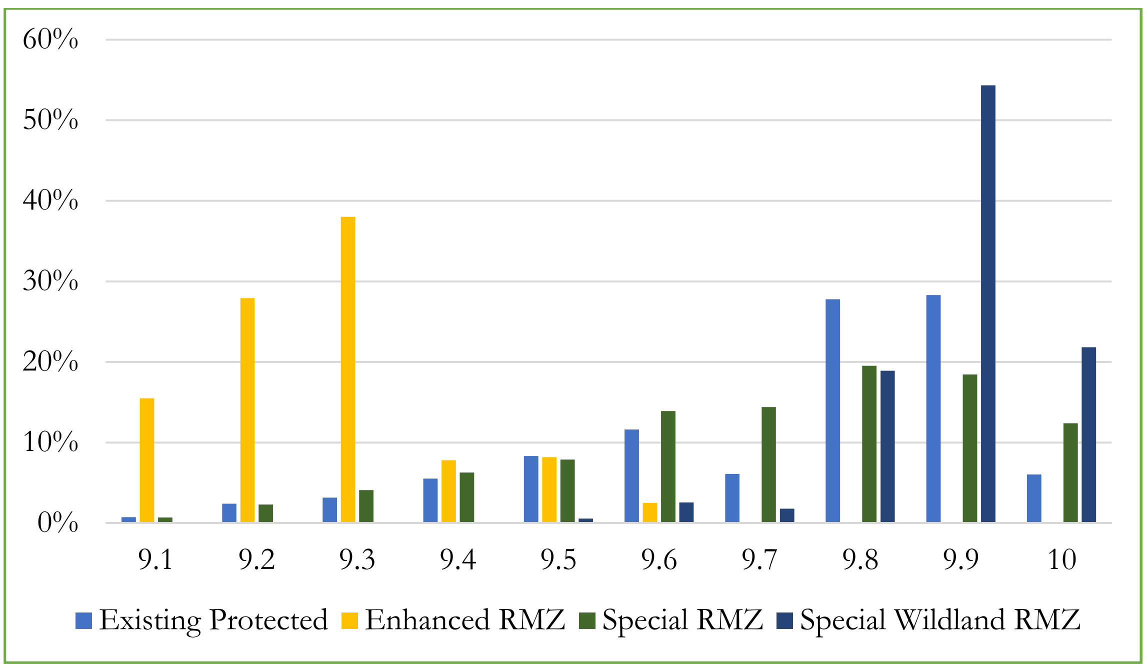


Figure 37. Percent of Ecological Wilderness Characteristic Values per Resource Management Zone (RMZ) in the Muskwa-Kechika Management Area (M-KMA).

6.2 The Social Wilderness Characteristic Model

Wilderness in the M-KMA includes both an ecological component and a social/ human component. The Social Wilderness Characteristic model contains three indicators of social wilderness values: solitude, remoteness and a human footprint model (also serving as the undeveloped layer) (as per Figure 11).

6.2.1 Social Human Footprint (Undeveloped layer)

As previously noted (see Section 5.6), this model used a more conservative human footprint model than the ecological model to adjust for the impacts of human use from visual and auditory sources. The developments with the highest impact in an area were emphasized over layers with less impact in the same area (Figure 38). Therefore, a development with a value of 1 was superimposed over a layer with any value higher.

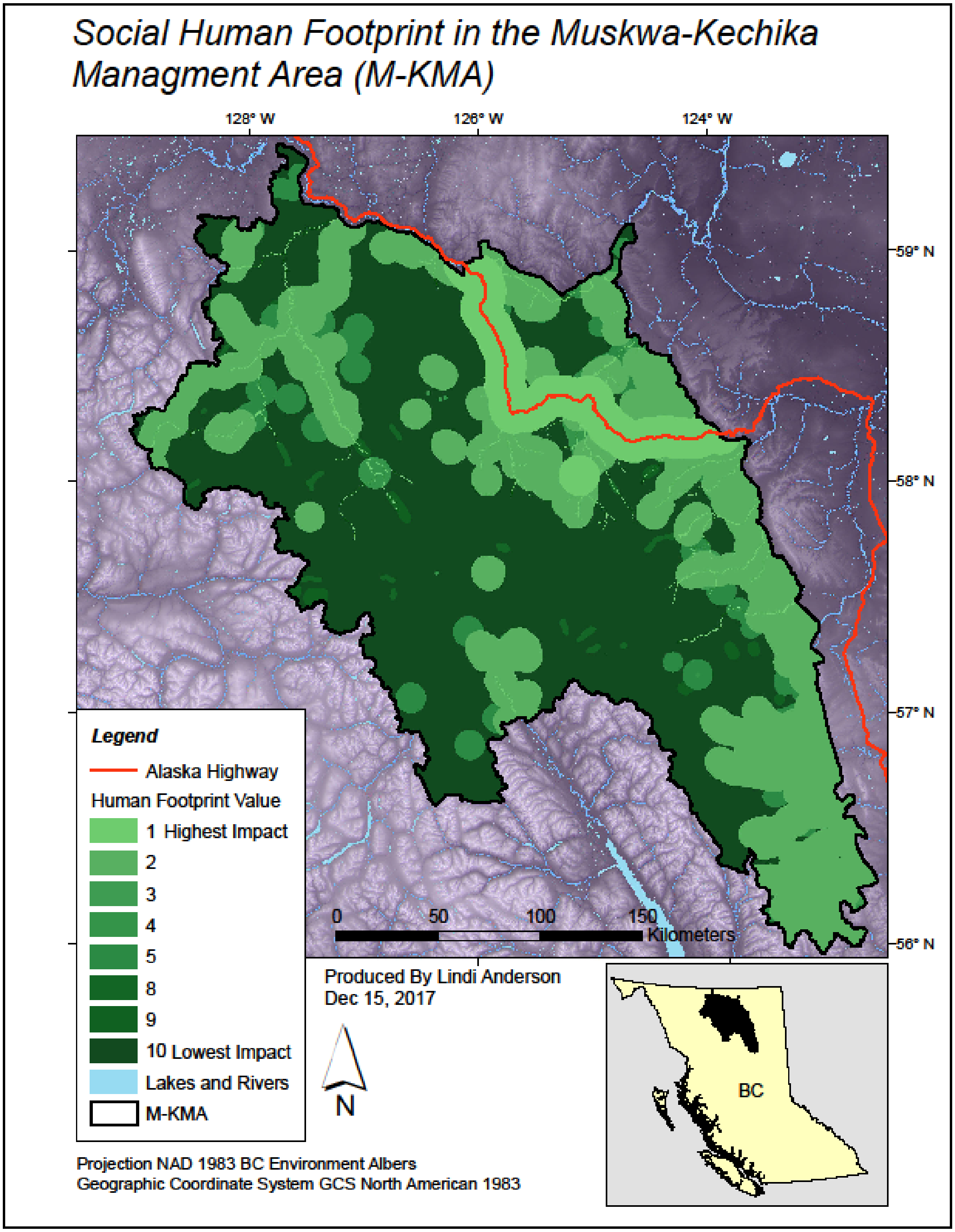


Figure 38. Social Human Footprint in the Muskwa-Kechika Management Area (M-KMA).

Indicative of the Social Human Footprint model being more conservative than the ecological footprint model, there is a higher representation of the lighter-green areas. There is a more equal representation of developed to non-developed area with the lower values (1 to 4 in this instance) representing 42.75% of the M-KMA and the higher values (5, 8, 9 and 10) representing 57.25% of the M-KMA (Table 16). After lowering the values of some of the developments from the Ecological Human Footprint model, there were no values 6 and 7 in the Social Human Footprint. The lower values are particularly associated with motorized access points for air planes, river boat access, motorized ATV access, and major tourism routes concentrated on the eastern edge of the M-KMA.

Table 16. Percent of Social Human Footprint Values in the Muskwa-Kechika Management Area (M-KMA)

Social Human Footprint Value	% of the M-KMA
1	7.663%
2	34.501%
3	0.094%
4	0.490%
5	4.534%
8	0.594%
9	0.684%
10	51.440%

Following reclassification of these values into four equal classes (lower (1), moderate (2 and 3), high (4 and 5) and very high (8, 9 and 10)), the predominant values in the M-KMA are moderate and very high wilderness values and only a small percentage (7.66%) is represented by the lowest value 1 (Figure 39).

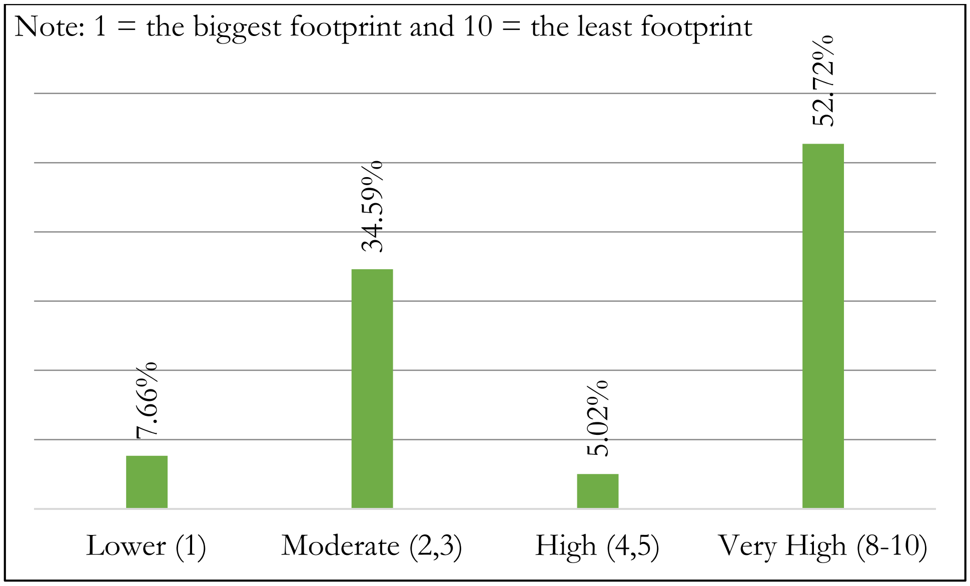


Figure 39. Percent of the Muskwa-Kechika Management Area (M-KMA) in Each of the Social Human Footprint Classes from Low Footprint to Very High Footprint.

The lower value of 1 for this model spatially represents the buffered and weighted development layer of the Alaska Highway and the immediate and residual effects of that main transportation corridor, as well as frequently used river boat access routes. The moderate values are representative of the motorized access routes on the eastern edge of the M-KMA and the sporadic buildings and airstrips in the central part of the M-KMA.

6.2.2 Solitude

Solitude, based on estimated values of total use per RMZ, is shown in Figure 40. An important caveat is that the scale from 9.1 to 10, with 9.1 representing areas that have the highest total visitors per year (5001-140,000) and 10 being areas that have 0-6 visitors per year, does not break in equal intervals (see Table 11).

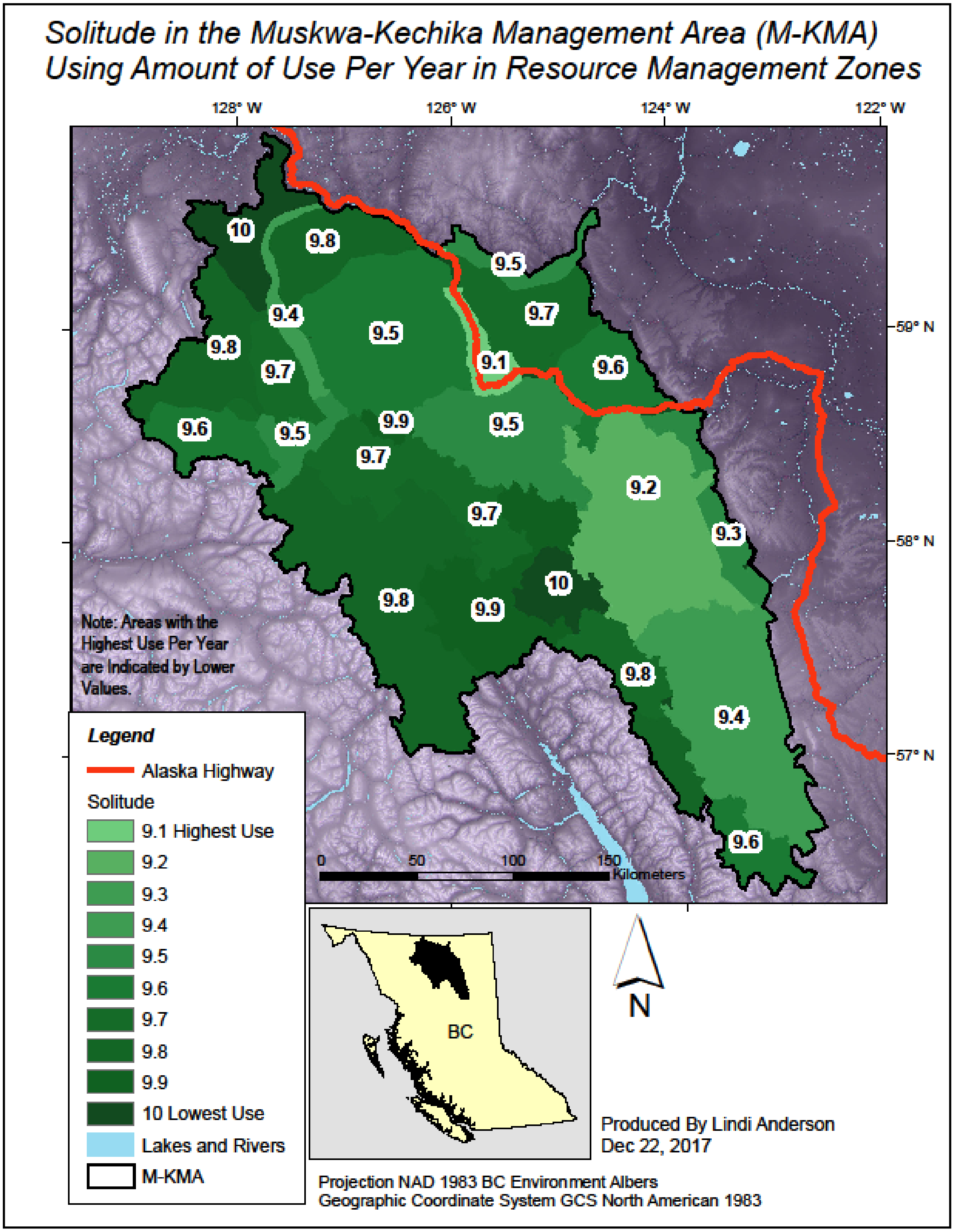


Figure 40. Solitude in the Muskwa-Kechika Management Area (M-KMA) Using Amount of Use Per Year in Resource Management Zones.

This solitude model is representative of estimates of independent tourists and guide outfitters and their clients, camp sites, and access trails. Not surprisingly, the higher-value solitude areas are remote locations that are harder to access and/or are in the center of the M-KMA where longer travel times is required. Areas that provide the highest degree of solitude are Aeroplane Special Management Zone and Kwadacha Park Protected Area. Areas that provide lower opportunities for solitude are Muncho Lake Provincial Park, the Northern Rocky Mountain Protected Area, the Muskwa West Special Management Zone, and the Besa Halfway Chowade Special Management Zone (Table 17, Appendix A and B: Figure B1).

Table 17. Percent of Solitude Values in the Muskwa-Kechika Management Area (M-KMA)

Solitude Value	% of the M-KMA
9.1	1.37%
9.2	10.44%
9.3	2.47%
9.4	9.27%
9.5	11.23%
9.6	16.88%
9.7	13.99%
9.8	21.96%
9.9	6.30%
10	6.09%

When compared to the Social Human Footprint, there is more overlap (49.87%) between the low solitude values (9.1 to 9.5) and areas with high human impact (Social Human Footprint values 1 to 4 than with areas of low human impact. Interestingly though, there is a very high correlation (100%) with high solitude values (9.6 to 10) and high Social Human Footprint values (5, 8, 9, and 10) representing least human impact (Figure 41). As these areas typically have tougher terrain impeding access, fewer access routes are available and they are relatively remote from cities and towns in BC, it is less likely to encounter another human or party.

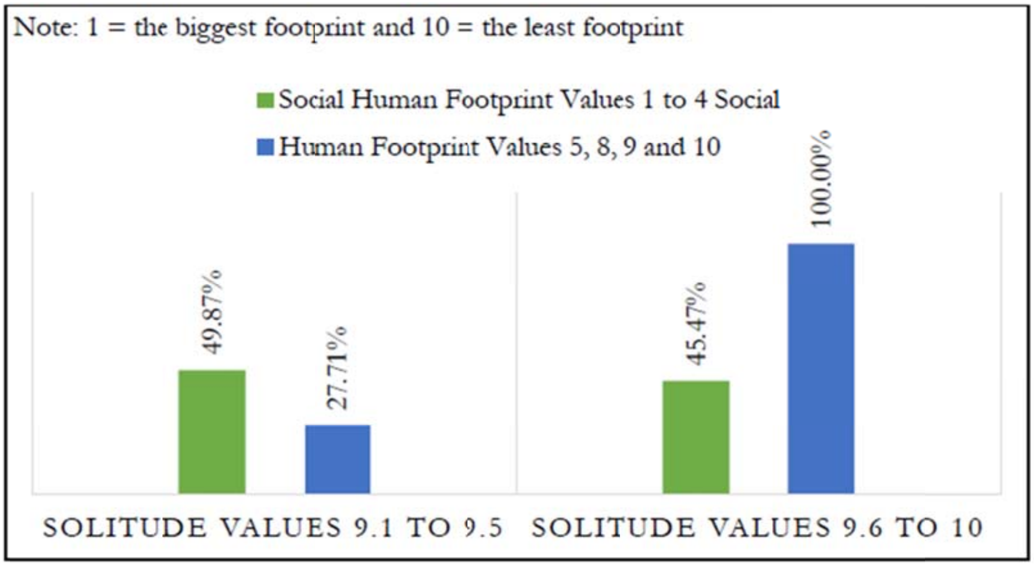


Figure 41. Percent Overlap in the Muskwa-Kechika Management Area (M-KMA) of Solitude Values with the Social Human Footprint (HF) Values.

6.2.3 Remoteness

Remoteness in the M-KMA, derived from buffer rings of 2, 4, 6, and 8 kilometers (which index relative travel time) from main access points into the M-KMA, is shown in Figure 42.

This remoteness model highlights the large number of access points along the eastern edge of the M-KMA. Compared to the western edge, the eastern edge is more easily accessed by cars, ATV's, snowmobiles, airplanes, and river boats. This makes the eastern edge of the M-KMA less remote than the western edge where only river boat access, float plane access and air strip access are available.

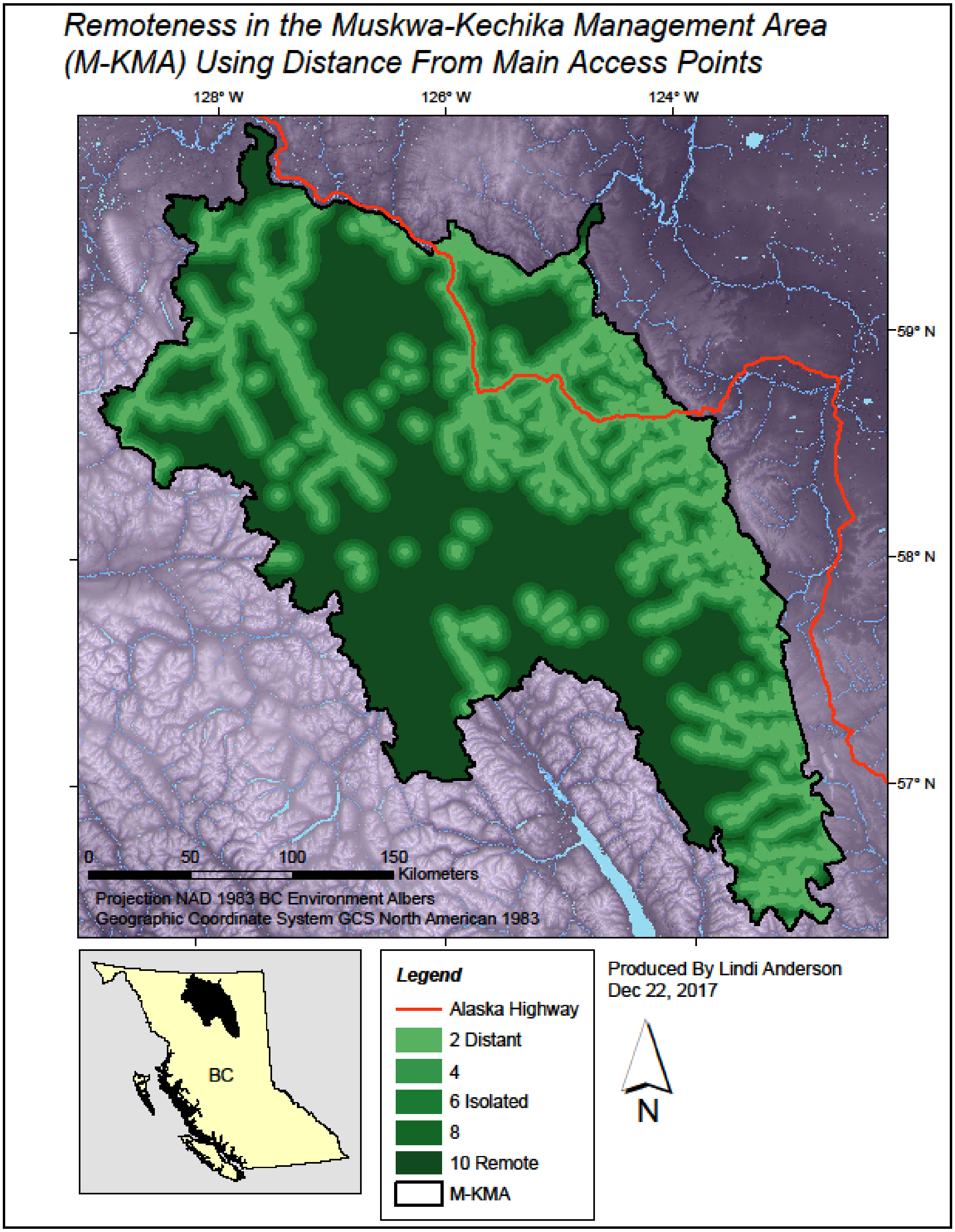


Figure 42. Remoteness in the Muskwa-Kechika Management Area (M-KMA) Using Distance (in km) from Main Access Points.

Figure 43 reveals that the majority of the M-KMA is still relatively remote as 36.80% is at least 10 kilometers from any major access point. However, roughly one quarter of the management area (24.50%) is only 2 kilometers from an access point. An important caveat is that I did not adjust the buffering system to adjust for plane, trail or jet boat access. That is, when landing at an air strip or traveling up a river by jet boat, the buffered rings of remoteness had the same starting point as along the Alaska Highway. This results in a potentially overly conservative approach to mapping remoteness, but there was no rationale in the literature to revise the buffering system.

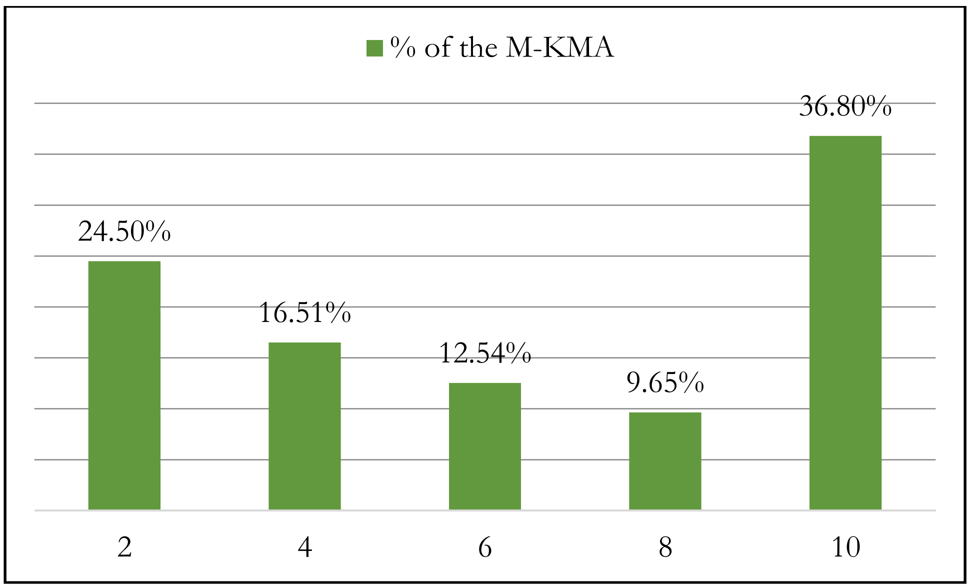


Figure 43. Percent of Remoteness Values (km from Main Access Point) in the Muskwa-Kechika Management Area (M-KMA).

As the access points used for this model were the same as the Social Human Footprint, we can assume that there will be a heavy overlap between areas that are remote and areas that are undeveloped.

6.2.4 Social Wilderness Characteristic

The Social Wilderness Characteristic map, derived from solitude, remoteness, and the Social Human Footprint model, for the M-KMA is shown in Figure 44.

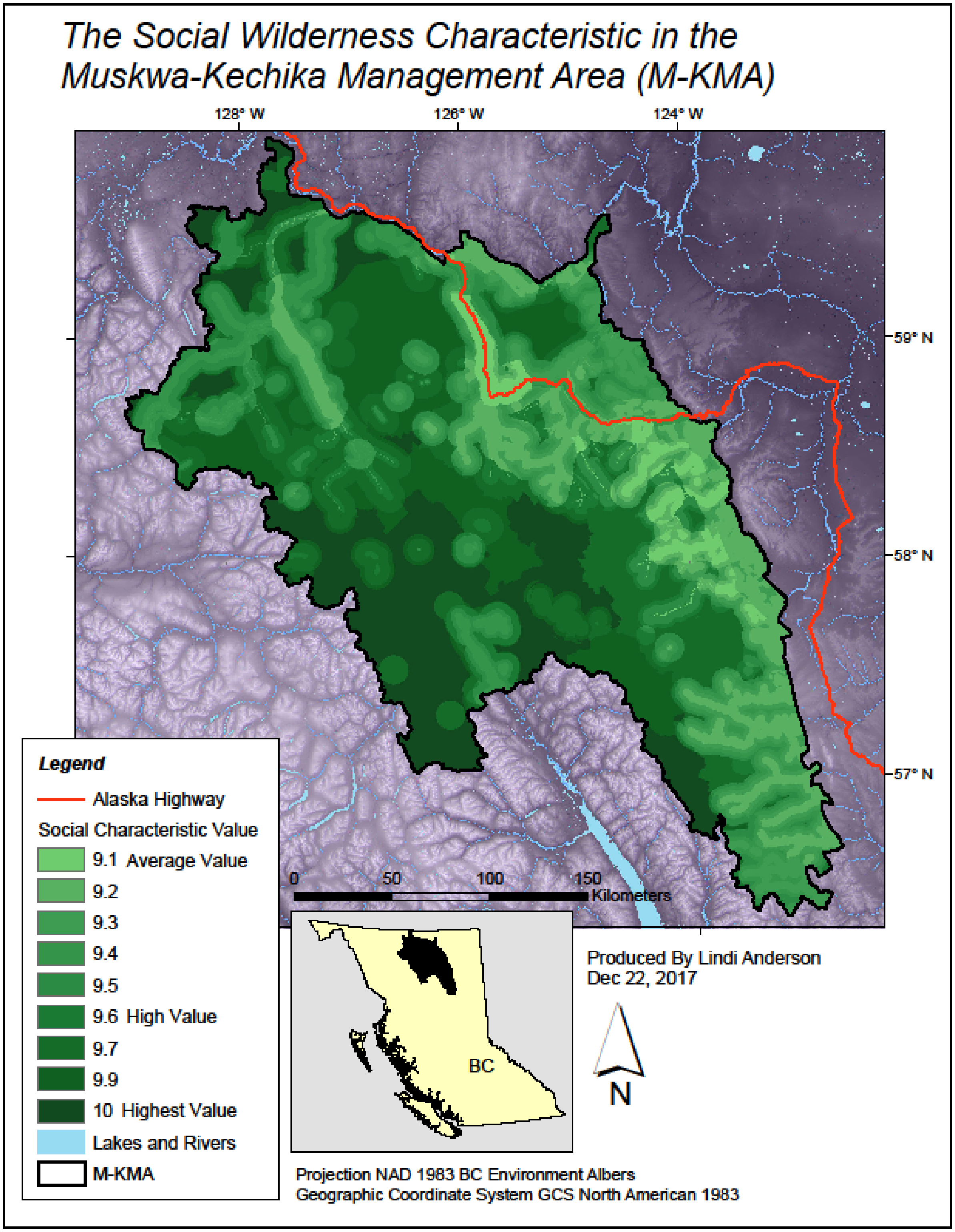


Figure 44. Social Wilderness Characteristic in the Muskwa-Kechika Management Area (M-KMA).

Figure 44 shows a gradient of lighter green, representing areas that are more developed and less remote, to darker green areas that are less developed and more remote. The Social Wilderness Characteristic map also indicates that a more remote experience with high chances of solitude can be achieved in the southwestern portion of the M-KMA, specifically in areas such as the McCusker Special Wildland, Frog Special Wildland, Obo River Special Management Zone, Finlay Russel Protected Area, Upper Pelly Special Wildland, Brain Special Wildland, and the Upper-Gataga Special Wildland (Appendix A and B: Figure B1). The eastern edge is once again showing lighter green shades due to the roads, developments and higher population numbers in that area. Table 18 shows a breakdown of the Social Wilderness Characteristic values:

Table 18. Social Wilderness Characteristic Values in the Muskwa-Kechika Management Area (M-KMA)

Wilderness Value	*% of Coverage in the M-KMA*
9.1	3.33%
9.2	11.94%
9.3	8.64%
9.4	9.35%
9.5	10.91%
9.6	6.28%
9.7	17.09%
9.9	14.50%
10	17.96%

In general, the majority of the M-KMA has very-high social wilderness values. When classified into four equal classes, 52.72% of the M-KMA has very-high social wilderness values and only 7.66% of the M-KMA has the lowest value (9.1) (Table 19).

Table 19: Breakdown of Social Wilderness Characteristic by Wilderness Category in the Muskwa-Kechika Management Area (M-KMA)

Wilderness Category	*% of the M-KMA*
Lower (9.1)	7.66%
Moderate (9.2 ,9.3)	34.59%
High (9.4, 9.5, 9.6)	5.02%
Very-High (9.7, 9.9 and 10)	52.72%

When compared to the Resource Management Zones, less than 1% of the very-high values are in the Enhanced RMZ. In addition, only 12.56% of the Protected Areas has a very-high value and 23.33% of very-high valued area is in the Special RMZ, where resource industry could be permitted (with restrictions) (Figure 45).

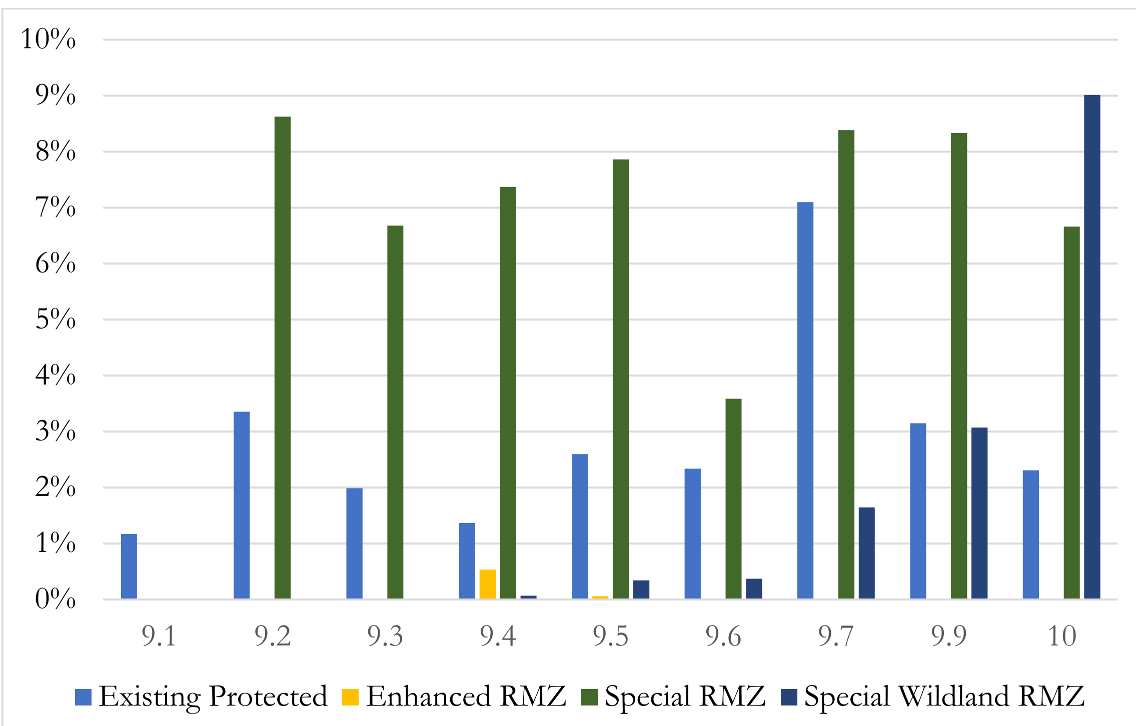


Figure 45. Percent of Social Wilderness Characteristic Values per Resource Management Zone (RMZ) in the Muskwa-Kechika Management Area (M-KMA).

6.3 Wilderness Character in the M-KMA

Wilderness Character of the M-KMA was based equally (50% each) on the Ecological and Social Wilderness Characteristic map layers. As the whole of the M-KMA is considered to have relatively high wilderness values compared to the surrounding area, a light green to dark green color pallet implies a gradient of degree of wilderness qualities. It is important to note that the intentions for creating this final map of *Wilderness Character in the M-KMA* (Figure 46) was to assess whether it would be possible to adequately spatially map the different wilderness values and settings in the M-KMA. It is intended to be an approach and tool to map wilderness quality, not a definitive map of wilderness qualities and extents. As data sets are improved and finer scale data are collected, the map can be refined.

When the values from Figure 46 are split into a lower and higher category, the higher values (valued 9.6 to 10) represent just over three-quarters (75.04%) of the total area of the M-KMA. Only 24.96% is represented within the lower values (9.1 to 9.5) (Table 20). The darker green colors of the highest value start from the middle of the northern boundary extent of the M-KMA and span from north to south of the whole M-KMA (Figure 46) down through the Fox Special Management Zone and the Finlay-Russel Special Management Zone. This dark green also spreads to the western edge of the M-KMA, showing high wilderness values in the Frog-Gataga Protected Area, the Frog Special Wildland and the Braid Special Wildland (Appendix A and B: Figure B1). The lighter colors converge around where the human influences affect either the Ecological or Social Wilderness Characteristic.

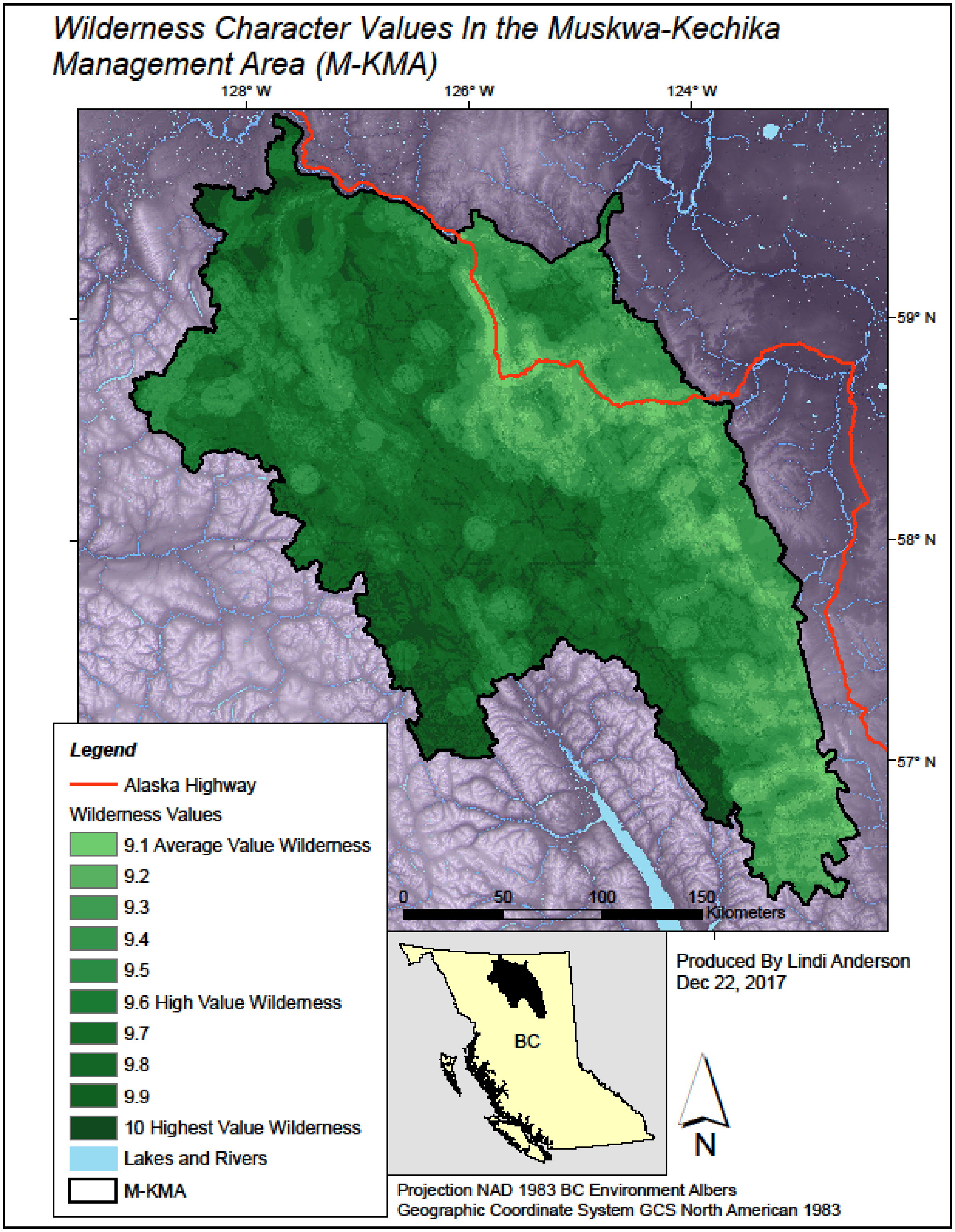


Figure 46. Wilderness Character in the Muskwa-Kechika Management Area (M-KMA).

Table 20. Percent of Wilderness Character Values in the Muskwa-Kechika Management Area (M-KMA)

Wilderness Value	% of Coverage in the M-KMA
Lower (9.1, 9.2 ,9.3)	9.25%
Moderate (9.4, 9.5)	15.71%
High (9.6, 9.7)	20.10%
Very High (9.8, 9.9, 10)	54.93%

When separated into four categories of wilderness quality, 54.93% is represented in the very high wilderness quality category and 20.10% is represented by the high wilderness category. Only 9.25% of the M-KMA is seen to have lower wilderness qualities compared to the rest of the M-KMA.

When overlaid with the RMZs, most of the areas with a 10 value (79.68%) – the highest wilderness value – are in the Special Wildland RMZ, whereas only 17.26% of the 10 values for the whole M-KMA are located in the Existing Protected areas (Figure 47). Of the Existing Protected wilderness areas, a large percentage (69.29%) has higher wilderness values (9.6 to 10), leaving 30.71% with values of 9.1 to 9.5.

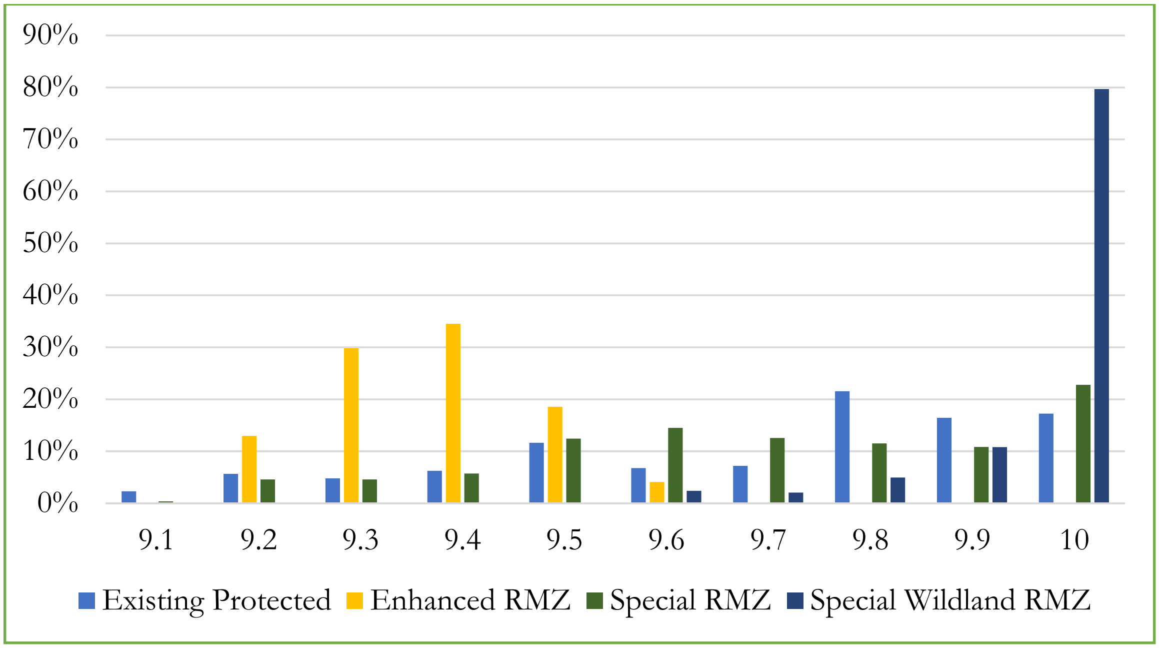


Figure 47. Percent of Wilderness Character Values per Resource Management Zone (RMZ) in the Muskwa-Kechika Management Area (M-KMA).

6.4 Potential Resource Overlap

My research was intended to provide a means of not only assessing the current state of wilderness, but also to examine change over time and compare to other uses of the M-KMA. Using data developed by other resource value mapping projects, land stewards and managers can assess possible resource conflict, compatibility, management, and planning. These data for the natural resource layers (forestry, oil and gas potential, mineral potential and wind energy potential) were previously developed (Suzuki & Parker, 2016). I reclassified each of the resource layers into four categories and then separated out the highest valued category for each resource to overlap with the very-high wilderness category. I mapped these areas of overlap between areas with high wilderness quality and high resource potential to explore the issue, but resource managers and wilderness monitors will need to develop richer data and analysis of these issues. Moreover, while I have only addressed overlap with high-value wilderness, it is not only high-value wilderness that is important in the M-KMA. The gradation of wilderness shows that the lower and moderate wilderness value areas are equally important as they are likely used most often for recreation (e.g., close to access and main populations). Furthermore, it is important to remember that although the human footprint models created for this project suggest that the eastern edge is heavily developed compared to the western edge, the buffering and weighting approach used was highly conservative. The following results are just the area of overlapping high-valued areas for both wilderness and other resources of importance in BC.

6.4.1 Forestry Potential

When values for high (top 25%) forestry potential are intercepted with the very-high (also top 25%) Wilderness Character category, there is an overlap of 28.76%. Figure 48 indicates that the overlap occurs throughout the M-KMA and suggests that there may be a conflict with low-lying areas in the Fox Special Management Zone heading north into the M-KMA. Areas that do not overlap appear to be snow/ice, water bodies, or areas that have a heavier human footprint influence (Table 21 and Figure 48).

Table 21. Very High Wilderness Character, High Forestry Potential and Overlap in the Muskwa-Kechika Management Area (M-KMA)

Very-High Value Wilderness (area Ha)	High Forestry Potential (area Ha)	Size of Overlap (area Ha)	% of M-KMA with Very High Wilderness Value and High Forest Potential
2538215	2181254	730022	28.76%

Note: The percentage of the Very-High Wilderness Character category used for this comparison is 54.93% of the M-KMA.[13]

[13] Table 20 for reference.

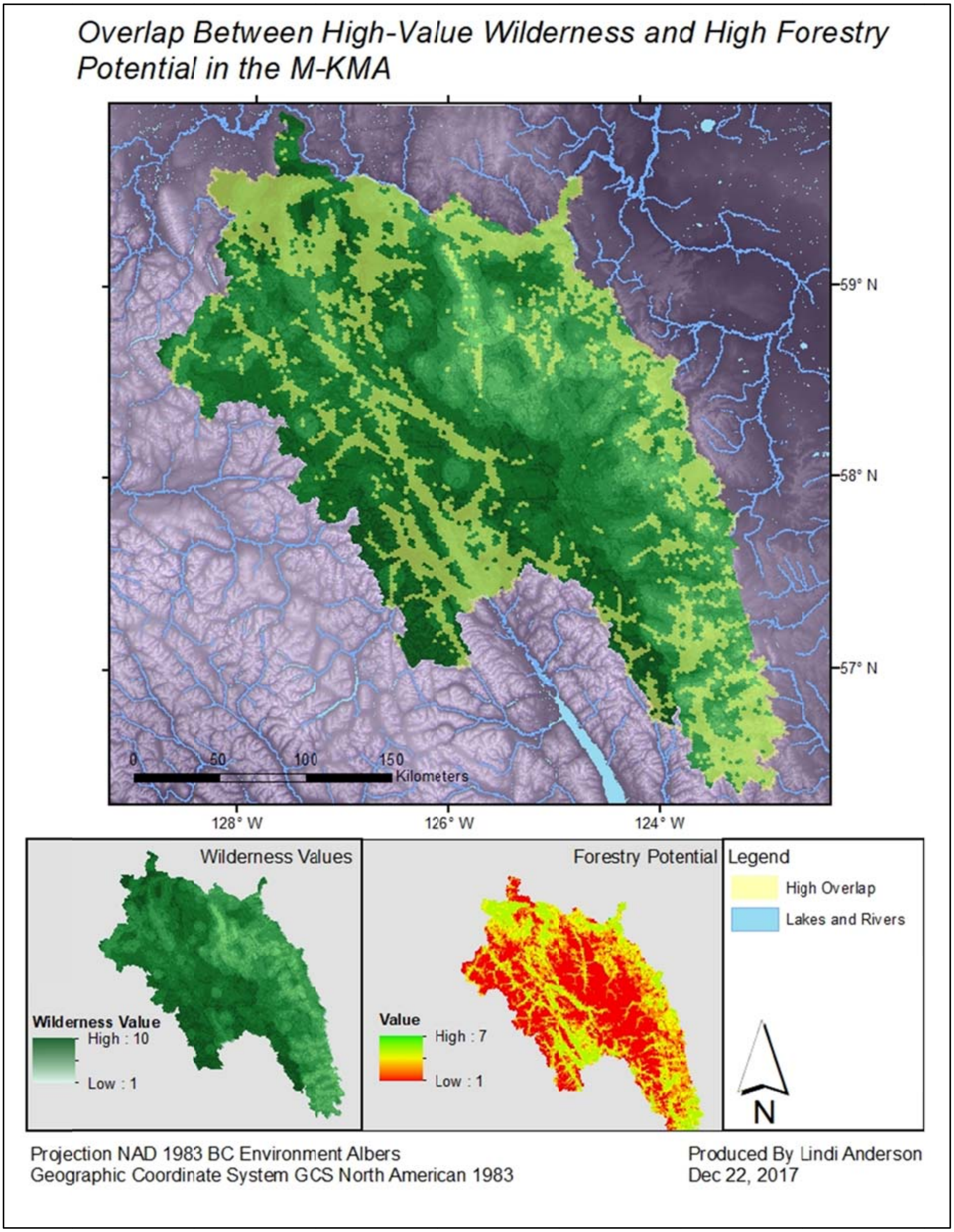


Figure 48. Overlap Between High-Value Wilderness Character and High Forestry Potential in the Muskwa-Kechika Management Area (M-KMA). Note: Forestry potential values from Suzuki and Parker (2016).

6.4.2 Oil and Gas Potential

As the oil and gas potential for the M-KMA is limited to the boreal plains on the eastern edge of the M-KMA, there was very little overlap with very-high Wilderness Charcter values. As previously discussed, the eastern edge of the M-KMA has relatively lower wilderness values compared to the rest of the management area. Thus, when wilderness values were intercepted with the high (top 25%) oil and gas potential layer, there was only an overlap of 6.87% (Table 22 and Figure 49).

Table 22. Very High Wilderness Character, High Oil and Gas Potential and Overlap in the Muskwa-Kechika Management Area (M-KMA)

Very-High Value Wilderness (area Ha)	High Oil and GasPotential (area Ha)	Size of Overlap (area Ha)	% of M-KMA with Very High Wilderness Value and High Oil and Gas Potential
2538215	1573423	174431	6.87%

Note: The percentage of the Very High Wilderness Character category used for this comparison is 54.93% of the M-KMA.[14]

[14] Table 20 for reference.

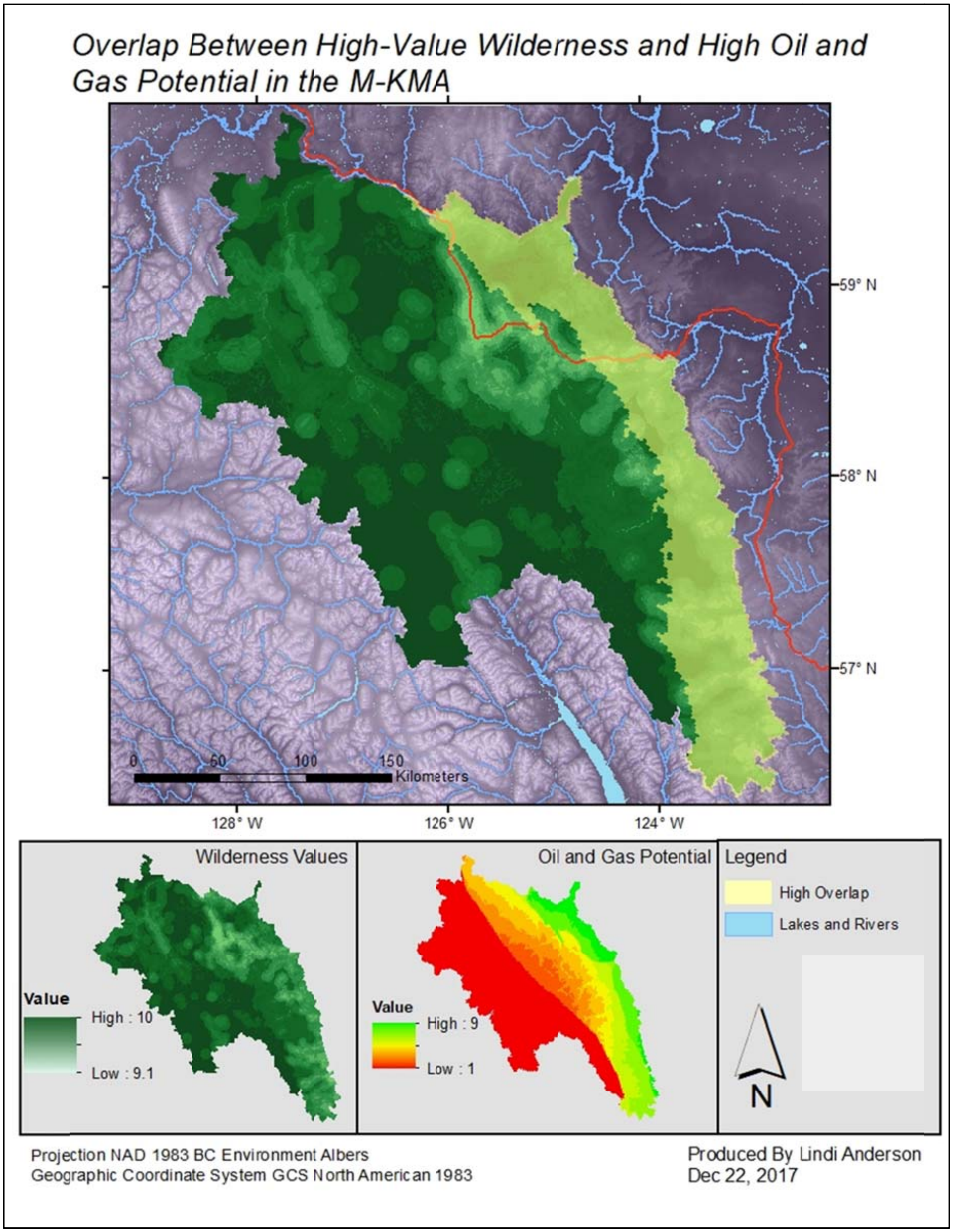


Figure 49. Overlap Between High-Value Wilderness Character and High Oil and Gas Potential in the Muskwa-Kechika Management Area (M-KMA). Note: Oil and gas potential values from Suzuki and Parker (2016).

6.4.3 Mineral Potential

The rich geology and enduring features of the M-KMA provide an array of potential mining opportunities for the area. When the Wilderness Character in the M-KMA layer was intercepted with the high (top 25%) mineral potential category, there was an overlap of 35.59% (Table 23 and Figure 50). The overlap is distributed in bands running from north to south with little-to-no overlap on the eastern edge of the M-KMA.

Table 23. Very High Wilderness Character, High Mineral Potential and Overlap in the Muskwa-Kechika Management Area (M-KMA)

Very-High Value Wilderness (area Ha)	High Mineral Potential (area Ha)	Size of Overlap (area Ha)	% of M-KMA with Very High Wilderness Value and High Mineral Potential
2538215	2267103	903403	35.59%

Note: The percentage of the Very High Wilderness Character category used for this comparison is 54.93% of the M-KMA.[15]

[15] Table 20 for reference.

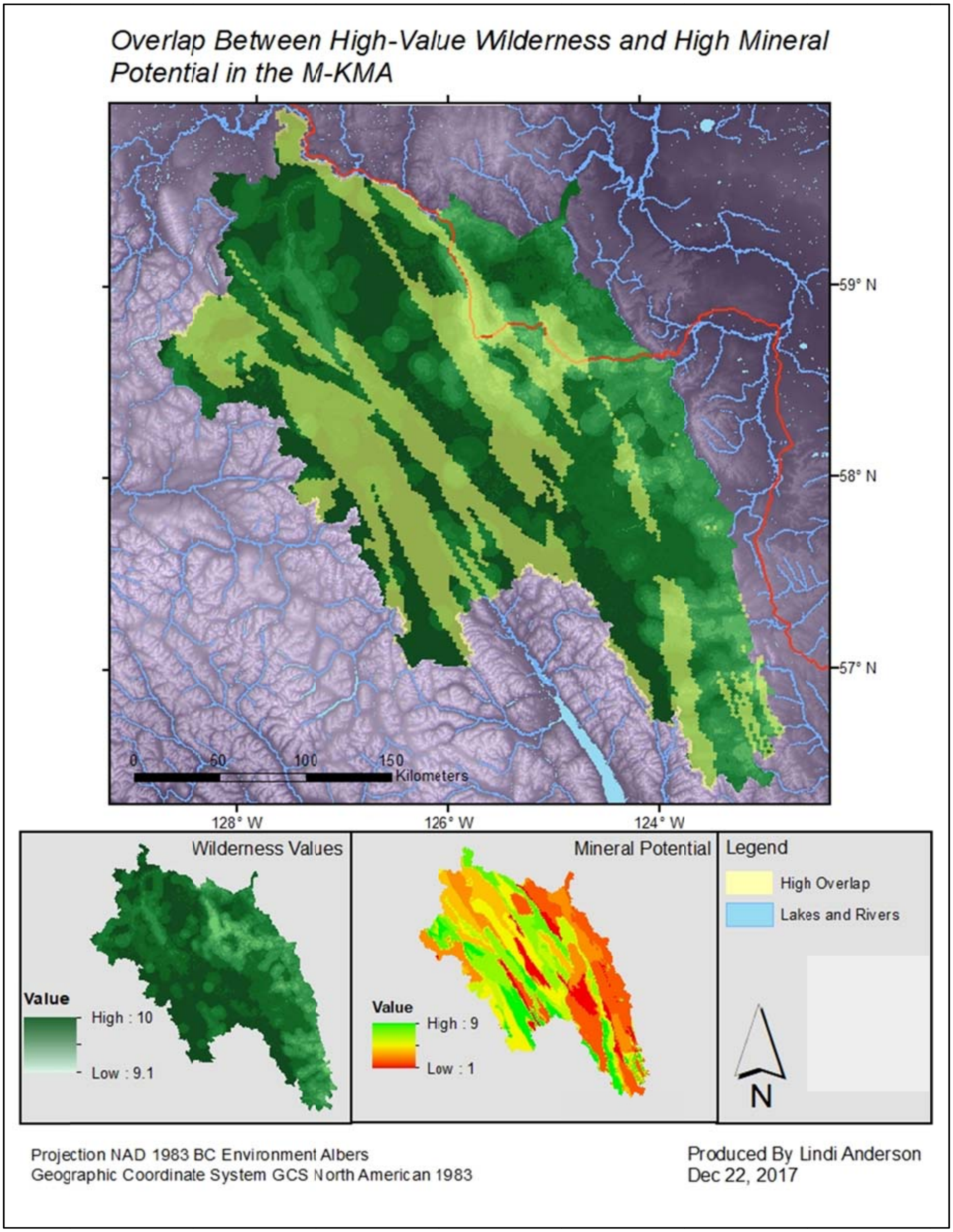


Figure 50. Overlap Between High-Value Wilderness Character and High Mineral Potential in the Muskwa-Kechika Management Area (M-KMA). Note: Mineral potential values from Suzuki and Parker (2016).

6.4.4 Wind Energy Potential

When reclassified into four categories, the high (top 25%) wind potential category covered 265,929 hectares. The high wind potential category and the very-high wilderness layer were intercepted to assess where the two resources could conflict. The result was a very small area of 1.76% (Table 24 and Figure 51).

Table 24. Very High Wilderness Character, Wind Energy Potential and Overlap in the Muskwa-Kechika Management Area (M-KMA)

Very-High Value Wilderness (area Ha)	High Wind Potential (area Ha)	Size of Overlap (area Ha)	% of M-MA with Very High Wilderness Value and High Wind Potential Value
2538215	265929	44708	1.76%

Note: The percentage of the Very High Wilderness Character category used for this comparison is 54.93% of the M-KMA.[16]

[16] Table 20 for reference.

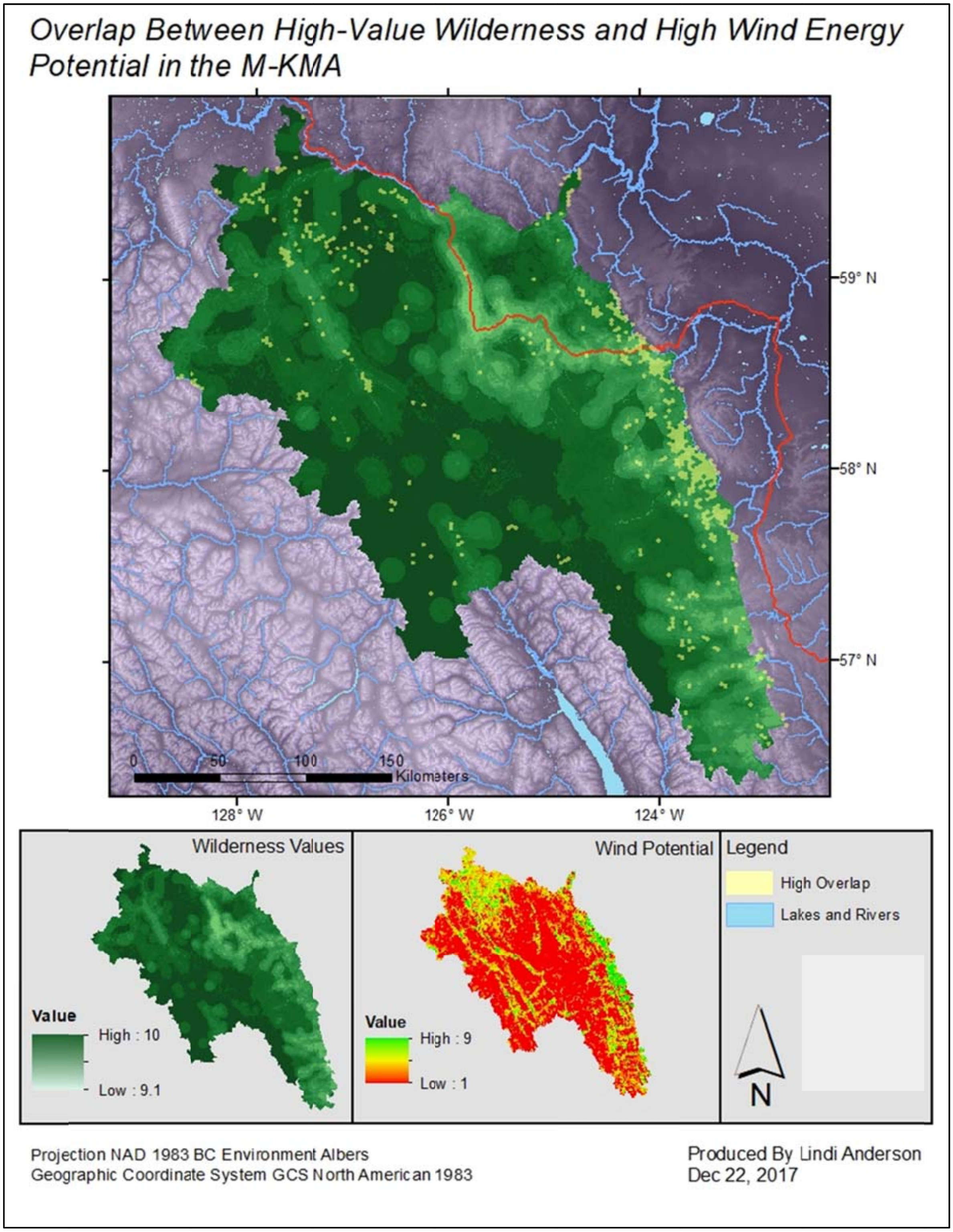


Figure 51. Overlap Between High-Value Wilderness Character and High Wind Energy Potential in the Muskwa-Kechika Management Area (M-KMA). Note: Wind potential values from Suzuki and Parker (2016).

6.4.5 Combined View of Potential Resource Overlap

To get an overall assessment of Wilderness Character and resource overlap for planning purposes, I merged the High Forestry Value, the High Oil and Gas Potential Value, the High Mineral Potential Value and the High Wind Energy Potential Value. As resource developments cannot take place in protected areas, I removed the values represented in already protected areas. The result of Figure 52 shows that there is a total of 26.24% overlap between the highest combined resource potential area and very-high wilderness values.

The dark red color in Figure 52 illustrates the areas that have the greatest potential for resource overlap based on this top 25% high-values comparison. This overlap is not necessarily restricted to one part of the M-KMA, but there are larger areas of overlap in the western and southern edges of the M-KMA compared to the eastern and northern edges.

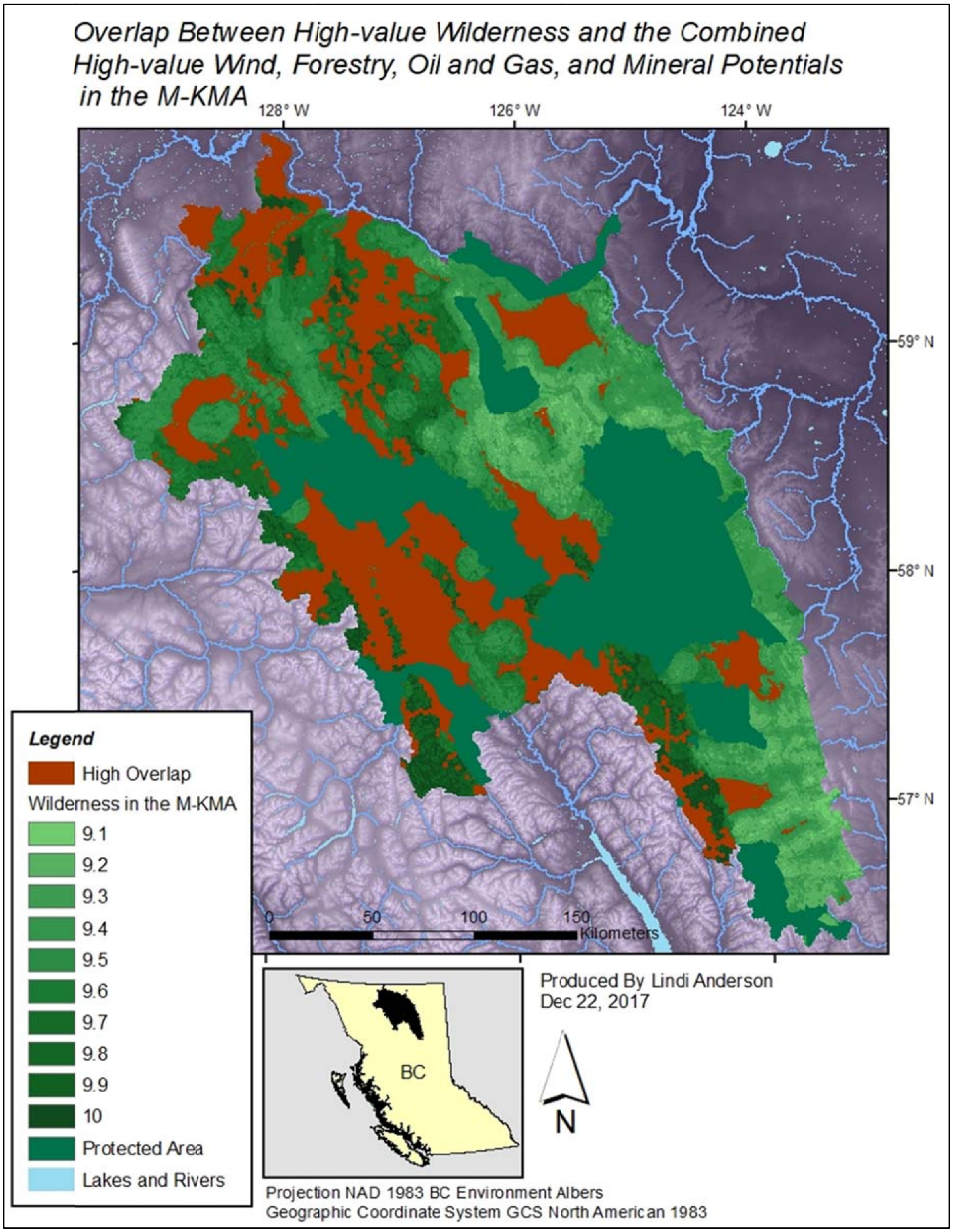


Figure 52: Overlap Between High-Value Wilderness Character and the Combined High-Value Wind, Forestry, Oil and Gas, and Mineral Potentials in the Muskwa-Kechika Management Area (M-KMA). Note: All potential values from Suzuki and Parker (2016).

Chapter 7: Discussion and Conclusion

Through a combination of research and practice, I mapped Wilderness Character in the Muskwa-Kechika Management Area in a meaningful and representative way. Many combinations of wilderness characteristics make each wilderness setting different, thus definitions vary. Working with M-KMA-specific legislation and the wilderness definition developed by the M-KAB, I mapped Ecological and Social Wilderness Characteristics and Wilderness Character in the M-KMA. As wilderness is an intangible concept, I developed a way to spatially represent different wilderness qualities and, ultimately, different wilderness settings.

7. 1 Representing the M-KMA: The Criteria and Indicator Framework

The indicators used to create the Ecological Wilderness Characteristic map, the Social Wilderness Characteristic map and the final map of Wilderness Character in the M-KMA were common in both M-KMA-specific legislation and popular wilderness literature (e.g., Aplet et al., 2000; Landres et al., 2008; Landres et al., 2009; Province of British Columbia, 1998; Pissot, 2002; Watson et al., 2016 etc.). Table 25 and Table 26 summarize the ecological and social indicators used to map Wilderness Character in the M-KMA. The tables generally describe how the indicators can be used to measure wilderness quality spatially. Although these indicators provided a good base for wilderness monitoring in the M-KMA, they are not the only important wilderness values. Furthermore, economic, spiritual and Indigenous values are also intrinsic to the area, but data to spatially represent these values were not available.

Table 25. Ecological Indicators for the Ecological Wilderness Characteristic Model

Indicator	Spatial Representation
Species Movement and Connectivity	Overlaid with the Human Footprint Model, this indicator shows the extent and severity of impact to connectivity using connectivity routes of four focal species: mountain goat, Stone's sheep, caribou, and moose (Yellowstone to Yukon Conservation Initiative, 2012).
Focal Species Habitat Suitability Index	Overlaid with the Human Footprint Model, this indicator shows the impact to habitat, which is suitable for seven focal species in the M-KMA: caribou, elk, mountain goat, Stone's sheep, grizzly bear, moose and wolf (Heinemeyer et al., 2004).
Enduring Features	Overlaid with the Human Footprint Model, this indicator shows the impact to diversity and rarity of enduring features (Yellowstone to Yukon Conservation Initiative, 2012).
Ecological Variability	Overlaid with the Human Footprint Model, this indicator shows the percentage of impacted diverse and rare Biogeoclimatic Ecosystem Classification (BEC) zones.
Special Features	Overlaid with the Human Footprint Model, this indicator shows the impact to diversity and rarity of special features such as wetlands, karst topography, and mineral licks. Missing data restrict this analysis currently to wetlands in the M-KMA.
Watershed Intactness	Overlaid with the Human Footprint Model, this indicator shows the impact to watershed intactness within the M-KMA.

Table 26: Social Indicators for the Social Wilderness Characteristic Model

Indicator	Spatial Representation
Solitude	A measure of use density for each Resource Management Zone (RMZ) using use estimates from the table: Values, Current Situation and Assumptions for Each Resource Management Zone in the Muskwa-Kechika Management Area (Rutledge & Davis, 2005).

Social Human Footprint	The Human Footprint Model shows the amount and extent of undeveloped landscape.
Remoteness	The recreation opportunity spectrum 8-km guideline for the 'wildest' area with 2-km buffer rings shows the gradation from access areas (British Columbia Ministry of Forests,1998).

My research used a multiple-indicator approach to map wilderness using a range of components representing many values intrinsic to the wilderness setting and experience. Compared to a single indicator approach that may only represent one aspect of wilderness (e.g., naturalness), the resulting final map of wilderness for the M-KMA outlines different types of wilderness quality; in addition, it outlines where varying wilderness recreational opportunities are likely to take place (e.g., motorized recreation on the eastern edge). Other multiple-indicator approaches to map wilderness have largely followed the US wilderness definition (see Chapter 3: Literature Review). Using the US Wilderness definition as a tool for research and guidance, my approach took advanced steps to map Wilderness Character in the M-KMA. Going beyond the four US wilderness characteristics, I used several indicators that were intrinsic to the M-KMA wilderness setting (ecological integrity, ecological variation, wildlife habitat, degree of solitude, remoteness) to ensure that the model would adequately represent the unique wilderness variations found in the area. The mapping tool can be used as an example for long-term wilderness monitoring in the M-KMA as it can be easily repeated, replicated and improved.

7.1.1 Data Collection and Assessment

Searching both qualitative and quantitative data sources, I found either readily available data or produced proxy measures that can be easily replicated. These measures can be enhanced as new or finer scale data become available. Wildlife data layers created by Heinemeyer et al. (2004) for the *Conservation Area Design for the Muskwa-Kechika Management Area (M-KMA)* were used for the wildlife indicator map. Enduring feature data and wildlife connectivity data were adapted from the 2012 *Muskwa-Kechika Biodiversity Conservation and Climate Change Assessment* (Yellowstone to Yukon Conservation Initiative, 2012). All other indicators were developed using data available through BC's government Data Catalogue service or were created. Using readily available, open-sourced data allows for this mapping approach to be replicated at a finer scale, or the same scale, adjusted or improved. As some of the finer detail for the area was missing or incomplete (e.g., vegetation inventory for the area was incomplete for all of BC as large portions of the M-KMA had missing or null information), the accuracy of this mapping can be improved over time with new data. The weights, buffers and layer representation for each indicator can also be adjusted to incorporate new data (e.g., the Special Features layer could be improved with karst topography features and/or a mineral lick component).

Throughout this thesis I describe the tool or its application as 'conservative'. By that I mean that where data were not available to prove or suggest otherwise, I took cautious approaches when developing the model and maps (e.g., with buffering and weighting). Further research and analysis of wilderness in the M-KMA will need to be done to get a more definitive model. In addition, detailed analysis of wilderness should be done at a finer scale when dealing with planning and management in the M-KMA (e.g., mapping done at the watershed or RMZ scale with enhanced data).

7.1.2 The Human Footprint Models

For my study I created both an Ecological Human Footprint Model and a Social Human Footprint Model. I looked at how developments affect both the ecological integrity of the environment and the social wilderness experience. I identified variable buffers that were used in previous works from sustainable forest management, wildlife studies, government legislation, research literature, guidelines and previous wilderness studies. Buffers were zones created around a development to represent the affect and influence a development has on the surrounding environment. Using these sources, a preliminary minimum allowable buffer was established for each development. The *Conservation Area Design (CAD) for the Muskwa-Kechika Management Area* (MKMA) looked at both long-term human footprint developments and short-term human footprint developments and their impact to wilderness (Heinemeyer et al., 2004). Mimicking their buffer approach, as it was the most conservative, the buffers were enhanced to fit their buffer scheme. However, as the M-KMA has relatively little use in most areas, I adjusted the buffer on the short-term human footprints such as airfields and landing lakes that may only see seasonal use. This buffer approach is more conservative than others previous taken. For example, the Y2Y *Biodiversity Conservation & Climate Change Assessment* used a universal 3.83 km buffer for all development layers (Yellowstone to Yukon Conservation Initiative, 2012). While this approach was resourceful in depicting relatively where developments and wilderness are, it does not recognize the full impact that humans have on the ecological and social values of wilderness (e.g., solitude, wildlife connectivity, remoteness etc.) Having a variety of different buffer sizes allowed me to more accurately represent the influence that different developments have on the environment and on the wilderness experience. When completed, the Ecological Human Footprint model and the Social Human Footprint model were both very conservative approaches to mapping the human footprint.

These models only show the developments within the study boundary or the M-KMA boundary line. The influence of development outside of the boundary can still influence the wilderness setting and experience near the border, but is not captured in the models. Monitoring of wilderness will require monitoring of adjacent lands. Threats to core values (e.g., wildlife connectivity) can happen outside of the management area through developments, water degradation, dust and smoke, wildfires, or disease (Casson et al., 2016). Lastly, the color scheme and grading for this mapping project are relative to the encroaching resource development on the adjacent lands (Figure 1 for reference). If repeated, the color and grading scheme might be adjusted to include the adjacent lands.

Both the Ecological Human Footprint and the Social Human Footprint used different methods when adding the influences of development together. This provided different representations of human influence on the land. The Ecological Human Footprint shows where developments are likely to have a larger impact on ecological integrity, as it highlights where more developments are in an area; more developments in an area usually means less ecological variation and more permanent structures. The Social Human Footprint shows where the societal influences may affect a wilderness experience; thus, noise and light pollution were taken into consideration for the Social Human Footprint. To improve upon this method, seasonal variation for these footprints would provide a much more detailed assessment of human influence on the land. This application would be beneficial for recreationists or land managers searching for a particular wilderness setting for an activity (e.g., snowmobiling).

7.2 Data Completeness and Accuracy for the Wilderness Mapping Model

With the development of this mapping tool, several proxies were used for indicators that did not have relevant or adequate data (e.g., Solitude and Special Features). Data for the solitude layer were taken from a 2005 report and therefore the rates of visitors to the M-KMA may not be as relevant today. In the future, an up-to-date assessment of visitors to the M-KMA would provide a more accurate model of solitude although the relative values may not necessarily change.

The Special Features model used wetlands as a proxy; this proxy would be greatly improved with other important special features data such as karst environments and mineral licks if the data become available. The wetlands layer itself is also outdated and has not been validated. This was a similar problem with many of the development layers. Much of the data did not have a date to check for relevance and accuracy and some development layers have never been clarified.

7.3 Analyzing Wilderness Compatibility with Other Resource Values

After the Wilderness Character in the M-KMA model was complete, I addressed overlap with other resource-value mapping. Through analysis I found that there is a possible total of 26.24% overlap of high resource potential area and very-high wilderness values. This analysis was done to assess how Wilderness Character can be comparable with other resource mapping, but it is preliminary, and caution should be exercised in planning purposes that require temporally explicit data.

7.4 The Final Mapping Result

The final map of Wilderness Character in the Muskwa-Kechika Management Area provides a detailed view of the wilderness spectrum in the M-KMA. There are several benefits to the wilderness modelling approach that I have taken. First, data for this research were readily available either through public databases or developed with guidance from key informants in the M-KAB. These data provided coverage for the whole M-KMA allowing for a complete wilderness spectrum covering the whole of the management area. In addition, the final wilderness map was created using two different characteristics and 10 associated indicators including two human footprint models. The result of all the overlapping indicators is a highly detailed 25 by 25-meter grid for the whole 64, 000-hectare area.

By combining both ecological and social indicators this map spatially represents the wilderness defined by the MKAB wilderness definition. In addition to providing high-quality detail using a multiple-indicator methodology, this mapping approach was beneficial because it spatially defined a very important resource in northern British Columbia and now has the possibility to aid in general planning and policy for the area.

The resulting *Wilderness Character in the Muskwa-Kechika Management Area* (Figure 46) shows a gradient of wilderness qualities across the M-KMA. Recognizing that perceptions of wilderness vary, this mapping model nonetheless is the most accurate mapping of Wilderness Character in the M-KMA to date.

At the proponent level, this tool can be repeated and projected at variable scales to show finer detail on the landscape and to assess the Wilderness Character before and after a development's inception and completion, thereby striving to meet the mandate of the M-KMA to retain the wilderness character 'in perpetuity'. At this level, the developments can be ground-truthed by the proponent, which will provide greater accuracy to this data. In addition, smaller developments such as docks and fences may then be added to provide greater detail to the Wilderness Character map for that area. Figure 53 shows an example of Muncho Lake Provincial Park's Wilderness Character mapped at a larger scale.

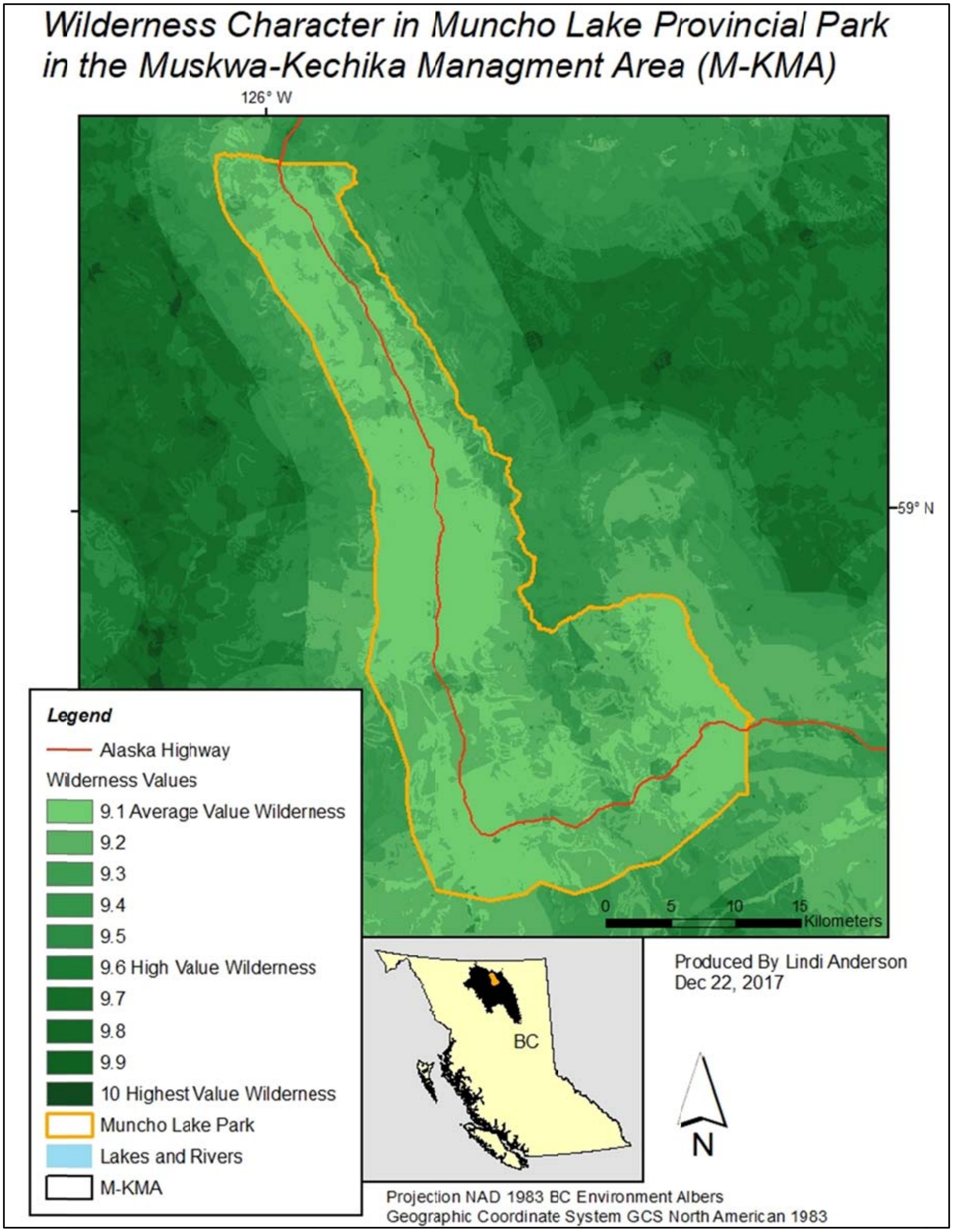


Figure 53. Wilderness Character in Muncho Lake Provincial Park in the Muskwa-Kechika Management Area (M-KMA).

My thesis took on the task of advancing wilderness mapping for the M-KMA, developing a mapping tool, and comparing that tool to other natural resource models. I used a highly conservative approach to mapping wilderness, which is appropriate given the intent and vision of the Muskwa-Kechika Management Act to ensure that wilderness values are maintained in perpetuity in the M-KMA. My research provides a new way of viewing wilderness modelling and monitoring. Future research is needed to gather data on a finer scale in the M-KMA for this modelling process to best guide planning and management scenarios. Updated use numbers, high-detailed wildlife modelling, and refined special features modelling would build upon and enhance these models.

Carver & Fritz (2016) claim that every last ecosystem on Earth is quickly being exploited. The global loss of terrestrial biomes puts wilderness mapping at the forefront of biodiversity planning and conservation. Wilderness is an important value socially, culturally, environmentally, and economically and new approaches to conservation modelling can help protect wilderness values. My research provides new insights into mapping wilderness and can be used as a guide for enhancing the wilderness management process.

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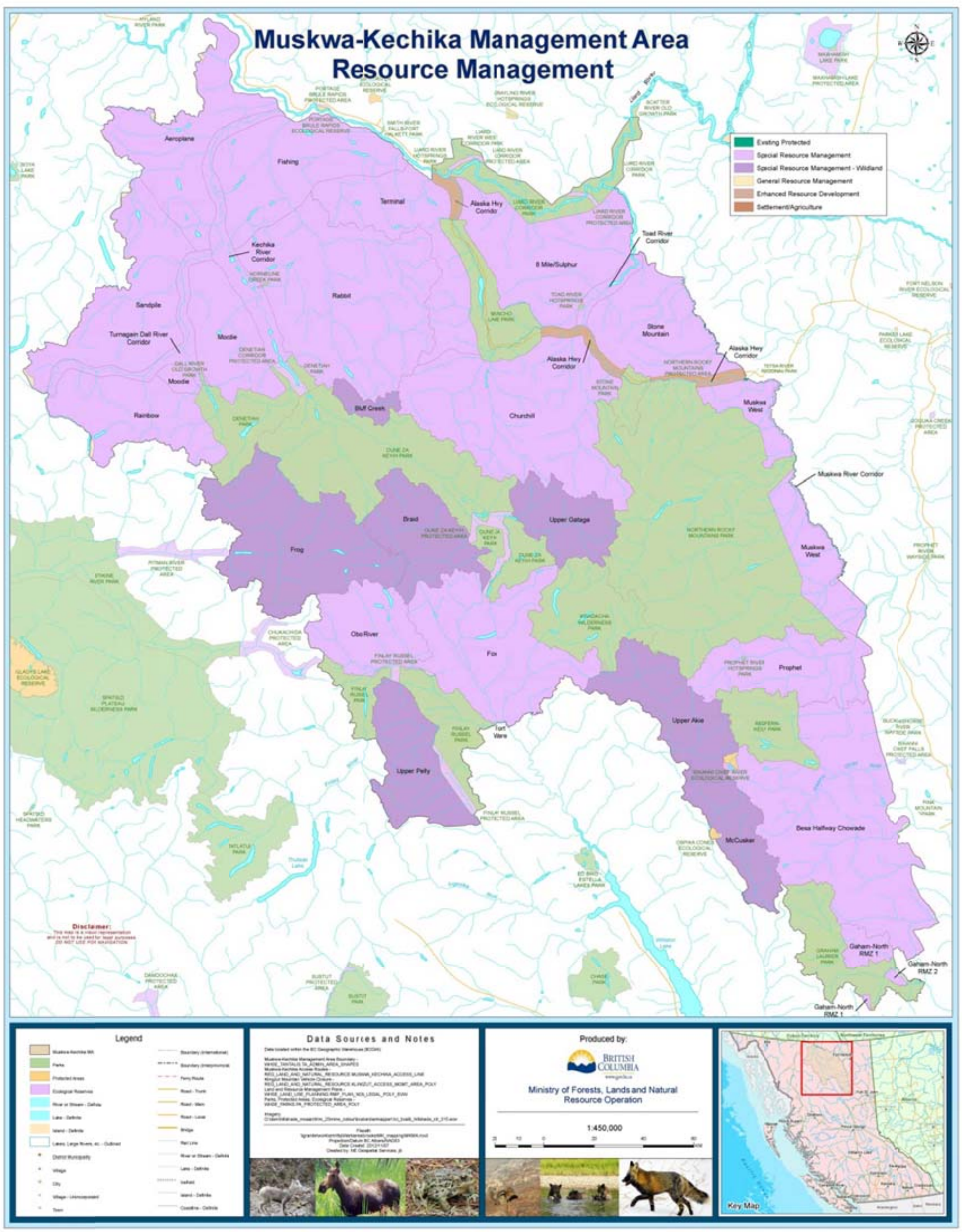
APPENDIX A: LAND DESIGNATIONS IN THE MUSKWA-KECHIKA MANAGEMENT AREA

Retrieved from Heinemeyer et al., 2004

Designation	Total Ha	% of MKMA	Management Direction
Protected Area	1,751,442	27.4	- All uses of Protected Areas must be assessed in regard to their impact on the ecological systems and the key natural, cultural and recreational values of particular areas. -Use of Protected Areas will be encouraged, where appropriate and consistent with the principle of maintaining ecological integrity, in order to realize the spiritual, recreational, educational, cultural, tourism and health benefits that Protected Areas can provide.
Special Wildland Area	923,447	14.5	-Priority for ecological conservation while providing for opportunities for commercial and industrial activities (mineral and oil and gas development). -Timber harvesting is not allowed and is excluded from the -Road development is temporary and once industrial activities are completed, roads are to be deactivated and returned to a vegetative state that approximates natural conditions.
Special Management Area	3,674,007	57.5	-Emphasis on identified non-extractive values with respect to either wildlife and wildlife habitat, fish and fish habitat, heritage and culture, scenic areas and recreation.

			-Opportunities for commercial and industrial activities (timber, mineral and oil and gas development) are allowable while managing to maintain the identified special values. -There may be permanent access with the remainder of roads as temporary.
Enhanced Resource Development Area	37,698	0.6	-Emphasis on timber growth and utilization with the recognition that mineral and oil and gas resource exploration and development may also benefit in this zone. -Fewer restrictions on industrial development and a permanent and more intensive access network is allowable. -May be small areas with restrictions for special values with respect to wildlife and wildlife habitat, fish and fish habitat, heritage and culture, scenic areas and recreation.

APPENDIX B: FIGURE B1: RESOURCE MANAGEMENT ZONES IN THE MUSKWA-KECHIKA MANAGEMENT AREA RETRIEVED FROM HTTP://WWW.MUSKWA-KECHIKA.COM/



APPENDIX C: COMMON INDICATORS OF WILDERNESS FOUND IN MUSKWA-KECHIKA LEGISLATIVE AND SCIENTIFIC DOCUMENTS

	M-KMA Act (MUSKWA-KECHIKA MANAGEMENT AREA ACT [SBC 1998] CHAPTER 38 Assented to July 30, 1998)	M-KMA Wilderness Statement (DRAFT)	Eco/ Adventure Tourism In the M-KMA: Challenges and Constraints (Garrity, 2013)	Muskwa-Kechika Advisory Board An Operational Wilderness Definition for the M-KMA February 29, 2004	State of the M-KMA Report (Crane, 2008)	Local Strategic Recreation Management Plan for the Muskwa-Kechika Management Area (Routledge & Davis, 2005).	Pre-Tenure Plans for Oil and Gas Development in the Muskwa-Kechika Management Area.2004. Government of British Columbia	Fort St John Working Group. 1997. Fort St. John Land and Resource Management Plan. File: 31090-25-04.	The Fort Nelson Working Group. 1997. The Fort Nelson Land and Resource Management Plan	Mackenzie Working Group. 2000. Mackienzie Land and Resource Management Plan. 1-405	Northrop, M. 2005. Protecting the 'Serengeti of the North': The Campaign for the Muskwa□ Kechika. Environmental Campaigns: Strategies & Tactics.
Biodiversity	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Natural Ecosystems	Yes			Yes			Yes	Yes		Yes	
Ecological Integrity	Yes	Yes		Yes	Yes	Yes	Yes			Yes	Yes
Wildlife Habitat	Yes	Yes				Yes	Yes	Yes			Yes
Solitude		Yes				Yes	Yes		Yes	Yes	
Undeveloped		Yes								Yes	
Aesthetic Quality		Yes				Yes	Yes		Yes	Yes	
Intact Watershed			Yes		Yes						
Minimal to no Linear Development				Yes	Yes	Yes		Yes	Yes	Yes	
No Noise Pollution					Yes						
Isolation						Yes			Yes		
Unique Topography						Yes				Yes	

Self-reliance, independence and risk (wilderness experience)						Yes		Yes			
Spiritually Relaxing/ Renewal										Yes	

APPENDIX D: VALUES, CURRENT SITUATION AND ASSUMPTIONS OF RECREATION USE NUMBERS FOR EACH RESOURCE MANAGEMENT ZONE

Retrieved from Rutledge & Davis, 2005

Resource Management Zone/ (Recreation Category)	First Nations & Cultural Heritage Values[1]	Important Features/ Facilities/Trails	Estimated Current Recreation Value[2]	Current Access Modes	Estimated Current Public Activities/ Use Levels	Estimated Current Commercial Activities/ Use Levels	Forecasted Public Rec. Activities/ Use Levels[3]	Forecasted Commercial Rec. Activities/ Use Levels	Environmental Considerations	Other Factors
Aeroplane Lake (2)	• Davie Trail; heavy Kaska TU around Aeroplane Lake.	• Aeroplane Lk.; Twin Island Lk.; Birches Lk.; Kitza and Calf Ck. Complexes; unroaded low rolling forested landscape; major guide camp.	• Moderate	• Floatplane; boat; horse; raft/canoe	• Hunt, fish, raft/canoe, wildlife view, camp, hike, trail ride/Low use	• Hunt, fish, raft/canoe, wildlife view, camp, hike/<6 suppliers; Low use	• Existing/Low increase in use	• Existing/Low increase in use	• Critical habitat around lakes for grizzly bear and moose.	
Alaska Highway Corridor (5)	• Kaska and Fort Nelson TU; highway was developed along traditional First Nations' trails Alcan Highway and associated artifacts.	• Alaska Highway; Liard, Trout, Racing, and Tetsa Rivers; McDonald Creek; Toad River Corridor; viewscapes; numerous trailheads; private land; lodges/hotels; major guide camps.	• Very High	• Vehicle, aircraft, ATV, snowmobile, floatplane, horse, raft, hike, mtn. bikes	• Sight seeing, wildlife view, camp, hike, trail ride, hunt, fish/ Very high use levels	• Sight seeing, wildlife view, camp, hike, trail ride, hunt, fish/ Very high use levels	• Existing plus ice-climbing/ Moderate increase in use	• Existing/ Moderate increase in use	• Mineral licks, water quality, vehicle-wildlife interactions (caribou and sheeo); bull trout habitat.	• Visual consider-ations; availability of private land for commercial recreation
Besa-Halfway-Chowade (4)	• Heavy Halfway River and Prophet TU; campsites and burial grounds. Bedaux and RCMP Trails; traditional human migration route.	• AMA Routes; Laurier Pass; Ten Mile; Robb, Marion, Koller, Twin, Cranswick, Colledge Lakes; Loranger and Nevis Cks.; Brown's Farm; Louis' Farm; major guide camps.	• Very High	• ATV; aircraft; floatplane; horse; vehicle; snowmobile	• Hunt, fish, camp, wildlife view, photo/ 3000+/yr.	• Hunt, fish, camp, wildlife view, photo/ <10 suppliers/ 500/yr.	• Existing/ Moderate increase in use, except for significant increase in snowmobiling	• Existing/ Moderate increase in use	• Mineral licks; critical habitat for moose, caribou, bison, elk, sheep and grizzly bear.	• Site specific horse forage

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Churchill (2)	• Heavy Kaska TU around Moose Lake and Toad River watershed; Kaska settlement sites; Fort NelsonTU and Indian Reserve at Moose Lake Potential archaeology and anthropology area.	• Moose, Emerald, Ram and Yedhe Lks.; Glaciers; old mining roads; Toad, West Toad, Racing rivers; Mt. Roosevelt; major guide camp.	• High	• Vehicles; ATV; riverboat; boat; horse; raft; aircraft; snowmobile floatplane	• Hunt, fish, camp, trail ride, sight-see, hike/ 300+/yr.	• Hunt, fish, camp, trail ride, trapline observation, raft/ <6 suppliers 70/yr.	• Existing/ Moderate increase in use	• Existing plus trekking/ Moderate increase in use	• Mineral licks; Moose habitat at Moose Lk. and alpine areas; critical goat and sheep habitat.	• Sustainability of fish stocks at Ram Lakes
Dall River Old Growth Park (1)	• Heavy Kaska TU with settlement sites and burial grounds.	• White spruce old growth; Dall River portion of McDame Trail.	• Low	• Horse	• Hunt, fish/ 10/yr.	• Hunt, fish/ 1 supplier/ 50/yr.	• Existing/ Low increase in use	• Existing/ Low increase in use		possible jet boat activity
Denetiah Park (2)	• Heavy Kaska TU, particularly around Dall and Denetiah Lakes; Davie Trail. Historic fur trading route, Davie Trail.	• Denetiah and Dall Lks.; • Davie Trail; Kechika (Heritage River) and Dall Rivers; viewscape of Gataga and Terminus Mountains; major guide camps.	• High	• Riverboat; horse; floatplane; boat; raft/canoe	• Hunt, fish, wildlife view, hike camp, photo, canoe, raft/ 100/yr.	• Hunt, fish, wildlife view, camp, photo, trail ride, rafting, canoeing/ 12 suppliers/ 350/yr.	• Existing/ Moderate increase in use	• Existing plus hike, snow-mobiling/ Moderate increase in use	• Lake char, northern pike and rainbow; critical habitat for grizzly and goat; licks.	

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Dune Za Keyih (Frog Gataga) (2)	• Section of the Davie Trail • Kaska interest in developing commercial recreation activities on the Davie Trail • Name of park means "Land of the Original People" in Kaska Dena • S. Gataga Lks. used for fishing & fishing cabins present • Confluence of the Kechika features a gravesite and trapline cabin • Trails: n. side of Gataga; from Weissener Lk. to S. Gataga • Concerns regarding high levels of motorized boat use on the Gataga, Frog, and Kechika Rivers	• 3 large, pristine river valleys: Gataga, Kechika & Frog • Davie Trail • S. Gataga River • Lakes: Ram, Mayfield, S. Gataga, Island, Beven, Pike • Gataga R.: jet boating and rafting • S. Gataga Lakes host fly-in fishing camps • Trapper's cabin on Mayfield Lk.	• High	• Floatplane into: Island Lk., Butterfly Lk., Johiah Lk., Mayfield & Rainbow Lakes • up the Kachika onto the Gataga R. • Horseback • Foot	• Canoeing, river boating, fishing, hunting, hiking, rafting, pack-trips • Resident hunting increased over the past decade • Jet boating activities are potentially a problem on the Gataga during hunting season	• 5 guide-outfitters • Commercial rafting on the Gataga [access from Mayfield Lake] (@ 3 trips/yr) • Packer activity • Wilderness trips with horses (12); @15 guests/yr (Sawchuk) • Fishing at Mayfield, Ram, Beven Lakes, South Gataga	• Anecdotal information suggests a decreasing number of resident hunting in this area • Air-based fishing is increasing including fixed-wing and helicopter access modes	• Given the high monetary value of this area and the above average number of commercial operators, use levels will likely increase moderately over time • Increasing rafting use on the Gataga • Resolve of Packer issue should allow for increased opportunity	• Contiguous management with Denetiah & Dall R. Old Growth parks • Very high moose and mtn. sheep values • The Frog River appears to be getting less volume • Sensitive goat habitat in the Forsberg Range • Ram & Beven Lakes are susceptible to fishing activities • Pike Lakes feature sensitive wet terrain; built infrastructure is not appropriate here	• ELU corridor designation • Motorized boats cannot navigate above Drift pile Rapids on the Gataga • LRMP restriction re: motor boat access above the Driftpile rapids • Concern regarding heli-skiing & heli-hiking in this RMZ • Levels-of-use thresholds should be identified for the Gataga, Kechika & Frog
Eight Mile/Sulphur (2)	• Kaska and T8 TU Hunt, fish, hike, wildlife view, raft, snow-mobiling, photo, camp/ 400/yr. (majority of use in vicinity of Nonda Ck. Road)	• Numerous trails; unroaded wilderness in mountainous terrain; Old Woman Lks.; Four Mile Lks.; Nonda Ck. Tower viewpoint; major guide camps.	• Moderate	• Vehicles; ATV; horse; riverboat; snow-mobiles; aircraft; floatplane; raft		• Hunt, fish, hike, wildlife view, raft, ecotours, camp/ <6 suppliers 125/yr.	• Existing/ Moderate increase in use	• Existing plus Heli-hiking, trapline observation, trail ride/ Moderate increase in use	• Mineral licks; critical habitat for grizzly bear; sheep and elk movement corridors.	

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Finlay Russell Provnicial Park and Protected Area (4)	• Caribou Hide trail • Close to Kwadacha Village • High fisheries values • High value sheep habitat down the Pelly R. & important goat range • Concerns regarding potential commercial heli-skiing/-hiking activities • Heavy use on the Finlay R.(fishing, hunting, trapping) up to the canyon & cabins along the river • Trail up the Finlay & NE side of Cut-off Creek • Cut-off Ck.- fishing • Hunting around Prairie Mtn. for deer, elk, caribou, bear • Rainbow Lk. – hunting (caribou, grizzly), fishing (trout). • John Finlay's expedition route on the Finlay River	• Finlay R., Fox R., U.Pelly Ck. Valley • Caribou Hide Trail	• Low	• Floatplane • Horseback • Backpack • Jet boat • Motorboat	• Hunting, fishing, rafting, kayaking, canoeing • Finlay R. hosts an occasional floater • Heavy motor boat use on the Finlay and parts of the Kwadacha • Winter snow-mobiling up to Rainbow Lk.	• 2 guide-outfitters & 1 vacant territory	• Given this zone's close proximity to Kwadacha Village and access roads, use trends will be dependent on population dynamics in the village as well as industrial use to the south.	• This depends on CR development activities (close to Kwadacha); whether any additional CR interest occurs due to the area's new park status; BC Parks' management guidelines pertaining to CR development.	• Important fish & wildlife habitat: caribou, moose, sheep, goat • Potential road access is of concern • Upper part of this contains high wildlife sensitivity for moose, goat and grizzly bear	• 2 ELU corridor designations with intent to access the U.Pelly & Obo R. RMZ's

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Fishing (2)	• Heavy Kaska TU, particularly around lakes. Kaska settlement and assembly sites and burial grounds (e.g., Graveyard Lake) Historic trail to Chee House Post.	• Fishing Lk.; Grant Lk.; Gemini Lks.; Graveyard Lks.; Niloil Lk.; Hare Lk.; Rabbit River; rolling hills in unroaded condition; Mt. Reid visible from Alaska Highway; major guide camp.	• Moderate	• Floatplane; boat; horse; raft.	• Hunt, fish, camp, raft wildlife view/50/yr.	• Hunt, fish, camp, raft wildlife view/ <6 suppliers/ 100/yr.	• Existing plus ice-fishing/Low increases in use	• Existing plus snow-mobiling, cross-country ski/Moderate increase in use	• Islands of high quality goat and grizzly bear habitat.	• Horse forage
Graham North #1 and #2 (4)	• Halfway and West Moberly TU.	• Graham River; Justice Ck.; AMA route; Emerslund trail; major guide camp.	• Moderate	• ATV; aircraft; horse; snowmobile	• Hunt, fish, camp, wildlife view/250/yr.	• Hunt, fish, camp/ <6 supplier/ 30/yr.	• Existing/ Moderate increase in use, except for significant increases in snowmobiling	• Existing/ Moderate increase in use	• Critical habitat for grizzly bear and bull trout.	
Graham-Laurier Provincial Park (2)	• Halfway River and West Moberly TU. RCMP Trail.	• Christina Falls; Graham River watershed; Lady Laurier Lk.; Summits; AMA route; Needham Ck.	• Low	• ATV; horse; aircraft; snow-mobile; floatplane; mtn. bike	• Hunt, fish, photo, camp, trail ride, wildlife view, hike feature view/ 100/yr.	• Hunt, fish, photo, camp, trail ride, wildlife view, feature appreciation/ 4 suppliers/ 50/yr.	• Existing plus ice-fish, canoeing/ Low increase in use	• Existing plus ice-fish, canoeing, heli-hike/ski/ Low increase in use	• Mineral licks; critical grizzly bear and caribou habitat; bull trout; fragmented/ Relic sheep and goat populations.	
Horneline Creek Park (1)	• Heavy Kaska TU around Horneline Creek.	• Riparian and wildlife habitats and features; canyon.	• Low	• Hike; horse	• Hunt, wildlife view/ 10/yr.	• Hunt, wildlife view/ 1 supplier/ 10/yr.	• Existing/ High increase in use	• Existing/ High increase in use	• Goats	• Horse forage; campsite availability

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Kechika River Corridor (3)	• Heavy Kaska TU; Davie Trail; numerous settlement sites Chee House Post, Davie Trail; Heritage river; McDame Trail.	• Kechika River; Scoop Lake; Heart of Rocky Mtn. Trench; major guide camp.	• Moderate	• Riverboat; floatplane; aircraft; raft; horse, canoe.	• Hunt, fish, wildlife view, camp,rafting/ 350/yr.	• Hunt, fish, camp, wildlife view, trailride,rafting/ 14 suppliers/ 250/yr.	• Existing plus canoe/ High increase in use	• Existing plus canoe/ High increase in use	• Mineral licks; critical elk habitat; moose winter range; bird migration/ staging areas.	• Site specific horse forage
Kwadacha Wilderness Provincial Park & Addition (2)	• Hunting cabin at the forks of the Warenford & Kwadacha rivers; access by snowmobile in the winter • Fishing at Quentin, Hayworth & Chesterfield Lakes • Trail along south side of Kwadacha River	• Big game • Chesterfield Lk. used for fishing and hunting base • Fern Lk. used as base for Elk hunting	• Moderate	• Floatplane to Chesterfield Lk., Elk Lk	• Hunting • Fishing	• 1 guide-outfitter, hosting < 6 clients/yr	• Due to remote nature and park status, use levels will likely be low	• Due to remote nature and park status, use levels will likely be low	• High wildlife habitat values: moose, grizzly bear, mtn. goat • Fern Lake; special fishing regulations	• Kaska are concerned regarding motorized boating on lakes in the park • Aircraft access to high use lakes should be reviewed and limited
Liard River Corridor Park (3)	• Fort Liard, Kaska and Fort Nelson TU; important trading route; high probability of burial grounds; Two Fort Nelson First Nations archaeological sites. Cultural artifacts (e.g., trading posts, etc.); important early access routes to northern interior of BC; old drilling rig near mouth of Toad River.	• Liard River and Grand Canyon; trail of '98 route; Fossil Ck. Caves; Old Growth Forests; Nordquist and Aline Lakes; Elk Mtn.; Deer River Hot Springs; chum salmon; inconnu; Arctic cisco; wood bison; major guide camp.	• Moderate	• Floatplane; riverboat, raft/canoe; horse; vehicle; ATV; snow-mobile; aircraft	• Hunt, fish, wildlife view, raft Feature Appreciation, camp, spelunking/ 300/yr.	• Hunt, fish, wildlife view, photo, camp, raft/ 10 suppliers/ 100/yr.	• Exsting/ Moderate increase in use	• Existing/ Moderate increase in use	• Wood bison herd; intact prerdator/Prey ecosystem; critical grizzly bear habitat.	• Fossil sites; churt formations; horse forage

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Liard River Hotsprings Park (Existing Park)	• Kaska and Fort Nelson TU. Old Alaska Highway route; fur trade; geological survey exploration route.	• Hotsprings and related habitat; campground and intensively used frontcountry park facilities- (interpretative services; boardwalk; picnic shelters; playground, etc.) beginning of AMA route.	• Very High	• Vehicle and ATV	• Camping, bathing, snowshoeing, wildlife view, fishing, photo, guided interpretation tours, nature appreciation/ 25,000/yr.	• Camping, bathing, snowshoeing, wildlife view, photo, guided interpretation tours, nature appreciation/ 15,000/yr.	• Existing/ Moderate increase in use, especially for winter activities	• Existing/ Moderate increase in use, especially for winter activities	• Hotsprings habitat; various red-listed species.	• Water quality in hotsprings; campsite availability
Moodie (2)	• Kaska TU.	• Moodie Lk.; Boreal Lk.; western edge of Rocky Mtn. Trench; mountainous terrain; major guide camp.	• Moderate	• Floatplane; boat; horse; canoe	• Hunt, fish, trail ride, canoe, wildlife view, camp/50/yr.	• Hunt, fish, trail ride, raft, photo, wildlife view, camp/7 suppliers; 130/yr.	• Existing/ Low increase in use	• Existing/Low increase in use	• Critical sheep habitat.	
Muncho Lake Park (Existing Park)	• Kaska and Fort Nelson TU. ALCAN Highway; archaeological sites.	• Muncho Lake, alluvial fans, interpretive signs, frontcountry campgrounds, Trout, Toad Rivers, Nonda Creek, hoodoos, Folding Mtn, Peterson Canyon; AMA routes; Gundahoo Pass, Prochniak, mineral lick, Strawberry and Sheep Flats Trails; major guide camp; Resort lodges.	• Very High	• Vehicle; aircraft; floatplane; boat; ATV; raft; snowmobile; hike	• Hunt, fish, camp, hike, wildlife view, rafting x-country ski, photo, canoeing, boating, snowmobiling, trail ride/ Very high use	• Hunt, fish, camp, hike, wildlife view, boat tours, rafting/ Very high use, especially associated with highway corridor and Muncho Lake area	• Existing/ High increase in use	• Existing/ High increase in use	• Mineral licks; critical sheep and goat habitat.	• Campsite availability in frontcountry

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Muskwa River Corridor (3)	• Fort Nelson and Prophet RiverTU; settlement sites and burial grounds.	• Muskwa River; view of Samuelson Mtn. from river.	• Very High	• Riverboat, ATV on east side of river, horse, raft, aircraft	• Hunt, fish, camp, trail ride wildlife view, raft/ 1200/yr.	• Hunt, fish, camp, trail ride wildlife view/ 10+ suppliers/ 500/yr.	• Existing/ Moderate increase in use	• Existing/ Moderate increase in use	• Fish habitat at mouths of creeks.	• Availability of campsites
Muskwa West (4)	• Prophet River campsites, burial grounds and food gathering sites; Halfway River TU.	• Foothills, rolling landscape; Kluachesi, Gathto, Beckman Cks.; Chischa and Muskwa Rivers.	• Moderate	• Horse; aircraft; snowmobile; riverboat; raft	• Hunt, fish, camp, trailride/ 200/yr.	• Hunt, fish, ecotours, trail ride, camp/ <10 suppliers/ 200/yr	• Existing/ Moderate increase in use	• Existing plus photo, hike/ Moderate increase in use	• Mineral licks; extensive climax grasslands for elk.	• Horse forage in northern portion
Northern Rocky Mountains Park (includes former Wokkpash Recreation Area) (4)	• Kaska Dena, Fort Nelson, Prophet River and Halfway River TU; Burial grounds and significant spiritual sites. Bedaux and High Trails; Fur trade; Mary Henry expedition.	• Tuchodi, Tetsa, Chischa Wokkpash and portions of the Muskwa Rivers and Gathto Ck.; Tuchodi, Tetsa, Kluachesi, Wokkpash and various alpine lks.; Summits (Mt. Mary Henry, Sleeping Chief and Mt. Sylvia)and glaciated landscapes; Hoodoos; Forlorn and Wokkpash Gorge; Fusillier Glacier; major guide camps.	• Very High	• Riverboat, floatplane, aircraft; raft/canoe; horse, snowmobile	• Hunt, fish, camp, wildlife view, photo, ice-fish, rafting, trail ride, snow-mobile, hike, sightsee/ 1500/yr.	• Hunt, fish, camp, wildlife view, photo, ice-fish, trail ride, snowmobile, hike, rafting, sightsee, trapline observation/ 30 suppliers/ 1,500/yr.	• Existing plus rock-ice climbing, summer glacier skiing, mtn. biking/ High increase in use	• Existing plus rock-ice climbing, summer glacier skiing/ High increase in use	• Mineral licks; Bull trout spawning habitats; cumulative effects of range burning; diverse wildlife values	• Horse forage; current high use and campsite availability within Tuchodi River and Muskwa River corridors during hunting season
Ospika Cones - Ecological Reserve (1)	• Within Tsay Keh Dene's traditional territory.	• Tufa terraces and pools formed by cold mineral springs • Wildlife mineral lick	• n/a	• No ground-based access permitted	• 2 guide-outfitters (g-o's): Blueberry Holdings/Angie Watson; Darwin Cary	• n/a	• n/a	• n/a	• One of few cold water tufa formations in BC; • Wildlife mineral lick.	

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Prophet (2)	• Prophet River and Halfway River TU; numerous archaeological sites Bedaux Trail.	• Prophet, Besa Rivers; Richards Ck.; Klingzut Mtn.; Old High trail; Numerous meadow complexes; Major guide camps.	• Very High	• Horse; aircraft; raft; riverboat; snowmobile/ floatplane	• Hunt, fish, trail ride, Photo, raft wildlife view, camp, hike/ 900/yr.	• Hunt, fish, trail ride, photo, wildlife view, raft, camp, hike/ 10 suppliers/ 500/yr.	• Existing/ Moderate increase in use	• Existing plus cross-country ski, trapline observation/ Moderate increase in use	• Mineral licks; diversity of wildlife populations. (sheep, caribou and goat).	• Horse forage
Prophet River Hotsprings Park (1)	• Prophet River and Halfway River TU; settlement sites, burial grounds, campsites and archaeological sites. Archaeological artifacts.	• Hotspring habitat and important wildlife features; Heritage River; tufa mound.	• Low	• Horse, snow-mobile, raft, riverboat	• Hunt, fish, camp trail ride, wildlife view/ 50/yr.	• Hunt, fish, camp trail ride, wildlife view/ 50/yr.	• Existing/ Low increase in use	• Existing/ Moderate increase in use	• Hotsprings habitat; wildlife; mineral licks.	• Campsite availability
Rabbit (2)	• Heavy Kaska TU around Netson Lake and Horneline Creek. Hunt, fish, camp, wildlife view/ 50-60/yr.	• Netson Lk.; Hornline Lk.; Moose Lk.; Pup Lk.; Lupus Lk.; Rabbit and Gundahoo Rivers; eastern edge of Rocky Mtn. Trench; Mountainous terrain; horse trails from Muncho Lake Park; Terminus Mtn.; major guide camp.	• High	• Floatplane; aircraft; boat; raft; horse		• Hunt, fish, camp, trail ride, rafting, hike, wildlife view/ 7 suppliers/ 230/yr.	• Existing plus hike, snow-mobiling/Low increase in use	• Existing plus snow-mobiling, cross-country ski, heli-skiing/ Moderate increases in use	• Critical habitat for caribou and grizzly bear.	• Horse forage
Rainbow (2)	• TU Samuel Black's pack route.	• Rainbow Lake; Cassiar River; mountainous scenery, e.g., Sharktooth Mountains.	• Low	• Floatplane; Horse; boat; helicopter	• Hunt, fish, camp, trail ride, wildlife view/Low use	• Hunt, fish, camp, raft, wildlife view/ <6 suppliers; 36-40/yr.	• Existing/Low increase in use	• Existing plus Heli-hike/Heli-ski/Low increase in use	• Critical goat and caribou habitat.	• Horse forage

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Redfern-Keily Provincial Park (4)	• Prophet River and Halfway River TU; spiritual and gathering sites. High Trail; Bedaux Trail; archaeological artifacts; geological surveyors (McCusker).	• Redfern, Trimble, and Fairy Lks.; Besa River and Keily Ck watersheds; alpine basins & peaks; glaciers, waterfall and tarns; hoodoos; AMA route; Plains Bison; Trimble Lake trail .	• High	• ATV; horse; floatplane; snowmobile; dogsled; raft/canoe/ Boat/ kayak, boat, aircraft	• Hunt, fish, trail ride, camp, hike, photo, Wildlife view, snowmobiling ATVing raft/canoe, Feature appreciation, hike/ 500+/yr.	• Hunt, fish, trail ride, camp, photo, Wildlife view, hike, Snow-mobiling raft/canoe, hike/ <6 suppliers/ 100/yr.	• Existing plus mountaineerin g, mtn biking/ Moderate increase in use, especially along AMA route	• Existing plus Cross-country ski/ High increase in use	• Mineral licks; Bear-human conflicts; critical grizzly bear and sheep habitat.	• Horse forage; campsite availability around Redfern Lk.
Sandpile (2)	• Mosquito Ck. Indian reserve; McDame Trail; Kaska settlement sites and burial grounds. • McDame Trail linking Davie Trail to McDame Post on Dease River.	• Blue Sheep Lk.;Solitary Lk.;Burnt Rose Lk.; Sandpile Lks.;Major Hart River; mountainous scenery; major guide camps.	• Moderate	• Floatplane; boat; horse; aircraft	• Hunt, fish, camp, trail ride, wildlife view/Low use	• Hunt, fish, raft, wildlife view/<6 suppliers; 36-40/yr.	• Existing/ Low increase in use	• Existing/Low increase in use	• Mineral licks; critical sheep and caribou habitat.	
Sikanni Chief River Ecological Reserve (Existing Park)	• Prophet River and Fort Nelson TU; spiritual and gathering sites. Heritage Trails, archaeological artifacts; geological surveyors (McCusker).	• Old Growth White Spruce Forest • Alpine Plant Communities & Wildlife in Pristine Environment	• n/a	• Fly in • Horse	• Guide Outfitting • Hunting	• Guide-Outfitter	• n/a	• n/a	• Protected Old Growth White Spruce Forest.	• Designated as a Provincial Park in 1999.
Stone Mountain (Existing Park)	• Kaska TU and settlement sites; T8TU.	• Ram and Snake Cks.; Dunedin River; Stone Mtn.; open grasslands; mountainous terrain.	• High	• Aircraft; horse; raft; snowmobile	• Hunt, fish, trail ride, camp, hike, sight-see, wildlife view/ 225/yr.	• Hunt, fish, ecotours, trapline observation, camp, raft, trail ride, wildlife view/ <6 suppliers/ 100+/yr.	• Existing plus Mtn. Trekking/ Moderate increase in use	• Existing plus Heli-hiking/ Low increase in use	• Mineral licks; fragmented habitat for grizzly bear, elk and sheep.	

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Stone Mountain Provincial Park (Existing Park)	• Kaska and Fort Nelson TU. Alcan highway, High Trail.	• Stone Mtn campgrounds; Summit Lake and Pass, McDonald Creek, Stone Range, Hoodoos, Mt. St. George and Mt. St. Paul, glacial features, North Tetsa River, Flower Springs Lake & trail; Baba Canyon, erosion pillars, Summit microwave tower trail; commercial lodge.	• Very High	• Floatplane; vehicle, horse, hike	• Hunt, fish, trail ride, hike, camp, wildlife view boating, climbing, photo feature appreciation/ Very high use	• Hunt, fish, wildlife view, trail ride, hiking/ <6 suppliers/ Very High use	• Existing/ Moderate increase in use	• Existing/ Low increase in use	• Fish stocks in lakes/streams Wildlife collisions; critical habitat for caribou and sheep.	• Campsite availability; horse forage
Terminal (2)	• Heavy Kaska TU around Long Mtn. Lake and along trial connecting Muncho Lake to Graveyard Lake; Kaska settlement sites; T8TU.	• Windfall Lk.; Lapie Lk.; Long Mtn. Lk.; Forcier Lk.; Skeezer Lk.; various alpine lakes; borders Muncho Lake Park; horse trail from Muncho Lake Park; Long Mtn.; major guide camp.	• High	• Floatplane; horse; aircraft; snowmobile	• Hunt, fish, wildlife view, hike, camp/ 50-60yr.	• Hunt, fish, trail ride, wildlife view, camp/ 7 suppliers/ 230/yr.	• Existing/Low increase in use	• Existing/Moderate increase in use	• Critical goat grizzly bear and caribou habitat.	• Horse forage
Tetsa River Park (Existing Park)	• Kaska, Fort Nelson and Prophet River TU.	• Campground; confluence of Tetsa River and Mill Creek; trail to Muncho Lake.	• Low	• Vehicle	• Swim, fish, camp, raft, wildlife, hunt view, hike, picnic/ 5,000/yr.		• Existing/ Low increase in use	• Low		

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Toad River Corridor (3)	• Kaska settlement sites and burial grounds; traditional trail along river; Fort Nelson TU.	• Toad River; open fire maintained grasslands.	• Low	• Riverboat; horse	• Hunt, fish, camp, wildlife view, trailride/ 75/yr.	• Hunt, fish, camp, trail ride, trapline obs, wildlife view/ <6 suppliers/ 50/yr.	• Existing plus rafting/ canoeing/ Moderate increase in use	• Existing plus rafting, hike, canoeing/ High increase in use	• Mineral licks and hot springs; movement corridor for grizzly bear and elk.	• Availability of campsites
Toad River Hot Springs Park (1)	• Kaska and Fort Nelson TU with spiritual and gathering sites and burial grounds.	• Hotsprings and related wildlife habitats.	• Low	• Riverboat, horses; hike	• Hunt, fish, wildlife view, camp/ 30/yr.	• Hunt, fish, camp, wildlife view/ 5 suppliers/ 20/yr.	• Existing/ Moderate increase in use	• Existing/ Moderate increase in use	• Hotsprings habitat and wildlife, mineral licks.	• Campsite availability
Turnagain/ Dall River Corridor (3)	• Heavy Kaska TU with settlement sites and burial grounds McDame Trail.	• Turnagain, Dall Rivers; Turnagain River Falls; oxbows; major guide camps.	• Moderate	• Aircraft; riverboat; raft; horse, floatplane	• Hunt, fish, wildlife view, camp/ 150/yr.	• Hunt, fish, camp, raft wildlife view, trail ride, photo/ 3 suppliers/ 50/yr.	• Existing/ moderate increase in use	• Existing/ Moderate increase in use	• Fish habitat at mouths of streams; critical habitat for caribou, sheep, goat.	• Availability of campsites

SMZ General	First Nations & Cultural Heritage Values[1]	Important Features/ Facilities/Trails	Estimated Current Recreation Value[2]	Current Access Modes	Estimated Current Public Activities/ Use Levels	Estimated Current Commercial Activities/ Use Levels	Forecasted Public Rec. Activities/ Use Levels[3]	Forecasted Commercial Rec. Activities/ Use Levels	Environmental Considerations	Other Factors
Nuhseha (Fox) (6)	• This zone is in the Kaska's backyard • A sensitive use area is the route between Kwadacha, Fox Lk., Fox R., and Fox Pass • 3 main high use rivers: Finlay, Upper Fox & Kwadacha • Trail up Caracajou to Spectre Peak and Weissener Lake • Cabin & burial ground near Beaver Pass • Youth camp at Weissener Lk. • Fish conservation values on Weissener & Fox lakes • Hunting & fishing camp at confluence of Warenford & Kwadacha Rivers • Trapping cabins located at Fox Pass, 9 mile, 18 mile, 27 mile (beaver cabin), 36 mile (Fox Lake)	• Weissener Lk., Kwadacha R., Warenford/ Kwadacha Forks, Sifton Pass, Baby Lk., Pass Lakes, Davie Trail, Finlay R., Fox Lk. & Pass • cabins located on Fox lk., Joe Poole, Rainbow Lk., Fox Pass (Brandon Ck.) • Mineral licks in the Fox Pass • Trail up Obo River to Obo Lake	• High	• Horseback • Floatplane • Hunters from Mackenzie & Prince George boat up the Finlay to hunt and fish	• Hunting • Fishing	• 4 guide-outfitters (with about 14 clients+?/yr)	• Mainly dependent upon population and use trends in Kwadacha & Tsay Keh Villages as well as industrial development trends	• Due to difficult terrain and less wildlife than the eastern slopes, hunting activities likely low growth • In some areas, hunting and fishing activities are increasing, suggesting moderate growth in other parts of this unit	• Sensitive wildlife habitat.	• LRMP directive to maintain a remote recreation experience at: Weissener Lk., U. Kwadacha R. and upper end of Weissener

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Yah-Hya "Johiah" (Obo River) (6)	• Fish conservation values on Spinel, Ridgeway & Obo lakes • Family traplines • Trail up Obo River to Obo Lake • Campgrounds south of Moose Lake	• The area of Spinel & Ridgeway Lakes • Obo R., Finlay R. • Cabins at Spinel and Obo Lks • Spinel Ck., Obo River Valley feature a number of mineral licks	• Moderate	• Floatplane • Horseback	• Fly-in fishing at Obo lk. in July & August • Obo river has the occasional floater	• 2 guide-outfitters	• May increase due to increased commercial floatplane activity out of Muncho Lake.	• Anecdotal information suggests growth in commercially guided hunting & fishing • CR interest in Obo lake may promote moderate growth in fishing activity	• Boundary adjacent to the Finlay-Russel PA	

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Bluff Creek (2)	• Kaska traditional use area • Lots of caribou in this zone	• Bluff Creek	• Low	• Foot • Horseback	• 2 guide-outfitters	• Hiking, wildlife viewing, hunting		• Western boundary follows the Due Za Keyih boundary		
Keh Wahkeludi "Burned Cabin" (Braid) (2)	• Davie Trail used by Kaska Dena, other First Peoples and also the NW Mounted Police to commute to the Yukon • Kaska interest in the Davie Trail • High use along the upper reaches of the Kechika	• Driftpile Lk. • Braid (Sheep)/ Kechika River confluence • Citreon (Big) Ck/Kechika confluence • Sifton Pass	• Low	• Snowmobile • Foot • Horseback • ?Jet boat	• Hunting	• 2 guide-outfitters • Wilderness trips (Sawchuk) • Potential to develop CR activities on the Davie Trail	• ?	• Due to development interests and diversifying CR products, moderate growth likely	• Sheep & moose habitat incl. sheep licks on the lower Braid; and between Driftpile and the Braid.	• Trail use management plan recommended in the LRMP for the Davie Trail

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McCusker (2)	• Blueberry Band has g-o territory here • Belongs within the traditional territory of the Tsay Keh Band	• U. Ospika & Denkman watershed	• Moderate	• Horseback • Foot • (Note: floatplane into Sikanni Chief just outside this RMZ)	• Hiking, hunting, wildlife viewing • Minimal public recreation use here	• 3 guide-outfitters	• Due to area's remote nature and difficult access, forecast as low	• Due to higher wildlife richness on the eastern-slopes, and difficult access, likely low	• Borders Dune Za Keyih PA • High mtn. goat & grizzly values • Large amount of pine beetle deadstand	• High oil & gas exploration interests • Road access severely restrained due to terrain
Thehahje (Frog) (2)	• Sensitive traditional use area • Cabin nr Driftpile Ck. & on Obo Lk. • Upper Obo Lk.: berry picking, trapping (ground hog), hunting (grizzly) • Paddy Ck.: hunting (mtn. sheep) • N. Rainbow, Johiah Lk. & Laidlaw Lakes : hunting (caribou) • Trails: along Obo River, the Frog and from Fox Lk. through Spinel and up from there	• Johiah Lk., Obo Lk., Frog R., lrg. unnamed lake west of Obo Lk.	• High	• Jetboat on the Frog as well as via the Kechika R. • Foot • Horseback	• Hunting, fishing, wildlife viewing, packing, jetboating • Few resident hunters enjoy the Frog R. area • Fly-in fishing on the Frog R. (~20 /yr)	• Liard Air/ Northern Rockies Adventures	• Interest in further developing fly-in fishing infrastructure; therefore, moderate use increases forecasted	• Interest in further developing fly-in fishing infrastructure; therefore, moderate use increases forecasted for non-residents	• High value habitat for Stone's sheep, mtn. goat, caribou, and grizzly in the NW portion • High value wildlife habitat along Rainbow and Butterfly Lakes	• LRMP directs to use 1998 levels of development to maintain Semi-Primitive & Primitive Recreation Opportunities here
Upper Gataga (2)	• Kaska Dena are interested in commercial river rafting • Stone Lk. to Gataga is good caribou habitat	• U. Gataga River with g-o's trail & cabin infrastructure • Northern Rockies Lodge from Muncho have a Cabin at S. Gataga River for Angling Guiding	• Moderate	• Horseback • Floatplane	• Hiking, fishing, hunting, wildlife viewing, hunting, rafting, canoeing, kayaking, packing, jetboating.	• 2 guide-outfitters (x + 6/yr) • River rafting • Jet-boat shuttles • Fly-in fishing (@20/yr – S. Gataga Lakes) • Wilderness trips (Sawchuk)	• Given this area's versatility and current diversity of activities, moderate growth is forecast to occur here	• River Rafting	• Considered keystone RMZ due to ecosystem functions & habitat connectivity	• Gataga is not navigable in its upper reaches

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Upper Tse Baje (Upper Pelly) (1)	• Upper Pelly: hunting (moose) • Above Bower Ck.: hunting (mtn. goat, sheep) • Burial ground up Bower Ck • General traditional use • Trapline down the Bower Ck	• Russell Range, • Bower Creek • Pelly Lake	• Moderate			• 2 guide-outfitters			• Area is unique as 2/3's surrounded by protected areas	• Has Pelly Lake been designated as VSA area?
Upper Ukai (Upper Akie) (2)	• Akie Trail & associated heritage features • Old trail up the Aki along Kwadacha • Hunting (moose, caribou, elk)	• Finlay R, Akie R., Pesike Cr.	• Moderate	• Horseback • Foot • Motor boat	• Fishing, hunting, hiking, wildlife viewing	• 4 g-o's • Fly-in packer	• Due to area's remote nature and difficult access, forecast as low	• Due to higher wildlife richness on the eastern-slopes, and difficult access, likely low	• N. boundary adjacent to Kwadacha PA • Sensitive mtn. goat habitat • A number of mineral licks along the Kwadacha at NW boundary	• Concern regarding helicopter activities