Species Status Assessment Report for the Wood Bison (*Bison bison athabascae*)



Photo credit: Doug Lindstrand

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ACRONYMS & ABBREVIATIONS USED

ADF&G	Alaska Department of Fish and Game
AWCC	Alaska Wildlife Conservation Center
BCA	Bison Containment Area
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CFR	Code of Federal Regulations
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
EINP	Elk Island National Park
ESA	Endangered Species Act
FR	Federal Register
GHG	Greenhouse gas
GWBNP	Greater Wood Buffalo National Park
IUCN	International Union for Conservation of Nature
IPCC	Intergovernmental Panel on Climate Change
NEP	Nonessential experimental population
RCP	Representative Concentration Pathways
SARA	Species at Risk Act
Service	U.S. Fish and Wildlife Service
SSA	Species Status Assessment
Tb	Tuberculosis
WBNP	Wood Buffalo National Park

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Chapter 1. Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U.S. Fish and Wildlife Service (Service) for the wood bison (*Bison bison athabascae*). We use the SSA framework to conduct an in-depth review of the species' biology and the various factors that influence the wood bison (both negative and positive), evaluate its current biological status, and predict the potential future status of resources and conditions as a means of assessing the wood bison's viability. This SSA report is a living document and is not an exhaustive list of everything known about the wood bison, but rather summarizes the results of our analysis using this framework. As new information becomes available, we intend to update this SSA report as needed so that it can support all functions of the Endangered Species program, if merited, such as consultation and recovery.

1.1 Review of Listing Actions

The listing history for wood bison is extensive and was reconstructed in the proposed rule to reclassify wood bison from endangered to threatened, which was published on February 8, 2011 (76 FR 6734). Please refer to that document for the complete listing history. Here we present only the most pertinent facts. The Service listed the wood bison in the United States under the 1969 Endangered Species Conservation Act when it was included on the first List of Endangered Foreign Fish and Wildlife, which was published in the Federal Register (FR) on June 2, 1970 (35 FR 8491). In 1974, the first list under the 1973 Endangered Species Act (ESA) appeared in the Code of Federal Regulations (CFR); the wood bison was listed as an endangered species based on its inclusion on the original 1969 list. Because the wood bison was listed under the 1969 Endangered Species Conservation Act, there is not a separate Federal Register notice that defined the population(s) and their range, or analyzed threats to the subspecies. On May 14, 1998, the Service received a petition from a private individual requesting that the Service remove the wood bison from the List of Endangered and Threatened Wildlife, primarily because it had been down listed from Appendix I to Appendix II under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In a 90-day finding published on November 25, 1998 (63 FR 65164), we found that the petitioner did not provide substantial information to indicate that the delisting may be warranted. On November 26, 2007, we received a petition from the co-chairs of Canada's National Wood Bison Recovery Team requesting that we reclassify the wood bison from endangered to threatened. On February 3, 2009, we published a 90-day finding (74 FR 5908) acknowledging that the petition provided sufficient information to indicate that reclassification may be warranted and that we would initiate a status review. On February 8, 2011, the Service published a proposed rule to reclassify wood bison (76 FR 6734), and on May 3, 2012, the Service published a final rule reclassifying wood bison as threatened under the Act (77 FR 26191).

In Canada, the Species at Risk Act (SARA) is the Canadian counterpart to the U.S. ESA. Under the SARA, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was established as the scientific body that identifies and assesses a species' status. The wood bison was recognized by COSEWIC as an endangered subspecies of Canadian wildlife in 1978. Wood bison was reclassified to threatened in June 1988, based on a status report prepared by the National Wood Bison Recovery Team. The National Wood Bison Recovery Team published a

national recovery plan in 2001 (Gates et al. 2001b, entire), which has guided recovery actions in Canada since that time. A subsequent review by COSEWIC, in 2000, confirmed that "threatened" was the appropriate designation at that time (Gates et al. 2010, p. 65).

The wood bison was listed in Appendix I of CITES on July 1, 1975, when the treaty first went into effect. On September 18, 1997, it was transferred to Appendix II, based on a proposal from Canada that described progress in implementation of the Canadian recovery plan (Government of Canada 1997, entire). CITES Appendix-II species are not necessarily considered to be threatened with extinction now but may become so unless trade in the species is regulated. The United States supported this change.

1.2 Purpose of this Assessment

The purpose of this document is to synthesize the best scientific and commercial information available for conducting a SSA (Service 2016, entire), which was recently developed and adopted by the Service specifically for considering the status of a species (or subspecies) under the ESA. It is intended to support an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The SSA approach involves identifying vital needs of the species and evaluating the current and future conditions affecting those needs at the individual, population, and species levels.

The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program, including Recovery and Consultations. As such, the SSA Report will be a living document upon which other decision documents, such as recovery plans, and 5-year reviews would be based. This SSA Report for the wood bison provides the biological support for the 5-Year Review document.

Importantly, the SSA Report does not make a determination on the listing status of the species. Rather, we use the SSA Report to inform our 5-year Review, which is our listing decision document. The 5-year Review results in a determination on whether the species still meets the current status (threatened), has declined (up listed to endangered), or has improved (delist), since the proposed rule to reclassify wood bison from endangered to threatened published February 8, 2011 (76 FR 6734). To support the 5-year Review and its determination, this SSA Report provides a review of the available information strictly related to the biological status of the wood bison. For the purpose of this assessment, we generally define viability as the ability of the wood bison to sustain natural populations across heterogeneous landscapes through time. Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Wolf et al. 2015, entire).

1.3 Resiliency, Representation, and Redundancy

To assess the viability of the wood bison, we used the conservation biology principles of resiliency, representation, and redundancy (Wolf et al. 2015, entire). These principles, referred to as the 3Rs, are distinct yet interrelated concepts (Figure 1-1). Viability is not a static state, but

rather there are degrees of variability. Generally speaking, the more resiliency, representation, and redundancy a species exhibits, the more protected it is against the vagaries of the environment, the more it can tolerate stressors, and thus, the more viable it is. The 3Rs framework is useful for comparing the degree of viability of a species through time.

1.3.1 Resiliency

Resiliency is the ability of a species to respond to and recover from disturbances and perturbations. These include the normal year-to-year variation in precipitation and temperatures and stochastic events such as flooding, fires, and storms. Simply stated, resiliency is having a means to recover from "bad years." To be resilient, a species must have healthy populations; that is, have populations that are able to sustain themselves through good and bad years. The healthier and the greater the number of healthy populations, the more resiliency a species possesses. For many species, resiliency is also affected by the degree of connectivity among populations and the diversity of ecological niches occupied. Connectivity among populations increases the genetic health of individuals (heterozygosity) within a population and bolsters a population's ability to recover from disturbances via rescue effects (immigration). Diversity of ecological niches improves a species resiliency by guarding against disturbances and perturbations affecting all populations similarly (i.e., decrease the chance of all populations experiencing bad years simultaneously or to the same extent).

1.3.2 Representation

Species level representation is the ability of a species to adapt to long-term changes in the environment; it is the evolutionary potential or flexibility of a species. Representation is the range of variation found in a species, and this variation (called adaptive diversity) is the source of a species' adaptive capabilities. Representation can be measured through the breadth of adaptive diversity of the species. The greater the adaptive diversity, the more responsive and adaptable the species will be over time, and thus, the more viable the species is. Maintaining adaptive diversity includes conserving both the ecological diversity and genetic diversity of a species. By maintaining these two sources of adaptive diversity across a species' range, responsiveness and adaptability of a species over time is preserved. Ecological diversity is the heritable physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations.

In addition to preserving the breadth of adaptive diversity, maintaining evolutionary potential requires maintaining the evolutionary processes that drive evolution; namely, gene flow, genetic drift, and natural selection. Gene flow is expressed through the physical transfer of genes or alleles from one population to another through immigration and breeding. The presence or absence of gene flow can directly affect the size of the gene pool available. Genetic drift is the change in frequency of alleles in a population due to random, stochastic events. Genetic drift always occurs, but is more likely to negatively affect populations that have a smaller effective population size (N_e) and populations that are geographically spread out and isolated from one another. Natural selection is the process by which heritable traits can become more (selected for) or less (not selected for) common in a population based on the reproductive success of an individual with those traits. Natural selection influences the gene pool by determining which alleles are perpetuated in particular environments. This selection process generates the unique

alleles and allelic frequencies, which reflect specific ecological, physiological, and behavioral adaptations that are optimized for survival in different environments.

1.3.3 Redundancy

Species-level redundancy is the ability of a species to withstand catastrophic events. Redundancy protects against the unpredictable highly consequential events for which adaptation is unlikely. In short, it is about spreading risk. Redundancy is best achieved by having multiple populations widely distributed across the species' range. Having multiple populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event. Given sufficient redundancy, no single or multiple catastrophic events are likely to wipe-out a species. Thus, the greater redundancy a species has, the more viable it will be. Furthermore, the more populations and the more diverse or widespread that these populations are, the more likely it is that the adaptive diversity of the species will be preserved. Having multiple populations distributed across the range of the species will help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the species.

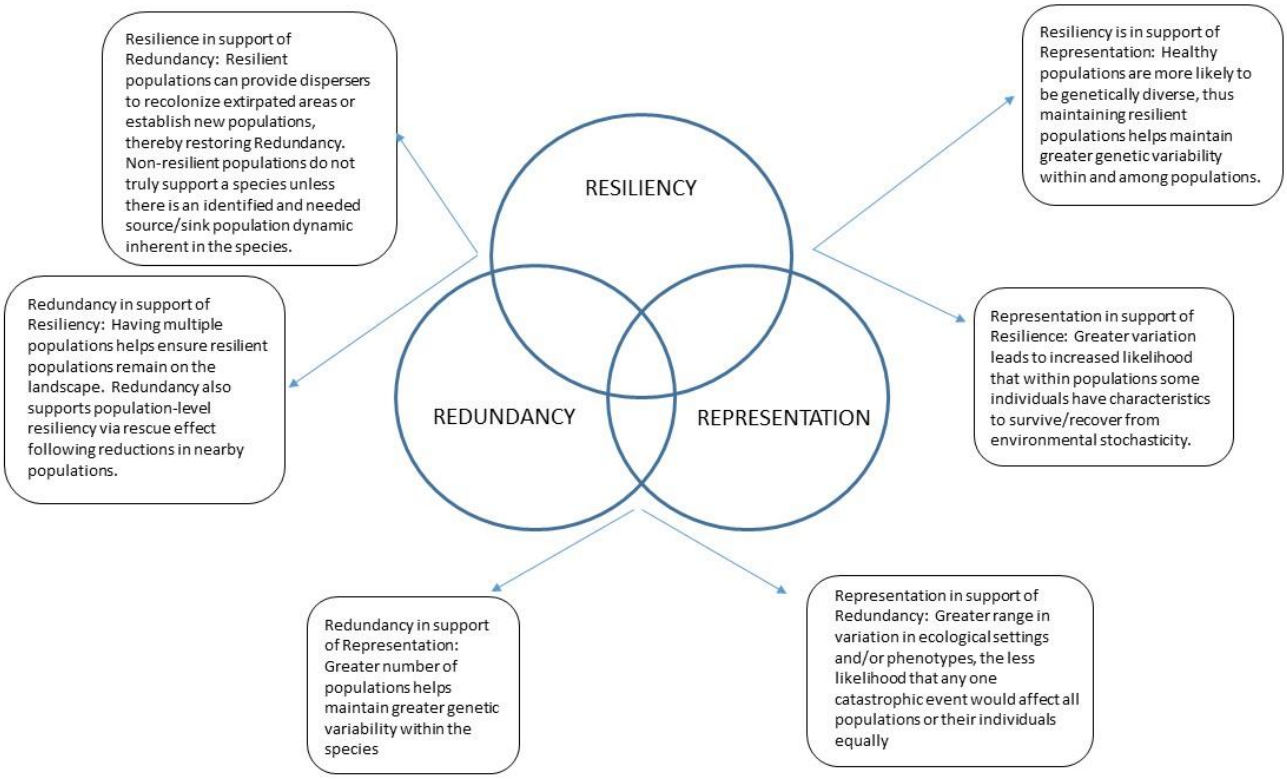


Figure 1-1. The interrelationships among resiliency, representation, and redundancy (3Rs). The 3Rs, in combination, reflect the species' viability (Syzmanski et al. 2016, p. 3).

Chapter 2. Species Description, Distribution, & Ecology

In this chapter, we provide a description of the wood bison and its taxonomy, distribution, and life history. We also provide a summary of the pertinent ecological requirements of the wood bison at the individual, population, and species level. These ecological requirements form the basis of our analyses.

2.1 Species Description

Wood bison is the largest native extant terrestrial mammal in North America (Reynolds et al. 2003, p. 1015). Average weight of mature males (age 8) is 910 kilograms (2,006 pounds) and the average weight of mature females (age 13) is 440 kilograms (970 pounds) (Reynolds et al. 2003, p. 1015). They have a large triangular head, a thin beard and rudimentary throat mane, and a poorly demarcated cape (Boyd et al. 2010, p. 16). In addition, the highest point of their hump is forward of their front legs, they have reduced chaps on their front legs, and their horns usually extend above the hair on their head (Boyd et al. 2010, p. 16). These physical characteristics distinguish them from the plains bison (*Bison bison bison*) (Reynolds et al. 2003, p. 1015; Boyd et al. 2010, p. 16) (Figure 2-1). For a review on the phenotypic differences between wood bison and plains bison see van Zyll de Jong et al. (1995, pp. 394-400) and COSEWIC (2013, pp. 4-7).

2.2 Taxonomy

Within the taxon American bison (*Bison bison*), two subspecies are recognized: plains bison (*Bison bison bison*) and wood bison (*Bison bison athabascae*). The taxonomy of American bison subspecies, however, is somewhat controversial. Some authorities argue that wood bison are not a valid taxon distinct from plains bison (e.g., Geist 1991, entire). Proponents of this view contend that molecular and morphological data do not clearly support a distinction among the two subspecies and further argue that phenotypic variation is clinal, most likely related to environmental conditions. Geist (1991, pp. 296-297) suggests that wood bison are best classified as an ecotype rather than a subspecies; however, morphological and molecular data suggests otherwise (van Zyll de Jong 1995, pp. 397-401; Wilson and Strobeck 1999, p. 494). Definitively assigning an individual to one subspecies or the other, however, is complicated due to phenotypic plasticity, some hybridization, and historical translocations associated with the species, particularly within populations in and adjacent to Wood Buffalo National Park (WBNP). As such, the taxonomic status of wood bison is likely to remain problematic.

In spite of the controversy, the Service currently recognizes wood bison and plains bison as distinct taxa. Within the United States, we adopt the widely accepted notion that wood bison is a valid subspecies. The established management of bison as two subspecies and the long-standing recognition of the two subspecies by the scientific community provide additional justification for treating wood bison and plains bison as two distinct subspecies. For a detailed account on the taxonomic classification and our rationale for accepting wood bison as a valid subspecies please refer to 78 FR 23533. Within Canada, COSEWIC, the National Bison Recovery Team, and SARA, have all retained the convention that there are two subspecies of American bison in North America (COSEWIC 2013, pp. 8-11).

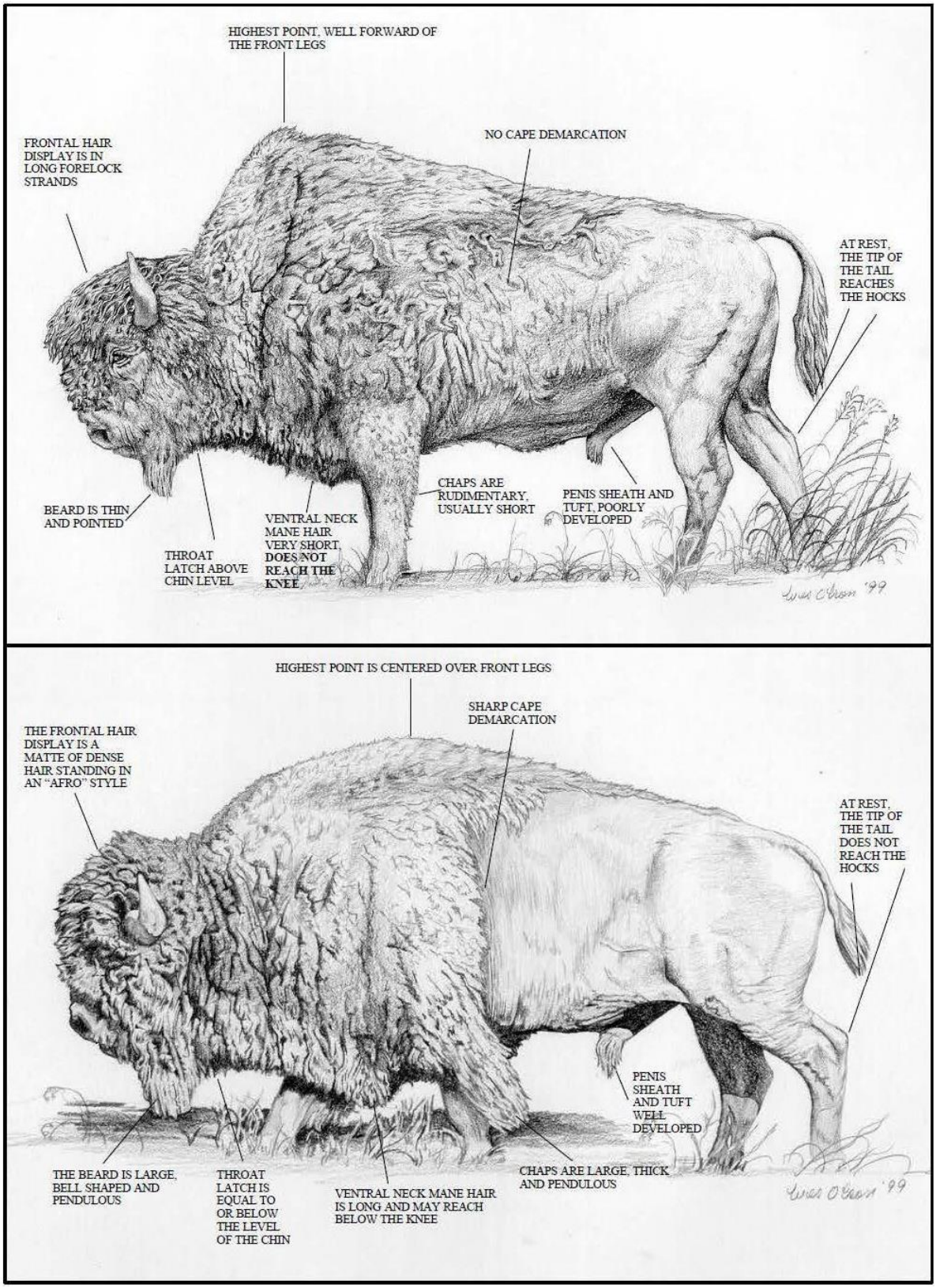


Figure 2-1. Physical characteristics distinguishing between mature wood bison (top) and plains bison bulls. Line drawing courtesy of Wes Olson (from COSEWIC 2013, p. 5).

The current classification of the wood bison is:

- Kingdom: Animalia
- Phylum: Chordata
- Class: Mammalia
- Order: Artiodactyla
- Family: Bovidae
- Subfamily: Bovinae
- Genus: Bison
- Species: bison
- Subspecies: athabascae

2.3 Distribution

Based on estimates made between 2010 and 2016, there are approximately 8,587 free-ranging wood bison in Canada: approximately 4,363 wood bison in nine free-ranging, disease-free local populations, approximately 4,224 in three free-ranging local populations with diseases, and 300 in one captive local population maintained for conservation purposes at Elk Island National Park (EINP) (Gates et al. 2001b, pp. 14–21; COSEWIC 2013, pp. 52–57; ECCC 2018, p. 7) (Table 4-3**)**. In 2015, the Alaska Department of Fish and Game (ADF&G) released 130 captive reared wood bison in western Alaska to create a wild, free-ranging herd known as the Lower Innoko-Yukon herd (hereafter Innoko-Yukon). This is currently the only free-ranging herd in Alaska. A more detailed description of the historical range of wood bison is provided in Chapter 4 of this document.

2.4 Life History

The wood bison's breeding season is from July to October. The age of first reproduction is variable and depends upon the nutritional condition and disease status of individuals (Gates et al. 2010, p. 49). Females may produce their first calf as early as 3 years old and may be reproductively successful up to age 20 (Wilson et al. 2002, p. 1545). Although capable of reproducing at age 2, males typically do not participate in the rut until they are 5 or 6, and reproductive success is at its maximum between age 7 and 14 (Wilson et al. 2002, p. 1544). The mating system of bison is polygynous, in which one male mates with several females (Wilson et al. 2002, p. 1538). Wood bison populations have demonstrated exponential growth potential when habitat is suitable and there are no other limiting factors (e.g., disease or predation) (Connelly et al. 1990, pp. 34-35; Gates and Larter 1990, p. 233).

2.5 Species Ecological Requisites

2.5.1 Individual Level Ecology

Wood bison are primarily grazers, relying on a variety of grasses (*Calamagrostis* spp.) and sedges (*Carex* spp.) found in meadows occurring on alkaline soils and early successional habitats (Reynolds et al. 1978, p. 586; Reynolds and Hawley 1987, p. 43). These meadows are typically interspersed among tracts of coniferous forest, stands of poplar or aspen (*Populus* spp.), bogs, fens, and shrublands. Meadows typically represent 5 to 20 percent of the landscape occupied by

wood bison where they occur in Canada (Larter and Gates 1991a, p. 2682; Gates et al. 2001b, p. 23).

Wood bison are extremely plastic in their ability to adapt to local resources and show strong seasonal changes in diet, selecting plants that yield the greatest protein (Larter and Gates 1991a, pp. 2682-2683) (Table 2-1). Wood bison generally tend to use wet meadows with predominantly native graminoid vegetation, such as sedges (*Carex* spp.) and grasses (*Calamagrostis* spp., *Scolochloa fesucacaea*), as winter grazing habitat. Summer grazing habitats often include meadows that contain slough sedge (*Carex atherodes*), northern reed-grass (*Calamagrostis canadensis*), and/or willow (*Salix* spp.). Deciduous and pine (e.g., Jack pine, *Pinus banksiana*) forests associated with these meadow types are used for resting, ruminating, avoiding biting flies, protection from deep snow and wind, and foraging at various times throughout the year (Reynolds et al. 1978, pp. 566-568; Larter and Gates 1991b, p. 133; Jung et al. 2015, p. 1283).

Table 2-1. Diet items of select local wood bison population within North American ecoregions. (From Gates et al. 2010, p. 48).

Ecoregion	Location	Season	Plant Type					Reference
			Grasses (%)	Sedges[1] (%)	Forbs (%)	Woody Plants (%)	Others (%)	
Northern Forests	Wood Buffalo NP and Slave Lake, NWT and AB	Spring	16	81	1	2		Reynolds et al. 1978, Reynolds. 1976 *in* Reynolds and Peden 1987
		Summer	24	59	8	8		
		Autumn	21	71	4	2		
		Winter	36	63		1		
Subarctic Boreal Forests	MacKenzie Bison Sanctuary, NWT	Spring	6	68	1	26		Larter and Gates 1991
		Summer	11	53	2	28	6[2]	
		Autumn	32	15	4	12	37[2]	
		Winter	2	96		2		
	Nahanni Population, NWT	Summer	6	37	29	14	1[3]	Larter and Allaire 2007; Larter, N.C. unpublished data
		Autumn	19	58	7	12	4[3]	
		Early Winter[4]	16	37	10	4	33[3]	
		Mid-Winter[4]	2	89	4	3	2[3]	

[1]Includes rushes (Juncaceae); [2]Lichens; [3]*Equisetum* spp.; [4]November/December is early winter, January/February is mid-winter

Wet meadows are rarely used in the summer, likely because of the energy required to maneuver through the mud, but they are used in late summer when they become drier, and in the winter when they freeze (Larter and Gates 1991b, pp. 133, 135; Strong and Gates 2009, p. 438). Wood bison do not appear to have specific habitat requirements for rutting, mating, or gestation; however, female groups tend to select larger meadows during the calving season (Calef and Van Camp 1987, pp. 19-20). Grassland/sedge habitat represents 5 to 20 percent of the land area in most wood bison ranges, usually interspersed among tracts of coniferous and aspen (*Populus* spp.) forest, bogs, fens, and shrublands (Larter and Gates 1991a, p. 2682; Gates et al. 2001b, p. 23).

2.5.2 Population Level Ecology

Self-sustaining populations are those that are able to respond to and recover from disturbances (stochastic events such as fire, flooding, storms) and perturbations (normal year-to-year environmental variation in temperature and rainfall). Simply said, healthy populations are those able to sustain themselves through good and bad years. To be self-sustaining, populations must: 1) be demographically, genetically, and physiologically robust; 2) occupy areas with suitable habitat conditions for all life stages and seasons; and 3) have only manageable stressors acting upon them. These three population level requisites are discussed below.

To respond and recover quickly from disturbances and to adapt to normal environmental variation, populations need to be demographically, genetically, and physiologically robust (adapted from Redford et al. 2011, pp. 40-42), which means having sufficient numbers of individuals and positive growth rates. The number of individuals is important because as the population size declines, a host of challenges arise.

As populations are reduced in size and become smaller, population dynamics become strongly influenced by demographic, environmental, and genetic stochasticity. Smaller populations may experience a higher chance of skewed sex ratios, greater vulnerability to fluctuations due to bad years that lead to extinction, and may have a higher chance of losing genetic variation, and hence, increase homozygosity stochasticity. Specifically, as a population decreases, its gene pool becomes smaller and loss of genetic diversity is more likely. As genetic variation declines, so too does a population's ability to respond to changes (disturbances and perturbations) in its environment. Genetic variation (which is the source of adaptability for a species) is determined by the joint action of natural selection and genetic drift (chance). In small populations, genetic drift is higher which can lead to deleterious alleles becoming more frequent and fixed in the population due to chance alone. Also, in small populations, related individuals are more likely to breed, which can lead to increased homozygosity (decreased genetic variation) in individuals. Similarly, as a population becomes smaller, greater fluctuations can occur in population demography (birth and death rates, sex ratio) due to chance. Greater fluctuations in demographic rates can lead to higher chances of population extirpation. Lastly, as a population becomes smaller, it becomes more vulnerable to environmental variation; they are less able to recover from bad years. Thus, to be demographically, genetically, and physiologically robust, population numbers should be above the species-specific population size in which small population vulnerabilities (genetic, demographic, and environmental consequences) begin to exert control over the population dynamics.

Recovery goals for the wood bison within Canada are set based upon short- and long-term objectives due in part to difficulties with eliminating the threat posed by bovine tuberculosis (*Mycobacterium bovis*) (Tb) and bovine brucellosis (*Brucella abortus*) over the long term (ECCC 2018, p. 25). Short-term population and distribution objectives are to maintain the disease-free status, population size, and current range of all wood bison populations occurring in Canada throughout their range. Long-term objectives build on short-term objectives and are structured to ensure the existence of at least five disease-free, genetically distinct, connected, self-sustaining, free-ranging local populations distributed throughout their original Canadian range, with a minimum population of 1,000 animals. Recovery goals for the wood bison estimate a population size of 1,000 animals is needed to maintain and minimize the loss of

genetic diversity in local populations over time (ECCC 2018, p. 26). Gross and Wang (2005; as reported in ECCC 2018, p. 26) determined that 1,000 bison are required to maintain a 90 percent probability of retaining 90 percent of allelic diversity within local wood bison populations.

Population trend (whether population size increases or decreases) is a function of the population's growth rate (λ). Population growth rate is fundamentally determined by four processes: increases through births and immigration, and decreases through deaths and emigration. For a population to grow, it must have a positive growth rate, where λ is greater than 1. That is, the population must experience more births and immigration than deaths and emigration. Currently, disease free wood bison populations essentially do not experience immigration or emigration, because populations are separated by a lack of habitat connectivity due to human management (Harper et al. 2000, pp. 27-28; Gates et al. 2001b, p. 22; COSEWIC 2013, p. 61; ECCC 2018, p.18). Therefore, the birth and death rates are the primary factors driving the species' growth rate.

Birth rate can be influenced by a population's age structure, sex ratio, and overall fitness (e.g., body condition, forage availability, etc.) (Brodie 2008, pp. 10, 20). Death rate can be influenced by the population's age structure, as well as through external factors such as disease, predation, environmental mortality factors (e.g., flooding, deep snow, wildfire, etc.), and human caused mortality factors (e.g., hunting, vehicle collisions, etc.) (Joly 2001 p. 102; Joly and Messier 2004, pp. 1171-1172; Brodie 2008, pp. 9-11, 20; Bradley and Wilmshurst, 2011, pp. 1202-1204). The factors influencing death rate can largely be classified as threats or stressors. Larger populations are better able to withstand stressors on an annual basis, and may be able to overcome a year of high mortality through a commensurately high birth rate. Smaller populations tend to be more vulnerable to extirpation in years of high mortality. Thus, even if a population is robust and has sufficient habitat availability, external stressors can exceed the ability of the species to recover. Stressors can lead to unsustainable mortality by directly killing individuals, such as through prevalence of disease, or indirectly, such as through habitat loss. Thus, for populations to be self-sustainable, they must be free of stressors or at least exposed to only manageable stressors.

To be self-sustaining over time, the population must be large enough to avoid genetic, demographic, and environmental consequences. Self-sustaining populations also require summer and winter habitat, connectivity among these habitats, and intact ecological processes that maintain suitable summer and winter habitats. Lastly, self-sustaining populations must have only manageable stressors acting upon them.

2.5.3 Species Level Ecology

For a species to persist and thrive over time, it must exhibit attributes across its range that relate to either representation or redundancy (Figure 1-1). Representation describes the ability of a species to adapt to changing environmental conditions overtime and encompasses the "ecological and evolutionary patterns that not only maintain but also generate species" (Shaffer and Stein 2000, p. 308). It is characterized by the breadth of genetic and environmental diversity within and among populations. For the wood bison to exhibit adequate representation, resilient populations should occur throughout the ecoregion to which it is native; these populations should occur at the widest extent possible across the historic range of the species; and they should occupy multiple areas of suitable habitat where they are native. The breadth of morphological,

genetic, and behavioral variation should be preserved to maintain the evolutionary variation of the species. Finally, connectivity should be maintained between representative populations because it allows for the exchange of novel and beneficial adaptations where connectivity is high or is the mechanism for localized adaptation and variation where connectivity is lower and the species is more isolated (Figure 1-1).

Redundancy describes the ability of a species to withstand catastrophic events. It "guards against irreplaceable loss of representation" (Tear et al. 2005, p. 841; Redford et al. 2011, p. 42) and minimizes the effect of localized extirpation on the range-wide persistence of a species (Shaffer and Stein 2000, p. 308). Redundancy for the wood bison is characterized by having multiple resilient and representative populations distributed throughout occupied areas throughout its historic range. For this species to exhibit redundancy, it must have multiple resilient populations with connectivity maintained among them. Connectivity allows for immigration and emigration between populations and increases the likelihood of recolonization should a population become extirpated.

Chapter 3. Stressors and Conservation Actions

This section discusses the external factors (stressors) that may negatively influence the 3Rs, and thus the viability, of the wood bison. We also take into consideration positive influences on the species and its habitat, such as beneficial management implemented through land management plans and strategies. Through careful review of the best available scientific and commercial information on wood bison, including information on conspecific or surrogate species when applicable, we evaluate stressors with the potential to negatively affect the species either through direct mortality, injury, habitat alteration, or reducing their ability to feed themselves or their young.

3.1 Historical Threats and Species Decline

During the early 1800s, wood bison numbers were estimated at 168,000; but by the late 1800s, the subspecies was nearly eliminated, with only a few hundred remaining (Gates et al. 2001b, p. 11). In the words of Soper (1941, p. 362), wood "bison appear to have been practically exterminated," and based on the fate of plains bison, in which 40 to 60 million animals were reduced to just over 1,000 animals in less than 100 years (Hornaday 1889, p 525; Wilson and Strobeck 1998, p. 180), overharvest may have been the cause for the decline (Harper and Gates 2000, p. 915). Factors leading to the extirpation of wood bison from Alaska most likely included hunting by humans, along with the isolation of subpopulations caused by changes in habitat distribution during the late Holocene (Stephenson et al. 2001, pp. 146-147). The fact that populations in Canada began to rebound once protection was in place and enforced supports the idea of overharvest and unregulated hunting as the most significant sources of decline (Soper 1941, pp. 362-363).

Wood bison were largely extirpated from much of their original range in Alaska and Canada by about 1900 (Stephenson et al. 2001, p. 140). At that time, only a few hundred animals existed in northeastern Alberta. Intensive conservation efforts in Canada beginning around 1900 are principally responsible for preventing the species' extinction (Gates et al. 2001b, pp. 10-14). In 1922, Wood Buffalo National Park, Canada, was set aside for the protection of the last remnant population of wood bison. Since that time, several additional herds have been established (Table 4-3). For a review of reintroduced wood bison herds and source of founders please review Gates, (2001b, pp. 12-20), ADF&G (2010, p. 11), Safranov et al. (2012, p. 35), and ECCC (2018, p. 57).

The translocation of surplus plains bison into WBNP in the 1920s (Carbyn et al. 1993, pp. 25-27) resulted in some genetic dilution of wood bison, as well as the introduction of domestic cattle diseases into this population (Gates et al. 2001b, p. 12). Cattle diseases (i.e., bovine Tb and brucellosis) are still a management concern in some herds in the WBNP area in Canada (Gates et al. 2010, pp. 28-32). The susceptibility of wood bison and other native ungulates to these diseases underscores the importance of rigorous disease-testing protocols prior to releasing wood bison in Alaska (ADF&G 2007, p. 14).

Another factor thought to have played a role in the decline of wood bison is a gradual loss of meadow habitat throughout forest encroachment (Stephenson et al. 2001, p. 143; Quinlan et al.

2003, p. 343; Strong and Gates 2009, p. 439). Although not quantified, it is likely that because of fire suppression, and subsequent forest encroachment on meadows, there was a net loss of suitable open meadow habitat for wood bison throughout their range through about 1990. More intensive fire management began in Canada in the early 1900s with the philosophy that fire was destructive and should be eliminated to protect property and permit proper forest management (Stocks et al. 2003, p. 2). However, wildfire is an integral component of boreal forest ecology (Weber and Flannigan 1997, p. 146; Rupp et al. 2004, p. 213; Soja et al. 2007, p. 277). Without fire, trees encroach on meadows and eventually the meadow habitat is lost and replaced by forest.

3.2 Risk Factors

The greatest current stressor to wood bison is the presence of bovine Tb and brucellosis and the resultant management actions taken to reduce exposure risk and transmission to disease-free populations. Management actions to reduce transmission include the use of "bison-free" control or surveillance zones, which greatly inhibits the dispersal of infected animals into disease-free wood bison populations. Bison observed within these areas are often actively removed by lethal methods through open hunting seasons. Bison control areas often contain high-quality habitat but are unavailable to wood bison or for reestablishment of populations given the proximity of these areas to infected populations. For example, the region designated as control zones surrounding WBNP includes some of the highest quality habitat within the core range of the species. Further, the control zone, or Bison Containment Area (BCA) program, implemented by the Government Northwest Territories aims to reduce the risk of disease transmittal (bovine Tb or brucellosis) from bison in WBNP and the Slave River Lowlands to other bison populations. Formed in 1989, the BCA's purpose is to create a barrier to bison movements and dispersal of free-ranging bison between diseased and disease-free populations within the Northwest Territories. The BCA program remains an important component of managing bovine Tb and brucellosis in the Northwest Territories.

Hunting and population control is a stressor common to several local populations of wood bison. Population numbers are maintained at a smaller size to prevent range expansion and potential contact between diseased and disease-free populations, reduce hybridization potential through contact with plains bison and domestic cattle, limit the risk to people and property, and to provide hunting opportunities. Social intolerance due to perceived competition with other ungulates, disease transmission, property damage, and human safety is a significant factor influencing policies that reduce, control, and limit the number of wood bison in large landscapes. Unregulated hunting of some subpopulations constrains effective population size where small population effects may negatively impact viability. Disease (livestock-borne and native, e.g., anthrax) and severe weather are other threats that have caused significant mortality events, both recently and historically.

3.2.1 Disease

Wood bison are susceptible to a variety of diseases that may affect their population dynamics. There are three major infectious bacterial diseases of concern to the conservation of wood bison, none of which are endemic to wood bison (Gates et al. 2010, pp. 28-32). Anthrax (*Bacillus anthracis*) and bovine Tb are considered to have the most serious disease implications for bison

restoration. Bovine brucellosis is also considered a significant stressor and an impediment to recovery.

Anthrax is a naturally occurring infectious bacterial disease that is transmitted through inhalation or ingestion of endospores (Gates et al. 2010, p. 28). The disease is rapidly fatal, with death usually occurring within several days once the clinical signs appear (Dragon et al. 1999, p. 209). Between 1962 and 2015, 24 outbreaks were recorded in northern Canada, killing at least 2,266 bison (Species at Risk Committee 2016, pp. 122, 223–224; Dragon et al. 1999, p. 209). Factors associated with outbreaks are high ambient temperatures, high densities of insects, and high densities of bison as they congregate in areas of diminishing forage and water (Dragon et al. 1999, p. 212). Sexually mature males are more susceptible than cows, juveniles, or calves, perhaps because of elevated levels of testosterone (Dragon et al. 1999, p. 211). Though captive bison can be vaccinated effectively and treated with antibiotics, anthrax is not treatable in free-ranging wildlife (Gates et al. 2001b, p. 22). Unlike anthrax, which occurs in outbreaks in which many animals die at one time, brucellosis and Tb are chronic diseases that weaken animals over time.

Bovine brucellosis is caused by the bacterium *Brucella abortus* (Tessaro 1989, p. 416). Although the primary hosts are bovids, other ungulates such as elk can be infected. The disease is primarily transmitted through oral contact with aborted fetuses, contaminated placentas, and uterine discharges. Greater than 90 percent of infected female bison abort during their first pregnancy (Gates et al. 2010, p. 30). Naturally acquired immunity reduces the abortion rate with subsequent pregnancies (Aune and Gates 2010, p. 30). Male bison experience inflammation of their reproductive organs and, in advanced cases, sterility. Both sexes are susceptible to bursitis and arthritis caused by concentrations of the bacterium in the joints, which may make them more susceptible to predation (Joly 2001, pp. 97-98). Two vaccines, S19 and SR B51, have been developed in an attempt to prevent bovine brucellosis (Aune and Gates 2010, pp. 30-31); however, brucellosis remains extremely difficult to eradicate in ungulates. The combined use of quarantine protocols, serum testing, slaughter, and vaccination is being explored as a means of controlling the disease (Nishi et al. 2002, pp. 230-233; Bienen and Tabor 2006, pp. 324-325; Aune and Gates 2010, p. 31).

Bovine Tb is a chronic infectious disease caused by the bacterium *Mycobacterium bovis* (Tessaro 1989, p. 417). Historical evidence indicates that bovine Tb did not occur in bison prior to contact with infected domestic cattle (Tessaro 1989, p. 416). Wood bison were infected in the 1920s, when plains bison were introduced into the range of wood bison (Tessaro 1989, p. 417). Currently, the disease is concentrated in bison in and near WBNP (Wabasca, Wentzel, and Slave River Lowlands herds). The disease is primarily transmitted by inhalation and ingestion of the bacterium, but may also pass to offspring through the placenta or contaminated milk (Connelly et al. 1990, p. 11). Bovine Tb is a chronic disease that progressively becomes debilitating; advanced cases are fatal. There is not an effective vaccine for immunization against Tb in wood bison (Connelly et al. 1990, p. 2). However, advances in disease management strategies (e.g., vaccination, selective culling, and genetic salvage) have been made in the past decade.

Development of bovine Tb and brucellosis DNA vaccines have shown some efficacy in treatments of cattle and bison (Clapp et al. 2011, p. 504-505). Improved methods of vaccine

delivery including injectable (Denisov et al. 2010, pp. 27-29) and oral vaccines (Rigano et al. 2006, p. 693-694; Floss et al. 2010, p. 11) have shown promise for administering vaccines to bison, yet delivery to wild, free-range populations remains problematic (Shury et al. 2015, p. 546). Most notably, difficulties arise from determining the frequency of vaccination, the proportion of the population to vaccinate, and how to deliver a vaccine without reducing its efficacy (Shury et al. 2015 p. 546). Selective culling techniques which involve capture, testing, and vaccination of wood bison, although costly, may be more acceptable than depopulation and eradication of diseased herds (Shury et al. 2015, p. 548). Captured wood bison that are test-positive are removed; test-negative wood bison are vaccinated to prevent future infection. Advanced reproductive techniques including embryo transfer, manipulating superovulation, semen harvest, and artificial insemination have shown promise for preserving genetic diversity (see Shury et al. 2015, entire for an overview of these techniques).

Wood bison in and around WBNP, Alberta and the Northwest Territories, Canada, are infected with brucellosis and bovine Tb. These diseased herds (i.e., WBNP, Slave River Lowlands, and Wentzel Lake) account for about half of the free-ranging wood bison and are the only known reservoirs of Tb and brucellosis among all of the herds (Gates et al. 2010, pp. 4, 35). Wood bison cows infected with both Tb and brucellosis are less likely to be pregnant, and infected herds are more likely to have their populations regulated by wolf predation (Tessaro et al. 1990, p. 179; Joly and Messier 2004, p. 1173; Joly and Messier 2005, p. 549).

3.2.2 Biological Resource Use

Hunting (intentional/ unintentional) - Stephenson et al. (2001, pp. 128-134) documented accounts from native elders in Canada and Alaska describing bison hunting in the subsistence lifestyle within the last few generations. Regulated hunting maintains interactions between bison, people, and the surrounding communities within the range of the herds. Hunting can be used to manage bison numbers (or herd size), curtail undesirable range expansion, reduce potential spread of disease, and reduce human-bison conflict issues, including safety on roads (ECCC 2018, pp. 17-18). In addition, regulated hunting provides revenue for monitoring and management of herds (79 FR 26178). Once nonessential experimental populations reach sufficient resiliency to support such actions, regulated hunting is expected to occur in Alaska (79 FR 26175). Unregulated hunting, however, is a threat (ECCC 2018, p. 18). The fur trade nearly eliminated wood bison by the late 19th century (79 FR 26177, Stephenson et al. 2001, pp. 128-134).

Persecution – The International Union for Conservation of Nature (IUCN) uses persecution as a term to represent the intentional removal or control of species for management purposes. Bison are persecuted for purposes of management and control such as to avoid hybridization of free-ranging wood bison with free-ranging plains bison, domestic bison, and cattle and to reduce the spread of disease (ECCC 2018, p. 18). In British Columbia, for example, active control zones are designated to prevent the hybridization of the wood bison with the plains bison (ECCC 2018, p. 18). Management zones, however, may inhibit natural dispersal and gene flow between local populations, which limits recovery through the loss of genetic diversity in isolated populations (ECCC 2018, pp. 18-19).

3.2.3 Invasive and Other Problematic Species

Canada thistle (*Cirsium arvense*), an aggressive invasive weed which may outcompete native plants, can reduce available forage habitat for wood bison. It is a suboptimal food source for bison, and in some areas bison avoid thistle and do not eat it (ECCC 2018, pp. 12, 21). Invasive thistle has spread further into bison habitat within Canada over the last several decades, and is expected to continue to expand as factors such as drying, fires, or other human disturbance appear to promote the survival and spread of thistle (ECCC 2018, pp. 12, 21). Bison movement patterns may be altered by non-native plant species, as bison may be drawn to some non-native species, or may avoid others, depending on if they are palatable (ECCC 2018, pp. 12, 21).

The threat of predation by wolves on bison has been observed by communities in bison range (ECCC 2018, p. 13), and appears to be rising particularly among recently introduced herds (Larter et al. 1994, p. 326; Jung 2011, pp. 127-128; ECCC 2018, p. 13). Interactions among disease (bovine Tb and brucellosis), habitat quality, and wolf predation may influence survival and reproduction of wood bison, although the relationships among these variables are complex and not well understood, and there are varying hypotheses to explain declines in bison populations (Carbyn et al. 1993, pp. 10-11; Joly and Messier 2004, pp. 1172-1174; Bradley and Wilmshurst 2005, p. 10; ECCC 2018, p. 20). Potential causes of the observed increases in predation may be related to the use of linear features (e.g., seismic lines, pipelines, access roads) by wolves to gain access to areas previously inaccessible (ECCC 2018, p. 23). However, work by DeMars et al. (2019, p. 28) suggests bison use of linear features may not lead to an increased risk of wolf predation.

3.2.4 Stochastic and Severe Weather Events

Measurements spanning several decades demonstrate that changes in climate are occurring globally, and that the rate of change since the 1950s is unprecedented (Intergovernmental Panel on Climate Change (IPCC) 2014, p. 40). Examples include warming of the atmosphere and the oceans, melting of glaciers and sea ice, and substantial increases in precipitation in some regions of the world and substantial decreases in other regions (e.g., IPCC 2014, pp. 40-42; Solomon et al. 2007, pp. 35-54, 82-85). Analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "extremely likely" (defined by the IPCC as 95 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from fossil fuels (IPCC 2014, pp. 47-49; Solomon et al. 2007, pp. 21-35). Further confirmation of the role of GHG comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 is caused by human activities.

The IPCC uses climate models to predict future climate change, with Representative Concentration Pathways (RCPs) used to describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions, and land use; these RCPs are the accepted standard of predicting future GHG emissions and associated climate effects (IPCC 2014, pp. 56-57). The RCPs represent the range of GHG emissions in the wider literature, and include a stringent mitigation scenario (2.6), two intermediate scenarios (4.5 and 6.0), and one scenario with relatively high emissions (8.5) (IPCC 2014, p. 57). In Chapter 5 Future Scenarios; Modeling Climate Change, we discuss in detail the significance between each RCP pathway and the potential warming effect they may produce.

There are several ways climate change may affect species at higher trophic levels (i.e., consumers). Changing physical conditions, such as fluctuating temperatures (e.g., freeze/thaw events), extreme precipitation, or drought may have direct effects on some consumer species. Other consumers will be affected via changes in the abundance, distribution, or other characteristics of their prey or forage species. Changes in the timing of seasonal events may lead to mismatches in the timing of consumers' life history requirements with their habitat conditions (including prey or forage availability as well as physical conditions; Durant et al. 2007, entire). The combination of these effects is likely to cause changes in community dynamics (e.g., competitive interactions, predator-prey relationships, or food resource availability). Adverse climatic conditions can be confined to a single season, or to climatic oscillations such as the Pacific North American Pattern, North Pacific Oscillation, and Southern Oscillation Index (La Niña and El Niño), which could have multi-year impacts on forage production and availability.

Changes in patterns of precipitation, drought, fluctuating temperatures, more extreme snowstorms, and flooding events modify habitat. Such changes may have positive effects, such as the reduction of ecological barriers or increased potential habitat and range of wood bison. Conversely, these changes may have negative effects, such as decreased suitable habitat, or increased risk of transmission, and effects of pathogens (ECCC 2018, pp. 23-24).

Changes in precipitation not only increase the risk of severe drought, but also increase the frequency of fire and flood events. For example, in 1974, a mass drowning of 3,000 bison was caused by a severe flood in the Peace-Athabasca Delta (ECCC 2018, pp. 23-24). Changes in ice and snow pack can alter habitat, creating new risks to bison. Wood bison in Canada, for example, have drowned by falling through the ice in early spring (ECCC 2018, pp. 23-24). Harsh winters, heavy snowfall, and increased ice can lead to starvation (ECCC 2018, pp. 23-24). In addition, harsh winters, heavy snowfall, and depth of snow pack can lead to starvation by limiting access to forage.

Changes in fire regime may be positive or negative for wood bison. The Species at Risk Committee frames fire as an integral component on the landscape, considering small-scale fires as perhaps beneficial and large-scale fires as more of a threat to wood bison and their habitat (Species at Risk Committee 2016, p. 58). As warmer climates increase fire frequency in forested areas, habitat is converted to non-forested upland, open shrub, and grassland habitats, increasing potential bison habitat by encouraging forage grasses and sedges (Species at Risk Committee 2016, p. 60; Strong and Gates 2009, p. 439).

Conversely, direct and indirect negative effects could increase with fire frequency and intensity. Direct mortality and increased stress may occur in areas that burn hot and fast (ECCC 2018, p. 19). If sedge and grass meadow habitat is destroyed, food resources could be reduced or susceptibility to predation could be increased (Environment Canada 2015; as cited in Species at Risk Committee 2016, p. 59). Fire suppression, on the other hand, can reduce bison habitat through enabling conversion of meadow habitats to shrubs and trees (ECCC 2018, p. 19). The best approach may be to utilize prescribed burning and focus on keeping fires small (Environment Canada 2015; as cited in Species at Risk Committee 2016, p. 59).

Finally, changing climates may cause increased precipitation, which could result in less frequent wildfires in areas for an unknown number of years. The lack of fire could modify plant succession, which could cause negative effects to bison as prolonged flooding late into the summer would render forage resources unavailable, and if those patterns continued for several years it could modify habitat (Species at Risk Committee 2016, p. 135).

3.2.5 Negative Genetic Effects

The founding size of most disease-free wood bison local populations is small, and small populations generally have lower genetic diversity and may experience higher genetic drift over time (ECCC 2018, p. 24). Low genetic diversity may affect survival of bison populations through inbreeding depression, which can reduce fitness (ECCC 2018, p. 24), and may affect a population's ability to respond to environmental changes over time (McFarlane et al. 2006, p. 8). In European bison (*Bison bonasus*), higher disease prevalence was associated with low genetic diversity (Luenser et al. 2005 as cited in ECCC 2018, p 34; ECCC 2018, p. 24). Inbreeding depression was associated with higher mortality and lower recruitment of bison calves in a population of plains bison (Halbert et al. 2004, p. 929; ECCC 2018, p. 24). In addition to the small founding size of most bison populations, several populations are managed at an artificially small size, and migration is limited for various reasons, including preventing range expansion and the spread of disease, preventing risk to people and property, and to provide opportunities for hunting (ECCC 2018, p. 24). While the threat of loss of genetic diversity to bison is suspected, the scope of the threat is pervasive, in that a significant portion of the species can be expected to be affected by the threat within 50 years or less (ECCC 2018, p. 14).

Hybridization is the interbreeding of genetically distinct populations (Rhymer and Simberloff 1996, entire). Such interbreeding can result in introgression, which is the gene flow between populations that have hybridized. Introgression can lead to loss of genetic diversity and has the potential to cause reduced fitness or even "genetic extinction" (Levin et al. 1996, p. 12; Rhymer and Simberloff 1996, pp. 104). For this reason, hybridization is a concern for wood bison, should they interbreed with plains bison. The introduction of plains bison to WBNP in the 1920s put the two distinct subspecies in contact with each other and threatened the genetic purity of wood bison (Gates et al. 2010, p. 17). The discovery of an isolated subpopulation of wood bison in 1957, and subsequent translocation of individuals, created the Mackenzie and EINP herds, which were thought to be pure wood bison (discussed in detail within Section 4.2). Genetic analysis indicate these bison had limited contact with plains bison, but it was minimal enough that the animals exhibit predominantly wood bison traits. Further, wood bison herds originating from these founders are genetically more similar to one another than they are to plains bison (van Zyll de Jong et al. 1995, pp. 401-404; Wilson and Strobeck 1999, p. 493). Although recovery actions in Canada emphasize maintaining the genetic integrity of wood bison (Gates et al. 2001b, p. 33; ECCC 2018, p. 30), the presence of plains bison on the landscape is increasing.

Expanding commercial plains bison operations in British Columbia in the early 1970s led to the formation of the (now) free-ranging Pink Mountain plains bison when plains bison escaped from an enclosure (COSEWIC 2004, p. 8). In 2003, the population was estimated to have 876 individuals (COSEWIC 2004 p.8). Given the spatial proximity of the Pink Mountain populations to local wood bison populations, active control zones were established to prevent hybridization with the Nordquist/Liard, Nahanni, and Hay Zama local populations (Harper et al.

2000, p. 11). Commercial plains bison operations and plains bison herds remove potential habitat for wood bison, and the presence of plains bison within the historical range of wood bison increases the probability that wood bison will come into contact with them. Because of consumer demand for bison meat, we expect commercial bison production will continue to expand, removing suitable habitat for wood bison recovery herds, and increasing the probability that escaped plains bison will be free on the landscape. For these reasons, loss of genetic integrity through hybridization is a stressor to wood bison. The status of genetic issues relating to hybridization could change relatively rapidly, especially if plains bison were to escape from captivity in close proximity to a wood bison herd. Currently, free-ranging wood bison and plains bison herds are widely separated from one another, but as herd size grows, the separation shrinks, increasing the odds that they may come into contact with one another.

3.2.7 Transportation and Service Corridors

Wood bison herds living near transportation and service corridors can be subject to increased direct mortality through collision with vehicles such as automobiles, trains, or shipping traffic (ECCC 2018, pp. 11, 17). Wood bison are known to use linear corridors for grazing and transit (ECCC 2018, p. 16; DeMars et al. 2019, p. 25), and wood bison on roadways are difficult to see at night and in inclement weather (ECCC 2018, pp. 54-55, Appendix 1), making them more susceptible to collisions. Roads can also facilitate an increase in mortality from intentional and unintentional hunting (hunting mortality is discussed further in section 3.2.2 Biological Resource Use) (ECCC 2018, p. 11). Wood bison are known to use large rivers as travel corridors to access high-quality forage within riparian habitats (Larter et. al. 2003, p. 410). Although river crossings in winter and summer are common (Larter et al. 2003, p. 410; ECCC 2018, p. 17), open water crossings in summer require wood bison to swim successfully. Water vehicle traffic, including recreation or transportation (e.g., barges) traffic, that occur during crossings may result in wood bison mortality through direct contact (collisions) or drowning through increased wave/wake action (Larter et al. 2003, p. 410).

3.3 Beneficial Factors (Conservation Actions)

In 1978, there was one free-ranging, disease-free herd with 300 individuals: the Mackenzie local population, (see Table 1; 77 FR 26191). By 2002, with the aid of conservation measures, the number of disease-free populations had grown to 6, with a total of approximately 2,800 individuals (see Table 1, 77 FR 79 26191). One additional population (Etthithun) was established in 2002 bringing the total number to 7, and the number of disease-free, free-ranging bison increased to approximately 4,400 (see Table 1, 77 FR 26191). In 2016, two populations (Ronald Lake and Wabasca) previously considered part of the Greater Wood Buffalo National Park metapopulation (GWBNP) were recognized as disease-free and genetically distinct from the GWBNP metapopulation (Gates et. al. 2001b, pp. 19, 20; Ball et al. 2016, p. 1532). In 2008, a captive wood bison population was established in Girdwood, Alaska, at the Alaska Wildlife Conservation Center (AWCC). In 2015, the first free-range wood bison population was established in the lower Innoko-Yukon region in western Alaska. Currently, there are approximately 9,000 free-ranging (including approximately 4,224 diseased), wood bison within Canada and the United States comprising 14 populations. A complete history of each population and current species summary may be found in Chapter 4 and Table 4-3.

3.3.1 Conservation and Management Plans

In Canada, the National Wood Bison Recovery Team published a national recovery plan in 2001 (Gates et al. 2001b, entire) to identify recovery actions necessary to protect and recover wood bison in Canada. The recovery plan by Gates et al. (2001b, entire) remained the guiding document for recovery efforts in Canada until 2018. Then under the Species at Risk Committee, the Canadian federal government published a revised recovery strategy (ECCC 2018, entire). The strategy is based upon information updated from the 2001 recovery plan (Gates et al. 2001b, entire) with consultation from the Canadian National Wood Bison Recovery Team.

The 2018 recovery strategy provides an account of recovery actions since 2001 and identifies future recovery actions through five broad strategies. Within Canada, past and present recovery actions related to research include studies, reports, and peer-reviewed articles on disease management, wood bison genetics (e.g., genetic salvage, maintaining genetic diversity), wolf predation, wood bison movement patterns, and socioeconomic impacts. A Technical Workshop was held to inform management decisions and to assess the feasibility of removing disease from WBNP. Recovery action reports related to past and current management actions include: the implementation of bison control areas, development of hunts and harvest quotas, local population management plans, fire management, relocation efforts, and public messaging campaigns. Studies and reports on wood bison habitat include broad topics such as forage availability and habitat use, seasonal range patterns, and incorporating local community and indigenous knowledge to document behavioral habitat use patterns. For detailed information and specific reference material for these recovery studies and reports reference ECCC (2018, p. 27-28).

The Recovery Strategy (ECCC 2018, entire) details five broad strategies for recovery with associated general research and management approaches to attain success (ECCC 2018, p. 29-32):

- Contain and prevent the spread of bovine Tb and brucellosis from wood bison local populations with diseases to disease-free local populations, cattle, and ranched bison, and evaluate current disease management options.
- Maintain at least 90 percent of the genetic diversity, as measured by allelic diversity, within the wood bison subspecies and local recovery populations for the next 200 years.
- Increase potential for connectivity among isolated local free-ranging, disease-free populations, and for population expansion (after the risk of brucellosis and Tb transmission has been eliminated).
- Address and reduce additional important key threats to wood bison and their habitat.
- Increase public awareness and acceptance for wood bison, including acknowledging and augmenting social, cultural, ecological, and economic relationships among wood bison and Indigenous peoples and local communities.

Updated wood bison action plans are anticipated by 2022 (ECCC 2018, p. vi). However, recommendations made by ECCC (2018, p. 1) to down list the wood bison from Threatened to Special Concern is under evaluation by ECCC. If a change in SARA designation results, a Management Plan will be produced.

Section 4(f) of the ESA directs the Service to develop and implement recovery plans for the conservation and survival of endangered and threatened species, unless the Director determines

that such a plan will not promote the conservation of the species. The Service does not intend to prepare a recovery plan for this species (79 FR 26184). However, the Canadian Recovery Plan (ECCC 2018, entire) may be adopted provided all statutory requirements of the Act are satisfied. The Canadian wood bison recovery plan and recovery strategy provide the over-arching approach to recovery of this species range-wide, and site-specific management plans will be prepared by the ADF&G. The ADF&G will specify how each reintroduction will be conducted. There would be no benefit in preparing an additional recovery plan under the Act. In addition, wood bison currently exist in the wild only in Canada, and the Service does not prepare recovery plans for species that occur only in foreign countries.

3.3.2 Conservation and Recovery Actions

To better increase wood bison redundancy and foster the restoration of wood bison in other parts of their original range, efforts were initiated to establish one or more free-ranging, disease-free populations in Alaska.

To facilitate reintroduction efforts in Alaska, a captive breeding and holding center for wood bison was established at the AWCC in Portage, Alaska. In June 2008, under permits obtained from the Service, U.S. Department of Agriculture, Canadian Wildlife Service, and the State of Alaska, 53 wood bison were translocated from the disease-free EINP herd to a temporary holding facility at the AWCC, where they joined a small existing herd that was confiscated in 2003 after being imported illegally. All of these animals were subjected to a rigorous disease-testing protocol while in preparation for release of a free-ranging wood bison herd in Alaska. The AWCC herd plays an important role in wood bison conservation because it is an isolated, disease-free herd and, consequently, provides security to the species through population redundancy. Thirteen wood bison were left at AWCC when 130 were transported to the wild in 2015. In 2020, 28 bison resided at AWCC, and about half of them are available for release. Future wood bison releases within Alaska will likely occur using wood bison from this location.

In 2013, the ADF&G submitted an Environmental Assessment for the designation of a nonessential experimental population status for wood bison in interior Alaska. Following the development of a cooperative management plan, the initial release site was evaluated to occur at the lower Innoko-Yukon River site (ADF&G 2013, entire). In 2014, the Service published a Final Rule establishing a nonessential experimental population (NEP) of wood bison in Alaska (79 FR 26175).

The reintroduction of wood bison to Alaska is patterned after successful reintroductions in Canada. The goal of the Alaska wood bison restoration project is to reestablish one to three free-ranging populations followed by a long-term monitoring and evaluation process to determine feasibility of establishing additional populations in the future. In addition to contributing to the conservation and recovery of wood bison in North America, objectives of the Alaska reintroduction effort include: (1) restoring a key indigenous grazing animal to northern ecosystems; (2) restoring biological and habitat diversity and natural processes; (3) increasing the total number of wood bison in free-ranging, disease-free herds, thereby enhancing the overall survival of the species in the wild; (4) providing a regulatory framework that allows for sustainable development, including opportunities for local tourism and hunting and guiding

businesses; and (5) reestablishing the historical cultural connection between bison and Alaska residents (ADF&G 2007, pp. 2-3).

Although many private landowners within the NEP area have indicated support for the presence of wood bison on their lands in the future, some private landowners have expressed concerns about the potential legal and regulatory burdens related to the ESA if wood bison are reintroduced. These concerns include potential effects of reintroduction on resource development activities. Provisions in the special rule are designed to ensure that reintroduction of wood bison will not impede existing or potential future resource development activities within release, or areas determined within the NEP. Future releases of wood bison will be completed only after a suitable management framework has been developed by the State in cooperation with landowners, land managers, the Service, conservation organizations, and Tribal and local governments.

Experience with bison reintroductions in Canada suggests that reintroduced wood bison populations are likely to prosper in the areas where the State of Alaska proposes to restore the species (ADF&G 2007, pp. 11-12). In February 2020, ADF&G held a 3 day wood bison workshop to update the management plan for the Innoko-Yukon herd. The new plans allow for future releases to augment the Innoko-Yukon population. Future releases are possible within the NEP area, but there is presently no plan developed to release bison away from the Innoko-Yukon area (ADF&G 2013, entire; Tom Seaton, pers. comm., 2020).

Chapter 4: Past and Current Conditions

In this Chapter, we describe our analyses of the current condition of the wood bison relative to historical conditions. Specifically, we report the population status of all known populations, and we characterize the current degree of resiliency, representation, and redundancy of the wood bison.

4.1 Historical Distribution

The documented historical distribution of wood bison occurred throughout much of North America's boreal forest biomes. The exact extent of the historical range of wood bison cannot be determined with certainty based on available information, but was limited to North America (Gates et al. 2001b, p. 11). However, historically, the range of the wood bison was generally north of that occupied by the plains bison and included most boreal forests of northern Alberta, northeastern British Columbia east of Cordillera, a small portion of northwestern Saskatchewan, the western Northwest Territories south and west of Great Slave Lake, the Mackenzie River Valley, most of the Yukon Territory, and much of interior Alaska (Reynolds et al. 2003, pp. 1011-1012) (Figure 4-1). Skinner and Kaisen (1947, pp. 158, 164) suggested that the prehistoric U.S. range likely extended from Alaska to Colorado. However, both wood bison and plains bison may have interacted where their distributions overlapped in areas that are now central Alberta and British Columbia.

The historical range of wood bison in Alaska is estimated based upon the locations of subfossil specimens (Gardner and DeGange 2003, pp. 2, 21-24). Stephenson et al. (2001, p. 140) concluded that wood bison were present within what is now defined as Alaska until their disappearance during the last few hundred years. Oral narratives of late Holocene bison in Alaska obtained from Athabascan elders indicate bison were widely distributed within the upper Yukon and Tanana drainages of eastern Interior Alaska. Specific areas of past occurrence include the Yukon flats near Beaver, Chandalar, Porcupine, Black, and Hodzana River drainages (Stephenson et al. 2001, p. 129).

4.2 Current Distribution and Description of Populations

The population status and current distribution of wood bison is summarized in ECCC (2018, pp. 5-8). There are approximately 8,587 free-ranging wood bison in Canada and about 113 free-ranging wood bison in the United States based upon estimates made between 2010 and 2018 (ECCC 2018, p. 7; Tom Seaton, pers. comm., 2019). In Canada, there are 13 free-ranging populations; nine disease-free (not infected with bovine Tb or brucellosis) populations; three diseased populations; and one captive, disease-free population (Table 4-3; Figure 4-2). In the United States, there is currently one free-ranging, disease-free population, which was established through captive release in 2015. We discuss the history, demographics, and status of each of the populations below (van Zyll de Jong 1986, p. 28; Gates et al. 2001b, p. 11; Stephenson et al. 2001, p. 136) (Figure 4-2).



Figure 4-1. Historical distribution of wood bison during the last 5,000 years (ECCC 2018, p. 4, adapted from Stephenson et al. 2001, p. 126).

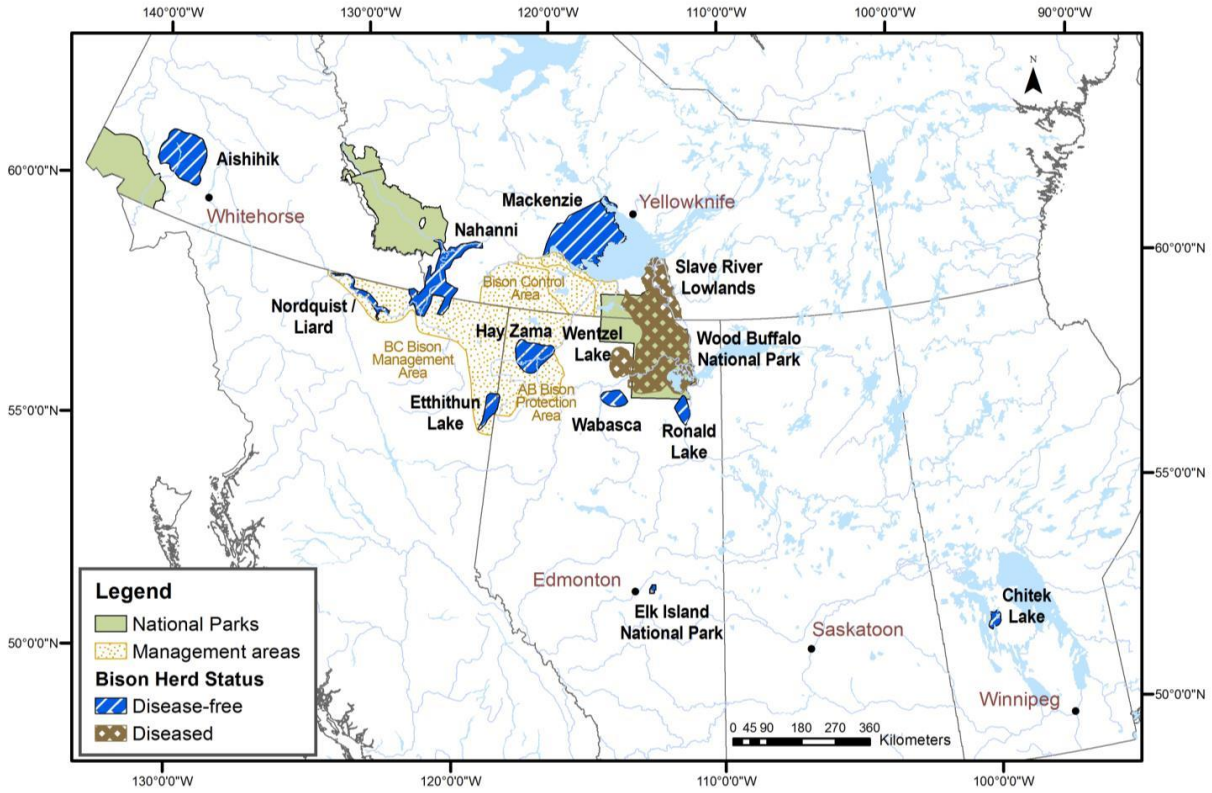


Figure 4-2. Free-ranging wood bison herds in Canada. Diseased status of each herd indicated within map inset to illustrate the presence or absence of bovine brucellosis and Tb. Light brown stippled areas represent wood bison control and management areas within Northwest Territories, British Columbia, and Alberta. Green areas represent National Parks. From ECCC (2018, p. 8).

In addition, there are an estimated 45 to 60 commercial herds of wood bison in Canada, which contain approximately 500 to 700 individuals (Gates 2001b, p. 14; ECCC, 2018, p. 5), and 1 captive conservation herd of 28 individuals in the United States at the AWCC in Portage, Alaska. Further, three populations of wood bison occur outside the historic range of the wood bison in Yakutia, Russia. These include two captive herds located at the Ust-Buotama and Tympynai reservations, and one free-ranging population within the Sinyaya Nature Park (Rob Found, pers. comm., 2020). Presently, there are 212 wood bison in Yakutia. We recognize wood bison may exist in captive and free-ranging herds outside the species' historic range that are not addressed in this assessment. Due to the inherent small size and lack of data, we focus this assessment on those herds and populations that appear to provide meaningful contributions to the overall viability of the species.

Alaska Population

To facilitate reintroduction of wood bison in the United States, on January 18, 2013, the Service published a final rule in the Federal Register designating the establishment of a NEP of wood bison in Alaska (79 FR 79 26175, entire). Under the ESA, the Service may establish an experimental population, allowing for the reintroduction of a species to its former range with special rules that allow for some of the management requirements of the ESA to be relaxed to facilitate acceptance by local landowners and managers.

4.2.1 Innoko-Yukon

The Innoko-Yukon population was established through efforts led by the ADF&G. In April, May, and June of 2015, successful releases of wood bison occurred, when 130 disease-free wood bison from the AWCC were reintroduced into the Lower Innoko-Yukon River area near the village of Shageluk, approximately 300 miles west of Anchorage. Through three release events, 50 adult cows, 30 adult bulls, and a mixture of young males and females (30 calves and 20 yearlings/2-year old were released (ADF&G 2015, p. 1-2; Tom Seaton, pers. comm., 2019). Since their release, the wood bison have expanded their range. The 2019 population estimate for the Innoko-Yukon herd is 113 individuals (Tom Seaton, pers. comm., 2020). Currently, the Innoko-Yukon population is the only known, free-ranging wood bison population in the United States (Harper and Gates 2000, p. 917; Stephenson et al. 2001, p. 140).

Under the current species status, the Innoko-Yukon population is not subject to regulated hunting, however three illegal shootings of wood bison have been confirmed in Alaska since 2015. Illegal shooting of wood bison occurred in 2016, 2017, and 2018. All of the confirmed shootings were of radio-collared animals; ADF&G suspects, based on logical extrapolation, that more were shot that did not have radio collars and were therefore undetected (Tom Seaton, pers. comm., 2020). As the population grows and juveniles roam, bison are increasingly likely to come into contact with novel villages, thus increasing their chance of being illegally harvested.

Occasional small-scale drowning events are a naturally-occurring factor and could be sustainable for a robust population. However, unusually large flooding events pose a threat due to the severity of their impact on current wood bison populations. Furthermore, additional factors beyond flooding can cause unusually significant drowning events. The Innoko-Yukon population is exploring new territories as they expand their range in Alaska. Although major flood events have not been observed as a source of drowning mortality for this population, in the first year following release into the Innoko-Yukon area, 22 percent of the wood bison population died as animals adjusted to the wild. The most common cause of death was drowning when individuals broke through thawing ice on waterbodies (ADF&G 2018, p. 2). The drowning of these individuals is attributed to a lack of familiarity with the surrounding landscape given their status as a newly introduced population. The Innoko-Yukon population have persisted upon the landscape and became more familiar with their environment, and as such, drowning related to non-flood events may decrease (Tom Seaton, pers. comm., 2019).

Harsh winters with heavy snowfall or thick ice formation via freezing rain or snow melts may lead to bison starvation or predation as observed with the Hay Zama population in 2012 (COSEWIC 2013, p. 54). The Innoko-Yukon population experienced a mortality event in March and April, 2018, where 35 percent of the population was lost when snow persisted 6 weeks longer than normal (Tom. Seaton, pers. comm., 2019). The spring thaw came late, and deep, hard snow conditions inhibited foraging opportunities and movement for bison. In addition to starving-induced mortality, the first signs of predation were recorded during this period. Evidence suggests wolves killed four young bison and injured at least one adult (ADF&G 2018, p. 2). Wolves were able to more successfully hunt and kill bison because snow depth and the consistency of the snow surface made the bison more vulnerable. Prior to the weather event, the Innoko-Yukon population was growing at a rate of 5 percent per year and the 2018 calving season saw 11 cows produce calves (demonstrating a level of adaptability).

Lack of connectivity to other wood bison herds may slow recovery in Alaska. The Innoko-Yukon wood bison population is an isolated population and is the only population within the United States. The closest herd is the Aishihik Herd located in British Columbia approximately 850 miles (1,375 km) away. Maintaining connectivity between populations is important for genetic exchange so populations do not become isolated and suffer the potential negative consequences of inbreeding (Hedrick and Kalinowski 2000, entire). The nearest free-ranging plains bison herd is located in Farewell, Alaska, approximately 200 miles direct distance east of the release site in Shageluk, Alaska. Three other free-ranging plains bison herds exist in Alaska, the Delta Junction (450 miles direct distance), Copper River (500 miles direct distance), and Chitina River (550 miles direct distance) local populations. The Chitina River and Copper River plains bison herds are isolated from the Innoko-Yukon population via the Kuskokwim, Alaska, and Talkeetna mountain ranges.

The final 10(j) rule establishing a NEP of wood bison in Alaska identified several overarching wood bison conservation actions and management actions (79 FR 26175). These activities are focused on population monitoring, disease monitoring and prevention, maintaining the integrity of wood bison genetic diversity, mortality assessments, protection measures, and outreach for public awareness and cooperation. The Final Rule also established ADF&G as the lead agency with management authority of the Innoko-Yukon population. As such, ADF&G has implemented a wood bison management plan for the lower Innoko-Yukon population to "through the collaboration of many, reintroduce and manage a sustainable wood bison herd while ensuring a healthy landscape benefiting all people for future generations" (Alaska Wood Bison Management Planning Team, 2015, entire). In support of the management plan, ADF&G and stakeholders are engaged in field surveys to collect biological data on seasonal diets, and seasonal ranges and movements as well as outreach with communities (Tom Seaton, pers. comm., 2020).

Finally, some may perceive that the mere protection status under the ESA could limit potential use or future opportunities for use of property within the range of wood bison. However, section 10 of the ESA offers a mechanism to authorize activities that would otherwise be prohibited. Under section 10(j), the Secretary of the Department of the Interior can designate reintroduced populations established outside the species' current range, but within its historical range, as "experimental." Under a 10(j) designation as "nonessential, experimental," both the take prohibitions and consultation requirements of the ESA are relaxed, easing regulatory burden associated with endangered species. Critical habitat is not designated for reintroduced populations that are designated as nonessential experimental populations. With the special allowances afforded under the 10(j) rule, landowners can continue to manage their lands without concern about violating the ESA by inadvertently harming a reintroduced species.

Canada Populations

Greater Wood Buffalo National Park Metapopulation

Three subpopulations (WBNP, Wentzel Lake, and the Slave River Lowlands) are all clustered in close geographic proximity around WBNP, which has led to these populations being referred to as the GWBNP metapopulation (Ball et al. 2016, pp. 1527, 1532; ECCC 2018, p. 5). Collectively, the GWBNP populations represent the largest, free-ranging and genetically diverse metapopulation of wood bison in the world (Wilson and Strobeck 1999, p. 492; Wilson et al.

2005, p. 912; McFarlane et al. 2006, p. 25, 26). All local populations within and around WBNP (including Wabasca and Ronald Lake) represent the only location worldwide where wood bison have continually persisted or naturally colonized.

4.2.2 Wood Buffalo National Park

Wood Buffalo National Park was established in northeastern Alberta in 1922 to provide refuge for approximately 1,500 to 2,000 wood bison and to preserve wood bison habitat (Soper 1941, p. 349; COSEWIC 2013, p. 19). From 1925 to 1928, 6,673 plains bison were transported to WBNP from Buffalo National Park, Wainwright, Alberta (Soper 1941, p. 375; Lothian 1981, unpaginated). The translocated plains bison hybridized with local wood bison and the resulting admixed population became the founding stock for all modern day wood bison (COSEWIC 2013, p. 20). The translocation of plains bison into WBNP also introduced bovine Tb (*Mycobacterium bovis*) and brucellosis (*Bovine abortus*) exposing wood bison to these two cattle-derived diseases (Tessaro 1989, p. 417; Joly and Messier 2001, p. 543). In 1959, a small group of wood bison were located within northwestern WBNP and determined to be disease free. Sixteen of these newly located animals were successfully transported to the Mackenzie Bison Sanctuary, and 23 were moved to EINP, Alberta. Thus, the population identified as the WBNP subpopulation has been an important source for the reintroduction of wood bison in Canada.

The current population estimate of wood bison in the WBNP subpopulation is estimated to be 3,363 individuals (ECCC 2018, p. 7). Disease prevalence of bovine Tb and brucellosis within the WBNP is 30 to 40 percent (ECCC 2018, p. 7). Population management is conducted to contain or reduce the proliferation of brucellosis and Tb in bison (Harper et al. 2000 p. 24; Gates et al. 2001b, p. 35; Nishi 2010, p. 31; Government of Alberta 2011, as cited in COSEWIC 2013) from the GWBNP metapopulation. The GWBNP ecosystem has a history of anthrax outbreaks; between 1962 and 2015 there have been 13 documented anthrax outbreaks occurring in WBNP. (Species at Risk Committee 2016, p. 122). Low public license or acceptance (ECCC 2018, Appendix 1) also limits potential range expansion of this population.

4.2.3 Slave River Lowlands

The Slave River Lowland local population occurs in the Northwest Territories and spans both sides of the Slave River into the area designated in 1922 as Wood Buffalo National Park. The Slave River Lowlands population is considered part of the GWBNP metapopulation based on gene flow (Ball et al. 2016, p. 1532) and the potential dispersal/migration between Wentzel Lake and WBNP local populations.

In 1970, the Slave River Lowlands population was estimated to be approximately 2,500 bison. By 1994, there were 212 bison in the eastern Slave River Lowlands (Hook Lake herd) and 463 in the western Slave River Lowlands (Little Buffalo herd) (Gates et al. 2001b, p. 20). The most recent estimated population size for the Slave River Lowlands population is 662 (ECCC 2018 p. 7). The Slave River Lowlands is currently a free-ranging local population infected with both bovine Tb and brucellosis (Gates et al. 2001b, p. 19).

The Slave River Lowlands local population is managed to prevent the transmission of bovine Tb and brucellosis to healthy wood bison outside the GWBNP (ECCC 2018, p. 18). This management, including implementation of the BCA surrounding the GWBNP metapopulation,

precludes existing disease-free bison from occupying and colonizing within these areas thereby limiting range expansion and connectivity among adjacent subpopulations. The continued presence of bovine Tb and brucellosis in the Slave River Lowlands area poses an ongoing risk that they will be transmitted to other wild bison populations. Anthrax is a naturally occurring disease in northern bison and outbreaks of varying proportions have arisen in the GWBNP ecosystem. Between 1962 and 2015 there have been eight documented anthrax outbreaks within the Slave River Lowlands (Gates et al. 1995, entire; Species at Risk Committee 2016, p. 22). The Slave River Lowlands local population within the Northwest Territories and Alberta is monitored annually and hunting is unregulated (Gates et al. 2001b, p. 17).

4.2.4 Wentzel Lake

The Wentzel Lake population ranges north of the Peace River between the southwest boundary of WBNP and Wentzel Lake (Gates et al. 2001b, p. 20). Although the Wentzel Lake local population is considered part of the GWBNP, it is managed and monitored separately under the authority of the Government of Alberta.

The Wentzel Lake population is considered part of the GWBNP metapopulation based on dispersal potential between the Wentzel Lake and WBNP subpopulations, potential gene flow, and its geographical location to other herds within WBNP (Ball et al. 2016, pp. 1527, 1532; ECCC 2018, p. 5). The most recent estimated population size for the Wentzel Lake herd is 199 (ECCC 2018, p. 7). The Wentzel Lake local population is currently a free-ranging local population infected with both bovine Tb and/or brucellosis (Gates et al. 2001b, p. 16; Government of Alberta 2017, p. 9).

The Wentzel local population is managed to prevent the transmission of bovine Tb and brucellosis to healthy wood bison outside the GWBNP (ECCC 2018, p. 18). This management, including implementation of the BCA surrounding the GWBNP metapopulation, precludes existing disease-free bison from occupying and colonizing within these areas thereby limiting range expansion and connectivity among adjacent subpopulations. The continued presence of bovine Tb and brucellosis in the Wentzel Lake local population poses an ongoing risk that they will be transmitted to other wild bison populations. The BCA surrounding the GWBNP metapopulation within the Northwest Territories and Alberta is monitored annually and hunting within the BCA is unregulated (Gates et al. 2001b, p. 17). The probability of the wood bison of the Wentzel population moving west is high (Gates et al. 2001a as reported in Government of Alberta 2017, p. 5).

4.2.5 Elk Island National Park

The EINP population in Alberta, Canada, was established in 1965 from 23 wood bison transferred from an isolated portion of WBNP. In 2017, an aerial census of wood bison within EINP reported 333 individuals (Parks Canada 2018, p. 11).

Shortly after their arrival in EINP, bovine brucellosis and Tb was detected in the herd and an intensive program of testing, vaccinations, and euthanasia ensued over the next couple of years to eradicate the disease. To maintain the herd, all females were euthanized after they calved, and calves were nursed with bottle feeding. As a result, the EINP wood bison population, and all herds derived from it, are descended from 11 bottle-fed calves (Blyth and Hudson 1987, as cited

in Parks Canada 2018, p. 11 Wilson and Stroebeck 1999, p. 494; MacDonald 2010, as cited in Parks Canada 2018, p. 11).

Currently, the captive herd at EINP is the Canadian national conservation herd and has provided disease-free stock for free-ranging populations and captive breeding herds in zoos and private commercial ranches (Gates et al. 1992, p. 153; Parks Canada 2018, p. 13). The first translocation of wood bison from EINP occurred in 1977 (Blyth 1995, as cited in Parks Canada 2018, p. 9). Since then, eight wood bison herds have been established in Canada, the United States, and Russia with wood bison translocated from EINP (Gates et al. 2010, as reported in Parks Canada 2018, p. 9). Much like WBNP, EINP has been an important source for wood bison reintroductions, and therefore has been a key component of recovery efforts. Elk Island National Park was the source of wood bison that were released into the wild in 2015 as part of Alaska's wood bison restoration effort.

Carrying capacity at EINP is approximately 350 animals; animals above this number are regarded as surplus and are removed to establish and supplement free-ranging populations in former areas of their historic range (Parks Canada 2009, unpaginated). Within EINP, management goals set the recommended minimum viable population for wood bison at 245 with a recommended adult population of 260-300 individuals (Parks Canada 2018, p. 11). Adult wood bison population targets based on minimum viable population levels are set to maintain genetic diversity of the herd.

Although the herd is fenced, the animals are semi-wild and spend the majority of their time roaming the 65 km^2 (25 mi^2) enclosure, interacting with the environment in a largely natural manner (Gates et al. 2001b, p. 18). The herd is round up annually to test for disease and to vaccinate for common cattle diseases. The age, sex, and condition of all the individuals are determined to inform management decisions. Using this information, individuals are selected for sale, donation, or the establishment of new herds, which also controls the population size of the herd (Parks Canada 2009, unpaginated).

4.2.6 Aishihik

From 1988 to 1991, 5 releases of wood bison, totaling 170 animals, established the Aishihik herd in southwestern Yukon, in a remote area west of Whitehorse, Canada. Herd size has totaled over 400 since 1999 (Gates et al. 2001b, p. 14). As of 2014, the Aishihik herd reported a population of approximately 1,470 animals, and is the second-largest herd at the time (Jung and Egli 2014, p. 4; ECCC 2018, p. 7). The Aishihik herd has steadily increased in size; calf recruitments were observed in the order of 17 to 21 percent per year (Government of Yukon 2012, p. 6).

The herd inhabits approximately 9,000 km^2 (3,475 mi^2) of largely undeveloped habitat near the community of Haines Junction, adjacent to Kluane National Park. The core range of the Aishihik herd currently extends eastward to the North Klondike Highway, southward to the Dezadeash River, northward to the Nisling River, and westward to the Ruby Range (Government of Yukon 2012; p. 5). Less than 5 percent of the range of the Aishihik herd is on private lands (First Nation Settlement Lands), and these landowners participate in a management planning team specifically for this herd. The remainder of the herd's range is owned by the Government of Canada.

The Aishihik herd has room to expand or shift its range, because there are no large-scale developments east, west, or north of the present range for several hundred kilometers. However, small-scale agricultural development to the south of the present range, could restrict expansion in this direction (Reynolds et al. 2004, p. 9).

Regulated hunting of this herd occurs with the goal of reducing population growth and size (Jung and Egli 2016, p. 1). Other than regulated harvest, no other limiting factors have been identified (Reynolds et al. 2004, p. 17; Government of Yukon 2012, p. 11). The Aishihik herd is managed by Environment Yukon, guided by Environment Yukon's Bison Program. Conservation actions undertaken in 2013-2014 included monitoring population trends, movements and spatial distribution, bison harvest, biological samples (e.g., blood, tissue, feces), and ecological impacts of bison (Jung and Egli 2016, entire).

4.2.7 Chitek Lake

The Chitek Lake herd was established in 1991, in Manitoba, Canada, when 13 wood bison were released into Chitek Lake Park Reserve, north of the Waterhen Wood Bison Ranch. An additional nine individuals (seven females and two males) were released in 1993 (Gates et al. 2001b, p. 14). The Chitek Lake herd was established from a captive wood bison herd at Waterhen, which originated from EINP translocated animals (Gates et al. 2001b, p. 14; COSEWIC 2013, p. 22). The herd is extralimital with respect to the original range of the wood bison, and is believed to have occupied an area of overlap between wood bison and plains bison during the winter months (COSEWIC 2013, p. 36). The Chitek Lake Management Committee maintains the herd at approximately 300 animals to keep the herd within the carrying capacity of the habitat. The 100,300-hectare (ha) (25,432-acre (ac)) Chitek Lake Park Reserve provides habitat protection for the core range of the herd. Although outside of the historic range of wood bison, the Chitek Lake herd plays an important role in wood bison conservation because it is an isolated, disease-free herd, and provides security to the species through population redundancy. The most recent population estimate for the Chitek Lake herd is 250-300 wood bison (ECCC 2018, p. 7). Limiting factors for the herd include mortality from drowning, winter nutritional stress (or deficiency), and predation (Manitoba Conservation, pers. comm., 2010 as reported in 77 FR 26191).

Grazing of livestock and privately owned bison on public lands is a local stressor for Chitek Lake wood bison in that operations preclude wild bison reintroduction and restoration on some suitable public lands (COSEWIC 2013, p. 67). Concern over wood bison reintroductions include exclusion of wood bison from provincial grazing dispositions and cattle or domestic/captive wood bison hybridization (COSEWIC 2013, p. 67).

Regulated hunting is used as a management tool to limit population growth of the Chitek Lake population. In 2014, the provincial government of Manitoba established Chitek Lake Provincial Park in a remote area of boreal forest approximately 215 miles northwest of Winnipeg. The park is off-limits to resource development from activities such as mining and logging.

4.2.8 Etthithun Lake

In 1999, a second attempt to establish a wild population of wood bison near Etthithun Lake occurred after an initial attempt failed when released animals mixed with a commercial plains bison herd (Harper and Gates 2000, as reported in COSEWIC 2013, p. 33). The founding stock for the 1999 reintroduction occurred when 19 animals were moved to a fenced enclosure from EINP to Etthithun Lake. The Etthithun Lake herd was established with the release of 42 wood bison in 2002 from the fenced enclosure near Etthithun Lake, British Columbia. The most recent population estimate for the Etthithun Lake herd is between 200-300 individuals (ECCC 2018, p. 7).

Factors limiting the size of this population include the amount and location of suitable habitat, conflicts with humans and industrial development, and potential contact with plains bison. The Etthithun Lake population lies in close proximity to agricultural lands, which limits the ability of for range expansion. Opposition from some commercial bison/cattle ranchers toward wild bison on the landscape may be a limiting factor, as well as the concern of disease transfer both to and from domestic animals.

4.2.9 Hay Zama

The Hay Zama herd was established in 1984, when 29 wood bison were transferred from EINP to the holding corral site near Hay Zama Lakes, Alberta (Gates et al. 2001b, p. 17). The population, then numbering 48 became free-ranging when portions of the corral they were being held in collapsed in 1993 (Gates et al. 2001b, p. 17). Since its establishment in 1984, the now free-ranging herd has grown to approximately 626 animals (ECCC 2018, p. 7).

Collisions with motor vehicles are the largest source of uncontrolled mortality for individuals in this herd (Mitchell and Gates 2002, p. 9). The Hay Zama herd occurs near transportation and service corridor Highway 35, a direct mortality source from collisions with vehicles (ECCC 2018, pp. 11, 17). Wood bison are known to use linear corridors for grazing and transit (ECCC 2018, p. 16), and wood bison on roadways are difficult to see at night and in inclement weather (ECCC 2018, pp. 54-55, Appendix 1), making them more susceptible to collisions.

To maintain the Hay Zama wood bison herds free of disease (bovine Tb and brucellosis), highly regulated hunting seasons are implemented to control increasing population numbers and range expansion. Hay Zama bison are disease-free and are within proximity to known, or assumed infected populations in and around WBNP (Government of Alberta 2017, p. 3; ECCC 2018, p. 18). The regulated harvest of Hay Zama bison helps protect the herd from infection by decreasing population numbers and dispersal/distribution.

In 1995, the Government of Alberta established a 36,000 km^2 (13,900 mi^2) Bison Management Area around the Hay Zama herd in the northwestern corner of the province. In this area, all wood bison are legally protected from hunting under Alberta's Wildlife Act; outside of the area they are not protected. Surveillance areas are identified to assist with detection of bison (presumably infected) moving from the east (WBNP) towards the Hay Zama herd or Hay Zama animals moving west towards infected areas. Similarly, a surveillance zone to the west of the herd helps detect (presumably infected) animals moving east from known infected herds in WBNP, Wabasca, and Wentzel Lake areas.

4.2.10 Mackenzie

The Mackenzie bison herd was established in 1963, with the translocation of 16 wood bison that were originally captured in an isolated area of WBNP. The Mackenzie Bison Sanctuary was established in 1979, and encompasses an area of 6,300 km^2 (2,432 mi^2) northwest of the Great Slave Lake. The current range of the Mackenzie bison herd (12,000 km^2 (4,663 mi^2)) extends well beyond the boundaries of the sanctuary.

The Mackenzie herd size has exceeded 400 individuals since 1987, with approximately 1,600 to 2,000 animals (Gates and Larter 1990, p. 233). The population reached its highest in 1989 with 2,400 animals and fluctuated between 1,800 and 2,400 animals between 1989 and 1999 (MBWG 2018, p. 8). The most recent population estimate for the Mackenzie herd was approximately 851 individuals in March 2016 (ECCC 2018, p. 7; MBWG 2018, p. 12).

The most significant threat for the Mackenzie population is disease (Species at Risk Committee 2016, p. 71). Bison Containment Areas to the south of the Mackenzie herd prevents dispersal from diseased populations within WBNP. The BCA ensure that no dispersal from wood bison populations elsewhere could occur with the Mackenzie herd (Species at Risk Committee 2016, p. 13). The nearest bovine Tb- and brucellosis-free wood bison are in the Nahanni population; however, the western portion of the BCA, the Mackenzie River, and an extensive area of habitat poorly suited to bison separate them from the Mackenzie herd. Although this separation typically is desirable to limit disease transmission, in this case the separation also limits genetic interchange between the populations and limits the opportunities for establishment of new populations in the area through dispersal. At this time, bovine Tb- and brucellosis are not thought to be present in the Mackenzie herd.

In recent years, mortality factors such as drowning and anthrax, coupled with reduced forage caused by flooding of inland lakes, reduced herd numbers to fewer than 1,000 animals. In May 1989, 177 animals drowned in Falaise Lake from a then population of 2,400 (Gates et al. 1991; as reported in MBWG 2018, p.8). In 1993, a major outbreak of anthrax occurred within the Mackenzie population resulting in the deaths of 172 individuals (Gates et al. 1995, p. 258). In 2012, a second major outbreak of anthrax occurred in the Mackenzie population resulting in the death of 451 individuals, a mortality rate of approximately 50 percent from among all age cohorts (McNab 2015, as reported in ECCC 2018, p. 22; Species at Risk Committee 2016, pp. 122, 234).

In addition to catastrophic mortality events, such as drowning, anthrax, weather, and flooding, Mackenzie bison are subject to harvest, bison–vehicle collisions, and habitat changes caused by rising water levels in shallow lake basins, which are important grazing areas (WBWG 2018, p. 8). Road mortality from bison-vehicle collisions is common between August and December in the Mackenzie population (GNWT 2010, p. 11). Approximately 20 incidents involving bison-vehicle collisions are reported each year in the Northwest Territories (Species at Risk Committee 2016, p. 126). The Mackenzie herd experiences the largest number of bison mortalities due to motor vehicle collisions of wild wood bison herds in Canada; over 380 bison were killed in vehicle collisions from 1989 to 2015 (Species at Risk Committee 2016, p. 127).

Some suggest an increase of water levels within the Great Slave Lake/Mackenzie River region have accounted for loss of grazing habitat, which may be a contributing factor to the decline of wood bison numbers since 1990 (MBWG 2018, pp. 46-47). Flooding from beaver activity may inundate low lying areas and temporarily reduce grazing habitats for wood bison. These areas may become available for grazing by wood bison after the beaver dams break and the dried ponds are recolonized by grass and sedge species (MBWG 2018, p. 47).

The Mackenzie herd first supported harvest and regulated hunting in 1987, when the herd had reached approximately 1,500 bison. This herd continued to grow, to a maximum estimated size of 2,400 around 1989, and supported an annual harvest of approximately 40 animals for several years after that point. Regulated hunting was temporarily ceased in 2012 to allow populations to return to more than 1,000 individuals; however, wood bison have always been managed by a quota set under provincial Big Game Hunting Regulations.

Wildfires are a component of wood bison habitat maintenance as they help maintain sedge meadows and grasslands within early stages of vegetation succession and seral stages. Wildfire suppression efforts in Canada at the turn of the 20th Century and in the mid-1900s may have contributed to a Northwest Territories regional reduction of wood bison carrying capacity (Strong and Gates 2009, p. 439). However, fire management that mimics natural fire regimes is not considered a threat to bison and may aid maintenance of sedge and grassland habitats (ECCC 2018, p. 19). See Section *3.2.4 Stochastic and Severe Weather* for a detailed discussion on this stressor.

In 2010, the Government of the Northwest Territories released the final Wood Bison Management Strategy which indicates sufficient habitat is present within the Northwest Territories to support expanding bison populations (GWNT 2010, entire). Habitat protections within the range of the Mackenzie bison herd is facilitated through the SARA and the Mackenzie Valley Resource Management Act of 1998. Although the Mackenzie Valley Resource Management Act does not specifically provide protection to wood bison, it did create a Land and Water Board, which is given the power to regulate the use of land and water, including the issuance of land use permits and water licenses. Under current management, an annual harvest is allowed and the Mackenzie herd size has exceeded 400 individuals since 1987, with approximately 1,600 to 2,000 animals (Gates and Larter 1990, p. 233).

The BCA is a program implemented by the Government Northwest Territories to reduce the risk of disease transmittal (bovine Tb) from bison in WBNP and the Slave River Lowlands to other bison populations. Formed in 1989, its purpose is to create a barrier to bison movements and dispersal of free-ranging bison between diseased and disease-free populations within the Northwest Territories. The BCA program remains an important component of managing bovine brucellosis and Tb in the Northwest Territories.

4.2.11 Nahanni

The Nahanni herd was established in 1980 with the release of 28 wood bison. The Nahanni wood bison herd occurs along both sides of the Liard River Valley Blackstone River in the Northwest Territories extending southeast to Yukon and southward to northern British Columbia. In 1981, population estimates for this herd had declined to 14 individuals, with the reduction

caused by accidental deaths and dispersal (Gates et al. 2001b, p. 17). The population was bolstered by supplemental releases of 12 animals in 1989 and 59 animals in 1998 (Larter and Allaire 2007, p. 3). Population size has been approximately 400 animals or more since 2006, and, based on surveys, was estimated at 413 in 2010 (Larter, pers. comm. as reported in 77 FR 26195). The most recent population estimate for the Nahanni herd is 431 individuals (ECCC 2018, p.7).

The most significant potential threat for the Nahanni population is a single large drowning event (Species at Risk Committee 2016, p. 71). The Liard River bisects the range of the Nahanni population (Larter et al. 2003, p. 410; ECCC 2018, p. 10). Wood bison regularly cross the Liard River to access forage in riparian habitats throughout the Liard Valley (Larter et al. 2003, p. 410). Because of these movements, Nahanni animals are susceptible to drowning as individuals caught along the river bank and riverine islands are exposed to fluctuating currents and water levels during spring break up (Larter et al. 2003, p. 411). Although drowning remains a source of mortality for individuals, no reporting of mass drowning within the Nahanni population have occurred as with the Mackenzie or WBNP populations (Gates et al. 1991, p. 32, as reported in MBWG 2018, p. 8).

Wood bison of the Nahanni herd are subject to collisions with recreation, transportation, or seismic exploration boating traffic on the Liard River (ECCC 2018, p17). Watercraft could cause bison mortality through direct contact (collisions) or through waves or turbulent water that can swamp bison while they are crossing the Liard River (Larter et al. 2003, p. 412).

Hunting is used as a management technique to restrict the distribution of bison in the Northwest Territories by preventing them from expanding their range into the BCA and establishing herds there. Management control actions (i.e., BCAs) are also used to prevent the hybridization of Nahanni wood bison with the Pink Mountain plains bison herd (Harper et al. 2000, p. 11). The Nahanni population was granted special protection from unrestricted hunting as a provision of being declared a species in danger of becoming extinct (Northwest Territories Act, as cited in Species at Risk Committee 2016, p. 121). Harvest of the Nahanni population has ranged from two to five animals annually since 2008 (Species at Risk Committee 2016, p. 121).

Low genetic diversity, inbreeding depression, and genetic drift, and hybridization with plains bison are additional stressors on the Nahanni population. The most immediate hybridization stressor is between the Nahanni wood bison population and feral plains bison in British Columbia, the Pink Mountain plains bison population. The genetic integrity of every wood bison herd existing today is already compromised by some plains bison introgression (Wilson and Strobeck 1999, pp. 492-494).

Conservation actions and management goals for the Nahanni population are developed in support of the Species at Risk Act Recovery Strategy for the Wood Bison in Canada (ECCC 2018, entire). Subsequent action plans by ECCC, Parks Canada, and other Canadian jurisdictions, agencies, and/or organizations are put forth to aid in the conservation of the species. The Environmental and Natural Resources, Government of the Northwest Territories, put together the Species at Risk Committee to compile and analyze the best available information on the biological status of the wood bison in the Northwest Territories. Hunting, land-use planning

activities, bison free buffer zones, disease control, fire management, and forestry remediation are conservation measures being implemented for conservation of the species and to varying degrees for the Slave River Lowlands, Mackenzie, and Nahanni populations within the Northwest Territories. For a complete review of these conservation measures as positive influences on wood bison populations within the Northwest Territories, please review Species at Risk Committee (2016, entire).

4.2.12 Nordquist/Liard

The Nordquist local population was established in March 1995 near the Liard River in northeastern British Columbia. Forty-nine animals (4 adult males, 5 adult females, 5 yearling males, 10 yearling females, 10 male calves, and 15 female calves) from EINP were released near Aline Lake in the Nordquist Flats area of the Liard River valley. The reintroduction site for this herd was approximately 80 km (~50 mi) from the southern edge of the Nahanni herd range. Population estimates reported in ECCC (2018, p. 7) suggest the Nordquist/Liard has an estimated population of approximately 200-250 individuals. Experts anticipate the Nordquist and Nahanni herds will eventually coalesce into one herd because of their close proximity and the presence of the river corridors that provide travel corridors (Gates et al. 2001b, p. 18). It is unknown if this has happened at this time. However, a combination of the two herds would increase the population to between 631 to 681 individuals (ECCC 2018, p. 7).

Because the majority of the herd occupies habitats near the Alaska Highway, vehicle collisions are a potential source of mortality (Reynolds et al. 2009, p. 6). Although uncommon, lone bulls and small groups of wood bison are known to create traffic hazards on the Alaska Highway in the vicinity of Liard Hot Springs (Harper et al. 2000, p. 17). Nordquist wood bison vehicle collision information presented at the 2006 Bison and Roads Committee meeting reported 74 to 76 wood bison road kills between 2005 and 2010 (Wildlife Collision Prevention Program, Accessed November 08, 2019; unpaginated).

The hybridization of the wood bison with free-ranging plains bison, domestic bison, and cattle is a stressor upon the Nordquist herd. The Pink Mountain plains bison herd is a free-ranging population established in British Columbia within the range of wood bison (ECCC 2018, p. 18). To mitigate the stressor of hybridization, a BCA was established to restrict movements and maintain mutually exclusive ranges between woods and plains bison in the region.

Maintaining isolation from plains bison is an ongoing practice to prevent hybridization. The Wood Bison Protection Area was designated as an active control zone to prevent the hybridization of the Nordquist/Liard, Nahanni, and Hay Zama wood bison herds with the Pink Mountain plains bison (Harper et al. 2000, pp. 19-21). Prescribed fire has been used in the past and will likely continue to be used to improve bison grazing habitat for the Nordquist/Liard population (Gates et al. 2001b, p. 17).

4.2.13 Ronald Lake

There is little information available describing the history of the Ronald Lake wood bison population. The population estimate for the Ronald Lake herd is approximately 200 individuals (ECCC 2018, p. 7). Ronald Lake, along with other local populations in and around the GWBNP,

represents the only location in the world where wood bison have continually persisted upon the landscape.

Given the close proximity of the Ronald Lake population to WBNP in northeastern Alberta, it was believed Ronald Lake bison were infected bison from WBNP. Ronald Lake was likely established from WBNP in the past. However, genetic data of this population was significantly different from that of the GWBNP metapopulation, suggesting the Ronald Lake population does not experience much genetic exchange or contact with the GWBNP populations (Ball et al. 2016, p. 153). Currently there are no control areas separating diseased populations (i.e., GWBNP) from the disease-free Ronald Lake herd. From 2011 to 2015, 73 individuals from the Ronald Lake herd were tested for disease; no animals tested positive for disease (Government of Alberta 2017, p. 9; ECCC 2018, p. 7). Based on these results, the Ronald Lake population is considered to be disease-free.

The presence of Canada thistle (*Cirsium arvense*) within the range of the Ronald Lake herd is considered a mechanism that maintains the separation between the diseased WBNP and disease-free Ronald Lake local populations; wood bison in WBNP avoid passage and grazing through areas where Canada thistle is present. Some speculate Ronald Lake wood bison may be pushed into these suboptimal habitats if development continues within their range (ECCC 2018, Appendix 1).

Resource and energy development projects, which are proposed for the Alberta oil sands area of northwest Alberta, would displace bison from all areas where open-pit mining may occur. Indigenous groups have expressed concern over the long-term viability of the Ronald Lake population within the northern periphery where proposed open-pit mining activities may occur (ECCC 2018, Appendix 1). Noise disturbance associated with forestry activities is reported to displace wood bison from those areas (Mikisew Cree First Nation 2015; as cited in ECCC 2018, p. 16). A variety of human-bison conflicts may arise where developments occur, including road mortality, aggressive behavior towards humans, or damage to human structures, which may result in deleterious effects to individual animals.

The Ronald Lake population of wood bison is considered a "*subject animal*" under Alberta's *Wildlife Act* (March 31, 2016) which places restrictions on the non-indigenous harvest of animals (ECCC 2018, p. 2). The Ronald Lake herd has high importance for the First Nations and Métis peoples in the area, because it is the only local wood bison population in the region that is disease-free and can be legally hunted by Indigenous people (ECCC 2018, Appendix 1). Historically, harvest of Ronald Lake wood bison has occurred on sustainable levels; however, increased access into the area associated with rising industrial activity may result in considerably higher hunting pressure (ECCC 2018, Appendix 1).

4.2.14 Wabasca (Wabasca/Mikkwa)

There is little historical information available on the Wabasca/Mikkwa population (hereafter Wabasca). The Wabasca population is a free-ranging, disease-free herd located between the Mikkwa and Wabasca rivers in Alberta, Canada. Gates et al. (2001a, p. 20) reported 51 bison were observed in 1996 during an incidental aerial survey flyover of the Mikkwa and Wabasca

rivers. Current estimates suggest the population is approximately 30 to 40 individuals (ECCC 2018, p. 7).

Genetic data of the Wabasca population was significantly different from that of GWBNP metapopulation and Ronald Lake populations suggesting the Wabasca population does not have much genetic exchange or contact with the GWBNP metapopulation (Ball et al. 2016, p. 153). *Brucella abortus* was cultured from one bison of six tested for brucellosis and Tb in the area of the Wabasca herd (Tessaro et al. 1990, p. 179). Currently, there are no control areas separating known diseased populations of the GWBNP populations from the disease-free Wabasca population, which is in close geographic proximity to diseased local populations. The geographic proximity of the Wabasca population to the GWBNP population poses a risk for transmission of Tb and brucellosis infection given the lack of control measures to prevent mixing of individuals from these populations.

The Wabasca population, along with other local populations in and around the GWBNP (including Ronald Lake), represent the only location in the world where wood bison have continually persisted upon the landscape throughout their range. Wood bison of the Wabasca population and surrounding local populations (i.e., GWBNP and Ronald Lake) retain the greatest level of genetic diversity (Wilson et al. 2005, p. 912).

Current Stressors Summary

We compiled a list of major stressors to wood bison populations that we determined through literature review and expert opinion to have the greatest influence on the viability of wood bison (See section *3.2 Risk Factors)*. Reviewed here, these include: (1) disease (i.e., anthrax, bovine Tb, bovine brucellosis), (2) biological resource use (i.e., hunting and persecution), (3) invasive and other problematic species (i.e., presence/spread of thistle, prevalence of wolf predation), (4) stochastic and severe weather events (i.e., flooding, fire), (5) negative genetic effects, and (6) transportation and service corridors. Not all stressors act upon every population. However, we indicate "Yes" or "No" to denote whether a particular stressor is acting upon a local population (Table A.1, Appendix 1).

Overall, the greatest current stressor to wood bison is the transmission of bovine Tb and brucellosis to disease-free populations and the corresponding management actions taken to reduce exposure risk between populations. One such management action is the use of bison control zones or bison management areas around a local population of concern or interest. Control zones often include some of the highest quality habitat within the core range of the species. In addition to preventing infections, control zones are used to prevent free-ranging wood bison from contact and hybridization with free-ranging plains bison or domestic cattle. For example, in British Columbia, a control zone prevents the hybridization of the Nordquist/Liard, Nahanni, and Hay Zama wood bison populations with the Pink Mountain plains bison (Harper et. al 2000, p. 23, 25). Control zones inhibit range expansion, natural dispersal, and gene flow between local populations, which limits recovery through the loss of genetic diversity in isolated populations (ECCC 2018, pp. 18-19).

Based on current conditions, we determined an overall magnitude of threats acting upon a given population based on the relative weight of each stressor (Table A.1, Appendix 1). Categorical values range from "Low" to "Moderate" to "High" based on the relative severity and impact of the stressor. We did not assign quantitative weighting values; rather, we applied a qualitative weighting system where we made status category assignments by examining the most important threats sequentially, with generally universal category assignment based on presence or prevalence of each threat. Disease presence, particularly bovine Tb and brucellosis, presents the greatest threat to wood bison populations and receives greater weight in the analysis; disease-affected populations were placed into a high threat, low condition category. Secondary weighting was given to stochastic and severe weather events. Stochastic events (e.g., freeze thaw cycles and flooding) are often sources of high mortality for wood bison, with implications for the survival and growth of small populations. Although stressors are listed individually, cumulative impacts and synergistic effects among stressors over time are not well understood.

Based on current conditions, we assigned an overall High magnitude of threats to four populations (WBNP, Wentzel Lake, Slave River Lowlands, and Mackenzie), a Moderate magnitude of threats to four populations (Chitek Lake, Nahanni, Nordquist/Liard, and Innoko-Yukon), and a Low magnitude of threats to six populations (EINP, Aishihik, Etthithun Lake, Hay Zama, Ronald Lake, and Wabasca) (Table A.1, Appendix 1).

4.3 Summary of Current Conditions

We assessed the current condition of each wood bison population based on the status of the primary biological needs (Table 4-1) and on the following concepts:

- High: Populations are expected to have high resiliency. The number of wood bison within the population exceeds 1,000 individuals, which is the recovery goal established by ECCC (2018, p. 25); the population trajectory is positive (i.e., lambda is greater than 1), where recruitment exceeds mortality. The population is free of anthrax, bovine Tb, and brucellosis with no likelihood of transmission from, or contact with, a diseased population. Exhibits no likelihood for exchange of genetic material with plains bison or domestic cattle (deleterious genetic material). Connectivity with disease-free populations is maintained or improved. The geographic expansion potential is high; plenty of habitat available and accessible. These populations are expected to persist in 50 years and withstand stochastic events.
- Moderate: Population is expected to have moderate resiliency. The number of individuals within the population is 250-999; population trajectory is stable (i.e., lambda equals approximately 1). The population is free of anthrax, bovine Tb, and brucellosis with a low likelihood of transmission from, contact with, a diseased population. Exhibits low likelihood for exchange of genetic material with plains bison or domestic cattle (deleterious genetic material). Some connectivity among disease-free populations may occur although not well established. Resiliency is less than under High conditions, but the population is expected to persist in 50 years; stochastic events may have a greater effect than for populations with High condition.
- Low: Population is expected to have low resiliency. The number of individuals within the population is less than 250; population trajectory is decreasing (i.e., lambda is less than 1). The population is diseased with subject of infections of anthrax, bovine Tb,

and/or brucellosis, with a moderate likelihood of transmission from, or contact with, at least one other diseased population. Exhibits moderate likelihood for exchange of genetic material with plains bison or domestic cattle (deleterious genetic material). No current potential for connectivity to other disease-free populations and little to no potential for geographic range expansion.

Assumptions: We make the assumption that population estimates reported in ECCC (2018, p. 7) reflect current population numbers. These values represent the most current information available on these populations.

4.3.1 Current Condition of Local Populations

Based on our analysis of the current condition of the biological needs of the 14 wood bison populations, we have determined that one population is in High condition (Aishihik), 10 populations are in Moderate condition (WBNP, Slave River Lowlands, EINP, Chitek Lake, Etthithun Lake, Hay Zama, Mackenzie, Nahanni, Nordquist/Liard, and Innoko-Yukon), and three populations are in Low condition (Wentzel Lake, Ronald Lake, and Wabasca) (Table 4-2). Recovery goals in Canada occur at both short- and long-term time-scales. One objective to meeting recovery goals at both scales is that populations maintain a minimum, sustainable population size of 1,000 individuals. Based upon information provided in ECCC (2018, p. 17), two populations meet the minimum population size, Aishihik and WBNP. However, currently no population in Canada meets all population and distribution objective criteria for long-term recovery (ECCC 2018, p. 25).

Table 4-1. Condition categories used to determine the overall current conditions and projected future conditions of wood bison populations.

	Demographic/ Distribution Factors			Connectivity			
Condition Category	**# individuals**	**Population trend (λ)**	**Diseases of special concern**	**Likelihood of disease transmission**	**Likelihood of deleterious genetic exchange**	**Connectivity to disease free populations**	**Geographic expansion potential**
HIGH	1000+	Increasing population trend	Disease free	No likelihood of transmission	No likelihood of genetic exchange	Confirmed	Plenty of available habitat
MODERATE	250-999	Stable population trend	1 or 2 of anthrax, Tb, or brucellosis	Low likelihood of transmission	Low likelihood of genetic exchange	Potential	Some available habitat
LOW	< 250	Decreasing population trend	All of anthrax, Tb, brucellosis	Moderate likelihood of transmission	Moderate likelihood of genetic exchange	No current potential	No available habitat
EXTIRPATTED	**0**	**X**	**X**	**X**	**X**	**X**	**X**

Tb – Bovine Tuberculosis

Table 4-2. Current Conditions by Population.

Region	*Population*		*# individuals*	*Population trend*	*Diseases of special concern*	*Likelihood of transmission*	*Likelihood of deleterious genetic exchange*	*Connectivity to disease free populations*	*Geographic expansion potential*	*Overall Condition*
Canada	*GWBNP*	*WBNP*	High	Moderate	Low	Low	High	Low	Low	**Moderate**
		Wentzel Lake	Low	Moderate	Low	Low	High	Low	Low	**Low**
		Slave River Lowlands	Moderate	Moderate	Low	Low	High	Low	Low	**Moderate**
	Elk Island NP		Moderate	Moderate	High	High	High	Low	Low	**Moderate**
	Aishihik		High	High	High	High	High	Low	High	**High**
	Chitek Lake		Moderate	Moderate	High	High	Moderate	Low	Low	**Moderate**
	Etthithun Lake		Moderate	Moderate	High	Moderate	Moderate	Low	Low	**Moderate**
	Hay-Zama		Moderate	Moderate	High	Moderate	Moderate	Low	Low	**Moderate**
	Mackenzie		Moderate	Low	High	High	Moderate	Low	Moderate	**Moderate**
	Nahanni		Moderate	High	High	Moderate	Low	Low	Moderate	**Moderate**
	Nordquist/Liard		Low	Moderate	High	Moderate	Low	Low	Low	**Moderate**
	Ronald Lake		Low	Moderate	Moderate	Moderate	Low	Low	Low	**Low**
	Wabasca		Low	Moderate	Moderate	Moderate	Low	Low	Low	**Low**
Alaska	*Innoko-Yukon*		Low	Low	High	High	High	Low	High	**Moderate**

4.3.2 Current Assessment of the 3 Rs

Resiliency

Resiliency of a species is having "healthy" populations; populations that are able to sustain themselves through good and bad years. The healthier and the greater the number of healthy populations, the more resiliency a species possesses.

There are 10 disease-free local populations, and one diseased, wood bison metapopulation, that are free-ranging as well as one disease-free captive population that are considered within this SSA. Of the 11 disease-free populations, one is currently considered High resiliency, eight Moderate resiliency, and two Low resiliency. One diseased metapopulation, GWBNP, is considered Moderate resiliency. The GWBNP metapopulation is comprised of three distinct populations: Slave River Lowlands, Wentzel Lake, and WBNP; these three populations are considered Moderate, Low, and Moderate resiliency respectively. These isolated populations are widespread across their range including four provinces in Canada and one U.S. state.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions over time and encompasses the "ecological and evolutionary patterns and processes that not only maintain but also generate species" (Shaffer and Stein 2000, p. 308). The wood bison does not currently exhibit high representation due to bottle necking and founder's effects associated with the GWBNP metapopulation and EINP.

We estimate that the wood bison has moderate adaptive potential because the level of genetic diversity within human-mediated translocated populations does not differ significantly from their source populations (Ball et al. 2016, p. 1532). All other extant populations were established through relocations from WBNP directly or by way of EINP (ECCC 2018, Appendix 3). Because of their direct ancestry from the last remaining wood bison, the GWBNP metapopulation and surrounding populations (i.e., Ronald Lake and Wabasca) contains the highest mean number of alleles (Ball et al. 2016, p. 1532). All disease-free wood bison local populations besides Ronald Lake and Wabasca have either been established from relatively few founders (EINP, Mackenzie), or have been founded from EINP (ECCC 2018, p. 57), and therefore, have lower genetic diversity than the original source population in WBNP (Wilson and Strobeck 1999, pp. 492, 493; Wilson et al. 2005, pp. 912, 913). Furthermore, several local populations are maintained at an artificially small size to prevent range expansion and contact between diseased and disease-free local populations, to manage the risk to people and property in communities, and to provide hunting opportunities.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. It "guards against irreplaceable loss of representation" (Tear et al. 2005, p. 841; Redford et al. 2011, p. 42) and minimizes the effect of localized extirpation on the range-wide persistence of a species (Shaffer and Stein 2000, p. 308). It is characterized by having multiple, resilient populations distributed throughout the species' ecological setting and across its range. For a species to exhibit greater redundancy, the populations should not be completely isolated and immigration and emigration between populations should be achievable.

Wood bison are widely distributed across the landscape within their former range but with little connectivity between populations. Two free-range, disease-free herds, Nordquist and Nahanni, are anticipated to eventually coalesce into one herd because of their close proximity and the presence of rivers that provide travel corridors (Gates et al. 2001b, p. 18). However, it is unknown if there is movement of animals between these two herds at present. Genetic analyses and proximity of diseased, free-range populations of wild bison in Alberta, suggests WBNP, Slave River Lowlands, and Wentzel Lake exhibit some degree of gene flow and animal movement between these populations (Ball et al. 2016, p. 1532; ECCC 2018, p. 5). Other than the aforementioned, no known naturally occurring immigration or emigration takes place among wood bison populations. The wood bison does not currently exhibit high redundancy due to lack of connectivity between free-range populations and the limited ability for range expansion of all populations.

While most populations are isolated from one another and immigration and emigration between them is not occurring, wood bison populations are heavily managed via provincial, territorial, and state governments. Wood bison reintroductions are occurring within their historical range and are an active component of recovery plans.

Table 4-3. Current Population Numbers. Current population estimates for wood bison across their range.

Local Population Category and Name	Location*	Year of Latest Estimate	Estimated Population Size
Free-Ranging, Disease-free Local Populations			
Aishihik	YT	2014	1,470 [1,306-1,684][b]
Chitek Lake	MB	2011	250-300[c]
Etthithun Lake	BC	2011	200-300[d]
Hay Zama	AB	2016	626[e]
Innoko-Yukon	US	2019	113
Mackenzie	NT	2016	851±209[f]
Nahanni	NT, YT, BC	2011	431±213[g]
Nordquist/Liard	BC, YT	2010	200-250[d]
Ronald Lake	AB	2013	~200[i]
Wabasca (or Wabasca/Mikkwah)	AB	2010	30-40[j]
Subtotal			*4,476*
Captive, Disease-free Conservation Local Populations – Public			
Elk Island National Park	AB	2014	300[k]
Subtotal Disease-free Local Populations		**~4,776**	
Free-Ranging Local Populations with Diseases			
Slave River Lowlands	NT	2016	662±175[l]
Wentzel Lake	AB	2015	199e
Wood Buffalo National Park	NT, AB	2014	3,363±893[m]
Subtotal Local Populations with Diseases		**~4,224**	
TOTAL =		**~9,000**	

* (YT = Yukon Territory, CA; MB = Manitoba, CA; BC = British Columbia, CA; AB = Alberta, CA; US = United States; NT = Northwest Territories, CA.)

CHAPTER 5. Future Scenarios

This SSA considers not just the factors that influence viability (Chapter 4), but assesses to what degree they influence risk (Smith et al. 2018, p. 6). Our analysis of the past, current, and future influences on what the wood bison needs for long-term viability revealed there are several influences that pose risks to the future viability of the species. These risks include direct effects from disease, negative genetic effects, hunting pressure, and transportation, and indirect effects through climate change. Climate change could cause indirect effects on wood bison through shifting changes in temperature and precipitation and increased frequency of severe weather events. Non-urban land use and land management, such as fire management, forestry, mining, and agriculture, may also alter habitat and dispersal between populations. To assess potential future condition for the wood bison, we consider three scenarios which vary with respect to combinations of climate conditions and conservation actions that could be undertaken to reduce effects of stressors (Table 5-1). We evaluate the expected outcomes of these scenarios in relation to anticipated changes in the resiliency for each of the wood bison subpopulations and the representation and redundancy at the range-wide scale.

Future Scenario Considerations

The stressors that we determined have the greatest influence on the viability of wood bison include: (1) disease (i.e., anthrax, bovine Tb, bovine brucellosis), (2) biological resource use (i.e., hunting and persecution), (3) invasive and other problematic species (i.e., presence/spread of thistle, prevalence of wolf predation), (4) stochastic and severe weather events (i.e., flooding, fire), (5) negative genetic effects, and (6) transportation and service corridors. We expect each of these stressors to continue to affect wood bison viability into the future. Some variability in response is anticipated across populations based on local and landscape scale differences (e.g., some sources of persecution are likely to be more significant in some populations than others). We have used the best available information to model and analyze future conditions.

Modeling Climate Change

Global climate change has been driven primarily by increasing concentrations of "greenhouse" gases that trap heat in the earth's atmosphere. Higher concentrations lead to greater warming and other climate anomalies. Evaluations of potential future scenarios have shown that GHG concentrations could range from approximately 430 to greater than 1,000 parts per million of carbon dioxide (CO_2) equivalent gases by the end of the century (usually expressed as a range of decades, such as 2080–2100). The IPCC has identified four RCPs that lead to distinctly different warming levels by 2100. Each of these four RCPs is identified by the warming effect it would produce, expressed as an average net increase in radiative energy relative to pre-industrial levels in joules (watts per square meter) by century's end (year 2100).

The four RCPs currently in use have replaced the "emission scenarios" used in IPCC assessments prior to 2014 (Figure 5-1). They range from aggressive mitigation to reduce emissions to a level that would maintain average global temperatures within 2 degrees Celsius (°C) of pre-industrial temperatures to meet the goals of the Paris Agreement (RCP 2.6) to unabated continuation of recent emission rates, with corresponding increases in atmospheric

GHGs and rises in global temperatures (RCP 8.5, closest to pre-2014 emission scenario A2). An intermediate pathway (RCP 4.5, closest to emission scenario B1) would require prompt and prudent mitigation in the coming decades and would result in relatively stable emissions after gradual increases in GHG emissions through mid-century, while RCP 6.0 (closest to emission scenario A1B) would require less aggressive mitigation and result in warming intermediate between RCPs 4.5 and 8.5 (van Vuuren et al. 2011, pp. 5-26; IPCC 2014, p. 57). The RCPs are not forecasts, absolutes, or prescriptive and none was considered more likely than another when developed (van Vuuren et al. 2011, p. 26).

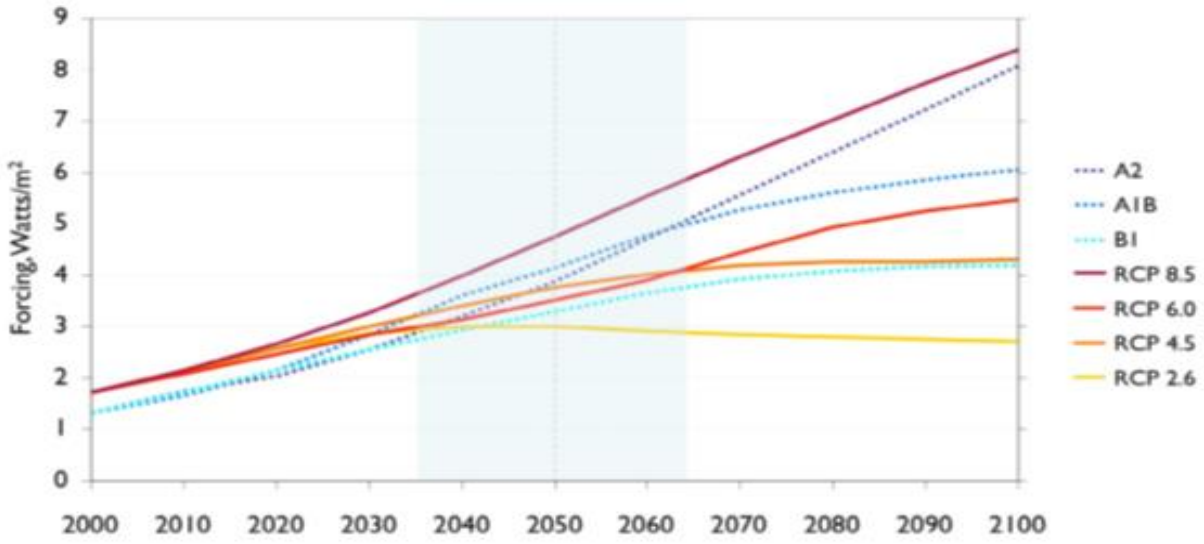


Figure 5-1. Changes in atmospheric radiation energy (or "radiative forcing") resulting from various RCPs used in IPCC climate modeling since 2014 and emission scenarios used prior to 2014 (A1B, A2, and B1). Each pathway or scenario represents a different level of GHG emissions from various sources, and varied human activity to reduce emissions, resulting in different rates of atmospheric warming. From Lukas et al. (2014, p. 41).

Future Scenarios - Methods

We forecast the wood bison's future conditions, in terms of resiliency, representation, and redundancy, under three plausible future scenarios. These three scenarios forecast the wood bison's viability over approximately 50 years, which is within the range of plausible future conditions. We used this duration as our foreseeable future because it is the temporal scale at which we may reasonably project climate change scenarios and their effects on wood bison. We describe the stressors/threats at the scale of each of the 14 current wood bison populations. We modeled three plausible future scenarios under which the factors that influence the condition of the species either (1) remain constant in relation to current conditions (Scenario 1), (2) improve (Scenario 2), or (3) become worse (Scenario 3).

Resiliency of wood bison populations depends on access to grazing and calving habitat connectivity, disease-free conditions, refugia from environmental conditions (ice, fire, flooding),

and levels of predation. We expect wood bison populations to experience changes to these resource needs under different scenarios. We project the expected future resiliency of each population based on events likely to occur under each scenario. We project an overall condition for each population as either High, Moderate, or Low based on the concepts presented in Table 5-1.

For each scenario, we used the best available scientific and commercial information to create a variety of plausible conditions projected to occur in the next 50 years. For example, we used peer-reviewed literature projections, wood bison expert advice and input, and our best professional judgment.

Table 5-1. Three plausible future scenarios.

SCENARIO #1 STATUS QUO	SCENARIO #2 OPTIMISTIC	SCENARIO #3 PESSIMISTIC
RCP 8.5	RCP 4.5	RCP 8.5
Only Innoko-Yukon population occurring in AK. No new populations in Canada	Establishment of two new populations in Alaska (Minto and Yukon Flats populations) over 30 years	Only Innoko-Yukon population occurring in AK, no new AK reintroductions. No new populations in Canada
Continued lack of connectivity between disease free populations	Improved connectivity between disease free populations (e.g., Nahanni and Nordquist)	Continued lack of connectivity between disease free populations
Similar risk of hybridization compared to Current Conditions	Reduced risk of hybridization with plains bison and domestic cattle through management of those species	Increases in hybridization with Plains bison or domestic cattle
Free-ranging, disease-free herds expanding at current rate. No new range expansion for diseased herds.	Range expansion of existing populations within AK, NWT, and YK	Range expansion of existing population remains same or decreases (e.g., habitat loss increases, increased disease requires further range restriction, etc.).
Unregulated hunting continues at low rates	Unregulated hunting continues at low rates	Unregulated hunting increases (e.g., poaching, hunting to control dispersal due to severe weather)
Genetic diversity remains similar to Current Conditions	Genetic diversity increases (work has already begun)	Genetic diversity further reduced (e.g., bottlenecking due to stochastic mortality)
Prevalence of disease similar to Current Conditions (i.e., three diseased populations, localized transmission of diseases)	Reduced disease transmission or effects from diseases mitigated through management (e.g., brucellosis vaccines, better control of transmission)	Increased disease transmission (e.g., spread by other vectors, reduced management efforts due to budget reductions or other shifts in management priority, etc.)
Anthrax outbreaks increase due to increased drought frequency causing more frequent spore releases	Reduced anthrax effects (e.g., improved delivery of anthrax vaccinations, rapid removal of carcasses with anthrax)	Anthrax outbreaks increase due to increased drought frequency causing more frequent spore releases
Worsening of severe weather events due to climate change (increased rates of wolf predation, increasing loss or access to winter forage)	Severe weather events continue at similar rate to current conditions	Worsening of severe weather events due to climate change (increased rates of wolf predation, increasing loss or access to winter forage)
Increase in thistle in areas of occurrence	Reduction of invasive, non-native thistle species	Increase in thistle in areas of occurrence

5.1 Scenario 1 (Status Quo)

Under Scenario 1, GHG emissions would continue at current rates, resulting in warming and associated conditions as projected by IPCC's RCP 8.5 pathway. Climate change is expected to influence environmental conditions throughout the range of wood bison. We expect these environmental changes to affect the other factors influencing wood bison populations, biological resource use, invasive and other problematic species, stochastic and severe weather events, and negative genetic effects. In some cases, these environmental changes could either magnify or reduce the relative threat of other stressors. Other than changes associated with the modeled climate pathway, we project the extent and magnitude of the other stressors to continue at levels similar to current conditions. This scenario assumes the current levels of translocation and monitoring capacity are consistent (i.e., no additional population augmentation would be implemented). The specific changes modeled for each stressor and their effects on wood bison populations are detailed below.

Scenario 1 - Analysis of Stressors

Using the future scenario described above, we analyzed potential changes to the magnitude and extent of stressor and their effects on wood bison.

5.1.1 Disease

Under this scenario, the threat of anthrax may be exacerbated by the drier conditions modeled under this climate change pathway. Anthrax spores are stored in soil for thousands of years, and in dry years they hatch and become airborne. Anthrax spores may be carried on the wind into water bodies where they settle to the bottom and become trapped in the substrate. Under this modeled scenario, drier conditions and increased ambient air temperatures may cause some waterbodies to evaporate, which could expose substrates containing anthrax spores to disturbance. If these substrates are then disturbed (e.g., wood bison movements kicking up soil) there could be an increased likelihood of trapped spores being released. Under this scenario, we expect anthrax outbreaks to continue in areas of previous outbreaks and also expect new outbreaks may occur in all other wood bison populations that have been previously unaffected. However, we do not expect extreme outbreaks of anthrax, and expect anthrax-related mortalities to be less than 50 percent for any population.

Under this scenario, all currently disease-free herds will remain unaffected by bovine Tb and bovine brucellosis, and all currently diseased herds will persist on the landscape within their currently restricted ranges. The primary factor that influences disease transmission is the interconnectedness of the local populations. Under this future scenario, we expect populations to remain relatively isolated due to a combination of human management and lack of suitable habitat connectivity.

5.1.2 Biological Resource Use

Under this scenario, regulated and unregulated hunting is expected to continue at low rates, where a few individuals per population are removed annually based upon management objectives.

Unregulated hunting currently limits the abundance and distribution of wood bison outside of designated management areas. This is likely to continue into the future under this scenario. Without management efforts, the range of wood bison will not expand in this future scenario due to continued unregulated hunting. We also expect illegal harvest to be a continuing threat under this scenario.

Previously, the only free-ranging bison populations that were subject to regulated hunting in Canada (quotas and permits) were the Aishihik, Mackenzie, and Slave River Lowlands subpopulations (Gates et al. 2001b, pp. 23). We predict management of these populations with quota and permit hunts, resulting in the harvest of low numbers per year, will continue into the future. For example, two to five individuals from the Nahanni herd are currently harvested each year (Species at Risk Committee 2016, p. 121); this harvest rate is expected to continue in the future. Since 2008, the Hay-Zama subpopulation has also been managed with an annual hunt (Alberta Environment and Parks and Alberta Conservation Association 2017, p. 58), which will likely continue into the future.

Under this scenario, we anticipate similar rates of persecution to maintain boundaries between healthy and diseased populations and to segregate wood bison from other free-ranging plains bison, domestic bison, and cattle. For example, we expect continued lethal removal of animals within Bison Control Areas between the Mackenzie and Hay Zama local populations and the GWBNP metapopulation. Similarly, we expect continued maintenance of active control zones designated to prevent the hybridization of the Nordquist/Liard, Hay Zama, and Nordquist local wood bison populations with the Pink Mountain plains bison (ECCC 2018, p. 18).

5.1.3 Invasive and other Problematic Species

Under this scenario, we anticipate an increase in the presence and spread of thistle in areas where it is currently established, due in part to an increase in drying conditions into the future (ECCC 2018, pp. 21, 22). Canada thistle will most likely continue to affect wood bison within the WBNP metapopulation, including Slave River Lowlands, WBNP, and Wentzel Lake sub-populations.

Under this scenario, we expect the extent of wolf predation to be similar to current conditions. Stochastic weather events, such as severe winter thaw-freezes, may continue to reduce bison fitness, making them vulnerable to predation. While this may not be an annual occurrence, we expect the stressor to continue to be a factor that slows population growth.

5.1.4 Stochastic and Severe Weather Events

Under this scenario, stochastic and severe weather events are anticipated to have a negative impact on wood bison throughout most of their range. Within Canada, wood bison currently inhabit a region covering three climatic regions where the highest rates of warming in Canada are predicted (ECCC 2018, p.23). If these trends continue as projected under this scenario (RCP 8.5), we expect an increased frequency and/or severity of stochastic weather-related events, such as droughts, flooding, severe winter snow and icing, and wildfires.

The Peace-Athabasca Delta region within WBNP has been in a drying period resulting from both climate change and the W.A.C. Bennet Dam hydroelectric project. As a result, a shift in

vegetation has occurred, including the proliferation of invasive weed species, most notably Canadian thistle. Continued drought conditions may reduce preferred forage plant species and shift plant communities away from sedge and grassland habitats.

Under this scenario, the Innoko-Yukon, Mackenzie, Nahanni, and GWBNP metapopulation are expected to continue to experience flooding effects similar to current rates. Flooding may reduce the availability and location of preferred habitat types (e.g., meadows) which may shift the distribution of wood bison within these areas. Severe flooding can have significant effects upon local populations via mass drownings, as happened in 1974 in the Peace-Athabascan Delta in WBNP (ECCC 2018, p. 10). The Nahanni local population consistently crosses the Liard River and flood events may result in more regular and frequent river drownings.

Under this scenario, the occurrence of freeze-thawing events may become more frequent with climate change conditions. An increase in intensity and frequency of freeze-thaw events may negatively affect the Innoko-Yukon and Hay Zama local populations. Winters with heavy snowfall or thick ice resulting from freezing rain or snow melt may lead to wood bison mortality through starvation and increased predation through decreased physical condition. In 2012, the Hay Zama local population experienced higher than usual mortality (approximately 20 percent) resulting from starvation attributed to winter conditions and limited access to forage (COSEWIC 2013, p. 54). The Innoko-Yukon population sustained higher mortality events during the spring of 2018 due to late winter snow and freezing rain. The first incidence of wolf predation upon the Innoko-Yukon local population was also observed during this period, and is thought to be related to the severe weather conditions (Tom Seaton, pers. comm., 2019).

Under this scenario, natural fire regimes are expected to shift as climatic conditions become warmer and drier. The effects of fire on wood bison habitats have both positive and negative effects. Fire maintains meadow habitats, a preferred habitat for wood bison. However, fires that burn at high temperatures (through fuel loading and fire suppression practices), or fires that burn too strongly may result in wood bison direct mortality or malnourishment due to exclusion from a region until recolonization of sedge and grass species occurs.

It is worth noting that some impacts from climate change may have beneficial effects upon wood bison. Particularly, habitats north of the current wood bison range may shift towards grassland habitats, resulting in increased habitat for wood bison in these areas.

5.1.5 Negative Genetic Effects

Under this scenario, we expect the factors affecting genetic diversity to remain similar to current conditions. Genetic exchange would remain limited between populations due to human management to address disease concerns, and limited natural dispersal due to a lack of habitat connectivity. Due to this lack of genetic exchange, local populations would continue to be affected by the impacts of isolation and potential bottleneck/founder's effects. The continued population isolation should have the benefit of limiting wood bison hybridization with free-ranging plains bison, domestic bison, and cattle.

5.1.6 Transportation and Service Corridors

Bison-vehicle collisions are an ongoing stressor and are expected to continue into the future for the Hay Zama, Mackenzie, Nahanni, and the Nordquist/Liard local populations at rates similar to current conditions. We predict future bison-vehicle collisions within the affected populations under this scenario will maintain at low levels resulting in mortality of a few individuals annually.

The Alaska Highway is the major thoroughfare in proximity to these local populations. The rate of animal vehicle collisions is primarily a function of the density of animals, traffic volume, and traffic speed. Vehicle collisions are the largest source of uncontrolled mortality in the Hay Zama herd (Mitchell and Gates 2002, p. 9), which occurs near transportation and service corridor Highway 35 (ECCC 2018, pp. 11, 17). Motor vehicle accidents continue to be a major mortality factor for wood bison in the Northwest Territories. For the Mackenzie local population, the greatest source of collisions occurs along Highway 3, the Yellowknife Highway (the only road to Yellowknife), which runs through the middle of the core range for the Mackenzie local population from Fort Providence to Yellowknife, Northwest Territories. As wood bison extend their range towards Yellowknife, the risk of collisions is likely to increase. Other factors that may increase in the future and could influence vehicle collision risk include the increased speed and volume of traffic; the movement and expansion of Mackenzie basin due to flooding in the Mackenzie Bison Sanctuary; and the straightening, widening, and increased maintenance of Highway 3. Vehicle collisions have also been documented in the Nordquist local population, and such incidents are expected to continue in the future.

Scenario 1 Stressors Summary

Under Scenario 1, the overall magnitude of threats is expected to increase compared to current conditions for the Chitek Lake (Moderate to High) and Hay Zama (Low to Moderate) local populations. The threat conditions for all other local populations are expected to remain the same as current conditions. A summary of the overall threat condition based on Scenario 1 conditions categorizes five populations with a High magnitude of threats (WBNP, Wentzel Lake, Slave River Lowlands, Chitek Lake, and Mackenzie), four as Moderate (Hay Zama, Nahanni, Nordquist/Liard, and Innoko-Yukon), and five as Low (EINP, Aishihik, Etthithun Lake, Ronald Lake, and Wabasca) (Table A.5, Appendix 1).

Scenario 1 - Summary of 3 Rs

Resiliency

Resilience is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance.

Future Condition under Scenario 1: Under this future scenario, we expect one population (Ronald Lake) to experience a change in overall condition status. We anticipate an overall improvement of the status of the Ronald Lake population based on an increase in the number of individuals within the herd, an increase of natural population growth, a decrease in the likelihood of genetic exchange with plains bison, and potential for some range expansion (Appendix 2). (Appendix 2).

We expect the future condition for one of the 14 populations to increase compared to current conditions, while the remaining populations maintain a similar condition to what they are experiencing now. We assess the overall resiliency of the wood bison as Moderate condition (unchanged) under Scenario 1.

Representation

Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (disease, predators) conditions. It can be thought of as the 'adaptability' of the species.

We do not expect any appreciable change to the species' representation under this future scenario. We expect the factors affecting genetic diversity to remain similar to current conditions, with continued limitations to exchange between populations due to human management to address disease concerns. Based on the continued genetic isolation of the current wood bison populations, we expect their ability to adapt to a changing environment to remain similar to current conditions.

Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy is measured by the duplication or distribution of populations across the range of the species.

Under this future scenario, we expect all current populations to remain extant and we do not expect the establishment of any new populations, so there should be no change in redundancy. Overall, under Scenario 1, we expect the wood bison to retain a similar duplication and distribution of populations across the landscape with a similar ability to withstand catastrophic events compared to current conditions.

Scenario 1 - Summary of Changes

Under this scenario, we expect the effects of stressors to remain relatively similar to current conditions but for an increase in stressor magnitude presented by disease (anthrax outbreaks) within Chitek Lake and Hay Zama populations (Table A.2, Appendix 1). This increase in stressor magnitude is not expected to result in appreciable change in the status of the species' most important biological needs (Table 5-2).

We expect most populations to remain in a similar condition compared to current conditions. The one exception is that we project the Ronald Lake population to improve from Low condition to Moderate condition (Table 5-3).

Table 5-2. Projected status of species' needs and overall population condition under Scenario 1.

Region	*Population*		*# individuals*	*Population trend*	*Diseases of special concern*	*Likelihood of transmission*	*Likelihood of deleterious genetic exchange*	*Connectivity to disease free populations*	*Geographic expansion potential*	*Overall Condition*
Canada	*GWBNP*	*WBNP*	High	Moderate	Low	Low	High	Low	Low	**Moderate**
		Wentzel Lake	Low	Moderate	Low	Low	High	Low	Low	**Low**
		Slave River Lowlands	Moderate	Moderate	Low	Low	High	Low	Low	**Moderate**
	Elk Island NP		Moderate	Moderate	High	High	High	Low	Low	**Moderate**
	Aishihik		High	High	High	High	High	Low	High	**High**
	Chitek Lake		Moderate	High	High	Moderate	Moderate	Low	Moderate	**Moderate**
	Etthithun Lake		Moderate	Moderate	High	High	Moderate	Low	Low	**Moderate**
	Hay Zama		Moderate	Moderate	High	Moderate	High	Low	Low	**Moderate**
	Mackenzie		Moderate	Moderate	High	Moderate	Low	Low	Low	**Moderate**
	Nahanni		Moderate	Low	High	High	Moderate	Low	Moderate	**Moderate**
	Nordquist/Liard		Low	Moderate	High	Moderate	Moderate	Low	Low	**Moderate**
	Ronald Lake		Moderate	High	Moderate	Moderate	Moderate	Low	Moderate	**Moderate**
	Wabasca		Low	Moderate	Moderate	Moderate	Low	Low	Low	**Low**
Alaska	*Innoko-Yukon*		Moderate	Moderate	High	High	High	Low	High	**Moderate**

Table 5-3. Current condition compared to future condition under Scenario 1, by population. Determination of rankings presented in the current overall condition column may be found within Table 4-2.

Region	*Population*		*Current Overall Condition*	*Scenario 1 (Status Quo)*
Canada	*GWBNP*	*WBNP*	Moderate	Moderate
		Wentzel Lake	Low	Low
		Slave River Lowlands	Moderate	Moderate
	Elk Island NP		Moderate	Moderate
	Aishihik		High	High
	Chitek Lake		Moderate	Moderate
	Etthithun Lake		Moderate	Moderate
	Hay Zama		Moderate	Moderate
	Mackenzie		Moderate	Moderate
	Nahanni		Moderate	Moderate
	Nordquist/Liard		Moderate	Moderate
	Ronald Lake		Low	Moderate
	Wabasca		Low	Low
Alaska	*Lower Yukon-Innoko*		Moderate	Moderate

Populations in High Condition	**1**	**1**
Populations in Moderate Condition	**10**	**11**
Populations in Low Condition	**3**	**2**

5.2 Scenario 2 (Optimistic)

Scenario 2 represents a potentially optimistic trajectory for the changes in stressor prevalence and magnitude. This scenario incorporates IPCC's projected climate change pathway RCP 4.5, which reflects implementation of prompt and prudent mitigation resulting in relatively stable emissions after gradual increases in GHG emissions through mid-century. This scenario assumes the current levels of translocation and monitoring capacity would increase compared to current conditions (i.e., population augmentation would be implemented across many or most populations on the landscape). Under this scenario, we anticipate improved management of disease, including controlled spread or elimination of bovine Tb and brucellosis. Successful management of disease would reduce the need for population containment, which could allow for greater range expansion of local populations. This increased movement could improve genetic exchange and could reduce the extent and magnitude of other threats that have otherwise been exacerbated by severely range-restricted/constrained populations. Examples of these effects are discussed further below.

Scenario 2 - Analysis of Stressors

Using the future scenario described above, we analyzed potential changes to the magnitude and extent of stressors and their effects on wood bison.

5.2.1 Disease

Under this scenario, we expect anthrax outbreaks may continue in areas of previous outbreaks, but we do not expect any additional spread of anthrax into previously unaffected populations. However, we anticipate timely and effective delivery of anthrax vaccine to affected populations. In addition, early detection of an anthrax outbreak and rapid response and removal of wood bison carcasses would further reduce proliferation of infection. Improved management for disease could result in all currently diseased herds experiencing reduced effects from Bovine Tb and Bovine brucellosis. We do not expect transmission of disease to occur within or between populations.

5.2.2 Biological Resource Use

Under this scenario, we expect regulated hunting to continue at relatively low rates, with an assumption that a few individuals per population would be removed annually based upon management objectives. We also expect Indigenous harvesting activities to continue, because we anticipate that local populations may be self-sustaining under the improved conditions. Unregulated hunting would be discontinued, because that activity is associated with maintenance of the Bison Control and exclusion zones, which may no longer be needed as a management objective. Illegal hunting may continue, but we expect the magnitude of this stressor to remain relatively minor compared to overall population levels.

Under this scenario, we expect continued regulated hunting of free-ranging bison populations in Canada (quotas and permits) at levels similar to current conditions. Levels of harvest would be commensurate with population levels and management objectives, which would result in the harvest of a low number of animals per year. Regulated hunting is not expected to occur for captive populations (i.e., EINP).

To segregate wood bison from other free-ranging plains bison, domestic bison, and cattle management objectives, we predict management methods to shift to a greater reliance on non-lethal removal of animals and exclusion zones. For example, non-lethal removal of animals may be necessary to prevent hybridization of the Nordquist/Liard, Hay Zama, and Nordquist local wood bison populations with the Pink Mountain plains bison. Under this scenario, we expect the effects of persecution and herd management to be similar to or less than current conditions.

5.2.3 Invasive and other Problematic Species

Under this scenario, we anticipate successful management actions would result in improved control of Canadian thistle in areas occupied by wood bison. This would result in improved habitat conditions in and around the GWBNP metapopulation, which includes the Slave River Lowlands, WBNP, and Wetzel Lake subpopulations.

If wood bison populations increase in numbers and begin dispersing into new areas, the likelihood of wolf predation could increase. However, we predict the overall effect of wolf predation to remain at a low level, consistent with current conditions. We believe wolf predation would fluctuate within acceptable rates typical of population dynamics and predator-prey relationships observed in other ungulate species. Increased risk of wolf predation has also been associated with freeze-thaw events due to bison having poorer body conditions and lessened ability to defend against predators. The Innoko-Yukon population sustained the first incidence of wolf predation during this a late winter snow and freezing rain in 2018 (Tom Seaton, pers. comm., 2019). We expect wolf predation to be less of a stressor if wood bison are better able to disperse during severe winter weather; their improved ability to find forage should allow them to maintain better body condition and be less susceptible to predation.

5.2.4 Stochastic and Severe Weather Events

Although this scenario uses RCP 4.5 to model an improvement in climate change trajectory, stochastic and severe weather events are still predicted to occur under this scenario. We expect continued weather-related events, such as droughts, flooding, severe winter snow and icing, and wildfires, to occur at rates similar to or less than those currently observed; we also expect these events could be less severe under more moderated climate change conditions. If management of invasive species, such as thistle, is successful, habitat suitability and connectivity could facilitate wood bison movement to areas largely unaffected by severe weather events, allowing wood bison to avoid the deleterious effects of such events.

Currently, the subpopulations of GWBNP experience drought induced habitat shifts, such as sedge and grassland habitat converting to forested habitats. Because bison are prevented from dispersing due to the BCAs and habitat fragmentation, they are unable to migrate to more suitable habitat and suffer reduced fitness due to a lack of high quality forage. Under this scenario, droughts may continue to cause habitat shifts, but wood bison would be better able to respond and adapt due to increased dispersal opportunities resulting from the reduced need for population containment.

Under this scenario, flooding is expected to continue at current rates and may affect the Innoko-Yukon, Mackenzie, Nahanni, and GWBNP metapopulation. Flooding may reduce the availability and location of preferred habitat types (e.g., meadows) which may shift the

distribution of wood bison within these areas. However, if dispersal opportunities were increased due to improvements in habitat quality and connectivity, it could allow bison to avoid flooded areas.

Freeze-thawing events may still become more frequent with climate change conditions. An increase in intensity and frequency of freeze thaw events may negatively affect the Innoko-Yukon and Hay Zama local populations. However, under Scenario 2, Innoko-Yukon wood bison may have greater ability to disperse to ice-free areas where there is greater food availability. Therefore, we expect fewer mortalities from severe freeze-thaw events.

Under this scenario, we anticipate natural fire regimes to be similar to current conditions. Fires can cause positive and negative effects on wood bison habitat. Fire maintains meadow habitats, which are a preferred habitat for wood bison. However, fires that burn at high temperatures (through fuel loading and fire suppression practices), or fires that burn too strong may result in wood bison direct mortality or malnourishment due to temporary loss of sedge and grass habitat. We expect these effects to be unchanged in this scenario compared to current conditions.

5.2.5 Negative Genetic Effects

Under this scenario, we expect factors affecting genetic diversity to improve relative to current conditions. Dispersal and genetic exchange between populations could potentially increase if habitat conditions improve and better habitat connectivity is established between populations. If genetic exchange increases, we would expect a corresponding reduction in the deleterious effects from genetic bottleneck/founder's effect. Populations that are currently geographically isolated (i.e., Chitek Lake) could experience increased gene flow through translocations from other populations. Under this scenario, we expect the frequency and geographic extent of wood bison reintroductions to increase in Alaska. An increase in reintroductions might include establishment of two new populations within the NEP area (ADF&G 2013, entire). To reduce hybridization of wood bison with other free-ranging plains bison, domestic bison, and cattle, we would still expect management actions to be implemented. However, these would be less frequently necessary and may allow a shift to non-lethal management options still focused on removal from exclusion zones. The populations that are most likely to see continued management to prevent hybridization would be the Nordquist/Liard, Hay Zama, and Nordquist local wood bison populations with separation from the Pink Mountain plains bison.

5.2.6 Transportation and Service Corridors

Under this scenario, we expect bison-vehicle collisions to continue into the future for the Hay Zama, Mackenzie, Nahanni, and the Nordquist/Liard local populations. Under this scenario we predict future bison-vehicle collisions within the affected populations will maintain low (less than 3 percent) reduction or declines when considering the scope and severity of the threat (ECCC 2018, p.11, 14). We still anticipate that road corridors will continue to attract wood bison, which will use them as linear corridors for movement, refugia during winter (roadway surfaces warmed by sun), and grazing (grasses within roadside right of ways). However, we expect that increased dispersal may lead bison away from road corridors in some populations.

We also expect that increased dispersal may actually reduce the overall density of bison on the landscape, because they will be distributed over a greater geographic area. The rate of animal

vehicle collisions is primarily a function of the density of animals, traffic volume, and traffic speed. We recognize increased population growth under this scenario may result in higher densities near transportation corridors. However, it is assumed a greater number of individuals will disperse to colonize new areas that are currently inaccessible. Although newly colonized areas may also contain transportation corridors, the density of animals in these areas may be significantly lower than elsewhere in the current range and therefore do not pose a significant known source of mortality for wood bison.

Under this scenario, the local populations that may remain at the greatest risk for vehicle collisions are the Hay-Zama population, the Mackenzie population, and the Nordquist population, all of which currently occur near transportation corridors (ECCC 2018, pp. 11, 17). However, based on the factors discussed above, we anticipate the extent and magnitude of this stressor to remain a negligible source of mortality for wood bison under this scenario.

Scenario 2 Stressors Summary

Under Scenario 2, the overall magnitude of threats is expected to decrease compared to current conditions for the Mackenzie (High to Moderate), Nahanni, Nordquist/Liard, and Innoko-Yukon (Moderate to Low) local populations; with a decrease in threats, these populations are expected to experience an increase in overall condition. A summary of the overall threat condition based on Scenario 2 conditions categorizes three populations as High (WBNP, Wentzel Lake, and Slave River Lowlands), two as Moderate (Chitek Lake and Mackenzie), and nine as Low (EINP, Aishihik, Etthithun Lake, Hay Zama, Nahanni, Nordquist/Liard, Ronald Lake, Wabasca, and Innoko-Yukon) (Table A.5, Appendix 1).

Scenario 2 - Summary of 3 Rs

Resiliency

Resilience is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance.

Future Condition under Scenario 2: Under this future scenario, we expect a change in overall condition status of nine populations (Wentzel Lake, Slave River Lowlands, Chitek Lake, Mackenzie, Nahanni, Nordquist/Liard, Ronald Lake, Wabasca, and Innoko-Yukon). Common to all nine populations is an increase in connectivity to other disease-free populations (Appendix 2). However, in only three of these populations (Wentzel Lake, Mackenzie, and Innoko-Yukon) do we observe an increase in the number of individuals (Appendix 2).

We expect the future condition of the 14 populations to increase and 5 to remain unchanged compared to current conditions. We do not anticipate a decrease in resiliency for any of the populations under Scenario 2. Based on these expected changes, we assess the overall resiliency of the wood bison as High condition (an increase) under Scenario 2.

Table 5-4. Projected status of species' needs and overall population condition under Scenario 2.

Region	*Population*		*# individuals*	*Population trend*	*Diseases of special concern*	*Likelihood of transmission*	*Likelihood of deleterious genetic exchange*	*Connectivity to disease free populations*	*Geographic expansion potential*	*Overall Condition*
Canada	*GWBNP*	*WBNP*	High	Moderate	Low	Low	High	Low	Low	**Moderate**
		Wentzel Lake	Moderate	Moderate	High	Moderate	High	High	High	**High**
		Slave River Lowlands	Moderate	Moderate	High	Moderate	High	High	High	**High**
	Elk Island NP		Moderate	Moderate	High	High	High	Low	Low	**Moderate**
	Aishihik		High	High	High	High	High	High	High	**High**
	Chitek Lake		High	High	High	High	Moderate	High	High	**High**
	Etthithun Lake		Moderate	Moderate	High	High	High	Low	Moderate	**Moderate**
	Hay Zama		Moderate	Moderate	High	High	High	Moderate	Moderate	**Moderate**
	Mackenzie		High	High	High	High	Moderate	Moderate	High	**High**
	Nahanni		High	Moderate	High	High	Moderate	Moderate	High	**High**
	Nordquist/Liard		Moderate	Moderate	High	High	Moderate	High	High	**High**
	Ronald Lake		Moderate	Moderate	High	High	Moderate	Moderate	Moderate	**Moderate**
	Wabasca		Moderate	Moderate	High	High	Moderate	Moderate	Moderate	**Moderate**
Alaska	*Innoko-Yukon*		High	Moderate	High	High	High	Moderate	High	**High**

Table 5-5. Current condition compared to future condition under Scenario 2, by population. Determination of rankings presented in the current overall condition column may be found within Table 4-2.

Region	*Population*		*Current Overall Condition*	*Scenario 2 (Optimistic)*
Canada	*GWBNP*	*WBNP*	Moderate	Moderate
		Wentzel Lake	Low	High
		Slave River Lowlands	Moderate	High
	Elk Island NP		Moderate	Moderate
	Aishihik		High	High
	Chitek Lake		Moderate	High
	Etthithun Lake		Moderate	Moderate
	Hay Zama		Moderate	Moderate
	Mackenzie		Moderate	High
	Nahanni		Moderate	High
	Nordquist/Liard		Moderate	High
	Ronald Lake		Low	Moderate
	Wabasca		Low	Moderate
Alaska	*Innoko-Yukon*		Moderate	High

Populations in High Condition	**1**	**8**
Populations in Moderate Condition	**10**	**6**
Populations in Low Condition	**3**	**0**

Representation

Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (disease, predators) conditions. It can be thought of as the 'adaptability' of the species.

We expect a significant change to the species' representation under this future scenario. We expect greater connectivity between populations could facilitate increased genetic exchange between populations. We expect the factors affecting genetic diversity to increase for all populations relative to current conditions. We expect improved genetic diversity to improve the species' adaptability, which should allow it to better respond to physical and biological changes on the landscape.

Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy is measured by the duplication or distribution of populations across the range of the species.

Under this scenario, we expect at least a modest increase in the wood bison's redundancy. We expect all current populations to remain extant. We also anticipate the establishment of two new populations in Alaska (within the NEP area). Furthermore, the currently extant populations could experience range expansion, which would likely result in new regions being inhabited and could potentially lead to the natural establishment of new populations, should the existing populations splinter across different geographic areas. Therefore, under this future condition, we anticipate a potential increase in redundancy. Overall, under Scenario 2, we expect the wood bison to have an increased ability to withstand catastrophic events compared to current conditions.

Scenario 2 - Summary of Changes

We expected overall conditions for the wood bison to improve under Scenario 2 compared to current conditions. We expect a reduction in the threats presented by stochastic and severe weather events and negative genetic effects. In relation to current conditions, we expect a few stressors to decrease, with an overall decrease in the magnitude of stressors acting upon the Mackenzie, Nahanni, Nordquist/Liard, and Innoko-Yukon local populations. This reduction in stressors is expected to result in improved status of many of the species' most important biological needs (Table 5-4).

Under Scenario 2, we expect eight populations in High condition and six populations in Moderate condition (Table 5-5). This represents an improvement in condition for nine populations, with six going from Moderate to High, two going from Low to Moderate and one going from Low to High. Under Scenario 2, we do not expect any populations to remain in Low condition.

5.3 Scenario 3 (Pessimistic)

Under Scenario 3, we have modeled that GHG emissions would continue unabated and at current rates, resulting in warming and associated conditions as projected by IPCC's RCP 8.5 pathway.

Stressors influencing current wood bison populations are assumed to increase into the future. We assume continued, and possibly worsened, effects from transportation and service corridors, biological resource use, invasive and other problematic species, stochastic and severe weather events, and negative genetic effects. This scenario assumes no new populations would be introduced upon the landscape and monitoring capacity is decreased. Another major change anticipated in this scenario is increased risk of disease transmission (e.g., occurrence or spread of new disease vectors, failure of containment areas, etc.), which would lead to the more extensive spread of bovine Tb and brucellosis among existing populations.

This scenario assumes that most existing regulatory mechanisms and voluntary conservation measures that are currently benefiting the species would remain in place. However, we also envision circumstances that could lead to funding and staffing constraints, which could potentially lead to reduced implementation of current measures and could prohibit significant additional protections. Under Scenario 3, multiple stressors acting synergistically on the landscape could result in significant wood bison declines. These declines could be exacerbated by the lack of new population reintroductions or augmentations. In general, this scenario considers a future where conditions are worse for the species across its range compared to current conditions.

Scenario 3 - Analysis of Stressors

Using the future scenario described above, we analyzed potential changes to the magnitude and extent of stressors and their effects on wood bison.

5.3.1 Disease

Under this scenario, we anticipate an increased number of populations to experience mortality due to anthrax outbreaks. Anthrax prevalence may be exacerbated by drying climate conditions. Anthrax spores are stored in soil for thousands of years, and in dry years spores hatch and become airborne. Anthrax spores may be carried on the wind into water bodies, where they settle and become trapped in the substrate. Dry conditions and increased ambient air temperatures in the future may cause some waterbodies to evaporate, exposing previously inundated substrates (including trapped anthrax spores) and making them accessible to disturbance (e.g., wood bison movements). We anticipate anthrax outbreaks similar to Scenario 1, but with greater frequency and intensity within populations previously exposed to outbreaks. Under this scenario, extreme outbreaks of anthrax may occur and significantly affect wood bison dynamics (i.e., up to 50 percent mortality within affected populations).

Under this scenario, we contemplate the occurrence of one or more novel vectors for the spread of bovine Tb and brucellosis. If these diseases are more readily spread, then currently disease-free local populations in close proximity to diseased populations could be at an elevated risk of infection. The populations most at risk of this increased stressor are Ronald Lake, Hay Zama, Wabasca, and Mackenzie.

5.3.2 Biological Resource Use

Under this scenario, both regulated and unregulated hunting are expected to continue at low rates where a few individuals per population are removed annually based upon management

objectives. We anticipate an increase in mortality from illegal hunting (poaching) as expanding transportation and service corridors provide increased human access into remote areas where wood bison occur. All forms of hunting are expected to reduce wood bison population numbers. Unregulated hunting currently limits the distribution of wood bison outside of designated management areas. Under this scenario, we expect the range of wood bison to continue to be limited by this stressor.

Currently, the only free-ranging bison populations that are subject to regulated hunting in Canada are the Aishihik, Mackenzie, and Slave River Lowlands subpopulations (Gates et al. 2001b, p. 28). We predict management of these populations with quota and permit hunts will continue under this scenario, resulting in the harvest of low numbers of bison per year.

Under this scenario, we anticipate continued persecution to be implemented to maintain boundaries between healthy and diseased populations and to segregate wood bison from other free-ranging plains bison, domestic bison, and cattle. Currently, lethal removal of animals occurs within Bison Control Areas between the Mackenzie and Hay Zama local populations and the GWBNP metapopulation. Active control zones are established to prevent the hybridization of the Nordquist/Liard, Hay Zama, and Nordquist local wood bison populations with the Pink Mountain plains bison (ECCC 2018, p. 18). We expect these local populations to continue to experience similar pressure.

5.3.3 Invasive and other Problematic Species

Under this scenario, we anticipate an increase in the presence and spread of thistle due, in part, to an increase in drying conditions (ECCC 2018, pp. 21, 22). We expect Canada thistle to continue to affect wood bison within the WBNP metapopulation, including Slave River Lowlands, WBNP, and Wentzel Lake. With the proliferation of thistle, we expect a decrease in the quantity and distribution of sedge and grassland communities within the GWBNP metapopulation and Ronald Lake local population.

Under this scenario, we predict the extent and magnitude of wolf predation will increase for some populations in relation to current conditions. The mortality rate of wood bison attributed to increases in wolf presence is not well understood (ECCC 2018, p. 23), however it does occur across the range of the species. Under this scenario, we assume wolf predation increases facilitated by an increase in the number of animals in poor health during winter months, and an increase in the ability of wolves to learn to hunt and kill wood bison on the landscape. Environmental conditions increasing in intensity, duration, and frequency during winter months (e.g., freeze-thaw events and increased snowfall) may result in depleted body condition and weakened animals. Increased rates of predation are anticipated to occur within the Innoko-Yukon population as wolves have demonstrated an ability to kill Innoko-Yukon wood bison much sooner than in other areas where wolves occur and new populations of free-range wood bison were released on the landscape. Under this scenario, we assume a greater level of wolf predation upon individuals within the GWBNP metapopulation mainly due to the effects of bovine Tb and brucellosis reducing productivity and increasing the vulnerability of infected individuals to predation (Gates 1993, p. 278; as cited in ECCC 2018 p. 22). The anticipated increase in transportation and service corridors create linear features along which wolves may

use as travel and hunting corridors to gain access where they may not have otherwise previously traveled (Dickie et al. 2017, pp. 259-260).

5.3.4 Stochastic and Severe Weather Events

Under this scenario, stochastic and severe weather events are anticipated to have an increasingly negative impact on wood bison throughout most of their range. Within Canada, wood bison currently inhabit a region covered by three climatic regions where the highest rates of warming in Canada are predicted (ECCC 2018, p. 23). If these trends continue as projected under this scenario (RCP 8.5), we expect an increased flooding frequency and/or severity of stochastic weather-related events, such as droughts, flooding, severe winter snow and icing (including freeze/thaw events), and wildfires.

Under this scenario, Innoko-Yukon, Mackenzie, Nahanni, and GWBNP metapopulation are expected to experience high intensity flooding events at greater frequencies than under current conditions. As the water holding capacity of the atmosphere increases in a warmer world, the increased moisture in the atmosphere drives a shift to heavier but less frequent rains. Heavier rains and surface flows may lead to an increase in flooding events. Flooding may reduce the availability and location of preferred habitat types (e.g., meadows) which may shift the distribution of wood bison within these areas. Severe flooding can have significant effects upon local populations via mass drownings; recent examples have occurred in the WBNP and Nahanni local populations (ECCC 2018, p. 10).

While an atmosphere that holds more moisture has an increased potential to produce heavier precipitation, precipitation events could also become less frequent and shorter, as it takes longer to recharge the atmosphere with moisture; this could result in an increased frequency of drought conditions. The Peace-Athabasca Delta region within WBNP has been in a drying period as a result from both climate change and the W.A.C. Bennet dam hydroelectric project; we expect conditions to worsen in this regard. A higher prevalence of drought conditions could promote an increased shift in plant communities and could also cause the proliferation of invasive weed species, most notably Canadian thistle. Drought conditions may reduce preferred forage plant species and shift plant communities away from sedge and grassland habitats.

Under this scenario, we project freeze-thaw events to be more frequent and of greater duration and extent. Climate change may cause an increase in snowfall intensity during winter storms. Winter storms with heavy snowfall or thick ice resulting from freezing rain or snowmelt may lead to increased wood bison mortality through starvation and increased predation by wolves. An increase in intensity and frequency of freeze-thaw events may negatively affect the Innoko-Yukon and Hay Zama populations, where such effects have already been observed under current conditions.

Under this scenario, natural fire regimes are expected to shift as climatic conditions become warmer and drier. Fire can have both positive and negative effects on wood bison habitats. Fires help maintain meadow habitats, a preferred habitat selected for by wood bison, by preventing succession to more woody habitat types. However, fires that burn at high temperatures (through fuel loading and fire suppression practices) or that burn too strong may result in wood bison

direct mortality or can cause a temporary loss of foraging habitat, which can result in malnourishment or starvation.

5.3.5 Negative Genetic Effects

Under this scenario, we expect the effects of limited genetic diversity to increase in intensity and magnitude compared to current conditions. Under this scenario, we expect dispersal and genetic exchange to be limited, with existing populations experiencing further isolation and no new populations introduced on the landscape. Due to the lack of genetic exchange, local populations would continue to be affected by the impacts of bottleneck/founder's effects. If management efforts fail and wood bison hybridize with free-ranging plains bison, domestic bison, or cattle, then additional deleterious genetic effects could occur.

5.3.7 Transportation and Service Corridors

Under this scenario, we anticipate an increase in the development of transportation and travel corridors. Additional transportation corridors could increase human access to local populations and herds, which might facilitate hunting (legal and illegal). Bison-vehicle collisions are an ongoing stressor and are expected to continue into the future for the Hay Zama, Mackenzie, Nahanni, and the Nordquist/Liard local populations. We predict future bison-vehicle collisions within the affected populations under this scenario will maintain low (less than 3 percent) reduction or declines (ECCC 2018, pp.11, 14). Although we expect an increase in the number of road and transportation corridors, the collision rate will remain low because of low bison numbers within affected populations.

Scenario 3 Stressors Summary

Under Scenario 3, we expect the overall magnitude of threats to increase compared to current conditions for Chitek Lake, (Moderate to High), Hay Zama (Low to High), Ronald Lake (Low to High), and Wabasca (Low to High). A summary of the overall threat condition based on Scenario 3 conditions categorizes eight populations High (WBNP, Wentzel Lake, Slave River Lowlands, Chitek Lake, Hay Zama, Mackenzie, Ronald Lake, and Wabasca), three populations Moderate (Nahanni, Nordquist/Liard, and Innoko-Yukon), and three populations Low (EINP, Aishihik, and Etthithun) (Table A.5, Appendix 1).

Scenario 3 - Summary of 3 Rs

Resiliency

Resilience is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance.

Future Condition under Scenario 3: Under this future scenario, we expect one population to experience a change in overall condition status (Nordquist/Liard). We anticipate an overall decline in status of the Nordquist/Liard local population based on a change in condition level linked with diseases of special concern (Table A.5, Appendix 1). Under this scenario we assume the occurrence of one or more unidentified vectors for the spread of bovine Tb and brucellosis. Vector uncertainty and proximity of disease-free herds to diseased herds are the drivers for the change in status from Moderate to Low condition (Table 5-7).

We expect the future condition for 1 of the 14 populations to decrease compared to current conditions. Based on this expected change, we assess the overall resiliency of the wood bison as Moderate condition (decrease) under scenario 3.

Representation

Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (disease, predators) conditions. It can be thought of as the 'adaptability' of the species.

We do not expect any appreciable change to the species' representation under this future scenario. We expect the factors affecting genetic diversity to remain similar to current conditions, with continued limitations to exchange between populations due to human management to address disease concerns. Similarly, for some populations, the increased likelihood of hybridization with cattle, domestic bison, or plains bison is a factor however mediated by management practices. Based on the continued genetic isolation of the current wood bison populations, we expect their ability to adapt to a changing environment to remain similar to current conditions.

Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy is measured by the duplication or distribution of populations across the range of the species.

We do not expect any appreciable change to the species' redundancy under this future scenario. We expect all current populations to remain extant, so there should be no reduction in redundancy. Similarly, we are not projecting the establishment of any new populations, or significant declines in existing range distribution under this future condition, so we would not anticipate any changes in redundancy. Overall, under Scenario 3, we expect the wood bison to retain a similar duplication and distribution of populations across the landscape with a similar ability to withstand catastrophic events compared to current conditions.

Scenario 3 - Summary of Changes

We expected overall conditions for the wood bison to decline under Scenario 3 compared to current conditions. We expect an increase in the threats presented by disease, and stochastic and severe weather events. In relation to current conditions, we expect a few stressors to increase, with an overall observed increase in the magnitude of stressors acting upon the Chitek Lake, Hay Zama, Ronald Lake, and Wabasca local populations. The increase in stressor magnitude is expected to result in decreased status of many of the species' most important biological needs (Table 5-6).

Under Scenario 3, we expect one population to be in High condition, nine populations to be in Moderate condition, and four populations to be in Low condition (Table 5-7). This represents a decline in condition for one population, going from Moderate to Low.

Table 5-6. Projected status of species' needs and overall population condition under Scenario 3.

Region	*Population*		*# individuals*	*Population trend*	*Diseases of special concern*	*Likelihood of transmission*	*Likelihood of deleterious genetic exchange*	*Connectivity to disease free populations*	*Geographic expansion potential*	*Overall Condition*
Canada	*GWBNP*	*WBNP*	High	Moderate	Low	Low	High	Low	Low	**Moderate**
		Wentzel Lake	Low	Moderate	Low	Low	High	Low	Low	**Low**
		Slave River Lowlands	Moderate	Moderate	Low	Low	High	Low	Low	**Moderate**
	Elk Island NP		Moderate	Moderate	High	High	High	Low	Low	**Moderate**
	Aishihik		High	High	High	High	High	Low	High	**High**
	Chitek Lake		Moderate	Moderate	Moderate	Moderate	Low	Low	Low	**Moderate**
	Etthithun Lake		Moderate	Moderate	Moderate	High	Moderate	Low	Low	**Moderate**
	Hay Zama		Moderate	Low	Moderate	Moderate	Moderate	Low	Low	**Moderate**
	Mackenzie		Moderate	Moderate	Moderate	Moderate	Low	Low	Low	**Moderate**
	Nahanni		Moderate	Moderate	Low	Moderate	Moderate	Low	Moderate	**Moderate**
	Nordquist/Liard		Low	Moderate	Moderate	Moderate	Low	Low	Low	**Low**
	Ronald Lake		Low	Moderate	Moderate	Moderate	Low	Low	Low	**Low**
	Wabasca		Low	Moderate	Low	Low	Low	Low	Low	**Low**
Alaska	*Innoko-Yukon*		Low	Low	High	High	High	Low	Low	**Moderate**

Table 5-7. Current condition compared to future condition under Scenario 3, by population. Determination of rankings presented in the current overall condition column may be found within Table 4-2.

Region	*Population*		*Current Overall Condition*	*Scenario 3 (Pessimistic)*
Canada	*GWBNP*	*WBNP*	Moderate	Moderate
		Wentzel Lake	Low	Low
		Slave River Lowlands	Moderate	Moderate
	Elk Island NP		Moderate	Moderate
	Aishihik		High	High
	Chitek Lake		Moderate	Moderate
	Etthithun Lake		Moderate	Moderate
	Hay Zama		Moderate	Moderate
	Mackenzie		Moderate	Moderate
	Nahanni		Moderate	Moderate
	Nordquist/Liard		Moderate	Low
	Ronald Lake		Low	Low
	Wabasca		Low	Low
Alaska	*Innoko-Yukon*		Moderate	Moderate

Populations in High Condition	**1**	**1**
Populations in Moderate Condition	**10**	**9**
Populations in Low Condition	**3**	**4**

Chapter 6. Synthesis and Summary of Viability

The goal of this assessment is to describe the current and plausible future conditions of wood bison in terms of resiliency, representation, and redundancy by using the best available scientific and commercial information. To capture the uncertainty associated with the degree and extent of potential future stressors and their impacts on the species' needs, we assessed potential future conditions using three plausible scenarios. These scenarios were based on a variety of negative and positive influences on the species across its current range, allowing us to predict potential changes in the condition of wood bison populations.

The results of our analysis describe a range of plausible conditions in terms of the number and distribution of wood bison populations (Table 6-1, Appendix 2). We assess the viability of the species by evaluating the ability of the species to maintain a sufficient number and distribution of healthy populations to withstand environmental stochasticity (resiliency), catastrophic events (redundancy), and changes in environment (representation) into the future.

Summary of 3 Rs

Resiliency is currently being impacted in some areas through the presence of the diseases bovine Tb and brucellosis. There are 10 disease-free local populations, and 1 diseased, wood bison metapopulation that are free-ranging, as well as 1 disease-free captive population (Table 6-1). Of the 11 disease-free populations, 1 is currently considered High resiliency, 8 Moderate resiliency, and 2 Low resiliency. One diseased metapopulation, GWBNP, is considered Moderate resiliency. The GWBNP metapopulation is comprised of three distinct populations: Slave River Lowlands, Wentzel Lake, and WBNP; these three populations are considered Moderate, Low, and Moderate resiliency respectively. Resiliency at current levels is expected to remain relatively constant. However, under a scenario where bovine Tb and brucellosis could be removed from the landscape, we would expect an associated increase in resiliency.

A species representation is measured by looking at the genetic, morphological, behavioral, and ecological diversity within and among populations across its range. The more representation, or diversity, a species has, the more likely it is to persist in changing environments. Historically, the wood bison has been distributed over a large longitudinal range, spanning the boreal forest biomes of the United States and Canada. Wood bison representation will remain moderate as isolated populations are widespread across their range including four provinces in Canada and one U.S. state. Even though natural range expansion and gene flow between existing populations is greatly diminished, management actions are being implemented to introduce additional disease-free, free-range wood bison populations on the landscape to aid representation of the species.

Wood bison are distributed throughout nearly the entire extent of their former range, however they occupy only small portions of their historical range and few of the varied habitats within it. In our future scenarios, we predict the wood bison will continue to occupy a small portion of their range with only one scenario (scenario 2 *Optimistic scenario*) projecting range expansion. Redundancy of the species is moderate despite limited range expansion of existing free-range wood bison populations. These conditions are expected to continue under most scenarios except where bovine Tb and brucellosis are removed as a stressor to wood bison recovery.

Summary of Plausible Future Conditions

We modeled a range of plausible changes in the stressors and biological needs of the species. The three future scenarios represent a spectrum of plausible outcomes. They do not represent an either/or choice of discreet outcomes, but rather model a full range of possibilities.

As indicated in Table 6-1, we predict a range of outcomes that include the species remaining in relatively similar status compared to current conditions with an overall Moderate status (Scenario 1), the species showing positive trajectory with an overall High-Moderate Status (Scenario 2), or the species showing a negative trajectory with an overall Moderate-Low Status (Scenario 3). Under all three scenarios, all 14 populations remain extant on the landscape.

The factors that are most likely to drive future status are the prevalence and spread of disease and the associated population management actions that limit dispersal, range expansion, and genetic exchange. Climate change and its effects on the frequency and severity of stochastic and extreme weather events are also likely to be important factors. We believe stressors such as invasive species, predation, and transportation corridors will continue into the future, but will have minor effects on species viability. Social license and acceptance remains an important factor in determining the possibilities for future range expansion through natural (dispersal/migration) and human aided (reintroductions) means.

Table 6-1. Current and future condition of wood bison, by population.

Region	*Population*		*Current Overall Condition*	*Scenario 1 (Status Quo)*	*Scenario 2 (Optimistic)*	*Scenario 3 (Pessimistic)*
Canada	*GWBNP*	*WBNP*	Moderate	Moderate	Moderate	Moderate
		Wentzel Lake	Low	Low	High	Low
		Slave River Lowlands	Moderate	Moderate	High	Moderate
	Elk Island NP		Moderate	Moderate	Moderate	Moderate
	Aishihik		High	High	High	High
	Chitek Lake		Moderate	Moderate	High	Moderate
	Etthithun Lake		Moderate	Moderate	Moderate	Moderate
	Hay Zama		Moderate	Moderate	Moderate	Moderate
	Mackenzie		Moderate	Moderate	High	Moderate
	Nahanni		Moderate	Moderate	High	Moderate
	Nordquist/Liard		Moderate	Moderate	High	Low
	Ronald Lake		Low	Moderate	Moderate	Low
	Wabasca		Low	Low	Moderate	Low
Alaska	*Innoko-Yukon*		Moderate	Moderate	High	Moderate

Populations in High Condition	**1**	**1**	**8**	**1**
Populations in Moderate Condition	**10**	**11**	**6**	**9**
Populations in Low Condition	**3**	**2**	**0**	**4**

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APPENDICES

Appendix 1. Magnitude of Threats for Current and Future Scenarios.

Table A.1. Summary of current condition threats. Values within the table indicate "yes" or "no" for the presence or absence of a given stressor acting upon a population. Categorical values for the overall magnitude range from "Low", "Moderate", and "High" based on relative severity and impact of stressor.

Population		***Summary of Current Condition Threats***							
		Disease		***Negative Genetic Effects***	***Stochastic and Severe Weather Events***	***Biological Resource Use (hunting, persecution)***	***Invasive and other problematic species***	***Transportation Corridors and Vehicle Collisions***	***Overall Number/ Magnitude of Threats***
		Tb Brucellosis	***Anthrax***						
GWBNP	*WBNP*	Yes	Yes	Yes	Yes	Yes	Yes	No	High
	Wentzel Lake	Yes	No	Yes	No	Yes	Yes	No	High
	Slave River Lowlands	Yes	Yes	Yes	Yes	Yes	Yes	No	High
Elk Island NP		No	No	Yes	No	No	No	No	Low
Aishihik		No	No	Yes	No	Yes	No	No	Low
Chitek Lake		No	No	Yes	Yes	Yes	Yes	No	Moderate
Etthithun Lake		No	No	Yes	No	Yes	No	No	Low
Hay Zama		No	No	Yes	No	Yes	No	Yes	Low
Mackenzie		No	Yes	Yes	Yes	Yes	No	Yes	High
Nahanni		No	No	Yes	Yes	Yes	No	Yes	Moderate
Nordquist/Liard		No	No	Yes	Yes	Yes	No	Yes	Moderate
Ronald Lake		No	No	Yes	No	Yes	Yes	No	Low
Wabasca		No	No	Yes	No	No	No	No	Low
Innoko-Yukon		No	No	Yes	Yes	Yes	Yes	No	Moderate

Table A.2. Summary of future condition threats under Scenario 1 (status quo). Values within the table indicate "yes" or "no" for the presence or absence of a given stressor acting upon a population. Categorical values for the overall magnitude range from "Low", "Moderate", and "High".

Population		***Summary of Scenario 1 Condition Threats (Status quo)***							
		Disease		***Negative Genetic Effects***	***Stochastic and Severe Weather Events***	***Biological Resource Use (hunting, persecution)***	***Invasive and other problematic species***	***Transportation Corridors and Vehicle Collisions***	***Overall Number/ Magnitude of Threats***
		Tb/ Brucellosis	***Anthrax***						
GWBNP	*WBNP*	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
	Wentzel Lake	Yes	Yes	Yes	Yes[2]	Yes	Yes	No	High
	Slave River Lowlands	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
Elk Island NP		No	Yes	Yes	Yes[2]	No	No	No	Low
Aishihik		No	Yes	Yes	Yes[2]	Yes	No	No	Low
Chitek Lake		No	Yes	Yes	Yes[1]	Yes	Yes	No	High
Etthithun Lake		No	Yes	Yes	Yes[2]	Yes	No	No	Low
Hay Zama		No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
Mackenzie		No	Yes	Yes	Yes[1]	Yes	No	Yes	High
Nahanni		No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
Nordquist/Liard		No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
Ronald Lake		No	Yes	Yes	Yes[2]	Yes	Yes	No	Low
Wabasca		No	Yes	Yes	Yes[2]	No	No	No	Low
Innoko-Yukon		No	Yes	Yes	Yes[1]	Yes	Yes	No	Moderate

Yes[1] = Disease and/or Invasive stressors present and documented evidence of historical stochastic event
Yes[2] = Disease and/or Invasive stressors present and no documented evidence of historical stochastic event

Table A.3. Summary of future condition threats under Scenario 2 (optimistic). Values within the table indicate "yes" or "no" for the presence or absence of a given stressor acting upon a population. Categorical values for the overall magnitude range from "Low", "Moderate", and "High".

Population		***Summary of Scenario 2 Condition Threats (Optimistic)***							
		Disease		***Negative Genetic Effects***	***Stochastic and Severe Weather Events***	***Biological Resource Use (hunting, persecution)***	***Invasive and other problematic species***	***Transportation Corridors and Vehicle Collisions***	***Overall Number/ Magnitude of Threats***
		Tb/ Brucellosis	***Anthrax***						
GWBNP	*WBNP*	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
	Wentzel Lake	Yes	No	Yes	No	Yes	Yes	No	High
	Slave River Lowlands	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
Elk Island NP		No	No	Yes	No	No	No	No	Low
Aishihik		No	No	Yes	No	Yes	No	No	Low
Chitek Lake		No	No	Yes	Yes[1]	Yes	Yes	No	Moderate
Etthithun Lake		No	No	Yes	No	Yes	No	No	Low
Hay Zama		No	No	Yes	No	Yes	No	Yes	Low
Mackenzie		No	Yes	Yes	Yes[1]	Yes	No	Yes	Moderate
Nahanni		No	No	No	No	Yes	No	Yes	Low
Nordquist/Liard		No	No	No	No	Yes	No	Yes	Low
Ronald Lake		No	No	Yes	Yes[1]	Yes	Yes	No	Low
Wabasca		No	No	Yes	No	No	No	No	Low
Innoko-Yukon		No	No	No	Yes[1]	Yes	Yes	No	Low

Yes[1] = Disease and/or Invasive stressors present and documented evidence of historical stochastic event
Yes[2] = Disease and/or Invasive stressors present and no documented evidence of historical stochastic event

Table A.4. Summary of future condition threats under Scenario 3 (pessimistic). Values within the table indicate "yes" or "no" for the presence or absence of a given stressor acting upon a population. Categorical values for the overall magnitude range from "Low", "Moderate", and "High".

Population		***Summary of Scenario 3 Condition Threats (Pessimistic)***							
		Disease		***Negative Genetic Effects***	***Stochastic and Severe Weather Events***	***Biological Resource Use (hunting, persecution)***	***Invasive and other problematic species***	***Transportation Corridors and Vehicle Collisions***	***Overall Number/ Magnitude of Threats***
		Tb/ Brucellosis	***Anthrax***						
GWBNP	*WBNP*	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
	Wentzel Lake	Yes	Yes	Yes	Yes[2]	Yes	Yes	No	High
	Slave River Lowlands	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
Elk Island NP		No	Yes	Yes	Yes[2]	No	No	No	Low
Aishihik		No	Yes	Yes	Yes[2]	Yes	No	No	Low
Chitek Lake		No	Yes	Yes	Yes[1]	Yes	Yes	No	High
Etthithun Lake		No	Yes	Yes	Yes[2]	Yes	No	No	Low
Hay Zama		Yes	Yes	Yes	Yes[2]	Yes	No	Yes	High
Mackenzie		Yes	Yes	Yes	Yes[1]	Yes	No	Yes	High
Nahanni		No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
Nordquist/Liard		No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
Ronald Lake		Yes	Yes	Yes	Yes[2]	Yes	Yes	No	High
Wabasca		Yes	Yes	Yes	Yes[2]	No	No	No	High
Innoko-Yukon		No	Yes	Yes	Yes[1]	Yes	Yes	No	Moderate

Yes[1] = Disease and/or Invasive stressors present and documented evidence of historical stochastic event
Yes[2] = Disease and/or Invasive stressors present and no documented evidence of historical stochastic event

Table A.5. Summary of Condition Threats under Current and Future Conditions under all scenarios. Values within the table indicate "yes" or "no" for the presence or absence of a given stressor acting upon a population. Categorical values for the overall magnitude range from "Low", "Moderate", and "High".

Population		Scenario	Disease		Negative Genetic Effects	Stochastic and Severe Weather Events	Biological Resource Use (hunting, persecution)	Invasive and other problematic species	Transportation Corridors and Vehicle Collisions	Overall Number/ Magnitude of Threats
			Tb/ Brucellosis	Anthrax						
GWBNP	WBNP	Current	Yes	Yes	Yes	Yes	Yes	Yes	No	High
		Scenario 1	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
		Scenario 2	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
		Scenario 3	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
	Wentzel Lake	Current	Yes	No	Yes	No	Yes	Yes	No	High
		Scenario 1	Yes	Yes	Yes	Yes[2]	Yes	Yes	No	High
		Scenario 2	Yes	No	Yes	No	Yes	Yes	No	High
		Scenario 3	Yes	Yes	Yes	Yes[2]	Yes	Yes	No	High
	Slave River Lowlands	Current	Yes	Yes	Yes	Yes	Yes	Yes	No	High
		Scenario 1	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
		Scenario 2	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
		Scenario 3	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	High
Elk Island NP		Current	No	No	Yes	No	No	No	No	Low
		Scenario 1	No	Yes	Yes	Yes[2]	No	No	No	Low
		Scenario 2	No	No	Yes	No	No	No	No	Low
		Scenario 3	No	Yes	Yes	Yes[2]	No	No	No	Low
Aishihik		Current	No	No	Yes	No	Yes	No	No	Low
		Scenario 1	No	Yes	Yes	Yes[2]	Yes	No	No	Low
		Scenario 2	No	No	Yes	No	Yes	No	No	Low
		Scenario 3	No	Yes	Yes	Yes[2]	Yes	No	No	Low
Chitek Lake		Current	No	No	Yes	Yes	Yes	Yes	No	Moderate
		Scenario 1	No	Yes	Yes	Yes[1]	Yes	Yes	No	High
		Scenario 2	No	No	Yes	Yes[1]	Yes	Yes	No	Moderate
		Scenario 3	No	Yes	Yes	Yes[1]	Yes	Yes	No	High
Etthithun Lake		Current	No	No	Yes	No	Yes	No	No	Low

	Scenario 1	No	Yes	Yes	Yes[2]	Yes	No	No	Low
	Scenario 2	No	No	Yes	No	Yes	No	No	Low
	Scenario 3	No	Yes	Yes	Yes[2]	Yes	No	No	Low
Hay Zama	*Current*	No	No	Yes	No	Yes	No	Yes	Low
	Scenario 1	No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
	Scenario 2	No	No	Yes	No	Yes	No	Yes	Low
	Scenario 3	Yes	Yes	Yes	Yes[2]	Yes	No	Yes	High
Mackenzie	*Current*	No	Yes	Yes	Yes	Yes	No	Yes	High
	Scenario 1	No	Yes	Yes	Yes[1]	Yes	No	Yes	High
	Scenario 2	No	Yes	Yes	Yes[1]	Yes	No	Yes	Moderate
	Scenario 3	Yes	Yes	Yes	Yes[1]	Yes	No	Yes	High
Nahanni	*Current*	No	No	Yes	Yes	Yes	No	Yes	Moderate
	Scenario 1	No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
	Scenario 2	No	No	No	No	Yes	No	Yes	Low
	Scenario 3	No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
Nordquist/Liard	*Current*	No	No	Yes	Yes	Yes	No	Yes	Moderate
	Scenario 1	No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
	Scenario 2	No	No	No	No	Yes	No	Yes	Low
	Scenario 3	No	Yes	Yes	Yes[2]	Yes	No	Yes	Moderate
Ronald Lake	*Current*	No	No	Yes	No	Yes	Yes	No	Low
	Scenario 1	No	Yes	Yes	Yes[2]	Yes	Yes	No	Low
	Scenario 2	No	No	Yes	Yes[1]	Yes	Yes	No	Low
	Scenario 3	Yes	Yes	Yes	Yes[2]	Yes	Yes	No	High
Wabasca	*Current*	No	No	Yes	No	No	No	No	Low
	Scenario 1	No	Yes	Yes	Yes[2]	No	No	No	Low
	Scenario 2	No	No	Yes	No	No	No	No	Low
	Scenario 3	Yes	Yes	Yes	Yes[2]	No	No	No	High
Innoko-Yukon	*Current*	No	No	Yes	Yes	Yes	Yes	No	Moderate
	Scenario 1	No	Yes	Yes	Yes[1]	Yes	Yes	No	Moderate
	Scenario 2	No	No	No	Yes[1]	Yes	Yes	No	Low
	Scenario 3	No	Yes	Yes	Yes[1]	Yes	Yes	No	Moderate

Yes[1] = Disease and/or Invasive stressors present and documented evidence of historical stochastic event
Yes[2] = Disease and/or Invasive stressors present and no documented evidence of historical stochastic event.

Appendix 2. Current and Future Condition

Region	Population		Scenario	# individuals	Population trend	Diseases of special concern	Likelihood of transmission	Likelihood of deleterious genetic exchange	Connectivity to disease free populations	Geographic expansion potential	Overall Condition
Canada	GWBNP	WBNP	Current	High	Moderate	Low	Low	High	Low	Low	Moderate
			Scenario 1	High	Moderate	Low	Low	High	Moderate	Low	Moderate
			Scenario 2	High	Moderate	Low	Low	High	Low	Low	Moderate
			Scenario 3	High	Moderate	Low	Low	High	Low	Low	Moderate
		Wentzel Lake	Current	Low	Moderate	Low	Low	High	Low	Low	Low
			Scenario 1	Low	Moderate	Low	Low	High	Moderate	Low	Moderate
			Scenario 2	Moderate	Moderate	High	Moderate	High	High	High	High
			Scenario 3	Low	Moderate	Low	Low	High	Low	Low	Low
		Slave River Lowlands	Current	Moderate	Moderate	Low	Low	High	Low	Low	Moderate
			Scenario 1	Moderate	Moderate	Low	Low	High	Moderate	Low	Moderate
			Scenario 2	Moderate	Moderate	High	Moderate	High	High	High	High
			Scenario 3	Moderate	Moderate	Low	Low	High	Low	Low	Moderate
	Elk Island NP		Current	Moderate	Moderate	High	High	High	Low	Low	Moderate
			Scenario 1	Moderate	Moderate	High	High	High	Low	Low	Moderate
			Scenario 2	Moderate	Moderate	High	High	High	Low	Low	Moderate
			Scenario 3	Moderate	Moderate	High	High	High	Low	Low	Moderate
	Aishihik		Current	High	High	High	High	High	Low	High	High
			Scenario 1	High	High	High	High	High	Low	High	High
			Scenario 2	High	High	High	High	High	High	High	High
			Scenario 3	High	High	High	High	High	Low	High	High
	Chitek Lake		Current	Moderate	Moderate	High	High	Moderate	Low	Low	Moderate
			Scenario 1	Moderate	Moderate	High	High	Moderate	Low	Low	Moderate
			Scenario 2	Moderate	Moderate	High	High	High	Low	Moderate	Moderate
			Scenario 3	Moderate	Moderate	Moderate	High	Moderate	Low	Low	Moderate
	Etthithun Lake		Current	Moderate	Moderate	High	Moderate	Moderate	Low	Low	Moderate
			Scenario 1	Moderate	Moderate	High	Moderate	High	Low	Low	Moderate
			Scenario 2	Moderate	Moderate	High	High	High	Moderate	Moderate	Moderate
			Scenario 3	Moderate	Low	Moderate	Moderate	Moderate	Low	Low	Moderate
	Hay Zama		Current	Moderate	Moderate	High	Moderate	Moderate	Low	Low	Moderate
			Scenario 1	Moderate	Moderate	High	Moderate	Low	Low	Low	Moderate
			Scenario 2	High	High	High	High	Moderate	Moderate	High	High
			Scenario 3	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Moderate
	Mackenzie		Current	Moderate	Low	High	High	Moderate	Low	Moderate	Moderate
			Scenario 1	Moderate	Low	High	High	Moderate	Low	Moderate	Moderate
			Scenario 2	High	Moderate	High	High	Moderate	Moderate	High	High
			Scenario 3	Moderate	Moderate	Low	Moderate	Moderate	Low	Moderate	Moderate
	Nahanni		Current	Moderate	High	High	Moderate	Low	Low	Moderate	Moderate
			Scenario 1	Moderate	High	High	Moderate	Moderate	Low	Moderate	Moderate
			Scenario 2	High	High	High	High	Moderate	High	High	High
			Scenario 3	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Moderate
	Nordquist/Liard		Current	Low	Moderate	High	Moderate	Low	Low	Low	Moderate
			Scenario 1	Low	Moderate	High	Moderate	Moderate	Low	Low	Moderate
			Scenario 2	Moderate	Moderate	High	High	Moderate	High	High	High
			Scenario 3	Low	Moderate	Moderate	Moderate	Low	Low	Low	Low
	Ronald Lake		Current	Low	Moderate	Moderate	Moderate	Low	Low	Low	Low
			Scenario 1	Moderate	High	Moderate	Moderate	Moderate	Low	Moderate	Moderate
			Scenario 2	Moderate	Moderate	High	High	Moderate	Moderate	Moderate	Moderate
			Scenario 3	Low	Moderate	Moderate	Moderate	Low	Low	Low	Low
	Wabasca		Current	Low	Moderate	Moderate	Moderate	Low	Low	Low	Low
			Scenario 1	Low	Moderate	Moderate	Moderate	Low	Low	Low	Low
			Scenario 2	Moderate	Moderate	High	High	Moderate	Moderate	Moderate	Moderate
			Scenario 3	Low	Moderate	Low	Low	Low	Low	Low	Low
Alaska	Innoko-Yukon		Current	Low	Low	High	High	High	Low	High	Moderate
			Scenario 1	Moderate	Moderate	High	High	High	Low	High	Moderate
			Scenario 2	High	Moderate	High	High	High	Moderate	High	High
			Scenario 3	Low	Low	High	High	High	Low	Low	Moderate