SYSTEMATIC CONSERVATION PLANNING IN TSAY KEH DENE TERRITORY: INCORPORATING CLIMATE CHANGE AND INTERWEAVING TRADITIONAL ECOLOGICAL KNOWLEDGE

by

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ABSTRACT

Systematic Conservation Planning (SCP) is the practice of comprehensively assessing a landscape for its conservation value via geospatial analysis. This research project applied SCP principles and tools to Tsay Keh Dene Nation Territory in north-central British Columbia, Canada. Working with the Tsay Keh Dene community, we articulated conservation goals and determined important features on the landscape that helped attain those goals. This effort also examined climate change and connectivity impacts on conservation, comparing which lands are most worth conserving today versus 30 and 60 years from now. Finally, this work explored the interweaving of Traditional Ecological Knowledge with the Western science-based SCP framework to ensure a more holistic and inclusive outcome. Our findings both validated ongoing conservation efforts in the Territory and identified additional high-value areas for future consideration. This research can also serve as a guide for other accessible TEK-focused or community-led SCP efforts.

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ABBREVIATIONS GLOSSARY

BEC: Biogeoclimatic Ecosystem Classification (zones)

CCE: Chu Cho Environmental

GIS: Geographic Information Systems

LRTO: Lands, Resources, and Treaty Operations office at Tsay Keh Dene Nation

SCP: Systematic Conservation Planning

TEK: Traditional Ecological Knowledge

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1.0 INTRODUCTION

1.1 The Biodiversity Crisis

Today, human activities dominate the earth and are having significant global, regional, and local impacts on ecosystems and the critical services they provide to humanity. Extinction rates are between 100- and 10,000-times evolutionary background rates, and shrinking populations and ranges are contributing to a massive anthropogenic erosion of biodiversity, which scientists have referred to as "biological annihilation" (Lamkin & Miller, 2016; Strona & Bradshaw, 2018). Habitat loss and degradation is a major driver of biodiversity loss not restricted to tropical environments but equally problematic across Canada and in northern British Columbia.

This is set against a backdrop of an increasingly changing climate where effects are magnified in Canada's boreal regions (Schindler & Lee, 2010). In our own backyard this means that without radical action, mountain caribou will likely be extinct in our lifetimes (Festa-Bianchet et al., 2011). Wolverine and other critical mid-trophic carnivores will be further isolated into patchy, ultimately genetically impoverished pockets (McKelvey et al., 2011). Moose populations will continue to decline (Rempel, 2011) and populations of boreal birds that rely on structurally complex forests in the north will become destitute (Stralberg et al., 2015).

Systematic Conservation Planning (SCP) represents a strategic area-based conservation approach to counteract both development- and climate change-related anthropogenic activity and safeguard biodiversity (Gillson et al., 2013). Conserving lands to combat climate change and protect biodiversity also helps contribute to Aichi Target 11 of

the Convention on Biological Diversity (17% terrestrial and inland waters protected by 2020) and Canada's Pathway to Target 1, which supports Indigenous Protected and Conserved Areas (IPCAs) as a vehicle to reach that 17% (Zurba et al., 2019). As 2020 came and went, protecting 30% of the planet by 2030 is the new goal of conservationists, and this project can help the Tsay Keh Dene Nation contribute to that goal within their mountainous corner of the world (Campaign for Nature, 2020).

This SCP can also serve as an act of continued stewardship by Indigenous peoples, not just counteracting anthropogenic activity in service to the world, but also counteracting the last few centuries of settler colonialism. Eli Enns – a Nuu-chah-nulth member and co-chair of Canada's Indigenous Circle of Experts (ICE) – states that "Whenever you find intact ecological biodiversity, you find intact, thriving, cultural holistic diversity" (Parks Canada, 2018, p. 73). The hope is that the products of this work strengthen the Nation's own ecological and cultural conservation initiatives, benefitting both the community and their relationships with the land.

1.2 Conservation Planning Need for the Tsay Keh Dene Nation

Tsay Keh Dene Nation Territory is located in the northcentral region of so-called British Columbia, Canada (Figure 1). The Tsay Keh Dene community is located roughly 360 km north of the city of Prince George, with Mackenzie being the closest sizable town at roughly 3,700 people. The Territory is a large, 32,000 km^2 area encompassing critical ecological and cultural values.

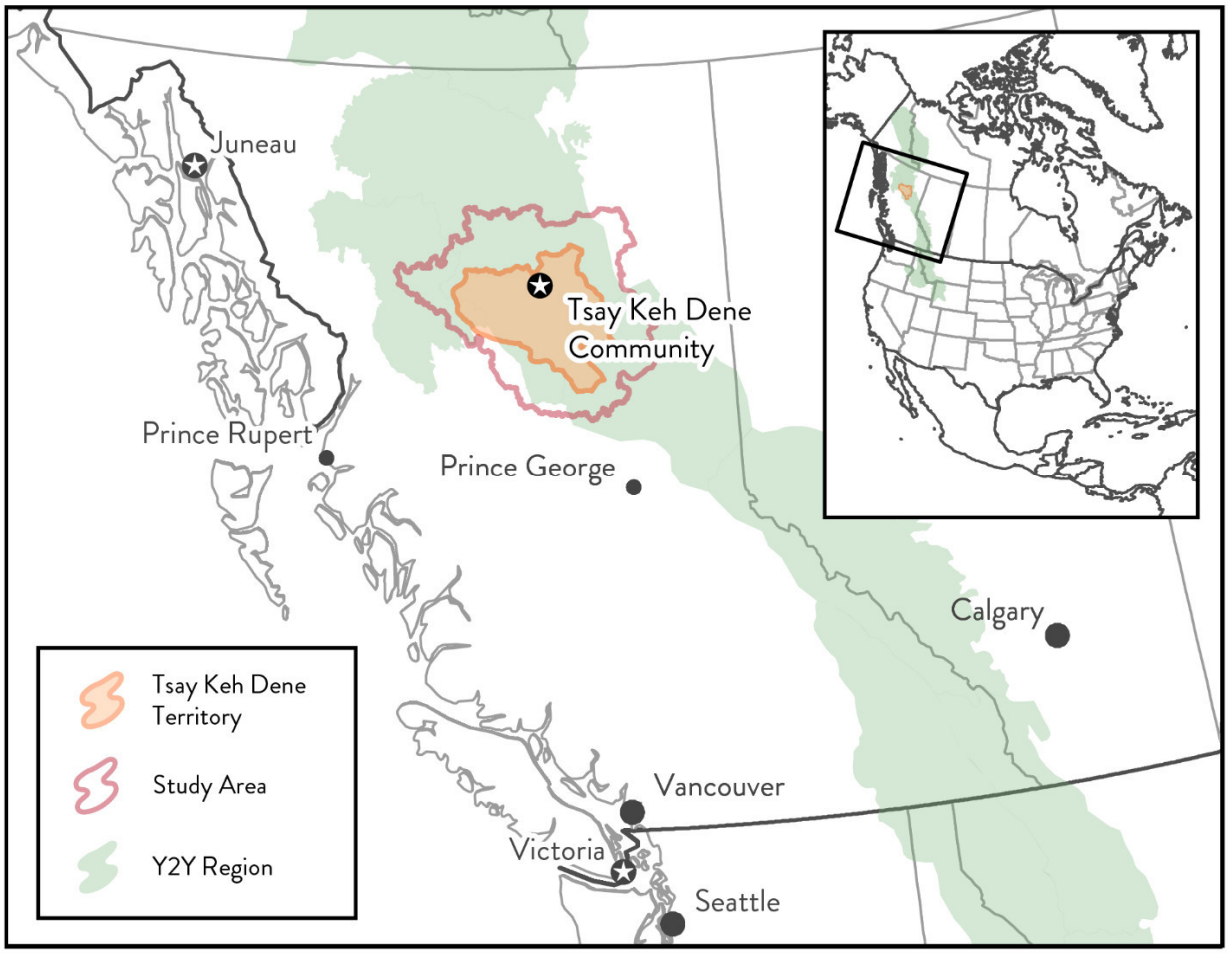

Figure 1. Contextual map showing the location of Tsay Keh Dene Territory, the study area, and the Yellowstone to Yukon (Y2Y) region within British Columbia and North America.

Located within the Rocky Mountain Trench region and encompassing portions of the Omineca and Rocky Mountains, the current resource development footprint is ecologically

significant in the region. My analysis revealed that 30% of the Territory has been impacted. There are five small-scale dams located within the Territory (the Kemess North, South, and East Diversion Dams, and the 3 Mile Creek and Woody Creek Dams) as well as the massive W.A.C. Bennett Dam on the Peace River located just outside of the Territory (Figure 2). Although the Bennett Dam site is located outside of the Territory, construction and subsequent flooding to create the Williston Reservoir have had immeasurable impacts on the Tsay Keh Dene people and the habitats within the Territory, both historically and today (Tsay Keh Dene Nation, personal communication, September 30, 2019). The Williston Reservoir's inundation resulted in the direct loss of approximately 1,500 km^2 of high-complexity lowland habitats, which are critical for many species (Fish and Wildlife Compensation Program, 2014). Furthermore, access roads associated with the reservoir allowed industry (e.g., forestry, mining) to expand throughout the area, resulting in continued, indirect impacts on wildlife species and the habitats they utilize today (Fish and Wildlife Compensation Program, 2014). Hunters and guide outfitters can also significantly impact wildlife in the region (Abadzadesahraei, personal communication, May 7, 2020).

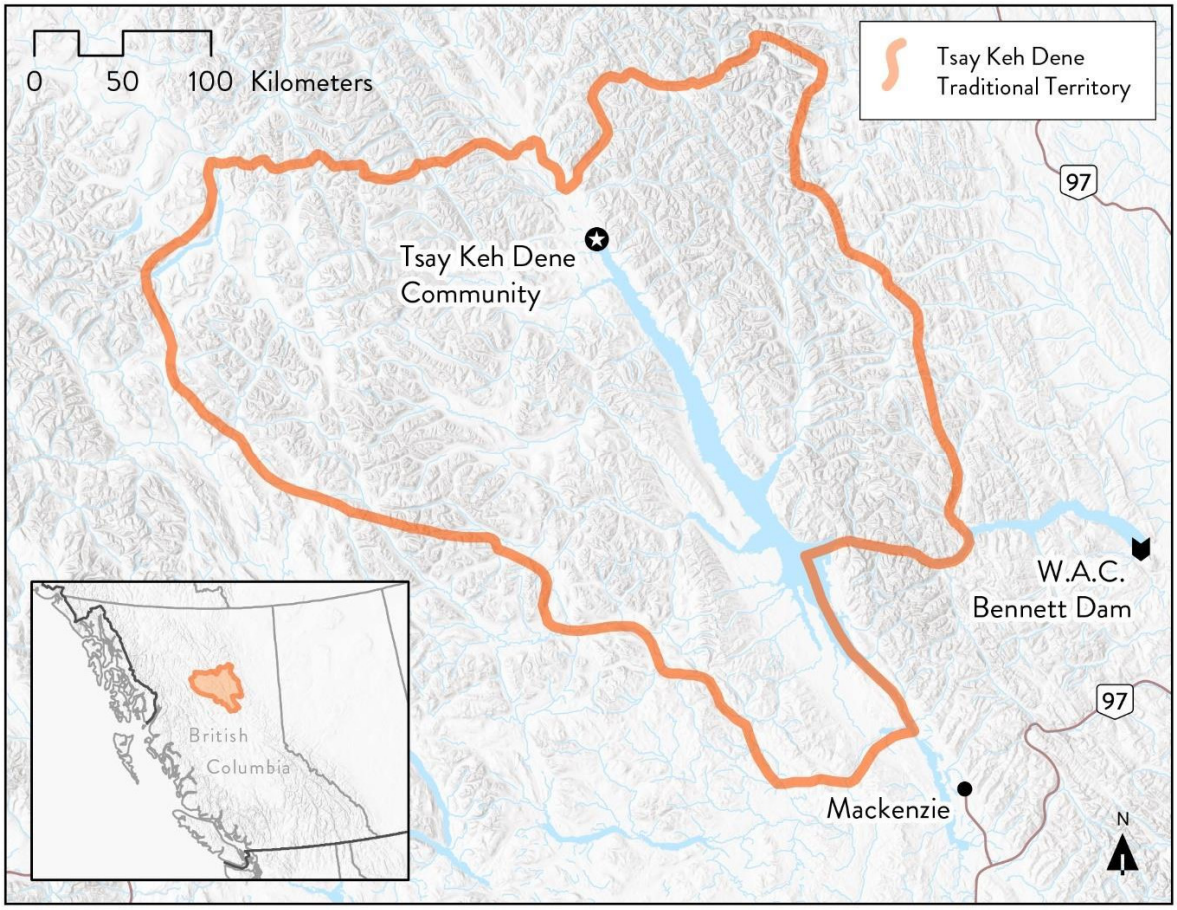

Figure 2. Contextual map showing Tsay Keh Dene Territory within so-called British Columbia.

Today, there are approximately 170 provincially red- or blue-listed species (including several woodland caribou populations) found within the Territory, along with numerous rare ecosystems and special features. In addition, 36 species listed under Schedule 1 of the Species at Risk Act occur within the Territory (Appendix A. Federal Species at Risk Act (SARA) Schedule 1 Species in Territory). Of particular interest to the Nation are the Chase, Wolverine, and Finlay herds of woodland caribou. Other focal species include bull trout, fisher, Stone sheep, mountain goat, moose, and grizzly bear (Tsay Keh Dene Nation, personal communication, September 30, 2019). Regionally, connectivity is critical to

maintaining populations of caribou and other wide-ranging mammal and fish species, particularly in light of the rapidly changing climate.

The intensity of current resource development in the Territory is such that the Nation is often overwhelmed by the number of referrals for resource activities that they receive. These referrals are, by their nature, limited in focus both to a specific geography and to a single industry or development. As a result, referral comments provided by the Nation are often site-specific and limited in scope. The Nation would like to take a much broader perspective and holistic approach in planning and managing, including being able to contextualize individual referrals within a larger scale conservation context (Tsay Keh Dene Nation, personal communication, September 30, 2019).

In the twenty-first century, much of the global conservation planning response to development pressures has been focused on the designation and management of parks and protected areas (Maxwell et al., 2020). Only 9% of Tsay Keh Dene Territory is currently under provincial protected status, though the Nation has recently declared an Indigenous Protected and Conserved Area in the Ingenika River valley. The largest of these protected areas (Omineca) is under 1,000 km^2 – well below minimum thresholds for species persistence of wide-ranging mammals (>3,000 km^2) (Gurd & Nudds, 1999; Newmark, 1995; Wright, 2016). While protected areas are an increasingly vital tool to combat loss of biodiversity and the climate crisis, conservation planning must occur across all land management systems and encompass a wide range of management tools and approaches.

1.3 Including Climate Change and Traditional Ecological Knowledge in Systematic Conservation Planning

Systematic Conservation Planning is widely considered the most effective method for designing wide, regional conservation approaches, including the identification of protected areas and other ecological networks (Pressey et al., 2007). The success and effectiveness of SCP can be attributed to its efficiency in using limited resources to achieve conservation goals, its flexibility and defensibility in the face of competing land uses, and its accountability in allowing decisions to be critically reviewed (Margules & Pressey, 2000). SCP uses detailed biogeographical information and selection algorithms to identify priority conservation areas (Knight & Cowling, 2007; Watson et al., 2011). It strives to move the prioritization of conservation lands beyond opportunism and toward scientific defensibility and improved efficacy (Pressey et al., 1993). Furthermore, SCP supports the identification of conservation networks that represent regional species and ecosystems diversity, are comprised of enough habitat of specific types to maintain viable species populations, enable continued community and population processes (including shifts in species' ranges), and allow natural patterns of disturbance (Baldwin et al., 2014).

Explicitly incorporating climate change as part of the Systematic Conservation Planning process is now possible. As the field expands its scope and perspectives, approaches become more effective at incorporating previously poorly understood or connected variables (Mann, 2020). With the widespread availability of emission scenarios and reliable climate change data, the SCP framework can incorporate climate information and evolve into a climate change-conscious approach to conservation planning (Stralberg et al., 2020).

This climate-conscious approach involves looking at areas of biotic refugia, or habitat that will remain viable and desirable for species despite climate change (Michalak, Lawler, et al., 2018). Another aspect of this approach is to consider climate velocity, which quantifies how far species will have to travel from a given area to find similar habitat in the future (forward velocity), as well as how far other species will have to travel to populate that same area in its now altered state (backward velocity) (Carroll et al., 2015). One of the first projects to undertake a climate-conscious conservation planning approach in Canada has been done in British Columbia's Peace Region (Mann, 2020). Methods developed and tested in that project will be used to inform the approach in this research.

This project is unique from Mann's (2020), however, in that it is being developed in conjunction with a First Nation. Indigenous-led conservation initiatives are gaining momentum in Canada and elsewhere in the world through the creation of Indigenous Protected and Conserved Areas (IPCAs) (Zurba et al., 2019). Establishing conservation areas is just one way to protect biodiversity, with other designations like Old Growth Management Areas (OGMAs) and Ungulate Winter Range (UWR) also serving as options. These sorts of initiatives help to further the self-determination of Indigenous peoples, creating conservation areas that embody their own biodiversity and cultural values as opposed to the colonial processes of the past that centered on a people-free 'wilderness'. By initiating and guiding this project, the Tsay Keh Dene Nation ensured that their values informed this project by helping scope it from the outset and providing input at each step along the way.

1.4 Research Purpose

The purpose of my research project was to explore which areas in Tsay Keh Dene Territory have high conservation value (both ecologically and culturally), landscape

connectivity, and resiliency to climate change. I used the Systematic Conservation Planning framework and interwove Traditional Ecological Knowledge throughout by taking a critical GIS perspective and community-led approach to identifying important conservation lands in the Territory for the Nation's consideration. By recognizing GIS as a colonial tool shaped by the Western scientific spatial understanding of the world, I assisted the Nation in the form of counter-mapping – using GIS technology to empower a community and share an accessible and defensible expression of their conservation goals. By allowing Tsay Keh Dene values to shape this process, local voices, views, and understandings were etched into this work (Burkhart, 2018).

The result was an actionable systematic conservation plan and accompanying tool that can assist the Nation with routine resource extraction referrals as well as long-range land use planning decisions. While the Nation already possesses a great deal of GIS capacity, this project complemented its strengths and provided a novel aspect to their geospatial information and conservation planning efforts. The end product included a set of curated maps and an updatable model for identifying the locations of key ecological and cultural values within Tsay Keh Dene Territory. By providing the Nation with a robust 'living tool' that takes present-day biodiversity, climate change, and connectivity of lands into account, diverse scenario planning can continue to take place once this research project has formally ended. Planning and management of the Territory for cultural, ecological, or economic purposes will be made easier and more defensible with this SCP framework in place. To achieve these goals, I sought to answer the following questions:

- Which portions of Tsay Keh Dene Territory have the highest ecological and cultural value for select present-day conservation features?
- Which portions of Tsay Keh Dene Territory retain conservation value when climate change is considered?
- How can landscape connectivity be explicitly included in the Systematic Conservation Planning process?
- Which stages of the Systematic Conservation Planning process provide an opportunity for the interweaving of Traditional Ecological Knowledge to produce a more inclusive conservation plan?

2.0 LITERATURE REVIEW

The Systematic Conservation Planning process consists of a set of common steps but remains highly adaptable to account for other critical aspects of ecology and conservation. This literature review explores how the SCP process became widely accepted and the theories behind the field's foundational approaches. I will then delve into the importance of movement corridors across the landscape and how to explicitly incorporate connectivity into the SCP process. Next, I will explain how climate change threatens biodiversity and how to conserve resilient habitats for future species assemblages by integrating climate metrics as SCP conservation features. Finally, I will examine Traditional Ecological Knowledge (TEK) as a way of knowing. I will explore the various ‘faces’ or aspects of TEK and how these

aspects have been used alongside Western science in the past, before concluding with how TEK has been interwoven into the SCP process by various conservation efforts to date.

2.1 Systematic Conservation Planning as the Gold Standard

Systematic Conservation Planning is the product of decades of conservation theory and practice, promoting representativeness and persistence of species and ecosystems in conservation area design. From the inception of SCP as a concept in the 1980s until its coalescence and increased prevalence in the early 2000s, the practice has become widely accepted within the field of conservation biology (Pressey et al., 2007; Smith et al., 2019). This is illustrated through its use by major organizations like the Nature Conservancy, heavily influencing legislation, policy, and real-world conservation initiatives, and cementing itself as a staple of relevant academic conferences (Pressey et al., 2007).

The development of this ecocentric, systematic approach to conservation in places like New South Wales, Australia has resulted in an increase in the establishment of conservation areas whose express purpose is to protect biodiversity – be it ecosystems, biological assemblages, a specific species, or even a particular population of a species (Margules & Pressey, 2000). Furthermore, integrating conservation areas within their larger landscapes and focusing on connectivity in general (not just amongst conservation areas) is critical (Schloss et al., 2011). Margules and Pressey (2000) also maintain that in order for conservation areas to achieve their goal of protecting biodiversity, they must be representative (a cross-section of the biodiversity of a region) and promote persistence (allowing for species and processes to naturally remain on the landscape). While representativeness remains a common goal of SCP, there has more recently been a shift

towards focusing on biodiversity hotspots and ecosystem services as either primary or supplemental goals (Mitchell et al., 2021; Smith et al., 2019).

SCP requires that users make several decisions to inform model construction. The SCP process is outlined in a series of stages (Margules & Pressey, 2000) that I have modified to explicitly include connectivity and climate change elements based on Mann's (2020) work (Table 1).

1. Set Conservation Goals/Select and Compile Conservation Feature Data
a) Develop conservation goals for the study area. b) Identify conservation features to serve as surrogates for present-day and future biodiversity. c) Compile data with sufficient rigor and consistency for inclusion in the analysis.
2. Develop a Human Footprint Layer
d) Compile a human footprint model to quantify and spatially model the present-day state of anthropogenic disturbance.
3. Identify Connectivity Corridors
e) Identify features that affect landscape permeability. f) Create a landscape resistance spatial layer. g) Perform a landscape connectivity analysis between conservation areas and ecologically-intact areas in the greater territory (Linkage Mapper). h) Perform a landscape connectivity analysis across the entire greater territory (Omniscape).
4. Set Conservation Targets
i) Translate goals into quantifiable targets for conservation in the greater territory that promote present-day and future biodiversity.
5. Review Existing Conservation Areas
j) Determine the extent to which the existing conservation areas network and ecologically-intact areas achieve the identified targets.
6. Identify a Portfolio of High-Value Conservation Lands
k) Use an SCP algorithm (*prioritizr*) to spatially delineate additional areas for conservation while minimizing costs.
7. Assess *prioritizr* Solutions Through Different Lenses
l) Compare areas within the resulting portfolio of high-value conservation lands for their diversity of conservation features captured. m) Compare high-value conservation lands for present-day and multiple future climate scenarios. n) Validate solutions with Traditional Ecological Knowledge.

Table 1. Modified stages of the Systematic Conservation Planning framework

In Stage 1, the user must identify conservation goals (e.g., promoting biodiversity, climate change resiliency, landscape connectivity, etc.). These goals set the basis for the rest of the process, guiding the selection of conservation features, representational targets, and the potential inclusion of other elements within the SCP framework. The user selects which 'conservation features' best represent their ideal ecological outcomes, realizing that this suite must be numerous and comprehensive enough to achieve one's conservation goals, yet not include so many features as to become unwieldy. Data with sufficient rigor and consistency must then be compiled for inclusion in the analysis.

In Stage 2, the user analyzes the location and severity of anthropogenic disturbance in the study area by creating a present-day human footprint layer. This allows the user to proceed to Stage 3 and identify features (natural and human footprint) that affect landscape permeability in order to create a resistance layer. The user can then quantify the permeability of the landscape (both overall and between identified core areas) and identify connectivity corridors.

In Stage 4, targets must be set for each conservation feature to identify what percentage of that feature's area must be selected as part of a conservation solution. These targets can be informed by the literature, best practices, or stakeholder priorities.

In Stage 5, the identified core areas are reviewed for how well they capture the targets. This allows the user to understand how much of each conservation feature target will have to be captured in the remaining portions of the study area.

In Stage 6, various scenarios are run to create a portfolio of conservation lands based on the conservation features' targets. In Stage 7, these scenarios' outputs are assessed through

different lenses (e.g., conservation feature diversity, climate change resiliency) to better understand their potential efficacy.

Further details on each stage will be outlined in the Methods section, but I will explore key concepts behind the stages as part of this Literature Review. I will first examine different approaches to capturing biodiversity (Stage 1), before moving on to connectivity (Stage 3), and ending with climate change and Traditional Ecological Knowledge, which inform each stage of the SCP process.

2.2 Selecting Key Biodiversity Features

Understanding how to distill biodiversity into selected features and providing well-vetted input data is critical, as these steps are the foundation of a conservation solution. The goal is to conserve biodiversity by selecting conservation features at the ecosystem and species levels using coarse- and fine-filter features, respectively, with the genetic diversity level indirectly conserved through sufficiently large and connected conservation areas.

A representation goal's intent is that a prospective conservation area is a microcosm of the biodiversity in the area, mirroring the region's various ecosystems and species at large (Wiersma, 2008). One option to achieve representation would be to procure spatial datasets of every known species, land facet category, and vegetative history – a feat that Lambeck (1997) argues is simply not possible in most instances. Conversely, one could strategically select the most important conservation features– whether ecologically, socioculturally, or economically.

Using one or just a few select conservation features is ill-advised, as the resulting areas calculated for conservation will represent only those features and not capture larger

biodiversity goals (Margules & Pressey, 2000). Tingley et al. (2014) argue that best practice is to employ several strategically selected conservation features at both coarse- and fine-filter levels, capturing umbrella species as well as the ecological patterns, biophysical processes, and abiotic components that shape the broader landscape.

Coarse-filter features such as ecoregional representation systems that focus on broad vegetative classes or abiotic representation approaches such as land facets are intended to capture the breadth of biodiversity across the landscape. Representation approaches focus on ecosystem diversity and the attendant environments that support species and genetic diversity.

An alternative or complementary approach is to explicitly conserve biodiversity hotspots, or Key Biodiversity Areas (KBAs), focusing on species richness and rarity at local scales (Ceauşu et al., 2015). This concept initially focused on the protection of endemic and threatened species as opposed to protecting the species composition of a particular area (Kullberg et al., 2019). The KBA approach has since broadened to include five criteria: A) Threatened Biodiversity, B) Geographically Restricted Biodiversity, C) Ecological Integrity, D) Biological Processes, and E) Irreplaceability Through Quantitative Analysis (IUCN, 2016). However, some suggest that KBAs, which can be rarely distributed across the landscape and in limited occurrence, may be less useful for protected areas planning and more suited towards the designation of Other Effective Area-Based Conservation Measures (OECMs) (Dudley et al., 2017), Old Growth Management Areas (OGMAs), Special Management Zones (BC Ministry of Forests, 2003; Government of British Columbia, 2020) or Ecological Reserves.

2.2.1 Coarse-Filter Approaches

The reasons for protecting the landscape rather than its inhabitants are two-fold: 1) developing and maintaining species data for the entirety of the plant and animal kingdoms is time- and cost-prohibitive, and 2) present-day biological assemblages are ephemeral (Tingley et al., 2014). The idea is that by conserving diverse ecosystems, present-day species assemblages (including those that little to no information is known about) will be conserved in the process, while conserving as diverse a collection of land facets as possible will conserve the inherent adaptive or evolutionary potential of species under future conditions. This way, both the present-day and future needs of most species will be inherent in the high-value conservation lands that make up the final product of the SCP (Schneider et al., 2011).

A coarse-filter conservation approach focuses on representation of biotic diversity within varied vegetative communities (e.g., biogeoclimatic zones) or abiotic diversity in varied soil, slope, and elevation units (Curtis, 2018). Biogeoclimatic Ecosystem Classifications, or BEC zones, are commonly used within British Columbia to ensure representation of various areas of vegetative communities and the abiotic (e.g., slope, elevation, and soils) and climatic environments that have shaped them (BC Environment, 1995). Other classification systems for vegetation-based ecological communities such as terrestrial ecoregions (Olson et al., 2001) and ecozones (Parks Canada, 2003) also provide approaches to understand and map biotic representation at global and national scales that are less biased by a resource-extraction focus. Schloss et al. (2011) note that vegetation-based ecological communities can also serve as a proxy for certain species when detailed species distribution data is limited.

Disturbance regimes – the historical patterns of natural processes that alter the landscape – act as a driver of ecological representation and diversity (Hobbs & Huenneke, 1992). Natural disturbances such as fires, storms, flooding, and insect outbreaks (among others) act as regulators of species composition. Different species thrive with varying frequency, intensity, and types of disturbance (Hobbs & Huenneke, 1992). British Columbia has classified disturbances into five natural disturbance types (NDTs), and for the sake of setting biodiversity objectives pairs them with BEC zones to aid in management decisions (BC Environment, 1995).

Unique combinations of natural disturbance regimes, biogeoclimatic ecosystem classifications (BEC) zones, and the age and burn history of a forest stand can translate to high-quality, biodiverse habitat. By managing today's forests to resemble historical forests shaped by natural disturbances, there is a greater chance that native species and ecological processes will persist (BC Environment, 1995). Seral stages (or forest ages) are also of biodiversity interest, as specialist species are often associated with the early shrub or mature stages of forest stands (BC Environment, 1995).

Abiotic, or land facet representation (a combination of aspect, elevation, slope, and landform), is a more recent focus given its potential to allow for persistence in the face of a changing climate (Tingley et al., 2014). Conservation plans that target high representation of land facet rarity and diversity, along with ecosystem diversity, help promote ecological processes, evolutionary interaction, and range shift – aiding in species' resiliency against climate change (Beier & Brost, 2010; Tingley et al., 2014). This approach requires the extraction of topographic data from a digital elevation model (DEM), the products of which are more stable and permanent in nature than the relatively ephemeral vegetation-based

ecological communities (Beier & Brost, 2010). The inclusion of land facets has been described as preserving the 'stage' or 'arena' and not just the 'actors' (species) (Beier & Brost, 2010).

Each of the above coarse-filter approaches and corresponding conservation features do not necessarily represent mutually exclusive attributes for inclusion in an SCP analysis. Rather, these options can be mixed and matched to provide different lenses for understanding diversity in a region and to attain different conservation objectives.

2.2.2 Fine-Filter Approaches

Fine-filter conservation approaches provide a lens for prioritizing lands for conservation that focuses on rarer landscape elements – like wetlands, mineral licks, or wildlife species that are unevenly distributed across the landscape and may 'fall through the cracks' of a coarse-filter approach (Curtis, 2018). Mammalian carnivores frequently serve as focal species in fine-filter analyses as they generally operate at the ecosystem scale. This helps to uncover habitat area thresholds lower in the food chain, as well as reveal levels of connectivity via their distribution on the landscape (Carroll et al., 2001). These are referred to as surrogate species because by accounting for these species[1], others with similar habitat needs are theoretically included.

In some instances, multiple focal species will be used to capture various facets of biodiversity in an attempt to be more inclusive. This was the case in Carroll et al.'s (2001)

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[1] Frequently the selected surrogates are umbrella species, so named because the protection of the species in question indirectly protects several other species under the same 'umbrella'.

study in the Rocky Mountain region, where researchers incorporated carnivores with similar ranges, but which occupied different trophic levels. The researchers chose fisher (*Martes pennanti*), lynx (*Lynx canadensis*), wolverine (*Gulo gulo*), and grizzly bear (*Ursus arctos*), for their varying levels of habitat overlap, as well as differing responses to the fragmentation effects of human population and roads. These species complement one another, whereas a single umbrella species might not capture the full diversity of an area.

Another approach to selecting focal species is to focus on species of conservation concern. Grizzly bear, fisher, and wolverine could be included in this approach, as they are categorized as blue- and red-listed (species of special concern and at risk of being lost, respectively) according to British Columbia's provincial Conservation Status Rankings (Government of British Columbia, 2019). This approach can lead to a large number of species as inputs in an attempt to reach conservation goals in each, as was the case in Horn's (2011) SCP work in the Central Interior of British Columbia, where 100 terrestrial animal species were selected.

Some research has called into question the use of umbrella or 'flagship' species as surrogates in SCP (Andelman & Fagan, 2000). In a situation where a database of species of concern and their geographic ranges was available, Andelman and Fagan (2000) found that strategically-selected species performed just as well as an equal number of randomly selected species as surrogates for conservation. Furthermore, some argue for including as many species as possible (provided suitable data exists) to aid in quantifying irreplaceability and identifying geographically restricted biodiversity in the name of global persistence of biodiversity (IUCN, 2016; R. Schuster, personal communication, May 1, 2020). While the utility of umbrella species as conservation feature inputs may have some limitations, the use

of wide-ranging, keystone or flagship species (i.e., big carnivores and charismatic species) is helpful for the attention they bring to SCP research (Andelman & Fagan, 2000), and practical as data is likely more widely available (Watson et al., 2011).

Ultimately, combining a range of biotic and abiotic coarse-filter approaches with a more nuanced species-based fine-filter approach is what makes for an effective SCP. Some researchers suggest that conservation goals cannot be achieved without using both strategies and that this will only grow truer in the face of uncertainty brought on by climate change (Tingley et al., 2014).

2.2.3 Boundaries of Analysis

Political boundaries are often chosen as study areas given jurisdictional considerations; however, ecological boundaries are better suited for ecological work. Landscape units such as watersheds can be relevant for representation and analysis at a number of scales (Groves, 2003). Watersheds provide natural units within which to assess biodiversity, as well as acting as zoogeographic range boundaries (Groves, 2003). These units are more organic than political boundaries, as they delineate natural processes as opposed to human ones (Ffolliott et al., 2003). Additionally, other sub-boundaries like climate regions and caribou herd ranges can be considered and assessed based on their suitability and partner priorities.

2.3 Connectivity and Persistence of Conservation Areas

"'Ecological connectivity' is the unimpeded movement of species and the flow of natural processes that sustain life on Earth" (Hilty et al., 2020, p. 2). Whether today or in a climate-altered future, species must be able to effectively move across the landscape to

persist. Best practices in conservation planning regarding the concepts of fragmentation and connectivity of conservation areas stem from landscape ecology. Landscape fragmentation occurs when effective habitat is fractured – typically through human development and resource extraction – into distinct and discontinuous patches. These patches have increased edge and less 'interior' habitat, increasing vulnerability for disturbance-sensitive species and biodiversity as one 'island' of core habitat is broken into multiple smaller 'islands' (Hansen & Defries, 2007). Additionally, many species require large home ranges for daily, seasonal, or genetic movement. Connectivity is important because it supports the movement of these species from one patch of habitat to another, allowing them relatively safe passage within their ranges during single animals' life histories (Catchpole, 2016). This increases fitness of wildlife populations while decreasing predation and human-wildlife conflict (Ghoddousi et al., 2021). Additionally, connectivity can ensure long-term genetic diversity by functionally connecting metapopulations (Stewart et al., 2019). This importance of contiguous habitats is why conservation planners focus on conserving corridors of land to serve as a link between existing conservation areas (Haber & Nelson, 2015).

By linking conservation areas, a landscape becomes more permeable (structural connectivity), facilitating the movement of species and their genetic material (functional connectivity) (Doerr et al., 2011). Connectivity between individual conservation areas of a given region (*in situ* connectivity) has proven effective in promoting ecological persistence, causing conservation scientists to explore the connection of much larger landscapes, even up to the continental scale (*ex situ* connectivity) as in the case of the Yellowstone to Yukon Conservation Initiative (Hodgson et al., 2011; Mann, 2020). These larger landscape connections not only facilitate the movement of species within their life histories but may

prove to be vital movement corridors in the face of climate change as species seek new habitat as climate refugees (Hilty et al., 2020).

Connectivity can be a meaningful addition to a systematic conservation plan, ensuring species movement between ecologically intact areas and effectively making a network of conservation areas greater than the sum of its parts. The SCP process provides a spectrum of connectivity analysis options, ranging from a visual overlay to inform prioritization of conservation lands after the solution has been generated (Mann, 2020), to a *post hoc* statistical analysis of connectivity value to prioritize selected conservation lands (Fajardo et al., 2014), all the way up to modelling the connectivity of a landscape and explicitly including it as part of the SCP process (Heinemeyer et al., 2003).

Most connectivity modeling methods are based on graph theory, a third way of thinking about the landscape beyond vector polygons and raster grids – a graph (or network) of interconnected nodes (Urban & Keitt, 2001). The identification of least-cost paths between core areas and the application of electronic circuit theory as a connectivity predictor are both born out of graph theory (Hilty et al., 2020). To apply these theories and methods, conservation scientists have developed a number of tools to model connectivity. Linkage Mapper looks for least-cost corridors between core areas, identifying a path of least resistance and assigning progressively lower values of connectivity as distance increases from the least-cost path (McRae et al., 2013). Alternatively, Omniscape looks at the connectivity of the landscape overall by using a 'moving window analysis' (Figure 3) to measure connectivity between a single grid cell and every grid cell within a stated radius (the 'window') (McRae et al., 2016). This exercise is performed for each grid cell in the study

area (the 'moving' aspect) and summed for a cumulative output (Landau, 2020). Both tools are open source and part of the Circuitscape library (McRae et al., 2013).

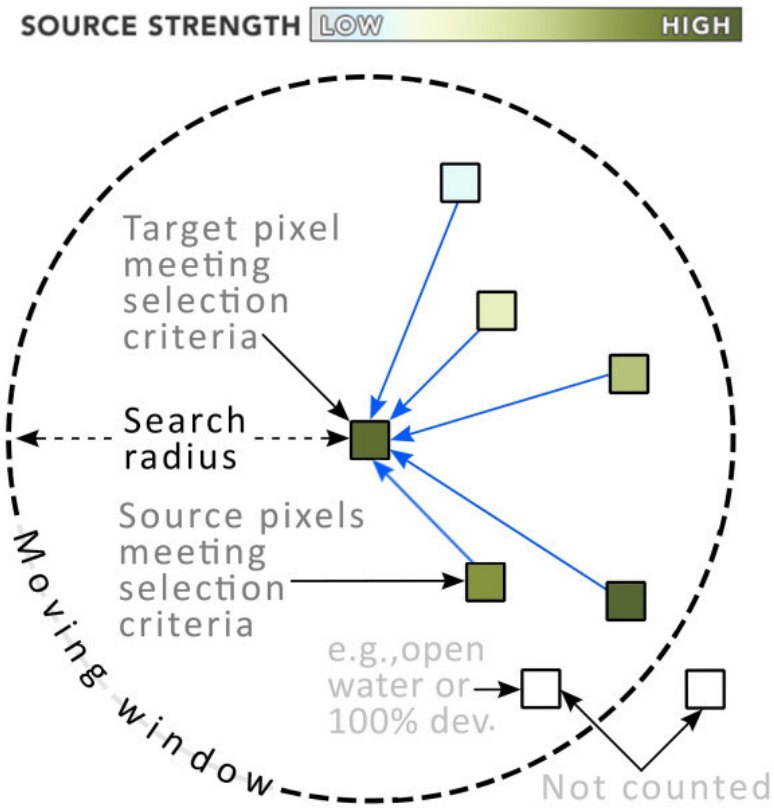

Figure 3. An illustration of a moving window iteration in the Omniscape algorithm (Landau, 2020).

Geographic context can play a large role in which tool is optimal in a given effort, largely dependent on how fragmented or intact the landscape is and what level of protection is already in place (Gallo et al., 2020). In a highly fragmented landscape with agreed-upon core areas (protected or largely intact), Gallo et al. (2020) argue that Linkage Mapper, with its ability to identify least-cost paths (as well as larger corridors), may be optimal for identifying connectors between declared core areas. Conversely, a relatively intact landscape with disparate protected areas may be better served by the omnidirectional nature of Omniscape, not allowing the output to be so influenced by defined core areas (Gallo et al.,

2020). Efforts to glean the most useful information out of tools like Omniscape (McRae et al., 2016) or combining tools like Linkage Mapper and Omniscape to maximize each of their strengths (Gallo et al., 2020) are experimental and ongoing, with a common theme of local context as an important factor.

2.4 Climate Change

Climate change from human activity is widely considered to be one of the greatest threats to biodiversity worldwide, first being officially recognized by the United Nations Convention on Biodiversity at its fifth meeting of the Conference of the Parties in Nairobi in 2000 (Lemieux et al., 2010). Despite climate change's leading role in biodiversity loss, SCP applications are just beginning to explicitly incorporate it within the framework (Reside et al., 2018). Previous SCP analyses may have excluded climate change data given a lack of reliable, conservation-focused climate data. In reality, conservation areas do not exist in a vacuum, and climate change-induced fluctuations in temperature, precipitation, snow cover, permafrost, and extreme weather events have just as much impact on areas that are protected as those that are not (Mann, 2020).

Provincial parks make up the greatest portion of conservation areas in Tsay Keh Dene Territory, yet a Canada-wide analysis suggests that they are some of the most susceptible areas to biome shifts due to climate change (Lemieux & Scott, 2005). While present-day ecoregional representation is important in a network of conservation areas, this approach becomes problematic if the targeted biome begins to shift or becomes altogether elusive. If an area is conserved with a certain species in mind, for example, and that species' habitat shifts outside of the area due to a change in climate, then that conservation area is no longer

serving its intended purpose and that species could be vulnerable to anthropogenic activity (Mann, 2020).

Thus, climate-conscious conservation area design that protects both the present-day and future needs of species has become the focus. Some researchers report success in capturing range shifts for most species within their protected area system designs under moderate climate change scenarios (Hannah et al., 2007). Rose and Burton (2009) furthered this approach, identifying what they call "temporal corridors", which are areas within the geographic range of a conservation target (i.e., a species) that are predicted to remain relatively consistent ecologically despite the generally warming climate. While traditional corridors offer spatial connectivity, these areas offer a sort of connectivity through time.

Locations that are resistant to climatic changes are known as refugia – as they provide refuge to species affected by climate change elsewhere in their range. One method of planning with future habitats in mind is targeting these refugia since they are predicted to remain as, or transition to, suitable habitat for some species in the future (Ashcroft, 2010). While specific species can be targeted, identifying climatic refugia can also benefit understudied and even undiscovered species since they represent habitats that are predicted to remain relatively unchanged (Garcia et al., 2014). These climatic refugia can be identified through an area's 'climate velocity' and help delineate novel and disappearing climates of the future.

In addition to protecting geophysically diverse land facets (combinations of geology, soil, and topography), there are climate-specific metrics that serve specialized roles in identifying areas for conservation. Climate change velocity is one, measuring the spatial and

temporal variations of climate on the landscape to determine the distance and rate of travel that species must undertake to keep pace with climate change and find analogous habitat (Loarie et al., 2009).

Forward velocity represents the rate at which climate is shifting across the landscape, with low velocity meaning that future climate analogs can be found nearby, while high velocity means that species must travel great distances to find analogous habitat (Carroll et al., 2015). Alpine areas typically exhibit high climate velocities, as warming climates mean that species must relocate to distant mountaintops to find a similar climate (Hamann et al., 2015). Forward velocities are useful in assessing the conservation status and populations of species under climate change and evaluating protected area networks (Carroll et al., 2015). Backward velocity represents the distance from a location, given its projected future climate, that various species from analogous habitats would have to travel from to colonize that location in the future (Carroll et al., 2015). In contrast to the high *forward* velocity of mountaintops, valley bottoms generally exhibit high *backward* velocities, as organisms here must travel long distances to find analogous climates (Hamann et al., 2015). Backward velocities can also be useful in evaluating protected area networks, as well as identifying species that may require assisted migration to reach analogous climates (Carroll et al., 2018).

Sites with excessively high forward or backward velocities help identify climates that are entirely novel or disappear altogether within the study area, while low climate velocities help identify areas that are resistant to climate change, also known as refugia (Mann, 2020). Locations with the highest forward velocity have extremely distant future analogous climates in relation to their present-day climate, possibly to the point where the climate no longer exists under certain climate change scenarios. In these cases of disappearing climates, an

area's present-day inhabitants are projected to become homeless, raising fears of species extinctions and the disruption of communities, especially in montane environments (Williams et al., 2007). Identifying disappearing climates and their associated species assemblages is vital to the proactive management of these species in order to combat genetic bottlenecks and potential extinctions (Jackson & Overpeck, 2000). Locations with the highest backward velocities have extremely distant present-day analogous climates in relation to their projected climate, possibly to the point where the projected climate does not currently exist elsewhere. In these cases of novel climates, unknowns abound as novel species associations form and the potential for other unexpected ecological responses (also known as "ecological surprises") arise (Williams et al., 2007). Determining where these novel climates are likely to arise can be valuable in anticipating and planning for novel communities, even if predictions on species assemblages are fuzzy at best (Williams & Jackson, 2007).

With the shifting, disappearance, and emergence of various climates described above, it is paramount that these areas of persistence be protected to safeguard the species found within them (Loarie et al., 2009). Researchers like Roberts and Hamann (2012) have examined the paleoecological record to better understand historical refugia in an effort to predict the locations of future refugia sites. Both species that prefer warmer climates and species that prefer cooler climates (glacial and interglacial refugia, respectively) should have their refugia conserved for the sake of species persistence, but those that prefer cooler conditions should be the immediate focus as global temperatures continue to rise (Ashcroft, 2010). Biotic refugia are species-specific subsets of climatic refugia that are biotically-informed (based on the behavior of taxa as opposed to climatic refugia that may not provide habitat to many species) (Sedell et al., 1990). Based on our understanding of the

paleoecological record, refugia provide not only a safe haven during periods of unfavorable climate but also serve as areas of recolonization if the climate becomes advantageous again (Morelli et al., 2016). Willis and Whittaker (2000) even argue that refugia are "species pumps", as they develop new species and act as biodiversity hotspots due to their persistence and isolation through time. Protecting these sites anticipated to experience climate change at slower rates and smaller magnitudes should be of great importance in any conservation area design.

While incorporating climate change into the SCP framework is highly desirable and increasingly necessary, effectively doing so can prove challenging due to the complexity of climate change models and the uncertainty that comes with predicting the future (Lawler & Michalak, 2017). Any modeling relies on making assumptions, in this case mainly around carbon emissions, and thus relying too heavily on a given model or set of models can prove problematic (Groves et al., 2012). Conservation biologists specifically argue that modeled simulations of climate change are not reliable enough to serve as the foundation of conservation planning (Beier & Brost, 2010), particularly when considering that modeled species distributions can carry their own level of uncertainty. These compounding effects of uncertainty can prove too much for some scientists to include climate change metrics in an SCP (R. Schuster, personal communication, May 1, 2020).

Furthermore, matching the scale of climate data to the scale of analysis is critical and some of the available data has mismatched scales (Heller & Zavaleta, 2009). There have been efforts to accurately downscale climate models for more local applications. For example, Wang (2016) used bilinear interpolation and elevation adjustment to generate scale-free point data for all of North America.

To facilitate incorporation of climate in SCP, Groves et al. (2012, p. 1652) developed a framework of various approaches to account for climate change: "(1) conserving the geophysical stage, (2) protecting climatic refugia, (3) enhancing regional connectivity, (4) sustaining ecosystem process and function, and (5) capitalizing on conservation opportunities emerging in response to climate change (e.g., Reducing Emissions from Deforestation and Forest Degradation [REDD])". Some of these strategies reinforce existing SCP principles, but the explicit inclusion of climatic refugia is key. Gillson et al. (2013) advocate for a similar three-pronged approach for area-based strategies to adapt to climate change: identifying the geophysical stage, identifying and protecting refugia, and maximizing cross-environment connectivity.

Previous SCP work has touched on climate change and implicitly included it via the "persistence" goal inherent to the framework (Sarkar et al., 2006), but Mann's (2020) framework explicitly includes climate change data in addition to land facet diversity and rarity data. Her work demonstrates that a climate change-conscious SCP framework can be constructed, and my project will build on the groundwork that she laid. I am specifically adopting her selection of various climate metrics, methods for molding them into a usable format, and use of conservative targets to justify their inclusion in an SCP.

2.5 Traditional Ecological Knowledge

In addition to incorporating climate change, this research also sought to interweave Traditional Ecological Knowledge with the SCP framework. Traditional Ecological Knowledge is a way of knowing that is born out of local experiences of Indigenous peoples who have harmoniously subsisted with the environment over many generations (Groves & Game, 2016). Some scholars and Indigenous peoples prefer the term 'Indigenous

Knowledge' to emphasize locality and empower contemporary knowledge holders who may not see themselves as 'traditional'; however, other scholars and Indigenous peoples prefer 'Traditional Ecological Knowledge' given its ability to convey the ancient roots of much of this knowledge and its transgenerational nature (Houde, 2007). I use the term Traditional Ecological Knowledge as it is more commonly used by the Tsay Keh Dene Nation and Chu Cho Environmental.

Knowledge of both species and the greater environment is often ingrained in the management of natural resources by Indigenous peoples, as many cultures hold deep bonds and social codes towards the land and its inhabitants that simply are not found in most settler societies (Groves & Game, 2016). While Traditional Ecological Knowledge had previously been considered inferior to Western science for purposes of resource management by the scientific community, consensus has grown over the past thirty years that Western and Indigenous Knowledge are complementary, with a combination of the two leading to better outcomes in natural resource management (Karjala et al., 2004). The inclusion of TEK is vital in any instance of natural resource co-management between Indigenous and settler governments for the sake of genuine cooperation, but TEK is also valuable in *any* situation where it is offered or available as a source of local ecological knowledge (Groves & Game, 2016).

In her article "What spiders can teach us about ecology", Polfus (2018) advocates for the legitimacy of TEK and its principles surrounding the interconnectedness of species, people, and place. She argues that the scientific method and the English language both prioritize the compartmentalization of information, "[E]mphasizing nouns, establishing boundaries, creating boxes, and fitting things into those boxes." If ecology claims to be the

study of *relations* among organisms and their physical surroundings, TEK and its inherent holism should be considered whenever it is offered if complete knowledge is truly being sought. In her book *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants*, Robin Wall Kimmerer (2013) describes the importance of combining our ways of knowing, writing:

> It was the bees that showed me how to move between different flowers—to drink the nectar and gather pollen from both. It is this dance of cross-pollination that can produce a new species of knowledge, a new way of being in the world. After all, there aren't two worlds, there is just this one good green earth. (p. 47)

In one prominent paper, Houde (2007) cautions that TEK cannot simply be reduced to another collection of data that simply complements existing government datasets, but that it must be considered in the value-based and cosmological contexts in which it was created. TEK does not necessarily conform to Western rules and is often minimized down to polygons for use in a Geographic Information System (GIS) since that is the language and realm that resource extraction companies and colonial governments speak in and understand (Houde, 2007). In doing so, there is an unavoidable loss of meaning, especially in cases where the Indigenous knowledge producers do not have a voice in how that information will be used. Houde goes on to outline six dimensions, or 'faces', of TEK which complement one another and range in levels of non-Indigenous comprehension (Figure 4). The more easily understood faces include factual observations, management systems, and past and current uses. In contrast, the more abstract include ethics and values, culture and identity, and the overarching concept of cosmology in which the other five faces are rooted (Houde, 2007; Groves & Game, 2016).

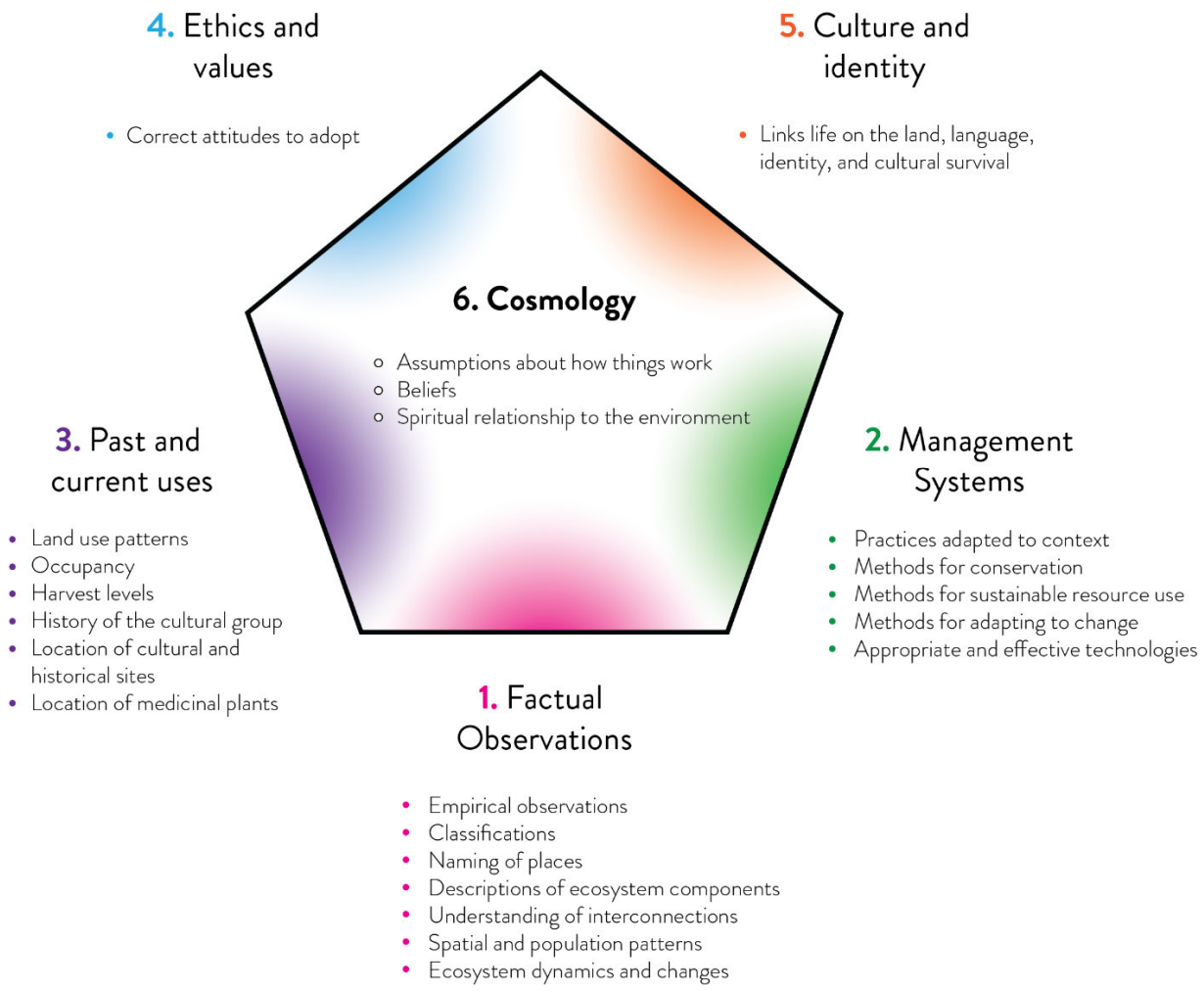

Figure 4. The six faces of Traditional Ecological Knowledge and the key components of each dimension. (Concept adapted from Houde, 2007; graphic adapted from Groves & Game, 2016).

Houde's (2007) more material faces of TEK (factual observations, management systems, and past and current uses) are understandably easier to implement, as was done by researchers Bethel et al. (2014) in coastal Louisiana, USA. These scientists focused on coastal restoration and leveraged TEK to help achieve their goals. Their methods for incorporating TEK included land-based meetings with members of the local Indigenous community, individual boating trips with each TEK expert to identify areas of importance and management strategies to focus on, and finally, validation of the synthesized results. Bethel et al. (2014) stressed that serious consideration should be placed on who from the community is selected as a TEK expert to ensure adequate geographic coverage of the study area, collect accurate information, and a consensus that the findings are valid. This means choosing well-respected community members from various subregions to ensure buy-in from the broader Indigenous community, other locals, and government agency personnel if possible. Bethel et al.'s (2014) research project is self-proclaimed to be rooted in GIS, which Groves and Game (2016) remind us leaves behind valuable context, but is an excellent first step in building mutually beneficial relationships with Indigenous communities to bridge TEK and Western science.

The more abstract of Houde's (2007) faces of TEK (ethics and values, culture and identity, and cosmology) are understandably more difficult to implement both in general and in the SCP framework. In her paper "Indians Don't Make Maps", Lucchesi (2018) refutes the colonial rhetoric stated in her article title, asserting that Indigenous peoples have historically and still continue to produce maps, but that these cartographic products do not always adhere to Western-style, resulting in Indigenous accomplishments being erased through racism and imperialist attitudes. Lucchesi (2018) maintains that the continuation and development of

Indigenous mapping praxes is a meaningful way of furthering culture and community. She uses the example of a Polynesian master navigator, Pius "Mau" Piailug, whose research contributions helped prove the sophisticated geographic knowledge held by his ancestors in non-instrumental wayfinding across the sea, revitalizing cultural identity and pride not only in his native island of Satawal, but across the Pacific islands.

Weiss et al. (2013) note that cultural ethics and values permeate throughout the natural resource management practices of Traditional Ecological Knowledge and Western science, and that these influences must be acknowledged within each way of knowing. TEK is fundamentally multidisciplinary, with nature, politics, and ethics all being interwoven, but Western science is regulated by the values of Western cultures. Western science has taken steps in the direction of viewing humans as part of the land-community thanks to ecologists like Aldo Leopold (1949). However, TEK goes a step further in its embrace of social and legal dimensions, emphasizing the web of relationships between humans, other species, and the land, as well as with spirits and ancestors (Weiss et al., 2013). Because of the cosmological threads in TEK, greater caution must also be placed on using this sacred knowledge without corrupting its purpose, betraying the privacy of the knowledge holder or of the sensitive information itself, as well as navigating legal constraints around said information in regards to treaty negotiations and related endeavours (Berkes, 2018; Ramos, 2018).

Other initiatives have addressed methods of bridging local perspectives and Traditional Ecological Knowledge into SCP approaches (Baker et al., 2011). This has included setting objectives and targets, providing conservation and cultural feature mapped

data, and verifying map outputs of the SCP process. However, there is an opportunity to further develop approaches to bridge SCP with Indigenous planning and perspectives.

SCP efforts involving Indigenous peoples have typically occurred when the plan is being conducted in close proximity to Indigenous territories, and in some cases on behalf of an Indigenous government itself. Working on behalf of the Taku River Tlingit First Nation of the Yukon, British Columbia, and Alaska, Heinemeyer et al. (2003) applied TEK in the form of distribution, ecology, and habitat use patterns to develop habitat suitability models for the focal species of their SCP. Knowledge was collected from taped interviews and translated into spatial data via community-drawn maps and verbal descriptions. This resulted in enhanced habitat suitability index (HSI) models for grizzly bear, moose, Stone sheep, mountain goat, caribou, and salmonids, in most cases utilizing extensive season-specific knowledge to build seasonal HSI models (Heinemeyer et al., 2003).

TEK has also been used in SCP in Namibia, integrating the Herero, Himba, and Damara people's knowledge to design a conservation area that links existing areas (Muntifering et al., 2008). This effort utilized local knowledge to build the land use and water feature mapping component of the plan, creating datasets related to water sources and usage, village characteristics, and grazing patterns in the region. These data were collected on the ground with local leaders and hired Indigenous guides, entered into a GIS, and then iteratively reviewed with local leaders for accuracy and final approval (Muntifering et al., 2008). Assessing and documenting Indigenous peoples' values and priorities through workshops that inform conservation tools and initiatives has been paramount in efforts facilitated by groups such as Round River Conservation Studies (Muntifering et al., 2008) and The Firelight Group (Kuntz & Vuntut Gwitchin First Nation, 2018).

In working on several Indigenous conservation efforts, Heinemeyer (2019) asserts that TEK enhances the SCP process overall due to the deep, longstanding knowledge that Indigenous peoples can provide for a specific area. This holds true for climate change – a great concern for many Indigenous communities – by creating climate-informed species distribution modeling that builds off TEK of species habitat requirements (Heinemeyer et al., 2019). The possibility of flipping this structure – having TEK at the center of an SCP-like analysis with Western science only playing a supplementary role – has been discussed by Drs. Jean Polfus and Richard Schuster, but this approach has not been fully formulated to date (R. Schuster, personal communication, May 1, 2020). Bridging Traditional Ecological Knowledge with the Western science-based SCP approach ultimately empowers Indigenous communities to develop a long-term vision for connected and ecologically resilient landscapes in their homelands now and into the future (Heinemeyer et al., 2019).

2.6 Conclusion

The field of Systematic Conservation Planning was born out of lessons learned in the historical establishment of conservation areas – that they should be designed as a linked network and be ecologically representative of the larger landscape, taking into account both ecosystems and the key species that inhabit them in order to effectively conserve biodiversity. Additionally, these conservation areas must be designed in such a way as to promote persistence on the landscape and provide corridors for movement that mirror species' natural migration. The tenets of representativeness (through informed conservation feature selection) and persistence (through effective conservation area design and connectivity) will continue to be the building blocks of Systematic Conservation Planning in the face of climate change. A multifaceted, holistic approach – including a climate change

lens and the interweaving of Traditional Ecological Knowledge – is the best path forward to effectively conserve the species and ecosystems of today, as well as be prepared for the shifts that will occur in the future.

3.0 CASE STUDY

3.1 The People of the Rocks

The Tsek'ene[2] (commonly spelled Sekani) are an ethnic group of Indigenous peoples that includes the Kwadacha Nation, McLeod Lake Indian Band, Takla Nation, and Tsay Keh Dene Nation (Sims, 2017). Their name means "people of the rocks" or "people of the mountains", and they share a common language, though there are dialects and regional variations (Littlefield et al., 2007). Anthropologists generally agree that there were five historical groups or bands that make up the Tsek'ene today, three of which went on to form the Tsay Keh Dene (the Sasuchan, T'lotona, and Tseloni peoples) (Jenness, 1937; Sims, 2017) (Figure 5).

Oral tradition, as well as archaeological evidence, suggests that this stretch of the Rocky Mountain Trench has had continuous human occupation since the last Ice Age, roughly 11,700 years ago (Sims, 2017). This period, when Tsek'ene lived freely, is fondly referred to as "The Singing Days", before outsiders brought resource development to their land (Christensen, 1987). Tsek'ene peoples traditionally viewed their relationship with the

[2] "Tsek'ene", "Tsek'ehne", "Tse'khene", or "Tse'kene" (depending on dialect) are considered to be more accurate spellings for the ethnic group and language commonly anglicized as "Sekani" (Sims, 2017).

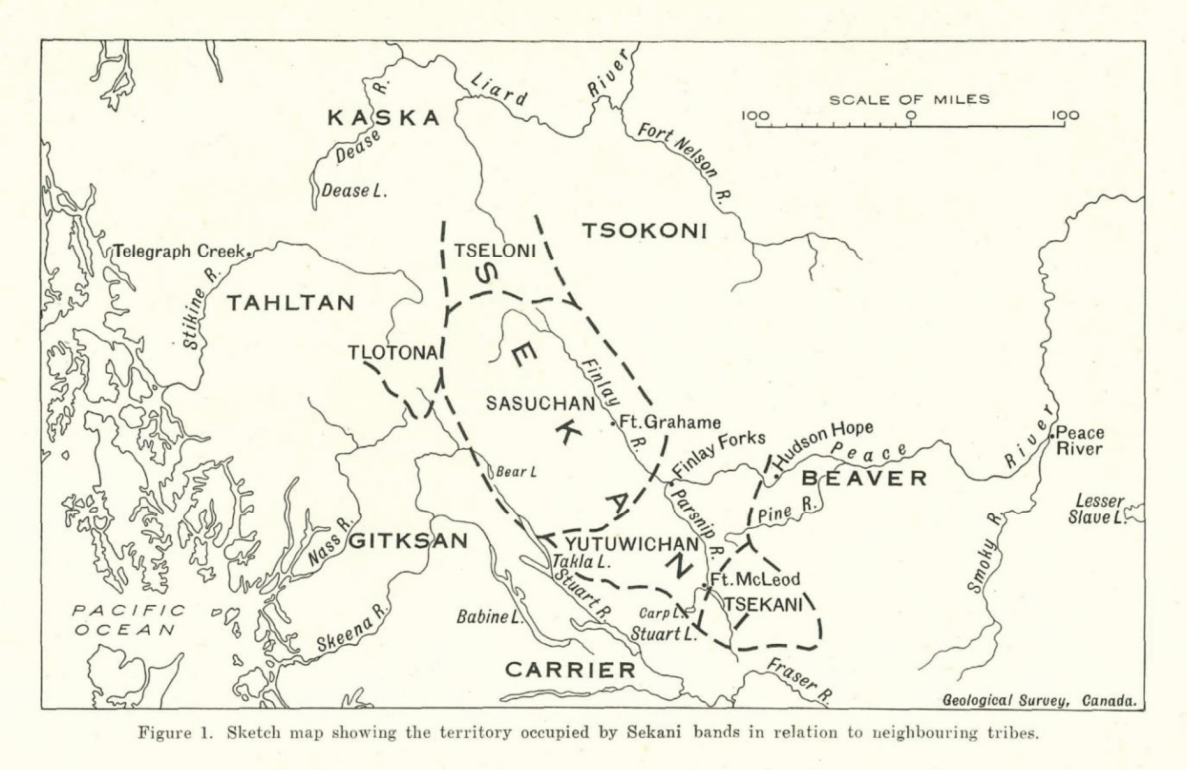

Figure 1. Sketch map showing the territory occupied by Sekani bands in relation to neighbouring tribes.

Figure 5. Map depicting the traditional territory of the five historical Tsek'ene groups and neighbouring First Nations. This figure predates the W.A.C. Bennett Dam and flooding of the Rocky Mountain Trench, and thus the channels of the Finlay, Parsnip, and Peace Rivers are shown (Jenness, 1937).

land and the concept of land ownership as similar to that of a marriage. The idea of 'possession' goes both ways, with the land conversely claiming the Tsek'ene as its own, with the right to reject the people if they were irresponsible towards the land (Sims, 2017). As such, Tsay Keh Dene and other Tsek'ene have sought to support the land since the beginning of time – a feat made more difficult since European contact in 1793 (Sims, 2017).

The Tsek'ene traditionally had their own economy in the form of harvest and trade activities prior to the advent of the Euro-Canadian fur trade. Each band held its own territory and each family held a sub-territory (Sims, 2017). These territories were not rigid when it came to other Tsek'ene, but Tsek'ene staunchly defend their territorial claims when other First Nations are involved. Even members of groups that they intermarried with like the

Gitsxan were killed on sight if found hunting in Tsek'ene territory (Jenness, 1937). According to the Gitsxan, "The Sekani came from a wolf, so they, like the Hagwilgate Indians [descended from a grizzly], are always killing people" (Jenness, 1934, p. 241). In practice, this meant that non-Tsek'ene cannot gain rights to the territory unless they are the parent of a Tsek'ene child or are a spouse of a Tsek'ene member, and only for the duration of the relationship (though exceptions have been made for those that have become ingrained in the community) (L. Gleeson, personal communication, April 15, 2021; Sims, 2017). The Tsek'ene were historically a nomadic people as well, moving with the seasons as game was too scarce to stay in any one place for too long. The places they migrated between were recognized by the Tsek'ene as village sites, even though a few were transformed into fur trade posts that Euro-Canadians took credit for establishing after the fact (Sims, 2017).

3.2 Geography and Natural History of Tsay Keh Dene Territory

The Territory of Tsay Keh Dene Nation is a river-filled and mountainous landscape north of Mackenzie, BC, and is a large, 32,000 km^2 area – similar in size to the Netherlands. Located within the Rocky Mountain Trench region and encompassing portions of the Omineca and Rocky Mountains, the Territory has an abundance of waterways, including the Peace, Omineca, Ospika, Osilinka, Mesilinka, Manson, Nation, Ingenika, Akie, Swannell, Parsnip, and Finlay Rivers (Figure 6). These rivers once naturally converged, but their confluence today is the Williston Reservoir, a result of the W.A.C. Bennett Dam constructed in 1968. The topography varies in the region from low elevation forested landscapes near the reservoir (670 m) to rugged mountainous terrain at the northern edge of the Territory near Mt. Ulysses (3,014 m) (Fish and Wildlife Compensation Program, 2014).

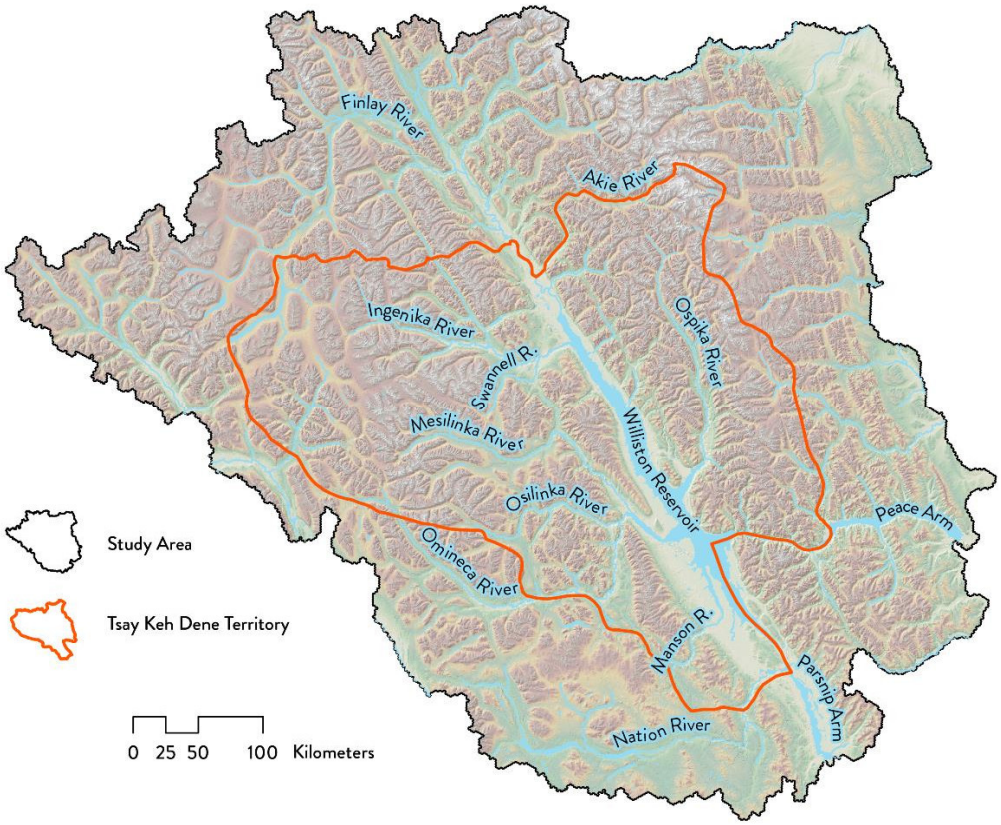

Figure 6. Topographical/hydrological map of Tsay Keh Dene Territory

The climate in the region is characterized by cold, snowy winters that result in deep snowpack, and mild, rainy summers that make for a short growing season. The reservoir moderates the temperature of its surroundings given its size, acting as a source of local climate change since its flooding. The mean annual temperature is 0.5 °C, where January sees an average of -18 °C and July sees an average of 13 °C. The common extreme temperatures experienced are -47 °C in the winter up to 32 °C in the summer (Fish and Wildlife Compensation Program, 2014). Annual snowfalls range from roughly 1 meter in the valleys on up to 4 or more meters in the mountains. Rainfall also varies greatly across the region, averaging anywhere from 250 mm to 1300 mm depending on location. The overall

average annual precipitation is 800 mm, split evenly between snow and rain (Fish and Wildlife Compensation Program, 2014).

Natural disturbance regimes within the Territory have been affected by the reservoir, with riparian and wetland habitats that fell in the confluence floodplains now lost following the inundation of the reservoir (Fish and Wildlife Compensation Program, 2014). Wildfires are a common occurrence in the region, with 112,000 hectares burned in 2014. Forest insects are also a prevalent natural disturbance in the region, often occurring cyclically with fire. Recently, the region has experienced significant mountain pine beetle outbreaks in 2005 and 2009, and western balsam bark beetle to a lesser extent. More recently, spruce beetle has been detected with increasing frequency (Nicholls, 2014, 2019).

The Territory consists of several Biogeoclimatic Ecosystem Classification (BEC) zones, as defined by British Columbia's Biodiversity Guidebook (BC Environment, 1995). These include Boreal White and Black Spruce, Engelmann Spruce-Subalpine Fir, Sub-Boreal Spruce, Spruce-Willow-Birch, and Boreal Altai Fescue Alpine.

Some of the key wildlife species found in the Territory include woodland caribou, grizzly bear, Stone sheep, moose, elk, fisher, mountain goat, and wolverine (Fish and Wildlife Compensation Program, 2014; Tsay Keh Dene Nation, personal communication, September 30, 2019). Riparian species like Arctic grayling, mountain whitefish, and rainbow trout persist in the area despite the reservoir. In contrast, lacustrine species like lake whitefish (half the fish population in the reservoir), bull trout, kokanee, lake trout, ling, and peamouth thrive (Loo, 2007).

3.3 Resource Extraction History and the W.A.C. Bennett Dam

Tsay Keh Dene Territory saw only limited development and settlement by Euro-Canadians from first contact up to 1956. Early on, Sir Alexander Mackenzie and later Simon Fraser established fur trade posts in the Territory, which meant intermittent but increasing exchanges as the fur trade evolved. Euro-Canadian trappers were the predominant non-Tsek'ene population in the Territory until 1861, when prospectors unearthed gold in the Parsnip River and ushered in the Peace River Gold Rush. After prospectors discovered gold along tributaries of the Omineca River in 1868, the Omineca Gold Rush began and brought even more settlers, including Roman Catholic missionaries. As migration flowed north, the North-West Mounted Police established a presence in the area, but that ebbed with the bust of gold mining interest (Sims, 2017).

Other settlement efforts in the Territory occurred throughout the first half of the twentieth century as mining went boom or bust and speculators anticipated railway construction through the Territory. The idea of clearing the land for agriculture in the region was also proposed by settlers living to the south, but neither this nor any of the aforementioned efforts ever truly materialized. This largely allowed the Tsek'ene to continue with their traditional lifestyle (Sims, 2017). Wartime in the 1940s saw the forest industry expand and start to reach northwards into the southern stretches of Tsek'ene Territory. This provided work for many Tsek'ene and was nearby for McLeod Lake people. Tsay Keh Dene, however, had much further to travel, ushering in a seasonal migration south in the spring and summer before returning home in the fall and winter to trap (Sims, 2017). Summit Lake north of Prince George was a popular destination for Tsay Keh Dene families seeking work

at the mill there; however, many families remained in their Territory (L. Gleeson, personal communication, April 15, 2021).

Construction of the Hart Highway in 1952 represented the first substantial connection between Tsek'ene Territory and the outside world, linking Tsek'ene Territory to Prince George in the south and the Peace River Country to the east via the Pine Pass – a link to the Alaska Highway. As transportation to, from, and within Tsek'ene Territory had been one of the major impediments to increased Euro-Canadian presence, the highway's completion brought more and more settlers to the region in the name of resource extraction (Sims, 2017). This influx of settlers was further exacerbated by the construction of the Pacific Great Eastern Railway from Prince George to Fort St. John, which runs alongside the Hart Highway. Moose were a frequent casualty of the newly introduced cars and trains. The highway and railway also contributed to the decline of local caribou herds by severing their range and increasing access to industry, which led to deforestation (Sims, 2017).

With increased access, harnessing the power of the Peace River became feasible. The Province and the recently nationalized BC Hydro crown corporation were ultimately the parties leading the charge for construction of a dam, and did most of their consulting – or rather, informing as Sims (2017) argues – of the Tsek'ene with Indian Affairs serving as a go-between. Sims (2017) also contends that the Tsek'ene were not properly consulted, but they may not have been overly concerned at the time even if they had been, as no development or settlement efforts to date had materialized in the Territory (Stanley, 2010). Construction of the W.A.C. Bennett Dam was completed in the fall of 1967 and initially flooded in the spring of 1968. The Province had not fully prepared for this event, failing to properly clear the reservoir basin and underestimating how quickly it would fill. The result

was a pool of debris that caught both people and wildlife in the area off guard, causing Tsek'ene to retreat to camps at higher ground and animals like moose to lose large swaths of habitat, or in some cases drown (Sims, 2017). The water body would come to be known as Williston Lake[3] (despite its unnatural formation), running 250 km north-south and 150 km east-west and ultimately resulting in the loss of approximately 1,500 km^2 of high-complexity lowland habitat (Fish and Wildlife Compensation Program, 2014; Loo, 2007).

3.4 Contemporary Resource Extraction and the Williston Reservoir

The habitats lost to the Williston Reservoir include woodlands, wetlands, floodplains, riverine, and lake habitats, which were replaced with homogenous, artificial reservoir habitats. This destruction of large riverine habitat was likely why 24 populations of Arctic grayling were lost from the drainage. Also lost were critical winter range and wildlife corridors for woodland caribou, Stone sheep, and grizzly bear. Furthermore, a host of other species were affected by the loss of riparian areas and forced migration to areas of higher elevation, where deeper snowpack made foraging difficult (Fish and Wildlife Compensation Program, 2014).

The effects of the Williston Reservoir were compounded with the opening of new transportation routes for industries like forestry and mining (Ingram, 2012). The reservoir serves as an easily navigable waterway, with booms and barges able to transport timber to the Hart or Alaska Highway and beyond. The added reach of logging companies meant

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[3] While the Williston Reservoir is officially named a Lake on settler maps, I have chosen to refer to it as a reservoir throughout given its artificiality and in accordance with the cultural and ecological practice of the Tsay Keh Dene.

additional harvesting in areas adjacent to the reservoir, further fragmenting habitat for species like caribou. Additionally, many of the impacts are linear in nature, with service roads and bridges having a significant cumulative impact not only on habitat but also on migration corridors. Road culverts hinder fish migration when poorly maintained. The reservoir itself is also a linear feature, significantly affecting various species by severing their home ranges and migration corridors (Fish and Wildlife Compensation Program, 2014).

Anthropogenic land use and the road network, as well as natural phenomena like land cover and slope of topography, all contribute to decreased levels of permeability on the landscape, making it more difficult for species to traverse landscapes in the Territory. Additionally, the percentage of the Territory that has been modified – 30% to date – will likely only increase over time.

3.5 The Tsay Keh Dene First Nation

In 1971, many Tsay Keh Dene abandoned the camps and government-selected reserves they had been living on near Mackenzie to settle at Ingenika Point on the reservoir's northwest tip, as well as other points along the Ingenika River (Grassy Bluff) and Pelly Creek (Tucha Lake) in the northwest part of the Territory (L. Gleeson, personal communication, April 15, 2021; Sims, 2017). Referred to by the Indian Act as the Ingenika Band at the time, the Tsay Keh Dene defied both the provincial and federal governments in this action in an attempt to live a more isolated and traditional lifestyle. They sought to have a new reserve established at this location, and families that remained on the Parsnip Reserve near Mackenzie eventually moved northward (L. Gleeson, personal communication, April 15, 2021). When requests to the government failed, the Ingenika Band appealed to public opinion, ultimately coming to an agreement with BC Hydro, the Province of British

Columbia, and Canada in 1989 that granted them a community site 16 km to the north, at the very northern tip of the reservoir. This agreement established not only the present-day Tsay Keh community site, but also the Tsay Keh Dene First Nation (Sims, 2017). The Tsay Keh Dene community site was officially designated a reserve in 2019 (L. Gleeson, personal communication, April 15, 2021).

The Nation has approximately 500 members today, with about half of those living in the Territory. Of those in the Territory, a majority live in the Tsay Keh community (British Columbia Assembly of First Nations, 2020; L. Gleeson, personal communication, April 15, 2021; Littlefield et al., 2007). In addition to the 2,100 acres at the village site, the Nation has 1,000 acres at the Blackpine Reserve, five acres at the old Ingenika Point site for a cemetery, and 320 acres at Police Meadows (Littlefield et al., 2007; Abadzadesahraei, personal communication, May 18, 2020). There were also two former reserves near Mackenzie: Tutu Creek (90 acres that were never inhabited) and Parsnip (80 acres that are no longer inhabited) (L. Gleeson, personal communication, April 15, 2021). The Nation's governance structure is a custom electoral system with an elected Chief and Council independent of any treaty or tribal association (British Columbia Assembly of First Nations, 2020). In addition to the elected Chief, the Nation allots three of the elected councillor positions to members living in the Tsay Keh community, with a fourth to an elected member that lives outside of the community to represent Tsay Keh Dene members who also live elsewhere (Tsay Keh Dene Nation, 2020b).

The Nation holds an administrative office in Prince George and has an Economic Development Corporation to build capacity within the Nation, with "[S]everal businesses that work hard to provide revenue and employment for the Nation and its members. The Nation's

businesses are overseen by a Governing Economic Development Board that reports to the Elected Chief & Council" (British Columbia Assembly of First Nations, 2020). Chief & Council work with the businesses to deliver on the vision of the Nation. These businesses include Chu Cho Industries, Chu Cho Environmental, Chu Cho Forestry, Tsay Keh Developments (which houses a guide outfitting business), and Ootsa Air (British Columbia Assembly of First Nations, 2020). The natural resource businesses in particular provide employment to many Tsay Keh Dene and provide a sustainable revenue stream to the Nation, as well as the opportunity to perpetuate cultural practices on the landscape within their Territory (Tsay Keh Dene Nation, 2020a).

3.6 Existing Conservation Areas

At the continental scale, Tsay Keh Dene Territory is nestled among large protected area systems – the national parks of the central Rocky Mountains and the provincial parks in and around the Muskwa-Kechika Management Area. Currently, 9.2% of the Territory is under protected area status (Table 2). Five of these protected areas (all provincial parks) are relatively large, each 200 km^2 or greater in size. These larger parks are generally at least 50 km from one another though, making movement between them more difficult for species. Designating additional conservation areas would further the Nation's values of biodiversity, and also help the federal government of Canada work toward its commitment of protecting at least 25% of the nation's land and inland waters by the end of 2025 (Liberal Party of Canada, 2019).

Protected Area Name	Protection Designation	Area (km^2)
Omineca Park	Provincial Park	914.1
Graham - Laurier Park	Provincial Park	779.1
Sustut Park	Provincial Park	498.3
Chase Park	Provincial Park	361.9
Redfern-Keily Park	Provincial Park	215.4
Muscovite Lakes Park	Provincial Park	57.1
Ed Bird - Estella Lakes Park	Provincial Park	55.9
Sikanni Chief River Ecological Reserve	Ecological Reserve	21.8
Sustut Protected Area	Protected Area	18.0
Omineca Protected Area	Protected Area	17.1
Ospika Cones Ecological Reserve	Ecological Reserve	12.8
Chunamon Creek Ecological Reserve	Ecological Reserve	3.4
Blackwater Creek Ecological Reserve	Ecological Reserve	2.9
Raspberry Harbour Ecological Reserve	Ecological Reserve	1.2

Table 2. Protected Areas by designation and size in Tsay Keh Dene Territory

In 2020, the Nation proclaimed the establishment of the Ingenika Conservation and Management Area (CMA), a 5,049 km^2 area centered on the Ingenika River watershed that connects Finlay-Russel and Chase Provincial Parks. An Indigenous-led management plan for this IPCA is in development, with the goal of protecting the Ingenika's biodiversity using Tsay Keh Dene values, management practices, laws, and Traditional Ecological Knowledge (Chu Cho Environmental, 2020b).

3.7 Historical and Projected Climates in Tsay Keh Dene Territory

The Territory warmed by 2-3 °C over the 20th century, although this was likely more pronounced in the mountainous portions of the Territory. The 1900s also saw an increase of 30 mm of precipitation, with increases in all seasons except winter snowfall over the latter half of the century (Pacific Climate Impacts Institute, 2013). More locally, the flooding of the

reservoir caused adjacent temperatures to drop by a few degrees, as well as causing a significant increase in windiness in the reservoir valley and increased humidity in the form of a fog layer that now occurs in the fall (Loo, 2007).

The climate of the Territory is projected to continue to warm through the 2020s, 2050s, and 2080s (Pacific Climate Impacts Institute, 2013) when compared against a 1961-1990 baseline (Table 3). The annual mean temperature is projected to consistently rise, as is annual precipitation, with much of the increase coming in the winter rather than the summer. Annual snowfall specifically will only modestly increase, while spring snowfall will decline drastically. Finally, there will be a corresponding increase in frost-free and growing-degree days and a decrease in heating-degree days as temperatures increase (Pacific Climate Impacts Institute, 2013).

These changes will not be uniform in this topographically diverse geographic setting given that temperature is affected by elevation and precipitation by topography. This means that the mountaintops will be cooler and wetter, while the valley bottoms found along the reservoir will experience higher temperatures (BC Agriculture & Food Climate Action Initiative, 2013). Extreme temperature and precipitation weather events are also predicted to increase in magnitude, frequency, and intensity in the region. Extreme cold temperatures are predicted to occur less frequently, while abnormally warm temperatures are predicted to occur more often. Longer droughts are also predicted in the summer along with spells of extreme rainfall events. The overall increase in precipitation may result in rising water levels in both the rivers and the reservoir (BC Agriculture & Food Climate Action Initiative, 2013).

Climate Variable	Season	2020s Projected Change from 1961-1990 Baseline		2050s Projected Change from 1961-1990 Baseline		2080s Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)	Ensemble Median	Range (10th to 90th percentile)	Ensemble Median	Range (10th to 90th percentile)
Mean Temperature (°C)	Annual	+1.0 °C	+0.5 °C to +1.7 °C	+1.8 °C	+1.4 °C to +2.8 °C	+2.8 °C	+1.7 °C to +4.5 °C
Precipitation (%)	Annual	5%	-2% to +10%	8%	+1% to +16%	10%	+2% to +25%
	Summer	2%	-4% to +9%	3%	-7% to +12%	1%	-10% to +17%
	Winter	7%	-1% to +12%	11%	-4% to +22%	16%	+3% to +29%
Snowfall* (%)	Winter	5%	-1% to +11%	7%	-7% to +17%	8%	-0% to +20%
	Spring	-30%	-48% to +2%	-55%	-69% to -16%	-70%	-89% to -19%
Growing Degree Days* (degree days)	Annual	+129 degree days	+54 to +177 degree days	+225 degree days	+139 to +380 degree days	+364 degree days	+200 to +626 degree days
Heating Degree Days* (degree days)	Annual	-352 degree days	-616 to -180 degree days	-651 degree days	-989 to -485 degree days	-996 degree days	-1625 to -617 degree days
Frost-Free Days* (days)	Annual	+9 days	+5 to +16 days	+16 days	+10 to +25 days	+26 days	+13 to +40 days

Table 3. Climate Projections for the territory

4.0 METHODS

This research project first sought to identify which portions of Tsay Keh Dene Territory have the highest conservation value both now and in the future. Next, it examined how to explicitly include connectivity within the systematic conservation planning framework. Finally, it explored which stages of the SCP process provided an opportunity for the interweaving of Traditional Ecological Knowledge to produce a more inclusive conservation plan. To address these questions, I used a modified SCP framework originally outlined by Margules and Pressey (2000) supported by community input and Traditional Ecological Knowledge to assess Tsay Keh Dene Territory (Figure 7). I took a critical GIS perspective and community-led approach, including input from the Nation whenever possible to enhance this community-initiated research project and further the Nation's goals in the face of settler agendas (Wilson, 2009). The result is an actionable and defensible Systematic Conservation Plan that can be used to assist the Nation with routine resource extraction referrals and long-range land-use planning decisions.

Selecting a relevant study area was essentially Stage 0 of the SCP process given its ecological relevance and downstream ramifications. I initially chose to use the Nation's Territory as my study area, as it is both the Tsay Keh Dene's ancestral lands and the focus of much of the environmental work performed by the Nation and their wholly-owned consulting firm – Chu Cho Environmental. The appropriateness of this extent was assessed with the Nation as part of establishing conservation goals for the SCP in Stage 1 of the process. The study area was ultimately built with caribou herds and supplemented with important watershed groups (Figure 8).

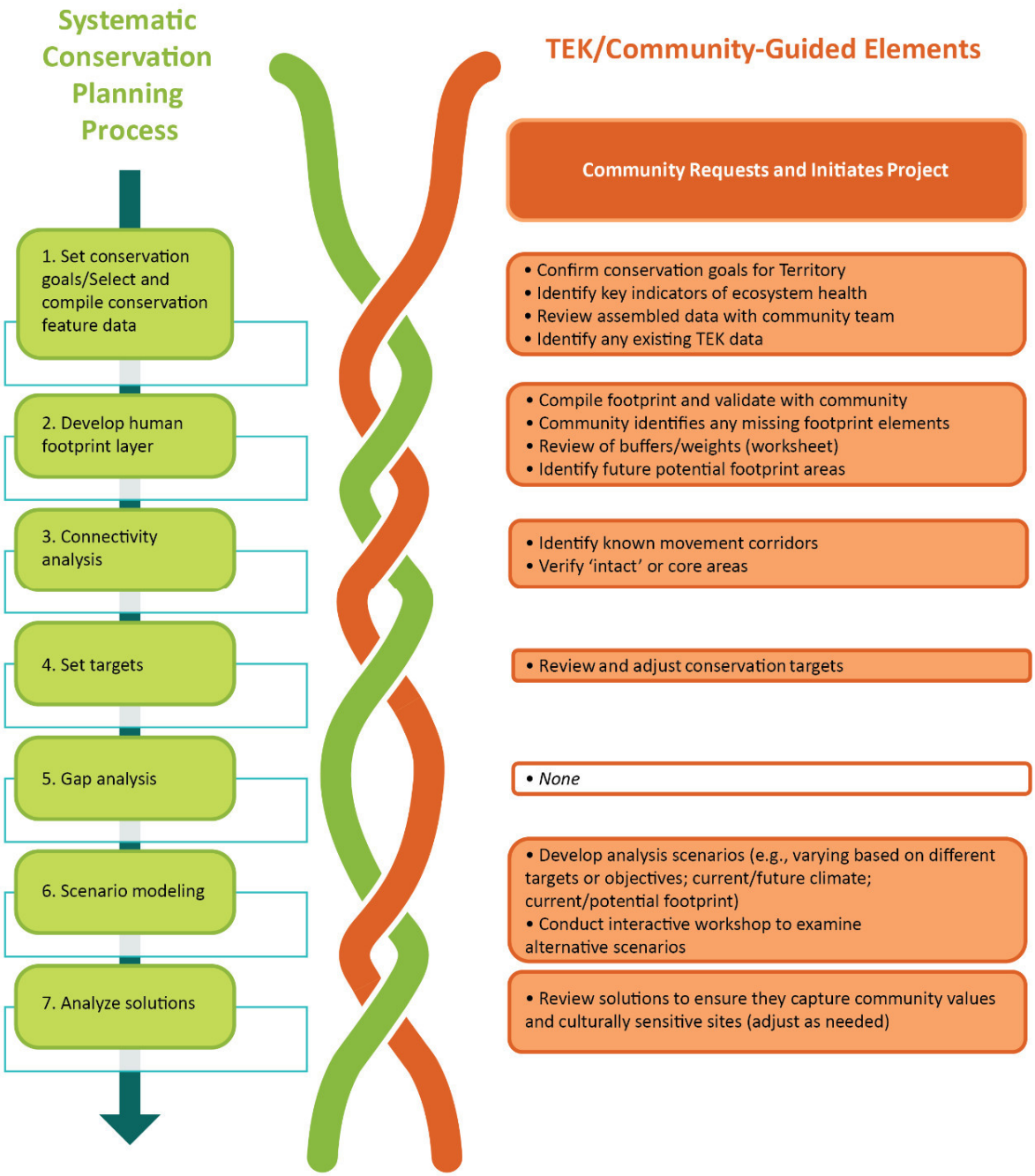

Figure 7. The Systematic Conservation Planning process and points for community guidance and the interweaving of Traditional Ecological Knowledge.

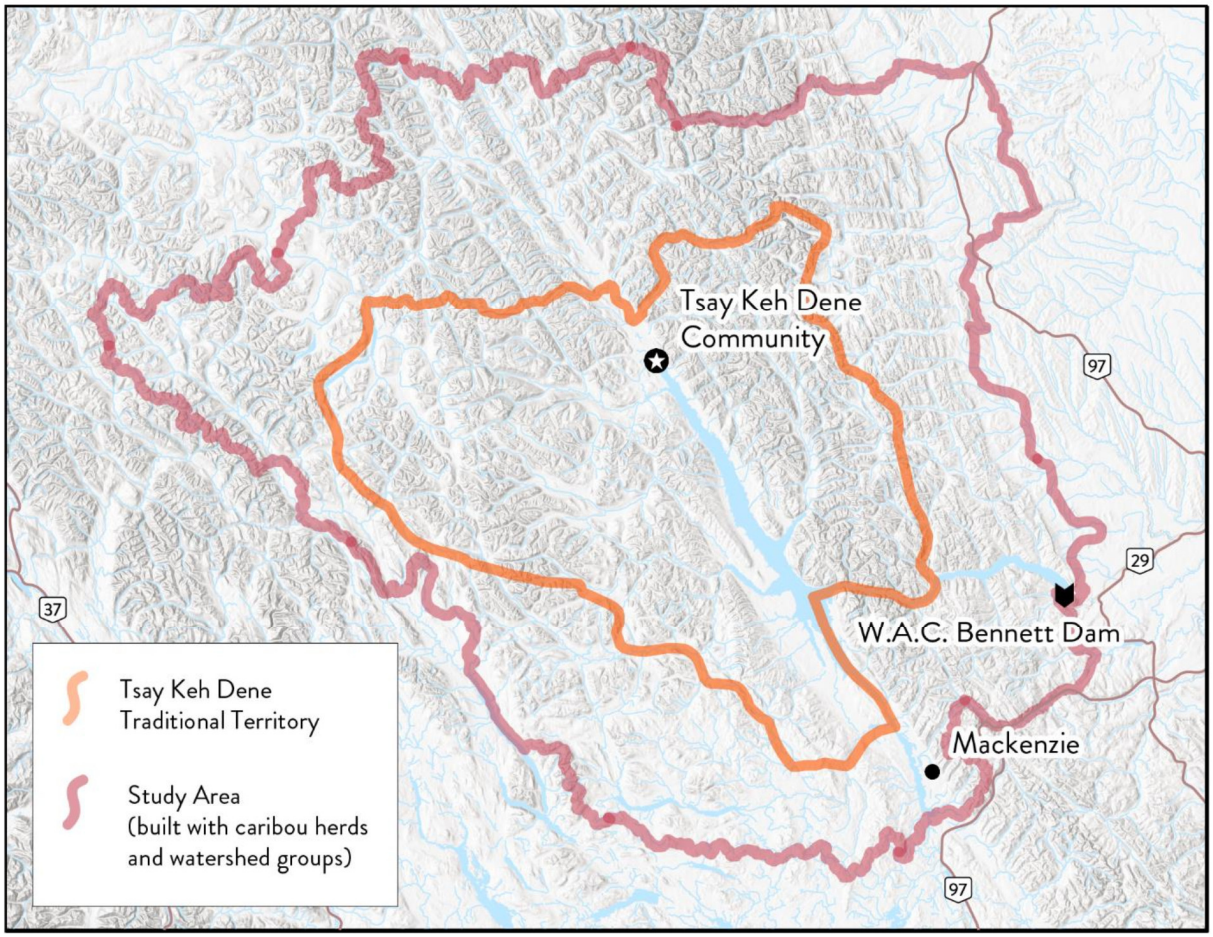

Figure 8. Contextual map showing the selected study area in relation to Tsay Keh Dene Territory.

The SCP process formally begins with the development of conservation goals for a chosen study area, so I first collaborated with the Nation to set goals for the greater territory. The next step was selecting which features on the landscape help attain those goals. I curated an initial set of conservation features based on previous work to present to the Nation for refinement. I then gathered spatial data for the agreed-upon conservation features in a GIS, utilizing provincial/federal government and Nation sources, as well as TEK-sourced data whenever it was available. Next, I delineated areas of human footprint with location and weighting input from the Nation in order to quantify connectivity between protected and ecologically intact areas across the landscape. I then set targets for the selected conservation

features based on ecological best practices and prior SCP work, and reviewed the targets with the Nation in an interactive format utilizing *prioritizr*, a conservation prioritization software (Hanson et al., 2021). Next, I reviewed the existing network of conservation areas to quantify how well they met those targets, and then identified a suite of ecologically valuable areas as a final product. I identified a suite of high-value conservation areas that are ideal for the present-day climate, but also for the projected climates of the 2050s and 2080s. This provided comparisons between present and future scenarios to allow decision-makers to select areas with the greatest resiliency for conservation.

4.1 Stage 1: Set Conservation Goals/Select and Compile Conservation Feature Data

I began by collaborating with the Tsay Keh Dene Nation to articulate conservation goals for the Territory. These goals were established from existing Nation objectives and conversations with employees and other representatives of the Nation and Chu Cho Environmental. The objectives from *The Greater Muskwa-Kechika* report (Weaver, 2019) served as an example. By establishing these goals, I identified which features on the landscape could help attain each goal and form the basis for the selection of conservation features.

The selection of conservation features (Table 4) was informed by the Systematic Conservation Planning work completed by Curtis (2018) and Mann (2020) and incorporated both fine- and coarse-filter features to focus on all levels of biodiversity. Including surrogate species and rare habitat data as fine-filters ensure that specific species and biological assemblages are conserved as part of the plan. Coarse-filter features capture ecosystem diversity and complement the fine-filter approach. The coarse-filter approach can capture representation of various habitats, with diverse topography and rare vegetative assemblages

rising to the top. The third level of biodiversity, genetic diversity, is indirectly accomplished through the SCP steps by maintaining connectivity, conserving areas large enough to maintain minimum viable populations of species, and the decision to represent species at fine scales (e.g., each caribou herd in the Territory was its own feature).

Traditional Ecological Knowledge is often thought of in a material sense, such as factual observations, management systems, and past and current uses of species and the land (Houde, 2007). While I utilized TEK-sourced data provided to me by the Nation whenever possible, the methods for this project were not designed to collect first-hand data through interviews with elders or other means. Instead, I consulted with staff scientists and other representatives of the Nation and Chu Cho Environmental, who gave voice to community values. They communicated the Nation's conservation goals and guided the selection of conservation features. In many cases, this involved the Nation sharing species and ecosystem data to include as part of the project. In some cases, those data were sourced from TEK through Traditional Use Studies (TUS) or other documentation efforts by the Nation. Some of these TEK-sourced spatial layers are of particularly sensitive information, such as medicinal plant locations or the location of cultural and spiritual sites. Data of this nature was used solely as an input to the conservation prioritization model and was never included in any visual representations (e.g., maps) to protect privacy.

Once an initial list of conservation features was compiled, I iteratively reviewed it with the Nation for feedback, data availability, and final approval to proceed. I then delineated the conservation features into five categories (Figure 9; Table 4) and documented how and why each was chosen within a spreadsheet for the sake of transparency. I noted the source and specific dataset used for each conservation feature (Appendix B. Conservation

Feature Data Sources). Additionally, I documented any modifications (e.g., buffers) that were made and the rationale for the changes. I then standardized each spatial layer into a consistent set of shapes known as 'planning units', allowing *prioritizr* to assess each conservation feature in a consistent fashion. While irregularly shaped planning units can be used (e.g., watersheds), I chose to systematically divide the landscape into a hexagonal grid, constructing planning units of uniform size and alignment. While I maintained the 1 km^2-sized planning unit used by Curtis (2018) and Mann (2020), I decided to opt for vector-based hexagons because hexagons possess a lower edge-to-area ratio than squares while still maintaining contiguous links to their neighbours (Horn, 2011).

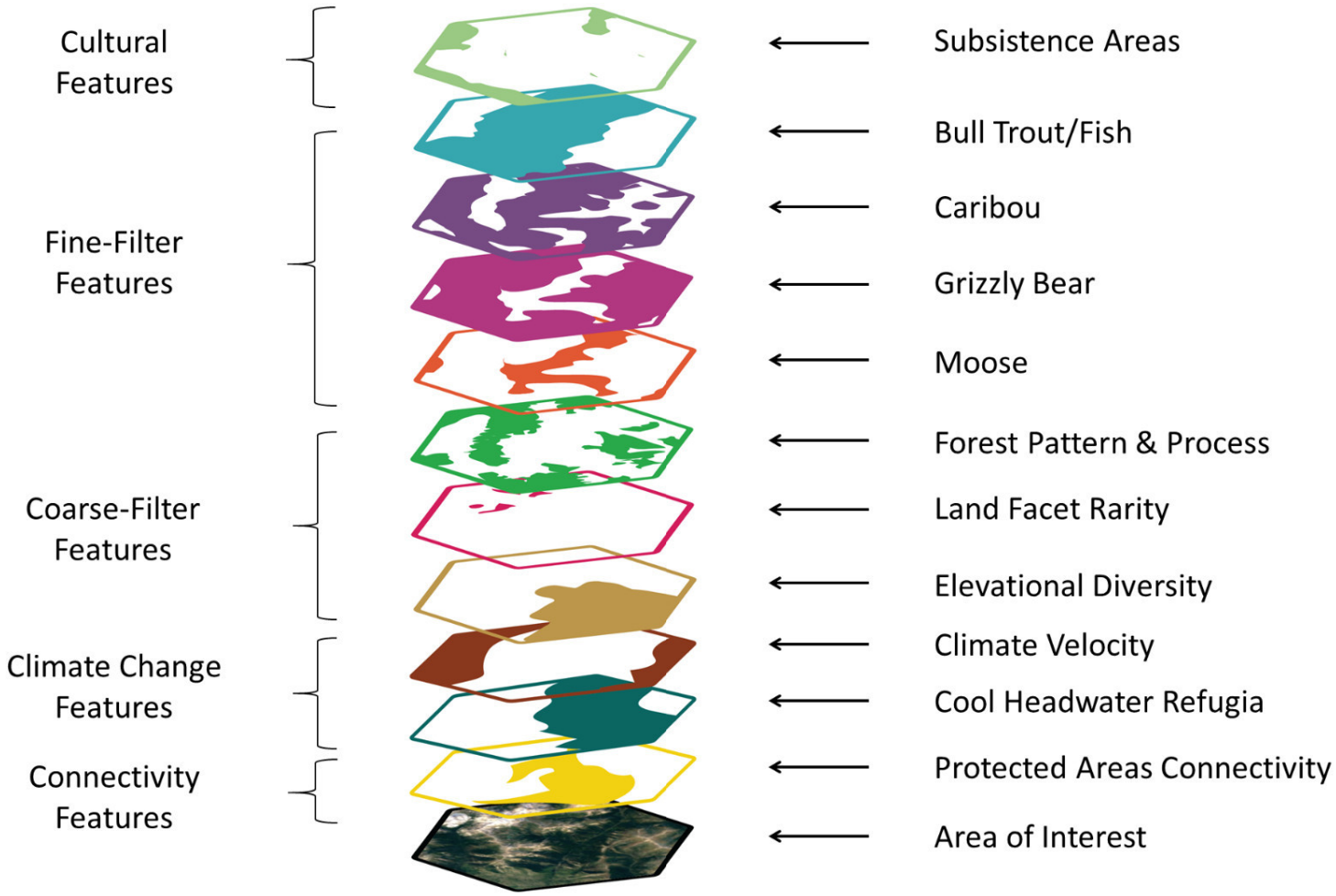

Figure 9. A stacked set of select conservation feature layers

Coarse-Filter Features		Description
Abiotic	Land Facet Diversity	Diverse combinations of slope, aspect, elevation and landform
	Land Facet Rarity	Rare combinations of slope, aspect, elevation and landform
Environmental	Elevational Diversity	Cluster of varying elevations
	Ecotypic Diversity	Diverse Ecological Land Units (made up of physical features, climate, and land cover type)
	Heat Load Index Diversity	Diverse collection of solar radiation exposure (i.e. how hot or cool an area is)
Biotic	(Disturbance)-(BEC Zone)-(Age/Burned) Ex 1: NDT1-ESSF-Burned Ex 2: NDT2-SBS-Mature/Old	Combination of disturbance, Biogeoclimatic Ecosystem Classification Zone, and age/burn history of tree stands to meet biodiversity goals from the Biodiversity Guidebook (B.C. Environment, 1995)
	Rare BEC Zones	Rare occurrances of BEC subzone variants in the territory
Fine-Filter Features		**Description**
Species	Grizzly Bear	Capable habitat for grizzly bear, enhanced with TEK
	Bull Trout/Fish	Critical habitat for bull trout focusing on spawning and juvenile rearing sites; enhanced with TEK on bull trout and other fish species
	Fisher	Suitable habitat for fisher based on denning, resting, moving, and foraging needs
	Caribou (by herd)	High quality habitat for caribou by herd, enhanced with TEK
	Moose	Year-round habitat for moose, enhanced with TEK
	Stone Sheep	Suitable habitat for Stone sheep, enhanced with TEK
	Mountain Goat	Suitable habitat for mountain goat, enhanced with TEK
	Wolverine	Suitable habitat for wolverine
	Bank Swallow	Suitable habitat for bank swallow
	Barn Swallow	Suitable habitat for barn swallow
	Western Toad	Suitable habitat for western toad
	Horned Grebe	Suitable habitat for horned grebe
	Little Brown Myotis	Suitable habitat for little brown myotis
	Northern Myotis	Suitable habitat for northern myotis
	Olive-Sided Flycatcher	Suitable habitat for olive-sided flycatcher
	Rusty Blackbird	Suitable habitat for rusty blackbird
Special Features	Wetlands	Wetlands by size of complex
	Lakes	Lakes by size
	Karst Deposits	Cave ecosystems based on likelihood of occurrence
Climate Change Features		**Description**
Migration	Backward Velocity 2055	Distance from a projected 2055 climate location back to analogous existing climate locations
	Backward Velocity 2085	Distance from a projected 2085 climate location back to analogous existing climate locations
	Forward Velocity 2055	Distance from a single source to multiple projected 2055 climate analogs
	Forward Velocity 2085	Distance from a single source to multiple projected 2085 climate analogs
	Climate Corridors	Connections between current and future locations of a climate type
Refugia	Cool Headwater Refugia	Areas predicted to have a mean annual temperature change of <1°C by 2080
	Climatic Refugia	Areas where climate-threatened species can continue to exist or readily colonize
	Biotic Refugia	Climatic refugia that are further informed with biological thresholds
Misc.	Bird Richness	Predicted summer habitat for 604 climate vulnerable bird species under a 3°C warming scenario
	Carbon Storage (above and below ground)	Above and below ground carbon storage
Cultural Features		**Description**
	Sites of Cultural Importance	TEK-sourced point data on habitation, subsistence, transportation, wildlife, and cultural/spiritual locations
	Cultural/Spiritual Areas	TEK-sourced polygon data on cultural areas like burial sites, medicinal plant locations, battlegrounds, campsites, and teaching places
	Subsistence Areas	TEK-sourced polygon data on subsistence areas like berry picking sites, hunting grounds, and fishing holes
Connectivity Features		**Description**
	Linkage Mapper	Highly connected areas between existing and proposed protected areas
	Omniscape	Highly connected areas throughout the entire landscape

Table 4. List of Conservation Features used in analysis

4.1.1 Coarse-filter Conservation Features

Coarse-filter conservation features are used as a means of representing ecosystem-level biodiversity, conserving the greatest diversity of physical landscapes as possible – including biotic, abiotic, and climatic representation.

4.1.1.1 Abiotic

The abiotic coarse-filter conservation features of this SCP include land facet diversity and land facet rarity. Using land facet data developed by Michalak et al. (2018), I developed layers for land facet diversity and land facet rarity. Land facet diversity was selected because it represents a varied collection of land facets within a relatively small area, allowing for different niches in close proximity. Diversity was generated using the 'variety' option in ArcMap's Focal Statistics tool. The most diverse portions were selected until 10% of the study area was achieved. Land facet rarity was selected because it represents unique combinations of physical features that are relatively scarce. For rarity, the least common land facets were selected until 10% of the study area was achieved.

4.1.1.2 Environmental

The environmental coarse-filter conservation features included elevational diversity, ecotypic diversity, and heat load index diversity. Like land facets, varied occurrences of these features in concentrated areas represent high conservation value for the diverse habitats they can hold (Carroll et al., 2017). The data were already processed to be measures of diversity (varied occurrences within a spatial neighbourhood) and were sourced from Carroll et al. (2017). Elevational diversity mapped dissimilar elevations in close proximity. Ecotypic diversity used ecological land units (ELUs), a classification developed by Sayre et al. (2014) and derived from growing degree days, an aridity index, landform, lithology, and land cover

type. This metric is similar to land facets but goes further by including climate and land cover data (Carroll et al., 2017). Heat load index (HLI) is a metric based on slope, aspect, and latitude (Mann, 2020). HLI estimates the annual solar radiation exposure of an area, predicting cool, warm, or hot microclimates (Carroll et al., 2017). The more desirable 50% of values were selected for all three of these layers.

4.1.1.3 Biotic

Biotic coarse-filter conservation features represent biodiversity as expressed through present-day vegetative communities, in this case derived from the concept of forest pattern and process (Curtis, 2018). The 'Mature/Old' classification varies by biogeoclimatic zone such that the stand is at a minimum anywhere between 80-120 years old. The 'Burned' designation, on the other hand, is consistent in that it means the stand has been exposed to wildfire within the last 40 years. By using the BEC zone and disturbance type combinations I ensured representation of each dominant tree species/climatic condition and disturbance frequency. From there I selected for a biodiversity emphasis of mature/old or naturally young (i.e., burned) forests. The classifications and methods described are derived from the *Biodiversity Guidebook of British Columbia* (BC Environment, 1995) (Table 5).

BEC zones also have subzones based on precipitation, temperature, or continentality, as well as further variants of those subzones reflecting their relative location or distribution within the subzone (BEC Program, 2011). Chu Cho Environmental staff expressed an interest in capturing rare BEC occurrences, so I adapted a rarity scoring spreadsheet from BC Parks (2020) to create a layer of the rarest BEC zones in the Territory down to the variant level.

Natural Disturbance Type (NDT)	
NDT1	ecosystems with rare stand-initiating events
NDT2	ecosystems with infrequent stand-initiating events
NDT3	ecosystems with frequent stand-initiating events
NDT4	ecosystems with frequent stand-maintaining events
NDT5	alpine tundra and subalpine parkland
Biogeoclimatic Ecosystem Classification (BEC)	
BAFA	Boreal Altai Fescue Alpine
BWBS	Boreal White and Black Spruce
ESSF	Engelmann Spruce—Subalpine Fir
SBS	Sub-Boreal Spruce
SWB	Spruce—Willow—Birch

Table 5. Disturbance and Biogeoclimatic Ecosystem Classifications from the Biodiversity Guidebook of British Columbia that are found in Tsay Keh Dene Territory.

4.1.1.4 Representation

Quantifying how various categories of the landscape are captured in a conservation solution provides valuable information even in the absence of target setting. While certain portions of existing BEC zones were targeted in other layers for their ecological value or rarity, including the zones as a whole for representation purposes provided additional insight.

Elevational representation was important for understanding if the existing network of protected areas or the identified potential conservation areas were biased towards low, moderate, or high elevation areas. I used three elevation classes approximating the break points used by Weaver (2019).

Ecoregions are a federal classification system used to assess ecological representation (Mann, 2020). Greater Tsay Keh Dene Territory contains nine distinct ecoregions, though

just four (Omineca Mountains, Northern Canadian Rocky Mountains, Central Canadian Rocky Mountains, and Boreal Mountains and Plateaus) make up most of the Territory. This classification system is characterized by distinct assemblages of natural communities and species (Olson et al., 2001). Consequently, assessing how well each ecoregion present in my study area was captured by existing protected areas and identified potential conservation areas was valuable information.

4.1.2 Fine-filter Conservation Features

Many of the focal species that applied to the Wild Harts Area of the Peace River Break (Curtis, 2018; Mann, 2020) also apply to Tsay Keh Dene Territory given boundary overlaps. These species include caribou, grizzly bear, fisher, and bull trout. Additionally, the Nation asked for the inclusion of moose, wolverine, Stone sheep, and mountain goats (Tsay Keh Dene Nation, personal communication, September 30, 2019). Data for these species were screened for availability and tied to specific ecosystem conditions as surrogates. Additional species were selected based on input from the Nation and Chu Cho Environmental data from species at risk work they have performed previously. In addition to Western science-sourced datasets, the Nation provided TEK-sourced data, some of which was used to enhance species data. I also included fine-filter layers of 'special features', which are ecosystem components that are highly biodiverse, sensitive, and/or rare on the landscape (Heinemeyer et al., 2004). While Curtis (2018) and Mann (2020) used a consolidated special features layer, I included wetlands, lakes, and karst deposits individually to ensure the capture of each. While mineral licks also fall into the special feature category, the only data available was TEK-sourced, and was included as a cultural feature (described later).

4.1.2.1 Species

There were a series of species with data constructed largely from Western science but enhanced with TEK. These included grizzly bear, caribou, Stone sheep, mountain goat, moose, and bull trout. The TEK-sourced species data was derived from traditional use studies and is part of the Nation's Cultural Knowledge Keeper database. While each species has scientific justification for their selection outlined below, it is important to note that they each hold inherent value to the Tsay Keh Dene and that was justification enough for their inclusion in this study.

Grizzly bears were included because they represented large, intact landscapes, open-canopy forests and avalanche chutes, and provided umbrella representation for a multitude of other species (Curtis, 2018). I used weighted habitat suitability data sourced from the BC Data Catalogue.

Caribou also represented large, intact landscapes, but more specifically alpine and subalpine parkland habitats. Additionally, they were characterized by old, mid-elevation tree stands containing arboreal lichens (Mann, 2020). I constructed a spatial layer of high-value caribou habitat in a stepwise fashion, beginning with data from Mann (2020) – largely based on data from Gustine and Parker (2008). High-quality caribou habitat outside of Mann's study area was supplemented first with data from Weaver's Muskwa-Kechika report (2019), then provincial Ungulate Winter Range data, and finally Demarchi and Demarchi's provincewide habitat assessment (2003) to fill the remaining study area gaps.

Stone sheep and mountain goats represent precipitous terrain in remote wilderness areas as well as areas of concentrated elevational diversity (Heinemeyer et al., 2004). These

layers were constructed in a similar stepwise fashion as caribou, each starting with data from Heinemeyer (2004) that selected high-quality winter and growing season habitat. Data from Weaver (2019) was used to supplement the sheep layer outside of Heinemeyer's study area, and Ungulate Winter Range was used to fill the study area extent for both species.

Moose represented a unique suite of ecosystems, including young deciduous (or mixed-wood) forests, productive lakeshores and wetlands, and dense, mature/old forests (Heinemeyer et al., 2004). This layer was constructed by beginning with the provincewide Demarchi (2003) summer moose model and averaged with a localized model by Suzuki and Parker (2016) in a concentrated area of overlap. The resulting layer was summed with the Demarchi winter model to create a year-round moose layer.

Bull trout symbolize healthy watersheds and cold, high elevation streams with clean gravel beds and undisturbed riparian vegetation (Weaver, 2019). This layer was constructed from critical habitat conservation work performed by Hagen and Weber (2019) for the Fish & Wildlife Compensation Program (FWCP) in the Williston Reservoir watershed. It focused on critical spawning and juvenile rearing habitats.

For each of the aforementioned species, TEK-sourced spatial data in the form of points and polygons were used to enhance the final conservation feature layer. This data was both valuable and relatively sparse, so TEK-identified areas were automatically given the highest score on each of the species' habitat quality scales. In the case of the bull trout layer, TEK data on other fish species were also included, resulting in a more generalized fish layer but with a bull trout focus.

Fishers were included because they represent connected forests and dense shrub cover, as well as coarse woody debris, large diameter trees, and complex forest structure (BC Fisher Habitat Working Group, 2017). Robust fisher data exists for the province thanks to the BC Fisher Habitat Working Group (2017). This data delineates four unique habitat zones (Boreal, Sub-Boreal Moist, Sub-Boreal Dry, and Dry Forest) and four distinct habitat needs (denning, resting, moving, and foraging). I laid each of these layers on top of one another, with overlapping areas receiving higher scores.

Wolverines were identified by the Nation as another focal species, and data for them along with eight other species from previous work by Chu Cho Environmental (Bonderud et al., 2020) were included as conservation feature layers. These include bank swallows, barn swallows, western toads, horned grebes, little brown myotis (bat), northern myotis (long-eared bat), olive-sided flycatchers, and rusty blackbirds. Habitat quality for each was rated on a scale of 1-4, with the quality levels included in the analysis being decided on a case-by-case basis depending on how much of the Territory was included.

4.1.2.2 Special Features

The rare or valuable ecosystem fine-filter special features I included were wetlands, lakes, and karst deposits. Wetlands provide ecosystem services like water filtration and provide important habitat for species like migratory waterfowl (Mann, 2020). I used data from the Williston Wetland Explorer Tool (Filatow et al., 2020) supplemented with data from the BC Data Catalogue to gain complete geographic coverage of my study area. To implement a hierarchical scoring system, I adapted guidance from the Nation's *Expectations for Industry in Tsay Keh Dene Territory* document (2019), with larger wetlands complexes receiving higher scores.

Lakes were also identified as an important landscape feature by the Nation, and there is scientific consensus on the importance of safeguarding freshwater resources (Weaver, 2019). I adopted Weaver's (2019) classification system for conservation value of lakes by size, and used data from the BC Data Catalogue.

Karst deposits were included because they provide habitat for plant and animal species that utilize cave ecosystems or calcareous deposits for some or all of their life histories (Curtis, 2018). Karst features were given numeric scores based on their likelihood of occurrence.

4.1.3 Climate Change Conservation Features

In order to identify which portions of the landscape have the highest ecological value not just today, but also thirty and sixty years from now, incorporating climate change data is paramount (Gillson et al., 2013). I included features relating to climate velocity, climate connectivity, refugia, carbon storage, and bird richness.

4.1.3.1 Climate Migration

I identified climate velocity and climate corridor metrics to include as features in my analysis. I looked at both forward and backward velocities of climate projections for two time periods – the 2050s and 2080s – to understand progressive changes. In each case I took the lower 50% of values from the median, as lower velocity is more desirable (Carroll et al., 2017).

I also looked at climate corridors, or connections between present-day and future locations of a climate type. These areas identify the best routes between climatic refugia, and

therefore represent connectivity in a future sense (Carroll et al., 2018). In that case I took the upper 50% of values from the median, as greater current flow is more desirable.

4.1.3.2 Refugia

Refugia are locations that are predicted to remain as is or transition to suitable habitat for some species in the future (Ashcroft, 2010). I looked at three different metrics with those future habitats in mind. The first is climatic refugia, or areas where climate-threatened species can continue to exist or readily colonize (Stralberg et al., 2020). Using data from Stralberg et al. (2020), I took the upper 50% of values from the median. Biotic refugia are climatic refugia that are further informed with biological thresholds, in this case with data on mammal, bird, amphibian and tree species (Michalak et al., 2018). I used data from Michalak et al. (2018), and stacked the results from their six different iterations (three models at two time stamps) to generate a continuous layer with overlapping areas scoring higher. The last feature was cool headwater refugia, where I targeted keystone sections of rivers given their ecological value and refugia potential. I used data from ClimateBC (Wang et al., 2016) and methodology from Weaver (2019) to identify areas predicted to have a mean annual temperature change of <1°C by 2080.

4.1.3.3 Bird Richness

Bird richness is a summary of predicted summer habitat for 604 climate vulnerable bird species under a 3°C warming scenario (Bateman et al., 2020). Using data from Bateman et al. (2020) I took the upper 50% of values from the median.

4.1.3.4 Carbon Storage

Carbon storage is a method to counteract (or at least stave off) climate change by keeping CO_2 out of the atmosphere and locked in the earth (Chan et al., 2006). I used data on above-ground biomass (Santoro et al., 2018) and below-ground carbon (Hengl et al., 2017). Data was normalized and added together to create a carbon storage layer. I then kept the upper 50% of values from the median.

4.1.3.4 Flying BEC Zones

With representation of present-day BEC zones included in the coarse-filter category, I also included predicted BEC zones under climate change scenarios for the years 2050 and 2080. I used data from ClimateBC (Wang et al., 2016), which sees the Territory add six novel zones by 2050 before losing one of those novel zones by 2080, all while maintaining the five that exist at present.

4.1.4 Cultural Conservation Features

The Tsay Keh Dene Nation's Office of Lands, Resources, and Treaty Operations provided me with TEK-sourced data from their Cultural Knowledge Keeper database. This data is derived from traditional use studies and is available as spatial data in the form of points, lines, and polygons under strict confidentiality. I used the point data to form a layer called 'Sites of Cultural Importance,' which contained data on habitation, subsistence, transportation, wildlife, and cultural/spiritual locations. Planning units received scores based on how many sites were located within them. I also used the polygon data, and divided it into two categories – 'Cultural/Spiritual Areas' and 'Subsistence Areas'. Examples include berry picking sites, hunting grounds, fishing holes, burial sites, medicinal plant locations, battlegrounds, campsites, and teaching places.

4.1.5 Connectivity Conservation Features

The results of connectivity analyses from both the Linkage Mapper and Omniscape approaches were incorporated as conservation features. In each case I kept the more desirable 50% of values from the median for possible selection in *prioritizr*. Details on the development of the connectivity analysis are provided in methods section 4.3.

4.2 Stage 2: Develop a Human Footprint Layer

The anthropogenic footprint in the region has been significant, primarily due to resource extraction activities. Just as *prioritizr* allows conservation features to be used as desirable inputs to be included in the identification of high-value conservation areas, it also allows for a 'cost layer' of areas that should be avoided. I categorized human development into three levels of footprint permanence (permanent, semi-permanent, and ephemeral), with the cost layer used in *prioritizr* growing progressively larger as additional footprint features were added (Table 6). The model user can choose one of three compounding options as human footprints to avoid: permanent, permanent plus semi-permanent, or permanent plus semi-permanent plus ephemeral. The different categories allow the user to plan with different levels of permanence in mind as some impacts like logging and agriculture can theoretically be restored, while others (e.g., dams like the W.A.C. Bennett) are more permanent. Furthermore, each footprint feature was assigned a buffer distance based on its impact on the landscape and wildlife from relevant literature (Appendix C. Human Footprint Feature Data Sources and Buffers). This categorization and buffering framework was vetted by the Nation and edits were made accordingly. Valuable insight and local knowledge were provided at this stage, namely in subcategorizing roads and cutblocks by their relative level of impact.

Footprint Layer Permanence		
Permanent	**Semi-Permanent**	**Ephemeral**
Dams	Agriculture	Alpine Skiing
Drillsites and Wellsites	Cutblocks	Heliskiing
Active	1940-1980	Snowmobiling
Orphan	1981-2020	Trail Riding
Dormant	Camps and Cabins	
Industrial Uses	Roads	
Mines	Outblock Trails	
Pipelines	Inblock Resource Main	
Power and Telecom Lines	Inblock Resource Secondary	
Quarries	Inblock Trails	
Reservoirs		
Residential Areas		
Roads		
Outblock Major		
Outblock Resource Main		
Outblock Resource Secondary		
Urban Areas		
Wind Turbines		

Table 6. Human footprint permanence framework and categorized layers.

4.3 Stage 3: Quantify Landscape Permeability to Identify Connectivity Corridors

Landscape permeability is the degree of difficulty that species experience in moving across the landscape, with highly permeable routes between ecologically intact areas serving as connectivity corridors. To quantify the landscape permeability of the Territory and understand the resistance that species face in traversing ground, I performed connectivity analyses using third-party extensions to ArcMap GIS software, as well as standalone scripts. These include Gnarly Landscape Utilities (McRae, Shirk, et al., 2013), Linkage Mapper (McRae, Shah, et al., 2013), and Omniscape (Landau, 2020; McRae et al., 2016). As these exercises did not include empirical movement data and were not species specific, their outputs are considered structural connectivity rather than functional connectivity. However,

areas identified for connectivity that overlap with planning units selected for their conservation value could be considered functionally connected (Keeley et al., 2021).

4.3.1 Resistance Layer

Building a resistance layer is the first step of performing connectivity analyses, and I calculated one for the Territory using the Resistance and Habitat Calculator tool from Gnarly Landscape Utilities. This entails populating a preformatted spreadsheet with each of the resistance layers, their sub-classifications, and relative resistance scores that fall between 0 (no resistance) and 100 (extreme resistance). Resistance input layers included variables such as land cover, slope, buffered roadways, private land, and the human footprint (minus roads since they are accounted for separately in this analysis) (Table 7). After creating a geodatabase of rasterized spatial files for each of the input resistance layers, the geoprocessing plugin tool matches each of the spatial layers to their respective resistance values to synthesize an overall resistance layer.

Data Layer	Class Description	Resistance Value
Land Cover	Agriculture	30
	Alpine	0
	Barren Surfaces	20
	Fresh Water	40
	Glaciers and Snow	60
	Mining	70
	Old Forest	0
	Range Lands	25
	Recently Burned	10
	Recently Logged	20
	Recreation Activities	10
	Selectively Logged	10
	Shrubs	0
	Sub alpine Avalanche Chutes	10
	Urban	100
	Wetlands	5
	Young Forest	0
Slope (in degrees)	0 - 5	1
	5 - 10	1
	10 - 15	1
	15 - 20	1
	20 - 25	1
	25 - 30	1
	30 - 35	1
	35 - 40	1
	40 - 45	1
	45 - 50	10
	50 - 55	20
	55 - 60	30
	60 - 65	40
	65 - 70	50
	70 - 75	60
	75 - 80	100
	80 - 85	100
Buffered Roads	Outblock Major Roads	70
	Outblock Resource Main Roads	50
	Outblock Resource Secondary Roads	30
	Outblock Trails	10
	Inblock Resource Main Roads	40
	Inblock Resource Secondary Roads	20
Human Footprint	Permanent Footprint (except roads)	70
	Semi-Permanent Footprint (except roads)	30
	Ephemeral Footprint	10

Table 7. Resistance features to inform connectivity analyses. Resistance Value on scale of 0-100.

4.3.2 Linkage Mapper

I then utilized the Linkage Pathways Tool from the Linkage Mapper Toolkit by Circuitscape. This ArcMap extension looks at the ability of a generalized species to traverse the landscape between a set of 'core areas', which in some instances are protected areas, but could also be non-protected areas found to be relatively intact from the human footprint analysis. I used legally designated protected areas plus the proposed boundary for the Ingenika Conservation and Management Area as my core areas after consulting with the Nation. After uploading the raster resistance layer from the previous step, this tool uses random walk analysis and electric circuit theory to find the paths of least resistance (also known as least-cost paths) between core areas by quantifying the level of permeability of each raster cell (McRae et al., 2008).

Next, I adapted methods from Heinemeyer et al. (2004) to explicitly include connectivity as part of the SCP process in an attempt to create an 'ecological network' of core habitats and ecological corridors (Hilty et al., 2020). I used the least-cost paths (LCPs) identified by Linkage Mapper to create a layer that could be 'locked in' as part of a conservation solution so that *prioritizr* would automatically select it.

Least-cost paths are lines that represent the easiest route across the landscape for species to move from one core area to another. While these paths can serve as important movement corridors, they do not necessarily represent ecologically valuable land. As such, I created a layer made up solely of the planning units traversed by LCPs and the core areas that they connect. This ensures structural connectivity between core areas without overemphasizing wider corridors that may not have ecological value. It does, however, still allow planning units adjacent to the LCPs to be selected for their ecological value and

functionally build a larger corridor between core areas. This method differs from Heinemeyer et al. (2004), who locked in larger corridors by including LCPs *plus* adjacent planning units with equally low resistance values. I ultimately included the Linkage Mapper output as a conservation feature (top 50% of values) despite the shortcomings outlined above, but did not set any target at all just to see how well it was incidentally captured in various scenarios.

4.3.3 Omniscape

Like Linkage Mapper, Omniscape uses electric circuit theory to theorize connectivity by analyzing how electric current flows across a landscape given its resistance. While Linkage Mapper looks for connectivity between core areas, Omniscape looks at the connectivity of the entire landscape.

Omniscape requires a set of parameters so the script knows how to execute the analysis. To replicate the 50 km moving window used in McRae et al. (2016) I took my 100 m resolution resistance layer and set a radius of 500 (a 100 m raster cell multiplied by 500 cells to reach 50,000 m or 50 km). I used a block size of 49 to coarsen the analysis of the resistance raster and speed up processing time (Figure 10). Larger block sizes have been found to produce only negligible differences in the output (Landau, 2020). A source strength raster defines how much electric current should be injected into each pixel, with intact areas or high-quality habitat serving as potential high source values. This layer can be created independently or be calculated on the fly as the inverse of the resistance raster. I opted to use the inverse of the resistance raster, as this analysis was not species-specific (Keeley et al., 2021).

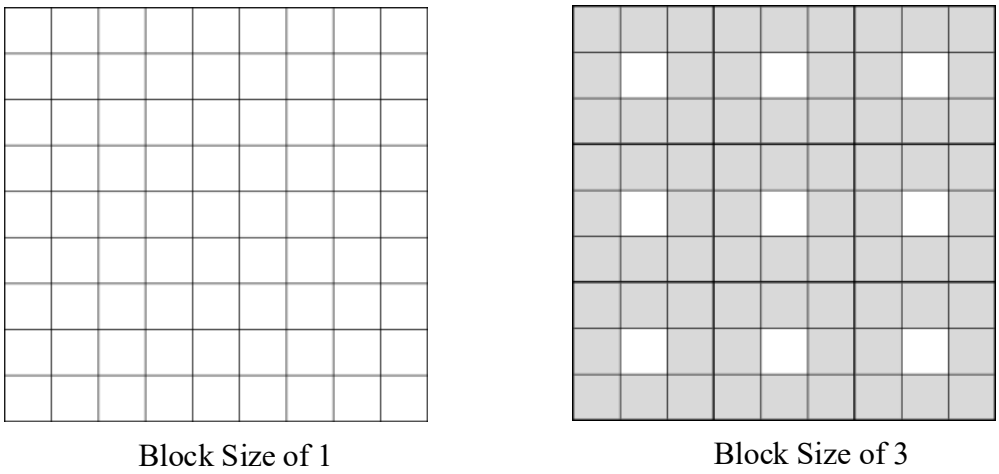

Figure 10. A visual representation of how different block sizes are used to improve computing time (Landau, 2020).

The default output of an Omniscape run is cumulative current flow, or the summed flow of current for a given pixel after all of the moving window iterations have been added together. Omniscape can also produce metrics known as flow potential and normalized current flow. Flow potential is what flow would look like if there was no resistance, using the same algorithm as cumulative current flow but with resistance set to 1 for the entire landscape (Landau, 2020). Normalized current flow takes the cumulative current flow and divides it by flow potential. This helps to identify channelized areas or 'pinch points' in more developed areas while high flow areas in largely intact landscapes (as would be expected) fade more into the background. Each output can be useful in interpreting flow, and local context is key (McRae et al., 2016).

I used the cumulative current flow output for inclusion in my *prioritizr* analysis, as this landscape remains highly connected relative to other locations, even given development pressures. I produced two 'locked-in' options as a result, one using the top two quantiles of flow, and another slightly thicker iteration using the top three quantiles of flow. My goal was to choose break points that locked in enough planning units for connectivity to translate to

the conservation solution, but not be overbearing on how many planning units were locked in to allow conservation prioritization to still occur.

Like with Linkage Mapper, I decided to also include my Omniscape output as a conservation feature, but without targets. This allows the user to at least see how well the top 50% of Omniscape connectivity values are incidentally captured in scenarios focused on other conservation features.

4.4 Stage 4: Develop Conservation Targets

The most common version of SCP problem solving is the 'minimum set objective'. This solution requires that overall conservation goals be translated into more specific, quantifiable targets for functional use (Margules & Pressey, 2000). With conservation features identified and compiled for our analysis, I set an initial target for each to inform the ultimate conservation solution. *prioritizr* requires these inputs for the tool to know how much of each conservation feature to capture when performing prioritizations (Hanson et al., 2021). *prioritizr*'s purpose is to then maximize the selection of ecologically high-value areas while minimizing the selection of areas with a high human footprint. I used *prioritizr* to return a single best solution of potential conservation areas as opposed to the conventional Marxan approach of comparing the selection frequency of different iterations (Beyer et al., 2016). For example, caribou are highly endangered in the region and would warrant a high target percentage such as 90%. A target of 90% tells *prioritizr* that in any prioritization process it performs that at least 90% of caribou habitat area must be included in the solution.

The initial target percentages for each conservation feature were carefully considered and drawn from a variety of sources. My draft set of targets was informed by the targets set

by Curtis (2018) and Mann (2020), as well as ecological best practices from other literature. For example, the Forest Pattern and Process layer targets were informed by the 'higher biodiversity emphasis' values of the *Biodiversity Guidebook* (BC Environment, 1995), while the caribou targets were based on the management objectives in the *Implementation Plan for the Ongoing Management of South Peace Northern Caribou* (British Columbia & Ministry of Environment, 2013). The sources behind each conservation feature target and the rationale for choosing the target was documented.

Traditional Ecological Knowledge and expertise provided by the Nation in the form of species reports and other management documents was also used to inform draft targets, along with other considerations unique to the study extent. I presented draft targets to the Nation in the form of an interactive workshop so representatives could weigh in on the targets and revise as necessary. While setting a specific and defensible target is important, the tool also allows the user to test multiple targets by running different scenarios. Experimenting with various targets for a specific conservation feature made sense when there was uncertainty due to a lack of literature on that feature, or if new information comes to light after the initial targets were set. The purpose was to imprint the Nation's values on these numbers to accurately portray the Nation's objectives when it comes to relative importance among conservation features, as well as taking relative abundance in the Territory into account. This process allowed me to affirm targets in cases of agreement, document disagreements and potential revisions, and provide additional justification for target choices.

4.5 Stage 5: Review Existing Conservation Areas Efficacy

A gap analysis quantifies how well an existing network of conservation areas captures the conservation features outlined in Stage 1 by comparing those numbers to the targets set in

Stage 4. This analysis was performed because designated conservation areas are unlikely to lose their protected status and were thus included as an option to 'lock in' as part of the conservation solution. By performing a gap analysis for the Territory I identified shortcomings in the network of existing conservation areas. To do so, I opted to lock in protected areas within *prioritizr* – revealing what percentage of conservation features selected are present in those areas. This review also helped inform the targets of certain conservation features in the context of this specific study area (Margules & Pressey, 2000). For example, if fisher and NDT1-SBS-B forest stands (recently burned sub-boreal spruce with rare stand-initiating events) were found to be poorly represented among the existing conservation area network, their targets would be adjusted accordingly. There was no community/TEK component to this stage, as this was a technical analytical process.

4.6 Stage 6: Identify a Portfolio of High-Value Conservation Lands

A conservation solution in this context is the most efficient array of planning units that meets the target of each conservation feature, known as the minimum set objective. This process was performed by the *prioritizr* R package within a planning tool developed for this project that runs as a program on a local computer. The tool works by synthesizing the spatial data of the selected conservation features and accounting for a cost (footprint) layer to develop its solution of high-value conservation lands. Since the present-day network of protected areas is pre-existing and unlikely to disappear, they were included as an option to lock into the solution, as were three connectivity focused layers to ensure pathways for movement. The planning tool also contains input options for a 'Boundary Length Modifier' and an 'Edge factor". These parameters encourage clustering of solutions and avoid penalizing planning units at the outer edge of the study area, respectively. Each were left at

their default values for the formal thesis scenarios, as the focus was on high-value areas regardless of clustering. The final step was entering the targets developed in Stage 4 for the algorithm to select the most efficient conservation solution for each scenario.

I ran six *prioritizr* base scenarios to address my research questions and account for climate change and connectivity within the growing human footprint. These included (a) setting targets for present-day conservation features, (b) setting targets for future conservation features focusing on the 2050s, (c) setting targets for future conservation features focusing on the 2080s, (d) setting targets for both present-day and future conservation features, (e) focusing on protected areas connectivity, and (f) focusing on landscape connectivity. As the planning tool was ultimately transferred to the Nation, additional scenarios can be run in the future as the Nation identifies other objectives or questions, or if specific needs arise. Parameters and targets can then be set accordingly to address those needs.

Present-day biodiversity is based on species and ecosystem presence today, while future biodiversity is based on an area's potential to serve as habitat under projected climatic conditions. The *prioritizr* tool was run through various iterations with different conservation features selected in order to compare the single best solution for the present with the single best solutions for the 2050s and 2080s. I started by using the foundational conservation features like species, forest pattern and process, and rare ecosystems data to produce a solution that maximizes conservation at the present. I also ran iterations that looked solely at the climate data outlined in section 4.1.3 (Climate Change Conservation Features), using datasets derived from both 2050s and 2080s climate models to produce solutions that maximized conservation for those respective timelines. A cumulative scenario was then run

where targets were set on conservation features for all three timeframes to see the extent of a conservation solution that conserves biodiversity for the present, near future, and distant future.

An additional two scenarios were run with a focus on connectivity. The first of these scenarios locked in protected areas and their least-cost paths with targets on present-day conservation features given that protected areas were generally designed with existing conditions in mind. The connectivity aspect of this layer was also quite conservative in that only planning units traversed by least-cost paths were locked in alongside the protected areas themselves. The second connectivity scenario focused on overall landscape connectivity and locked in select high values from the Omniscape output. This scenario set targets on future conservation features, as Omniscape focuses on the naturalness of a landscape (considered a coarse-filter conservation strategy) and represents structural connectivity (Keeley et al., 2021).

As mentioned in Stage 4, conservation feature targets can be experimented with on the fly, as *prioritizr* can quickly produce conservation solutions. Therefore, I held an interactive workshop with the Nation where additional use cases were identified. While we did not run any corresponding scenarios in real time, the Nation gained an understanding of how to translate additional conservation goals into parameters for the tool.

4.7 Stage 7: Assess *prioritizr* Solutions Through Different Lenses

The areas selected by *prioritizr* containing high ecological value were then reviewed through a set of various lenses to assess how the solution fared in regard to local biodiversity, climate change, and agreement with local knowledge of biodiverse areas.

4.7.1 Assess Conservation Feature Complementarity

Complementarity is the degree to which conservation features are similar to one another, measuring the percentage of each conservation feature's extent that is contained within a focal conservation feature. By setting a target of 100% for a lone feature, I determined the percentage of each other feature that falls within this focal layer. This exercise helped determine which features can potentially serve as surrogates for other features, as well as provide general insight into the similarities of each feature.

4.7.2 Compare Diversity of Conservation Features within Solutions

While *prioritizr* solutions are simply presence/absence spatial data, the diversity of selected conservation features can be calculated within ArcMap to help identify which of the selected solution areas exhibit high diversity. This sort of insight can prove useful in probing for which areas are 'hotspots' for conservation features and can potentially be considered for even further prioritization.

4.7.3 Compare Ideal Conservation Lands for 2020s, 2050s, and 2080s Climates

With conservation land portfolios for the 2020s, 2050s, and 2080s in hand, the three time periods can be compared for overlap to identify areas with the greatest levels of biodiversity and climate resiliency. I also analyzed what percentage of conservation features were incidentally captured as part of each scenario where they were not the focus and no targets were set. For example, in the present-day (2020s) scenario, I noted what percentage of climate conservation features for the 2050s and 2080s happen to be captured even though they were not the focus of the scenario. I also compared the total amount of area required to meet the conservation targets in each scenario – both as a raw total (in km^2 or ha) and as a

percentage of the total area of the Territory. These were also compared with the all-encompassing scenario that uses targets for all three time periods. Finally, areas of overlap between all six scenarios were quantified to identify those areas with the greatest conservation value through time.

4.8 Documenting Adaptations to the SCP Process

In multiple instances, my research project adapted the methods of Systematic Conservation Planning to include other elements. Documenting the process and approach I took to include connectivity, incorporate climate change, and interweave Traditional Ecological Knowledge into the SCP framework is critical to ensure rigor and transparency. The methods I used to document each are described briefly below.

I outlined in sections 4.3.2 (Linkage Mapper) and 4.3.3 (Omniscape) how I chose to explicitly include connectivity in this analysis, adapting methods from Heinemeyer et al. (2004) to lock in connected areas, as well as including connected areas as a feature with no targets. While coarse-filter and climate change conservation feature targets were largely based on Mann's (2020) methodology of incidental capture in a present-day conservation feature scenario, any adjustments that were made were documented and justified.

There is even less precedent for using Traditional Ecological Knowledge in an SCP. Considering that TEK can also be more qualitative in nature, I documented decisions surrounding its use in both a factual and reflective manner. For example, in the conservation feature selection process, when the Nation shared an idea for a specific feature and data source, I documented the impetus for this sharing of information, what feature was shared, the rationale behind it, who provided the idea, and where the data came from. After making

an effort to incorporate this knowledge, I documented the productiveness of this idea in a Reflective Journal to record how well it could be integrated, what I learned or experienced from this effort, and what could be done differently in the future. This serves to not only document my attempts to interweave TEK with the SCP process, but also allowed me to examine my own personal assumptions and values and how they may affect these attempts (Ortlipp, 2008).

5.0 RESULTS

This section reviews the results of completing the seven stages of the systematic conservation planning process outlined above. Many of these results are illustrated through maps of the greater territory study area. These maps also contain inset maps to give the reader a finer scale understanding of the results, not necessarily to highlight a specific area's results.

5.1 Conservation Goals

The Nation voiced seven goals for this systematic conservation planning effort to achieve:

1. Ensure the direction of systematic conservation planning reflects the vision and goals of the Tsay Keh Dene Nation. Community engagement will provide guidance, support a greater understanding of culturally-important areas and values, and inform refinements to this work.

2. Represent the full range of natural ecosystem variation across the Territory.

3. Identify and prioritize ecologically intact, high biodiversity habitats.

4. Identify and prioritize high-value habitat for priority plant, fish, and wildlife species.

5. Identify and prioritize rare ecosystems for conservation.

6. Identify and prioritize connectivity corridors of lands and waters across the landscape.

7. Incorporate an understanding of ecosystem shifts due to climate change into long-term resiliency planning, including identification of climate refugia.

5.2 Conservation Feature Layers

I developed a total of 41 conservation features for selection in this analysis. Some features included subcategories (e.g., caribou herds and forest pattern and process combinations), which resulted in a total of 64 layers for selection. An additional five representation features and their subcategories accounted for 38 more layers. While some layers were represented in planning units in a binary manner, those layers with continuous values maintained their hierarchical nature to facilitate preferential selection within *prioritizr*. Each conservation feature is described below, along with the proportion of the study area that it occupies. The study area extends beyond Tsay Keh Dene Territory and encompasses 89,007 km^2.

5.2.1 Coarse-filter Conservation Features

There were seven coarse-filter conservation features used in this analysis. The extent of each layer is described below, with maps depicting each coarse-filter feature included at the end of this group of descriptions.

5.2.1.1 Land Facet Diversity

The land facet diversity layer makes up 5% of the study area. This feature is speckled across the Territory, with the most notable concentration occurring along the shores of the Parsnip Arm of the Williston Reservoir near Mackenzie (Figure 11) representing the area of highest topographic complexity.

5.2.1.2 Land Facet Rarity

The land facet rarity layer makes up 5% of the study area. This feature is scattered across the Territory, generally found in river valleys and certain mountain ridges. The most notable clustering, however, is found along the Peace and Parsnip Arms of the Williston Reservoir (Figure 12).

5.2.1.3 Elevational Diversity

The elevational diversity layer makes up 50% of the study area. This feature is predominantly found in the central and northern portions of the Territory, with the highest values clustered around the Rocky Mountain Trench (Figure 13) where a full range of elevational classes are located within close proximity.

5.2.1.4 Ecotypic Diversity

The ecotypic diversity layer makes up 50% of the study area. This feature is generally found in less mountainous portions of the Territory and has its greatest concentration of high values in the southwest along the Omineca River valley (Figure 14).

5.2.1.5 Heat Load Index Diversity

The heat load index diversity layer makes up 50% of the study area. This feature centers on the northern part of the Territory, with an arm that reaches down the eastern side

of the Rocky Mountain Trench, as well as high value areas along the Finlay and Ingenika Rivers (Figure 15).

5.2.1.6 Forest Pattern and Process

The twelve forest pattern and process layers (described in section 4.1.1.3 Biotic) collectively make up 44% of the study area. These old or recently burned biodiverse forests are distributed mainly along river valleys and in other low and moderate elevation portions of the Territory (Figure 16). Given the criteria and data inputs, alpine portions of the Territory are not represented in these layers.

5.2.1.7 Rare BEC Zones

The rare BEC zones layer makes up 25% of the study area. This feature is found at the very center of the study area and along its eastern and western edges. The highest values are found in high elevation areas just east of the Williston Reservoir, as well as along the Sustut and Skeena Rivers to the west (Figure 17). The BEC subzones/variants included in this layer are listed in Table 8.

BEC Subzone/variant Code	Descriptor	% of Study Area	Rarity Score
BWBS wk 1	Murray Wet Cool	0.004%	3
BWBS wk 3	Kledo Wet Cool	0.01%	3
ESSF wvp	Wet Very Cold Parkland	0.1%	3
ESSF wv	Wet Very Cold	0.1%	3
SBS vk	Very Wet Cool	0.2%	3
SBS mc 2	Babine Moist Cold	0.9%	3
ESSF wcp	Wet Cold Parkland	0.9%	3
SBS wk 3	Takla Wet Cool	1.1%	3
ESSF mcp	Moist Cold Parkland	1.3%	3
ESSF mv 2	Bullmoose Moist Very Cold	1.3%	3
ESSF wk 2	Misinchinka Wet Cool	1.6%	3
BWBS mw	Moist Warm	2.0%	3
BWBS wk 2	Graham Wet Cool	2.3%	3
ESSF wc 3	Cariboo Wet Cold	2.6%	3
BWBS mk	Moist Cool	3.1%	3
ESSF mc	Moist Cold	3.4%	3
SBS wk 2	Finlay-Peace Wet Cool	3.5%	2
SBS mk 2	Williston Moist Cool	4.4%	2
ESSF mvp	Moist Very Cold Parkland	4.8%	2
SBS mk 1	Mossvale Moist Cool	4.9%	2
SWB mks	Moist Cool Scrub	6.8%	2
BWBS dk	Dry Cool	7.5%	1
ESSF mv 4	Graham Moist Very Cold	8.9%	1

Table 8. BEC subzones and variants included in the 'Rare BEC Zones' layer.

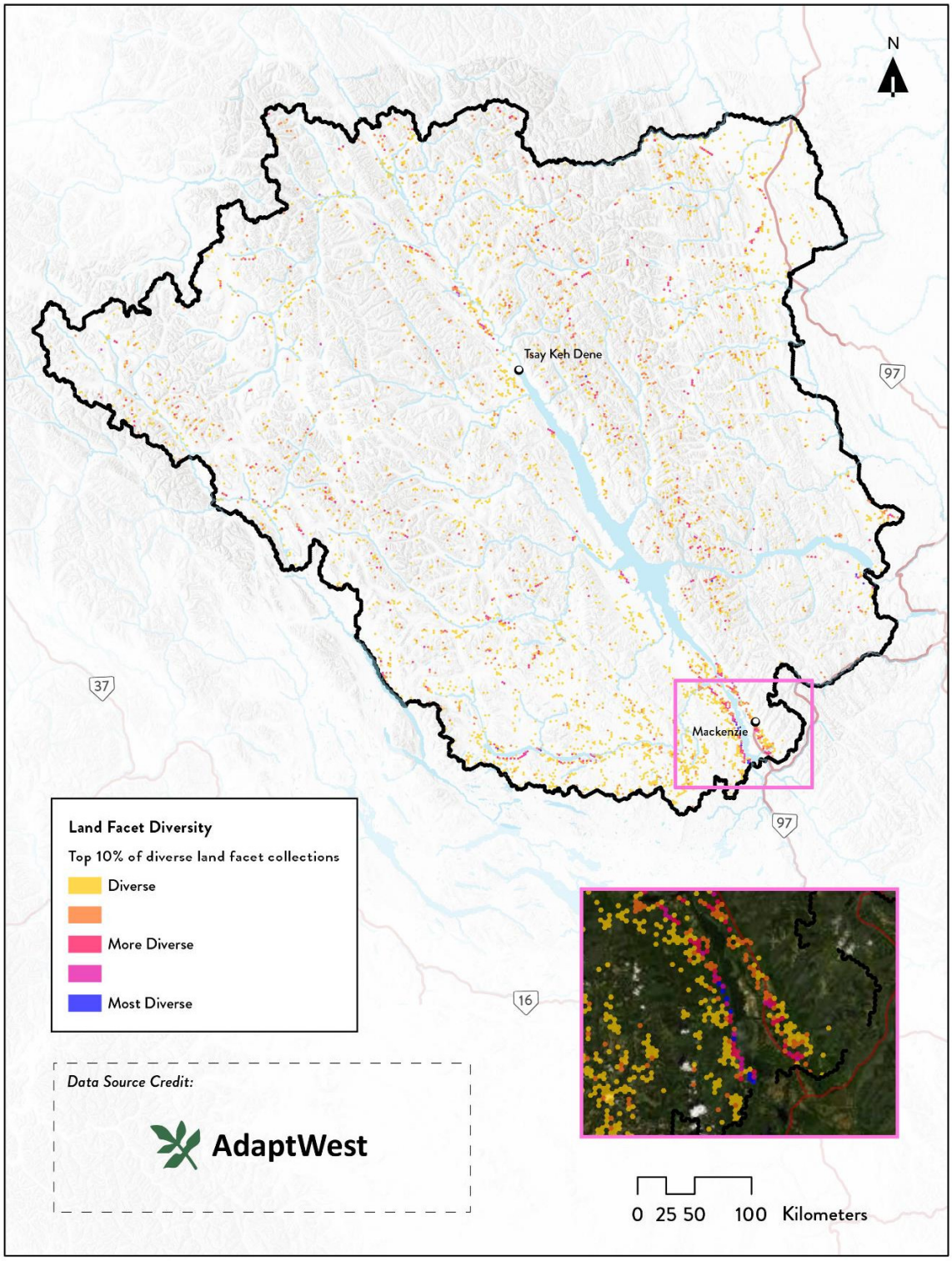

Figure 11. Spatial extent of the Land Facet Diversity layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

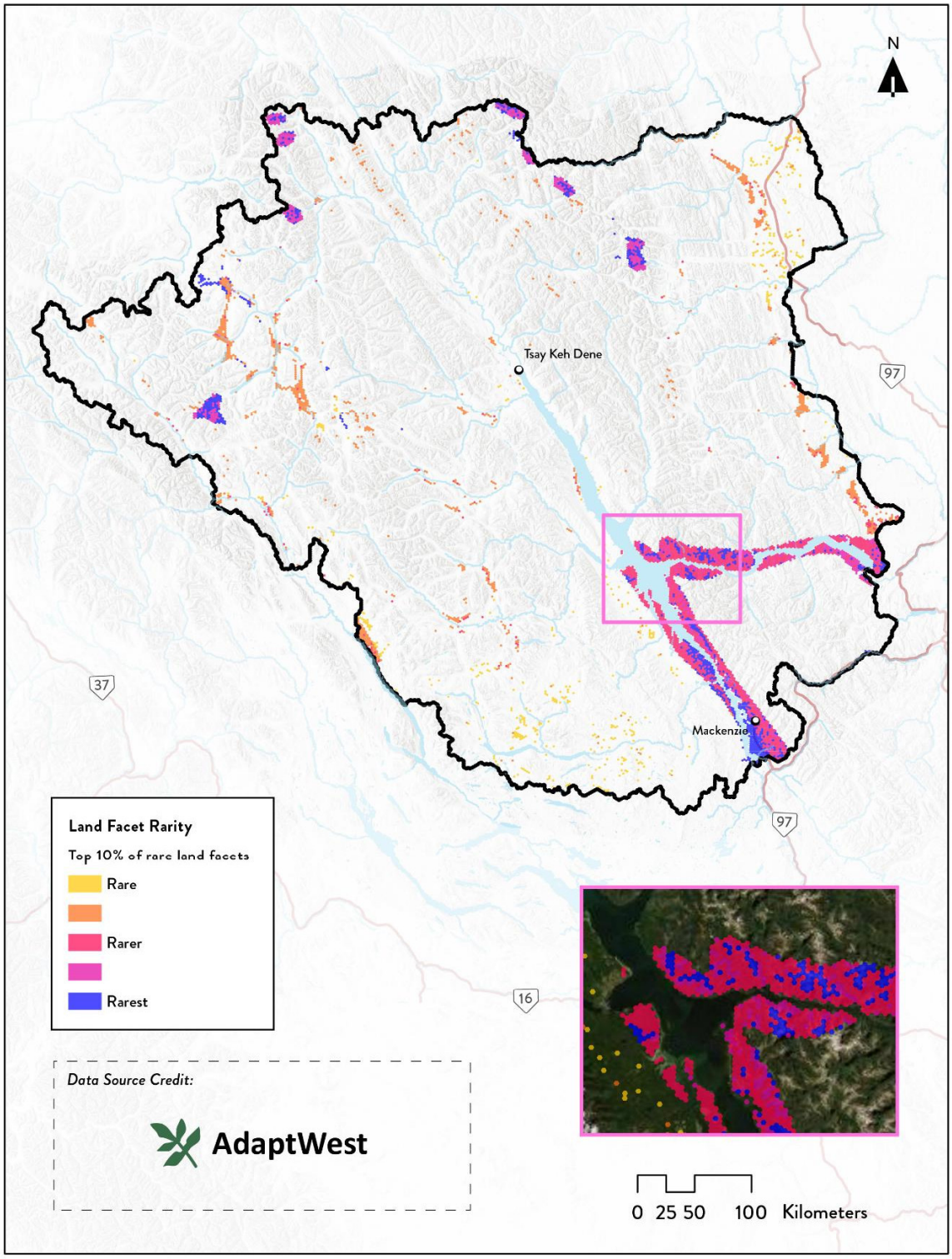

Figure 12. Spatial extent of the Land Facet Rarity layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

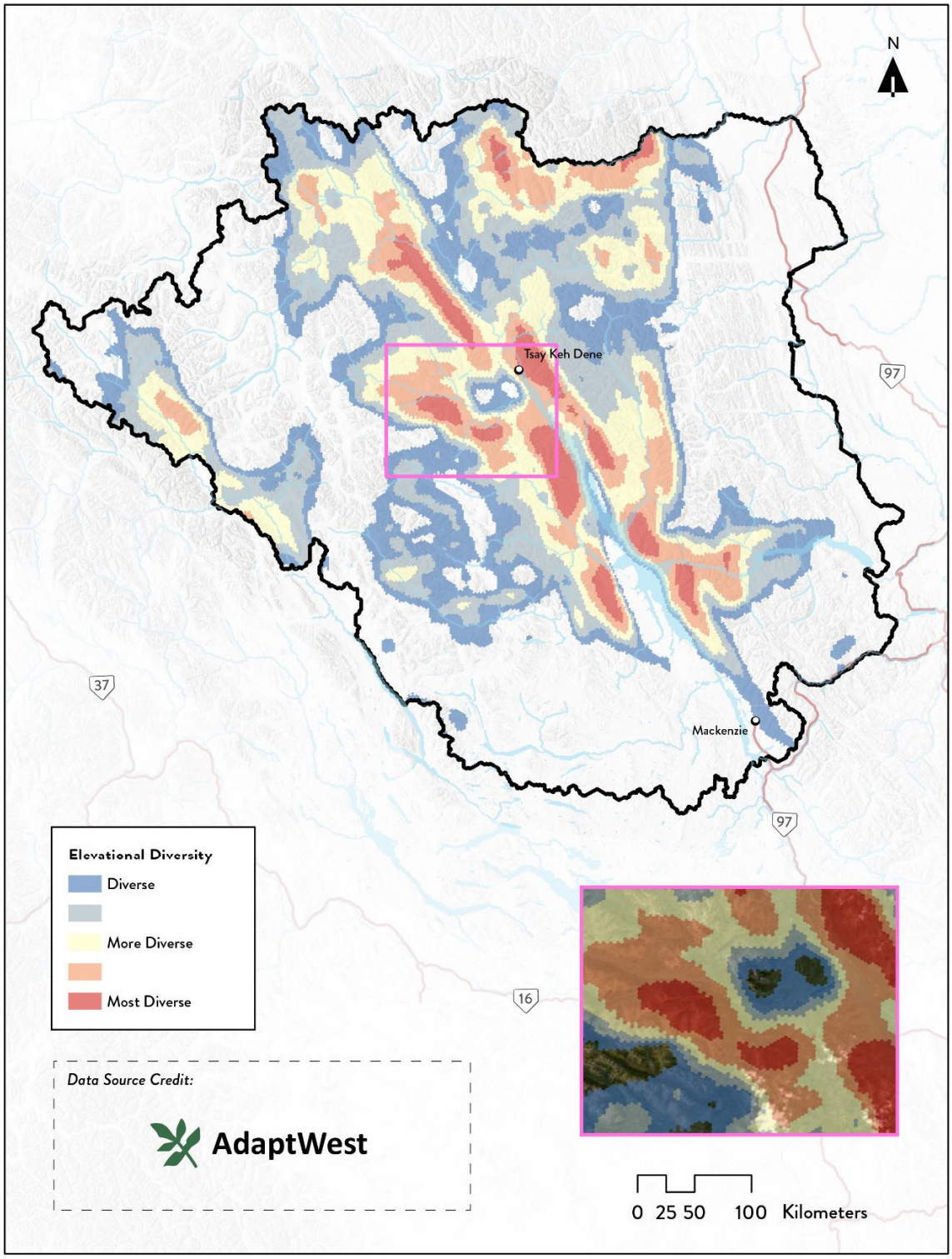

Figure 13. Spatial extent of the Elevational Diversity layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

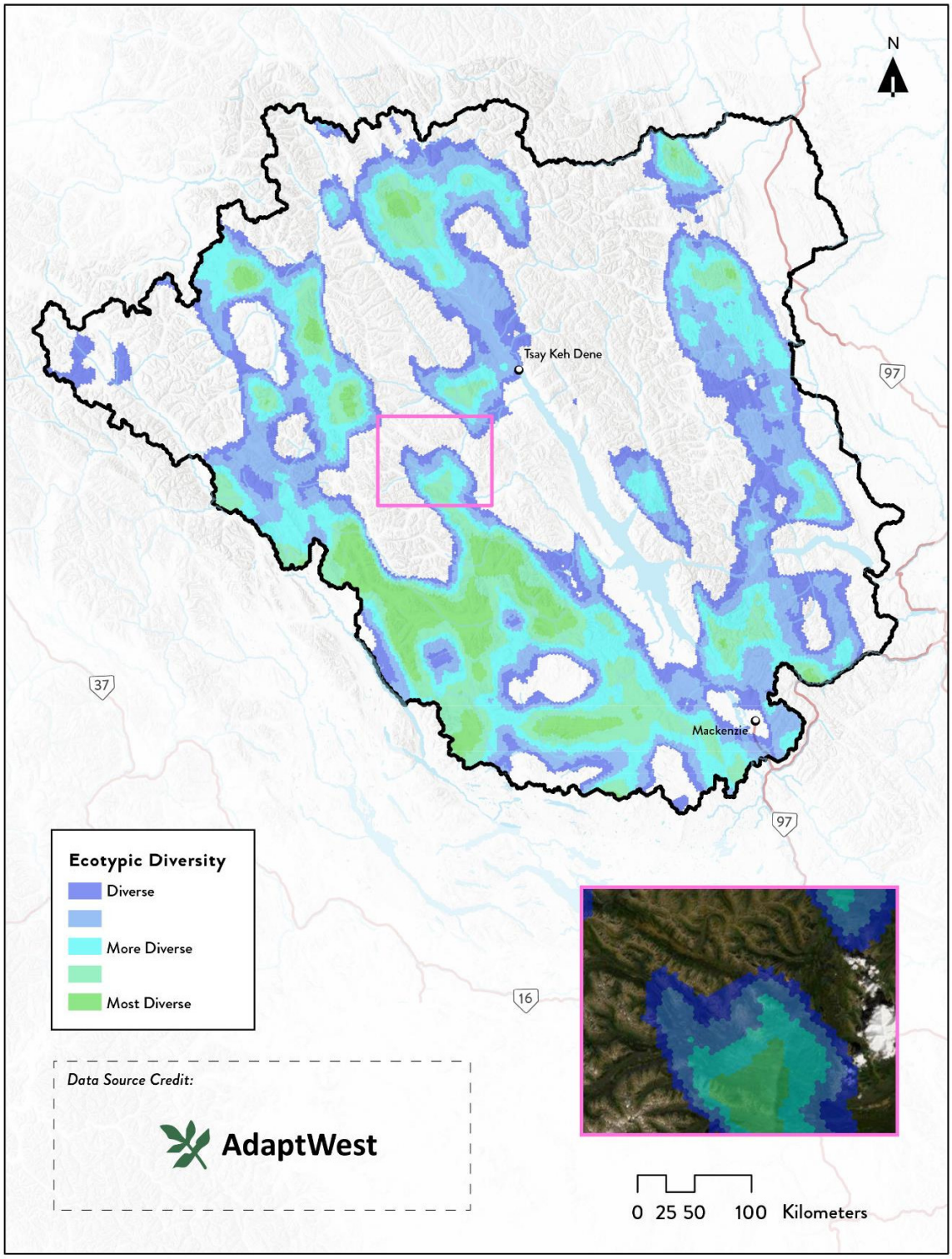

Figure 14. Spatial extent of the Ecotypic Diversity layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

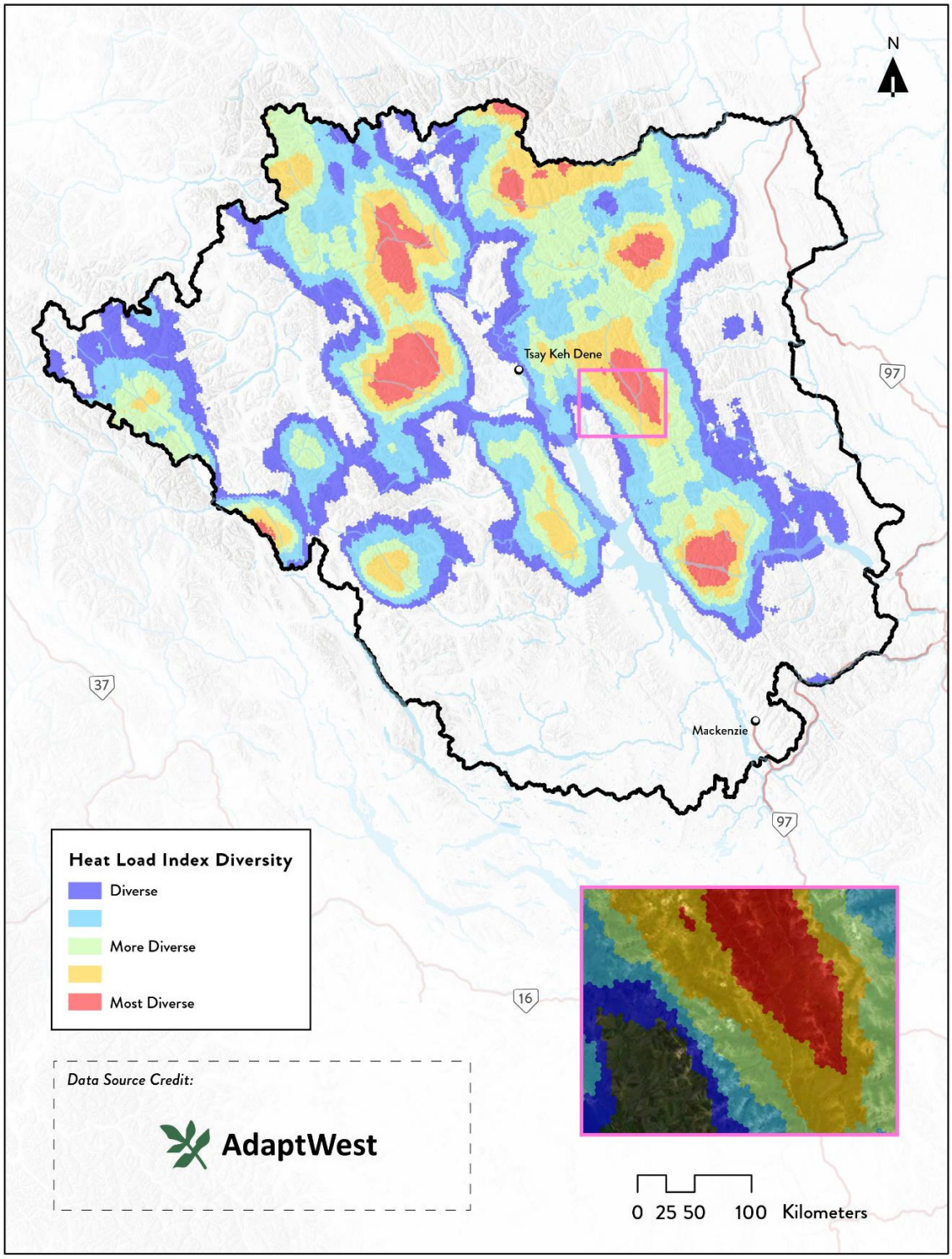

Figure 15. Spatial extent of the Heat Load Index Diversity layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

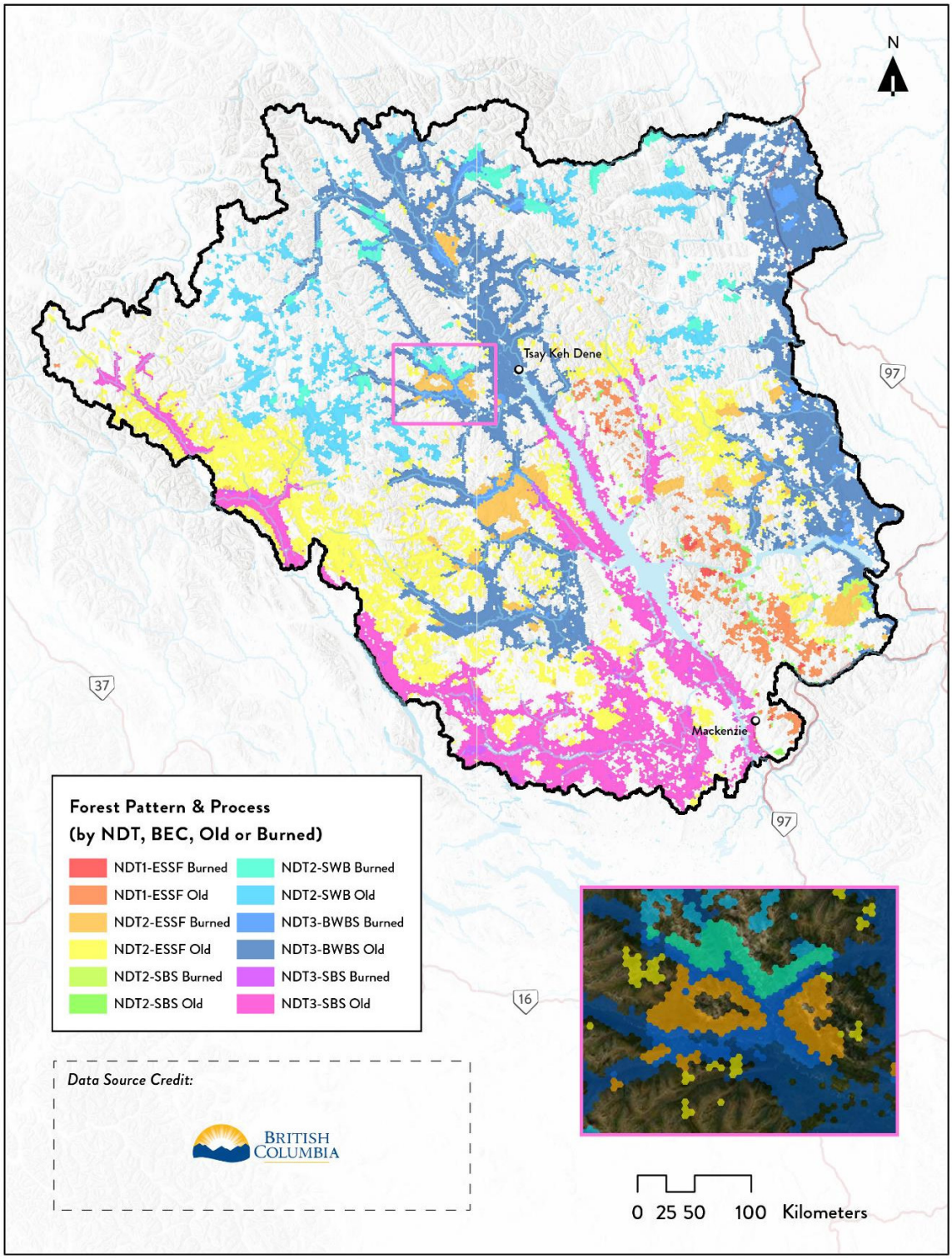

Figure 16. Spatial extent of all the Forest Pattern and Process layers used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

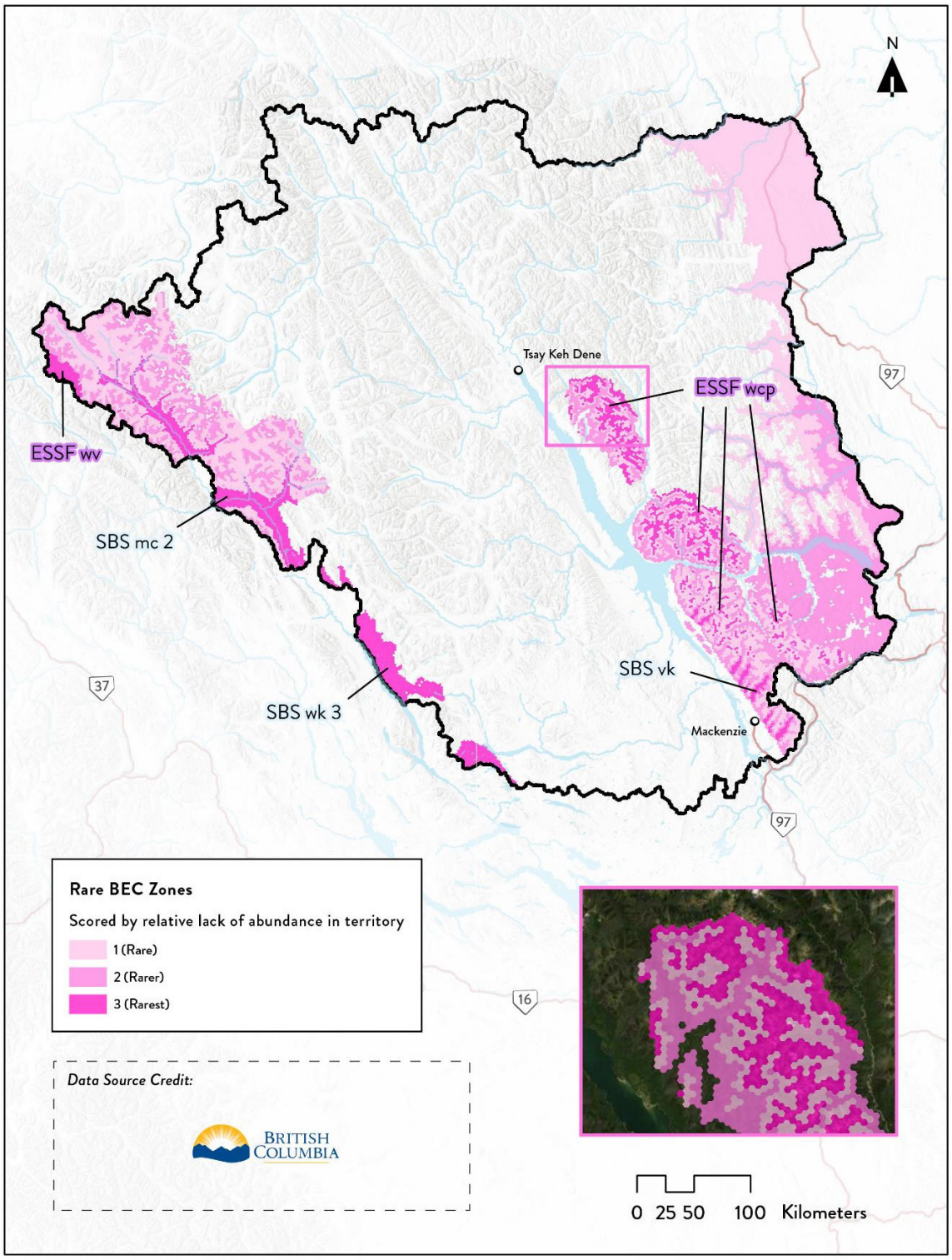

Figure 17. Spatial extent of the Rare BEC Zones layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame. Select level 3 (rarest) subzones/variants are labeled.

5.2.2 Fine-filter Conservation Features

There were eighteen fine-filter conservation features used in this analysis. The extent of each layer is described below, with maps depicting each fine-filter feature included at the end of this group of descriptions. Features developed from Chu Cho Environmental Habitat Suitability Indexes (wolverines, bank swallows, barn swallows, western toads, horned grebes, little brown bats, northern long-eared bats, olive-sided flycatchers, and rusty blackbirds) only have coverage for Tsay Keh Dene Territory and not for the entire study area. Features that included traditional knowledge for SCP analysis have had their TEK data removed from these maps for display purposes out of respect for the sacredness and sensitivity of this knowledge.

5.2.2.1 Wetlands

The wetlands layer makes up 57% of the study area. This feature is spread widely across the Territory with high values found adjacent to large river systems. There is also a noteworthy cluster of large, high value wetlands in the northeastern corner of the study area in the lower elevation Muskwa Plateau along the Alaska Highway (Hwy 97) (Figure 18).

5.2.2.2 Lakes

The lakes layer makes up 21% of the study area. This feature is well dispersed across the Territory, but is denser on the western half and contains more high value large lakes as well. The most noteworthy large lakes are found in the northwest (Kitchener, Tatlatui, and Thutade Lakes) and southwest (Tsayta, Tchentlo and Nation Lakes) (Figure 19).

5.2.2.3 Karst Deposits

The karst deposits layer makes up 27% of the study area. This feature is found in bands across the landscape within the Rocky Mountains, with the highest values and greatest abundance found in the Muskwa Ranges in the east (Figure 20).

5.2.2.4 Grizzly Bear

The grizzly bear layer makes up 29% of the study area. This feature is best represented in the southern half of the Territory in moderate to high elevation areas, with arms of high-value habitat reaching into the northern stretches of the study area along the Finlay and Skeena Rivers (Figure 21).

5.2.2.5 Bull Trout/Fish

The bull trout/fish layer makes up just 3% of the study area. This feature is heavily concentrated in the north-central part of the study area, though there is representation to the west and south along the Omineca River and Clearwater Creek, respectively. As this layer was solely sourced from confidential Fish & Wildlife Compensation Program (FWCP) data and TEK data, no map is provided.

5.2.2.6 Fisher

The fisher layer makes up 38% of the study area. This feature is found in low elevation areas, almost exclusively along river valleys, reaching like tentacles into mountainous areas off of the Rocky Mountain Trench. The one notable exception is the concentration of high-value habitat in the Muskwa Plateau in the northeastern corner of the study area (Figure 22).

5.2.2.7 Caribou

The caribou layers (divided by herd) collectively make up 35% of the study area. This feature is found almost exclusively in moderate and high elevation areas, but with a few river valleys also represented. High-value habitat can be found in much of the study area, with notable gaps in the northeast, northwest, south, and one central location along the Ospika River (Figure 23).

5.2.2.8 Moose

The moose layer makes up 39% of the study area. This feature is found predominantly in low elevation areas along the Rocky Mountain Trench, with notable collections in the eastern and southwestern portions of the study area (Figure 24). Unsurprisingly, this feature overlaps significantly with the wetlands layer.

5.2.2.9 Stone Sheep

The Stone sheep layer makes up 6% of the study area. This feature is found in high elevation areas in the northern half of the study area in the Rocky and Omineca Mountains, with a few exceptions of patches in the southern Muskwa Ranges, northern Misinchinka Ranges, and southern Omineca Mountains (Figure 25).

5.2.2.10 Mountain Goat

The mountain goat layer makes up 10% of the study area. Similar to Stone sheep, this feature is found in the northern half of the study area in the Rocky and Omineca Mountains with a few stretches to the south. The difference, however, is that mountain goats have a greater presence in the west in the mountains on either side of the Skeena River (Figure 26).

5.2.2.11 Wolverine

The wolverine layer makes up 19% of the study area. This feature is predominantly found in moderate elevation areas and is well spread throughout the Territory, likely due to their general preference of conifer forests that occur in many BEC zones (Figure 27).

5.2.2.12 Bank Swallow

The bank swallow layer makes up 6% of the study area. This feature is highly concentrated along the Williston Reservoir and its southwestern valley of the Rocky Mountain Trench, with offshoots along the many rivers that feed the reservoir (Figure 28). This is likely due to their nesting requirements along riverbanks (specifically cutbanks) as their name suggests.

5.2.2.13 Barn Swallow

The barn swallow layer makes up 8% of the study area. Similar to the bank swallow, this feature is highly concentrated along the Williston Reservoir and its valleys. However, the barn swallow is also found at moderate elevations throughout the Territory, with a unique high-value clustering along Thutade Lake (Figure 29).

5.2.2.14 Western Toad

The western toad layer makes up 12% of the study area. This feature is fairly well spread across the Territory, namely at low and moderate elevations with a few pockets of higher quality habitat (Figure 30). Many of the locations are along lakes and wetlands as western toads require shallow, warm water for breeding.

5.2.2.15 Horned Grebe

The horned grebe layer makes up 10% of the study area. This feature is clustered around the Williston Reservoir and the rivers that feed it, with the highest habitat values found in low elevation valleys along the southwestern shore of the reservoir (Figure 31).

5.2.2.16 Little Brown Myotis

The little brown myotis bat layer makes up 25% of the study area. This feature is widespread throughout the Territory, save for high elevation areas. The greatest preponderance of high habitat values are found in the Muskwa Ranges, overlapping with the karst deposits that represent cave habitat (Figure 32).

5.2.2.17 Northern Myotis

The northern myotis bat layer makes up 11% of the study area. This feature is less widespread than the little brown myotis and is found predominantly in river valleys. Clusters of high-value habitat are found along the shores of the Williston Reservoir and the Ospika River, among others (Figure 33).

5.2.2.18 Olive-Sided Flycatcher

The olive-sided flycatcher layer makes up 9% of the study area. This feature has partial coverage across the Territory, namely at low and moderate elevations along the Mesilinka River, Finlay River, and the southwestern shores of the Williston Reservoir (Figure 34).

5.2.2.19 Rusty Blackbird

The rusty blackbird layer makes up 13% of the study area. This feature has moderate coverage across the Territory along riparian corridors and low elevation forests. Similar to

the olive-sided flycatcher and horned grebe, its high-value habitat groupings are found in the low elevation wetlands just southwest of the reservoir (Figure 35).

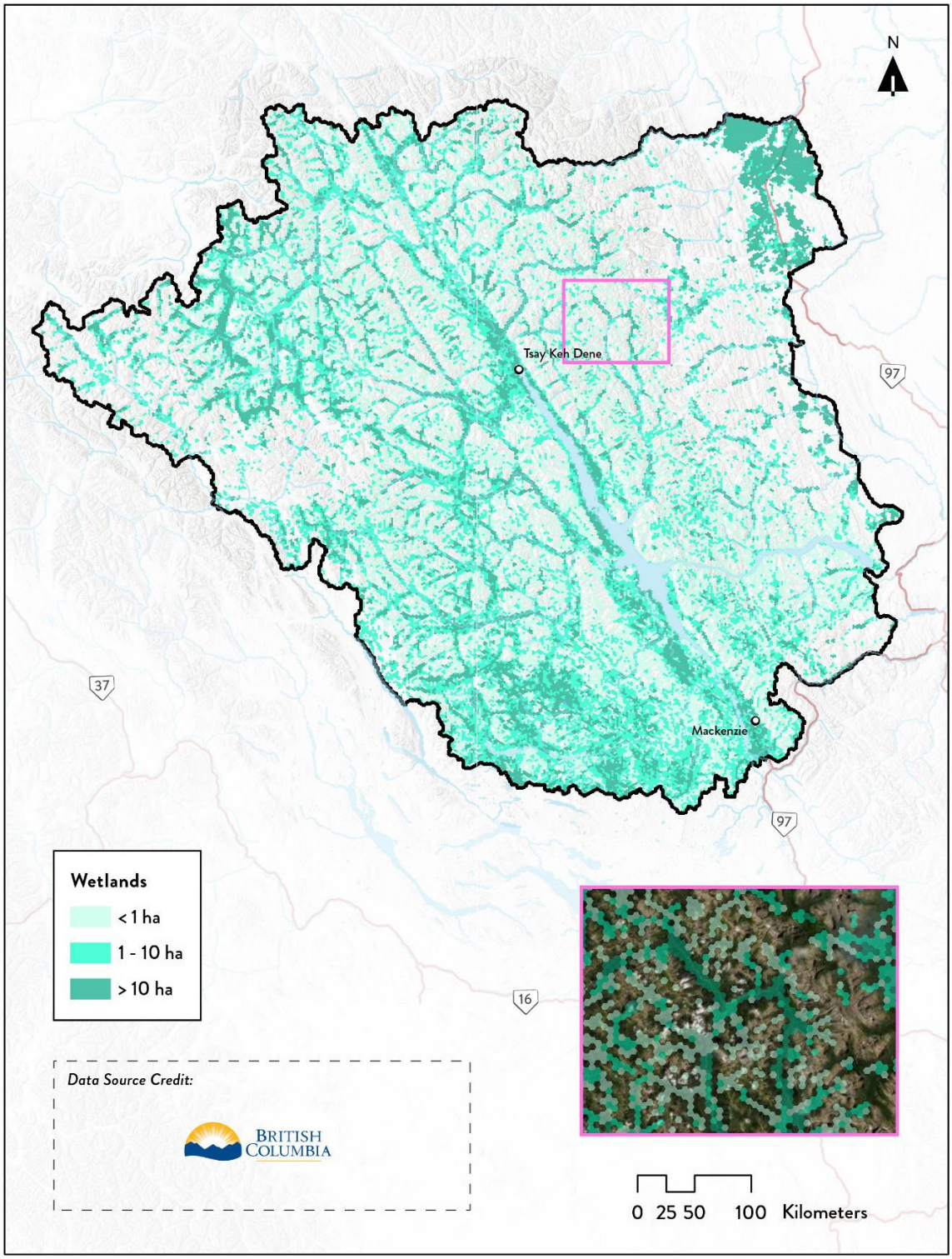

Figure 18. Spatial extent of the Wetlands layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

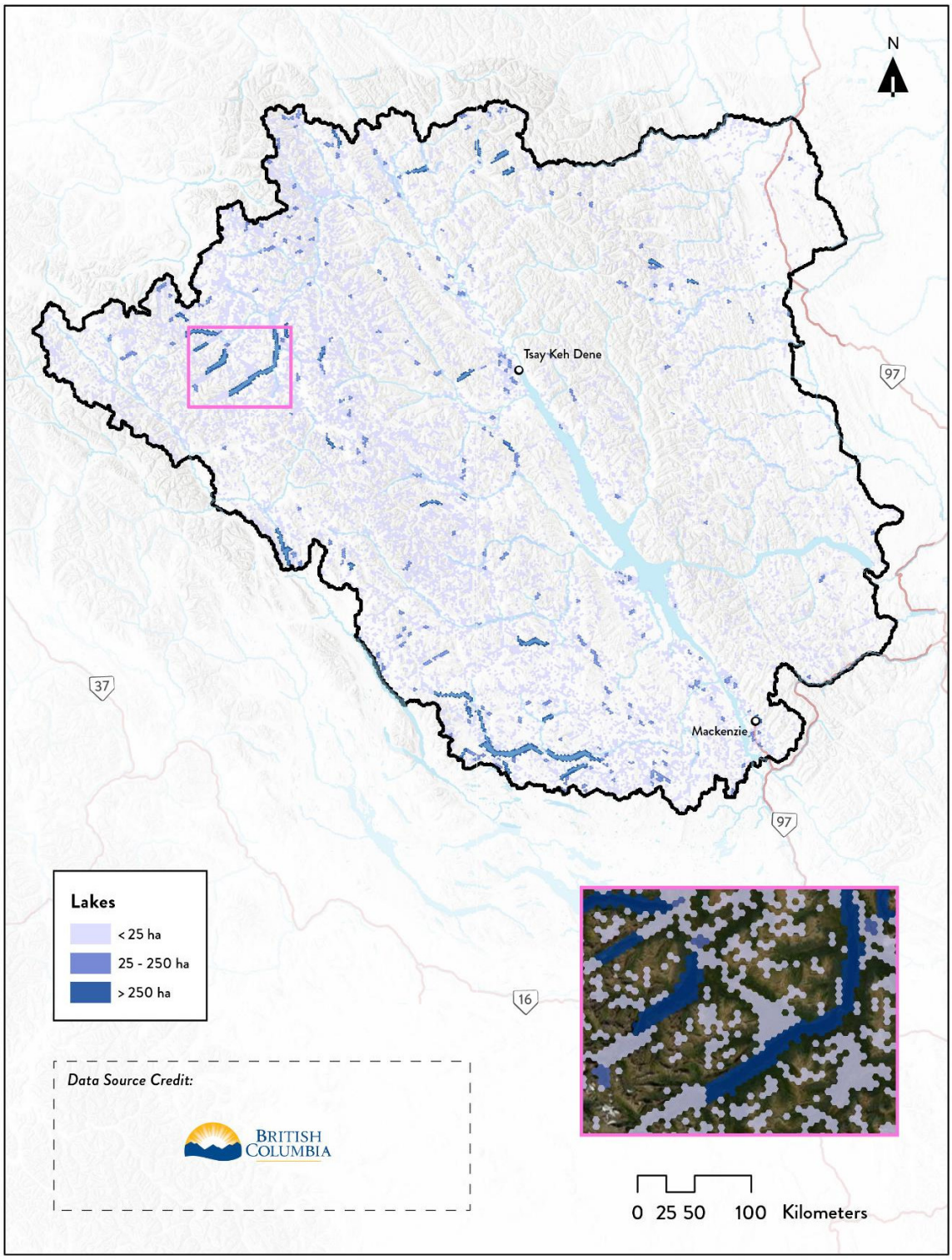

Figure 19. Spatial extent of the Lakes layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

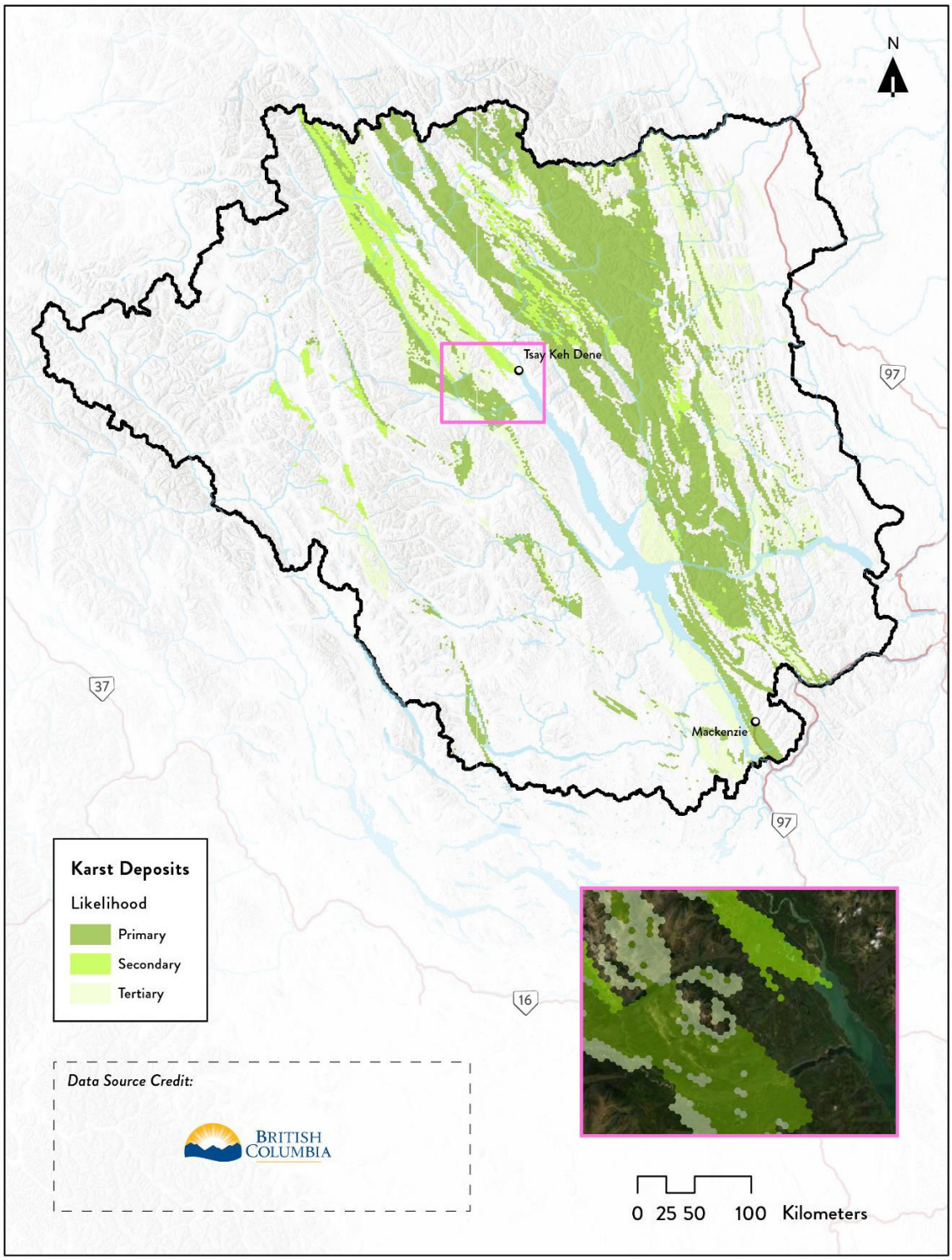

Figure 20. Spatial extent of the Karst Deposits layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

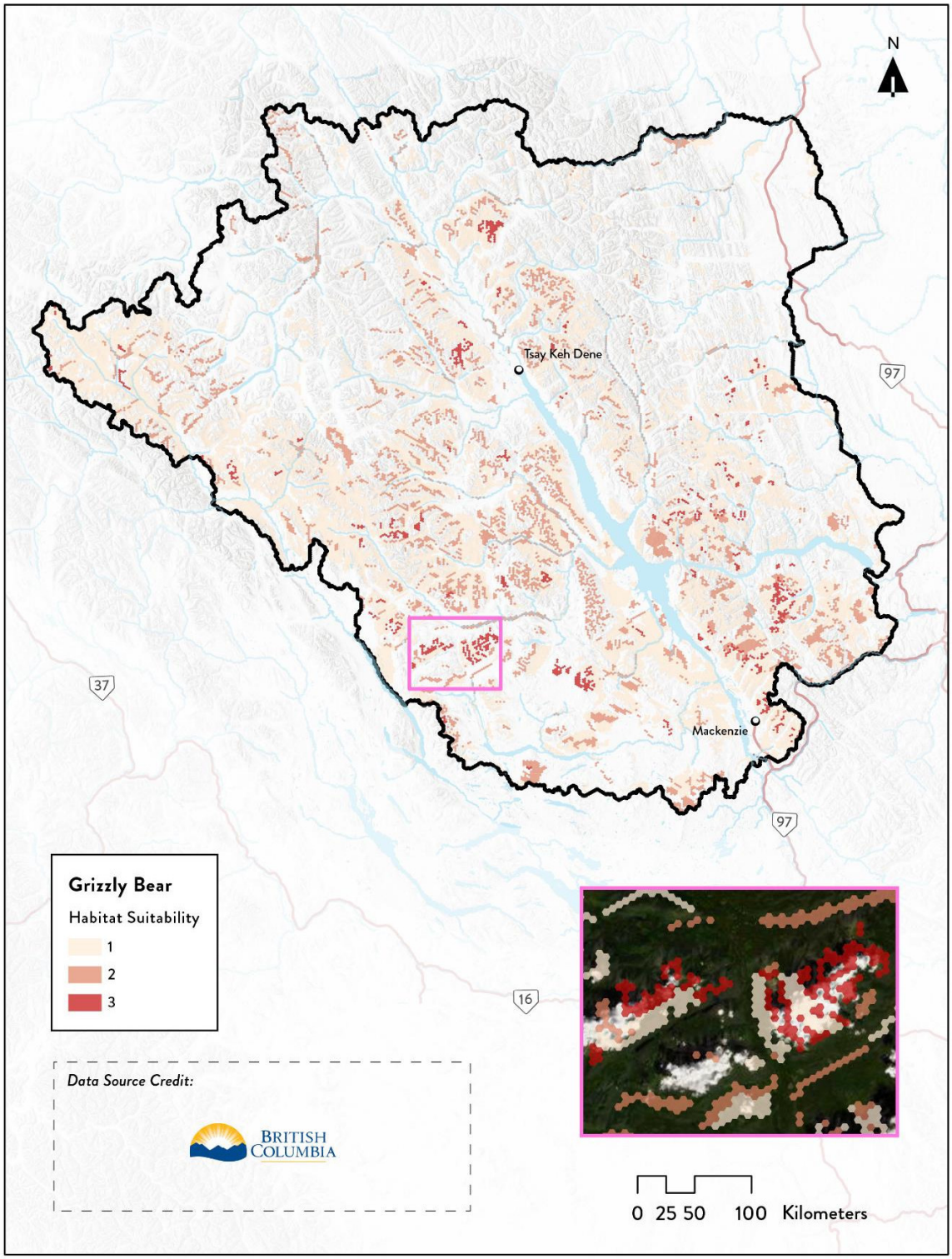

Figure 21. Spatial extent of the Grizzly Bear layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

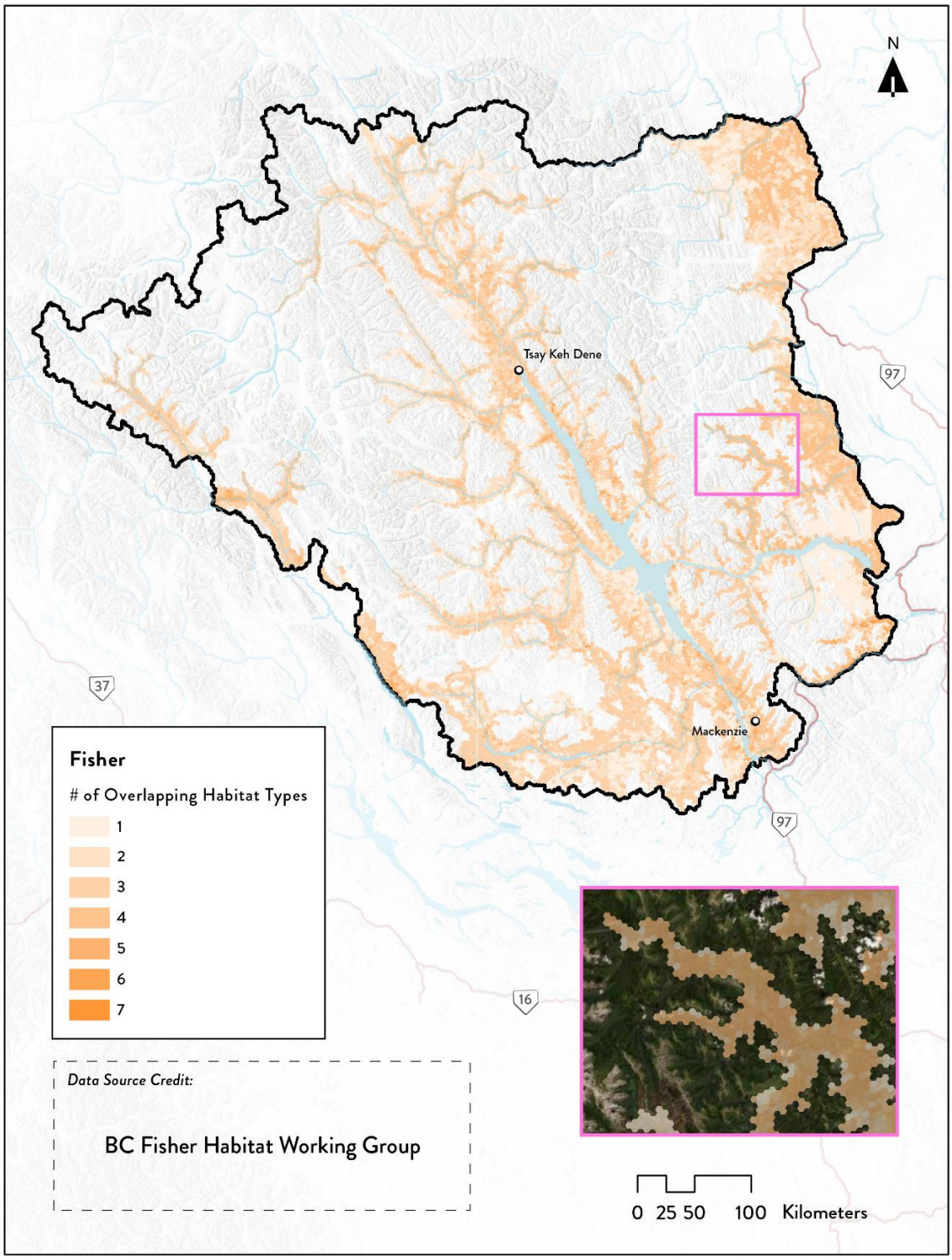

Figure 22. Spatial extent of the Fisher layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

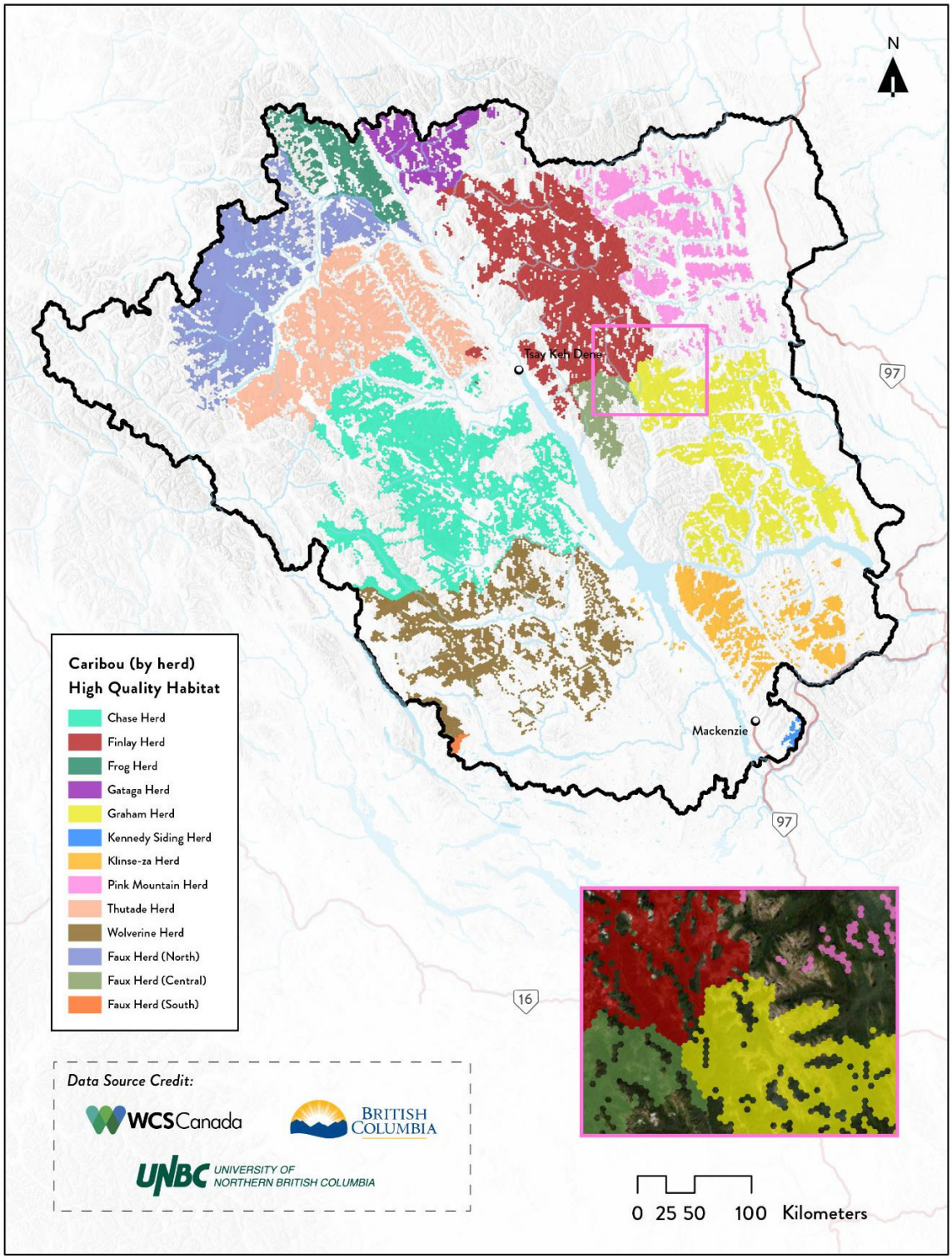

Figure 23. Spatial extent of the Caribou layers used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame. 'Faux' herds are areas where high-quality caribou habitat is found but no existing herd boundaries overlap.

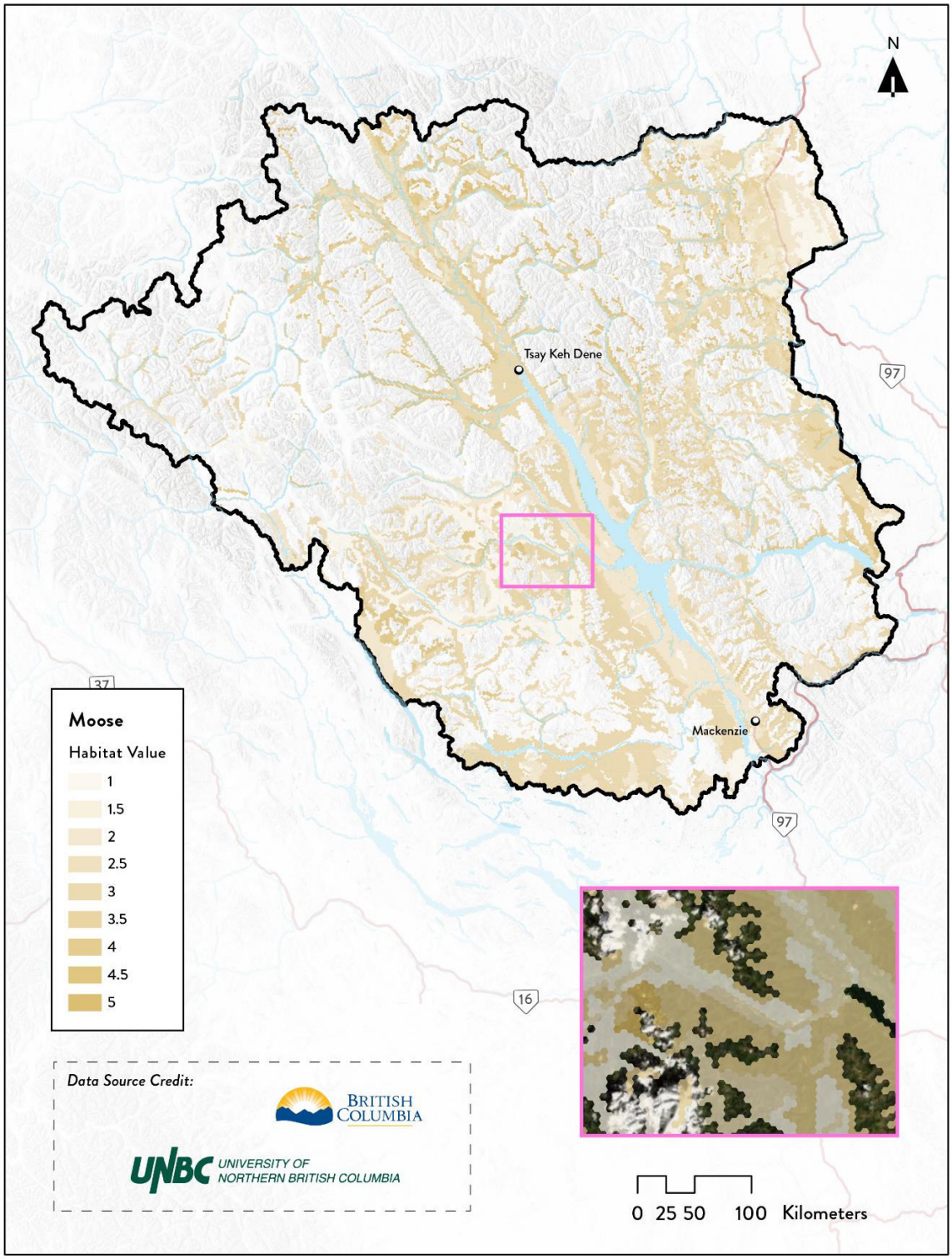

Figure 24. Spatial extent of the Moose layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

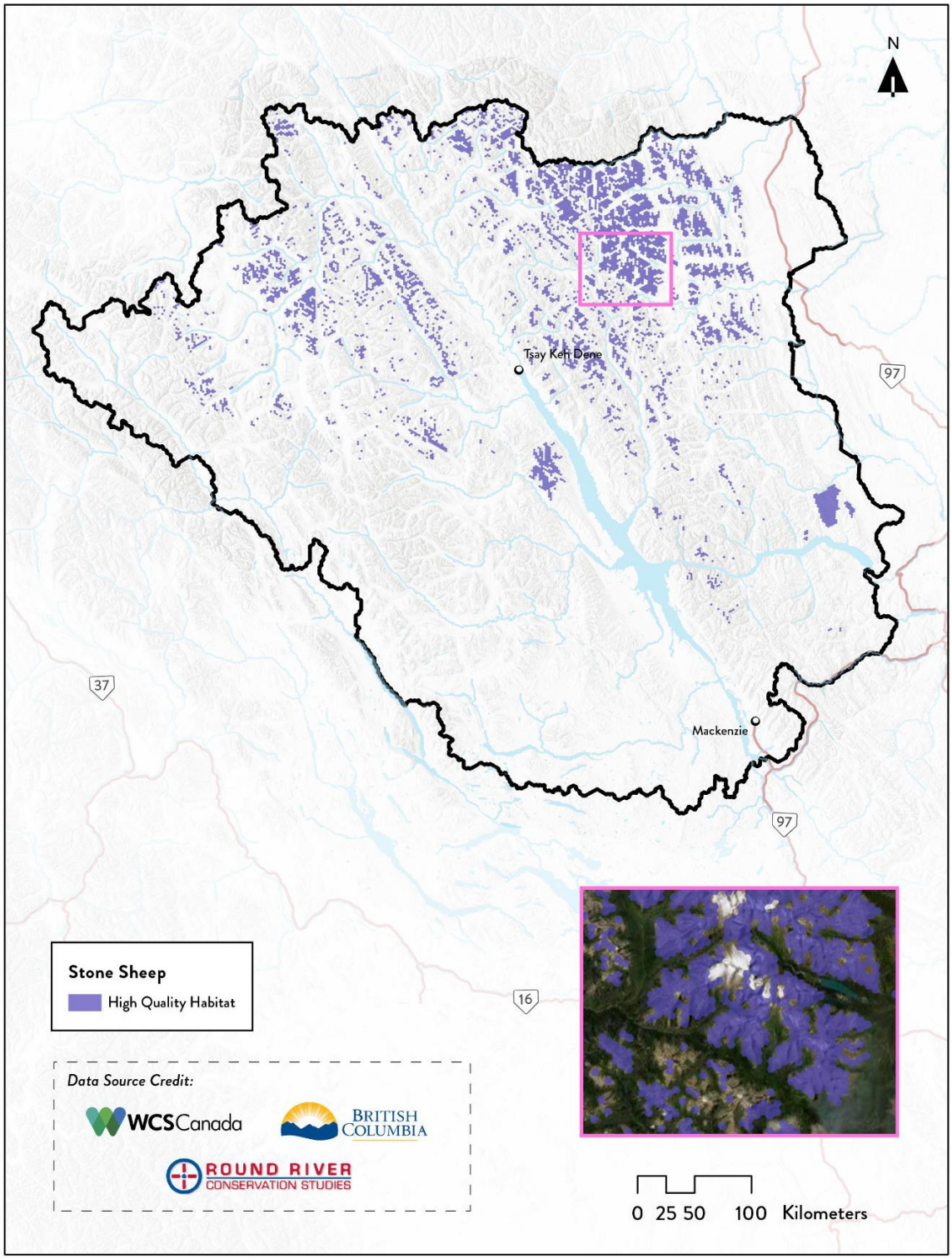

Figure 25. Spatial extent of the Stone Sheep layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

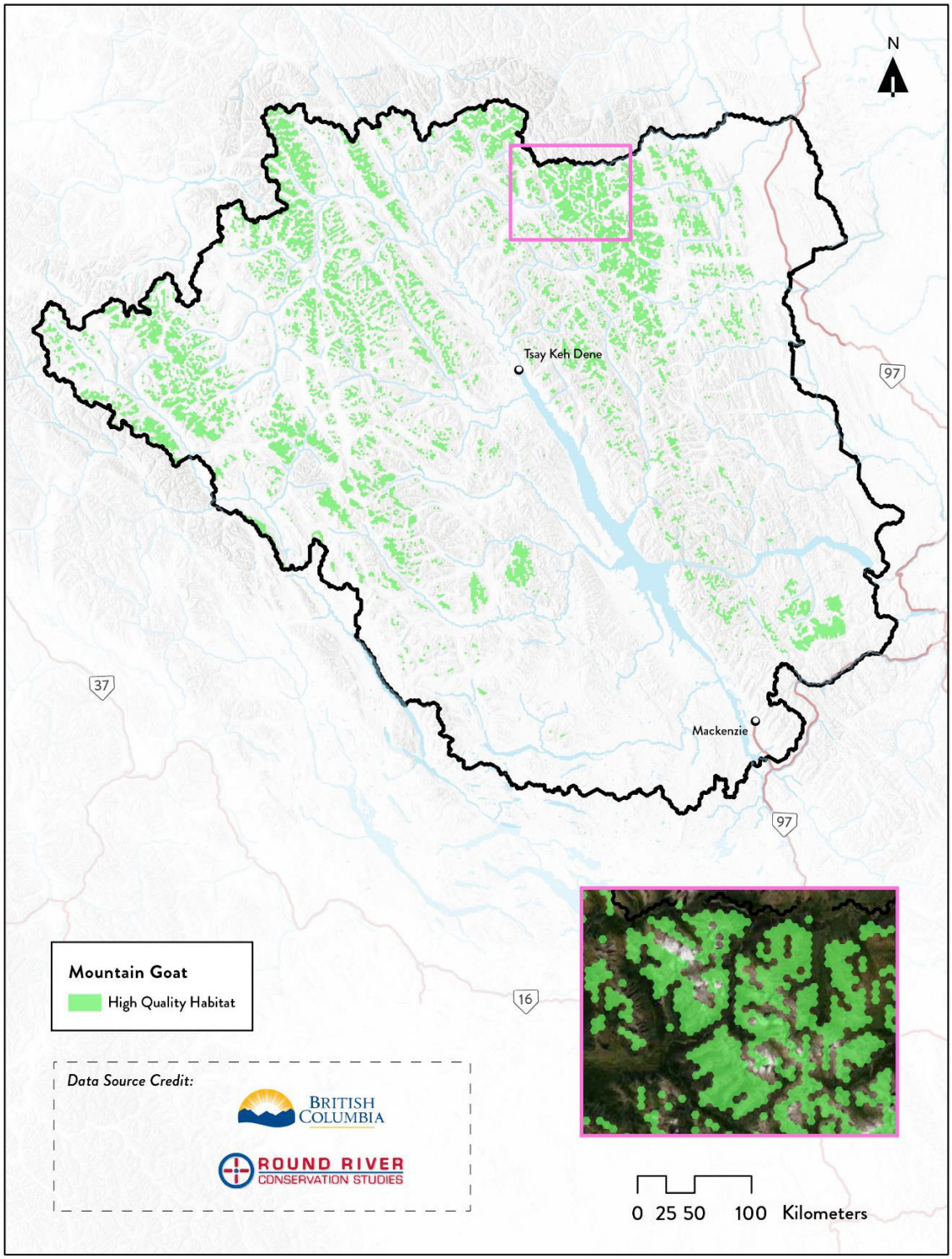

Figure 26. Spatial extent of the Mountain Goat layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

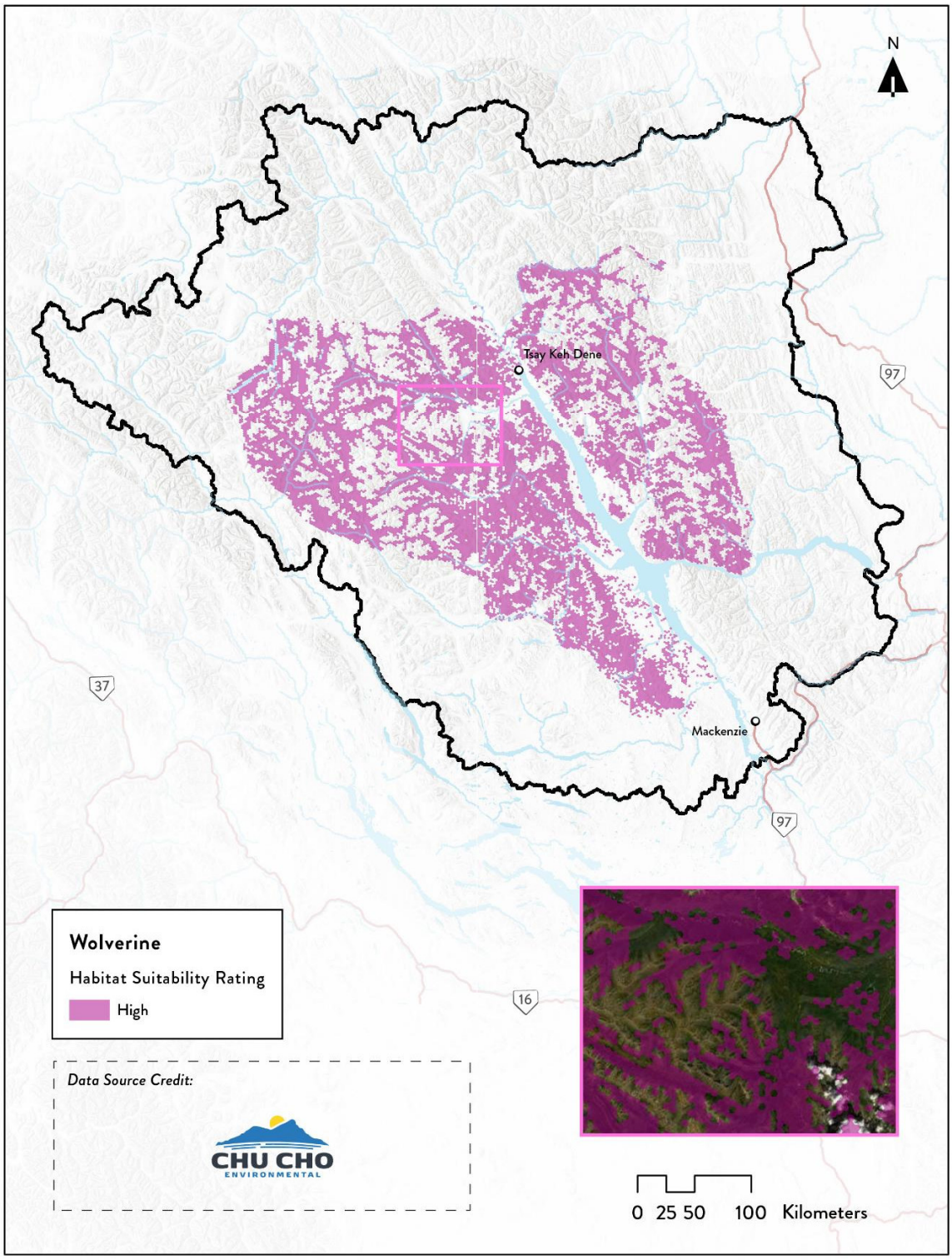

Figure 27. Spatial extent of the Wolverine layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

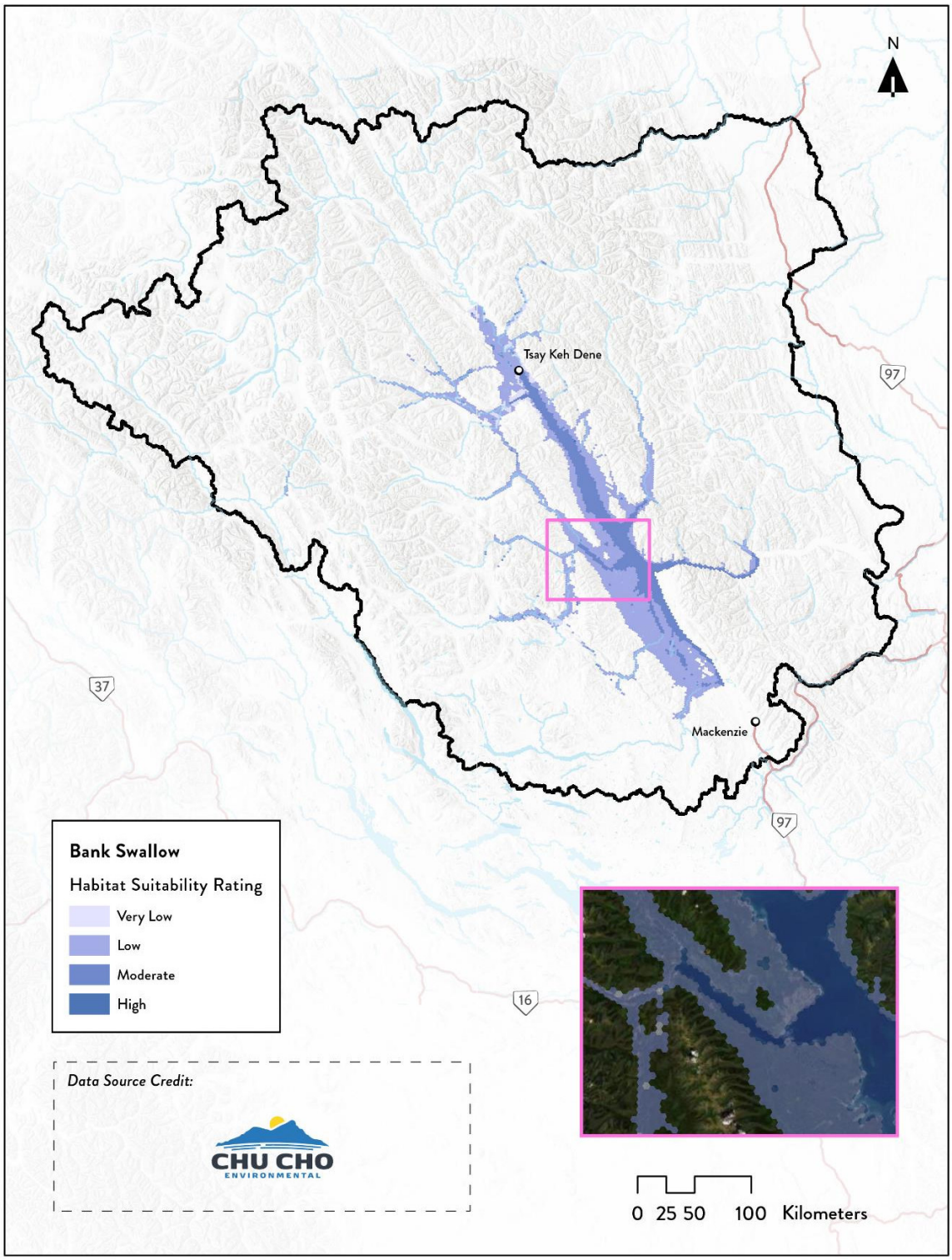

Figure 28. Spatial extent of the Bank Swallow layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

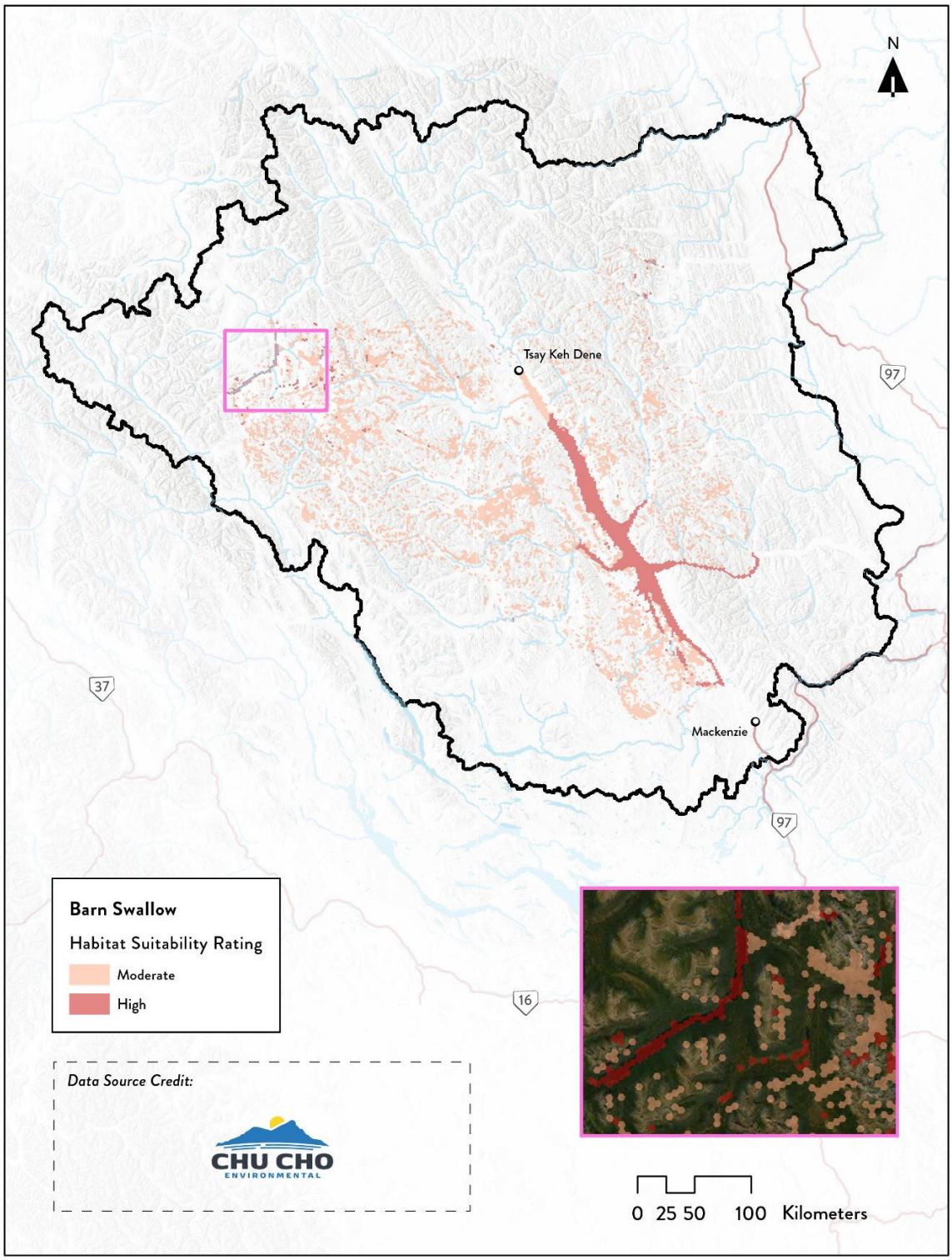

Figure 29. Spatial extent of the Barn Swallow layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

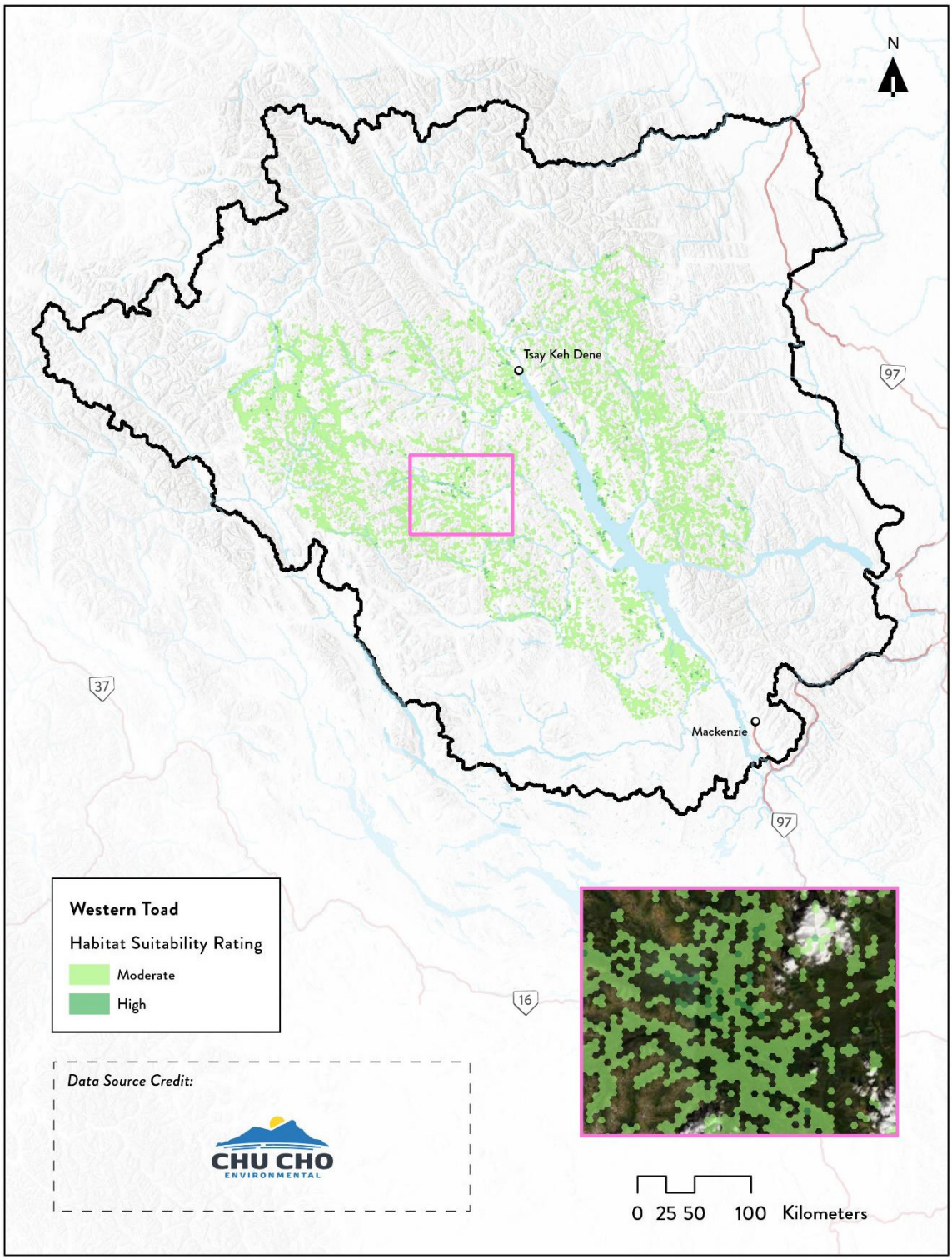

Figure 30. Spatial extent of the Western Toad layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

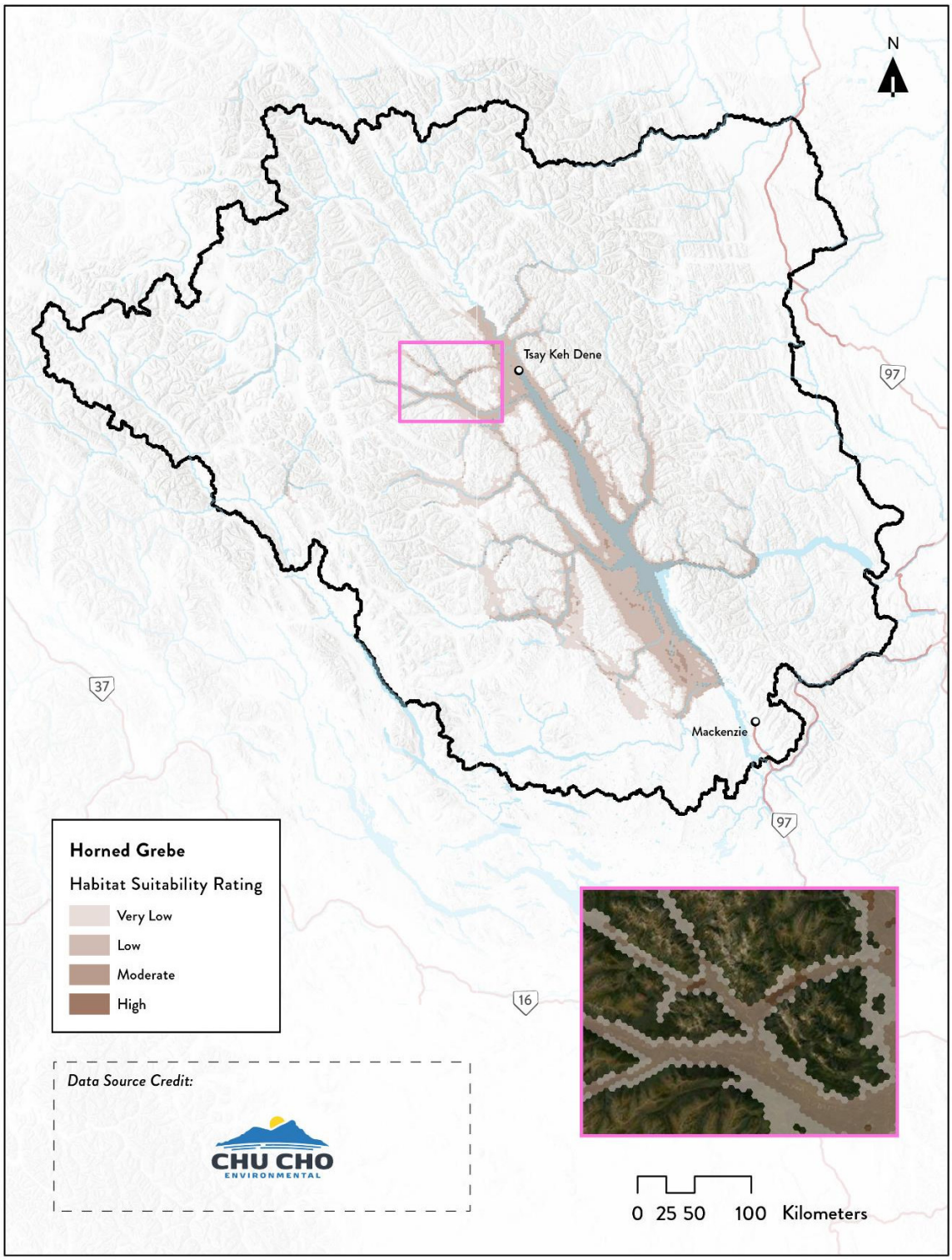

Figure 31. Spatial extent of the Horned Grebe layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

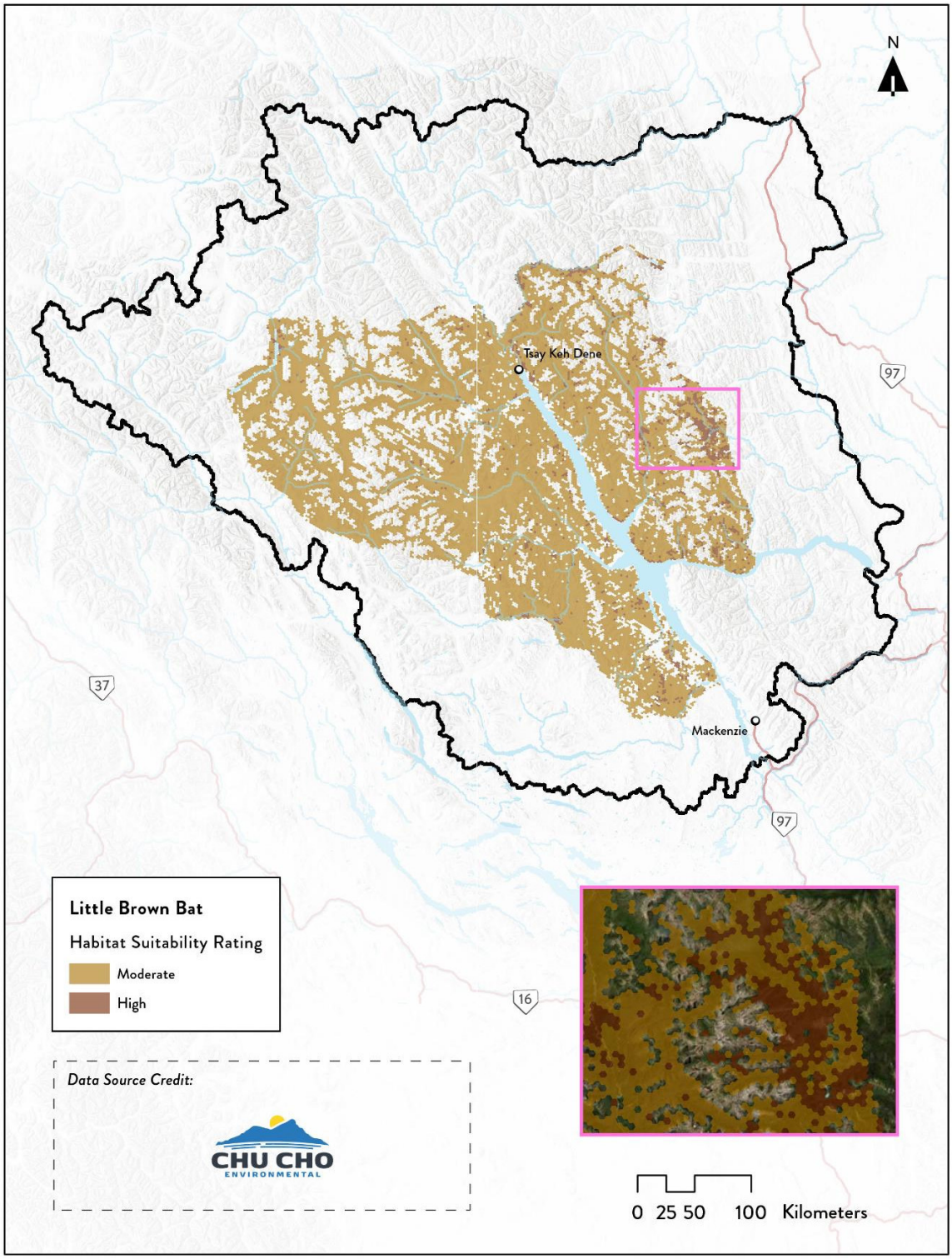

Figure 32. Spatial extent of the Little Brown Myotis (Bat) layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

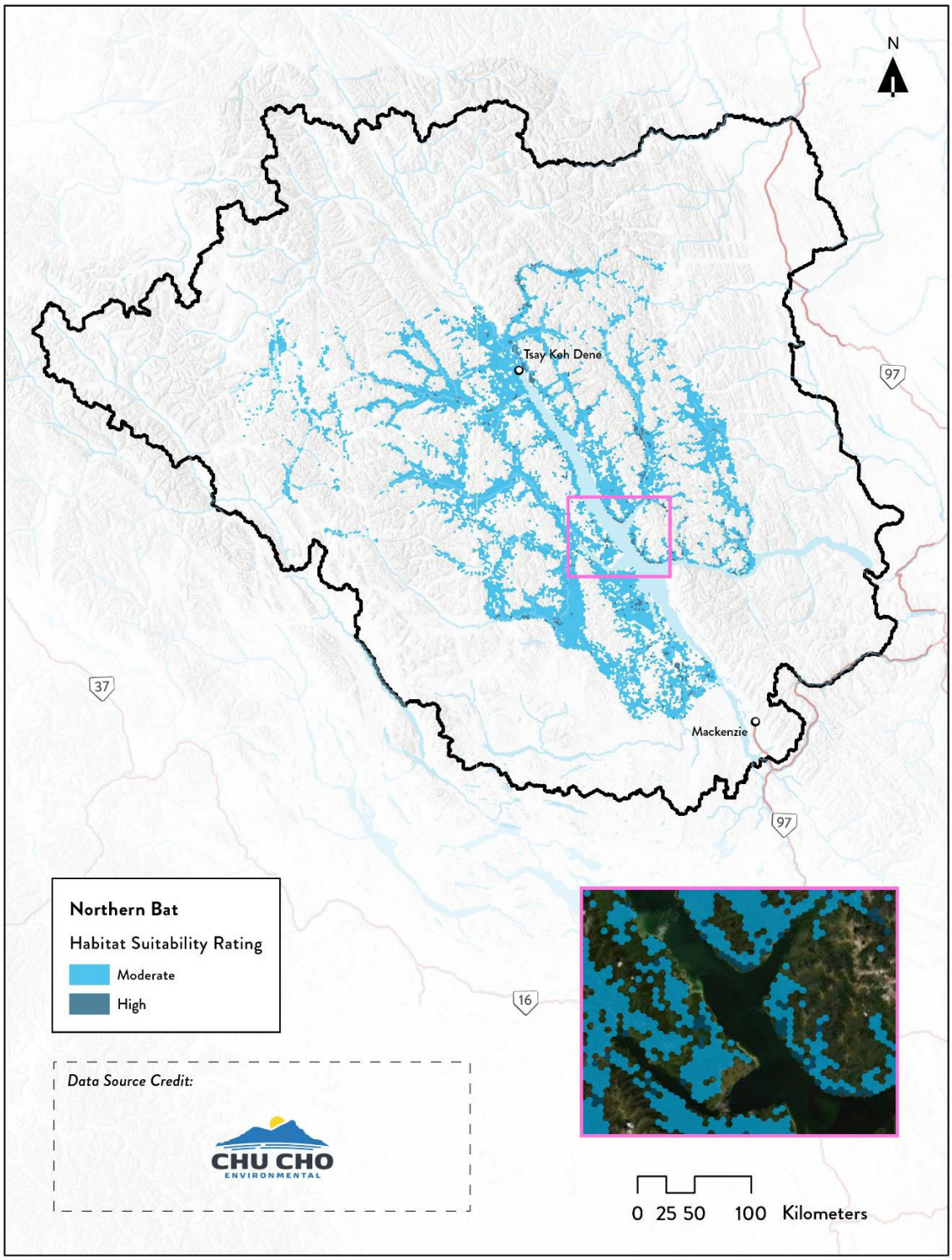

Figure 33. Spatial extent of the Northern Myotis (Long-eared Bat) layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

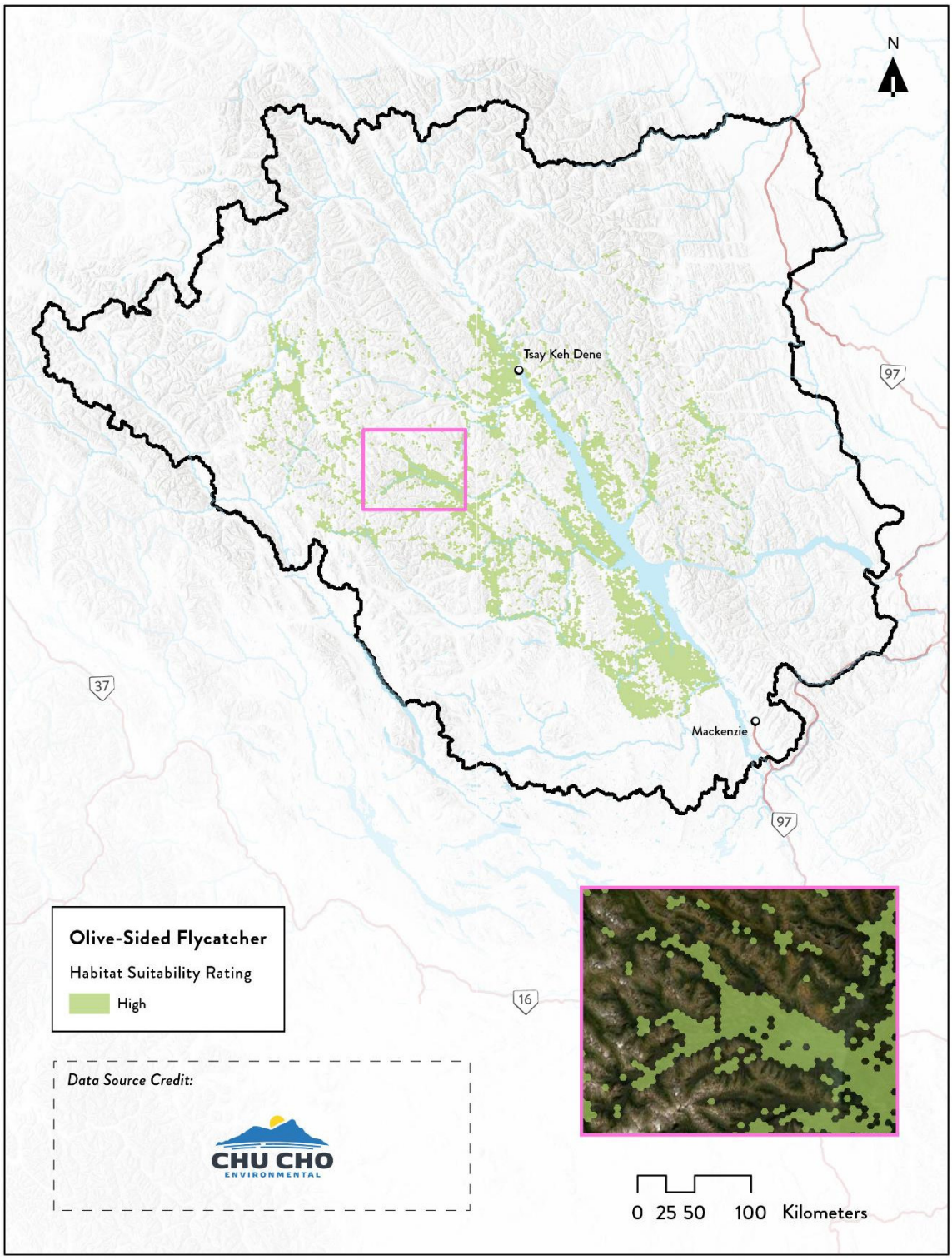

Figure 34. Spatial extent of the Olive-sided Flycatcher layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

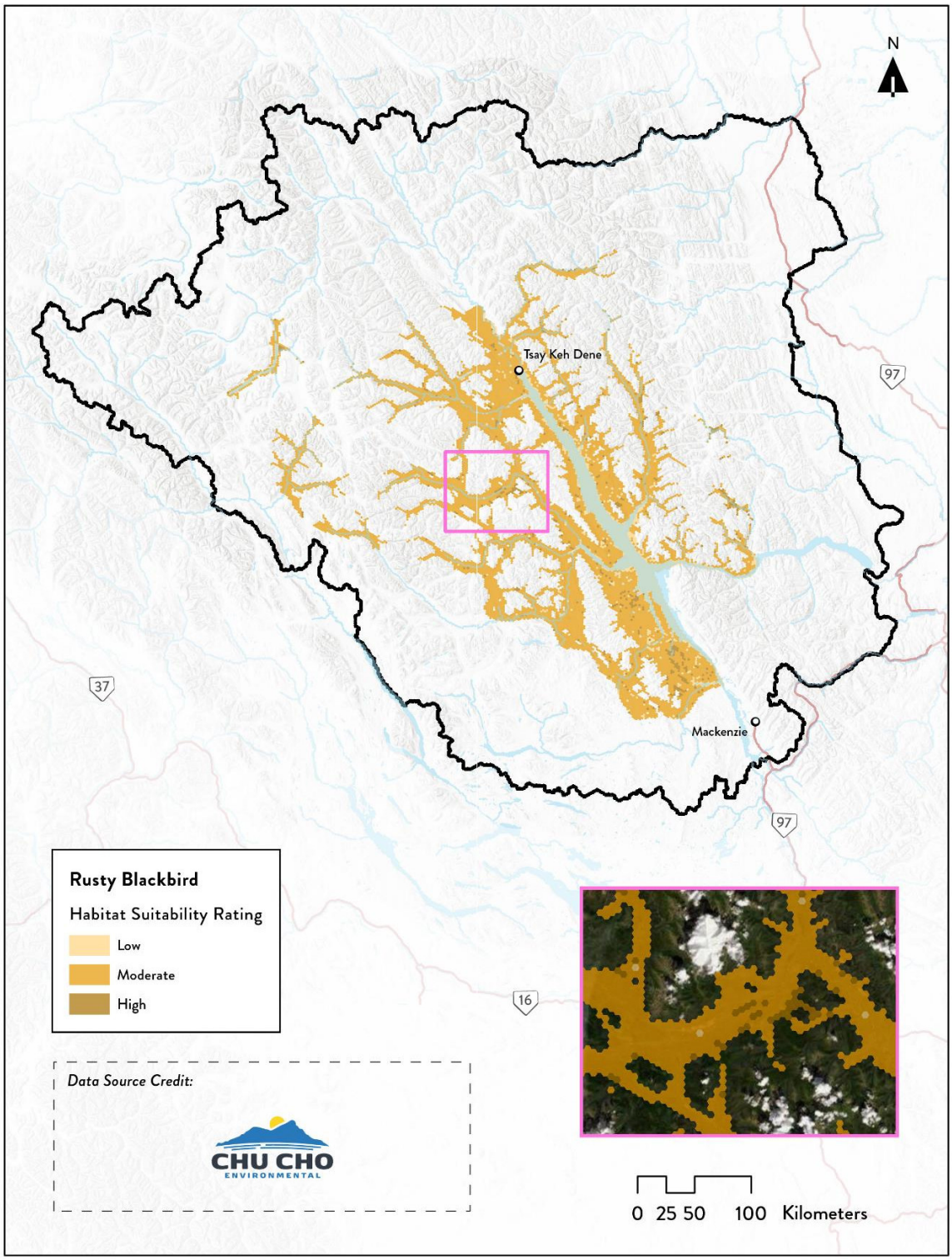

Figure 35. Spatial extent of the Rusty Blackbird layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.2.3 Climate Change Conservation Features

There were ten climate change conservation features used in this analysis. The extent of each layer is described below, with maps depicting each climate change feature included at the end of this group of descriptions.

5.2.3.1 Climate Corridors

The climate corridors layer makes up 54% of the study area. This feature occurs in mountainous portions in both the eastern and western portions of the study area. The greatest concentration of high values is found in the east like a spine through the Rocky Mountains (Figure 36).

5.2.3.2 Backward Velocity 2055

The backward velocity 2055 layer makes up 50% of the study area. This feature occurs as a band across the middle of the study area from east to west, straddling the Williston Reservoir. The most desirable areas are found at moderate to high elevations in the southern Muskwa Ranges (Figure 37).

5.2.3.3 Backward Velocity 2085

The backward velocity 2085 layer makes up 50% of the study area. This features occurs almost entirely in the western half of the study area, save for some high elevation occurrences in the east. The greatest concentration of desirable values is found in the northwest corner of the study area in the Omineca Mountains surrounding the Skeena River (Figure 38).

5.2.3.4 Forward Velocity 2055

The forward velocity 2055 layer makes up 50% of the study area. This feature is clustered in the southern third of the study area with an arm up the Rocky Mountain Trench connecting to lower value areas along the northern edge of the study area. The most desirable areas are clustered in the Misinchinka Ranges and the Wolverine Range to the west of Parsnip Arm (Figure 39).

5.2.3.5 Forward Velocity 2085

The forward velocity 2085 layer makes up 50% of the study area. This feature is quite similar to its 2055 counterpart in both extent and location of desirable values; however, in this instance, the most desirable values are even more concentrated in the Misinchinka Ranges of the Rocky Mountains (Figure 40).

5.2.3.6 Cool Headwater Refugia

The cool headwater refugia layer makes up 6% of the study area. This feature is found predominantly at high elevation in the northeastern portion of the study area in the Muskwa Ranges. There is also a smattering of values to the west at high elevation in the Omineca Mountains (Figure 41).

5.2.3.7 Climatic Refugia

The climatic refugia layer makes up 57% of the study area. This feature is spread across the northern half of the study area in the Omineca Mountains and the Muskwa Ranges. The greatest concentration of high values are in the Ominecas northeast of Thutade Lake and in the eastern Muskwa Ranges near the Rocky Mountain Foothills (Figure 42).

5.2.3.8 Biotic Refugia

The biotic refugia layer makes up 16% of the study area. This feature is similar in extent to the cool headwater refugia layer, but somewhat more widespread. Small pockets of high values can be found at high elevations in the Muskwa Ranges, Misinchinka Ranges, and Omineca Mountains (Figure 43).

5.2.3.9 Bird Richness

The bird richness layer makes up 52% of the study area. This feature is fairly evenly spread across the Territory save for gaps in the Misinchinka Ranges and the Rocky Mountain Foothills. High value locations are exclusively along riparian corridors, specifically the Nation, Omineca, Osilinka, and Mesilinka Rivers (Figure 44).

5.2.3.10 Carbon Storage (above and below ground)

The carbon storage layer makes up 49% of the study area. This feature is well spread out across the Territory save for a gap in the Rocky Mountain Foothills. There is a concentration of high values in the Muskwa Ranges between the Ospika and Peace Arms of the Williston Reservoir. The greatest concentration, however, is found along the western edge of the study area in the valleys of the Skeena, Bear, and Sustut Rivers (Figure 45).

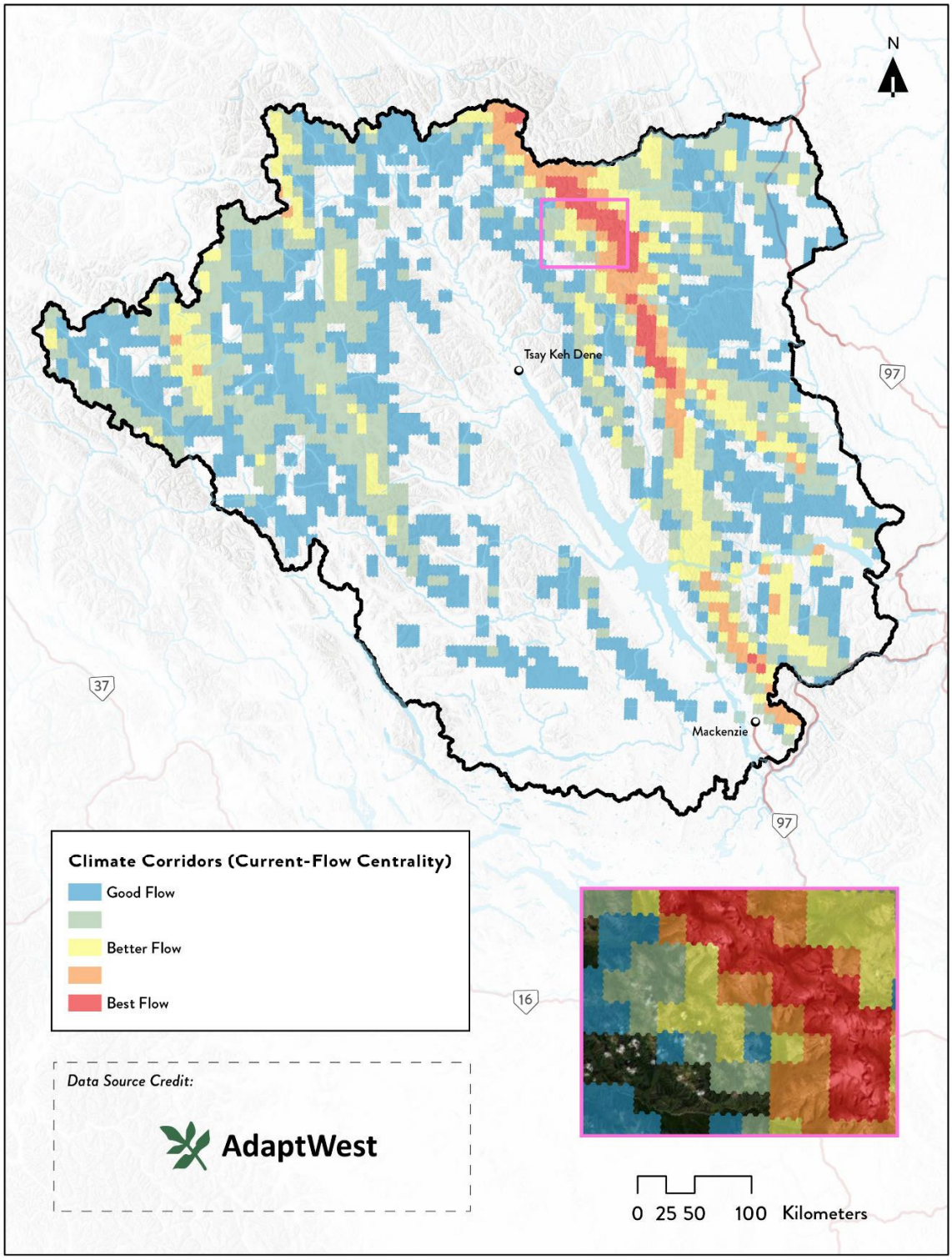

Figure 36. Spatial extent of the Climate Corridors layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

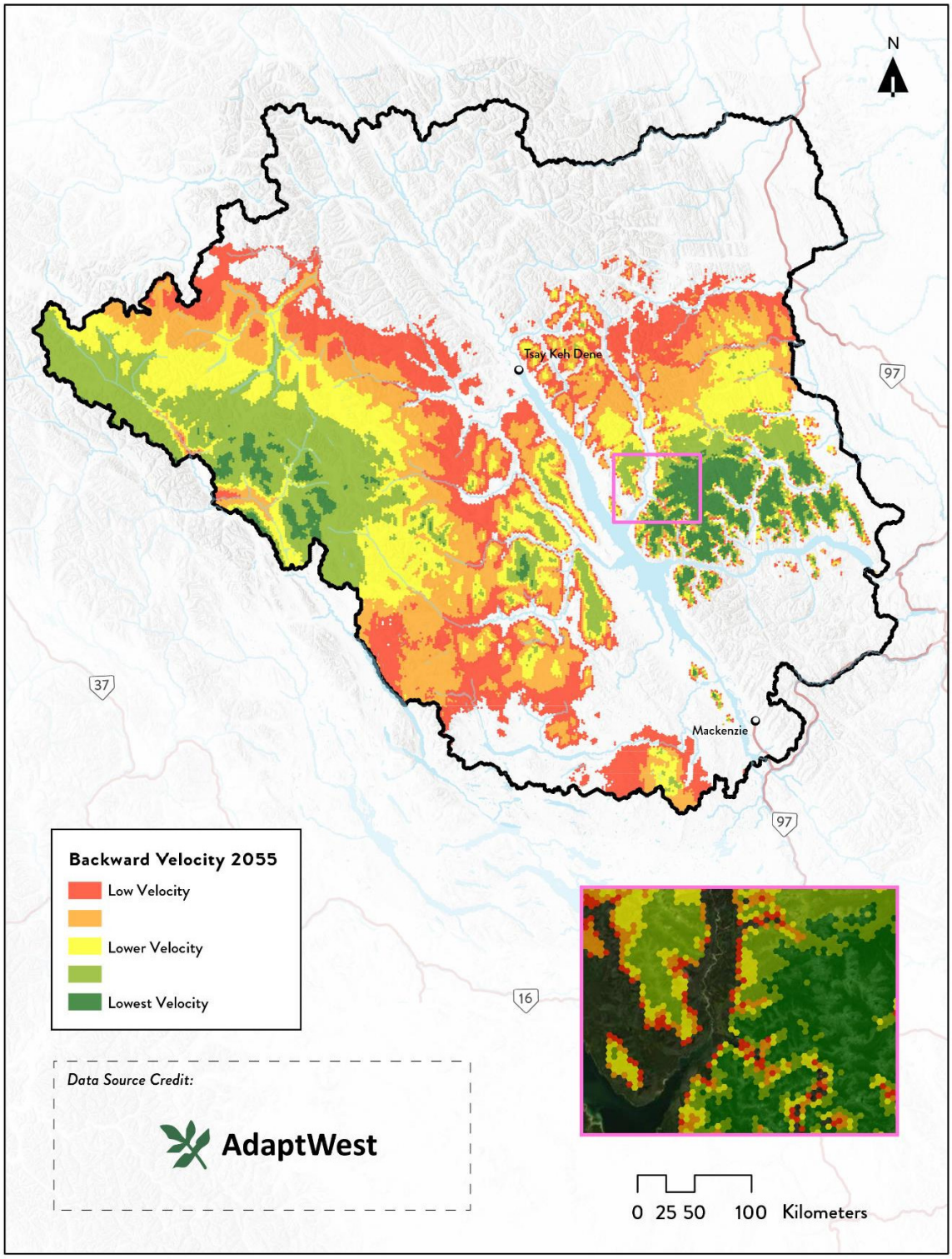

Figure 37. Spatial extent of the Backward Velocity (2055) layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

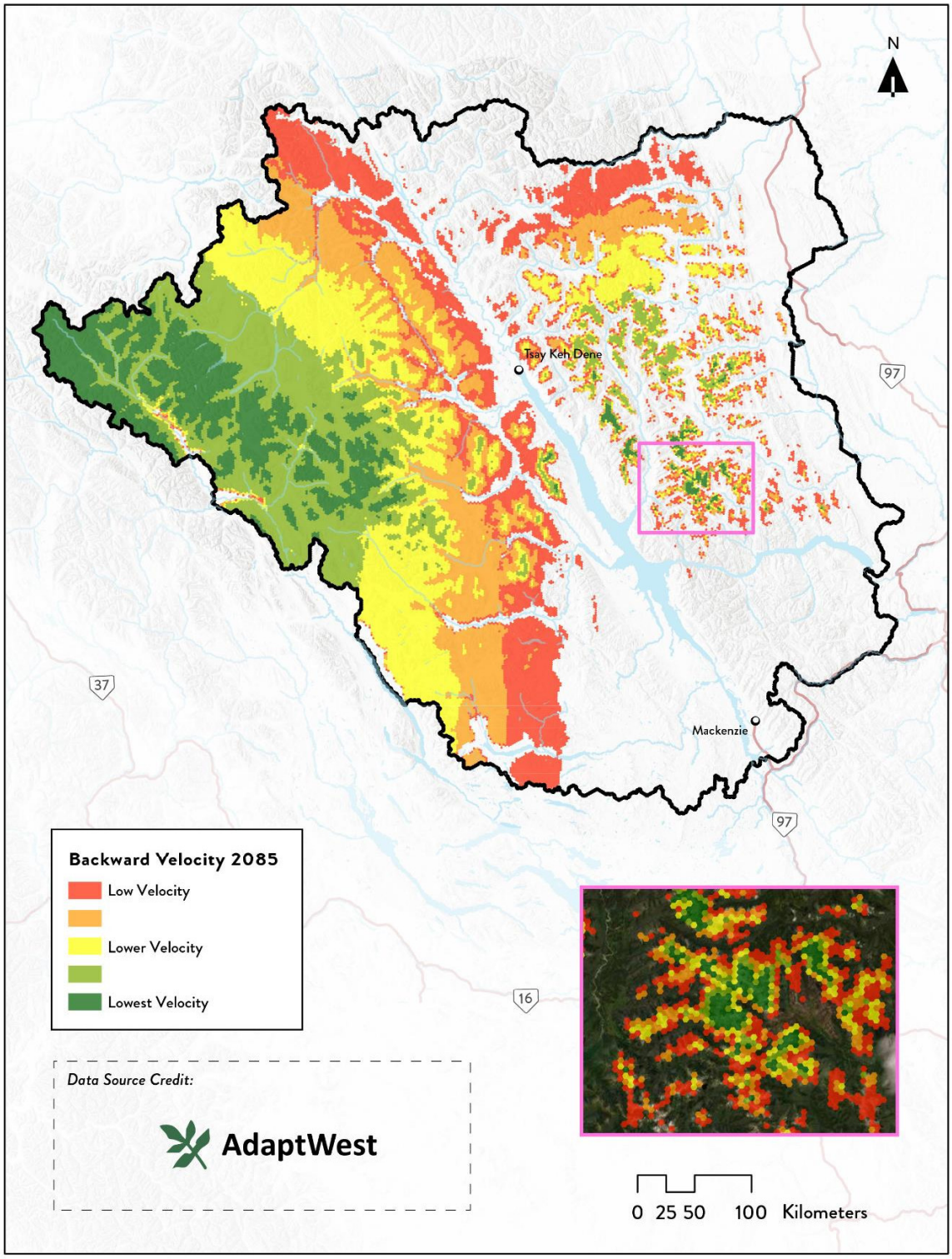

Figure 38. Spatial extent of the Backward Velocity (2085) layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

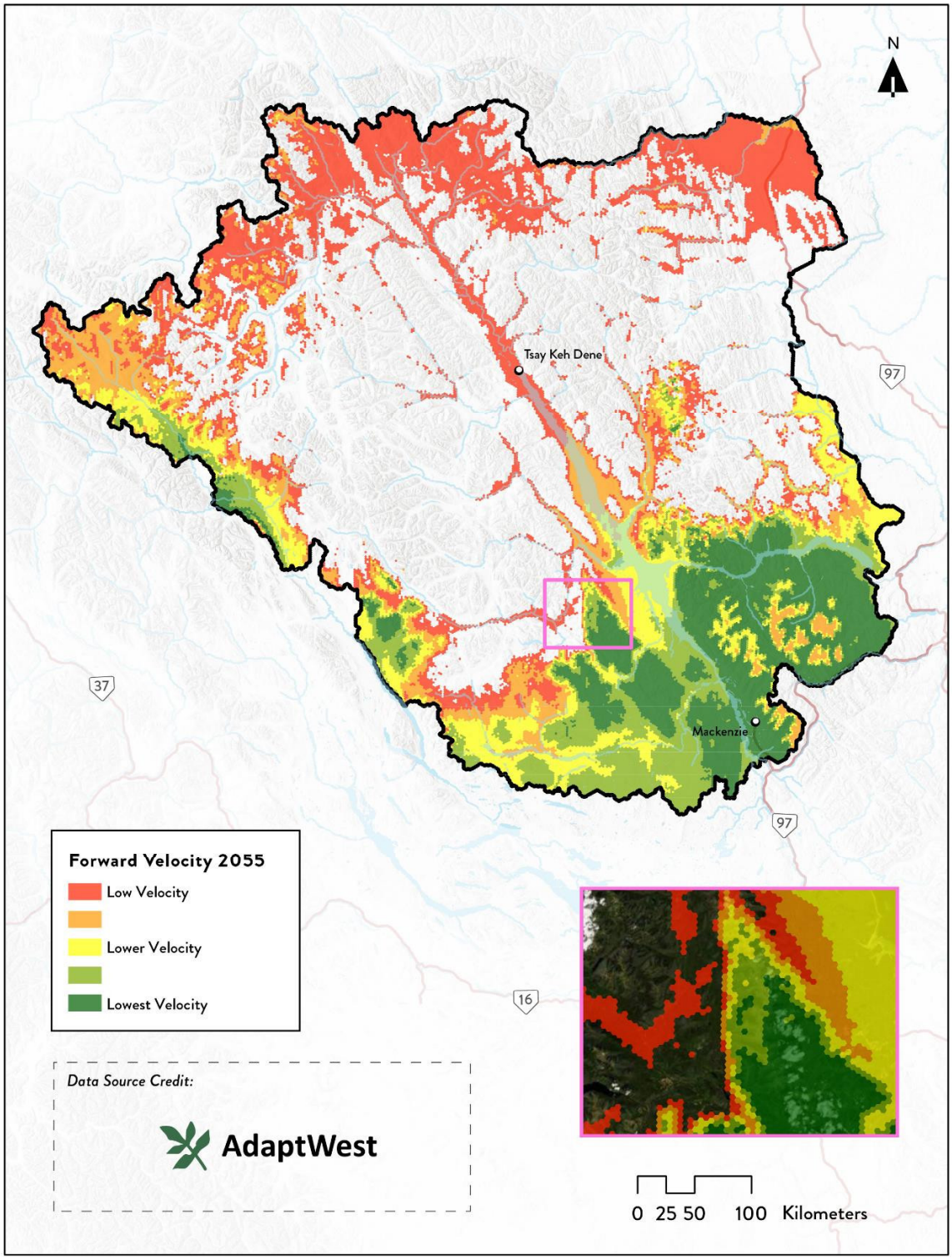

Figure 39. Spatial extent of the Forward Velocity (2055) layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

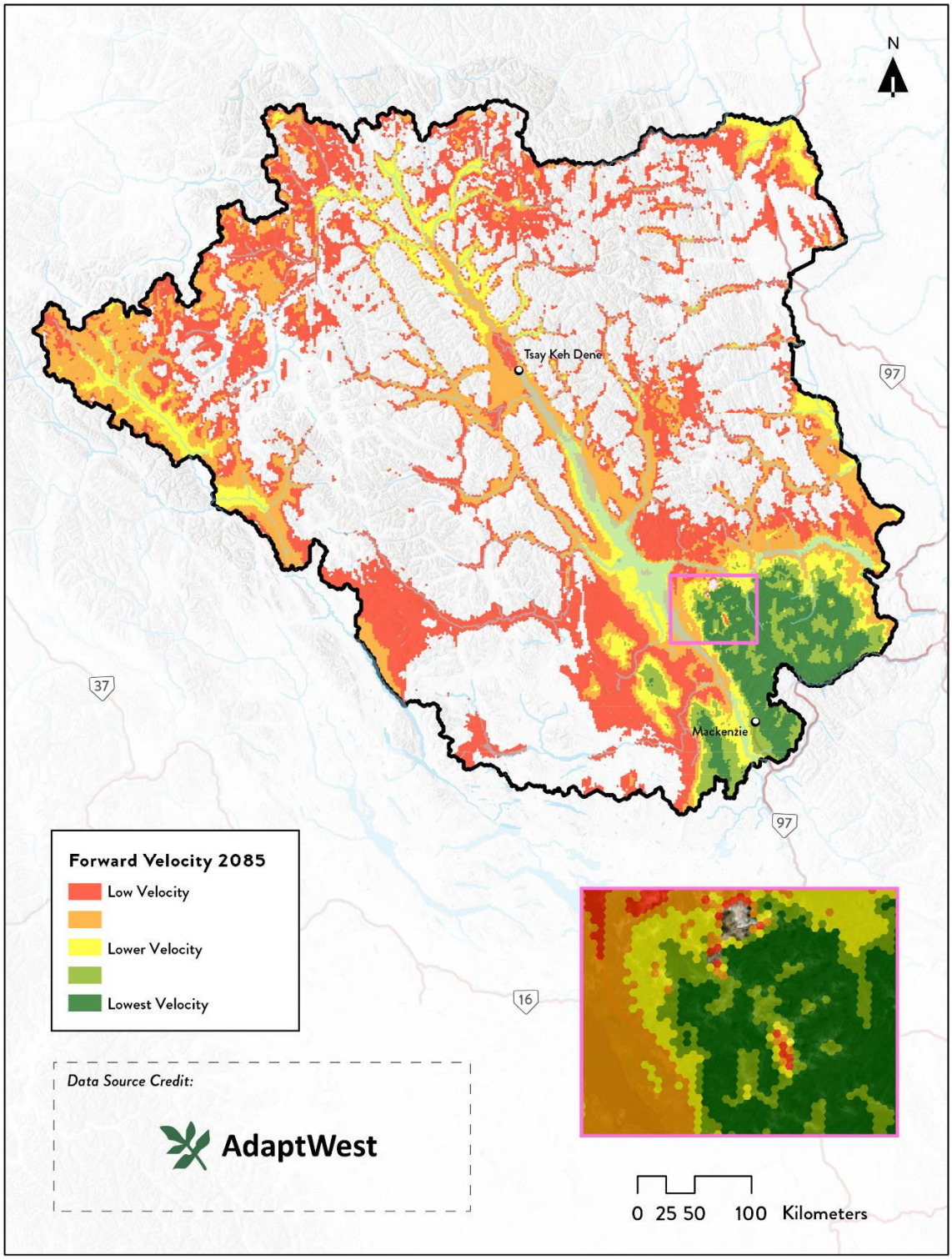

Figure 40. Spatial extent of the Forward Velocity (2085) layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

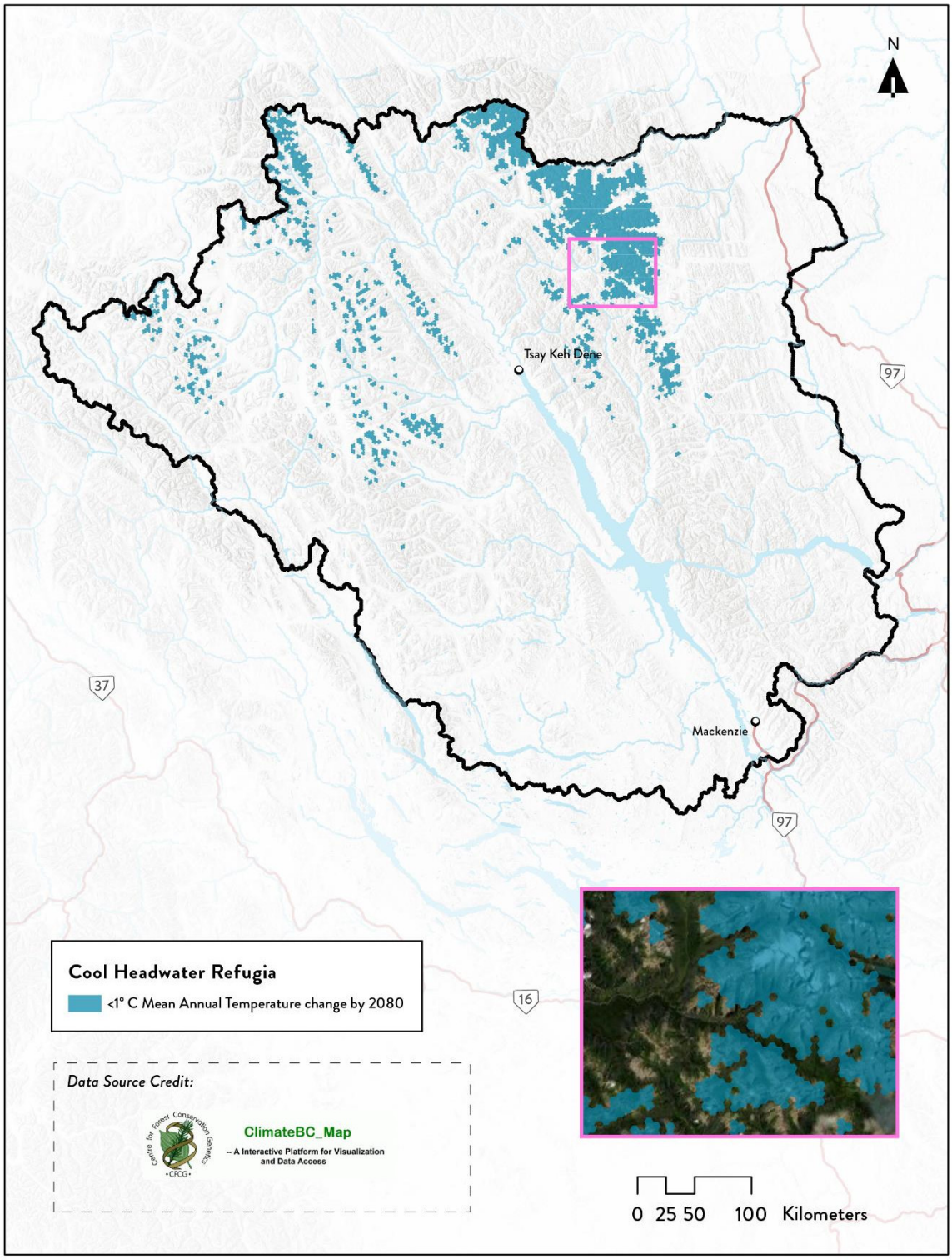

Figure 41. Spatial extent of the Cool Headwater Refugia layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

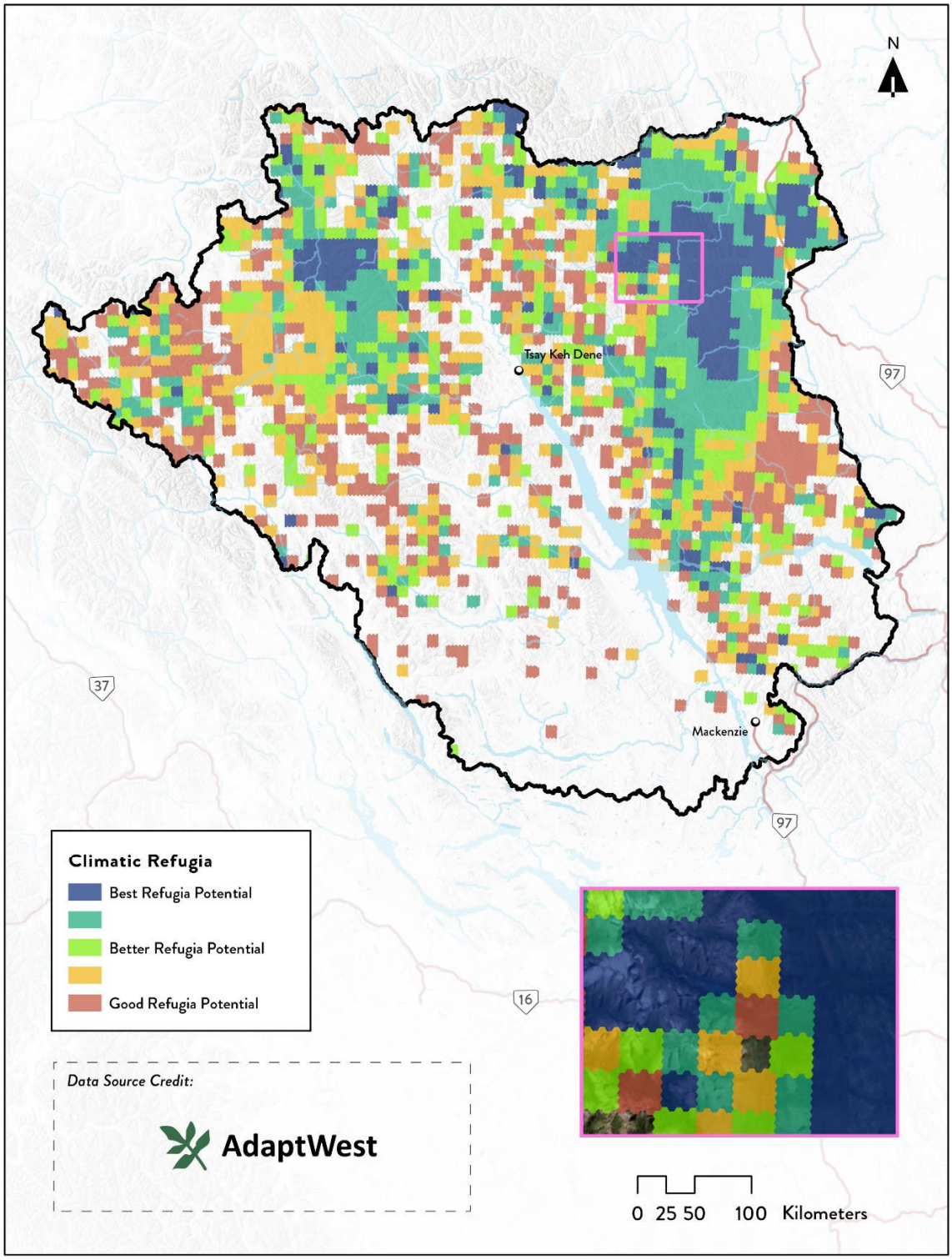

Figure 42. Spatial extent of the Climatic Refugia layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

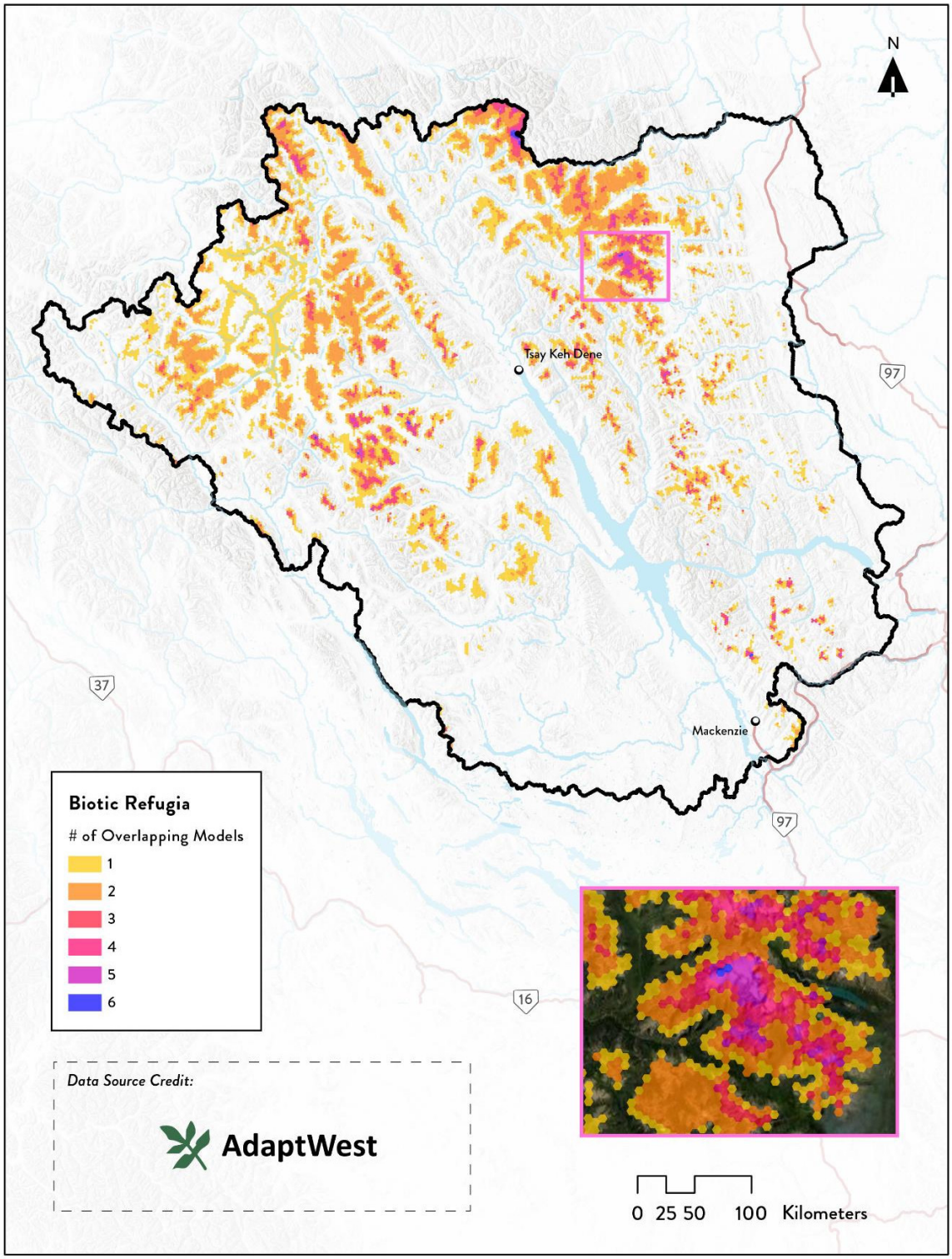

Figure 43. Spatial extent of the Biotic Refugia layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

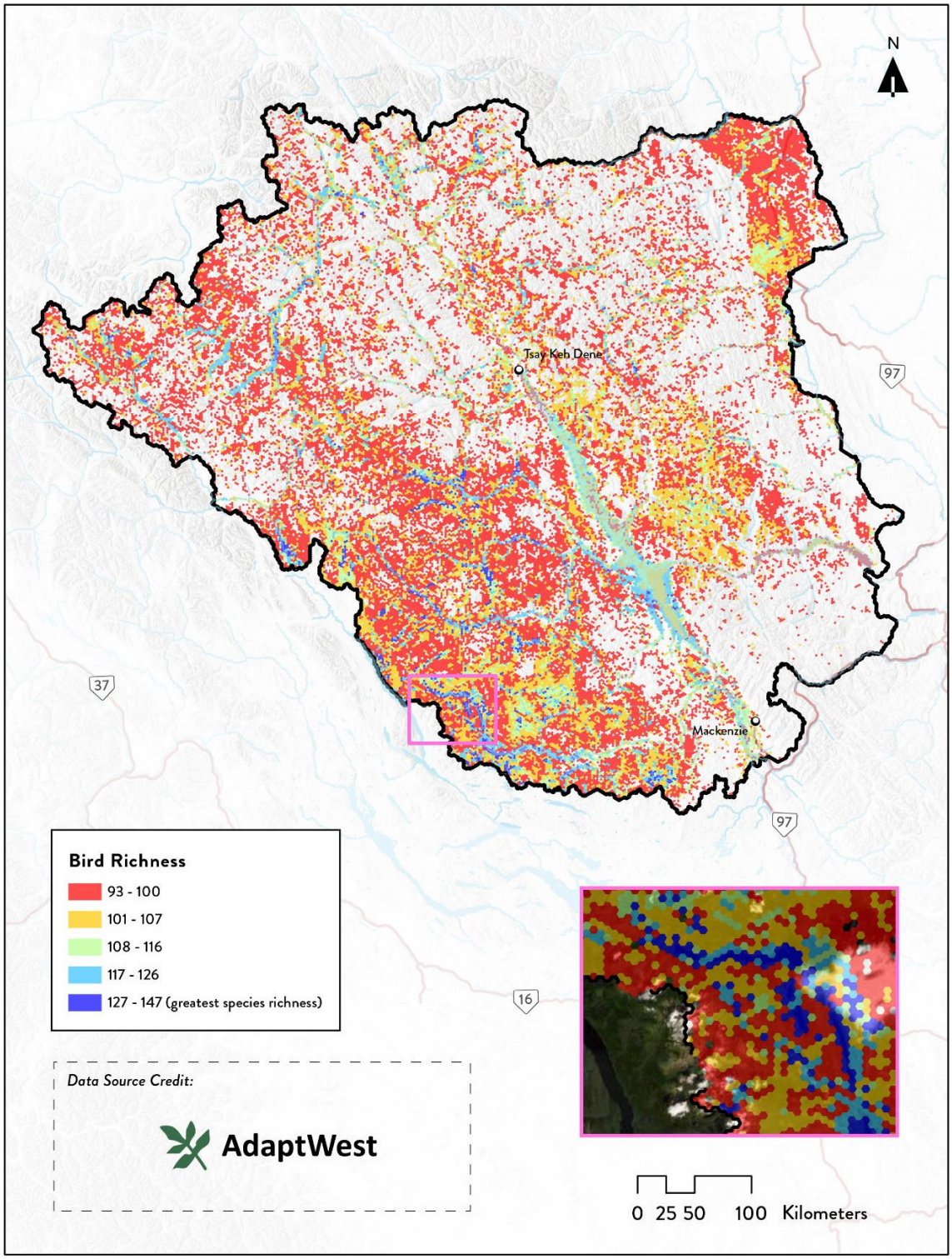

Figure 44. Spatial extent of the Bird Richness layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

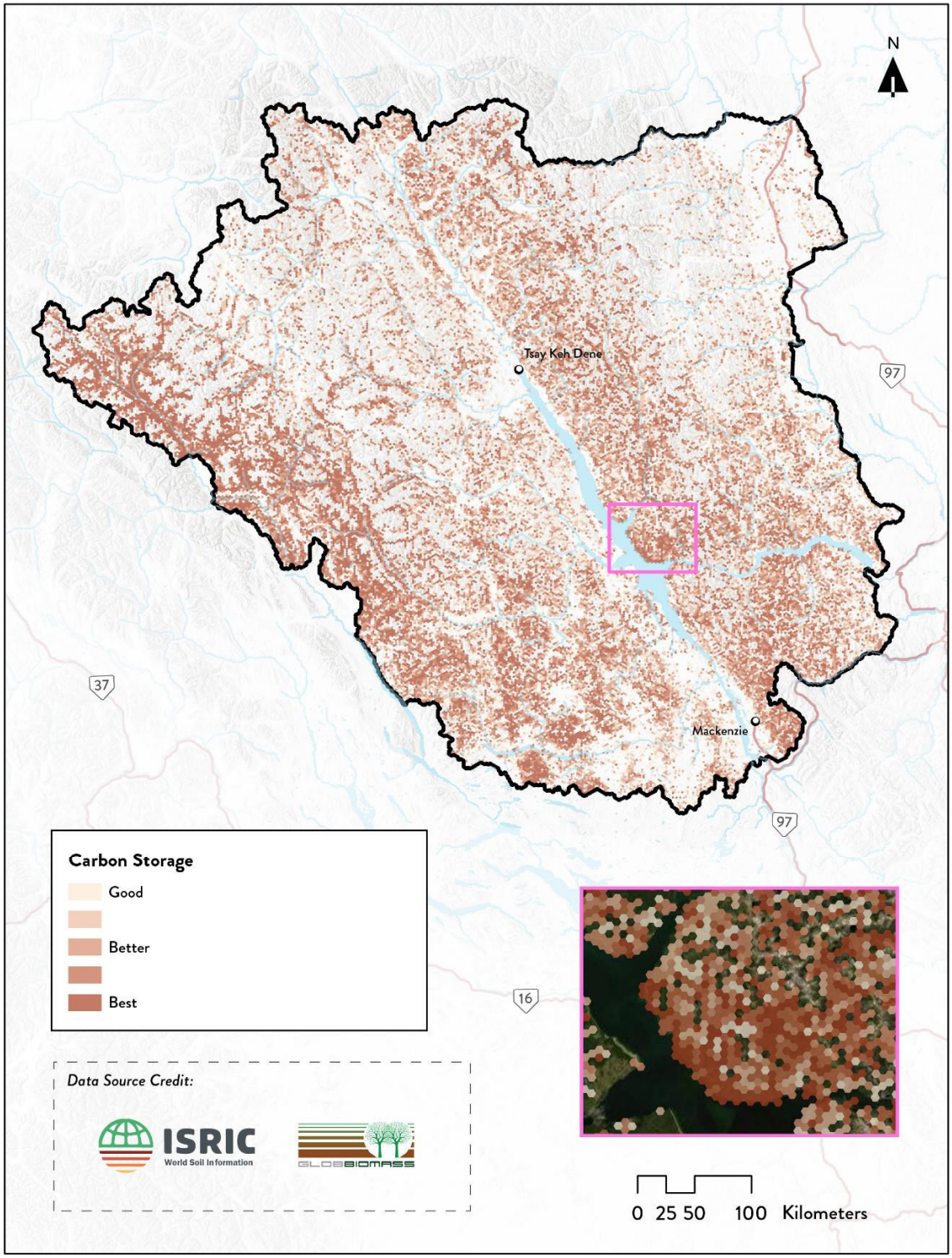

Figure 45. Spatial extent of the Carbon Storage layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.2.4 Cultural Conservation Features

There were three cultural conservation features used in this analysis. No maps nor descriptions of their extent beyond areal percentages are provided given the sacred and sensitive nature of the knowledge that informed the data for these layers. The percent that each layer makes up of the study area is as follows: sites of cultural importance 0.5%, cultural/spiritual areas 9%, subsistence areas 1%.

5.2.5 Connectivity Conservation Features

There were two connectivity conservation features used in this analysis. These two layers were products of the aforementioned connectivity analyses. The extent of each layer is described below, with maps depicting each connectivity feature included at the end of the descriptions.

5.2.5.1 Linkage Mapper

The Linkage Mapper layer makes up 50% of the study area. This feature is found between protected areas given its nature of linking "core" areas. Noteworthy groupings of high-value corridors are found in the east – a triangle between Ed Bird-Estella Lakes, Redfern-Keily, and Graham-Laurier Provincial Parks, and as a mass in the southern Muskwa Ranges between the Ospika and Peace Arms of the Williston Reservoir (Figure 46).

5.2.5.2 Omniscape

The highest quality (top 49%) omnidirectional connectivity values are predominantly found at low and moderate elevations away from the Williston Reservoir, with the highest flows of current found at pinch points and along riparian corridors. Sizable areas of high

current flow are found along the Omineca River, the northern span of the Rocky Mountain Trench, and the Graham River (Figure 47).

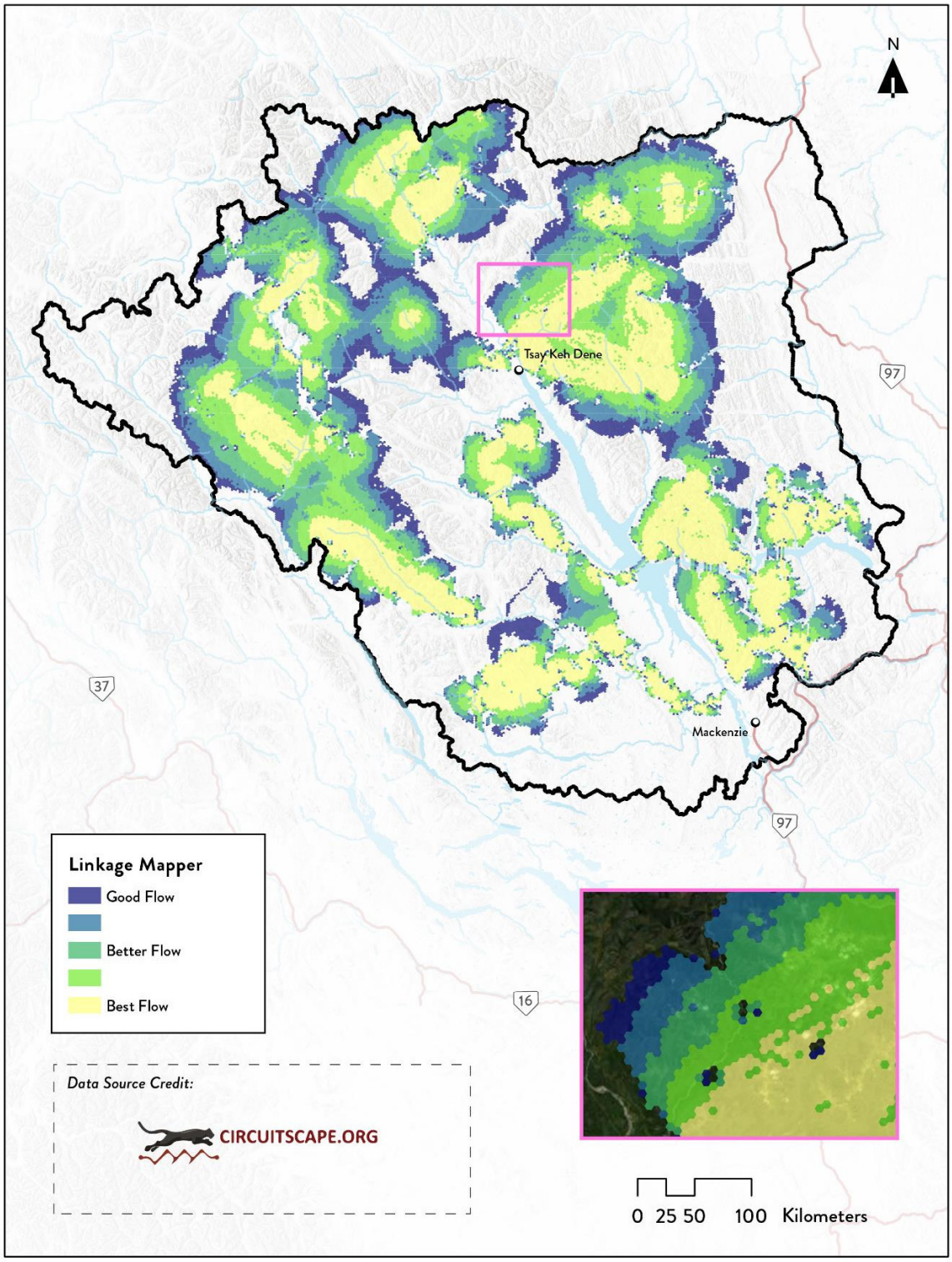

Figure 46. Spatial extent of the Linkage Mapper layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

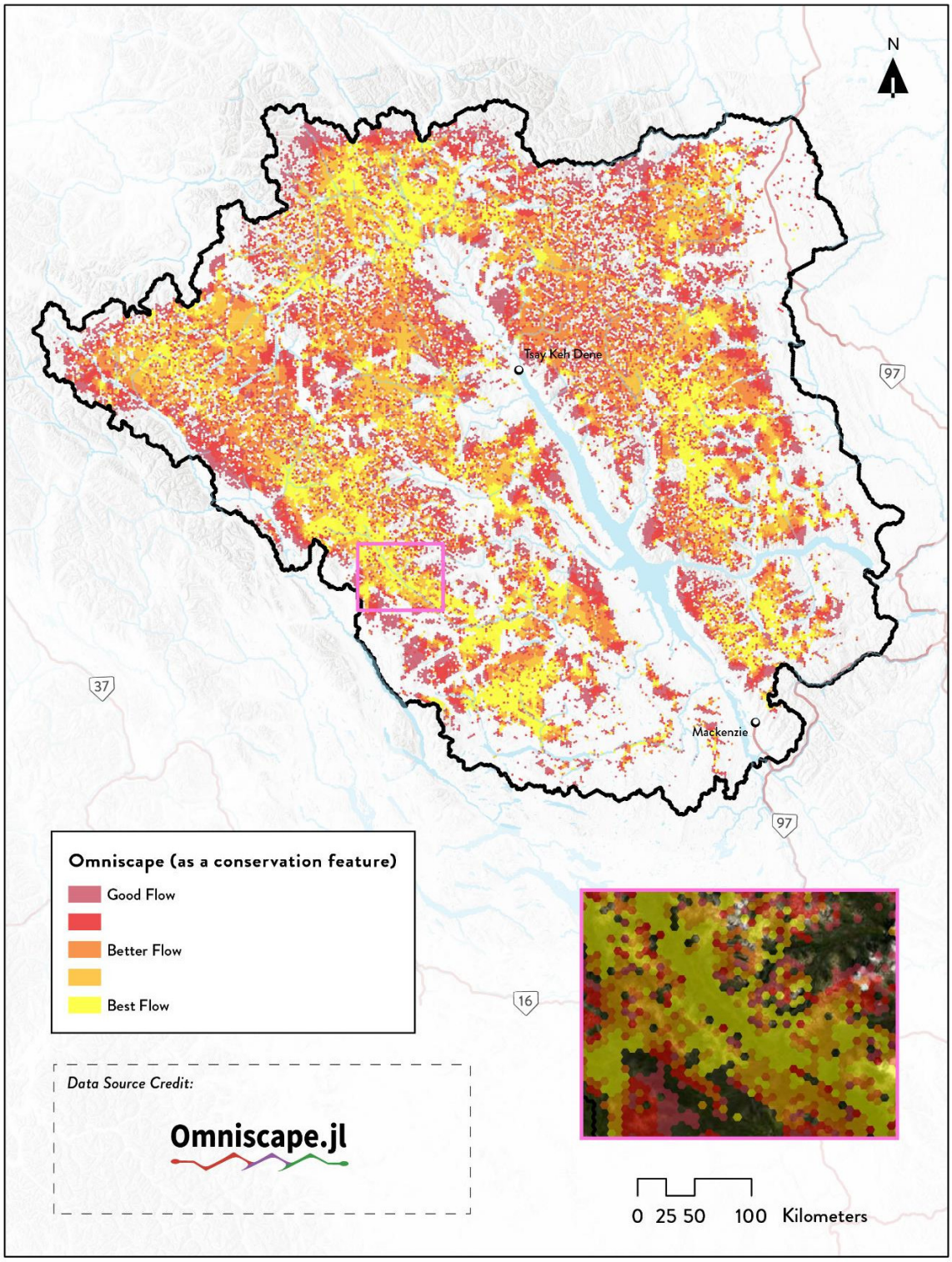

Figure 47. Spatial extent of the Omniscape layer used to prioritize lands for conservation in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.2.6 Representational Zones

There were five representation conservation features used in this analysis. The intent was to not necessarily set targets on these features for selection by *prioritizr,* but rather to assess how well each category was captured in a given scenario's solution to understand how well different aspects of the landscape were represented. Each layer covers the entirety of the study area by nature, but notable patterns will be described below with maps depicting each representation feature included at the end of this group of descriptions.

5.2.6.1 Elevational Representation

The elevational representation layer divided the study area into three classifications – high (17%), moderate (42%), and low (42%). The low elevation class is found along the Williston Reservoir, river valleys throughout the Territory, and the Muskwa Plateau in the northeast. The division of moderate elevations is apparent between the Rocky Mountains in the east and the Omineca Mountains in the west, with the high elevation class perched within these groupings (Figure 50).

5.2.6.2 Ecoregional Representation

The ecoregional representation layer is dominated by four ecoregions that converge near the Tsay Keh Dene community at the northern tip of the Williston Reservoir (clockwise from the northwest: Boreal Mountains and Plateaus, Northern Canadian Rocky Mountains, Central Canadian Rocky Mountains, and Omineca Mountains. There are an additional five ecoregions that have only a marginal presence in the greater territory and are found along the fringe of the study area (Figure 51).

5.2.6.3 BEC Zones (2020, 2050, 2080)

BEC zones are included for three time periods to illustrate the shifts that are predicted to occur under a changing climate. While only five BEC zones exist in the Territory at present, BEC zones are predicted to diversify to eleven by 2050 before subsiding to ten by 2080 (Figure 48). While SBS, ESSF, and BWBS are predicted to remain fairly consistent in area, they are expected to migrate northward over time. Meanwhile, BAFA and SWB decline significantly, largely in favour of ICH (Figure 49, Figure 52, Figure 53, and Figure 54).

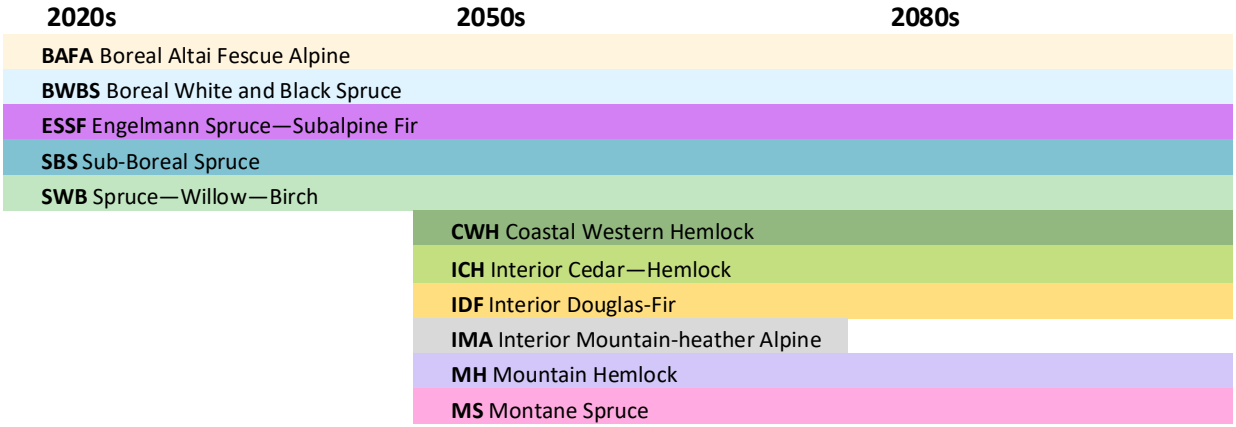

Figure 48. Time series of each biogeoclimatic ecosystem classification zone found in the Greater Tsay Keh Dene Territory Study Area; 2020s are the existing conditions while 2050s and 2080s are predicted conditions.

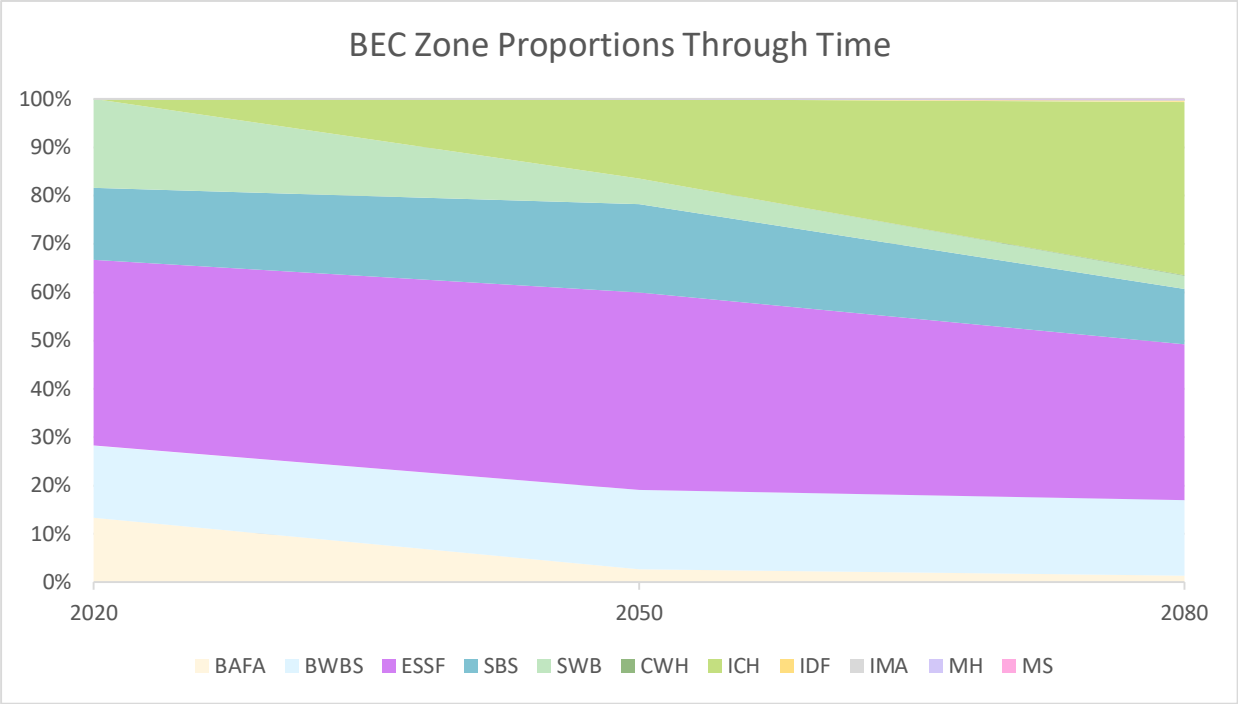

Figure 49. Proportions of each biogeoclimatic ecosystem classification zone found in the Greater Tsay Keh Dene Territory Study Area through time; 2020s are the existing conditions while 2050s and 2080s are predicted conditions. Five BEC zones (CWH, IDF, IMA, MH, MS) are so scarce as to barely register on the graphic.

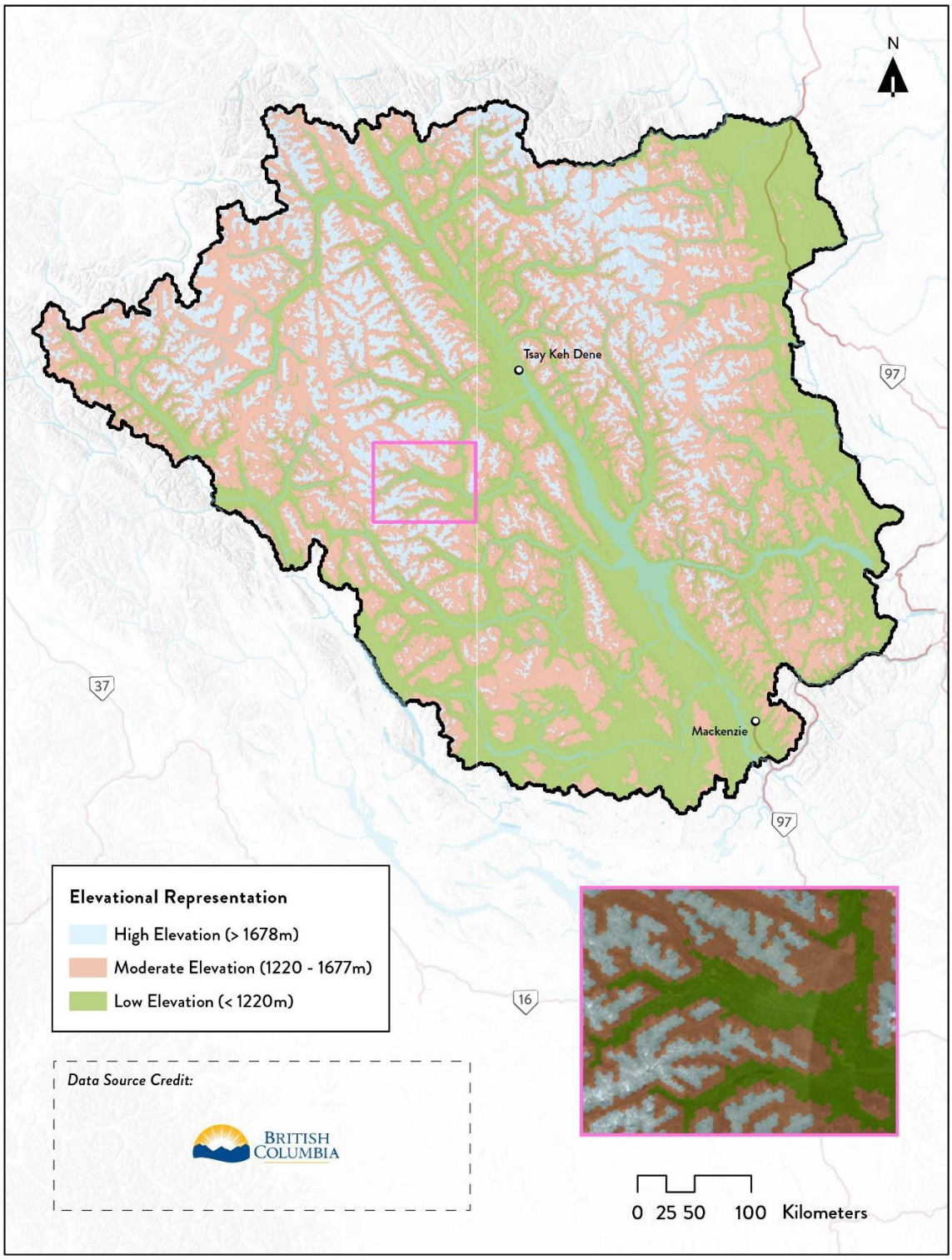

Figure 50. Spatial extent of the Elevational Representation layer used to understand representation within selected conservation lands in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

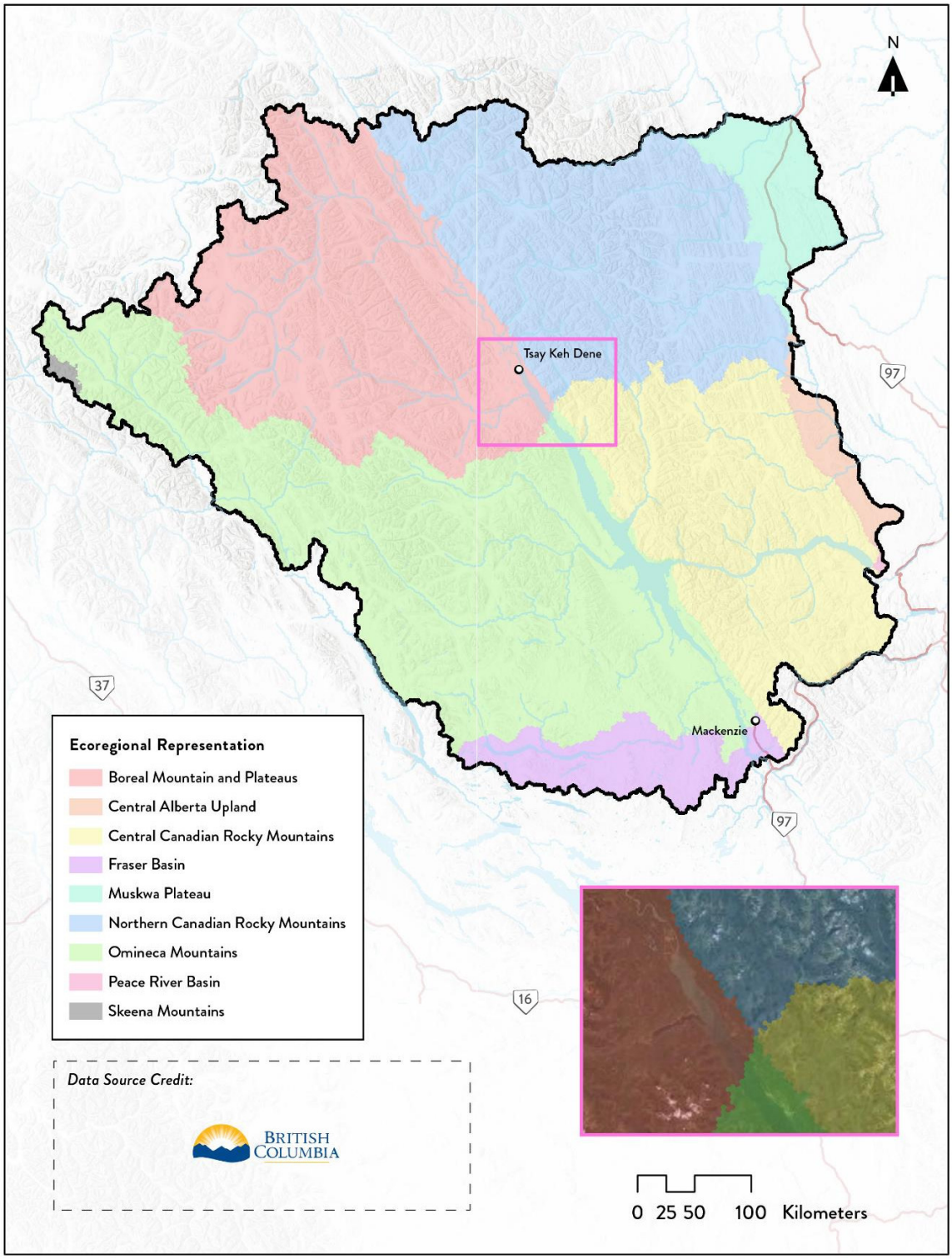

Figure 51. Spatial extent of the Ecoregional Representation layer used to understand representation within selected conservation lands in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

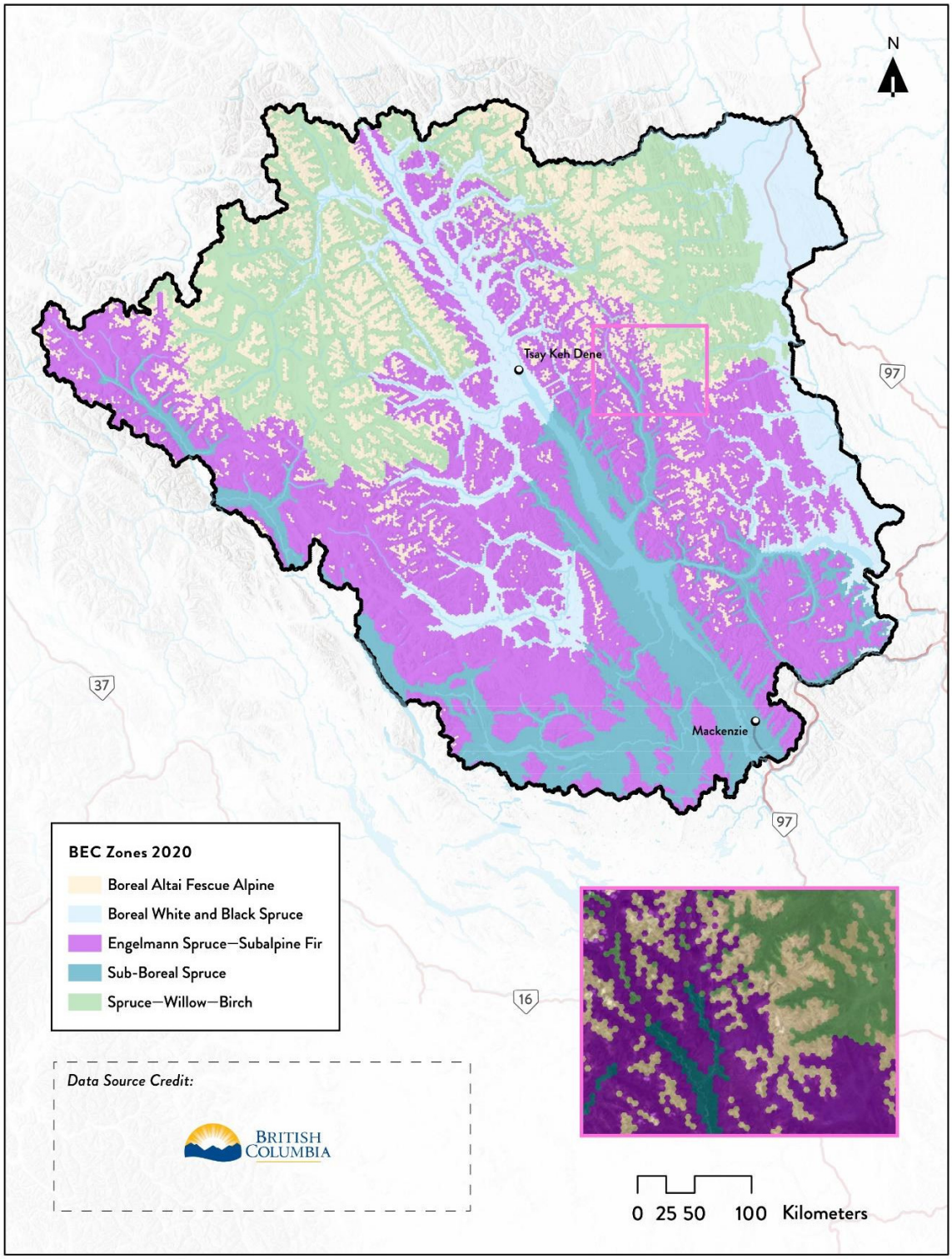

Figure 52. Spatial extent of the BEC Zones 2020 layer used to understand representation within selected conservation lands in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

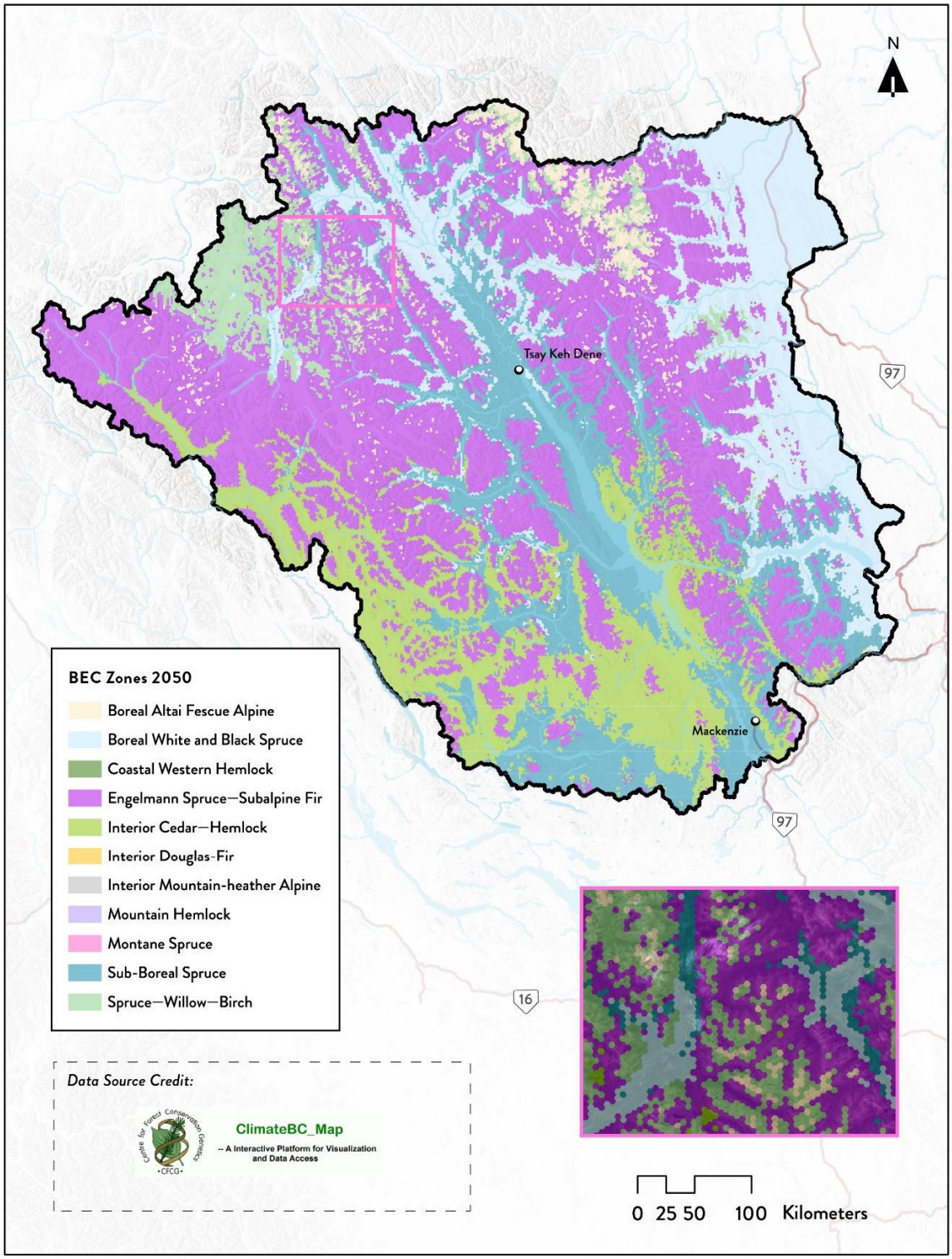

Figure 53. Spatial extent of the BEC Zones 2050 layer used to understand representation within selected conservation lands in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

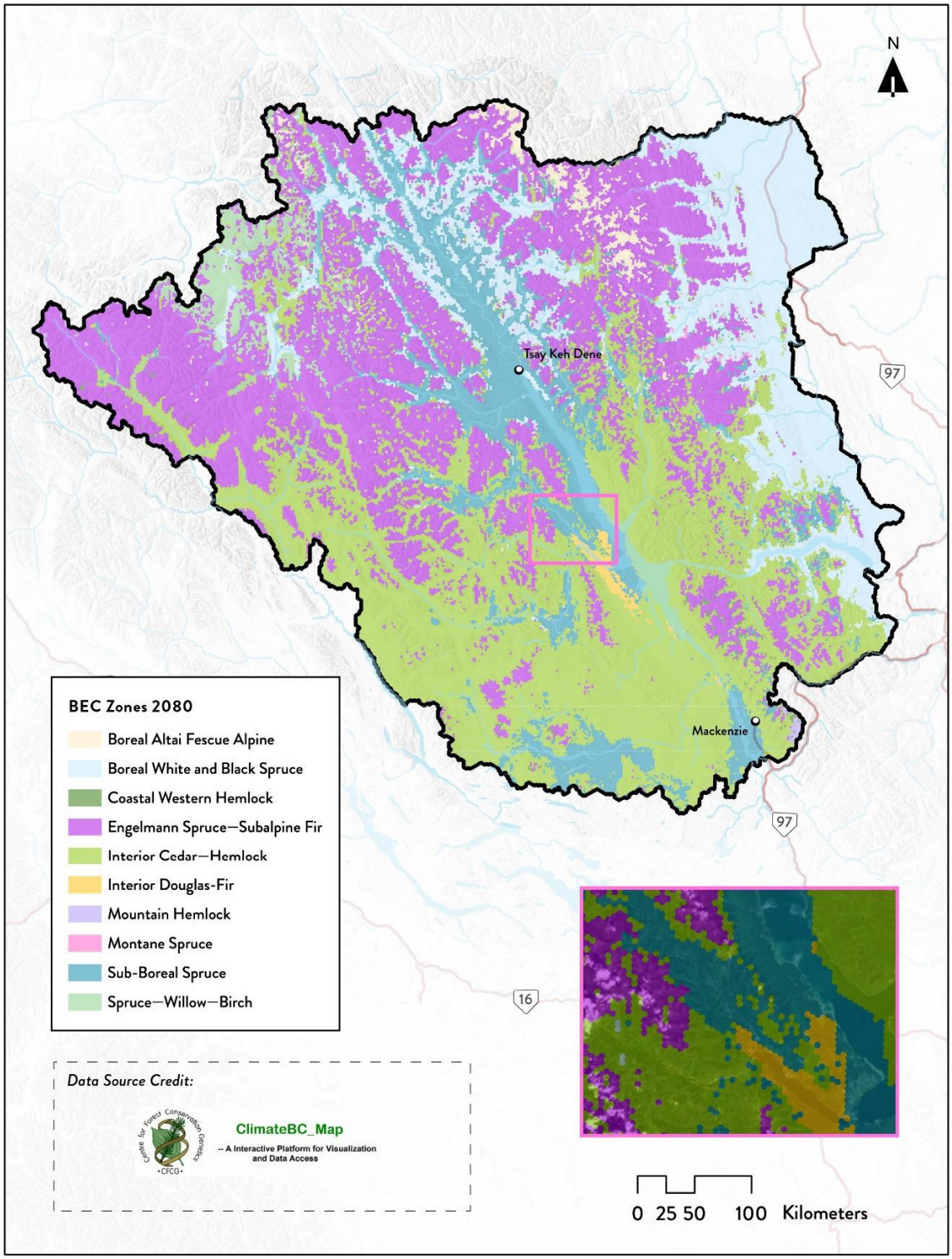

Figure 54. Spatial extent of the BEC Zones 2080 layer used to understand representation within selected conservation lands in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.3 Human Footprint

I developed three human footprint layers to operate as cost layers within *prioritizr*. These layers are represented in a binary manner and allow the user to choose how conservative to be in avoiding human disturbances as part of a conservation solution. The classifications are permanent-sensitive, semi-permanent-sensitive, and ephemeral-sensitive, with each category building on the one before it.

5.2.1 Permanent-Sensitive Footprint

The permanent-sensitive human footprint makes up 24% of the study area. This layer forms much of the entire human footprint, as a majority of the features in this analysis are considered permanent. The highways of the Territory – both literal roads and easily traversable river valleys – provide access to this remote area and thus are where the greatest footprint is found. Populated areas to the south near Mackenzie and in the east along the Alaska Highway (Hwy 97) make up the greatest concentrations of footprint near the periphery of the study area. The Williston Reservoir and the valleys of the rivers that feed it provide access to the interior of the Territory, and thus the greatest concentrations of footprint at the core of the study area are found along their banks and shores (Figure 55).

5.2.2 Semi-Permanent-Sensitive Footprint

The semi-permanent-sensitive human footprint is comprised of both permanent and semi-permanent features and makes up 29% of the study area. That additional 5% is predominantly made up of cutblocks and is almost exclusively found adjacent to the permanent footprint layer. Notable clusters of the semi-permanent footprint can be found just west of Mackenzie and along the Ingenika and Finlay Rivers (Figure 55).

5.2.3 Ephemeral-Sensitive Footprint

The ephemeral-sensitive human footprint is comprised of permanent, semi-permanent, and ephemeral features and makes up 30% of the study area. Ephemeral features in this analysis are all recreation-based and generally found near roadways. Notable clusters of ephemeral footprint can be found east of Mackenzie, west of the Skeena River, and near Redfern-Keily Provincial Park (Figure 55).

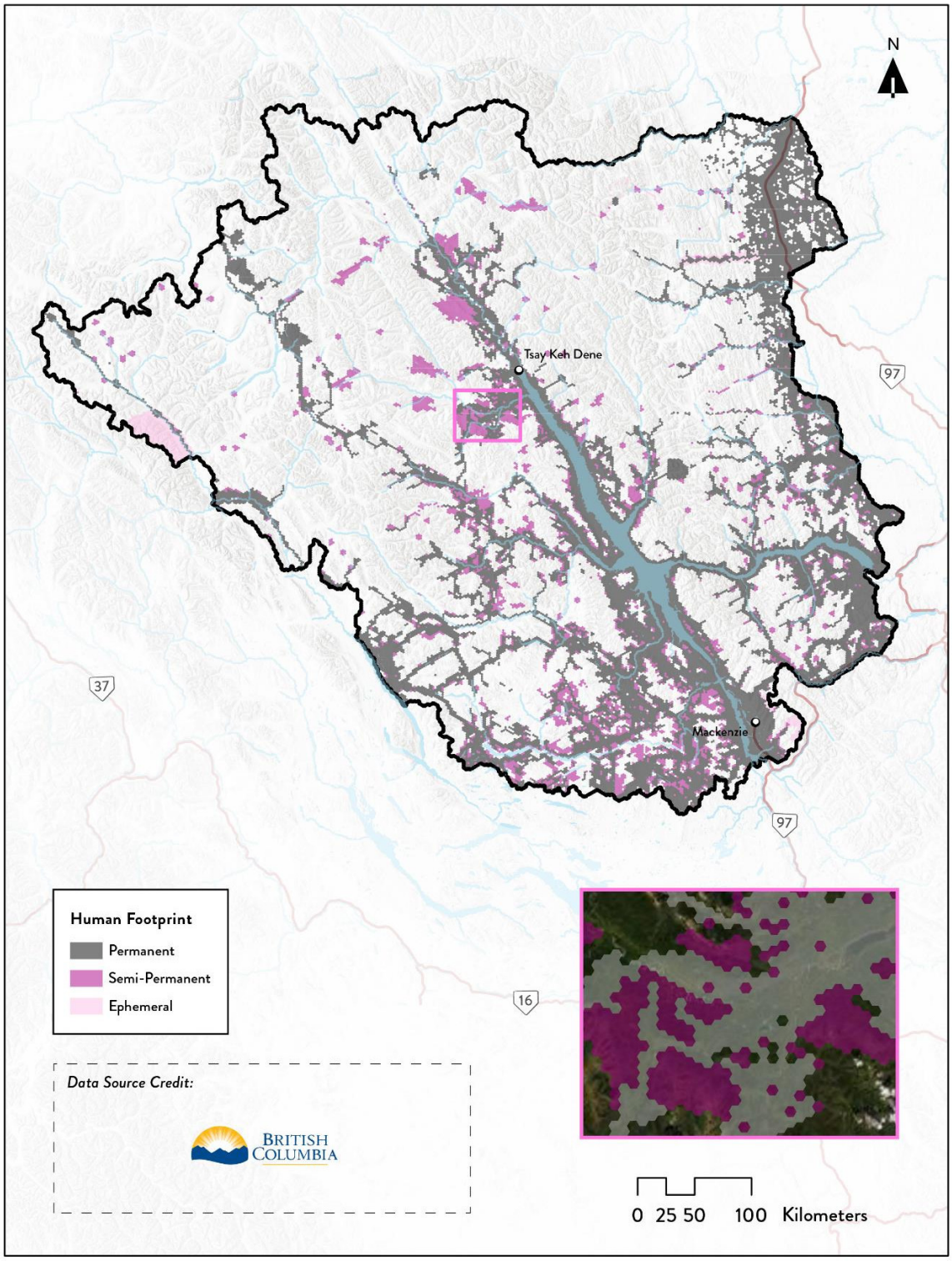

Figure 55. Spatial extent of the Human Footprint layers used to avoid development in the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.4 Landscape Resistance and Connectivity

The connectivity analysis informed multiple aspects of this project, with output data serving as both conservation features and locked-in areas. The data for the foundational resistance layer – as well as the outputs for both Linkage Mapper and Omniscape – cover the entirety of the study area. In contrast, derivative data products focus on high-value subsets of that data and cover only portions of the study area.

5.3.1 Resistance Layer

The resistance layer looks strikingly similar to the human footprint layers because the footprint is one of the main components of resistance. However, the resistance layer also takes land cover and slope into account, and these more subtle variables can be seen in light grey in the steepest portions of the Rocky and Omineca Mountains (Figure 56). Their nuance is most visible in the red diffuse connected areas in the Omniscape Cumulative Current map (Figure 58).

5.3.2 Linkage Mapper

The Linkage Mapper layer is based on connections between 'core areas' (protected areas in this case), and thus high-value portions of the landscape appear as fairly direct corridors between existing protected areas and the proclaimed Ingenika Conservation and Management Area. These corridors are generally found along river valleys and relatively undisturbed mountain ranges, most notably along the Omineca River and in the Germansen Range in the southwest of the study area, as well as the mountain ranges surrounding the Peace Arm and a triangle between Ed Bird-Estella Lakes, Redfern-Keily, and Graham-Laurier Provincial Parks in the east (Figure 57).

5.3.3 Omniscape

The Omniscape layer assesses connectivity for the entire landscape regardless of protected status, though there were portions of the landscape identified as high value by both Omniscape *and* Linkage Mapper. The most notable areas identified by both tools include the Omineca River and Germansen Range corridors mentioned above, as well as the area between Finlay-Russel and Kwadacha Wilderness Provincial Parks north of the community of Kwadacha. High-value areas identified solely by Omniscape include areas within Graham-Laurier Provincial Park and Ingenika Conservation and Management Area (Figure 58).

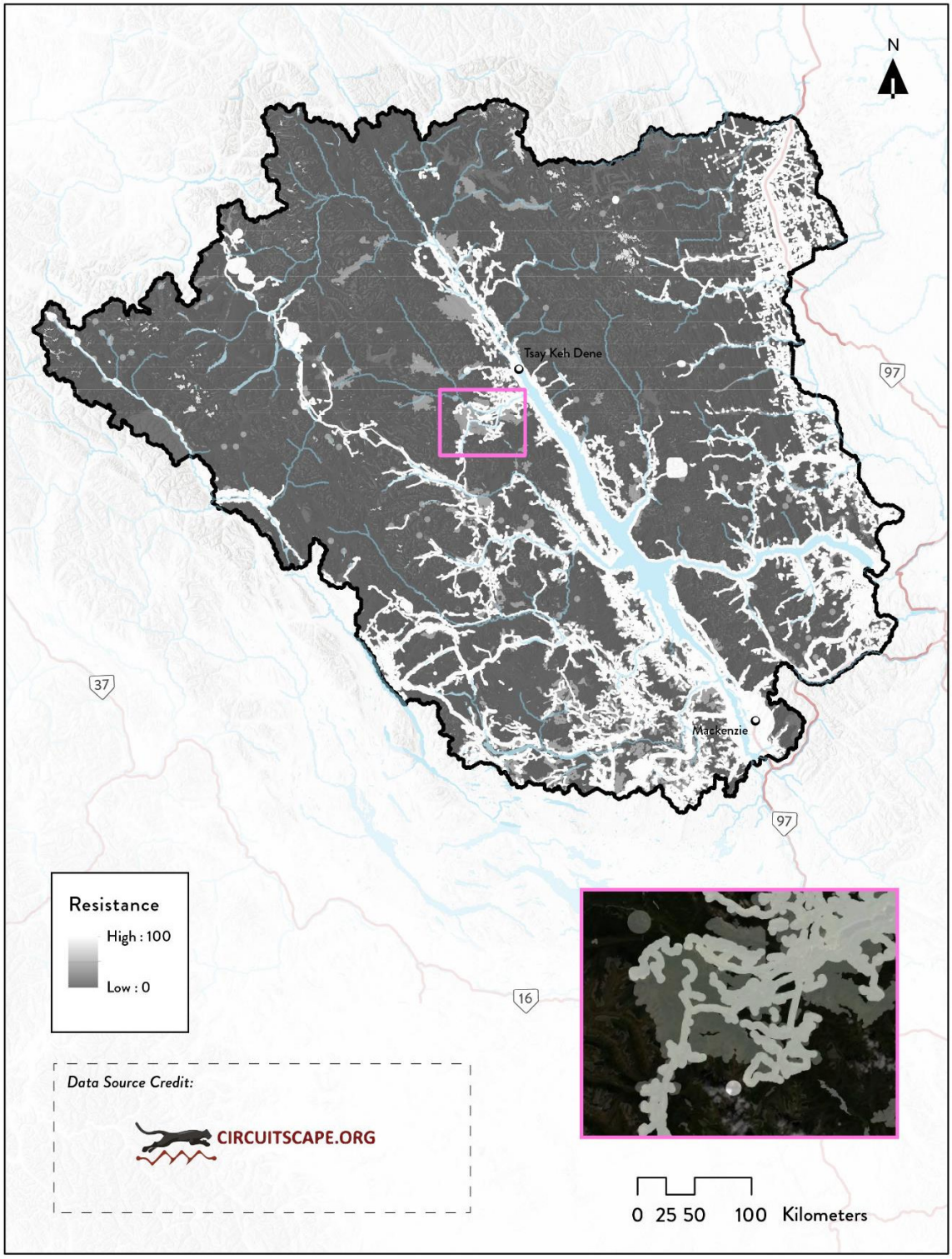

Figure 56. Spatial extent of the Resistance layer used to quantify connectivity for the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

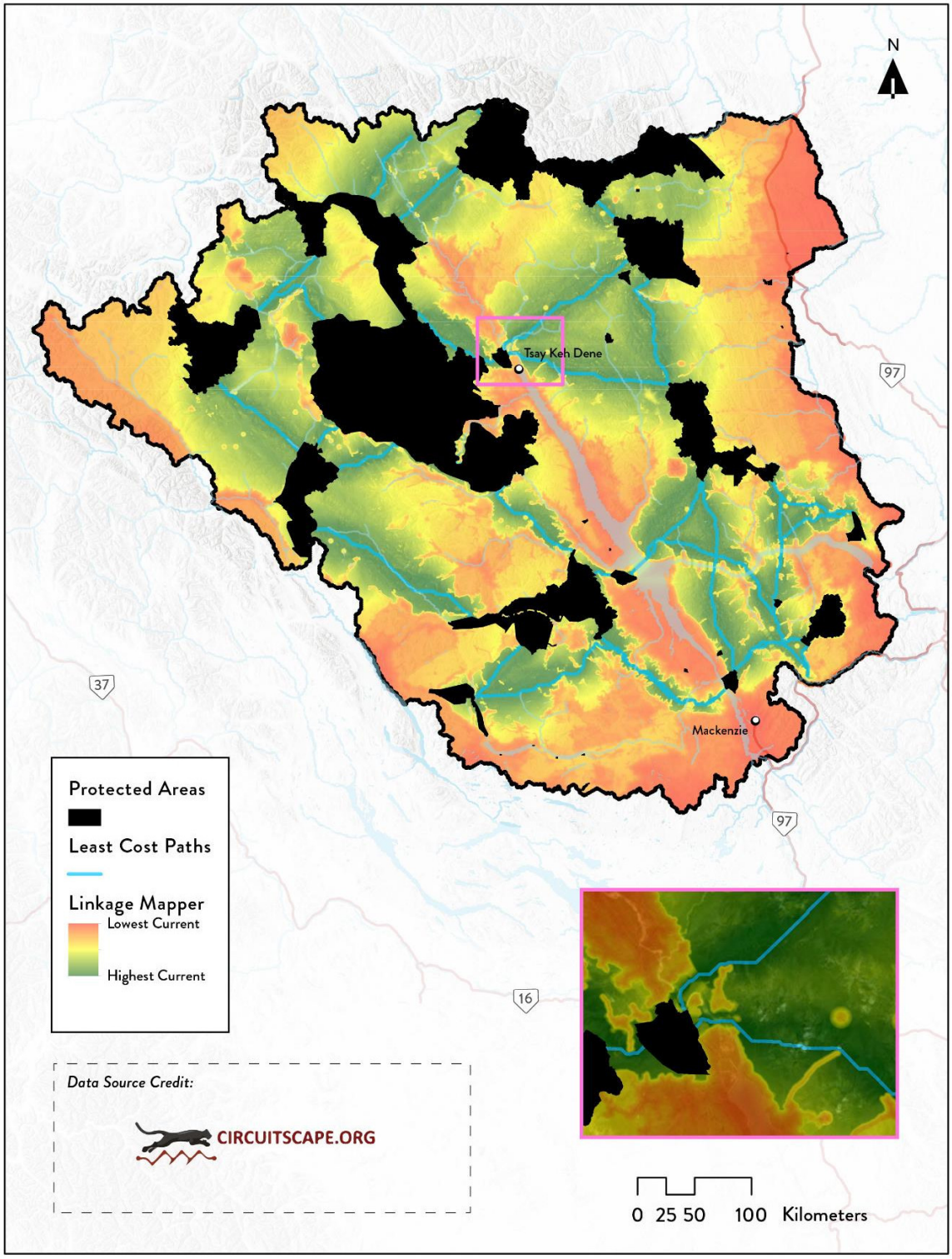

Figure 57. Spatial extent of the Linkage Mapper connectivity layer used to inform the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

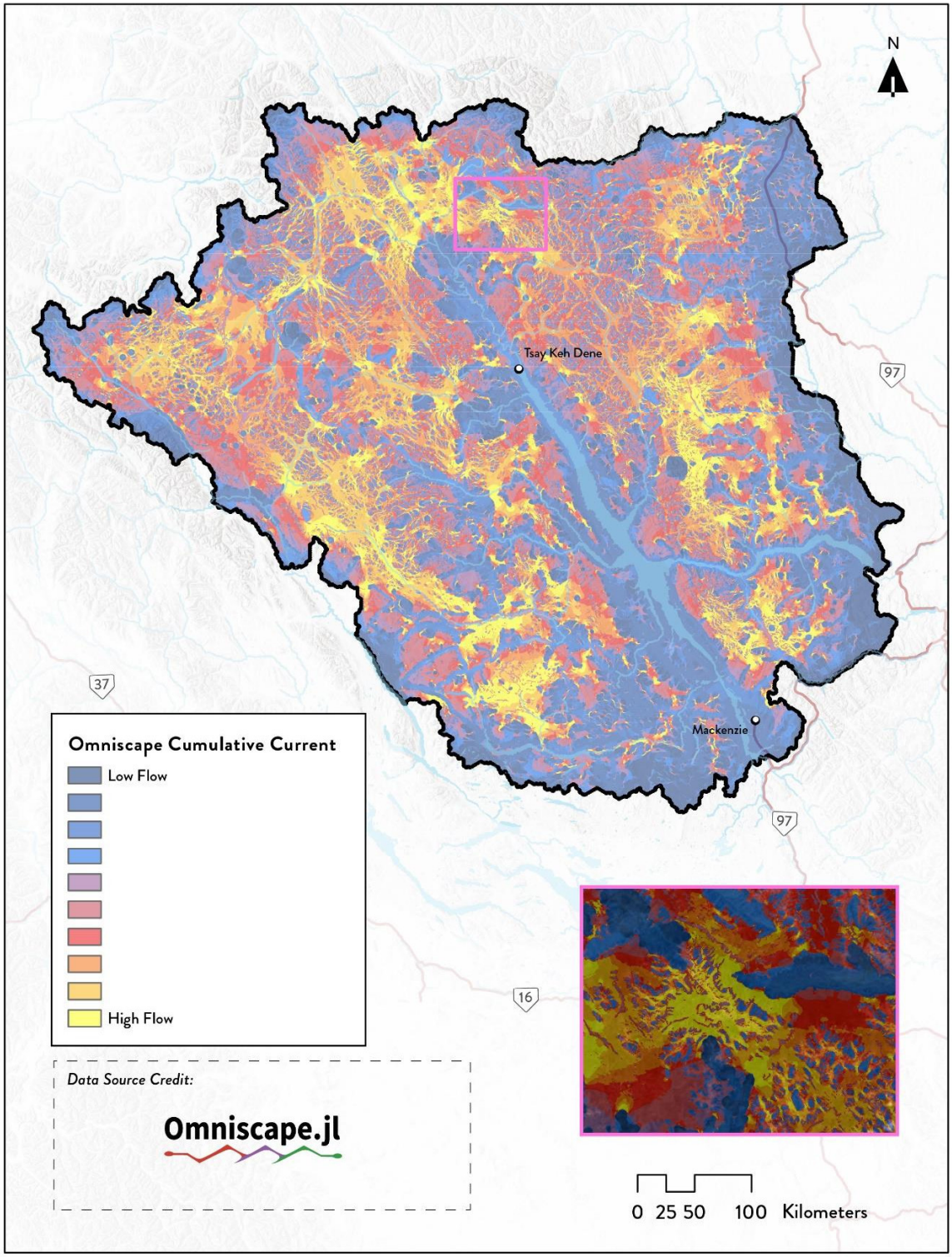

Figure 58. Spatial extent of the Omniscape connectivity layer used to inform the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.5 Locked-in Areas

'Locked-in areas' are portions of the landscape that the user wants to guarantee for inclusion in a conservation solution. By choosing to lock in a certain layer we are ensuring that it is selected, in this case for practical or connectivity purposes. I included four layers as lock-in options, though the user can also choose to not lock anything in. Protected areas are included for practicality, as they are already legally protected and unlikely to be delisted. Thus, the existing network of protected areas can logically be part of a conservation solution. The exception is the Ingenika Conservation and Management Area, which was included but is not yet recognized by the provincial or federal governments. The remaining three locked-in options focus on connectivity, seeking to include a skeleton of connected lands that can be built out further with ecologically valuable portions of the landscape. The Omniscape layers are colloquially named for accessibility and to describe their relative breadth.

5.4.1 Protected Areas

Protected areas make up 11% of the study area, or 17% when including the proposed Ingenika Conservation and Management Area. The protected areas network is fairly well distributed across the greater territory, with the Ingenika serving as a valuable addition given its significant size (504,857 ha) and strategic location for connectivity (Figure 59). However, a noticeable gap exists in the Muskwa Ranges near Ospika Cones Ecological Reserve, notable because this is the heart of Tsay Keh Dene Territory and leaves the Finlay Caribou Herd virtually unprotected.

5.4.2 Protected Areas + Least-Cost Paths

This layer is made up of the protected areas from the previous layer plus the least-cost paths derived from Linkage Mapper, and makes up 18% of the study area. With smaller and more numerous protected areas in the south, more parallel and intersecting least-cost paths exist. For example, the paths from Omineca and Nation Lakes Provincial Parks are coterminous for much of their routes to Heather-Dina Lakes Provincial Park. Additionally, there are numerous paths converging near and traversing the Peace Arm, while paths east from Muscovite Lakes Provincial Park take a 6 km crossing of the Williston Reservoir rather than circumnavigating its southern shore (Figure 60).

5.4.3 Omniscape 'Bones'

The 'bones' layer is made up of values from the top two quantiles of the Omniscape analysis, and makes up 19% of the study area. This thin layer has clusters in the northern reaches of the greater territory, along the Omineca River, and the relatively flat area east of Nation Lakes Provincial Park (Figure 61).

5.4.4 Omniscape 'Meat'

The 'meat' layer is made up of values from the top three quantiles of the Omniscape analysis, and makes up 29% of the study area. This thicker layer is a slightly more built-out version of the 'bones' layer, and contributes additional areas of connectivity in the Muskwa Ranges east of the Tsay Keh Dene community, in addition to augmenting clusters from the 'bones' layer (Figure 62).

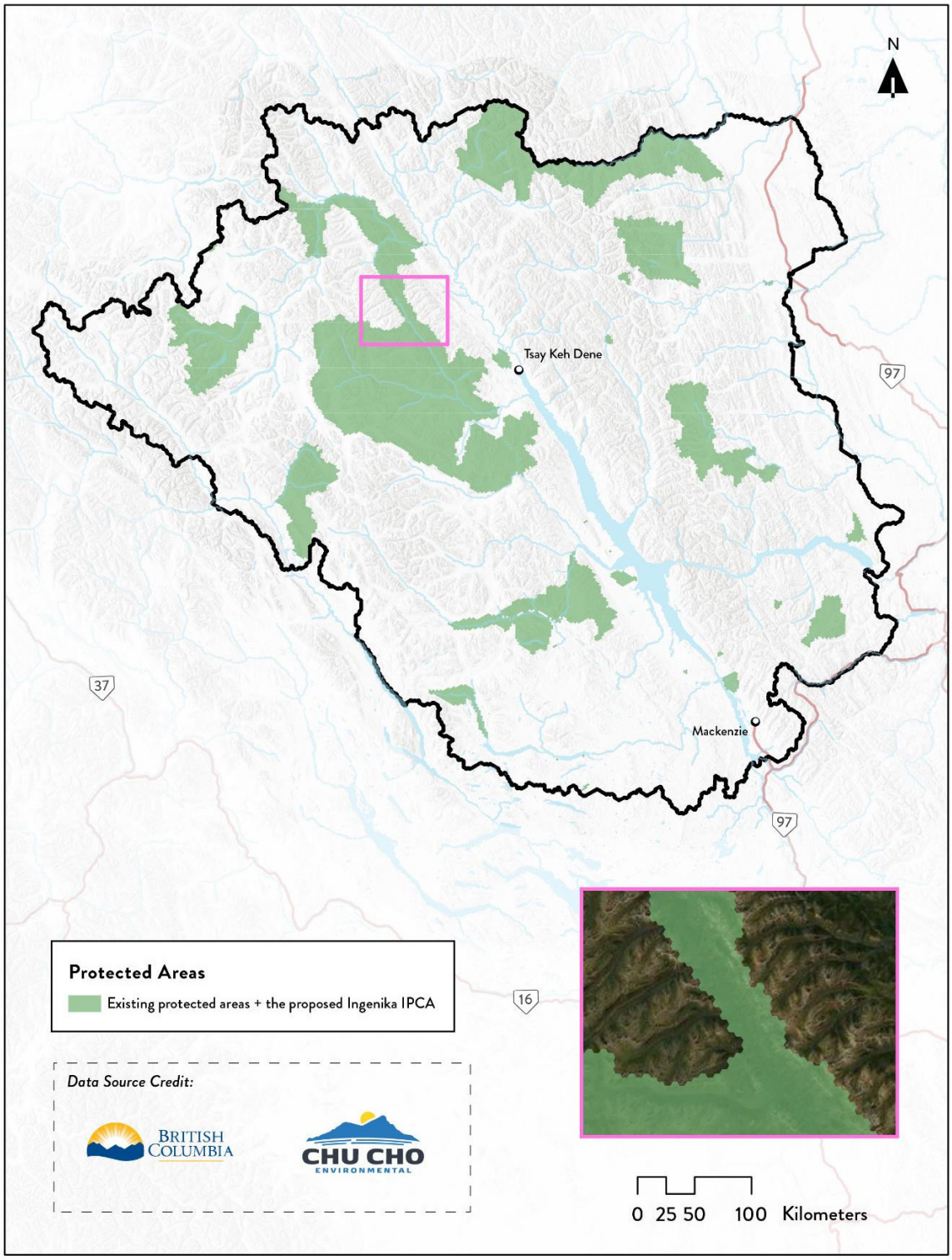

Figure 59. Spatial extent of the Protected Areas layer used to 'lock-in' areas as part of the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

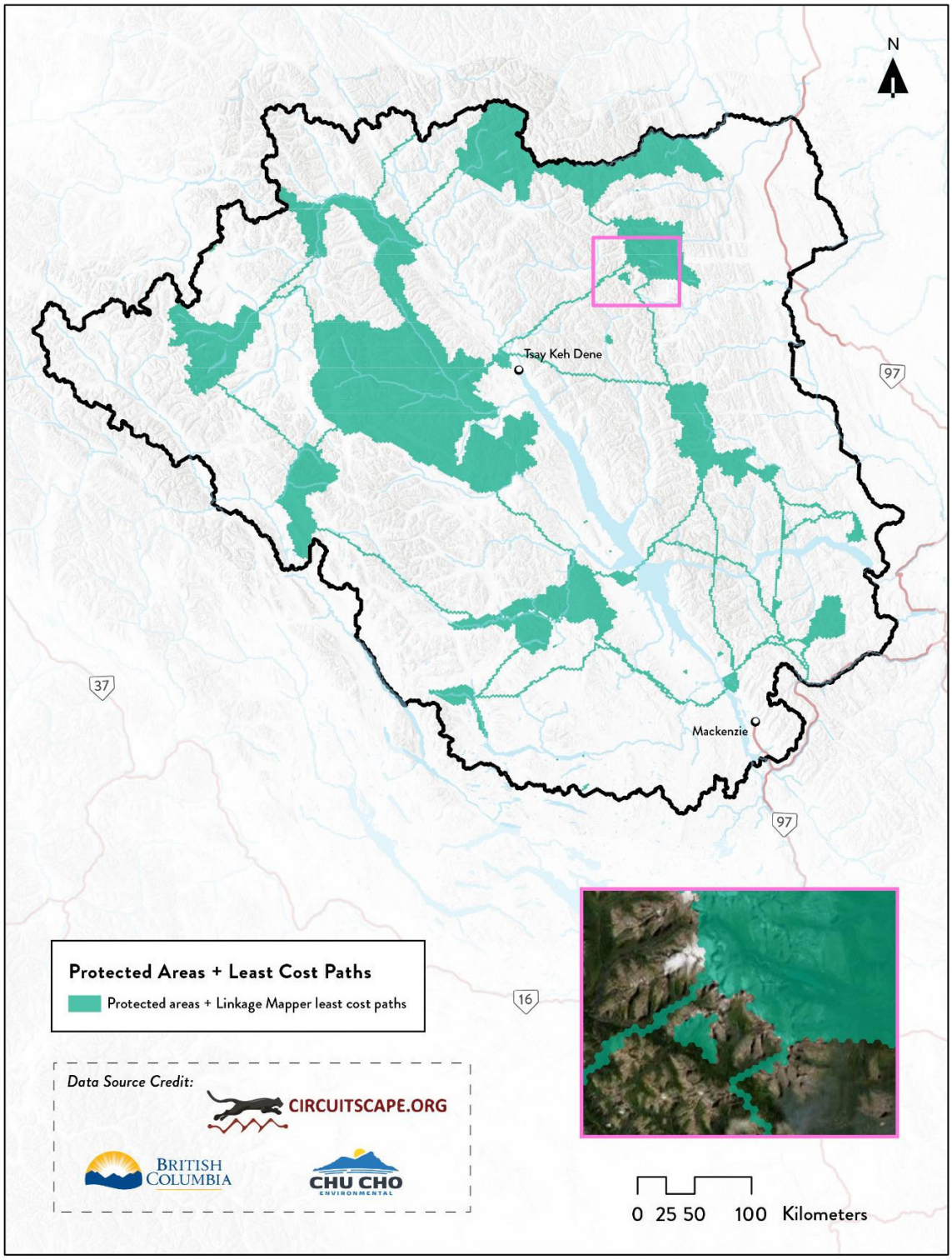

Figure 60. Spatial extent of the Protected Areas + Least-Cost Paths layer used to 'lock-in' areas as part of the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

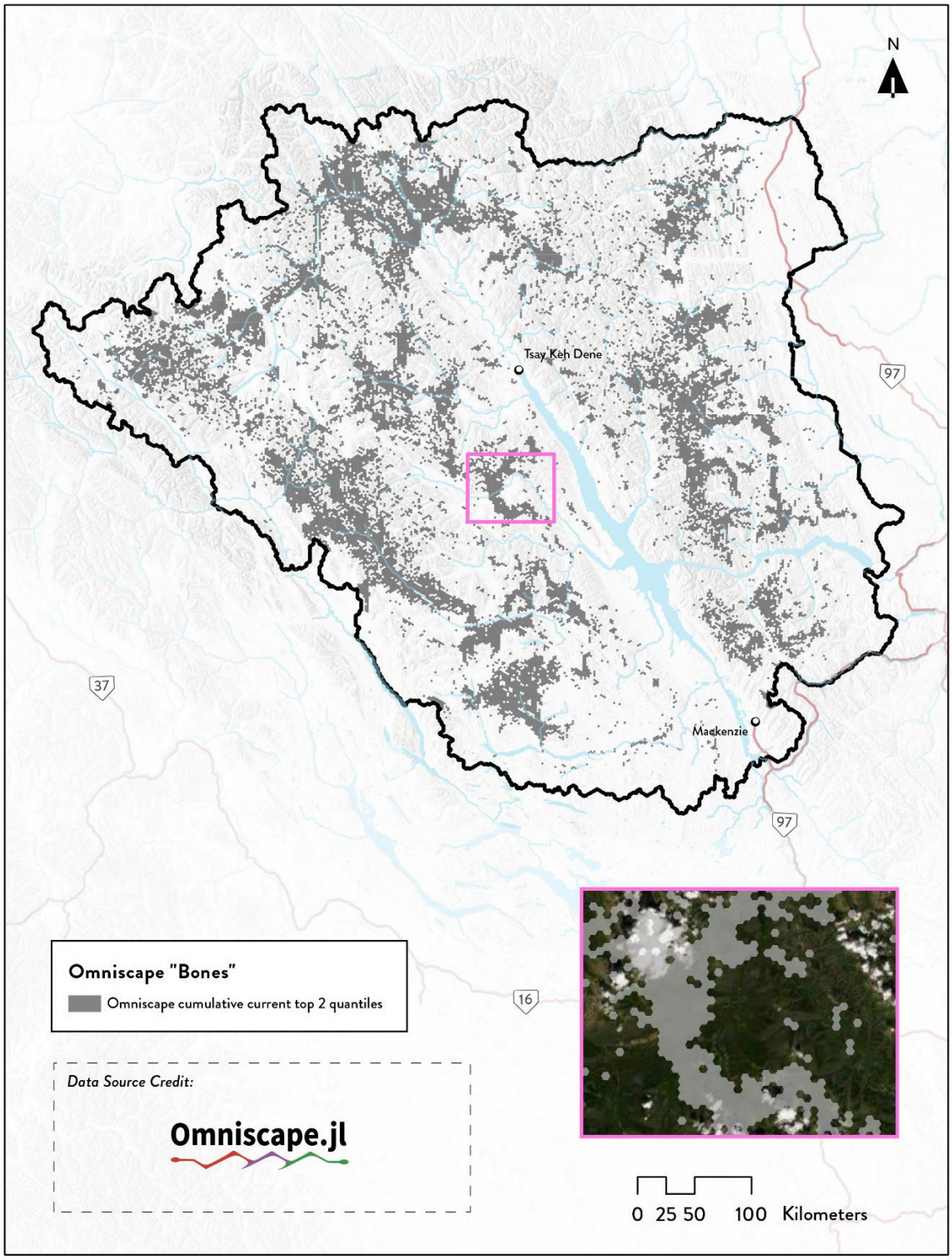

Figure 61. Spatial extent of the Omniscape "Bones" layer used to 'lock-in' areas as part of the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

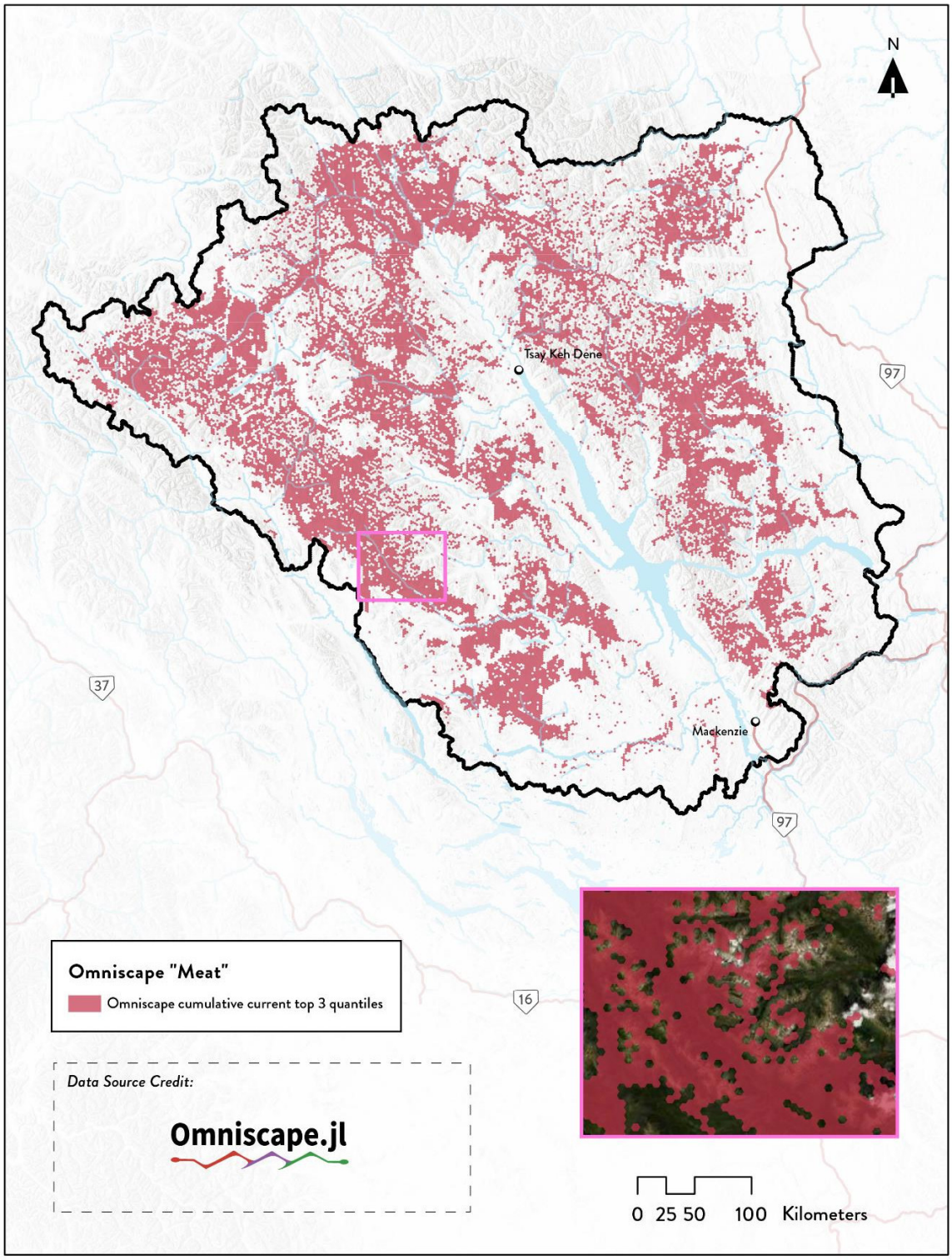

Figure 62. Spatial extent of the Omniscape "Meat" layer used to 'lock-in' areas as part of the conservation prioritization process for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.6 Gap Analysis

The representation of each conservation feature within the existing network of protected areas varied greatly, ranging from no protection up to 61% protected (Table 9, Table 10). It is worth noting, however, that most features fall somewhere in the middle, and that extreme high and low levels of protection were generally found in features with sparse extents. On average, conservation features were 17% protected.

Conservation features that were relatively well represented include cool headwater refugia (37%), Tsay Keh Dene subsistence areas (38%), and the Chase Caribou Herd (39%). The best protected conservation feature, however, was the NDT2-SWB-Burned layer at 61% (recently burned areas of the Spruce–Willow–Birch biogeoclimatic zone with infrequent stand-initiating events). Conversely, poorly protected conservation features include recently burned and mature/old portions of the Engelmann Spruce–Subalpine Fir biogeoclimatic zone with rare stand-initiating events (NDT1-ESSF-Burned: 0.0%; NDT1-ESSF-Old: 0.8%), as well as the Finlay Caribou Herd at just 0.5%. More generally, present-day biodiversity conservation features (16%) were only slightly less represented than future biodiversity conservation features (18%).

Conservation Feature (present-day)	% of Study Area	% Protected	Target %
Sites of Cultural Importance	0.5	11	100
Cultural/Spiritual Areas	9	21	80
Subsistence Areas	1.3	38	80
Wetlands	57	14	50
Lakes	21	21	70
Karst Deposits	27	21	60
Grizzly Bear	29	14	60
Bull Trout/Fish	3	20	80
Fisher	38	10	60
Chase Caribou Herd	6	39	90
Finlay Caribou Herd	5	0.5	90
Frog Caribou Herd	1.1	5	90
Gataga Caribou Herd	1.0	4	90
Graham Caribou Herd	4	15	90
Kennedy Siding Caribou Herd	0.1	0.0	90
Klinse-za Caribou Herd	2	14	90
Pink Mountain Caribou Herd	2	21	90
Thutade Caribou Herd	4	33	90
Wolverine Caribou Herd	4	8	90
Faux North Caribou Herd	4	31	0
Faux Central Caribou Herd	0.7	0.0	0
Faux South Caribou Herd	0.1	0.0	0
Moose	39	12	70
Stone Sheep	6	28	70
Mountain Goat	10	24	70
Wolverine	19	25	60
Bank Swallow	6	11	40
Barn Swallow	8	20	60
Western Toad	12	21	60
Horned Grebe	10	14	40
Little Brown Myotis	25	24	60
Northern Myotis	11	24	60
Olive-Sided Flycatcher	9	15	40
Rusty Blackbird	13	16	60

Table 9. Representation of present-day conservation features by protected areas in the Greater Tsay Keh Dene Territory Study Area.

Conservation Feature (present-day)	% of Study Area	% Protected	Target
NDT1-ESSF-Burned	0.1	0.0	100
NDT1-ESSF-Old	2	0.8	70
NDT2-ESSF-Burned	2	24	100
NDT2-ESSF-Old	10	13	56
NDT2-SBS-Burned	0.4	4	100
NDT2-SBS-Old	0.8	2	88
NDT2-SWB-Burned	1.0	61	100
NDT2-SWB-Old	4	27	52
NDT3-BWBS-Burned	2	35	100
NDT3-BWBS-Old	16	18	52
NDT3-SBS-Burned	0.5	2	100
NDT3-SBS-Old	11	4	62
Rare BEC Zones	25	5	60

Conservation Feature (future)	% of Study Area	% Protected	Target
Land Facet Diversity	5	12	80
Land Facet Rarity	5	12	80
Elevational Diversity	50	23	67
Ecotypic Diversity	50	15	59
Heat Load Index Diversity	50	24	68
Climate Corridors	54	19	61
Backward Velocity 2055	50	17	64
Backward Velocity 2085	50	21	60
Forward Velocity 2055	50	5	50
Forward Velocity 2085	50	8	52
Bird Richness	52	15	58
Carbon Storage (above and below ground)	49	14	61
Cool Headwater Refugia	6	37	80
Climatic Refugia	57	21	63
Biotic Refugia	16	30	70

Conservation Feature (connectivity)	% of Study Area	% Protected	Target
Omniscape	49	23	0
Linkage Mapper	50	19	0

Table 10. Representation of current, future, and connectivity conservation features by protected areas in the Greater Tsay Keh Dene Territory Study Area.

5.7 *prioritizr* Scenario Outputs

This section reports the solutions of the six *prioritizr* scenarios developed to prioritize lands for conservation in the greater territory study area (Table 11). Each of the six scenarios represent the most efficient collection of planning units that still meet the targets set for each conservation feature. The target percentages and actual percent captured for each scenario are reported in Table 12.

	Scenario A	**Scenario B**	**Scenario C**	**Scenario D**	**Scenario E**	**Scenario F**
Targets Set for:	Present	Future (2050s)	Future (2080s)	Present + Future (both)	Present	Futures (both)
Footprint:	Permanent + Semi-Permanent	Permanent	Permanent	Permanent + Semi-Permanent	Permanent + Semi-Permanent	Permanent
Locked-in Areas:	None	None	None	None	Protected Areas + Least-Cost Paths	Omniscape "Bones"

Table 11. Parameters for each scenario.

5.6.1 Scenario A – Present Conservation Features

Scenario A's solution encompasses 59% of the greater territory study area. Given its focus on existing high-quality habitat for a broad collection of species, the solution contains clusters along both river valleys and moderate to high elevation mountain ranges. River valleys of note include the Omineca, Ospika, Mesilinka, and Ingenika. Important montane areas include the northern Misinchinka Ranges and Wolverine Range in the southern extent of the study area, as well as the Omineca Ranges west of Kwadacha in the north (Figure 63).

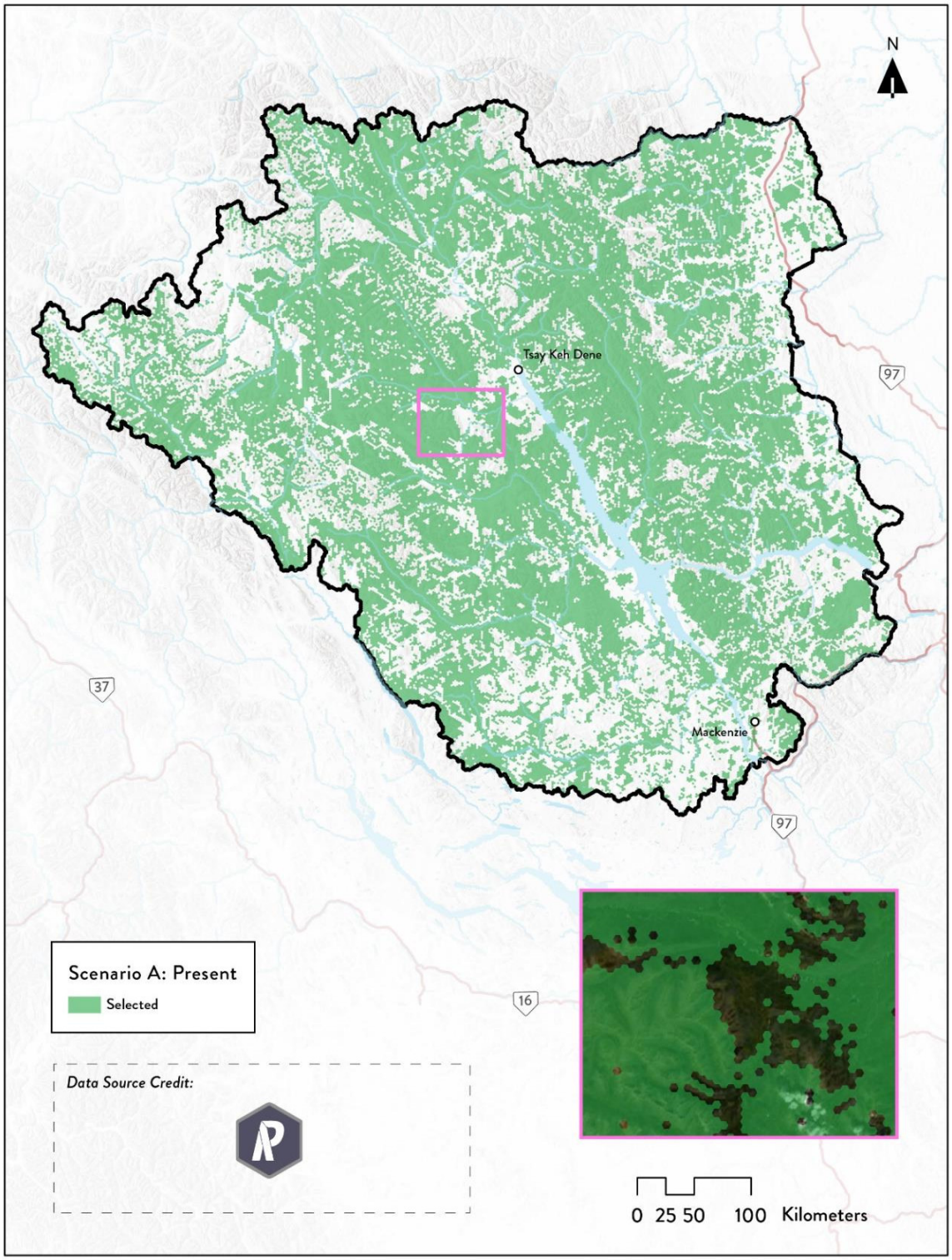

Figure 63. Spatial extent of the conservation solution for Scenario A: Present Conservation Features within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.6.2 Scenario B – Future (2050s) Conservation Features

Scenario B's solution encompasses 52% of the greater territory study area. Given its emphasis on future climates, moderate to high elevation areas are well represented as they serve as refugia in a warming landscape. Clustering is quite evident in this solution, particularly in the Rocky Mountains along the eastern shores of the Williston Reservoir. Additional clusters can be found along the Skeena River, in the Muskwa Ranges west of Redfern Lake, and along the Finlay River (Figure 64).

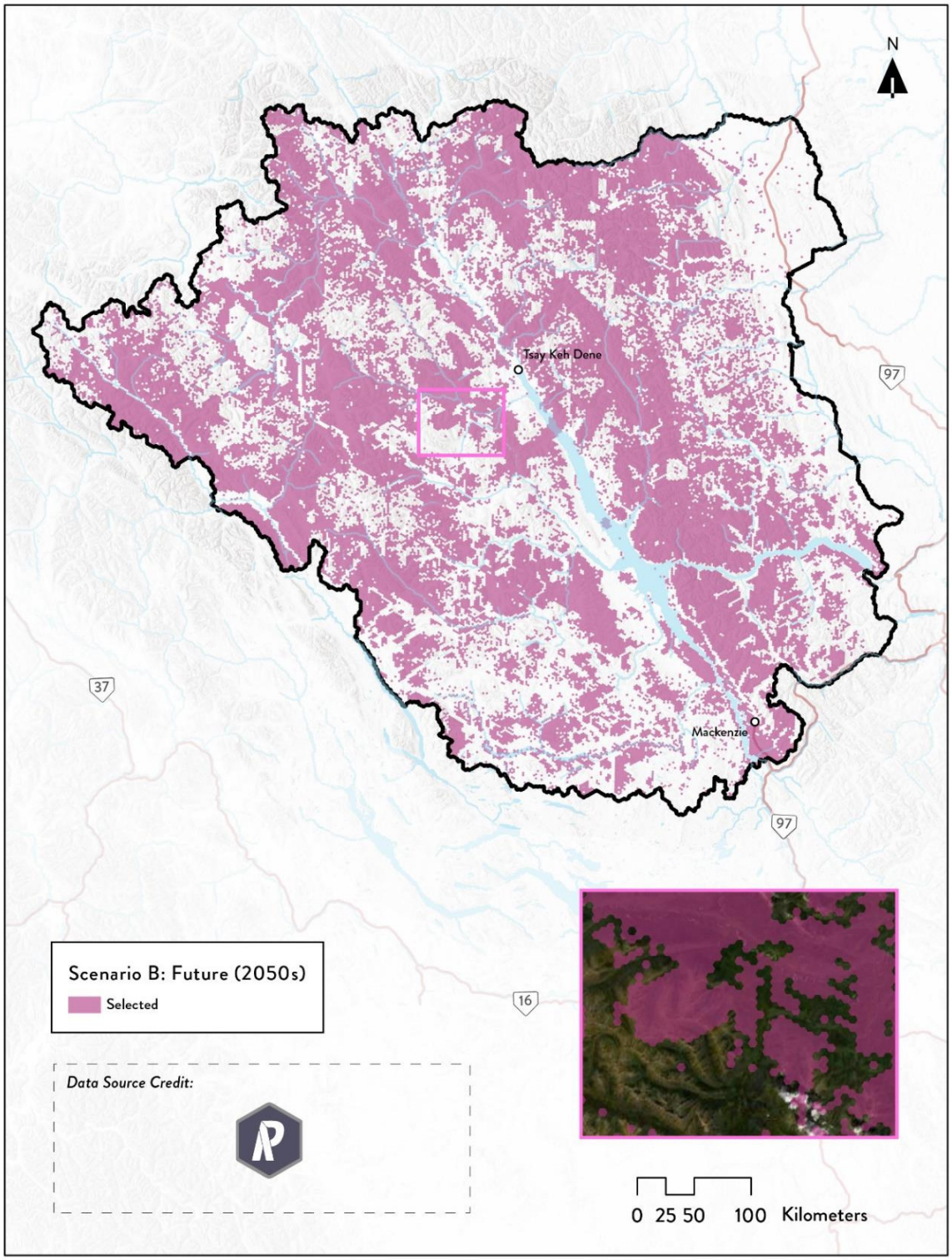

Figure 64. Spatial extent of the conservation solution for Scenario B: Future (2050s) Conservation Features within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.6.3 Scenario C – Future (2080s) Conservation Features

Scenario C's solution encompasses 52% of the greater territory study area. As only a few of the climate change features are time period specific, this solution is incredibly similar to that of Scenario B. A notable shift northward is evident, however, with low elevation patches in the southwest and east migrating northward and bolstering higher elevation patches (Figure 65).

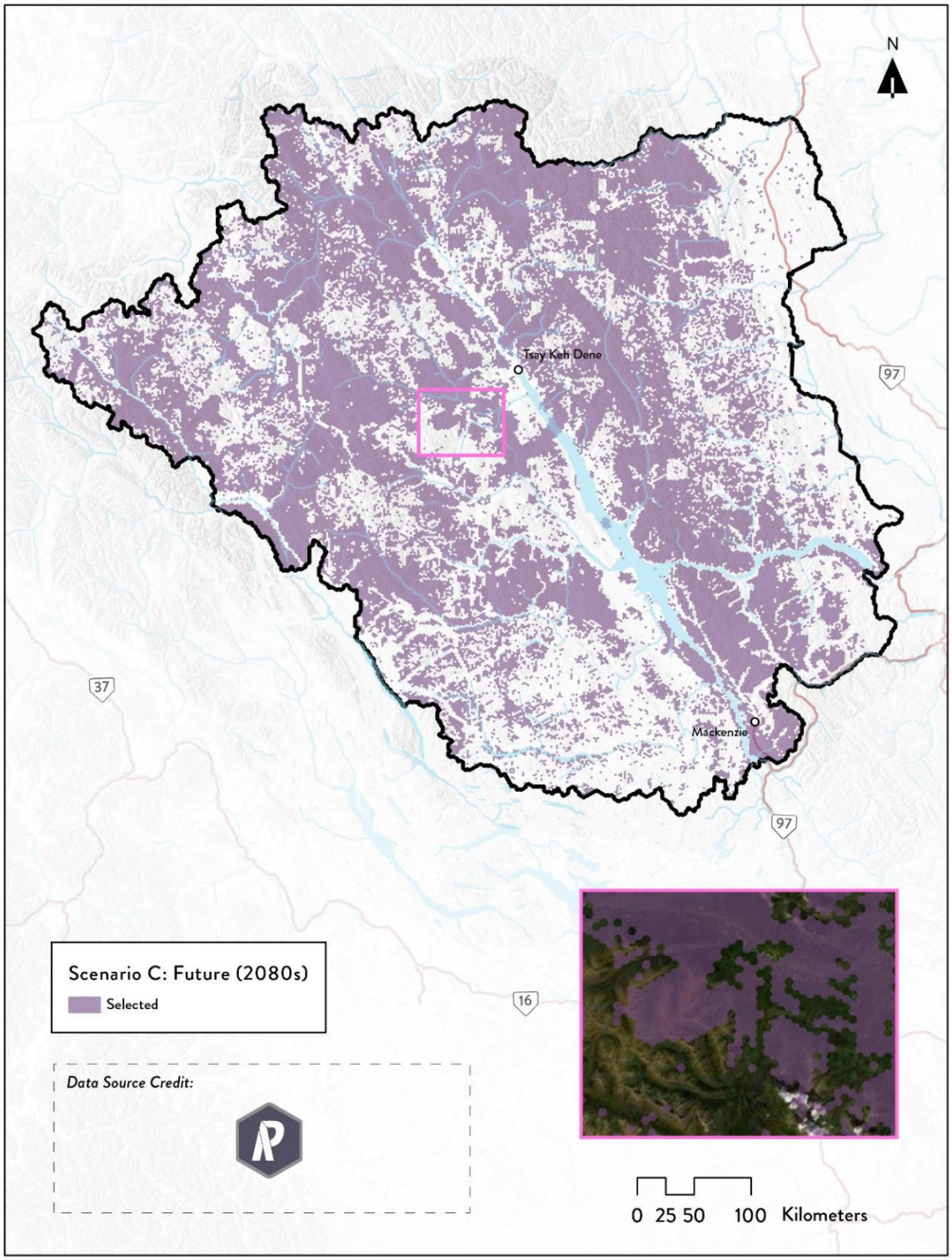

Figure 65. Spatial extent of the conservation solution for Scenario C: Future (2080s) Conservation Features within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.6.4 Scenario D – Present-day and Future (2050s and 2080s) Conservation Features

Scenario D's solution encompasses 61% of the greater territory study area. This is the largest solution yet, which is expected given that targets were set on both present and future features. It is noteworthy, however, that this solution is only 2% larger than the present scenario. As it combines targets from the previous three scenarios, the clustered high value areas are understandably similar, with the most notable blocks found on either side of the northerly half of the Williston Reservoir (Figure 66). Figure 67 allows for comparisons among the first four solutions.

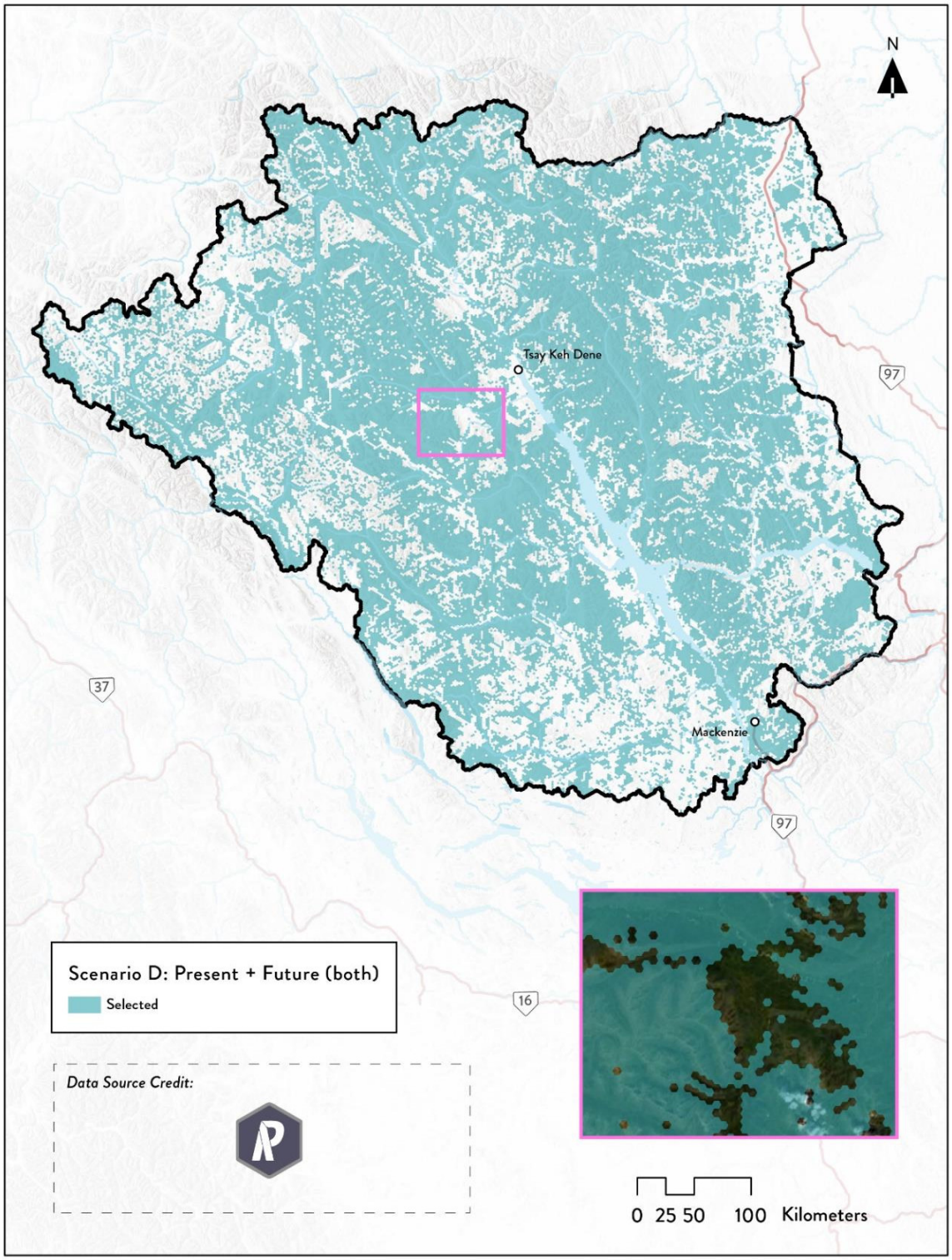

Figure 66. Spatial extent of the conservation solution for Scenario D: Present-day and Future (2050s and 2080s) Conservation Features within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

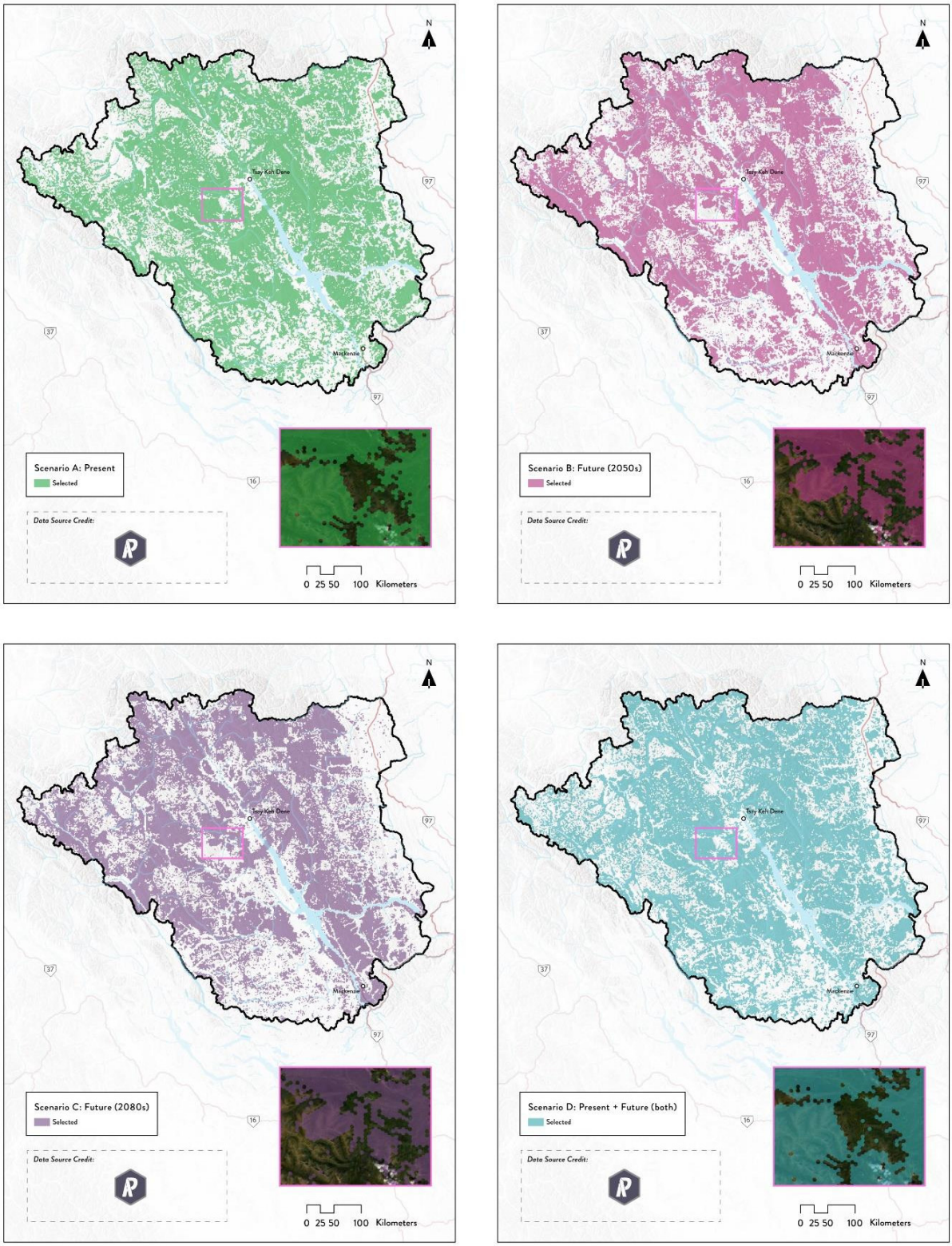

Figure 67. Spatial extent of solutions A-D in the Greater Tsay Keh Dene Territory Study Area for comparison purposes; inset represented by pink frame.

5.6.5 Scenario E – Protected Areas Connectivity

Scenario E's solution encompasses 62% of the greater territory study area. Ignoring existing protected areas – as they were locked in for this solution – the most notable clusters are found along the Ospika and Omineca Rivers, the Mesilinka River south of Chase Provincial Park, and the northern edge of the Misinchinka Ranges (Figure 68).

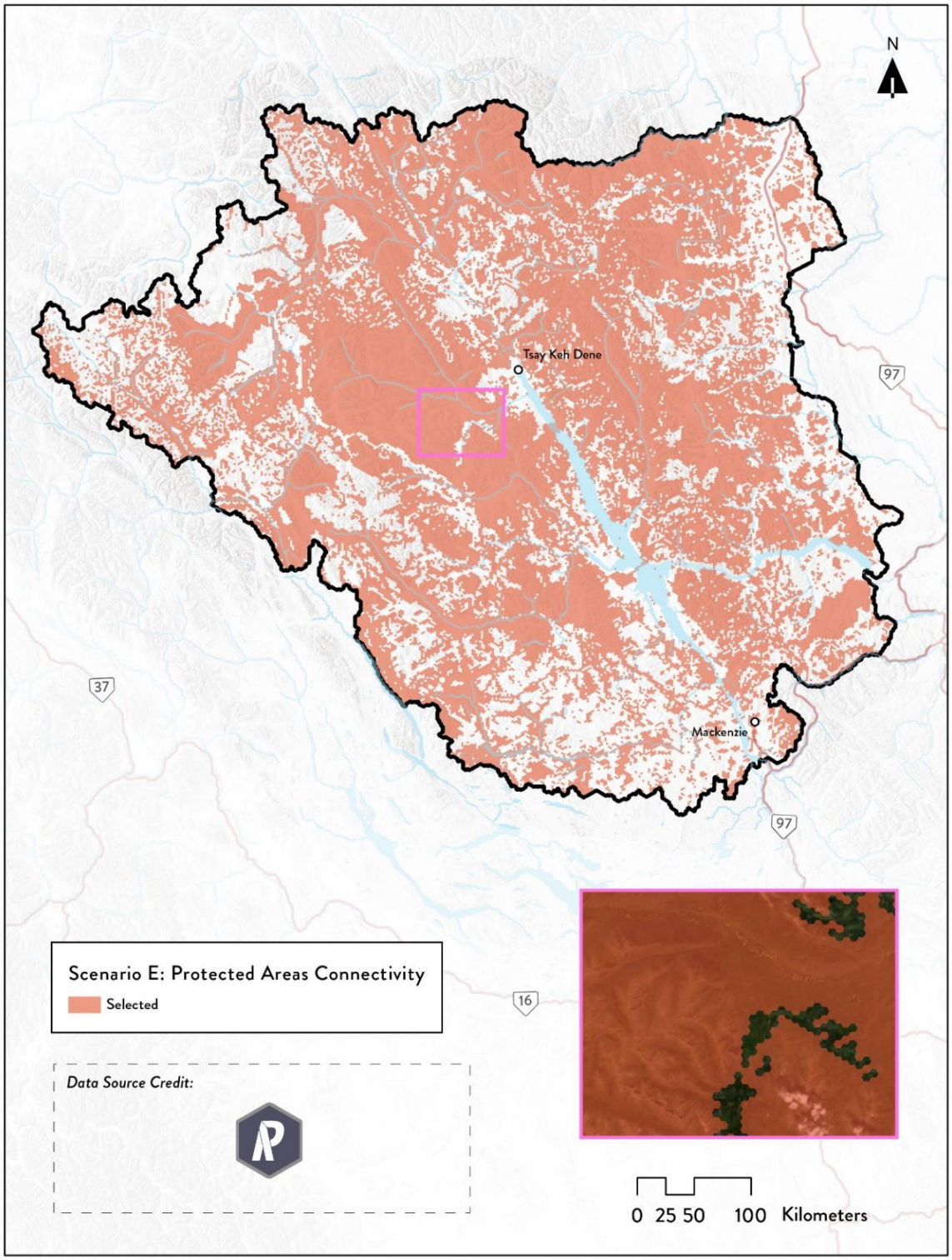

Figure 68. Spatial extent of the conservation solution for Scenario E: Protected Areas Connectivity within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.6.6 Scenario F – Landscape Connectivity

Scenario F's solution encompasses 54% of the greater territory study area. Despite its focus on overall landscape connectivity and not just connectivity between protected areas, scenario F shares a remarkable amount of overlap with scenario E. Scenario F is generally a leaner version of Scenario E, with the exception of more robust collections in the southern Muskwa Ranges, south of Omineca Provincial Park, and along the Skeena and Omineca Rivers (Figure 69).

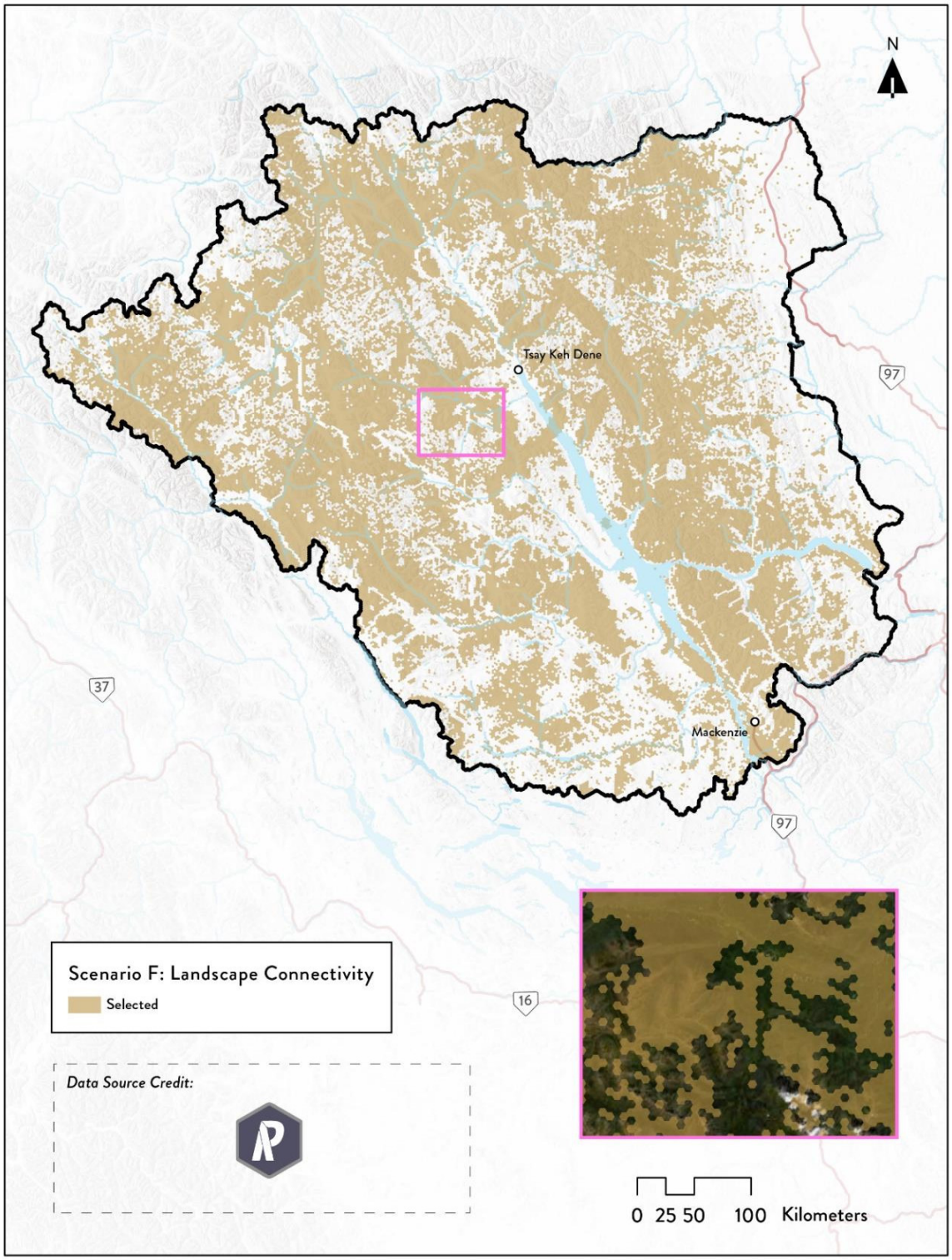

Figure 69. Spatial extent of the conservation solution for Scenario F: Landscape Connectivity within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

5.6.7 Scenario Stack

I stacked each of the aforementioned six scenarios to reveal which areas were consistently selected despite each scenario having different focuses on the present, future, and connectivity. This exercise acknowledged areas of cultural significance, as we placed the same high targets on them in each scenario, but also revealed other portions of the landscape that were consistently selected. These include the northern edge of the Misinchinka Ranges, the southern Muskwa Ranges, the Omineca, Sustut, and Skeena River valleys, the Toodoggone and Fox River watershed groups, and portions of the Besa and Prophet River valleys (Figure 70).

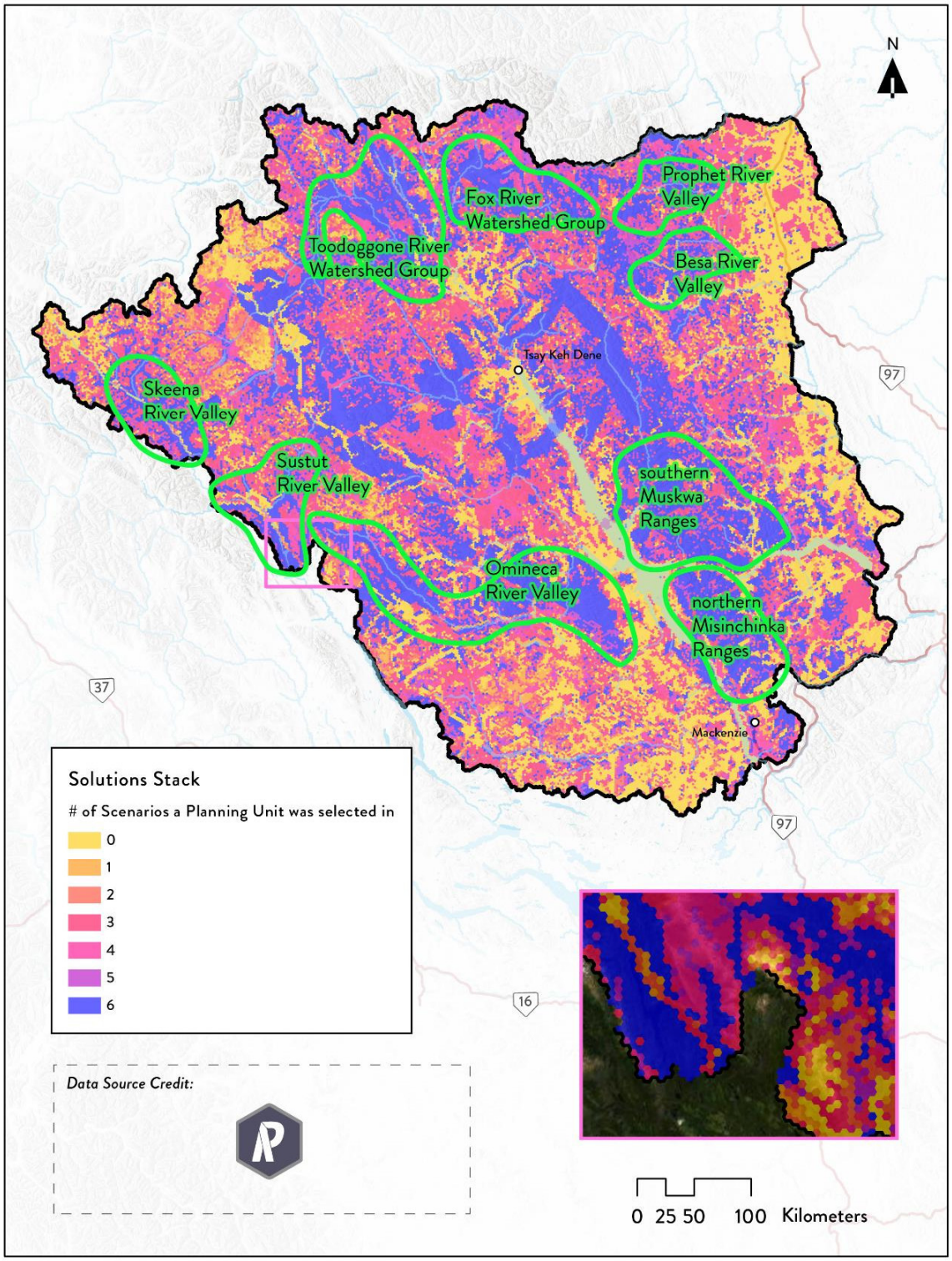

Figure 70. Spatial extent of conservation solutions for Scenarios A-F stacked atop one another to reveal areas that were consistenly selected in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame and referenced areas outlined and labeled in green.

5.6.8 Conservation Feature Diversity

I also stacked each of the conservation features for which targets were set (52 in all) to identify 'hotspot' areas of overlap, or conservation feature diversity. These were predominantly in river valleys near confluences. Notable hotspots included: the Sustut River near Red Creek; Pelly Creek near the Ingenika River and Tucha Creek; the Mesilinka River near Carina Lake; the headwaters of the Davis River; the Ospika River from McCusker Creek to the Williston Reservoir; the Wicked River near Ignatieff and Cowart Creeks; and the Omineca River near Henschel Creek. One additional, non-riparian hotspot was located north of the Nation Arm of the Williston Reservoir near Maybeline Lake. Each of the aforementioned locations contained one or more planning units with at least 25 overlapping conservation features. The maximum number of overlapping conservation features was 28 – found in just two planning units across the study area. One was at the Davis River headwaters hotspot, the other on Stevenson Creek near the Ospika River hotspot. These two planning units were selected in all six of the scenarios I ran (Figure 71). Figure 72 allows for comparisons between the connectivity-centric solutions, as well as between the stacked outputs.

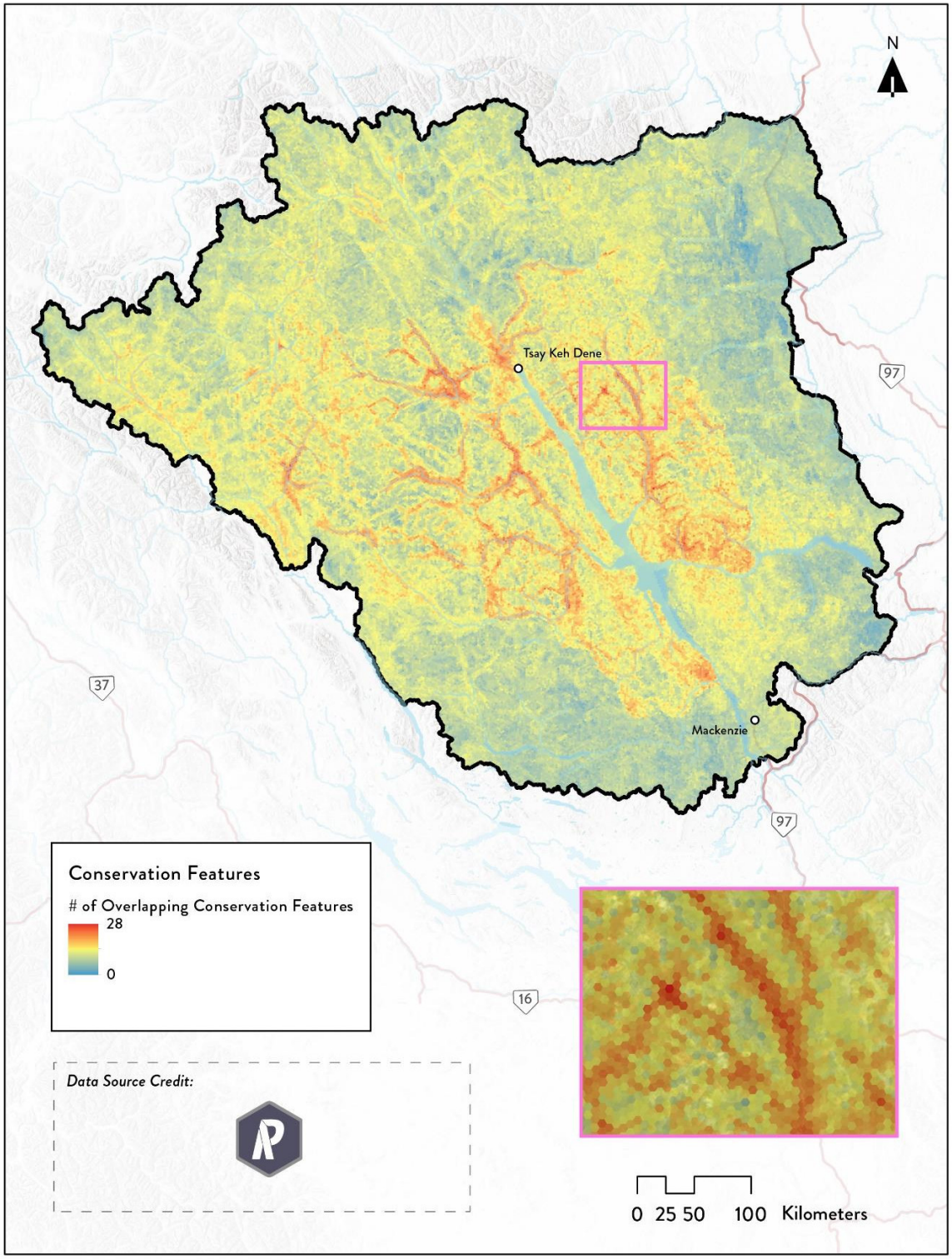

Figure 71. Spatial extent of all conservation features stacked atop one another to reveal areas of high conservation feature diversity, or 'hotspots' in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

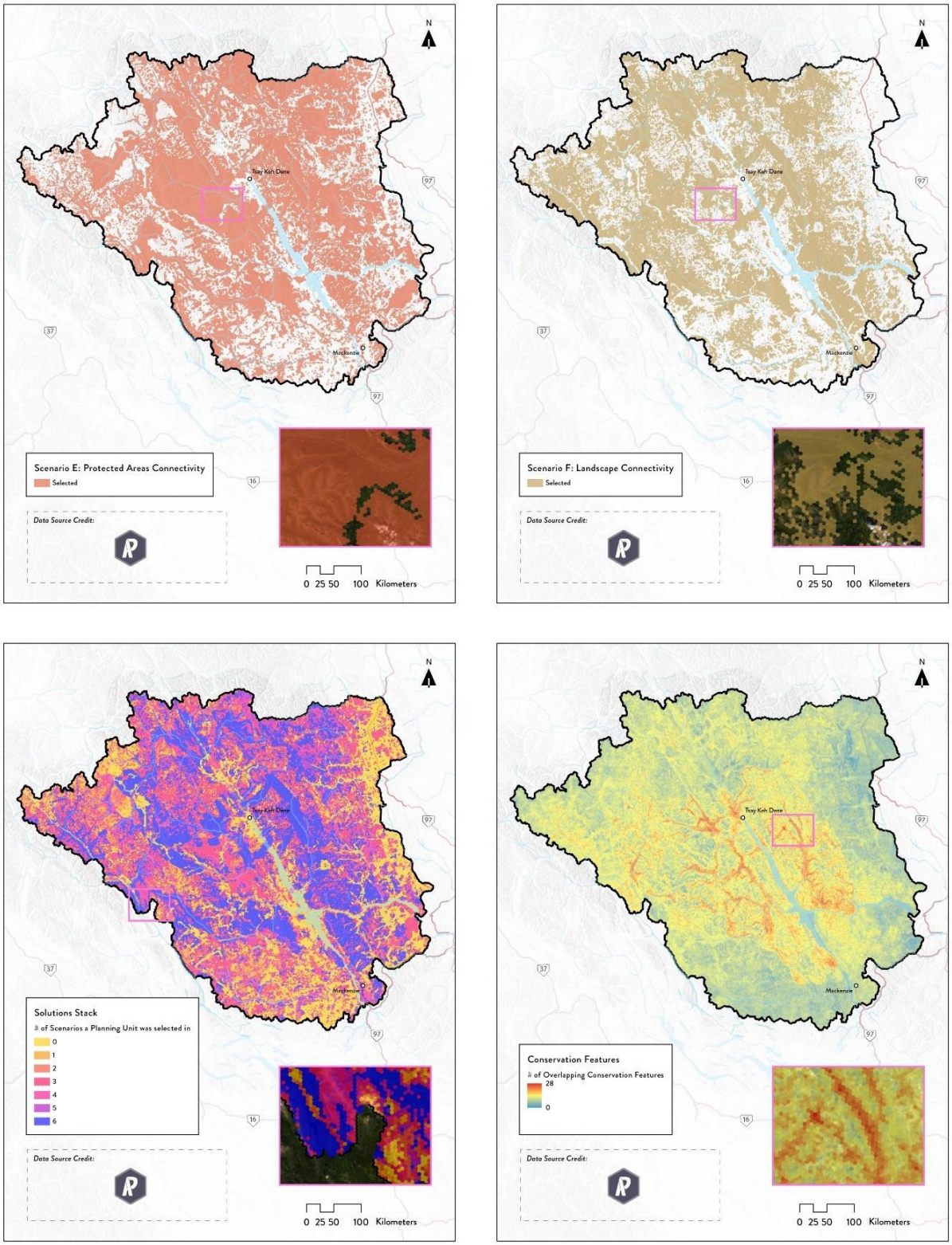

Figure 72. Spatial extent of solutions E and F in the Greater Tsay Keh Dene Territory Study Area for comparison purposes; stacked solutions and conservation feature stack also shown side by side for comparison purposes; inset represented by pink frame.

Conservation Feature	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E		Scenario F	
	% Target	% Captured	% Target	% Captured	% Target	% Captured	% Target	% Captured	% Target	% Captured	% Target	% Captured
Sites of Cultural Importance	100	100	100	100	100	100	100	100	100	100	100	100
Cultural/Spiritual Areas	80	80	80	80	80	80	80	80	80	80	80	80
Subsistence Areas	80	80	80	80	80	80	80	80	80	80	80	80
Wetlands	50	58	0	48	0	48	50	60	50	60	0	50
Lakes	70	70	0	54	0	54	70	70	70	70	0	54
Karst Deposits	60	68	0	67	0	68	60	74	60	75	0	68
Grizzly Bear	60	64	0	58	0	58	60	64	60	65	0	60
Bull Trout/Fish	80	80	0	64	0	66	80	80	80	80	0	67
Fisher	60	60	0	37	0	36	60	60	60	60	0	38
Chase Caribou Herd	90	90	0	54	0	54	90	90	90	90	0	58
Finlay Caribou Herd	90	90	0	66	0	68	90	90	90	90	0	65
Frog Caribou Herd	90	90	0	62	0	63	90	90	90	90	0	68
Gataga Caribou Herd	90	90	0	45	0	49	90	90	90	90	0	49
Graham Caribou Herd	90	90	0	69	0	57	90	90	90	90	0	64
Kennedy Siding Caribou Herd	90	92	0	47	0	86	90	91	90	91	0	47
Klinse-za Caribou Herd	90	90	0	79	0	83	90	90	90	90	0	83
Pink Mountain Caribou Herd	90	90	0	61	0	66	90	90	90	90	0	60
Thutade Caribou Herd	90	90	0	57	0	61	90	90	90	90	0	56
Wolverine Caribou Herd	90	90	0	49	0	49	90	90	90	90	0	52
Faux North Caribou Herd	0	27	0	48	0	57	0	36	0	44	0	56
Faux Central Caribou Herd	0	85	0	70	0	69	0	87	0	82	0	69
Faux South Caribou Herd	0	20	0	93	0	65	0	22	0	13	0	80
Moose	70	70	0	47	0	47	70	70	70	70	0	48
Stone Sheep	70	70	0	66	0	67	70	76	70	83	0	62
Mountain Goat	70	70	0	65	0	66	70	70	70	70	0	64
Wolverine	60	72	0	61	0	61	60	73	60	75	0	64
Bank Swallow	40	45	0	27	0	28	40	45	40	45	0	28
Barn Swallow	60	60	0	43	0	43	60	60	60	60	0	44
Western Toad	60	71	0	60	0	60	60	71	60	73	0	61
Horned Grebe	40	52	0	33	0	33	40	51	40	51	0	34
Little Brown Myotis	60	71	0	60	0	60	60	72	60	75	0	62
Northern Myotis	60	71	0	51	0	52	60	71	60	72	0	53
Olive-Sided Flycatcher	40	59	0	42	0	42	40	59	40	58	0	43
Rusty Blackbird	60	62	0	44	0	45	60	62	60	62	0	46

Table 12. Percentage of each conservation feature by target and actual amount captured for each scenario.

Conservation Feature	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E		Scenario F	
	% Target	% Captured	% Target	% Captured	% Target	% Captured	% Target	% Captured	% Target	% Captured	% Target	% Captured
NDT1-ESSF-Burned	100	100	0	74	0	77	100	100	100	100	0	80
NDT1-ESSF-Old	70	70	0	77	0	79	70	72	70	72	0	78
NDT2-ESSF-Burned	100	100	0	42	0	44	100	100	100	100	0	46
NDT2-ESSF-Old	56	61	0	65	0	61	56	61	56	60	0	65
NDT2-SBS-Burned	100	100	0	30	0	32	100	100	100	100	0	34
NDT2-SBS-Old	88	88	0	45	0	44	88	88	88	88	0	46
NDT2-SWB-Burned	100	100	0	72	0	75	100	100	100	100	0	72
NDT2-SWB-Old	52	65	0	63	0	66	52	65	52	69	0	66
NDT3-BWBS-Burned	100	100	0	44	0	48	100	100	100	100	0	48
NDT3-BWBS-Old	52	63	0	39	0	42	52	62	52	64	0	43
NDT3-SBS-Burned	100	100	0	22	0	22	100	100	100	100	0	26
NDT3-SBS-Old	62	62	0	37	0	32	62	62	62	62	0	36
Rare BEC Zones	60	60	0	50	0	49	60	60	60	60	0	50
Land Facet Diversity	0	58	80	80	80	80	80	80	0	60	80	80
Land Facet Rarity	0	48	80	80	80	80	80	80	0	54	80	80
Elevational Diversity	0	67	67	67	67	67	67	69	0	72	67	67
Ecotypic Diversity	0	59	59	59	59	59	59	59	0	61	59	59
Heat Load Index Diversity	0	68	68	68	68	68	68	70	0	74	68	68
Climate Corridors	0	61	61	61	61	61	61	64	0	66	61	61
Backward Velocity 2055	0	64	64	64	0	60	64	64	0	66	64	64
Backward Velocity 2085	0	60	0	60	60	60	60	61	0	63	60	62
Forward Velocity 2055	0	49	50	50	0	44	50	51	0	49	50	50
Forward Velocity 2085	0	52	0	49	52	52	52	53	0	53	52	52
Bird Richness	0	58	58	58	58	58	58	59	0	61	58	58
Carbon Storage	0	61	61	61	61	61	61	62	0	64	61	61
Cool Headwater Refugia	0	57	80	80	80	80	80	80	0	75	80	80
Climatic Refugia	0	63	63	63	63	63	63	65	0	68	63	63
Biotic Refugia	0	62	70	70	70	70	70	71	0	72	70	70
Omniscape	0	71	0	65	0	65	0	73	0	76	0	76
Linkage Mapper	0	70	0	67	0	67	0	72	0	75	0	73

	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F
Total Area	58.8%	52.1%	51.9%	60.6%	62.1%	53.7%

(Table 12 continued)

5.8 Conservation Feature Complementarity

I ran auxiliary scenarios for each conservation feature where a 100% target was set for that feature alone. In doing so, I determined the degree to which each feature contributed to a focal feature (i.e., how well each feature complemented one another). For example, referencing the fisher row in Table 13, I evaluated what percentage of other conservation features (columns) fall within the extent of the fisher layer. As the fisher layer takes up much of the lower elevation portions of the study area, it contains 62.9% of the moose layer and 100% of the bank swallow layer. Conversely, the fisher layer contains only 21.7% and 29.4% of the Chase caribou herd and grizzly bear layers, respectively – species that gravitate towards higher elevations. Features that were 50% or more represented within another feature were considered to have high complementarity and are identified in bold. Where a column and row of the same feature align, values of "100" are highlighted diagonally across the complementary matrix. This also revealed instances where one feature was completely contained within another feature.

Conservation Feature	Sites of Cultural Importance	Cultural/Spiritual Areas	Subsistence Areas	Wetlands	Lakes	Karst Deposits	Grizzly Bear	Bull Trout/Fish	Fisher	Chase Caribou Herd	Finlay Caribou Herd	Frog Caribou Herd	Gataga Caribou Herd	Graham Caribou Herd	Kennedy Siding Caribou Herd	Klinse-za Caribou Herd	Pink Mountain Caribou Herd	Thutade Caribou Herd	Wolverine Caribou Herd	Moose	Stone Sheep	Mountain Goat	Wolverine	Bank Swallow	Barn Swallow	Western Toad	Horned Grebe	Little Brown Myotis	Northern Myotis	Olive-Sided Flycatcher	Rusty Blackbird	NDT1-ESSF-Burned	NDT1-ESSF-Old	NDT2-ESSF-Burned	NDT2-ESSF-Old	NDT2-SBS-Burned	NDT2-SBS-Old	NDT2-SWB-Burned	NDT2-SWB-Old	NDT3-BWBS-Burned	NDT3-BWBS-Old	NDT3-SBS-Burned	NDT3-SBS-Old	Rare BEC Zones	Land Facet Diversity	Land Facet Rarity	Elevational Diversity	Ecotypic Diversity	Heat Load Index Diversity	Climate Corridors	Backward Velocity 2055	Backward Velocity 2085	Forward Velocity 2055	Forward Velocity 2085	Bird Richness	Total Biomass	Cool Headwater Refugia	Climatic Refugia	Biotic Refugia	Omniscape	Linkage Mapper
Sites of Cultural Importance	**100**	3.3	7.5	0.9	0.9	0.4	0.5	4.6	1.1	0.6	0.5	0	0	0.2	0	0	0	0.5	0.2	1.0	0.3	0.2	1.1	3.9	1.3	1.5	3.5	1.7	2.9	2.3	2.8	0	0.4	0.3	0.2	1.1	1.2	0.2	0.4	0.7	0.9	2.2	1.1	0.3	0.3	0.3	1.0	0.5	0.7	0.3	0.4	0.3	0.3	0.5	0.6	0.6	0.1	0.5	0.3	0.4	0.5
Cultural/Spiritual Areas	41.9	**100**	25.0	11.3	9.6	9.8	9.4	43.6	11.4	19.2	14.3	0	0	2.1	0	0.9	0	8.0	14.9	11.2	6.1	6.1	22.0	36.3	23.5	23.2	35.6	24.4	30.4	28.8	32.0	0.8	6.5	9.2	6.7	7.4	9.0	2.3	15.9	9.2	13.5	7.4	8.3	2.7	8.7	6.0	13.8	10.2	9.3	7.0	9.4	9.2	4.2	6.4	11.4	9.4	4.7	7.7	7.6	8.2	8.5
Subsistence Areas	14.0	4.5	**100**	1.4	1.5	1.4	1.9	7.8	2.0	4.9	1.0	0	0	0	0	0	0	3.7	0	1.4	1.1	0.4	3.0	7.8	4.5	3.0	6.8	3.4	4.5	4.1	4.9	0	0.2	2.5	0.3	1.1	1.2	8.2	2.0	7.1	1.8	1.5	2.4	0.0	1.3	3.5	2.5	1.1	1.8	0.3	0.7	1.0	0.7	1.0	1.3	1.1	0.6	1.2	0.7	1.0	0.6
Wetlands	**80.4**	**68.7**	**61.9**	**100**	**83.7**	**52.1**	**60.8**	**79.2**	**72.3**	**65.5**	46.3	**57.1**	**62.4**	25.1	**90.9**	**63.0**	6.0	**64.9**	**80.1**	**68.6**	15.7	20.4	**64.5**	**78.1**	**62.7**	**72.4**	**81.0**	**67.9**	**83.2**	**95.8**	**85.2**	**50.0**	**71.2**	**55.9**	**54.8**	**65.1**	**75.8**	45.9	**62.5**	**71.5**	**67.9**	**83.1**	**84.3**	46.6	**65.6**	**69.5**	**53.8**	**63.2**	48.6	47.1	45.7	47.0	**68.7**	**66.2**	**68.9**	**59.3**	22.5	45.8	36.4	**52.2**	**53.8**
Lakes	27.5	22.4	20.1	33.7	**100**	13.5	19.5	21.5	22.4	27.1	5.4	25.1	16.5	6.1	7.8	16.0	8.3	29.2	27.4	21.5	8.9	16.0	18.2	20.5	19.3	28.5	21.7	18.8	23.0	36.3	23.2	4.0	10.0	9.0	17.8	6.0	8.6	14.4	28.1	18.1	21.3	19.9	30.4	17.6	27.7	24.8	17.0	23.2	17.5	20.0	22.0	27.3	20.1	18.2	29.1	16.8	17.3	18.2	23.6	19.3	18.3
Karst Deposits	25.4	27.3	38.5	23.1	18.0	**100**	25.2	44.8	22.5	14.3	**74.6**	**50.3**	45.4	**54.3**	10.4	42.6	**57.9**	24.0	5.2	26.2	**57.4**	36.2	31.8	21.0	23.4	36.5	23.2	32.1	34.3	23.5	27.4	**81.5**	**56.3**	25.1	15.0	16.5	41.2	**61.9**	30.8	30.8	23.6	21.8	16.3	20.0	37.2	47.8	37.9	23.1	42.3	34.1	20.4	14.8	23.6	26.3	21.0	25.5	**57.4**	35.3	36.9	32.2	38.1
Grizzly Bear	24.2	25.4	39.9	29.3	24.4	26.6	**100**	26.1	24.0	43.2	25.6	12.0	8.7	31.6	**89.6**	**64.5**	7.3	18.9	36.2	26.6	13.2	17.5	47.1	22.8	34.7	41.7	22.3	42.8	30.0	40.3	29.7	44.4	**65.9**	49.0	**60.4**	43.1	42.0	12.0	18.5	22.6	16.9	34.6	31.5	37.2	33.4	26.3	30.5	30.7	29.3	26.3	40.3	32.4	37.5	38.6	28.5	38.1	8.2	25.4	14.7	30.0	29.6
Bull Trout/Fish	21.5	14.6	15.7	4.4	3.1	5.1	2.6	**100**	5.7	7.9	7.6	0	0	1.6	0	0	0.3	1.1	0.5	4.8	1.8	1.0	7.5	10.2	4.0	7.8	12.4	9.1	14.6	8.8	14.0	0	2.4	4.2	1.7	0.3	11.2	4.0	3.4	10.2	8.0	2.7	2.9	1.0	1.8	0.5	5.2	1.9	4.4	1.2	1.5	1.6	1.0	3.3	3.4	3.4	1.2	3.1	0.9	3.0	3.6
Fisher	**69.2**	**51.6**	**54.6**	**51.9**	42.9	30.2	29.4	**72.0**	**100**	21.7	17.4	9.1	40.4	16.7	0	8.2	0.5	0.6	38.6	**62.9**	2.4	1.3	31.3	**100**	48.1	33.3	**99.5**	40.0	**76.5**	**64.9**	**90.1**	**51.6**	21.6	41.8	15.5	**100**	**100**	37.1	3.4	**100**	**100**	**100**	**100**	**57.8**	42.8	**63.1**	36.4	41.6	26.5	19.2	15.0	10.1	**59.5**	**58.1**	45.9	38.1	0.1	28.1	0.4	20.9	20.0
Chase Caribou Herd	7.4	13.4	24.1	7.1	7.7	2.9	9.9	17.4	3.4	**100**	0	0	0	0	0	0	0	0	0	4.4	5.5	3.3	18.2	3.8	14.7	14.6	6.6	16.4	12.7	14.8	12.5	0	0	19.4	11.2	0.3	3.1	3.8	12.7	10.1	6.1	22.6	2.8	0.0	3.2	1.8	9.5	5.1	8.6	3.9	10.4	11.8	0.2	0.8	7.8	6.1	4.8	5.1	8.7	8.1	5.6
Finlay Caribou Herd	5.3	6.6	3.7	3.6	1.2	16.1	4.7	12.8	2.3	0	**100**	0	0	0	0	0	0	0	0	3.2	18.7	11.1	7.1	0.5	2.1	7.2	1.2	6.4	4.5	1.5	3.1	0	0.4	1.0	3.3	1.1	0.4	7.1	7.3	4.7	4.5	0.7	0.3	0.2	6.2	1.5	9.5	1.4	10.0	6.9	1.4	3.9	0.2	1.1	3.1	5.2	20.6	6.3	12.8	6.5	8.9
Frog Caribou Herd	0	0	0	1.0	1.3	1.8	0.6	0	0.3	0	0	**100**	0	0	0	0	0	0	0	0.5	0.6	2.6	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0	1.6	0.9	0.6	0.6	0	0	0	0.5	1.5	2.1	0.9	2.4	1.6	0	0.3	0.3	0.6	0.7	0.8	2.3	1.5	2.4	1.6	1.6
Gataga Caribou Herd	0	0	0	1.1	0.9	2.2	0.3	0	1.0	0	0	0	**100**	0	0	0	0	0	0	1.4	2.0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0.8	1.0	1.1	2.5	0	0	0	1.0	0.2	0.8	1.1	1.2	1.6	0	0	0.2	0.5	0.8	1.0	2.3	0.9	1.4	1.3	2.3
Graham Caribou Herd	1.1	0.8	0	1.6	1.1	8.6	4.6	2.3	1.7	0	0	0	0	**100**	0	0	0	0	0	3.5	6.1	1.3	4.7	0.1	3.3	6.2	0.3	4.6	4.3	2.1	1.0	13.7	5.2	7.4	7.7	0.3	0.8	0	0.1	1.1	2.8	0	0.6	3.7	5.2	3.5	2.5	4.2	5.6	7.2	13.3	2.0	3.2	1.1	3.7	4.7	2.1	7.0	3.1	6.7	5.8
Kennedy Siding Caribou Herd	0	0	0	0.1	0.0	0.0	0.3	0	0	0	0	0	0	0	**100**	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0	0	0	0	0.2	0	0.1	0.0	0.2	0.0	0.1	0	0	0.2	0.6	0	0.2	0	0.0	0.3	0	0
Klinse-za Caribou Herd	0	0.2	0	1.8	1.3	3.5	4.7	0	0.3	0	0	0	0	0	0	**100**	0	0	0	1.0	0.7	5.0	0.1	0.5	0.1	0.2	0.4	0.1	0.3	0.3	0.3	20.2	21.3	4.2	1.2	2.2	1.4	0	0	0	0	0	0.3	6.6	2.6	3.2	1.9	2.7	1.4	3.1	0.9	0	6.5	11.8	0.5	2.3	0	1.9	1.9	2.3	3.4
Pink Mountain Caribou Herd	0	0	0	0.3	0.9	4.1	0.5	0.2	0.0	0	0	0	0	0	0	0	**100**	0	0	1.2	18.3	7.2	0.1	0	0.2	0.2	0	0.1	0.1	0.1	0	0	0	0	0	0	0	6.2	4.3	0.1	0.0	0	0	0.0	1.7	0.6	2.3	1.9	3.6	4.1	0.4	1.9	0.0	0.1	1.0	0.7	10.0	4.4	6.2	2.7	3.4
Thutade Caribou Herd	3.6	3.7	10.9	4.5	5.2	2.5	2.7	1.6	0.0	0	0	0	0	0	0	0	0	**100**	0	0.9	7.6	6.9	7.2	0	6.9	8.1	0.0	6.2	2.1	4.6	0.4	0	0	0	0.1	0	0	8.5	17.6	0.4	0.1	0	0	0.0	1.9	1.8	4.1	3.8	4.8	5.8	3.6	8.7	0.1	0.2	2.9	2.9	4.8	6.2	10.3	5.5	6.0
Wolverine Caribou Herd	0.9	5.3	0	5.4	4.6	0.8	6.0	0.6	3.4	0	0	0	0	0	0	0	0	0	**100**	4.4	0	2.1	4.1	2.3	2.5	3.1	3.5	4.0	4.9	4.1	4.5	0	0	3.4	8.2	0	2.7	0	0	0.6	4.6	1.5	4.2	0.2	3.8	1.0	2.9	6.9	0.9	1.7	4.5	3.5	4.1	0.9	5.8	5.3	0	0.9	0.9	4.2	3.3
Moose	**63.6**	49.2	42.4	**53.5**	43.9	34.3	37.6	**65.6**	**71.4**	37.2	17.4	13.3	38.6	28.5	36.4	21.0	14.8	6.0	**58.7**	**100**	4.4	4.5	47.4	**67.4**	37.4	48.8	**71.5**	**52.7**	**75.5**	**72.0**	**75.4**	**54.8**	42.8	**51.6**	36.7	37.9	**67.3**	34.0	18.3	**73.5**	**74.1**	**78.4**	**66.8**	41.3	49.6	**57.3**	36.7	43.6	31.1	25.9	27.4	16.5	46.0	45.6	47.8	41.7	0.8	34.4	4.5	29.9	28.7
Stone Sheep	2.7	3.5	5.3	1.2	2.3	13.1	3.0	3.6	0.2	5.2	22.5	3.1	11.7	8.6	0	2.3	48.5	11.3	0	1.0	**100**	44.0	1.3	0	1.2	2.3	0.0	1.0	0.2	0.2	0.0	0.8	0.2	3.1	1.5	0.3	0	12.1	6.3	0.6	0.6	0.5	0.0	1.4	2.6	4.7	8.8	3.7	10.4	10.3	4.0	7.6	0.7	0.8	2.4	2.4	39.0	9.4	24.7	7.0	9.1
Mountain Goat	4.1	6.0	3.1	2.7	7.0	14.6	6.8	3.5	0.3	5.3	22.7	23.4	12.9	3.2	0	27.5	32.7	17.5	5.9	1.4	**75.1**	**100**	2.2	0.1	4.4	5.5	0.2	2.0	0.3	0.9	0.2	5.7	4.3	4.8	8.0	0.3	0.5	8.3	7.1	0.1	0.2	0	0.5	9.4	7.4	9.4	13.4	6.0	16.2	16.8	11.7	19.2	4.1	6.1	5.7	4.8	**57.2**	14.3	40.6	11.6	14.0
Wolverine	38.9	44.2	44.5	20.9	16.4	23.5	30.8	**50.1**	16.2	**55.1**	27.5	0	0	21.3	0	0.5	1.2	34.3	21.3	22.2	4.2	4.2	**100**	21.1	37.5	**63.1**	30.2	**75.6**	**67.0**	**58.6**	49.8	34.7	34.0	46.4	36.5	9.6	32.4	15.9	39.7	24.3	20.6	27.7	13.7	9.4	19.6	14.2	26.6	17.9	24.3	16.5	28.2	20.7	10.2	8.2	22.1	26.0	2.3	18.3	7.8	24.3	26.0
Bank Swallow	45.8	25.0	33.2	10.1	6.4	4.2	5.2	25.5	14.8	3.9	0.8	0	0	0.1	0	1.8	0	0	3.9	9.9	0	0.1	7.2	**100**	33.5	15.5	**75.9**	14.2	32.7	33.9	42.5	0	0.2	0.6	0.0	5.2	5.5	0.4	0	11.3	9.6	21.3	19.9	0.4	6.2	10.8	8.4	4.1	4.4	0.9	0.2	0.1	8.6	10.4	8.3	3.6	0	2.5	0	1.4	1.6
Barn Swallow	20.9	20.6	26.6	9.3	8.2	7.3	10.8	11.7	7.6	20.1	3.7	0	0	6.7	0	0.4	0.7	14.6	5.8	7.1	1.7	3.8	17.0	49.8	**100**	27.4	41.0	16.8	12.4	27.1	26.2	10.5	2.5	32.0	7.3	4.7	5.5	10.0	15.7	12.7	3.8	26.5	11.3	3.2	8.8	7.3	10.1	6.5	8.3	5.8	10.1	8.7	7.2	6.3	10.7	6.8	2.0	6.3	4.3	5.9	7.4
Western Toad	32.3	30.4	26.4	17.6	16.1	17.7	17.8	32.2	10.7	27.9	17.7	0	0	17.6	0	1.3	1.3	24.4	10.3	13.9	4.6	6.6	39.8	29.1	38.8	**100**	30.5	39.6	38.6	**58.3**	34.6	28.2	16.5	16.2	17.2	5.8	7.5	9.2	29.1	11.9	11.3	12.8	12.0	6.6	17.2	12.4	14.6	10.8	14.6	11.7	18.7	14.3	6.8	5.3	15.7	14.0	3.6	11.9	6.0	12.7	15.6
Horned Grebe	**60.6**	40.3	44.5	16.4	11.8	8.4	8.0	**50.0**	25.5	13.7	3.3	0	0	1.2	0	1.8	0	0.1	11.8	17.8	0.0	0.2	19.5	**100.0**	41.5	27.0	**100**	28.2	**64.5**	**55.9**	**74.7**	9.7	3.2	10.4	1.7	11.8	23.6	2.9	0.8	27.1	23.3	36.8	27.6	2.3	8.2	14.8	14.6	8.9	8.4	2.5	1.8	1.6	11.6	13.6	13.5	8.2	0	5.6	0.2	4.1	4.2
Little Brown Myotis	**73.9**	**64.8**	**64.9**	28.7	21.7	29.4	36.1	**77.9**	25.7	**63.9**	31.5	0	0	25.4	0	1.8	1.4	38.1	27.0	31.3	4.2	4.8	**96.2**	**51.4**	47.9	**80.2**	**60.4**	**100**	**99.4**	**80.5**	**78.7**	33.9	35.4	**54.3**	38.1	15.1	36.5	19.0	41.5	34.8	28.7	41.7	23.9	11.7	25.6	21.8	34.7	22.1	29.7	18.8	31.9	23.0	14.3	12.9	28.5	32.0	2.8	22.5	8.7	28.0	30.4
Northern Myotis	**55.6**	36.6	35.5	16.5	11.9	13.4	10.8	**54.8**	22.3	21.4	9.4	0	0	10.9	0	1.8	0.3	5.6	14.0	18.9	0.3	0.3	37.1	**51.4**	15.3	34.1	**59.9**	44.0	**100**	**54.2**	**65.5**	13.7	9.8	20.8	10.1	11.0	24.5	6.4	12.2	28.9	24.8	35.5	21.5	3.5	8.4	13.6	15.2	10.1	11.4	5.5	6.5	3.9	8.2	9.3	13.4	12.2	0.3	8.8	0.6	9.0	8.5
Olive-Sided Flycatcher	36.4	28.4	26.3	16.8	14.6	6.9	11.5	26.7	15.5	20.0	2.6	0	0	4.2	0	1.4	0.2	9.8	9.6	13.6	0.3	0.7	26.2	45.9	27.6	41.8	46.0	28.3	43.9	**100**	47.6	1.6	6.2	12.4	9.2	4.1	10.2	2.4	12.3	12.9	14.4	15.4	19.8	1.8	8.7	12.4	9.8	9.3	6.9	4.8	7.7	6.1	8.2	7.2	12.2	8.1	0.5	5.3	2.1	4.9	5.5
Rusty Blackbird	**66.9**	48.0	49.8	20.3	14.9	12.0	12.3	**62.2**	29.9	24.4	7.7	0	0	2.6	0	1.8	0	1.1	15.2	21.8	0.0	0.2	32.0	**100**	48.4	35.9	**99.8**	39.9	**76.7**	**69.5**	**100**	19.4	10.3	21.3	8.4	16.8	36.6	5.0	5.7	33.6	28.7	41.9	30.6	4.7	8.8	17.6	19.2	12.0	12.0	4.4	5.4	4.3	13.6	15.2	17.6	12.6	0.0	8.5	0.5	7.4	8.0
NDT1-ESSF-Burned	0	0.0	0	0.1	0.0	0.5	0.2	0	0.2	0	0	0	0	0.5	0	1.5	0	0	0	0.2	0.0	0.1	0.3	0	0.2	0.3	0.1	0.2	0.2	0.0	0.2	**100**	1.6	0.1	0.0	14.3	1.5	0	0	0	0	0.3	0.0	0.6	0.2	1.2	0.3	0.2	0.2	0.3	0.2	0	0.5	0.4	0.1	0.2	0	0.2	0.0	0.1	0.3
NDT1-ESSF-Old	0.8	0.9	0.3	1.7	0.7	3.9	3.8	1.3	1.0	0	0.1	0	0	1.9	40.3	18.4	0	0	0	1.8	0.1	0.7	2.8	0.1	0.5	2.2	0.3	2.4	1.5	1.2	1.3	18.6	**100**	0.1	0.3	2.2	33.0	0	0	0	0	0	0.0	6.0	1.6	3.1	1.8	1.9	1.9	2.7	1.3	0.3	4.7	7.5	0.9	2.8	0.0	1.9	0.8	2.0	3.0
NDT2-ESSF-Burned	0.8	2.0	3.9	1.8	0.9	2.0	3.5	3.0	1.7	6.4	0.4	0	0	3.6	0	4.8	0	0	1.9	2.4	1.1	1.0	5.1	0.2	7.7	2.8	1.4	4.6	4.1	3.0	3.7	1.6	0.1	**100**	4.3	42.9	4.6	0.6	0.1	24.6	3.1	25.5	1.2	1.9	1.1	0.5	2.4	2.2	2.2	1.1	2.5	1.0	1.7	2.7	2.1	2.4	0.0	1.7	0.4	1.8	1.7
NDT2-ESSF-Old	3.1	6.7	2.3	9.5	8.2	5.7	20.9	6.0	4.0	18.3	6.9	0.4	0.8	18.8	0	6.8	0	0.3	23.0	9.5	2.6	8.1	19.7	0.0	8.7	14.6	1.1	16.3	9.8	11.1	7.0	0.8	2.0	21.4	**100**	9.1	21.5	0	3.6	2.8	2.8	5.2	8.3	10.9	10.5	1.5	9.4	11.9	10.8	9.3	22.4	17.8	11.7	8.8	12.4	16.4	0.6	8.3	3.4	13.5	12.9
NDT2-SBS-Burned	0.9	0.5	0.3	0.4	0.1	0.3	0.6	0.0	0.8	0.0	0.1	0	0	0.0	0	0.5	0	0	0	0.4	0.0	0.0	0.2	0.4	0.2	0.2	0.4	0.3	0.4	0.2	0.5	41.9	0.6	8.3	0.4	**100**	7.9	0	0	4.9	0.6	4.2	0.2	1.5	0.3	1.1	0.3	0.3	0.2	0.2	0.0	0	1.6	1.7	0.1	0.5	0	0.1	0	0.1	0.2
NDT2-SBS-Old	1.6	0.8	0.8	0.9	0.3	1.5	1.2	3.2	2.4	0.4	0.1	0	0	0.2	0	0.6	0	0	0.6	1.4	0	0.0	1.4	0.7	0.5	0.5	1.5	1.3	2.0	1.0	2.5	8.9	17.1	1.8	1.7	16.2	**100**	0	0	0.6	0.1	0	0.4	2.7	0.3	2.4	1.0	1.0	0.9	0.7	0.1	0	2.9	3.9	0.3	1.3	0	0.8	0	0.4	0.7
NDT2-SWB-Burned	0.6	0.2	6.3	0.8	0.8	1.9	0.4	1.5	0.7	0.6	1.5	1.5	0.8	0	0	0	2.8	2.2	0	1.2	2.1	0.8	0.9	0.1	1.2	0.8	0.2	0.8	0.6	0.3	0.4	0	0	0.3	0	0	0	**100**	3.2	16.0	1.5	0	0	0.1	1.0	0.4	1.8	1.4	1.8	1.1	0.4	0.7	0.1	0.4	0.8	0.8	0.5	1.7	0.5	0.9	0.7
NDT2-SWB-Old	3.8	7.3	6.4	5.4	6.3	5.1	2.9	5.0	0.4	8.8	6.4	3.4	4.4	0.1	0	0	8.4	19.3	0	2.6	4.7	3.0	9.1	0	8.2	10.5	0.2	7.4	5.0	6.3	2.0	0	0	0.1	1.5	0	0	13.5	**100**	0.8	0.9	0	0.1	0.1	3.6	3.9	3.5	4.8	5.3	7.2	5.7	8.1	0.4	0.8	4.3	4.3	3.2	6.3	4.5	6.1	6.6
NDT3-BWBS-Burned	3.9	2.2	11.6	3.1	2.1	2.3	1.8	8.3	5.1	3.5	2.1	1.1	2.4	0.6	0	0	0.1	0.2	0.4	4.4	0.2	0.0	2.8	3.8	3.2	2.2	5.0	3.1	5.9	3.3	6.0	0	0	25.8	0.6	26.4	1.6	34.4	0.4	**100**	10.9	2.0	0.1	2.7	1.1	3.1	2.8	2.4	2.7	1.0	0.4	0.4	1.5	2.7	2.4	1.6	0	2.4	0.1	1.4	1.1
NDT3-BWBS-Old	24.3	23.6	21.4	21.8	16.3	13.5	9.3	44.8	43.6	15.1	14.2	8.4	38.9	10.5	0	0	0.3	0.5	19.8	28.6	1.6	0.3	17.0	22.4	6.9	15.0	30.9	18.6	37.1	26.5	36.4	0	0	23.2	4.3	23.6	1.9	23.3	3.1	**78.7**	**100**	1.5	0.2	19.6	12.6	12.5	16.8	17.2	13.9	9.5	5.8	3.1	6.6	14.6	18.6	13.9	0.1	16.6	0.3	12.2	10.9
NDT3-SBS-Burned	1.7	0.6	0.5	0.8	0.5	0.3	0.6	0.4	1.3	1.6	0.1	0	0	0	0	0	0	0	0.2	0.9	0.0	0	0.7	1.6	1.4	0.5	1.6	0.8	1.5	0.8	1.5	0.8	0	5.6	0.2	4.7	0	0	0	0.4	0.0	**100**	3.9	0.7	0.5	0.3	0.5	0.5	0.4	0.1	0.2	0.1	0.8	0.4	0.7	0.4	0	0.2	0	0.2	0.2
NDT3-SBS-Old	23.4	11.0	19.1	17.4	18.2	5.7	10.9	10.8	31.3	4.7	0.6	0	0	1.5	0	1.5	0	0	11.9	16.8	0.1	0.6	7.5	33.9	14.5	10.7	30.2	10.4	21.6	24.3	25.5	0.8	0.1	5.9	8.4	4.7	4.6	0	0.1	0.3	0.1	**90.0**	**100**	16.7	20.0	20.0	7.3	13.5	5.5	2.7	6.6	6.5	25.3	12.5	15.5	12.4	0	3.3	0.0	4.0	3.0
Rare BEC Zones	11.9	5.3	0.6	20.8	18.4	18.3	33.0	7.0	40.9	0.1	0.8	0	0	23.8	**100**	**96.7**	0.5	0.2	0.8	26.0	4.9	21.5	13.4	1.1	8.9	14.3	3.4	12.9	7.7	5.7	8.9	**100**	**100**	21.5	30.1	**77.5**	**67.3**	5.5	1.2	35.4	40.8	22.1	24.9	**100**	24.2	44.6	20.2	21.9	20.3	29.9	33.8	27.8	45.7	**57.7**	21.0	30.1	2.3	27.7	8.8	19.6	20.5
Land Facet Diversity	2.7	4.5	4.6	5.9	6.4	5.7	5.4	3.0	6.1	2.5	5.1	2.2	4.3	5.3	0	5.7	3.4	1.9	4.9	5.9	1.9	2.9	4.5	5.0	4.8	6.4	4.6	4.6	4.1	5.3	3.9	4.0	3.6	2.7	4.3	3.0	1.5	5.1	3.5	2.8	4.1	4.9	9.6	4.4	**100**	7.6	4.1	5.2	4.0	3.7	4.6	3.1	6.3	4.3	5.6	4.5	1.5	3.8	2.1	3.9	4.1
Land Facet Rarity	4.9	3.6	11.6	7.5	6.8	7.6	4.5	1.0	9.9	2.0	1.5	6.9	1.4	3.7	3.9	7.7	1.2	2.9	2.4	7.2	3.3	3.9	3.9	8.6	4.7	5.6	7.7	4.7	6.7	8.0	7.2	38.7	8.9	1.2	0.8	12.6	13.3	2.6	5.4	7.5	5.1	4.7	10.7	10.3	9.4	**100**	4.9	4.0	3.8	4.9	3.8	3.2	12.1	8.8	5.7	4.7	8.1	4.6	5.9	2.4	3.9
Elevational Diversity	**82.4**	**71.7**	**82.5**	43.3	39.6	**73.2**	**54.0**	**87.5**	44.4	**73.8**	**96.9**	**90.6**	41.5	30.0	27.3	48.5	**50.8**	**50.8**	41.3	47.8	**72.2**	**66.2**	**67.6**	**66.6**	**59.9**	**59.9**	**68.5**	**68.4**	**68.3**	**54.9**	**70.3**	**83.1**	**53.6**	**58.1**	46.4	31.9	**56.3**	**79.0**	41.5	**62.2**	**52.4**	49.0	33.5	43.7	46.8	49.2	**100**	40.0	**79.9**	49.0	44.7	46.7	35.6	42.8	45.7	**50.7**	**81.7**	**56.0**	**62.7**	**55.0**	**59.9**
Ecotypic Diversity	46.8	**53.5**	41.5	**54.6**	**57.3**	38.6	**53.6**	33.6	**55.3**	39.3	14.4	39.4	**53.5**	49.3	**100**	**72.2**	42.8	47.0	**91.4**	**55.4**	30.8	29.1	46.1	31.8	37.7	44.2	38.6	44.5	47.2	**53.7**	47.1	**56.5**	**58.2**	**52.7**	**57.1**	37.1	**61.6**	**66.9**	**54.5**	**54.4**	**53.7**	**50.3**	**63.4**	45.9	**52.8**	33.8	39.2	**100**	34.1	43.3	**50.7**	46.3	**61.9**	**62.2**	**51.2**	**54.9**	5.9	39.7	25.7	**50.2**	47.3
Heat Load Index Diversity	**64.1**	**50.0**	**67.2**	39.6	41.0	**78.1**	**51.0**	**74.2**	33.4	**68.0**	**95.1**	**100**	**61.1**	**63.6**	6.5	36.2	**78.3**	**58.4**	12.4	43.2	**82.5**	**77.3**	**62.1**	37.1	48.9	**58.8**	40.2	**59.9**	**52.9**	41.2	46.6	**70.2**	**55.8**	**52.7**	**52.7**	23.4	49.3	**79.0**	**59.8**	**57.4**	43.7	41.9	25.4	42.9	46.0	36.6	**78.4**	34.9	**100**	**60.0**	**57.4**	**56.5**	26.9	32.4	44.4	48.8	**93.1**	**65.0**	**74.5**	**60.4**	**65.5**
Climate Corridors	26.2	39.9	13.3	44.1	**50.5**	**67.0**	**50.2**	22.0	28.6	34.1	**69.6**	**77.0**	**85.7**	**87.9**	**61.0**	**85.6**	**92.8**	**80.0**	26.0	38.6	**86.5**	**84.3**	46.9	8.4	37.1	**51.7**	11.8	42.1	28.3	30.5	19.4	**87.9**	**85.7**	29.7	49.7	25.3	47.6	**60.2**	**88.8**	25.2	33.8	11.3	14.7	**61.3**	46.6	48.4	**51.0**	48.2	**64.0**	**100**	**67.8**	**71.3**	39.3	**51.0**	44.3	49.9	**94.9**	**71.8**	**88.5**	**64.2**	**66.9**
Backward Velocity 2055	37.1	**56.0**	46.4	44.8	**55.0**	36.5	**61.2**	40.4	27.5	**92.0**	29.2	0	0	**96.4**	0	15.4	17.0	**56.4**	**83.7**	40.5	35.8	48.6	**72.4**	3.2	**55.6**	**69.3**	11.8	**65.4**	39.7	47.1	31.3	46.0	37.7	**67.1**	**86.2**	6.6	15.8	28.0	**66.8**	20.0	28.5	44.1	41.2	**52.5**	47.7	30.1	45.3	**52.9**	**50.0**	**53.6**	**100**	**86.1**	33.7	17.1	**57.3**	**55.5**	30.8	**51.1**	**51.9**	**62.0**	**56.6**
Backward Velocity 2085	26.8	48.9	**54.1**	44.4	**57.9**	40.6	**53.5**	37.3	18.7	**90.5**	**54.9**	**69.9**	0.6	35.3	0	0.4	**72.1**	**100.0**	**71.8**	27.4	**79.3**	**83.2**	**57.6**	2.1	48.6	**55.8**	10.1	**50.4**	28.7	39.6	25.5	0	7.6	**54.9**	**72.5**	0	0.7	47.1	**76.8**	26.9	23.3	28.7	32.3	36.9	38.5	25.4	**53.8**	48.9	**58.8**	**57.8**	**75.4**	**100**	20.5	15.2	**51.1**	49.2	**82.0**	**53.7**	**86.4**	**63.1**	**59.7**
Forward Velocity 2055	**55.3**	33.9	31.1	**59.6**	**54.8**	38.9	**51.9**	31.6	**71.4**	5.3	13.7	**64.8**	**84.3**	35.5	**100**	**100**	5.1	6.7	49.3	**58.0**	17.0	27.3	23.8	**88.0**	44.2	28.9	**75.0**	29.5	44.9	44.7	**54.2**	**94.4**	**83.0**	27.3	47.7	**97.3**	**88.6**	38.4	25.8	**51.9**	44.8	**76.7**	**93.5**	**79.8**	**58.8**	**76.8**	41.8	**54.1**	38.0	43.7	35.7	35.2	**100**	**93.7**	**52.3**	**54.5**	11.9	38.3	13.9	38.2	41.2
Forward Velocity 2085	**69.5**	**52.2**	48.2	**58.2**	**51.6**	45.2	**51.6**	**66.2**	**75.6**	16.7	26.0	**61.1**	45.9	33.4	**100**	**98.7**	9.0	13.6	38.5	**59.6**	19.8	32.0	36.7	**99.3**	**50.6**	39.4	**94.0**	43.6	**70.2**	**63.0**	**80.5**	**94.4**	**83.6**	40.3	45.5	**99.5**	**94.4**	43.0	30.1	**77.9**	**66.7**	**63.5**	**68.5**	**79.1**	**51.1**	**79.0**	**51.3**	**51.4**	45.3	45.2	34.3	37.2	**86.8**	**100**	49.2	**52.4**	20.3	44.0	20.3	39.1	40.7
Bird Richness	**57.6**	**62.3**	49.8	**66.4**	**73.2**	41.0	**51.7**	**59.1**	**58.8**	**63.1**	32.9	32.5	40.6	45.6	0	15.2	23.7	38.8	**80.4**	**59.0**	21.8	30.1	**59.7**	**72.5**	**67.9**	**66.3**	**70.5**	**60.3**	**64.0**	**71.2**	**66.8**	47.6	28.9	**52.6**	**62.6**	15.1	18.8	40.8	**51.4**	**55.7**	**59.4**	**73.3**	**73.2**	43.3	**59.0**	48.9	47.7	**53.1**	46.3	42.5	**58.9**	**53.1**	48.1	33.3	**100**	**51.9**	24.6	44.4	33.9	48.8	47.5
Total Biomass	**50.6**	48.3	43.5	48.5	42.0	47.5	**62.0**	**58.6**	**50.9**	47.1	**51.1**	36.8	**51.7**	**54.8**	**83.1**	**61.4**	15.7	35.9	**68.7**	**53.9**	19.7	22.5	**66.2**	29.5	40.0	**56.3**	36.5	**64.6**	**58.2**	47.8	**50.4**	**64.5**	**82.2**	**58.9**	**74.1**	**62.6**	**75.9**	37.8	48.8	37.9	45.6	46.8	**57.4**	**56.9**	49.5	44.4	**50.2**	**54.5**	47.9	44.6	**54.6**	45.0	**59.6**	**57.8**	49.1	**100**	12.9	45.2	19.3	**53.1**	**53.1**
Cool Headwater Refugia	2.0	2.4	2.4	1.7	4.2	13.7	1.5	2.3	0.0	4.1	22.8	11.1	12.5	2.8	0	0	24.5	6.6	0	0.2	35.9	30.9	0.7	0	1.3	1.6	0	0.6	0.1	0.3	0.0	0	0.1	0.1	0.3	0	0	2.4	4.0	0	0.0	0	0	0.7	2.4	10.4	9.0	0.7	10.9	11.2	2.4	8.1	0.4	0.7	2.5	1.5	**100**	8.4	36.0	5.8	7.9
Climatic Refugia	**54.5**	47.9	**53.2**	46.4	**50.0**	**73.1**	**52.1**	**62.6**	43.0	48.2	**74.4**	**72.8**	**54.3**	**92.0**	16.9	**59.4**	**96.9**	**86.1**	16.0	**51.9**	**84.3**	**78.3**	**56.1**	23.9	44.0	**57.1**	29.5	**54.5**	48.3	37.3	39.7	**73.4**	**71.1**	48.8	47.6	20.1	**57.1**	**86.8**	**80.9**	**62.7**	**59.7**	23.5	18.8	**59.0**	49.3	49.6	**64.6**	46.4	**75.0**	**76.5**	**64.6**	**65.2**	33.1	43.4	49.4	**53.8**	**82.8**	**100**	**79.0**	**65.7**	**65.0**
Biotic Refugia	9.9	12.7	9.9	9.7	17.7	21.9	11.3	4.6	0.2	22.9	39.7	36.0	23.7	13.1	**62.3**	13.2	43.9	42.3	5.3	3.1	**59.1**	**57.0**	8.6	0	9.9	10.1	0.2	7.5	1.3	5.0	0.9	4.8	7.9	4.4	6.9	0	0	11.3	20.8	1.0	0.5	0	0.1	7.0	8.6	16.4	19.3	9.4	23.6	27.3	20.2	32.7	2.1	4.9	10.9	7.8	**82.2**	22.0	**100**	20.6	22.5
Omniscape	31.4	39.8	38.5	42.1	43.3	**60.7**	**52.9**	**51.0**	25.0	**62.6**	**67.9**	**67.4**	**62.4**	**75.4**	0	**62.3**	**64.6**	**70.7**	**55.2**	39.6	**62.8**	**60.6**	**62.2**	10.1	34.3	**52.1**	15.5	**56.3**	40.5	27.7	29.0	45.2	**59.6**	43.8	**64.5**	11.0	26.1	42.9	**70.3**	28.6	36.5	22.3	18.6	38.4	44.4	23.0	**55.5**	50.0	**61.4**	**59.8**	**65.7**	**64.6**	30.7	34.4	46.1	**54.1**	**56.3**	**57.8**	**63.9**	**100**	**77.9**
Linkage Mapper	36.7	41.8	37.0	43.1	44.9	**72.0**	**50.8**	**55.6**	24.8	42.7	**81.5**	**63.6**	**97.4**	**62.6**	0	**82.7**	**74.0**	**87.1**	42.5	39.4	**78.6**	**71.2**	**62.0**	13.3	43.2	**59.5**	18.7	**57.8**	40.8	32.1	31.6	**79.0**	**76.4**	44.2	**59.0**	16.5	38.4	**56.2**	**77.5**	30.9	34.5	25.0	15.8	38.2	45.2	38.5	**59.6**	46.8	**66.2**	**63.4**	**59.6**	**60.0**	33.8	38.6	45.2	**52.4**	**74.9**	**58.5**	**73.9**	**74.3**	**100**

*Table 13. Conservation feature complementarity matrix. Values above **50% are bolded**, values of **100% are highlighted**.*

5.9 Adaptations to the SCP Process

5.8.1 Climate Change

Given the compounding uncertainties of including both modeled species habitat data and modeled climate change data in this SCP, I followed Mann's (2020) conservative approach in target setting on climate change features. This entailed running a scenario where targets were only set for present-day conservation features and the percentages of future conservation features that were incidentally captured were noted. After assessing these figures, they were either adopted as targets for future-focused scenarios or adjusted with documented rationale.

5.8.2 Connectivity

To explicitly include connectivity within *prioritizr* – not just as auxiliary data in the SCP process – I included outputs from both Linkage Mapper (protected areas connectivity) and Omniscape (overall landscape connectivity) as both conservation features and as locked-in options. Targets were not set on the connectivity conservation features in any of the scenarios I ran, but including them allows the user to see what percentage of highly connected lands are incidentally captured in a given scenario. Including prime connectivity lands as locked-in options allows the user to run connectivity-focused scenarios and ensure a certain degree of connectedness in their conservation solution.

5.8.3 Traditional Ecological Knowledge

Much of the TEK applied to this project was in guiding the process and influencing each stage with the Nation's values rather than explicitly changing or adding stages to the SCP framework. This was the case in selecting a study area boundary, setting conservation

goals, selecting conservation features, outlining criteria for continuous data within conservation features, honing the human footprint, and translating community values into conservation targets. Including TEK-sourced cultural data as the basis for some conservation features and the enhancing of others represents the most material addition to the standard SCP process, as this is a relatively new category that goes beyond the more conventional ecological-, recreational-, or industrial-based conservation features for selection. The various discussions and workshops held around guiding the SCP process with the Tsay Keh Dene's values are detailed in the Discussion chapter.

6.0 DISCUSSION

The Rocky Mountain Trench has been home to the Tsay Keh Dene since time immemorial – a landscape sacred to both their ancestors and Tsay Keh Dene that live there to this day. The effects of both human development and climate change are increasingly felt in the territory. The purpose of this project was to identify areas of this landscape that contain high conservation value (both in an ecological and cultural sense) and to help the Tsay Keh Dene Nation provide further evidence for the protection of these areas in the face of change. The prioritization tool developed over the course of the project was also transferred to the Nation to facilitate ongoing planning and management efforts.

The methods of Systematic Conservation Planning were adapted to address this task, with the goals of: (a) identifying which portions of the landscape have the highest conservation value today; (b) identifying which portions of the landscape are predicted to have the highest conservation value 30 and 60 years from now considering climate change;

(c) explicitly accounting for landscape connectivity across the study area; and (d) interweaving the Traditional Ecological Knowledge of the Tsay Keh Dene throughout the project to ensure an inclusive and more holistic outcome. This final goal intended to develop a product that is not only accurate and useful, but one that is accepted as valid by the Nation, scientists, and government.

This chapter is centered on my four specific research questions and goals, and weaves together reflections on the methods, results, and other literature. It also includes reflective notes I took throughout the process on the efficacy of interweaving TEK. Finally, I discuss other noteworthy concepts that arose but that did not fit neatly within the four specific goals.

6.1 Which portions of Tsay Keh Dene Territory have the highest ecological and cultural value for select present-day conservation features?

In the face of ever-increasing development in the Territory, a scientifically defensible, systematic approach to identifying high-value conservation areas could prove invaluable both in the short- and long-term. By including community knowledge, the tool provides an inclusive and comprehensive view of the greater territory to help place specific natural resource referrals into the larger landscape. This enables decision-makers within the Nation to better understand how the impacts of a single project may affect the broader landscape puzzle cumulatively. Furthermore, it sets a course for a range of conservation interventions, including identifying areas for restoration, areas to informally avoid development in, and the potential addition of conservation areas – among other avenues. The findings can also serve as the basis for future, more targeted conservation plans.

6.1.1 Solution Characteristics

Scenario A focused on present-day conservation value and biodiversity, with targets set and achieved for each of the species and ecosystem conservation features. This solution occupied 59% of the landscape and met targets for 44 features. By comparison, Mann's (2020) and Curtis' (2018) counterpart solutions required 68% and 46% of the landscape, respectively, in the adjacent Peace River Break. All three percentages fall in the aggressive yet imperative range near 50% – the target of the Nature Needs Half Movement (Dinerstein et al., 2019; Locke, 2013).

Given the number of features that tend to favour lower elevations (ecosystems like old and burned forests, lakes, and wetlands; species like bull trout, fisher, moose, birds, toad, and bats), one might expect valleys to be disproportionately represented in this conservation solution. Instead, low elevation is the least represented classification at 55%, with 62% of both moderate and high elevation captured (Table 14). The inclusion of several species that prefer moderate to high elevations, and the aggressive targets on some (caribou, Stone sheep, and mountain goat) were likely the cause of increased representation of higher elevations.

Elevation Classification	% Captured						
	PAs	Scen A	Scen B	Scen C	Scen D	Scen E	Scen F
High Elevation (> 1678m)	28	62	60	60	68	70	63
Moderate Elevation (1220 - 1677m)	18	62	62	62	63	66	64
Low Elevation (< 1220m)	10	55	39	38	55	56	40

Table 14. Percentage of each elevation classification captured by scenario. These were purely representational features and no targets were set for them.

Scenario A was configured to avoid both permanent and semi-permanent human footprint features. As cutblocks are considered semi-permanent and can theoretically be restored, they appear to be one part of the landscape that was often selected despite human

development. For example, the mouth of the Ingenika River has seen significant forestry activity, but the area retains high-value wetlands and moose habitat. While many SCPs rightfully focus on ecologically intact habitats, that is only one piece of the puzzle, and a restorative conservation lens must also be placed on these compromised landscapes (Schuster, 2014). Additional time and effort will be required to restore these areas relative to existing intact areas; however, the only alternative is to lower the targets which ultimately degrades the conservation goals.

Larger resource roads throughout the territory and study area were considered permanent features, and yet these areas were selected as having high conservation value in many instances – likely because roads tend to be found in valleys and run roughly parallel to the rivers themselves. As roads are highly disruptive and fragmenting landscape features (Polfus et al., 2011), further examination is needed to see if the impacts from these roads are significant enough to offset the value of the conservation features selected in these areas. This examination could also assess whether road impacts can be mitigated. As targets are uncompromising, human-impacted areas will be selected if they contain a significant number of conservation features or if those features are not found elsewhere. These areas that serve as transportation corridors for people have long served as habitat and transportation corridors for many species, and their value for conservation purposes cannot be undervalued moving forward. Thus, restoring these linear features to their natural states should be a priority once they are no longer needed, as Tsay Keh Dene Nation and Chu Cho Environmental are actively doing near Johanson Lake as part of their Chase Caribou Herd Road Restoration Program (Chu Cho Environmental, 2021).

The four predominant ecoregions in the study area were all well represented: Boreal Mountains and Plateaus – 61%, Northern Canadian Rocky Mountains – 65%, Central Canadian Rocky Mountains – 67%, and Omineca Mountains – 55% (Table 15). The large number and diversity of conservation features in this scenario likely resulted in this widespread geographic coverage of the study area. Furthermore, much of the human footprint in the Territory is found along the southern and eastern peripheries of the study area, which also happen to be the edges of other ecoregions in several instances. The 59% of the total area that was ultimately selected trended towards the more remote portions of the study area and was well distributed, likely due to the heterogeneity of the landscape. While this solution is quite scattered, my approach was intended to be idealistic in finding planning units with the highest conservation value – not just moderately valuable, neatly grouped areas that may be easier to designate for conservation purposes. Thoughtful delineation of areas for conservation interventions can come later from the Nation. Furthermore, this broad distribution of valuable conservation lands should be considered an asset, as it gives the Nation choices for conservation action based on their priorities rather than being resigned to a few obvious areas that may require restoration.

Ecoregion	% Captured						
	PAs	Scen A	Scen B	Scen C	Scen D	Scen E	Scen F
Boreal Mountain and Plateaus	38	61	56	61	65	69	60
Central Alberta Upland	0	29	9	9	29	28	9
Central Canadian Rocky Mountains	9	67	61	58	68	68	61
Fraser Basin	0	43	30	20	44	41	29
Muskwa Plateau	1	39	4	5	39	39	7
Northern Canadian Rocky Mountains	19	65	61	64	70	74	62
Omineca Mountains	10	55	50	48	55	55	52
Peace River Basin	0	13	80	82	95	13	80
Skeena Mountains	0	75	56	53	93	83	43

Table 15. Percentage of each ecoregion captured by scenario. These were purely representational features and no targets were set for them. Purple ecoregions are significant in size and collectively make up 90% of the study area.

6.1.2 Focal Areas

There were five focal areas representing clusters of high-value conservation lands identified by the tool outside of existing and proposed protected areas (Figure 73). The first was the Omineca River valley (Area 1) connecting Sustut and Omineca Provincial Parks, likely selected because it contains bull trout habitat and low to moderate elevation caribou habitat – both features with very high targets. As the most linear of the five identified areas, protecting this area would not only safeguard these species' habitat, but also provide a crucial connectivity corridor for wildlife between sizable protected areas in the region. This area is also at the interface of the Chase and Wolverine caribou herds, and could contribute to gene flow among these threatened populations (Roffler et al., 2012).

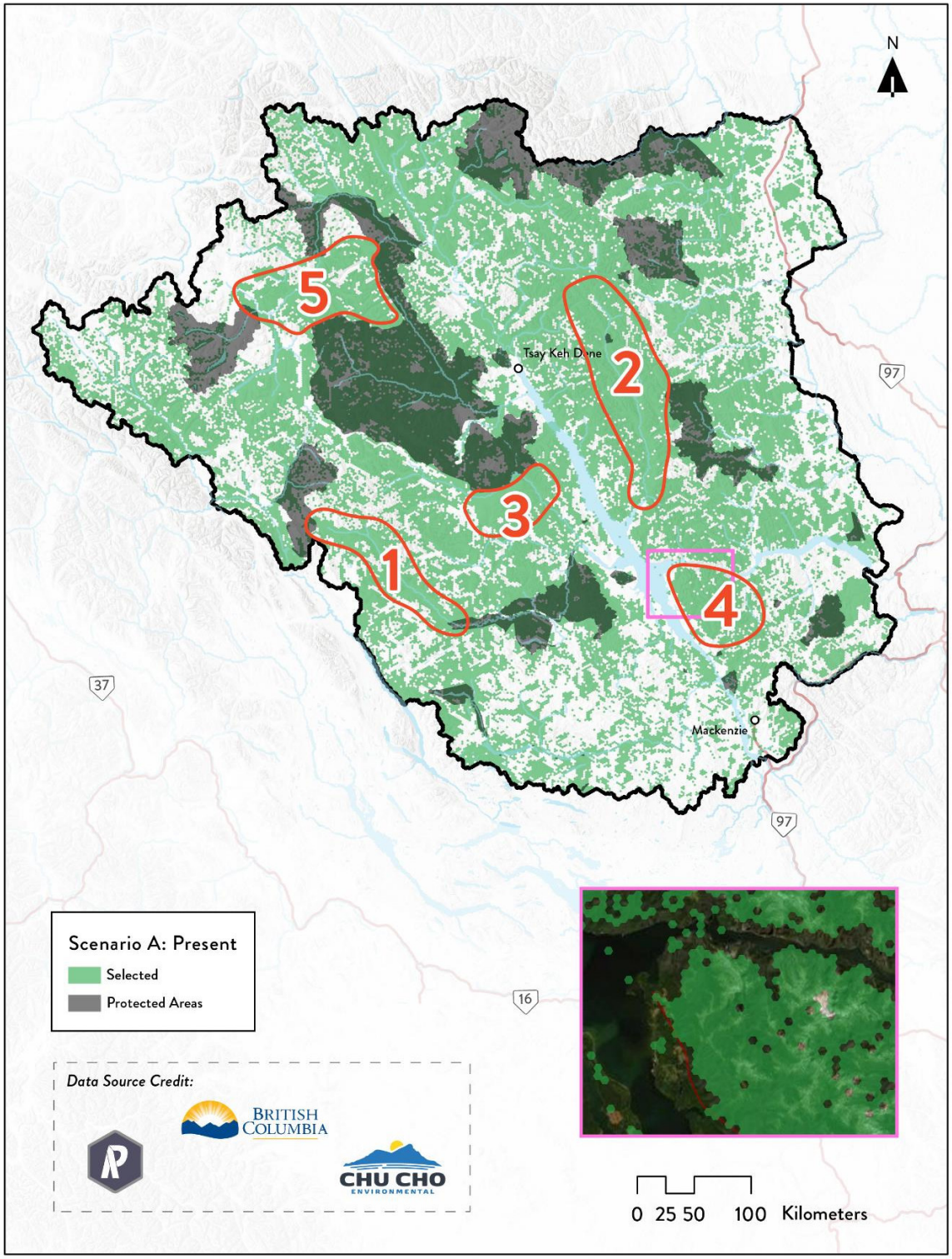

Figure 73. Focal areas (outlined in orange and numbered) and protected areas overlaid with the spatial extent of the conservation solution for Scenario A: Present-day Conservation within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

The next focal area was the Ospika River valley and adjacent mountain ranges (Area 2) that contain karst deposits and high-quality habitat for a great deal of focal species (fish, fisher, moose, three herds of caribou, Stone sheep, mountain goat, wolverine, bats, and birds). Protecting this area would not only conserve these species' habitat, but also protect a number of cultural/spiritual areas of the Tsay Keh Dene, as the Ospika, or 'Əsbagah, River valley is of great importance. Additionally, this somewhat linear focal area could serve as a connectivity corridor for wolverine between Redfern-Keily and Graham-Laurier Provincial Parks.

The Mesilinka River valley south of Chase Provincial Park (Area 3) was selected for its abundance of burned Engelmann Spruce–Subalpine Fir forest stands with infrequent stand-initiating events – a feature with a 100% target. While these young, biodiverse forests stands were the reason for this area's selection, the area is also home to fisher, bull trout, moose, and caribou habitat. Protecting this area would add roughly 1,000 km^2 of habitat for fire-obligate species and contain features like burned snags that are not found in young managed forests (Curtis, 2018). This addition would also complement the adjacent forests found in Chase Provincial Park and the proposed Ingenika Conservation and Management Area while also building out the conservation complex.

The northern Misinchinka ranges (Area 4) house both karst deposits and a number of territorially-rare BEC subzone variants, but the leading cause of this selection was likely the fact that it holds high-quality moderate elevation habitat for the Klinse-za caribou herd. This finding confirmed the location of a portion of the Caribou Conservation Partnership Agreement between British Columbia, Environment and Climate Change Canada, West Moberly First Nation, and Saulteau First Nation (Environment and Climate Change Canada

et al., 2020). While the areas identified in both efforts largely overlap, my findings suggest that the governments lower their elevation threshold to include a broader portion of the mountain range. While this change adds only slightly more land to an industry moratorium, it significantly reduces the edge-to-area ratio of the patch, therefore increasing vital interior habitat for Klinse-za caribou – one of the focal herds of the partnership agreement.

The final focal area is in the Omineca Mountains west of Kwadacha (Area 5), nestled between the Ingenika Conservation and Management Area, Finlay-Russel Provincial Park, and Tatlatui Provincial Park. This region has several high-value wetlands complexes, as well as high-quality habitat for the Thutade caribou herd, moose, and Stone sheep that likely led to its selection. There is currently only one significant resource road in the area for mining and forestry. Protecting this entire area – or at least the highly connected corridors between the aforementioned protected areas – would minimize further road-building and reduce fragmentation. It would also create a robust conservation network with a complex that includes Mount Edziza, Stikine River, Spatsizi Plateau Wilderness, and Chase Provincial Parks, Gladys Lake Ecological Reserve, and Pitman River and Chukachida Protected Areas. This network would span over 400 km from Chase Provincial Park in the southeast to Mount Edziza Provincial Park in the northwest.

6.1.3 Protected Areas Placement

Completing the SCP allowed me to look at the location of the existing protected areas relative to the conservation feature information mapped in the SCP – information that wasn't available when these protected areas were designated. According to this SCP solution, the existing protected areas network has mixed results regarding the efficacy of their placement. Provincial parks like Omineca, Nation Lakes, Klinse-za, and Graham-Laurier had much of

their extent included as part of the present-day solution, while Northern Rocky Mountains/Kwadacha Wilderness and Tatlatui had very little. Additionally, the proposed boundary of the Ingenika Conservation and Management Area is substantiated by the conservation solution.

Accordant parks consistently contained biodiverse forests from the forest pattern and process layers and a collection of wildlife habitats. Klinse-za Provincial Park and its expansion is one of the best placed parks according to the solution, largely due to the caribou herd of the same name. Old and burned Engelmann Spruce–Subalpine Fir stands are among the biodiverse forests included in the Addition. Mountain goat, and to a lesser extent grizzly bear habitat, likely also played a role in confirming its location. This park expansion, born out of the same Caribou Conservation Partnership Agreement mentioned earlier, is entirely validated by this solution and a great example of contemporary informed protected area design.

The parks that do not align with the solution appear to be lacking in biodiverse forests. This does not mean that protected areas not in agreement with the solution do not hold value (e.g., Tatlatui contains several large lakes, which are of the utmost importance to the Nation), but that the features located within them are either not diverse enough or not rare enough to merit their selection given the parameters of the SCP scenario. While Tatlatui may be an example of the global practice of protecting high elevation areas of "rock and ice" (Joppa & Pfaff, 2009), it still contains some present-day conservation features. It is important to recognize that these parks were selected as part of multi-stakeholder land use planning initiatives and likely include a range of values that my SCP did not account for.

The placement of the proposed Ingenika Conservation and Management Area was also broadly confirmed by the present-day SCP solution – an important finding given the deep cultural bonds the Tsay Keh Dene have to this area. Containing several major river valleys, this area contains high-value wetland complexes and habitat for moose, fisher, western toad, bats, and birds. The moderate to high elevation areas found in this region contain high-value caribou habitat for the Thutade and Chase herds. The Nation has been working specifically to recover the population of the Chase herd, and this solution includes hundreds of square kilometers of habitat within their range. This SCP's affirmation of the Ingenika CMA's placement is vital, as the Tsay Keh Dene have a profound connection with the caribou, or wədzih (Figure 74). Historically, the sight of healthy, migrating caribou has brought the Tsay Keh Dene comfort and indicated the changing of seasons (Chu Cho Environmental, 2020a). More recently, their noted absence has weighed heavily on the hearts and minds of the people. Tsay Keh Dene feel a responsibility for the well-being of the caribou, and have voluntarily stopped hunting them out of respect and to reduce strains on the population (Chu Cho Environmental, 2020a). The concurrence of the conservation solution with the Nation's proposed conservation and management area boundary further validates their efforts.

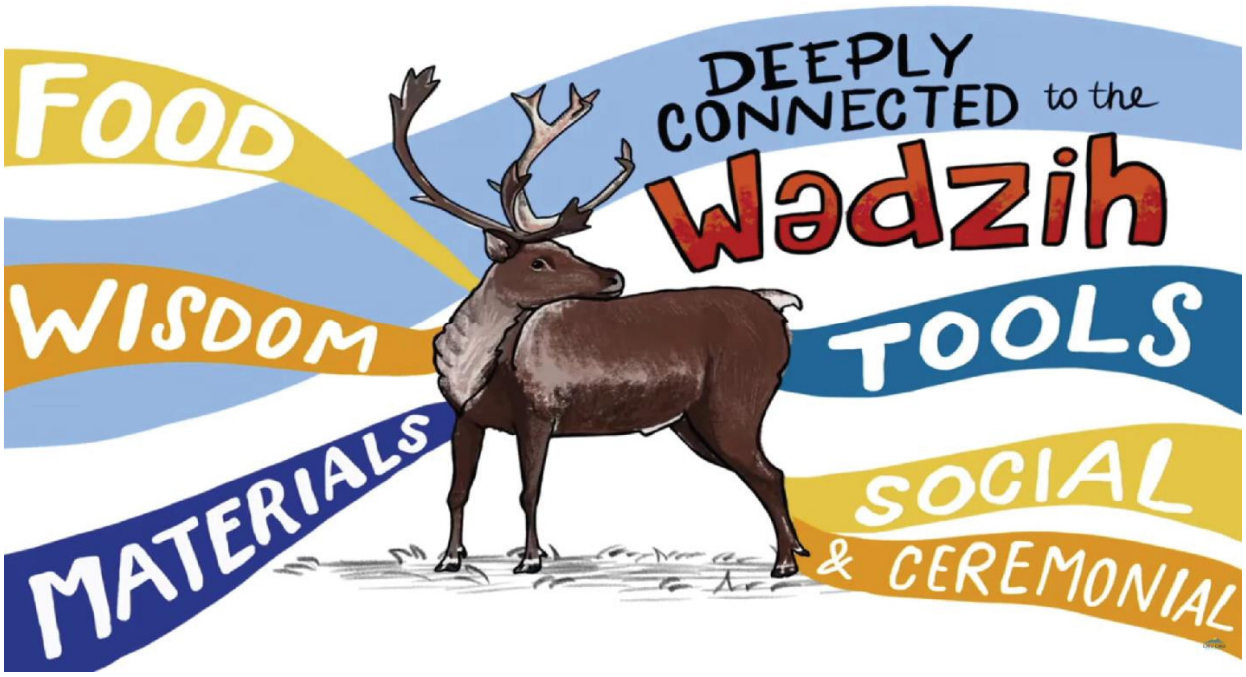

Figure 74. A still from the "Wedzih - The Caribou" video illustrating the holistic importance of caribou to the Tsay Keh Dene (Chu Cho Environmental, 2020).

6.1.4 Avoiding Triage and Defeatism

One extreme approach to conservation has been the adoption of the triage concept of medical care employed in battle or times of disaster, where the wounded are classified based on the severity of their injury. The result is that some individuals are deemed beyond saving and resources are then focused on treating those with a good likelihood of survival. In a conservation context, this means that certain species are deemed too far gone to viably be saved due to dangerously low population numbers or lack of habitat (Tingley et al., 2014). However, urgency is one of the catalysts for action and scientific innovation, and by simply disregarding the most endangered species we are essentially lowering our sense of urgency towards finding conservation solutions (Bottrill et al., 2008).

The target setting function of SCP allows users to avoid the triage method, as highly vulnerable species or ecosystems can have aggressive targets to select most or all of the specified land that remains. This avoids outcomes of only moderately diverse, moderately threatened species assemblages – a major criticism of the triage approach, which is seen as well-intentioned but promoting defeatism (Bottrill et al., 2008). While I set default wildlife targets of 60%, the flexibility to set loftier targets on threatened species – particularly bull trout and caribou – ensures that almost all of their identified habitat will be included as part of a conservation solution. These bold targets may give the tool less room to prioritize complementarity (as only the target minimum was captured for bull trout and all but one caribou herd), but it guarantees the inclusion of habitat for these vital populations.

6.1.5 Data Availability

The availability and completeness of data for identified conservation features presented one of the biggest hurdles in the process, as accurate input data from reputable sources is vital to a valid model. There was a spectrum of how much data gathering and processing needed to take place for each layer. In some instances, data could be directly downloaded from provincial sources and used with only minimal processing (e.g., grizzly bear, karst deposits). In other instances, data had to be pieced together from several sources and standardized to suit our needs (e.g., caribou, Stone sheep, mountain goat). In some instances, trustworthy data existed but was not at the resolution required to match up with the selected 1 km^2 planning units. In these cases, data was resampled to match the grid and was represented at a scale that it was not necessarily intended to be. The broad scale nature of this project served to mitigate these resampling issues, however. Additionally, completing geographic coverage of the study area was not feasible in all cases. The species at risk

Habitat Suitability Indexes developed by Chu Cho Environmental were only for the Territory proper and supplementary data was not available to round out the study area. With high enough targets on these species at risk, the solution will be biased towards the Territory proper, but including these available data gives the user greater capabilities. While features should be meaningful and not just included because data is available (Wiersma & Sleep, 2016), the user always has the option of not setting targets on these features or setting conservative targets as I did.

There was one noteworthy potential conservation feature that was not included at this time. Key Biodiversity Areas, or KBAs, are sites that significantly contribute to the global persistence of biodiversity, and are identified using a standard IUCN process worldwide (IUCN, 2016). While KBAs would have been a worthwhile addition to present-day conservation scenarios and this study overall, the work being done to identify and document these areas in Canada was not far enough long at the time of writing to be included. Additionally, of the initial KBAs identified by this working group, none fall within the study area of this project, with the closest being the Liard River Hot Springs near British Columbia's northern border. If KBA mapping is completed within the study area it will be interesting to see the extent to which it overlaps with areas already selected in the SCP model.

6.2 Which portions of Tsay Keh Dene Territory retain conservation value when climate change is considered?

Areas identified as biodiverse or otherwise containing high conservation value today may look very different 30 and 60 years from now. Using conservation-focused metrics based on the best climate change predictions available allows us to identify which areas are

predicted to remain or become ecologically valuable in the future. When these areas overlap with areas identified for their present-day conservation value, they are considered ecologically valuable and climate-resilient and should be further prioritized.

6.2.1 Solution Characteristics

A bias towards higher elevations was expected in climate change-focused future scenarios given their relative coolness, and that proved to be true. Solutions B (2050s) and C (2080s) each captured more than 60% of both moderate and high elevation classes in the territory while only capturing 39% and 38% of the low elevation class, respectively. This was likely due to coarse-filter and climate change features favouring montane environments for their lower backward velocity and refugia potential. Solution D (all time periods), however, captured 55% of low elevation, 63% of moderate elevation, and 68% of high elevation. As this scenario had to capture both current biodiversity often found in lower elevations *and* predicted future biodiversity that trends towards moderate and high elevations, this solution was calibrated to select planning units that can serve both roles.

Solutions for the 2050s, 2080s, and multi-time periods were each able to capture over 50% of the predominant four ecoregions in the study area, save for the 2080s solution only capturing 48% of the Boreal Mountains and Plateaus ecoregion. As the name suggests, the decreased topographic variation of plateaus in this ecoregion likely led to its lower representation in the 2080s climate change scenario. The overall strong representation across the landscape in these climate change-focused scenarios was likely due to how mountainous this region is as a whole (Loarie et al., 2009). Of the four main ecoregions, the highest percentage captured in this set of scenarios was the Northern Canadian Rocky Mountains in the multi-time periods solution with 70%, presumably due its role as both critical present-day

habitat for Finlay and Pink Mountain caribou, Stone sheep, and mountain goat, as well as its high refugia potential into the future.

The 2050s and 2080s solutions were configured to avoid permanent human footprint features, with the understanding that semi-permanent features could theoretically be ecologically restored over time. Permanent features like roads and mines were largely avoided, however areas adjacent to the Williston Reservoir that fell within its buffered impact area were selected in many cases – likely because this altered landscape still contains diverse and rare land facets. This was particularly true along the Peace and Parsnip Arms. If further access to these areas remains limited, then they have the potential to serve as important habitat for several bird species despite their alterations. The Parsnip Arm has seen more development with roads and forestry, leaving the Peace Arm with greater conservation potential.

Human development (especially that which is permanent in nature) is not often found in the moderate to high elevation areas that these climate-conscious scenarios favour. The footprint likely played less of a role in which areas were selected as part of this solution. Like the present-day solution, the multi-time period solution was configured to avoid both permanent and semi-permanent footprints. The multi-time period solution expectedly selected footprint areas in a similar fashion to the present-day solution (cutblocks) and 2050s and 2080s solutions (reservoir adjacent areas). The conservation implications of each hold true – cutblocks must be viewed through a restoration lens for how they could contribute to the larger landscape, and topographically-diverse reservoir-adjacent areas can still hold conservation value if further development is limited.

The predicted changes in climate for this landscape can be readily understood by shifts in BEC zones (Table 16). Sub-Boreal Spruce, Engelmann Spruce—Subalpine Fir, and Boreal White and Black Spruce are predicted to remain in abundance and likely migrate slowly enough to allow their inhabitants to track with them. In contrast, Boreal Altai Fescue Alpine is expected to contract further and further up mountain peaks until only 'islands' remain. This could spell serious trouble for high elevation species like Stone sheep and mountain goat, not only limiting movement within single animals' life histories, but cutting off gene flow among populations and potentially leading to extinction (Parks et al., 2015). Perhaps even more dramatic is the almost complete collapse of the Spruce—Willow—Birch zone. The most northerly subalpine zone in British Columbia, this zone is predicted to drastically shrink and migrate northwestward within the study area. This means current moose and caribou populations (namely the Pink Mountain, Thutade, and Frog herds) accustomed to summering in this zone for its open, shrubby valley bottom habitats will either have to adapt or move northward as soon as 2050 (British Columbia Forest Service, 2007).

BEC Zone	Present (% Captured)							2050s (% Captured)							2080s (% Captured)						
	PAs	Scen A	Scen B	Scen C	Scen D	Scen E	Scen F	PAs	Scen A	Scen B	Scen C	Scen D	Scen E	Scen F	PAs	Scen A	Scen B	Scen C	Scen D	Scen E	Scen F
BAFA	28	62	62	62	68	70	63	40	48	78	78	74	72	79	45	43	85	85	77	74	84
BWBS	16	57	34	36	57	57	37	11	55	35	36	56	56	37	9	54	35	36	55	55	37
ESSF	12	62	62	60	62	63	64	22	66	63	62	67	70	64	26	64	61	61	66	70	63
SBS	3	48	31	28	50	49	31	13	56	43	43	57	57	45	17	60	47	47	59	61	49
SWB	29	60	57	61	63	70	58	23	43	54	61	52	52	59	19	33	45	55	44	39	52
CWH	0*	0*	0*	0*	0*	0*	0*	0	50	50	30	60	50	40	0	70	80	77	70	69	80
ICH	0*	0*	0*	0*	0*	0*	0*	6	54	49	46	55	56	50	10	59	53	51	60	60	54
IDF	0*	0*	0*	0*	0*	0*	0*	0	100	0	0	100	100	0	7	34	12	13	34	35	13
IMA	0*	0*	0*	0*	0*	0*	0*	67	0	33	33	33	67	67	0*	0*	0*	0*	0*	0*	0*
MH	0*	0*	0*	0*	0*	0*	0*	0	60	19	55	62	60	19	0	59	35	60	61	59	34
MS	0*	0*	0*	0*	0*	0*	0*	0	100	50	50	100	100	50	3	63	41	47	63	60	50

Table 16. Percentage of each BEC zone captured by scenario by time period. These were purely representational features and no targets were set for them.

6.2.2 Focal Climate Areas

The 2050s and 2080s solutions are strikingly similar, likely because they share a majority of the same conservation features and only a few are time specific. While these solutions share many of the same focal areas with the present-day solution, they contain a few unique groupings of values (Figure 75). The first is in the southern Muskwa Ranges between the Ospika and Peace Arms (Area 1), likely selected for its rare land facets, elevational diversity, heat load index diversity, low backward velocity, and carbon storage. Protecting this area would provide a link to Graham-Laurier Provincial Park and safeguard climate resilient habitat for wolverine, grizzly bear, and the Graham caribou herd. Furthermore, this area contains regionally significant carbon storage, a crucial ecosystem service. Keeping carbon sequestered is a widely-accepted protected areas strategy to mitigate climate change globally (Mitchell et al., 2021).

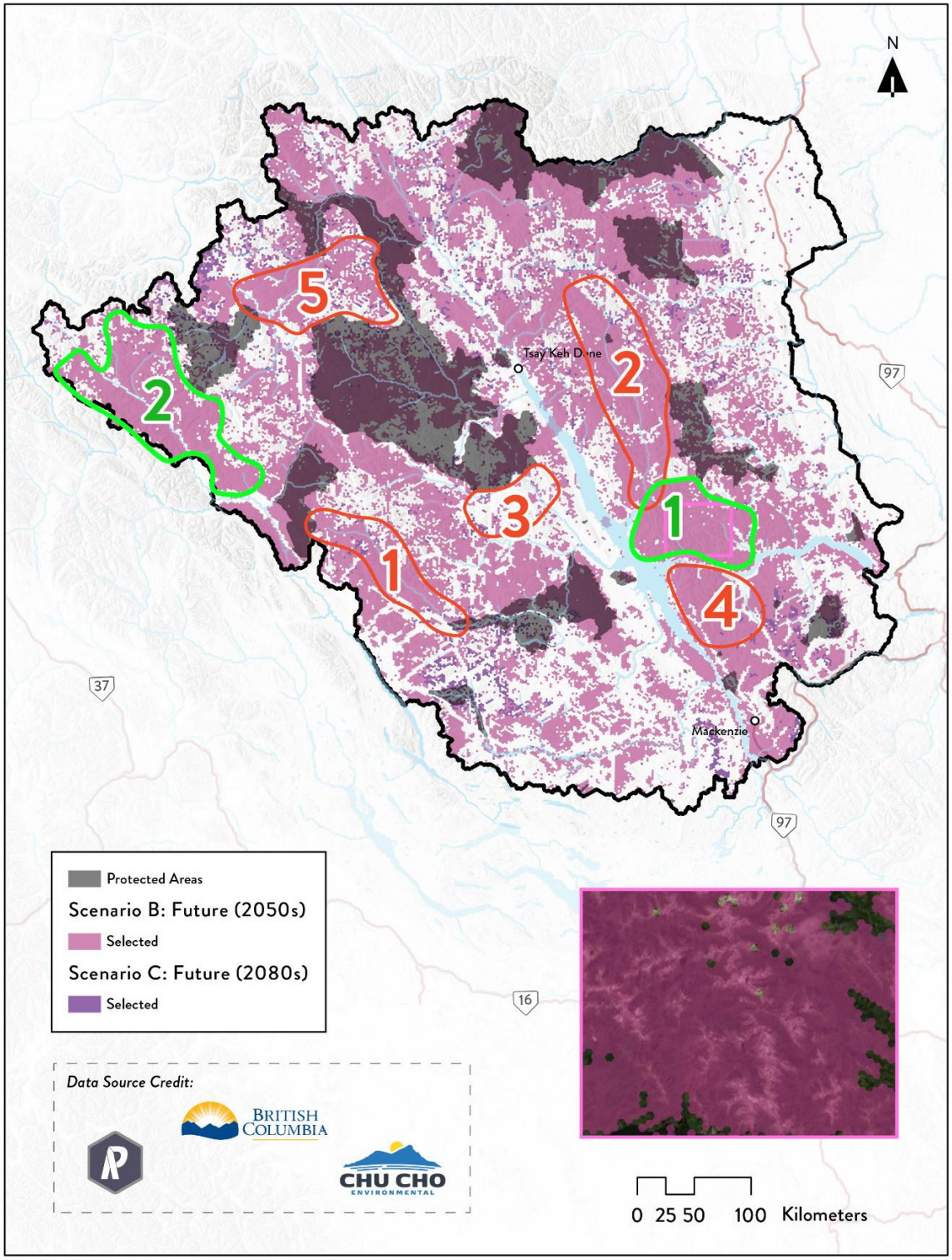

Figure 75. Climate focal areas (outlined in green and numbered) and protected areas overlaid with the spatial extent of the conservation solution for Scenarios B: Future (2050s) and C: Future (2080s) Conservation within the Greater Tsay Keh Dene Territory Study Area; Present-day focal areas outlined in orange for comparison purposes; inset represented by pink frame.

The other novel focal area is in the Omineca Mountains on either side of the Skeena River (Area 2). Similar to the previous region, this area was likely chosen due to its rare land facets, elevational diversity, low backward velocity, and carbon storage; however, low forward velocity also likely played a role in this area's selection. The climate change implications of protecting this area are twofold: the valleys of the Skeena River and its tributaries are carbon storage hotspots, while the surrounding higher elevation mountain ranges are climatic refugia. The 2050s and 2080s solutions each occupied 52% of the landscape.

The multi-time period scenario had targets set for both present-day and climate change conservation features, and thus its solution is a sort of hybrid of the solutions for each individual time period. Somewhat expectedly, this solution does not reveal any novel large groupings of selected planning units; rather, it looks largely similar to the present-day solution but with slight shifts northward and upslope in the name of climate resiliency. As targets are uncompromisingly met in this tool, the multi-time period solution required slightly more land base to reach every target, occupying 61% of the landscape as opposed to 59% in the present-day solution. While more land was needed to meet the targets, this modest increase is remarkable in that only 2% more of the study area was needed to meet the needs of two very different scenarios. The tool had been successfully calibrated to efficiently account for both present-day and climate change conservation features.

6.2.3 Protected Areas Placement

Many protected areas fared differently in the prioritization solutions when climate change was the focus of the scenario. Of the protected areas that were poorly represented in the present-day scenario, the Northern Rocky Mountains/Kwadacha Wilderness Provincial

Parks were very well represented in this iteration, while Tatlatui was poorly represented once again. Tatlatui does contain moderately valuable planning units for a number of coarse-filter and climate change metrics, but largely did not rise to the level of selection save for a valley east of its major lakes. All of the protected areas that fared well in the first iteration (Omineca, Nation Lakes, Klinse-za, and Graham-Laurier Provincial Parks) were only moderately climate resilient according to this scenario. Additionally, the Ingenika Conservation and Management Area's core was selected, while its northern and southern edges were not.

Sustut and Redfern-Keily Provincial Parks were almost entirely selected in the 2050s and 2080s solutions. For Sustut, this suggests that it will continue to serve its role as pristine wilderness habitat for species like grizzly bear, caribou, and Stone sheep. Its basaltic cliffs in particular serve as high-value habitat for mountain goats, while its waterways should sustain salmon and steelhead trout (BC Ministry of Environment, 2021b). Redfern-Keily contains considerable amounts of refugia from all three types used in this study. The rare land facets of its western peaks in particular are poised to maintain their high-value habitat for Pink Mountain caribou, Stone sheep, and mountain goat. The park's numerous forests, as well as valley and alpine meadows should also continue to support wide-ranging grizzly bears, which are provincially blue-listed (of special concern) (BC Ministry of Environment, 2021a).

The Kwadacha Wilderness/Northern Rocky Mountains Provincial Park complex holds far greater value under climate change conditions according to the tool, largely for their refugia potential. Both parks exhibit elevational diversity, while Kwadacha Wilderness boasts rare land facets and Northern Rockies contains ecotypic diversity. These parks currently support wildlife including moose, fisher, and wolverine, and the highly diverse

elevations found there could prove to be invaluable microrefugia for these species (Stralberg et al., 2020). Additionally, the most important climate corridor in the entire study area runs directly north from Graham-Laurier Provincial Park, winding past Redfern-Keily before ending at Northern Rocky Mountains Provincial Park (Figure 76). Thus, climate refugee species to the south could very well colonize the Northern Rocky Mountains/Kwadacha Wilderness complex in the future. As this area already holds reasonable landscape connectivity under current conditions, it should be considered for protection as a climate-resilient connectivity corridor.

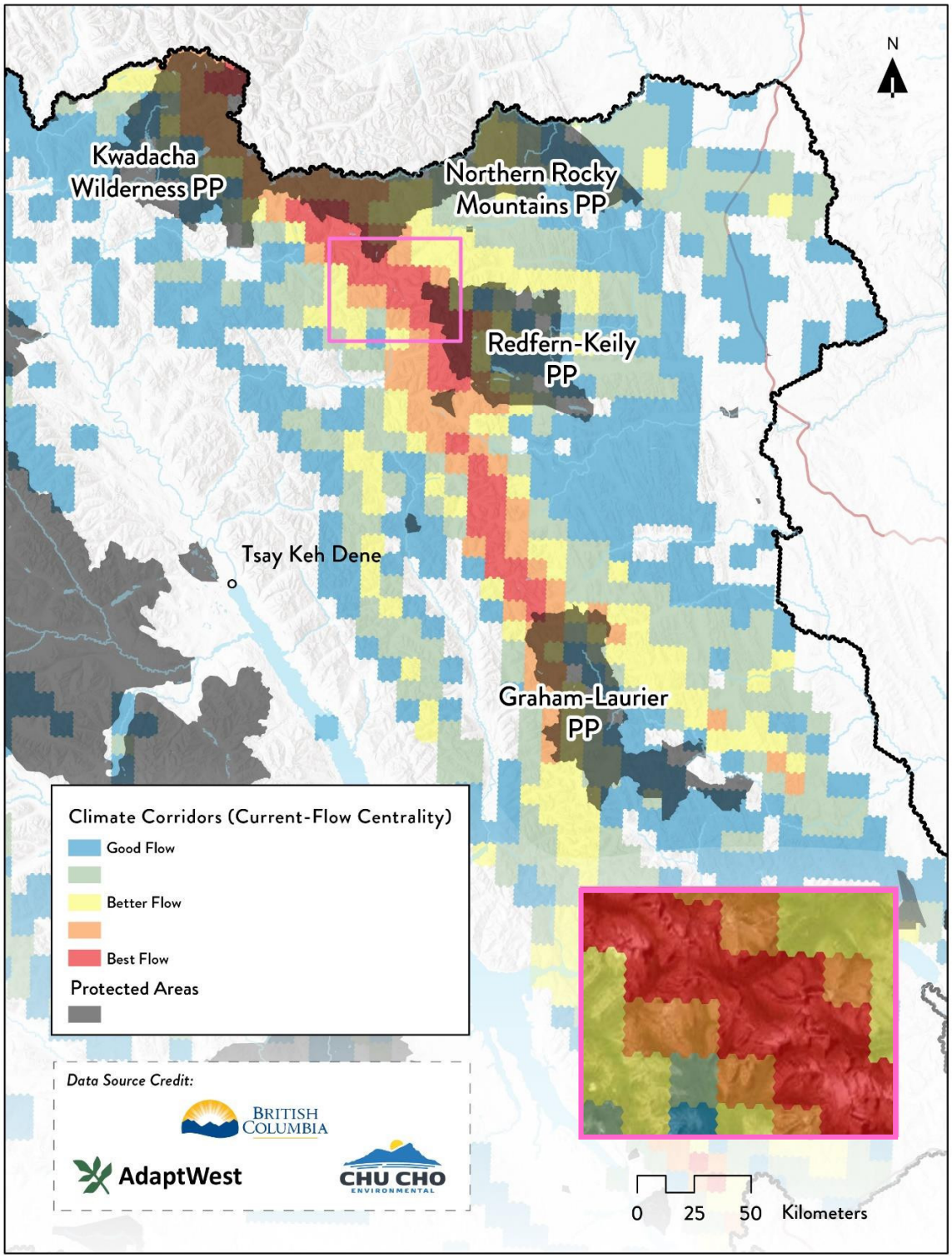

Figure 76. Optimal climate connectivity corridor within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

The placement of the proposed Ingenika Conservation and Management Area was less substantiated by the 2050s and 2080s solutions; however, its Cultural Epicenter subunit was almost entirely selected given its climate resiliency, as was the western half of the Management Area subunit. This is beneficial, as the Cultural Epicenter of the Ingenika is the portion that is planned to receive legal protections, while the rest will be heavily managed to preserve values but not formally protected. This finding provides climate-conscious Western scientific justification to parallel the cultural and spiritual value of this area as the Nation campaigns for an official conservation designation.

6.2.4 Considering the Yale Framework

The Yale Mapping Framework was introduced in 2015 and continues to gain attention as an important tool for integrating climate adaptation into landscape conservation planning (Carrasco et al., 2021; Schmitz et al., 2015; Wineland et al., 2021). The framework provides a set of six objectives that users can choose from, and a suite of appropriate tools based on the level of ecological analysis (species, ecosystems, or landscape) to help attain each objective (Conservation Biology Institute, 2021). The adaptation objectives include: (1) Protect current patterns of biodiversity, (2) Protect large, intact, natural landscapes and ecological processes, (3) Protect the geophysical setting, (4) Identify and appropriately manage areas that will provide future climate space for species expected to be displaced by climate change, (5) Identify and protect climate refugia, and (6) Maintain and restore ecological connectivity (Conservation Biology Institute, 2021). This project did not formally adopt the Yale Framework, and while its principles were largely followed given the multi-faceted nature of this project, some steps could have been conducted differently.

While all six objectives of the framework are touched on, a few could have been more fully developed. The first three objectives focus on strengthening current conservation efforts. Current patterns of biodiversity were protected through the delineation of high-quality habitat for sixteen species and several key ecosystems. This project did separate out caribou herds to recognize population level issues but could have delved further on other species to assess population sizes/viability and genetic patterns at a finer scale as the framework suggests. Large, intact natural landscape and ecological processes were protected through the inclusion of umbrella species, representative and biodiverse forest types, and the scale of the project in general. The project did not explicitly consider ecosystem services, however, as Mitchell et al. (2021) did as the focus of their national-scale conservation planning effort. Doing so in the future would be beneficial given the Nation Government's responsibility towards its people and ongoing issues like dust storms near the community. Finally, I was explicit in addressing the protection of the geophysical setting in which ecological processes play out and would not approach this objective any differently. My use of landscape features like land facets, elevational diversity, ecotypes, and heat load index thoroughly addressed this objective.

The last three objectives focus on anticipating and responding to future conditions. Future climate-altered habitats were identified and selected for by including features like forward and backward climate velocity for two future time periods. While BEC zones were included as non-target representational features for the 2020s, 2050s, and 2080s, rare BEC subzone variants were only included as a conservation feature in their current state. Including the predicted locations of rare BEC subzone variants in a climate-altered future could help address the framework's goal of protecting climate-vulnerable rare ecosystems. The

identification of climate refugia was also sufficiently addressed. I incorporated three separate refugia layers based on different criteria, including one that explicitly addressed the framework's specification for spring-fed streams – the cool headwater refugia feature (Weaver, 2019). Finally, ecological connectivity was maintained by explicitly including protected area and landscape connectivity data in the SCP process. Both instances address structural connectivity and are well-suited for the ecosystem and landscape scale; however, other connectivity measures (e.g., those that include empirical movement data) would need to be included to adequately address functional connectivity for the life histories and migration of specific species.

While using the Yale Mapping Framework from the outset of this project may have changed the lens through which I made some decisions along the way, the essence of the project would have remained largely unchanged. Adequately addressing all six objectives at all three levels of ecological analysis would have added a considerable amount of work and likely would have pushed the boundaries of the scope of a master's level project – especially given the TEK aspect of my work. The ecosystem services and functional connectivity aspects in particular would have required significant additional effort and likely extended the project's timeline for completion.

6.2.5 Use of Climate Change Metrics

While climate change metrics are based on models that carry uncertainty, Mann (2020) outlined a measured approach to utilize this valuable data without being over-reliant on it. Some conservation scientists argue that the compounding uncertainty of climate change metrics within an SCP (a simulation in itself) can prove too risky (Schloss et al., 2011). If

used correctly, however, these metrics are certainly worthwhile for the insights they can provide.

Mann's (2020) method was one of incidental capture of a variety of climate change metrics. She took a multi-faceted approach by including strategies for protecting the geophysical stage, low climate velocity areas, and climate refugia – objectives 3-5 of the Yale Framework. This entailed setting targets solely on present-day conservation features and documenting the percentage of each climate change feature that was captured by happenstance. Using these incidental capture percentages as conservative targets on the climate change features, she was able to calibrate her model for future biodiversity scenarios and ultimately fine-tune a scenario that captured both present-day and predicted future biodiversity. In her case this final scenario resulted in a solution that did not select any more land than the initial present-day biodiversity scenario, but one that was more informed in which planning units to select to account for climate change. In my case it resulted in a 2% increase in area selected. This shows that climate change considerations do not automatically result in either/or decisions of present and future biodiversity when identifying what land to conserve. Mann's (2020) work and this project confirm that little to no additional land is required to better select for climate resilient lands – at least in these more mountainous landscapes of northern BC – just a modest reshuffling of which planning units are selected once the tool has been calibrated.

Species-centered approaches to climate change have also been used, as opposed to the climate/environment-centered approach of this project (Reside et al., 2018). While species habitat modeling carries its own uncertainty, this method can look at species movements from recent decades and reasonably predict species' range shifts into the future. In contrast,

Mann's (2020) approach can be seen as both more holistic and further removed from reality as it seeks to be inclusive of all species by being more theoretical. Mann's method is superior if the goal is overall biodiversity, but if robust data exists for range shifts of a surrogate species or if a conservation plan is being developed with a specific species in mind, then her method (and this project) could be seen as having limitations.

Lawler and Michalak (2017) argue that any climate-conscious SCP approach is worthwhile by virtue of being a thoughtful attempt to consider future conditions. They maintain that concerns of uncertainty surrounding model-based climate change metrics are misguided given that methods for protecting the geophysical setting and quantifying connectivity also contain large amounts of uncertainty but are generally taken at face value. For example, soil data that informs ecotypic diversity and land cover data that informs resistance for connectivity calculations can each hold a great deal of error, yet these methods are more often accepted (Lawler & Michalak, 2017). No model will be perfect, but that is no reason to dismiss the use of climate change data and cease the work of developing novel approaches.

One creative method has been to apply abiotic goals to reconstructed ice age conditions – an exercise that allowed researchers to test how well geophysical feature targets performed over time given that we can observe present conditions as the outcome of the ice age's future (Williams et al., 2013). While the results showed that biotically-informed strategies were more effective at larger scales (e.g., climate velocity), abiotic methods can still be effective at identifying microrefugia. By using features that represent the geophysical stage, climate velocity, and refugia, I took a diverse climate change approach that mitigates uncertainty by not being overly reliant on any one strategy. Furthermore, I explicitly

addressed connectivity – another climate strategy rooted in the idea that connecting intact ecosystems boosts their inherent value and provides safe passage for climate refugee species (Groves et al., 2012). By building on an already multi-faceted approach with connectivity, I further diversified my climate change portfolio to develop a strategy that mitigates any one facet's shortcomings through variety (Groves et al., 2012; Mann, 2020).

To make my climate change strategy even more robust according to Groves et al. (2012), I would need to focus further on ecosystem process and function, as well as capitalizing on opportunities emerging in response to climate change. The former would entail expanding the forest pattern and process layers I used to include more disturbance regimes. This proves difficult given how poorly understood some processes are and the limited data surrounding them, as well as problematic given how much it could shift the focus away from biodiversity itself (Groves et al., 2012). The latter proves challenging because it requires building alliances with activities that may not be conservation-focused, coupled with the fact that these initiatives may not easily translate into spatial data for use in an SCP (Groves et al., 2012).

The multi-faceted approach that I used translates well to this relatively intact landscape. Considering the geophysical stage, climate velocity, refugia, and connectivity addresses three of the five approaches examined by Groves et al. (2012), while addressing all six of the Yale Framework objectives to at least some degree (Schmitz et al., 2015). There is still room for improvement given local context, however. My strategy could be enhanced by steps such as integrating beetle disturbance regimes to address the ecosystem process and function approach, as well as an increased focus on ecosystem services like carbon storage to capitalize on climate change-driven opportunities. All approaches carry uncertainty, and so

the pursuit of ever more robust strategies for effectively incorporating climate change within SCPs should continue.

6.3 How can landscape connectivity be explicitly included in the Systematic Conservation Planning process?

Landscape connectivity has been recognized as a crucial ecological component of systematic conservation plans, but most efforts to date have used it as a post-hoc or supplementary analysis rather than a core component of the model (Fajardo et al., 2014; Mann, 2020). There are many existing tools to quantify permeability and connectivity of the landscape, but efforts to explicitly include their outputs within terrestrial SCPs have been limited (Heinemeyer et al., 2004; Hermoso et al., 2012). Keeley et al. (2021) have synthesized the relevant literature and provided a helpful decision tree for users to decide which tool best suits their needs based on the context of their work. I incorporated connectivity explicitly in my model by using current flow metrics from Linkage Mapper and Omniscape to capture structural connectivity. The relative intactness of the Greater Tsay Keh Dene Territory Study Area justified my use of current flow metrics according to Keeley et al. (2021), the nuances of which are described below.

6.3.1 Choice and Use of Connectivity Tools

The Omniscape connectivity tool requires users to input both a resistance layer (how difficult it is to traverse the landscape) and a source layer (intact areas). I used the inverse of the resistance layer as my source layer (also known as naturalness), which Keeley et al. (2021) equate to structural connectivity and consider to be a coarse-filter conservation strategy. This was my goal, as I set out to quantify generalized landscape connectivity – not

structural connectivity of a specific species or functional connectivity for a specific species based on movement data.

SCP prioritization is designed to select the most efficient array of planning units that meet each of the user's targets. Individual planning units are assessed in a vacuum, and thus it can be a challenge to ensure that a conservation solution is sufficiently contiguous so as to promote connectivity across the landscape. Including connectivity data as a conservation feature does not address this issue – though I did include both Linkage Mapper and Omniscape outputs as conservation features to be able to assess incidental capture. My strategy to ensure that conservation solutions could be connected was to include options for 'locking in' connected lands.

As Keeley et al. (2021) argue that assessing structural connectivity and using naturalness is a coarse-filter conservation strategy, it follows that scenarios relying on these locked-in connected areas should focus on future-oriented climate change features. I used this strategy in scenario F when I locked in the leaner Omniscape 'Bones' layer, setting targets solely on coarse-filter and climate change features (including both 2050 and 2080 time periods). However, in scenario E existing protected areas (PAs) and the least-cost paths between them served as the locked-in connectivity layer. This scenario has more of a present-day focus given that these protected areas were designated with their current attributes in mind. Thus, I set targets on present-day features for this scenario.

6.3.2 Solution Characteristics

While the PA connectivity solution was influenced by the locking in of protected areas, its solution was similar to the present-day solution – its counterpart in present-day

conservation feature target setting. The least-cost paths seemed to have little effect on the overall solution, likely due to how lean the corridors were. At just one to two planning units wide, these corridors were only somewhat latched onto by high-value conservation planning units to create broader, functionally connected corridors as intended. The LCPs – particularly those in the south – were often not selected in the present-day solution, suggesting that they do not hold ecological value on their own.

There were two focal areas selected in the PA connectivity solution but not the present-day solution (Figure 77). The first is in the Rocky Mountains between Ed Bird-Estella Lakes Provincial Park and Sikanni Chief River Ecological Reserve (Area 1). This region was likely selected given its high patch connectivity potential due to the number of protected areas in the region (including Graham-Laurier and Redfern-Keily Provincial Parks) coupled with high biodiversity in the Ospika River valley and surrounding mountain ranges. The other focal area is in the southwest corner of the study area along Takla Lake (Area 2). With protected areas and LCPs locked in, this solution had to look elsewhere to capture targets, resulting in a 3% larger solution than scenario A. This area was likely selected due to its proximity to the large lake, quality fisher habitat, rare BEC subzone variants, and abundance of old growth Sub-Boreal Spruce forests with frequent stand-initiating events.

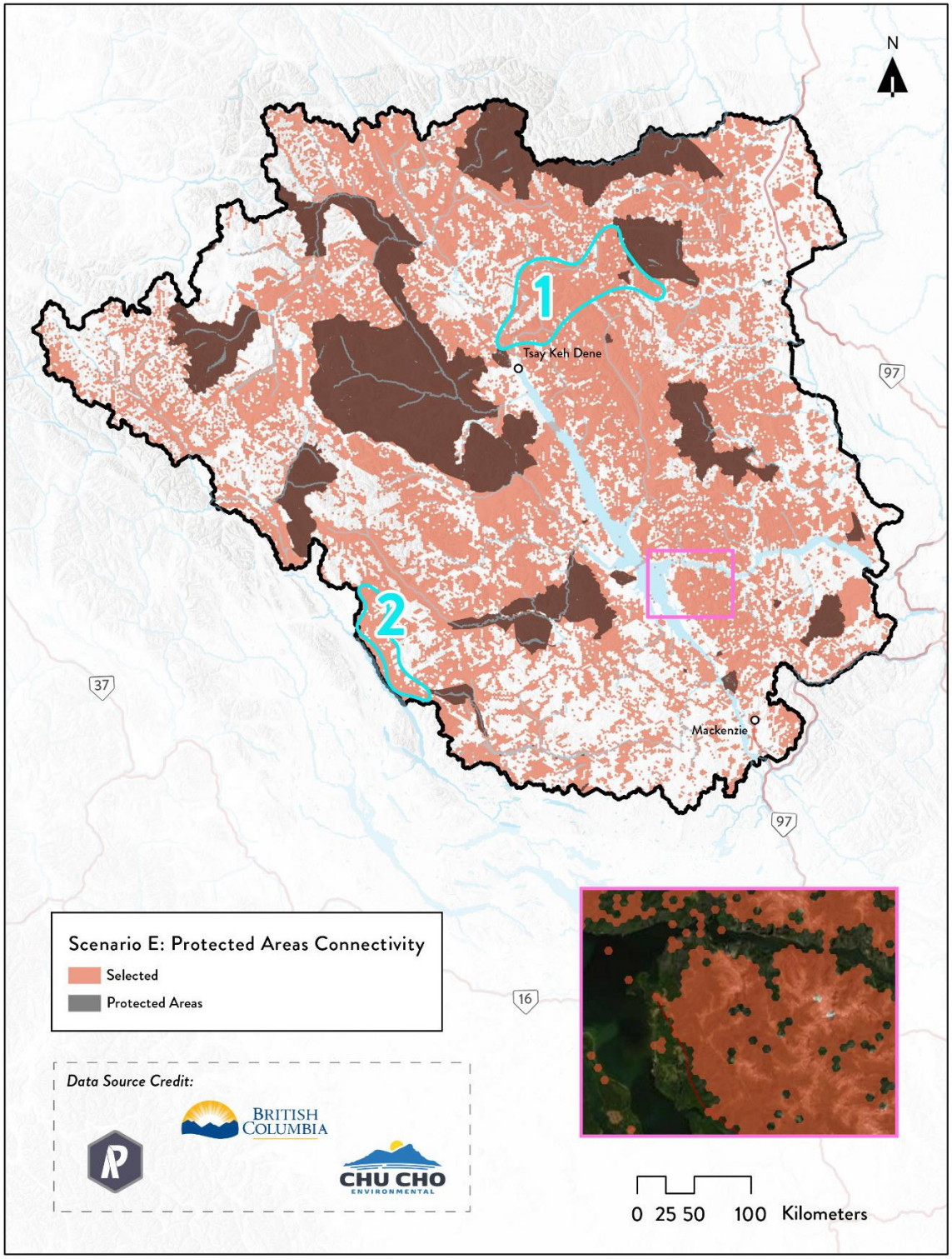

Figure 77. Focal areas (outlined in light blue and numbered) and protected areas overlaid with the spatial extent of the conservation solution for Scenario E: Protected Areas Connectivity within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

The landscape connectivity scenario can be compared to the 2050s and 2080s climate scenarios given their almost identical targets. The landscape connectivity solution was influenced by the locking in of Omniscape connectivity corridors, resulting in the selection of novel focal areas and a 2% increase in area over the 2050s and 2080s solutions. Many of these novel areas were likely identified by Omniscape as highly connected but did not necessarily have value in a climate-altered landscape (Figure 78). These instances were found along the northern Rocky Mountain Trench between Finlay-Russel and Kwadacha Wilderness Provincial Parks (Area 1), the Sikanni and Osilinka Ranges east of Sustut Provincial Park (Area 2), the Tenakihi Range south of Chase Provincial Park (Area 3), and the Rocky Mountain Foothills north and east of Graham-Laurier Provincial Park (Area 4). The most sizable focal area was in the south between Omineca Provincial Park and Tchentlo Lake, though it was somewhat dispersed (Area 5). This area appears to be partially influenced by landscape connectivity, but ecotypic diversity, carbon storage, and low climate velocities also seem to have played a role in its selection.

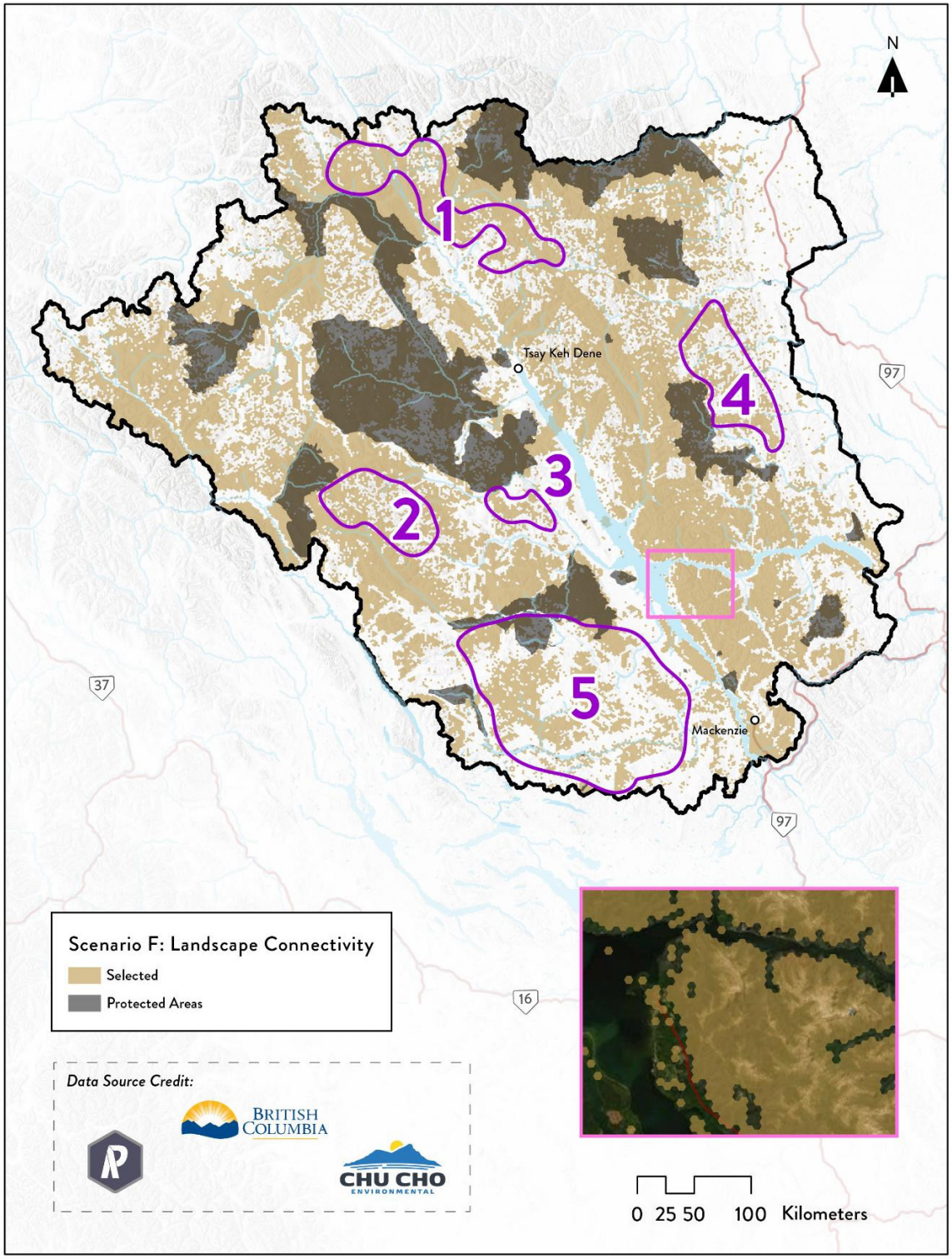

Figure 78. Focal areas (outlined in purple and numbered) and protected areas overlaid with the spatial extent of the conservation solution for Scenario F: Landscape Connectivity within the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

6.3.3 Traditional Ecological Knowledge of Connectivity

The connectivity stage could have potentially benefited from further community input and local knowledge on movement corridors as part of the factual observations face of TEK. While the Nation's knowledge and values did inform the human footprint layer and therefore the resistance/permeability input in my connectivity analyses, existing TEK-sourced connectivity data was not available. As previously mentioned, the Nation does have polyline data within their Cultural Knowledge Keeper database; however, this data is limited in extent and largely focuses on trails used by people and not necessarily wildlife. I did not pursue procuring connectivity data from other Nation sources in the interest of time and due to the difficulty of first-hand data collection from the community given the pandemic. Charting movement or migration corridors known to elders and other community members who know the land would be a worthwhile addition to this project by the Nation after the fact, or for other community-guided SCP projects.

Had known migration corridor data existed it would have been interesting to develop a methodology for explicitly including it – whether it be standalone or interwoven with the outputs of the least-cost path or moving window analysis methods. This stage demonstrated that even in an Indigenous-led project, deferring to the Western science default might occur as a backup when no documented TEK exists, provided the community understands and approves of this method. Further exploration of how to appropriately collect TEK-sourced connectivity data and how best to interweave this knowledge is needed.

6.3.4 Future Use of Connectivity within SCPs

Solely including connectivity data as a regular layer for *prioritzr* to select from in an SCP analysis is not ideal because the tool assesses each conservation feature in a vacuum at the planning unit level, ignoring whether that specific conservation feature is found in neighbouring planning units or not. Only after the data have been synthesized into the conservation solution can weights be adjusted to encourage grouping or clumping of selected areas. That is to say, a connectivity dataset does not prove most useful as a regular input layer in the *prioritizr* analysis. As disparate portions of different corridors would likely be selected, this method defeats the purpose of including a layer whose inherent value comes from its contiguity (Mann, 2020). Including connectivity data as an option to 'lock-in' as part of the solution is one simple and accessible path forward, as it gives the user an opportunity to ensure a connected landscape within their solution. A post-hoc or other connectivity analysis can always be used later instead of, or in addition to, a locked-in option. Deciding how to utilize the outputs of Linkage Mapper and Omniscape to develop locked-in layer options then becomes the question. *prioritizr* can also encourage connected and contiguous solutions through penalties and constraints, even supporting connectivity data as inputs to parameterize these functions.

Research surrounding best practices for considering connectivity in conservation planning is ongoing (Keeley et al., 2021). I found helpful guidance after completing my scenario simulations that would likely change my approach to including protected areas connectivity in the future. In the absence of species-specific movement data, I would adopt a 2 km minimum buffer as a useful rule of thumb for adequate connectivity corridor width (Beier, 2019). In my protected areas connectivity locked-in layer, I only included planning

units traversed by least-cost paths. As my 1 km^2 planning units are just over 1 km across, the resulting corridors fall below this threshold in most cases. Thus, in future efforts I would buffer least-cost paths to achieve the minimum 2 km width.

Omniscape is preferable to Linkage Mapper in a relatively intact landscape such as this given its comprehensive focus. The only exception is if the objective is connectivity between specific areas, in which case Linkage Mapper may be better suited. There is a delicate balance of choosing how much of the Omniscape output to include as a locked-in option to ensure connectivity, yet not be heavy-handed and still allow the tool to perform conservation prioritization. My method of dividing the Omniscape output into quantiles and including multiple locked-in options is a helpful way to navigate this predicament, as it allows the user to experiment and find the optimal level of locked-in connectedness for their conservation purposes.

The Nation has already expressed confidence in the connectivity outputs, to the extent that they have amended the proposed internal boundaries of the Ingenika Conservation and Management Area based on the Omniscape analysis. Specifically, the connectivity corridor portion of the CMA between the Cultural Epicenter (the portion to receive legal protected status) and Chase Provincial Park was altered to maximize areas with concentrated current flow. My connectivity outputs could also help inform other portions of the CMA boundary as well as any new protected area efforts as project results are reviewed.

6.4 Which stages of the Systematic Conservation Planning process provide an opportunity for the interweaving of Traditional Ecological Knowledge to produce a more inclusive conservation plan?

The most novel and challenging portion of this project was determining how to effectively and inclusively interweave Traditional Ecological Knowledge and community input with the SCP process. As Western and Indigenous worldviews can sometimes appear to be at odds, blending these two ways of knowing in a manner that is respectful to TEK's sacred and cosmological origins while adhering to SCP methodology proved to be a delicate balance at times. While I was in regular contact with the Nation and working in their office throughout the process, I had to remain careful not to corrupt this knowledge by using it in a way that it was not intended.

I used GIS not just as a tool, but also as a critical approach to understanding community and conservation needs. GIS inherently privileges the Western scientific spatial understanding of the world in which it was created and can marginalize other ways of knowing (Burkhart, 2018). Recognizing GIS as a colonial tool and working to interweave local community knowledge from Indigenous peoples is an attempt to counter or disrupt that status quo. While the SCP methodology is also rooted in Western science, it is worth noting that this project was initiated by the Tsay Keh Dene First Nation and seeks to further *their* conservation and natural resource management goals – not solely for, or in co-management with a colonial government. This Indigenous community-led distinction is what makes this a TEK project, as the Nation's ethics and values were imprinted on the project as they guided my use of the SCP framework throughout (Figure 7). This is consistent with Houde's (2007)

depiction of TEK as being holistic and multi-faceted – not just factual observations as TEK can sometimes be portrayed.

6.4.1 Contrasting with Other TEK-guided SCP Efforts

Community-based research is more involved than a strictly academic exercise by virtue of listening to more voices; however, the additional time and effort required results in a more meaningful and fulfilling project with a greater chance of uptake and real-world impact (Strand et al., 2003). Building relationships, holding workshops, and fostering productive discussions certainly extended the amount of time required to complete this project, but were vital steps in producing a plan that reflected the visions and goals of the Tsay Keh Dene Nation.

Previous SCP work performed in close proximity to Tsay Keh Dene Territory has provided meaningful insights into the Wild Harts and Peace River Break areas; however these efforts were not community-led (Curtis, 2018; Mann, 2020). These projects were more of an academic exercise, though they did have support and interest from the Yellowstone to Yukon Conservation Initiative (Y2Y). Backing from larger organizations like Y2Y can be crucial for broader awareness and financial support but can lack the invaluable local insights and buy-in that community engagement often provides. Furthermore, when the local community in question is a First Nation there is even more nuance to consider. Communications and decision-making must be viewed through a culturally appropriate lens by considering centuries of colonialism and making good faith attempts to understand a Nation's worldview (Reid et al., 2021). Presenting a project and its facets must be done in a manner that respects all belief systems.

Heinemeyer et al.'s (2003) work with the Taku River Tlingit First Nation is a great example of taking a TEK-driven SCP even further than this project was able to. Their effort was a multi-year, multi-organization feat that included several champions, and the resulting breadth and depth of their work is apparent. Working with many community members over a longer time period, they were able to gather TEK through taped interviews and mapping workshops to chart species distributions. This exhaustive effort included semi-structured interviews with 60 potential questions, and resulted in over 1200 pages of transcribed responses (Heinemeyer et al., 2003). Their data collection was extensive enough to inform season-specific habitat suitability models for several focal species. In contrast, I utilized existing TEK wildlife data that was not necessarily intended to inform a habitat suitability model. Its limited extent also meant using it as an enhancement to existing Western science models rather than standalone TEK wildlife layers. With more time and greater freedom to visit with community members in a post-pandemic world, this work could be improved with a more intensive TEK data collection effort.

6.4.2 Community-centric Planning

A truly community-centric approach would look more like the Taku River Tlingit effort of knowledge collection as opposed to this project that focused more on using already available information. An enhanced knowledge gathering effort would have to be thoughtfully organized and include community mapping workshops to document the distribution of features on the landscape. Individual semi-structured interviews with elders would also be beneficial if circumstances allowed. With more robust TEK-sourced feature data layers in hand, additional decisions would have to be made on how to implement hierarchy within datasets, as well as how and if to attempt to blend this information with

Western science models to create hybrid layers. This cross-pollination of perspectives or marrying of both worlds holds real potential for better conservation outcomes if navigated thoughtfully (Polfus, 2018). Furthermore, 'biocultural approaches' such as this are better set up for success given that local communities have contributed to the work and have a vested interest in conservation goals coming to fruition (DeRoy et al., 2021). Accomplishing any or all of the above tasks would likely require increased staff time and resources from the Nation to assist an outside researcher like me.

Decisions still had to be made with the cultural data that was available, but these were more technical than philosophical. I was provided with cultural data from the Nation in the form of points, lines, and polygons from their Cultural Knowledge Keeper database. I ultimately did not use the linear data since it was solely made up of trails, but there is an argument to be made for the cultural importance of these routes and they could be included in future efforts by the Nation. I scored planning units commensurate with the number of 'Sites of Cultural Importance' found within them (i.e., a planning unit with four sites received a score of four). Finally, given the uncertainty around the spatial extent of some of the polygons behind the 'Cultural/Spiritual Areas' and 'Subsistence Areas' layers, planning units were scored higher based on the number of overlapping polygons present following Darvill and Lindo's (2015) methodology for quantifying community-generated spatial data.

The decisions on which portions of the Cultural Knowledge Keeper database to use and how to use them within the tool were largely made by me individually. While these decisions were ultimately signed off on by Nation representatives, determinations on how many layers to create, how to score them, and what targets to set on them may well have looked different if discussions with staff from the Nation and Chu Cho had taken place from

the outset. The target setting workshop I held was one instance of collaborative discussion that served to confirm my actions with only slight adjustments. Nation staff are generally aware of community consensus but decided to go a step further and send out a survey to community members to help quantify the relative importance of cultural/spiritual areas as well as specific species and ecosystems. There were twelve respondents in the end, and their answers reinforced the preferences voiced by Nation staff. This led me to adjust targets on moose, Stone sheep, and mountain goat, elevating them above the default value set for other species. It also prompted me to raise the lakes value, as this was the unanimously most important conservation feature according to Tsay Keh community members.

The survey also provided additional useful information. There was an open-ended question on what additional features should be included in future efforts, which could prove useful if the Nation wants to expand the tool. Other features mentioned included: weasels, eagles, elk, additional cultural elements, low elevation pine lichen habitat, beaver, blue grouse, ptarmigan, and natural springs. The survey also provided a short answer box that allowed participants to provide context for why they answered the way they did. These comments centered around the belief that all life is important and interconnected in the territory. To quote one response, "All living things hold importance to each other. Our great ecosystem that creates a natural balance of all life. Each value has equal importance; if we take away one the other will be affected in some way. We must protect this life balance for our future generations."

This brief survey provided just a taste of what a more community-centric approach could look like. Rather than serving to confirm notions of importance, future efforts could concentrate on community engagement from the outset, learning which features matter most

and how to measure them. This would require research ethics approval if being performed by the student and would ideally be done via in-person workshops in the community rather than the online survey performed by the Nation due to the COVID-19 pandemic. Delineated features could then be plotted on large maps at subsequent workshops for further discussion and validation. We discussed the feasibility of these tasks early on in this project; however, given its already large scope and the remoteness of the community we realized how difficult it might be. The pandemic all but made the final decision for us.

Beyond learning more about the community's values as they relate to my project, the COVID-19 pandemic precluded me from forming relationships with many Nation members, as visiting the Tsay Keh Dene community was not possible given safety measures. This not only kept me from gaining an understanding of local context from site visits but also robbed me of the ability to make connections with the people this work sought to benefit. It would have been deeply beneficial for me to learn of Tsay Keh history through the voices of elders and not just existing literature, as hearing stories of customs, traditions, and the devastation caused by the dam from the source would have better grounded my work in the worldview of the Tsay Keh Dene.

6.4.3 Partner Backgrounds

I was also somewhat limited in my ability to coordinate with Nation staff members and Chu Cho Environmental employees in a face-to-face manner in Prince George – especially at the beginning of the pandemic. Remote communication methods such as email, video chats, and phone calls were utilized throughout the project. As pandemic safety protocols were developed, I was eventually able to work out of Chu Cho's office once a week. The ability to be in the same space as my collaborators proved invaluable in building

connections and relationships and improved the project overall. It allowed me to better understand the Nation's capacity and specific interests surrounding my work, allowing me to better tailor products to suit their needs.

Of the six Nation and Chu Cho staff members that made up the informal team supporting this project, five were non-Indigenous. The one Tsay Keh Dene member provided invaluable guidance regarding Nation priorities and community values and was a great resource in building out the case study chapter with history of the people and the land. Non-Indigenous staff also possess a meaningful understanding of the community's values and were able to convey those perspectives as well as provide their own valuable feedback given their backgrounds in Western science. For example, the biologists were able to offer context on how to use the Habitat Suitability Indexes they had developed for species at risk within the Territory. While these Western and community-informed perspectives were valuable, they are not a stand-in for being immersed in the community and truly engaging Tsay Keh Dene members to help guide the project.

Having community partners on the ground is a tremendous asset, as they can serve as champions of this work and take advantage of its findings. This distinction sets this effort apart from SCPs without a local community aspect. Furthermore, the staff at Chu Cho Environmental and Tsay Keh Dene's Lands, Resources, and Treaty Operations office are highly capable. Together they are extremely involved in natural resource decisions in the Territory – from resource extraction referrals to the creation of Indigenous Protected and Conserved Areas. With their leadership, the final products of this work can have real-world impacts in instances like identifying which areas to avoid timber harvest in, or where to focus efforts for a second IPCA. The staff's broad, existing capacity in fields like forestry, biology,

conservation science, and Geographic Information Systems meant I only had to focus on teaching the specifics of the tool I created. Once they understood its innerworkings, their local knowledge and extensive experience in environmental science allowed them to fully leverage the tool and truly make it their own.

6.4.4 Reflections on SCP Stages

The main theme that emerged from this community-led approach to the SCP process was the importance of providing sufficient context and conveying the implications of each decision that had to be made. Selecting a study area boundary was an early example. While this step is relatively simple in theory, it carries huge ramifications. It would be very time-consuming to change course after data gathering and manipulation has taken place, so if it is possible that the study extent might be revisited then it is better to err on the side of too large of a study boundary. It is significantly easier to cut down extent rather than go back and re-download and process data for a larger extent.

A good example of providing context was in the goal articulation stage. I found that providing the Nation with the goals from a similar, albeit non-Indigenous-led effort was helpful in beginning the discussion (Weaver, 2019). After receiving a first draft of goals from the Nation I had to provide further context and propose some changes to bring their goals in line with what the SCP approach was capable of accomplishing. For example, wetlands restoration was important to the Nation, but SCP can only identify and prioritize areas containing wetlands. The Nation's original goal is valid and can stand as written for their own conservation actions stemming from this work, but for this project the modification was necessary.

As the project progressed towards more complex and sometimes nebulous tasks, it became apparent that discussions were more productive when ample background was provided. I also began to provide a first draft of ideas for the Nation to respond to based on my reading of relevant literature and understanding of the Nation's priorities for conservation feature selection, target setting, and human footprint features and buffers. This was a balance of not going too far down a single path before consulting with partners while still providing enough material to react to and not overburden or overwhelm already busy staff members. I had to be especially conscious of not overpriming community partners given the Western biases of GIS and SCP. While I wanted to effectively convey the parameters of the project, I still wanted authentic ideas from the Nation and not answers that were overly pigeonholed by the conventional SCP framework.

Another benefit of providing substantial context is that it allowed the Nation to assess the appropriate personnel to involve at each stage. For example, Chu Cho brought their GIS specialist into the conversation at the human footprint stage given their expertise on data availability and awareness of ongoing and imminent work being carried out on the land. This led to more accurate and precise road, drill site, mine, and cutblock features for inclusion in the human footprint layer. While not explicitly a material face of TEK, this contemporary local knowledge of the Territory and community values on regional issues provided valuable insight on a number of occasions. Chu Cho has since expressed enough confidence in the resulting human footprint layer to use it as a detailed disturbance layer to inform moose and caribou habitat modeling work in the territory.

The target setting stage proved especially challenging – both for the cultural sensitivity involved in quantifying the relative importance of features, and the general

uncertainty that underlies the selection of these targets. Targets were informed by ecological best practices or Nation priorities and were both transparent and well-documented. In cases where neither of these approaches could help inform a conservation target or there were concerns around data quality, conservative estimates were chosen to ensure consistency and adequate feature capture. Additionally, *prioritizr*'s nimble nature allows for flexibility by running multiple scenarios with differing targets set for an uncertain conservation feature, thereby mitigating the risks associated with a given feature.

The staff's experience in navigating both Western and Indigenous knowledge was indispensable in the target setting stage, as quantifying the relative importance of features is challenging enough on its own. Undertaking a task that can appear contradictory to the underlying beliefs of the community further complicated the matter, but it is a necessary step in the SCP process. Hearing staff perceptions of community values towards wildlife and ecosystems helped translate priorities into numeric targets, and having the Nation initiate a survey of community members that ultimately backed up those claims with data was affirming. By asking community members to essentially prioritize certain cultural elements, species, and ecosystems ahead of others, I knew there was the potential of offending them with a question that could be interpreted as antithetical to their worldview. The Nation deemed it appropriate though, and it was a valuable addition to the project in the end.

Another takeaway was to earnestly consider any idea that was offered by our partners and think creatively about how it could be integrated into the project, within reason. For conservation features that had not been used in previous efforts (e.g., moose, Stone sheep, and mountain goats), this meant compiling trustworthy habitat data and assembling it in a piecemeal fashion to cover the study area in a defensible manner. Another example was

leveraging knowledge from existing sources like an ‘expectations for industry’ document developed by the Nation with knowledge sourced from many elders (Chu Cho Environmental & Tsay Keh Dene Nation Lands, Resources and Treaty Operations Department, 2019). This helped me develop an ordinal structure within certain features. Wetlands, for example, were scored based on their size: 3 points if greater than 10 ha, 2 points if less than 10 ha but greater than 1 ha, and 1 point if less than 1 ha. When values are voiced, it is the researcher’s responsibility to examine how they can be effectively integrated into the project.

Engaging Nation representatives throughout the process undoubtedly required more time and effort than if I had made executive decisions based on my understanding of their wants and needs. Their insights on community values undeniably resulted in a better product, as has been discussed previously. What their involvement also added, however, was a sense of investment in the project that led to meaningful understanding and eventual uptake of the tool. When the time came for a final technical workshop to put the completed product on display, staff were better equipped to appreciate the tool and how they might use it in the future. This demonstration was paramount in providing tangibility to what often seemed like a nebulous concept when described in scoping meetings. It also served as the culmination of previous workshops, displaying how the information and guidance they provided along the way was leveraged within the now fully assembled tool.

The community was able to conceive of potential applications given their understanding of the inner workings of the tool and some potential applications that I suggested. With a tangible tool in front of them, their attention was captured and several types of analysis were formulated. Requests for additional functionality like subunit analysis (i.e., planning at the watershed level within the study area) and area budget-based analysis

(as opposed to feature target-based) were communicated and confirmed as feasible additions. These inquiries signaled a clear interest and engagement in the project that indicated a sense of enthusiasm for its use moving forward to assist in activities like systematic resource extraction referral responses and the identification of a core area for a second IPCA in the Territory.

6.5 Other thoughts

A few concepts were born out of this project that did not fit neatly into one of the above research questions but are still worthy of discussion. These revolved around contributions to national and global conservation efforts, the decision to set persistent targets on cultural features in every scenario, the decision not to use a certain human footprint layer, and the logistics of transferring the planning tool to community partners.

6.5.1 Contributions to larger conservation efforts

While not an explicit goal of this project, any conservation efforts stemming from this work will indirectly contribute to conservation on the national and global scale – particularly if new protected or conserved areas are established as a result. For example, the Government of Canada has committed to protecting 25% of Canada's lands and oceans by the year 2025, while global efforts are focused on protecting 30% of the Earth's lands and oceans by 2030 (Campaign for Nature, 2020; Liberal Party of Canada, 2019).

As it stands, 9% of the Territory and 11% of the study area are currently protected. When including the entirety of the Ingenika Conservation and Management Area, the Territory reaches 25% protection while the study area reaches 17% protection. As it stands the Ingenika CMA is only recognized by the Nation itself though, and provincially-

recognized protection is only being sought for the core of the CMA with the rest being managed through other conservation means. While the Ingenika effort is first and foremost by and for the Tsay Keh Dene, its establishment contributes to Canada's area-based goal of 25% by 2025. The establishment of any additional Indigenous Protected and Conserved Areas by the Nation would likely be informed by the products of this collaborative research project and advance towards the global goal of 30% protection by 2030.

These contributions are meaningful, but area-based goals are political and aspirational in nature and may be ecologically flawed, which is why I focused on conservation feature-based targets throughout this project (Wiersma & Sleep, 2016). The Nation still sees value in area-based target setting though, as it could be a means to an end for appealing to the federal government while advancing their own political agenda of IPCA-creation. During our final workshop one staff member voiced their intention of doing so, referring to the products of this effort as, "[A] really dynamic negotiating tool." With a defensible methodology for identifying the 30% of the Territory with the greatest conservation value, the Nation could present powerful evidence for their conservation efforts to be recognized.

6.5.2 Persistent targets on cultural features

I used consistently high targets on each of the three cultural conservation features given the sacredness of the places they represented. This was my initial proposal based on the nature and extent of these features, and that idea was affirmed by the Nation in our target setting workshop. When I stacked each of the six solutions to reveal which areas were consistently selected, the result naturally displayed these important cultural, spiritual, and subsistence areas. This could be interpreted as a bias towards cultural features; however, other areas were selected in all six scenarios purely on their ecological merit. Second, there is

nothing inherently wrong with weighting cultural areas so strongly that they heavily influence the outcome. The concept of human culture and nonhuman nature as separate worlds is a European construct that perpetuates imperialist attitudes on the division of culture and nature (Pacini-Ketchabaw & Nxumalo, 2015). This conflicts with the Nation's worldview of life as a web of related beings, and so this artificial Settler division was discarded given that this is a project of and for the Nation. The Tsay Keh Dene are the foundation of this project and this work seeks to further their holistic conservation goals.

6.5.3 Ephemeral-Sensitive Footprint Layer

I ultimately did not use the ephemeral-sensitive footprint layer in any of the scenarios for the thesis, but it remains an option within the tool for the Nation to use moving forward. This will prove useful should they decide to run scenarios focused on entirely undisturbed areas, which is relevant for extremely sensitive species like caribou. As ephemeral features were activities such as heliskiing and horseback riding, it felt short-sighted to dismiss areas that could otherwise hold great conservation value simply because recreation occasionally took place there. While management, policy, and land tenure decisions can be complicated, these areas could be reverted to undisturbed conditions overnight if the political will was there instead of semi-permanent cutblocks that can take decades or even centuries to fully regenerate.

6.5.4 Tool Handoff

While not a stage of the SCP process, working with a community means ensuring that they understand the process you are undertaking and can continue to use the tool you are developing on their behalf once the project is formally over. From the outset of this project,

the goal was to have a living tool that the Nation could update and expand as new data became available. This could be replacing or augmenting the spatial data for an existing conservation feature (e.g., new ungulate habitat modeling work was completed) or the addition of an altogether new conservation feature like one of the species named in the community survey. For this to happen, the tool needed to be made accessible to Nation staff.

I packaged the vast amount of spatial data generated over the course of the project into a user-friendly format and uploaded it, as well as the tool itself, onto an external hard drive to give to Chu Cho staff. I then assisted in loading the tool and underlying data onto the Nation's network so anyone with an organizational computer can run the tool. I also developed a guide outlining how to both update and add data, as well as ensure that the various components of the tool are working properly so that the entire package can continue to operate. These technical steps were paramount in ensuring the tool's efficacy moving forward and making good on our promised deliverable of an adaptive tool that can respond to the Nation's dynamic needs.

7.0 RECOMMENDATIONS

This research analyzed conservation value across greater Tsay Keh Dene Territory and served to both confirm ongoing conservation efforts and identify where future initiatives could be focused. The scenario stack solution, in particular, should be referenced in conservation efforts, as it combines a number of relevant scenarios to delineate which portions of the Territory meet goals on present-day biodiversity, climate change, and connectivity. The Nation should perform validation of these findings to ensure that they are

well-founded, but then there are countless possibilities for how they can apply the tool to future use cases to meet their needs.

7.1 Validation

This entire process is a simulation, and so any conservation solution will need to be verified and validated before decisions are made on the ground. One final way to include local, Indigenous knowledge is to have members of the Nation validate the conservation solutions to ensure that the areas they deem to be ecologically or culturally significant are properly captured in the analysis. The solutions will also require increased scrutiny and potential site visits when local decisions are being made. Initial discussions have taken place to have a Chu Cho staff member who lives in the community perform TEK validation by plotting results on maps and sitting down with elders to discuss findings and mark up the maps. This exercise could serve to endorse or challenge research findings but could also further develop a TEK-SCP methodology by formalizing this interaction and making it part of the interweaving process.

A complementary Western validation approach could also be undertaken to systematically verify the solutions. Hirsh-Pearson (2020) developed a method of inspecting the level of human footprint visible in satellite imagery using random sampling and contrasted those visual results with what available spatial data stated was present. When used systematically, this method generates confidence metrics for the findings as a whole. Using satellite imagery to verify specific areas of interest is also possible though. This could be used as a cost-effective approach to vetting specific areas, with genuine ground-truthing efforts taking place when an area starts to receive serious consideration for conservation action.

A supplementary approach to validation could also be performed with auxiliary data. These could be spatial datasets that depict an aspect of conservation value, but for one reason or another do not merit inclusion in the tool itself. For example, if reputable elk habitat suitability data is developed in an adjacent area but does not cover the entire extent of the study area, it could be used as an overlay. This allows the user to validate a conservation solution for its elk potential without having to incorporate that data within the tool explicitly.

Another potential validation dataset could be a conservation plan performed by a neighbouring First Nation. This could identify areas of mutual interest, foster cooperation, and potentially lead to conservation designation and co-management efforts like the West Moberly and Saulteau First Nations in their Caribou Conservation Partnership Agreement (Environment and Climate Change Canada et al., 2020). For example, the northern periphery of the study area overlaps with the Kaska Dena's Dene K'éh Kusān IPCA, allowing for a potential partnership for conservation efforts in the region (Dena Kayeh Institute, 2019).

Finally, the Tsay Keh Dene Nation is in the process of performing archaeological work within the Territory, though this effort is not yet finalized. Spatial data from this effort could also be overlaid with solutions to validate whether culturally important areas beyond those explicitly included in the tool were captured in a solution. Depending on the nature of the archaeological findings and available data, this layer could eventually move beyond being a supplementary feature and explicitly be included in the tool for target setting purposes.

7.2 Future Use Cases

There are a multitude of ways that the Nation can use the tool to help solve community-specific needs moving forward. At the final workshop, I outlined some potential uses to initiate further thought and discussion amongst Nation staff, the end-users of the tool. These talks centered around examining tool parameters, focusing on specific conservation features, using project outputs to better inform ongoing conservation efforts, and exploring novel conservation efforts.

One scenario that gained traction in the final workshop and merits additional exploration was to increase clustering within the tool. None of the scenarios run for the thesis encouraged clustering via the 'boundary length modifier' parameter, opting instead for the most efficient array of high conservation value planning units. The scattered result can be difficult to protect in practice, though. Clustered solutions provide more coherent areas that allow for more straightforward delineation and eventual protection, though they generally require a greater percentage of the landscape to meet conservation targets (Figure 79). This areal issue can be countered with a conservative blanket target for each feature (e.g., 40%); however, these lower targets also represent a compromise. Ultimately, clustered outputs can be more relevant and pragmatic for conservation action and should be further explored.

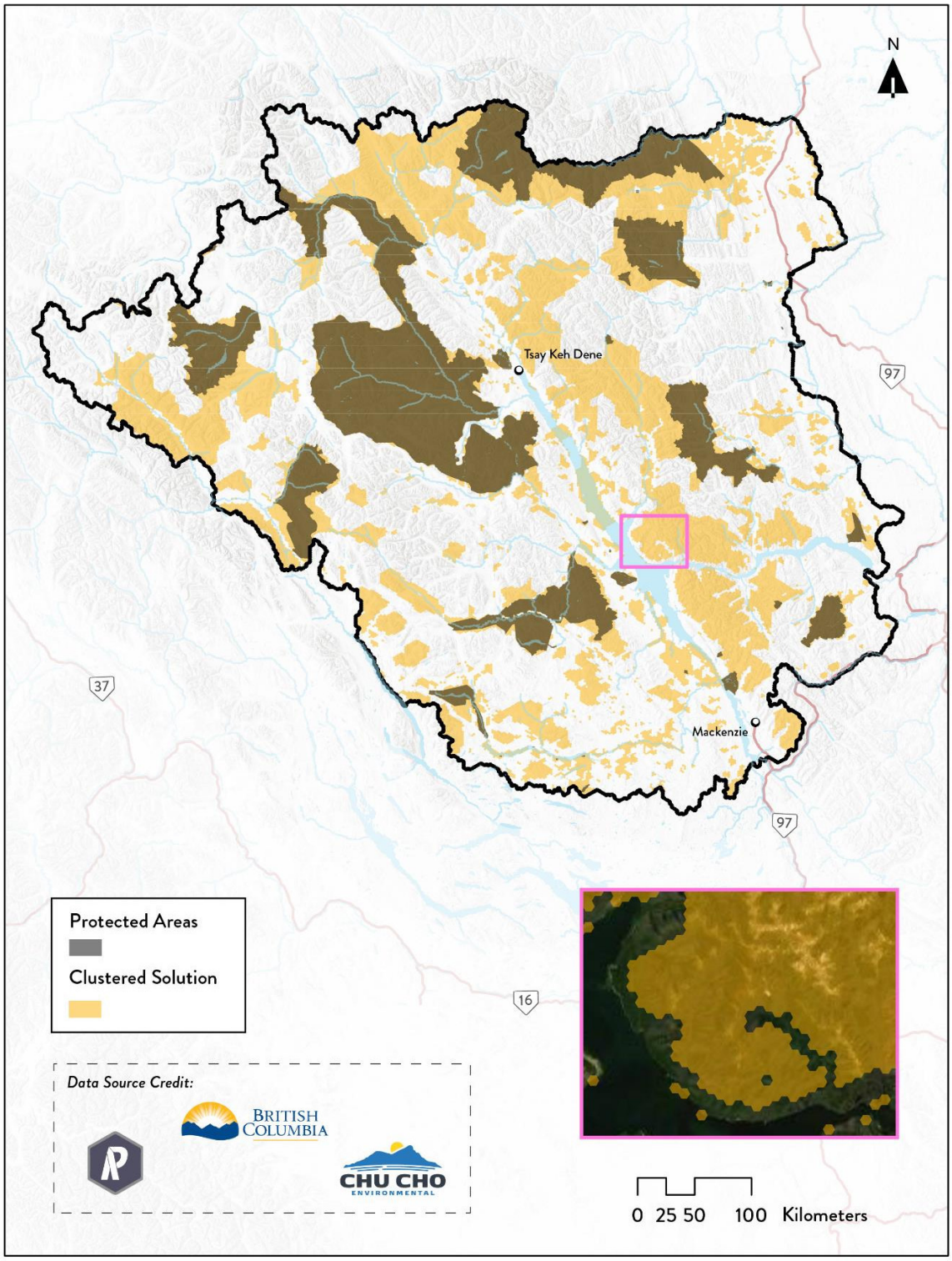

Figure 79. Spatial extent of a clustered conservation solution in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame. A conservative 40% blanket target was used.

The Nation should also consider honing in on specific conservation features and setting targets accordingly. This could mean setting aggressive targets on a single feature or set of features, or focusing on one feature and setting conservative targets on the rest. This strategy could provide valuable insight when the Nation has conservation concerns about a specific feature or a few related features. One example is a focus on mature and old-growth forests throughout the Territory (Figure 80). Setting 100% targets on the mature/old forest pattern and process layers would clearly delineate these invaluable ecosystems for conservation action.

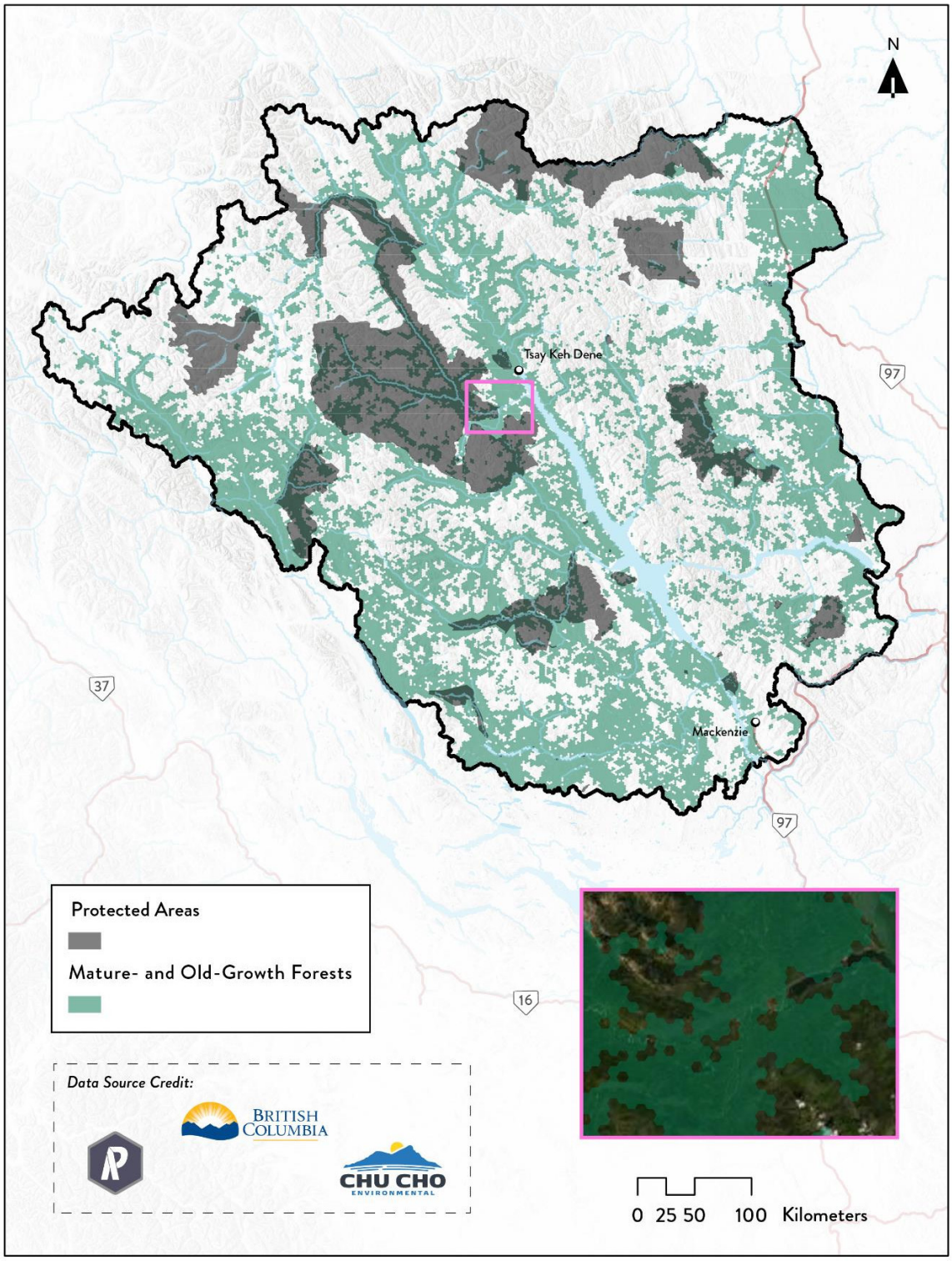

Figure 80. Spatial extent of mature- and old-growth forests in the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame. 100% targets were set on relevant layers, with no targets set for other layers.

The clustered and scenario stack solutions provide the optimal catalog for identifying coherent high-value areas. They should be considered in tandem when scouting locations for an additional IPCA or other effective area-based conservation measures (OECMs) in the Territory (Figure 81). The scenario stack provides a modestly grouped solution that represents consistently selected areas across varying conservation goals. The clustered solution – based on grouping with conservative blanket targets – provides a structure of consolidated areas to choose from. Together they co-produce a pragmatic framework to facilitate delineation around consistently selected areas.

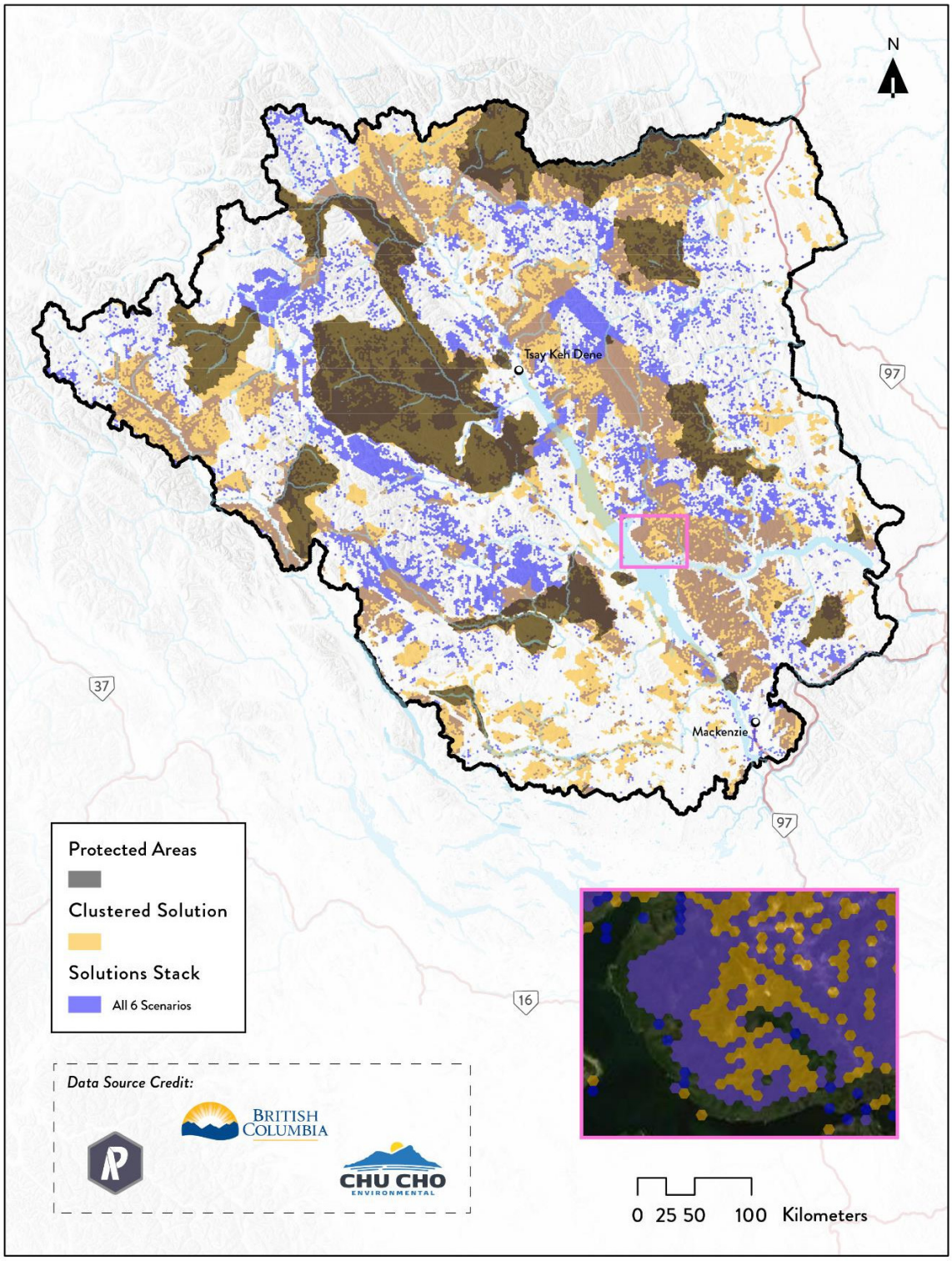

Figure 81. Spatial extent of the clustered conservation solution atop the planning units selected in all six of the thesis scenarios for the Greater Tsay Keh Dene Territory Study Area; inset represented by pink frame.

Finally, the connectivity analysis – particularly the outputs of Omnicape – should be used to inform conservation decisions. Omniscape connectivity has already proven helpful in refining the internal subunit boundaries of the Ingenika Conservation and Management Area. It could also prove useful in designing additional conservation areas – either as overall boundary delineation or strategically placing a smaller area as a potential stepping stone for movement across the landscape.

These are just a few possibilities out of the countless use cases that Nation staff can develop and ultimately apply the tool to help solve. By mixing and matching conservation features, adjusting targets, locking in different areas, and avoiding varying levels of development, the tool provides users at Chu Cho Environmental and Tsay Keh Dene Nation's Lands, Resources, and Treaty Operations office with a dynamic and agile tool to meet their conservation planning needs now and into the future.

8.0 CONCLUSION

Both people and wildlife are being forced to adapt to environmental changes at contemporarily unprecedented rates. Human development presents continued disturbance to species and ecosystems – even in this remote corner of a country with low population density. Climate change is exacerbating these issues, even altering areas that have remained relatively unaffected by encroaching industry and settlement. This systematic conservation planning project was an effort to counter ongoing biodiversity loss using an area-based strategy that focuses on important landscape features like key species and ecosystems. I sought an outcome of inclusion and reciprocity by attempting to interweave the Traditional

Ecological Knowledge of the Tsay Keh Dene throughout the process. The main goal of this work was to benefit the Tsay Keh Dene and the land they call home. At the same time, this effort benefitted immensely from the invaluable knowledge of these Indigenous land stewards and those working on their behalf.

The Tsay Keh Dene have occupied this mountain- and river-filled landscape in so-called northern British Columbia since time immemorial. They have thoughtfully managed these landscapes for millennia and continue to even in the aftermath of a devastating reservoir and continually encroaching development. A consistent message throughout this effort, from the scoping stages to the final workshop, was that the Nation was burdened with the number of resource extraction referrals they routinely receive and could benefit greatly from a systematic review process. This project's final product planning tool will allow the Nation to place these forestry and mining requests in a broader context so more holistic decisions can be made. Furthermore, the tool facilitates location scouting for high-value conservation areas, allowing for proactive conservation efforts and furthering ambitions for IPCAs.

The adaptability of the SCP process proved vital as I adopted methods for considering climate change, explicitly included landscape connectivity data, and sought to interweave TEK throughout the project. By including data on the geophysical stage, areas with low climate velocity, and refugia, I accounted for predicted changes on the landscape over the next 30 to 60 years. A conservative target-setting approach helped mitigate the uncertainty underlying some of these metrics. Landscape connectivity was explicitly included as an option to lock into conservation solutions, both ensuring movement corridors for wildlife today and acting as a climate adaptation strategy into the future. The last but most important

modification to the SCP framework was using a community-led approach and taking a critical GIS perspective. Tsay Keh Dene TEK and community input were the foundation of this project and undoubtedly led to an enhanced and more inclusive outcome.

By building a Western science-based GIS tool, Tsay Keh Dene knowledge, values, and priorities are articulated in a manner that is readily understood by the provincial and federal governments. My findings can serve to not only validate ongoing conservation efforts in the Territory but help guide future efforts by identifying additional high-value areas. These efforts will encourage not only ecological health in the Territory, but also further cultural restoration through the preservation of spiritual areas. The defensible nature of the SCP framework will help justify Nation-led conservation initiatives if and when formal negotiations take place between governments. Living in harmony with the land will always be a tenet of the Tsay Keh Dene way of life. By interweaving TEK with sound conservation science on biodiversity, climate change, and connectivity, we have developed an Indigenous-led SCP framework. This work can serve as a guide for conservation planning that promotes multiple ways of knowing – a strategy that is our best path forward given the urgency of the climate and biodiversity crises.

9.0 LITERATURE CITED

Abadzadesahraei, S. (2020). *Proposal Review* [Personal communication].

Andelman, S. J., & Fagan, W. F. (2000). Umbrellas and flagships: Efficient conservation surrogates or expensive mistakes? *Proceedings of the National Academy of Sciences*, *97*(11), 5954–5959. https://doi.org/10.1073/pnas.100126797

Ashcroft, M. B. (2010). Identifying refugia from climate change. *Journal of Biogeography*, *37*(8), 1407–1413. https://doi.org/10.1111/j.1365-2699.2010.02300.x

Baker, N., Beger, M., McClennen, C., Ishoda, A., & Edwards, F. (2011). Reimaanlok: A national framework for conservation area planning in the Marshall Islands. *Journal of Marine Biology*, *2011*, 1–11. https://doi.org/10.1155/2011/273034

Baldwin, R., Scherzinger, R., Lipscomb, D., Mockrin, M., & Stein, S. (2014). *Planning for land use and conservation: Assessing GIS-based conservation software for land use planning* (RMRS-RN-70; p. RMRS-RN-70). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-RN-70

Bateman, B. L., Wilsey, C., Taylor, L., Wu, J., LeBaron, G. S., & Langham, G. (2020). North American birds require mitigation and adaptation to reduce vulnerability to climate change. *Conservation Science and Practice*, *2*(8), e242. https://doi.org/10.1111/csp2.242

BC Agriculture & Food Climate Action Initiative. (2013). *Regional Adaptation Strategies: Peace Region* (Peace Region Adaptation Strategies, p. 43). BC Agriculture & Food Climate Action Initiative. https://www.bcagclimateaction.ca/wp/wp-content/media/RegionalStrategies-Peace-2013-report.pdf

BC Environment (Ed.). (1995). *Biodiversity Guidebook*. Forest Service, British Columbia : BC Environment.

BC Fisher Habitat Working Group. (2017). *User's guide – Fisher habitat spatial data*. https://www.bcfisherhabitat.ca/wp-content/uploads/2017/05/Users-guide-to-spatial-data-May-2017.pdf

BC Ministry of Environment. (2021a). *Redfern-Keily Provincial Park – BC Parks*. Province of British Columbia. https://bcparks.ca/explore/parkpgs/redfern/nat_cul.html#conservation

BC Ministry of Environment. (2021b). *Sustut Provincial Park and Protected Area*. BC Parks; Province of British Columbia. https://bcparks.ca/explore/parkpgs/sustut/

BC Ministry of Forests. (2003). *British Columbia's forests and their management*. Government of British Columbia. https://www.for.gov.bc.ca/hfd/pubs/Docs/Mr/Mr113/BC_Forest_Management.pdf

BC Parks. (2020). *Terrestrial protected areas representation by biogeoclimatic zone—Data Catalogue*. https://catalogue.data.gov.bc.ca/dataset/terrestrial-protected-areas-representation-by-biogeoclimatic-zone

BEC Program. (2011). *How BEC works*. Ministry of Forests, Lands and Natural Resource Operations. https://www.for.gov.bc.ca/hre/becweb/system/how/index.html

Beier, P. (2019). A rule of thumb for widths of conservation corridors. *Conservation Biology*, *33*(4), 976–978. https://doi.org/10.1111/cobi.13256

Beier, P., & Brost, B. (2010). Use of land facets to plan for climate change: Conserving the arenas, not the actors. *Conservation Biology*, *24*(3), 701–710. https://doi.org/10.1111/j.1523-1739.2009.01422.x

Berkes, F. (2018). *Sacred Ecology* (Fourth). Routledge.

Bethel, M. B., Brien, L. F., Esposito, M. M., Miller, C. T., Buras, H. S., Laska, S. B., Philippe, R., Peterson, K. J., & Parsons Richards, C. (2014). Sci-TEK: A GIS-based multidisciplinary method for incorporating Traditional Ecological Knowledge into Louisiana's coastal restoration decision-making processes. *Journal of Coastal Research*, *297*, 1081–1099. https://doi.org/10.2112/JCOASTRES-D-13-00214.1

Beyer, H. L., Dujardin, Y., Watts, M. E., & Possingham, H. P. (2016). Solving conservation planning problems with integer linear programming. *Ecological Modelling*, *328*, 14–22. https://doi.org/10.1016/j.ecolmodel.2016.02.005

Bonderud, E. S., Marini, K. L. D., & Herkes, J. (2020). *Species at risk in Tsay Keh Dene Nation: Habitat suitability index models final report*. Chu Cho Environmental LLP.

Bottrill, M. C., Joseph, L. N., Carwardine, J., Bode, M., Cook, C., Game, E. T., Grantham, H., Kark, S., Linke, S., McDonald-Madden, E., Pressey, R. L., Walker, S., Wilson, K. A., & Possingham, H. P. (2008). Is conservation triage just smart decision making? *Trends in Ecology & Evolution*, *23*(12), 649–654. https://doi.org/10.1016/j.tree.2008.07.007

British Columbia Assembly of First Nations. (2020). *Tsay Keh Dene*. British Columbia Assembly of First Nations. https://www.bcafn.ca/first-nations-bc/northeast/tsay-keh-dene

British Columbia Forest Service. (2007). *Spruce—Willow—Birch zone description*. Province of British Columbia. https://www.for.gov.bc.ca/hre/becweb/downloads/downloads_subzonereports/swb.pdf

British Columbia & Ministry of Environment. (2013). *Implementation plan for the ongoing management of South Peace northern caribou (Rangifer tarandus caribou pop. 15) in British Columbia*. Ministry of Environment.

Burkhart, T. (2018). *Counter-mapping for conservation: Digital conservation atlas case study* [Master's Thesis]. University of Northern British Columbia.

Campaign for Nature. (2020, November 5). *Getting to 30%*. Campaign for Nature. https://www.campaignfornature.org/getting-to-30

Carrasco, L., Papeş, M., Sheldon, K. S., & Giam, X. (2021). Global progress in incorporating climate adaptation into land protection for biodiversity since Aichi targets. *Global Change Biology*, *27*(9), 1788–1801. https://doi.org/10.1111/gcb.15511

Carroll, C., Lawler, J. J., Roberts, D. R., & Hamann, A. (2015). Biotic and climatic velocity identify contrasting areas of vulnerability to climate change. *PLOS ONE*, *10*(10), e0140486. https://doi.org/10.1371/journal.pone.0140486

Carroll, C., Noss, R. F., & Paquet, P. C. (2001). Carnivores as focal species for conservation planning in the Rocky Mountain region. *Ecological Applications*, *11*(4), 961–980. https://doi.org/10.1890/1051-0761(2001)011[0961:CAFSFC]2.0.CO;2

Carroll, C., Parks, S. A., Dobrowski, S. Z., & Roberts, D. R. (2018). Climatic, topographic, and anthropogenic factors determine connectivity between current and future climate analogs in North America. *Global Change Biology*, *24*(11), 5318–5331. https://doi.org/10.1111/gcb.14373

Carroll, C., Roberts, D. R., Michalak, J. L., Lawler, J. J., Nielsen, S. E., Stralberg, D., Hamann, A., Mcrae, B. H., & Wang, T. (2017). Scale-dependent complementarity of climatic velocity and environmental diversity for identifying priority areas for

conservation under climate change. *Global Change Biology*, *23*(11), 4508–4520. https://doi.org/10.1111/gcb.13679

Catchpole, R. D. J. (2016). Connectivity, networks, cores and corridors. In S. J. Carver & S. Fritz (Eds.), *Mapping Wilderness* (pp. 35–54). Springer Netherlands. https://doi.org/10.1007/978-94-017-7399-7_3

Ceauşu, S., Gomes, I., & Pereira, H. M. (2015). Conservation planning for biodiversity and wilderness: A real-world example. *Environmental Management*, *55*(5), 1168–1180. https://doi.org/10.1007/s00267-015-0453-9

Chan, K. M. A., Shaw, M. R., Cameron, D. R., Underwood, E. C., & Daily, G. C. (2006). Conservation planning for ecosystem services. *PLoS Biology*, *4*(11), e379. https://doi.org/10.1371/journal.pbio.0040379

Christensen, B. (1987, November 4). The Sekani Indians of Ingenika: 'We're refugees in our own land'. *Prince George Citizen*, 5.

Chu Cho Environmental. (2020a, October 26). *Wedzih—The caribou*. https://www.youtube.com/watch?v=o7lWkqMiz5s

Chu Cho Environmental. (2020b, November 10). *Tsay Keh Dene Nation—Ingenika Protected Area*. https://www.youtube.com/watch?v=jVS_HDW3zOY

Chu Cho Environmental. (2021, February 11). *The Chase caribou road restoration program*. https://www.youtube.com/watch?v=tvVLogfahAk

Chu Cho Environmental & Tsay Keh Dene Nation Lands, Resources and Treaty Operations Department. (2019). *Expectations for industry in Tsay Keh Dene Territory*. Tsay Keh Dene Nation.

Conservation Biology Institute. (2021). *The framework matrix | Yale framework*. Data Basin. https://yale.databasin.org/pages/matrix/

Curtis, I. (2018). *Systematic conservation planning in the Wild Harts Study Area* [Master's Thesis]. University of Northern British Columbia.

Darvill, R., & Lindo, Z. (2015). Quantifying and mapping ecosystem service use across stakeholder groups: Implications for conservation with priorities for cultural values. *Ecosystem Services*, *13*, 153–161. https://doi.org/10.1016/j.ecoser.2014.10.004

Demarchi, D. A., & Demarchi, D. (2003, February). *British Columbia wild ungulates habitat assessment* [EcoCat:The Ecological Reports Catalogue]. Ministry of Environment. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=1434

Dena Kayeh Institute. (2019). *Kaska Dena conservation analysis for an Indigenous Protected and Conserved Area in British Columbia*. Kaska Dena Council. https://denakayeh.com/kaska-dena-conservation-analysis-september-2019/

DeRoy, B. C., Brown, V., Service, C. N., Leclerc, M., Bone, C., McKechnie, I., & Darimont, C. T. (2021). Combining high-resolution remotely sensed data with local and Indigenous Knowledge to model the landscape suitability of culturally modified trees: Biocultural stewardship in Kitasoo/Xai'xais Territory. *FACETS*, *6*(1), 465–489. https://doi.org/10.1139/facets-2020-0047

Dinerstein, E., Vynne, C., Sala, E., Joshi, A. R., Fernando, S., Lovejoy, T. E., Mayorga, J., Olson, D., Asner, G. P., Baillie, J. E. M., Burgess, N. D., Burkart, K., Noss, R. F., Zhang, Y. P., Baccini, A., Birch, T., Hahn, N., Joppa, L. N., & Wikramanayake, E. (2019). A global deal for nature: Guiding principles, milestones, and targets. *Science Advances*, *5*(4), eaaw2869. https://doi.org/10.1126/sciadv.aaw2869

Doerr, V. A., Barrett, T., & Doerr, E. D. (2011). Connectivity, dispersal behaviour and conservation under climate change: A response to Hodgson et al. *Journal of Applied Ecology*, *48*(1), 143–147.

Dudley, N., Ali, Kettunen, M., & MacKinnon, K. (2017). Editorial essay: Protected areas and the sustainable development goals. *Parks*, *23*(2), 9–12.

Environment and Climate Change Canada, Province of British Columbia, Saulteau First Nations, & West Moberly First Nations. (2020). *Intergovernmental Partnership Agreement for the conservation of the Central Group of the Southern Mountain Caribou*. Province of British Columbia. https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/caribou/partnership_agreement_for_the_conservation_of_the_southern_mountain_caribou__central_group_2020-02-21.pdf

Fajardo, J., Lessmann, J., Bonaccorso, E., Devenish, C., & Muñoz, J. (2014). Combined use of systematic conservation planning, species distribution modelling, and connectivity analysis reveals severe conservation gaps in a megadiverse country (Peru). *PLoS ONE*, *9*(12), e114367. https://doi.org/10.1371/journal.pone.0114367

Festa-Bianchet, M., Ray, J. C., Boutin, S., Côté, S. D., & Gunn, A. (2011). Conservation of caribou (Rangifer tarandus) in Canada: An uncertain future. *Canadian Journal of Zoology*, *89*(5), 419–434. https://doi.org/10.1139/z11-025

Ffolliott, P. F., Baker, M. B., Tecle, A., & Neary, D. G. (2003). A watershed management approach to land stewardship. *Journal of the Arizona-Nevada Academy of Science*, *35*(1), 1–4. JSTOR.

Filatow, D., Harvey, G., Carswell, T., & Cameron, E. (2020). *Williston Wetland Explorer Tool* [Web Application]. Ministry of Environment and Climate Change Strategy. https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=5a59fc13b9064cf7b19398f29ceaac9e

Fish and Wildlife Compensation Program. (2014). *Peace Basin Plan*. BC Hydro, BC Ministry of Environment, Department of Fisheries and Oceans. http://fwcp.ca/app/uploads/2015/07/fwcp-peace-basin-plan-march-31-20141.pdf

Gallo, J., Butts, E., Miewald, T., & Foster, K. (2020). *Comparing and combining Omniscape and Linkage Mapper connectivity analyses in western Washington.* Conservation Biology Institute. https://doi.org/10.6084/M9.FIGSHARE.8120924

Garcia, R. A., Cabeza, M., Rahbek, C., & Araujo, M. B. (2014). Multiple dimensions of climate change and their implications for biodiversity. *Science*, *344*(6183), 1247579–1247579. https://doi.org/10.1126/science.1247579

Ghoddousi, A., Buchholtz, E. K., Dietsch, A. M., Williamson, M. A., Sharma, S., Balkenhol, N., Kuemmerle, T., & Dutta, T. (2021). Anthropogenic resistance: Accounting for human behavior in wildlife connectivity planning. *One Earth*, *4*(1), 39–48. https://doi.org/10.1016/j.oneear.2020.12.003

Gillson, L., Dawson, T. P., Jack, S., & McGeoch, M. A. (2013). Accommodating climate change contingencies in conservation strategy. *Trends in Ecology & Evolution*, *28*(3), 135–142. https://doi.org/10.1016/j.tree.2012.10.008

Gleeson, L. (2021). *Case Study Review* [Personal communication].

Government of British Columbia. (2019). *BC Species and Ecosystems Explorer*. Ministry of Environment. http://a100.gov.bc.ca/pub/eswp/search.do?method=reset

Government of British Columbia. (2020). Old Growth Management Tools. *Old growth strategic review*. https://engage.gov.bc.ca/oldgrowth/old-growth-management-tools/

Groves, C. (2003). *Drafting a conservation blueprint: A practitioner's guide to planning for biodiversity*. Island Press. https://web-b-ebscohost-com.prxy.lib.unbc.ca/ehost/ebookviewer/ebook/ZTAwMHhuYV9fMTMxOTU3X19BTg2?sid=1efb4219-52dc-46b3-bf64-7c031a557178@pdc-v-sessmgr06&vid=0&format=EB&rid=1

Groves, C. R., & Game, E. T. (2016). *Conservation planning: Informed decisions for a healthier planet*. Roberts and Company Publishers.

Groves, C. R., Game, E. T., Anderson, M. G., Cross, M., Enquist, C., Ferdana, Z., Girvetz, E., Gondor, A., Hall, K. R., & Higgins, J. (2012). Incorporating climate change into systematic conservation planning. *Biodiversity and Conservation*, *21*(7), 1651–1671.

Gurd, D. B., & Nudds, T. D. (1999). Insular biogeography of mammals in Canadian parks: A re-analysis. *Journal of Biogeography*, *26*(5), 973–982. https://doi.org/10.1046/j.1365-2699.1999.00334.x

Gustine, D. D., & Parker, K. L. (2008). Variation in the seasonal selection of resources by woodland caribou in northern British Columbia. *Canadian Journal of Zoology*, *86*(8), 812–825. https://doi.org/10.1139/Z08-047

Haber, J., & Nelson, P. (2015). *Planning for Connectivity: A guide to connecting and conserving wildlife within and beyond America's national forests* [Guide]. Defenders of Wildlife, Center for Large Landscape Conservation, Wildlands Network, Yellowstone to Yukon Conservation Initiative.

Hagen, J., & Weber, S. (2019). *Limiting factors, enhancement potential, critical habitats, and conservation status for bull trout of the Williston Reservoir Watershed: Information synthesis and recommended monitoring framework* (p. 160). Fish & Wildlife Compensation Program – Peace Region.

Hamann, A., Roberts, D. R., Barber, Q. E., Carroll, C., & Nielsen, S. E. (2015). Velocity of climate change algorithms for guiding conservation and management. *Global Change Biology*, *21*(2), 997–1004.

Hannah, L., Midgley, G., Andelman, S., Araújo, M., Hughes, G., Martinez-Meyer, E., Pearson, R., & Williams, P. (2007). Protected area needs in a changing climate. *Frontiers in Ecology and the Environment*, *5*(3), 131–138. JSTOR.

Hansen, A. J., & Defries, R. (2007). Ecological mechanisms linking protected areas to surrounding lands. *Ecological Applications*, *17*(4), 974–988.

Hanson, J. O., Schuster, R., Morrell, N., Strimas-Macket, M., Watts, M. E., Arcese, P., Bennett, J., & Possingham, H. P. (2021). *prioritizr: Systematic conservation prioritization in R* (R package version 7.0.1) [Computer software]. Comprehensive R Archive Network (CRAN). https://CRAN.R-project.org/package=prioritizr

Heinemeyer, Kim, Tingey, R., Ciruna, K., Lind, T., Pollock, J., Griggs, J., Iachetti, P., Bode, C., Olenicki, T., Parkinson, E., Rumsey, C., & Sizemore, D. (2004). *Conservation area design for the Muskwa-Kechika Management Area (MKMA)* (p. 804). Nature Conservancy of Canada; Round River Conservation Studies; Dovetail Consulting Inc.

Heinemeyer, Kimberly, Lind, T., & Tingey, R. (2003). *A conservation area design for the Territory of the Taku River Tlingit First Nation: Preliminary analyses and results* (A Report Prepared for the Taku River Tlingit First Nation, p. 98). Round River

Conservation Studies. https://www.roundriver.org/wp-content/uploads/pubs/taku/reports/TAKUCADrpt.pdf

Heinemeyer, Kimberly, Triska, M., O'Keefe, J., & Sizemore, D. (2019, July 23). *Conservation planning with Indigenous communities: Bridging two ways of knowing for a shared future*. Species on The Move International Conference, Kruger National Park, South Africa.

Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, *142*(1), 14–32. https://doi.org/10.1016/j.biocon.2008.10.006

Hengl, T., Mendes de Jesus, J., Heuvelink, G. B. M., Ruiperez Gonzalez, M., Kilibarda, M., Blagotić, A., Shangguan, W., Wright, M. N., Geng, X., Bauer-Marschallinger, B., Guevara, M. A., Vargas, R., MacMillan, R. A., Batjes, N. H., Leenaars, J. G. B., Ribeiro, E., Wheeler, I., Mantel, S., & Kempen, B. (2017). SoilGrids250m: Global gridded soil information based on machine learning. *PLOS ONE*, *12*(2), e0169748. https://doi.org/10.1371/journal.pone.0169748

Hermoso, V., Kennard, M. J., & Linke, S. (2012). Integrating multidirectional connectivity requirements in systematic conservation planning for freshwater systems. *Diversity and Distributions*, *18*(5), 448–458. https://doi.org/10.1111/j.1472-4642.2011.00879.x

Hilty, J., Worboys, G. L., Keeley, A., Woodley, S., Lausche, B. J., Locke, H., Carr, M., Pulsford, I., Pittock, J., White, J. W., Theobald, D. M., Levine, J., Reuling, M., Watson, J. E. M., Ament, R., & Tabor, G. M. (2020). *Guidelines for conserving connectivity through ecological networks and corridors* (C. Groves, Ed.). IUCN,

International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2020.PAG.30.en

Hirsh-Pearson, K. (2020). *A framework for mapping cumulative threats and its application to Canada* [Master's Thesis]. University of Northern British Columbia. https://doi.org/10.24124/2020/59107

Hobbs, R. J., & Huenneke, L. F. (1992). Disturbance, diversity, and invasion: Implications for conservation. *Conservation Biology*, *6*(3), 324–337. JSTOR.

Hodgson, J. A., Moilanen, A., Wintle, B. A., & Thomas, C. D. (2011). Habitat area, quality and connectivity: Striking the balance for efficient conservation: Area, quality and connectivity. *Journal of Applied Ecology*, *48*(1), 148–152. https://doi.org/10.1111/j.1365-2664.2010.01919.x

Horn, H. L. (2011). Strategic conservation planning for terrestrial animal species in the Central Interior of British Columbia. *Journal of Ecosystems and Management*, *12*(1). http://jem.forrex.org/index.php/jem/article/view/70

Houde, N. (2007). The six faces of Traditional Ecological Knowledge: Challenges and opportunities for Canadian co-management arrangements. *Ecology and Society*, *12*(2), art34. https://doi.org/10.5751/ES-02270-120234

Ingram, D. (2012). *Community-based knowledge capture: Tsay Keh Dene develop an online archival system* [Master's Thesis]. University of Northern British Columbia. https://doi.org/10.24124/2012/bpgub1546

IUCN. (2016). *A global standard for the identification of Key Biodiversity Areas* (Version 1.0). International Union for Conservation of Nature. https://portals.iucn.org/library/sites/library/files/documents/2016-048.pdf

Jackson, S. T., & Overpeck, J. T. (2000). Responses of plant populations and communities to environmental changes of the late Quaternary. *Paleobiology*, *26*(4), 194–220. JSTOR.

Jenness, D. (1934). Myths of the Carrier Indians of British Columbia. *The Journal of American Folklore*, *47*(184/185), 97–257. https://doi.org/10.2307/535461

Jenness, D. (1937). *The Sekani Indians of British Columbia*. J. O. Patenaude.

Joppa, L. N., & Pfaff, A. (2009). High and far: Biases in the location of protected areas. *PLoS ONE*, *4*(12), e8273. https://doi.org/10.1371/journal.pone.0008273

Karjala, M. K., Sherry, E. E., & Dewhurst, S. M. (2004). Criteria and indicators for sustainable forest planning: A framework for recording Aboriginal resource and social values. *Forest Policy and Economics*, *6*(2), 95–110. https://doi.org/10.1016/S1389-9341(02)00117-X

Keeley, A. T. H., Beier, P., & Jenness, J. S. (2021). Connectivity metrics for conservation planning and monitoring. *Biological Conservation*, *255*(109008). https://doi.org/10.1016/j.biocon.2021.109008

Knight, A. T., & Cowling, R. M. (2007). Embracing opportunism in the selection of priority conservation areas. *Conservation Biology*, *21*(4), 1124–1126. https://doi.org/10.1111/j.1523-1739.2007.00690.x

Kullberg, P., Di Minin, E., & Moilanen, A. (2019). Using key biodiversity areas to guide effective expansion of the global protected area network. *Global Ecology and Conservation*, *20*, e00768. https://doi.org/10.1016/j.gecco.2019.e00768

Kuntz, J. & Vuntut Gwitchin First Nation. (2018). *Nanh kak ejuk gweedhaa nakhwaandèe hah gwanaa'in "Watching changes on the land with our eyes."* The Firelight Group.

https://firelight.ca/wp-content/uploads/2016/04/VGFN_Report_FINAL_11MAY2018.pdf

Lambeck, R. J. (1997). Focal Species: A multi-species umbrella for nature conservation. *Conservation Biology*, *11*(4), 849–856. https://doi.org/10.1046/j.1523-1739.1997.96319.x

Lamkin, M., & Miller, A. I. (2016). On the challenge of comparing contemporary and deep-time biological-extinction rates. *BioScience*, *66*(9), 785–789. https://doi.org/10.1093/biosci/biw088

Landau, V. (2020). *Circuitscape/Omniscape.jl: V0.3.0* (v0.3.0) [Computer software]. Zenodo. https://doi.org/10.5281/ZENODO.3955123

Lawler, J. J., & Michalak, J. (2017). *Planning for climate change without climate projections?* (Vol. 1). Oxford University Press. https://doi.org/10.1093/oso/9780198808978.003.0021

Lemieux, C. J., Beechey, T. J., Scott, D. J., & Gray, P. A. (2010). *Protected areas and climate change in Canada: Challenges and opportunities for adaptation* (No. 19; Occasional Paper, p. 170). Canadian Council on Ecological Areas (CCEA). https://www.ccea.org/wp-content/uploads/2015/10/P19_Proteced-areas-and-climate-change-in-canadaLow.pdf

Lemieux, C. J., & Scott, D. J. (2005). Climate change, biodiversity conservation and protected area planning in Canada. *Canadian Geographer / Le Géographe Canadien*, *49*(4), 384–397. https://doi.org/10.1111/j.0008-3658.2005.00103.x

Leopold, A. (1949). *A sand county almanac: And sketches here and there* (First). Oxford University Press.

Liberal Party of Canada. (2019). *More conservation | Our platform*. https://liberal.ca/our-platform/more-conservation/

Littlefield, L., Dorricott, L., & Cullon, D. (2007). *Tse Keh Nay traditional and contemporary use and occupation at Amazay (Duncan Lake): A Draft Report* (p. 154).

Loarie, S. R., Duffy, P. B., Hamilton, H., Asner, G. P., Field, C. B., & Ackerly, D. D. (2009). The velocity of climate change. *Nature*, *462*(7276), 1052–1055. https://doi.org/10.1038/nature08649

Locke, H. (2013). Nature needs half: A necessary and hopeful new agenda for protected areas. *PARKS*, *19*(2), 13–22. https://doi.org/10.2305/IUCN.CH.2013.PARKS-19-2.HL.en

Loo, T. (2007). Disturbing the Peace: Environmental change and the scales of justice on a northern river. *Environmental History*, *12*, 895–919.

Lucchesi, A. H. (2018). "Indians don't make maps": Indigenous cartographic traditions and innovations. *American Indian Culture and Research Journal*, *42*(3), 11–26. https://doi.org/10.17953/aicrj.42.3.lucchesi

Mann, J. (2020). *Climate change conscious systematic conservation planning: A case study in the Peace River Break, British Columbia* [Master's Thesis]. University of Northern British Columbia.

Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. *Nature*, *405*(6783), 243–253.

Maxwell, S. L., Cazalis, V., Dudley, N., Hoffmann, M., Rodrigues, A. S. L., Stolton, S., Visconti, P., Woodley, S., Kingston, N., Lewis, E., Maron, M., Strassburg, B. B. N., Wenger, A., Jonas, H. D., Venter, O., & Watson, J. E. M. (2020). Area-based

conservation in the twenty-first century. *Nature*, *586*(7828), 217–227. https://doi.org/10.1038/s41586-020-2773-z

McKelvey, K. S., Copeland, J. P., Schwartz, M. K., Littell, J. S., Aubry, K. B., Squires, J. R., Parks, S. A., Elsner, M. M., & Mauger, G. S. (2011). Climate change predicted to shift wolverine distributions, connectivity, and dispersal corridors. *Ecological Applications*, *21*(8), 2882–2897. https://doi.org/10.1890/10-2206.1

McRae, B.H., Popper, K., Jones, A., Schindel, M., Buttrick, S., Hall, K., Unnasch, R. S., & Platt, J. (2016). *Conserving nature's stage: Mapping omnidirectional connectivity for resilient terrestrial landscapes in the Pacific Northwest* (p. 47). The Nature Conservancy. http://nature.org/resilienceNW

McRae, B.H., Shah, V. B., & Mohapatra, T. K. (2013). *Circuitscape 4 user guide*. The Nature Conservancy. http://www.circuitscape.org

McRae, B.H., Shirk, A. J., & Platt, J. T. (2013). *Gnarly Landscape Utilities: Resistance and Habitat Calculator user guide*. The Nature Conservancy. https://www.circuitscape.org/gnarly-landscape-utilities

McRae, Brad H., Dickson, B. G., Keitt, T. H., & Shah, V. B. (2008). Using circuit theory to model connectivity in ecology, evolution, and conservation. *Ecology*, *89*(10), 2712–2724.

Michalak, J. L., Carroll, C., Nielsen, S. E., & Lawler, J. J. (2018). *Land facet data for North America at 100m resolution* [Data set]. Zenodo. https://zenodo.org/record/1344637

Michalak, J. L., Lawler, J. J., Roberts, D. R., & Carroll, C. (2018). Distribution and protection of climatic refugia in North America. *Conservation Biology*, *32*(6), 1414–1425. https://doi.org/10.1111/cobi.13130

Mitchell, M. G. E., Schuster, R., Jacob, A. L., Hanna, D. E. L., Dallaire, C. O., Raudsepp-Hearne, C., Bennett, E. M., Lehner, B., & Chan, K. M. A. (2021). Identifying key ecosystem service providing areas to inform national-scale conservation planning. *Environmental Research Letters*, *16*(1), 014038. https://doi.org/10.1088/1748-9326/abc121

Morelli, T. L., Daly, C., Dobrowski, S. Z., Dulen, D. M., Ebersole, J. L., Jackson, S. T., Lundquist, J. D., Millar, C. I., Maher, S. P., Monahan, W. B., Nydick, K. R., Redmond, K. T., Sawyer, S. C., Stock, S., & Beissinger, S. R. (2016). Managing climate change refugia for climate adaptation. *PLOS ONE*, *11*(8), e0159909. https://doi.org/10.1371/journal.pone.0159909

Muntifering, J., Lockhart, C., & Tingey, R. (2008). *Kunene regional ecological assessment* (Prepated for the Kunene People's Park Technical Committee, p. 28) [Introduction and Methods: Volume 1 of 3]. Round River Conservation Studies. https://www.roundriver.org/wp-content/uploads/2016/04/KREA_Intromethods_VOL1.pdf

Newmark, W. D. (1995). Extinction of mammal populations in western North American national parks. *Conservation Biology*, *9*(3), 512–526. https://doi.org/10.1046/j.1523-1739.1995.09030512.x

Nicholls, D. (2014). *Mackenzie Timber Supply Area: Rationale for allowable annual cut (AAC) determination*. British Columbia Ministry of Forests, Lands and Natural Resource Operations.

Nicholls, D. (2019). *Mackenzie Timber Supply Area: Rationale for allowable annual cut (AAC) partition amendment*. British Columbia Ministry of Forests, Lands and Natural Resource Operations.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., & Kassem, K. R. (2001). Terrestrial ecoregions of the world: A new map of life on Earth. *BioScience*, *51*(11), 933. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

Ortlipp, M. (2008). Keeping and using reflective journals in the qualitative research process. *The Qualitative Report*, *13*(4), 695–705.

Pacific Climate Impacts Institute. (2013). *Climate summary for: Omineca Region* (Part A of a series on the resource regions of BC). University of Victoria. https://www.pacificclimate.org/sites/default/files/publications/Climate_Summary-Omineca.pdf

Pacini-Ketchabaw, V., & Nxumalo, F. (2015). Unruly raccoons and troubled educators: Nature/culture divides in a childcare centre. *Environmental Humanities*, *7*(1), 151–168. https://doi.org/10.1215/22011919-3616380

Parks Canada. (2003). *Terrestrial ecozones of Canada*. Government of Canada. http://parkscanadahistory.com/publications/fact-sheets/eng/ecozones.pdf

Parks Canada. (2018). *We rise together: Achieving pathway to Canada target 1 through the creation of Indigenous protected and conserved areas in the spirit and practice of reconciliation : the Indigenous circle of experts' report and recommendations.*

Government of Canada. http://publications.gc.ca/collections/collection_2018/pc/R62-548-2018-eng.pdf

Parks, L. C., Wallin, D. O., Cushman, S. A., & McRae, B. H. (2015). Landscape-level analysis of mountain goat population connectivity in Washington and southern British Columbia. *Conservation Genetics*, *16*, 13. https://doi.org/10.1007/s10592-015-0732-2

Polfus, Jean L. (2018, January 17). What spiders can teach us about ecology. *Canadian Geographic*. https://www.canadiangeographic.ca/article/what-spiders-can-teach-us-about-ecology

Polfus, J.L., Hebblewhite, M., & Heinemeyer, K. (2011). Identifying indirect habitat loss and avoidance of human infrastructure by northern mountain woodland caribou. *Biological Conservation*, *144*(11), 2637–2646. https://doi.org/10.1016/j.biocon.2011.07.023

Pressey, R. L., Humphries, C. J., Margules, C. R., Vane-Wright, R. I., & Williams, P. H. (1993). Beyond opportunism: Key principles for systematic reserve selection. *Trends in Ecology & Evolution*, *8*(4), 124–128.

Pressey, Robert L., Cabeza, M., Watts, M. E., Cowling, R. M., & Wilson, K. A. (2007). Conservation planning in a changing world. *Trends in Ecology & Evolution*, *22*(11), 583–592. https://doi.org/10.1016/j.tree.2007.10.001

Ramos, S. C. (2018). Considerations for culturally sensitive Traditional Ecological Knowledge research in wildlife conservation: Considerations for culturally sensitive TEK. *Wildlife Society Bulletin*, *42*(2), 358–365. https://doi.org/10.1002/wsb.881

Reid, A. J., Eckert, L. E., Lane, J.-F., Young, N., Hinch, S. G., Darimont, C. T., Cooke, S. J., Ban, N. C., & Marshall, A. (2021). “Two-eyed seeing”: An Indigenous framework to

transform fisheries research and management. *Fish and Fisheries*, *22*(2), 243–261. https://doi.org/10.1111/faf.12516

Rempel, R. S. (2011). Effects of climate change on moose populations: Exploring the response horizon through biometric and systems models. *Ecological Modelling*, *222*(18), 3355–3365. https://doi.org/10.1016/j.ecolmodel.2011.07.012

Reside, A. E., Butt, N., & Adams, V. M. (2018). Adapting systematic conservation planning for climate change. *Biodiversity and Conservation*, *27*(1), 1–29. https://doi.org/10.1007/s10531-017-1442-5

Roberts, D. R., & Hamann, A. (2012). Predicting potential climate change impacts with bioclimate envelope models: A palaeoecological perspective: No-analogue climates in bioclimate envelope modelling. *Global Ecology and Biogeography*, *21*(2), 121–133. https://doi.org/10.1111/j.1466-8238.2011.00657.x

Roffler, G. H., Adams, L. G., Talbot, S. L., Sage, G. K., & Dale, B. W. (2012). Range overlap and individual movements during breeding season influence genetic relationships of caribou herds in south-central Alaska. *Journal of Mammalogy*, *93*(5), 13.

Rose, N.-A., & Burton, P. J. (2009). Using bioclimatic envelopes to identify temporal corridors in support of conservation planning in a changing climate. *Forest Ecology and Management*, *258*, S64–S74. https://doi.org/10.1016/j.foreco.2009.07.053

Santoro, M., Cartus, O., Mermoz, S., Bouvet, A., Le Toan, T., Carvalhais, N., Rozendaal, D., Herold, M., Avitabile, V., Quegan, S., Carreiras, J., Rauste, Y., Balzter, H., Schmullius, C. C., & Seifert, F. M. (2018). *GlobBiomass global above-ground biomass and growing stock volume datasets* (p. 174 data points) [Text/tab-separated-

values]. PANGAEA - Data Publisher for Earth & Environmental Science. https://doi.org/10.1594/PANGAEA.894711

Sarkar, S., Pressey, R. L., Faith, D. P., Margules, C. R., Fuller, T., Stoms, D. M., Moffett, A., Wilson, K. A., Williams, K. J., Williams, P. H., & Andelman, S. (2006). Biodiversity conservation planning tools: Present status and challenges for the future. *Annual Review of Environment and Resources*, *31*(1), 123–159. https://doi.org/10.1146/annurev.energy.31.042606.085844

Sayre, R., Dangermond, J., Frye, C., Vaughan, R., Aniello, P., Breyer, S., Cribbs, D., Hopkins, D., Nauman, R., Derrenbacher, W., Wright, D., Brown, C., Convis, C., Smith, J., Benson, L., VanSistine, D. P., Warner, H., Cress, J., Danielson, J., … Grosse, A. (2014). *A new map of global ecological land units—An ecophysiographic stratification approach* (p. 46). Association of American Geographers.

Schindler, D. W., & Lee, P. G. (2010). Comprehensive conservation planning to protect biodiversity and ecosystem services in Canadian boreal regions under a warming climate and increasing exploitation. *Biological Conservation*, *143*(7), 1571–1586. https://doi.org/10.1016/j.biocon.2010.04.003

Schloss, C. A., Lawler, J. J., Larson, E. R., Papendick, H. L., Case, M. J., Evans, D. M., DeLap, J. H., Langdon, J. G. R., Hall, S. A., & McRae, B. H. (2011). Systematic conservation planning in the face of climate change: Bet-hedging on the Columbia Plateau. *PLOS ONE*, *6*(12), e28788. https://doi.org/10.1371/journal.pone.0028788

Schmitz, O. J., Lawler, J. J., Beier, P., Groves, C., Knight, G., Jr, D. A. B., Bulluck, J., Johnston, K. M., Klein, M. L., Muller, K., Pierce, D. J., Singleton, W. R., Strittholt, J. R., Theobald, D. M., Trombulak, S. C., & Trainor, A. (2015). *Conserving*

biodiversity: Practical guidance about climate change adaptation approaches in support of land-use planning. Natural Areas Journal, 35(1), 190–203.

Schneider, R. R., Hauer, G., Farr, D., Adamowicz, W. L., & Boutin, S. (2011). Achieving conservation when opportunity costs are high: Optimizing reserve design in Alberta's oil sands region. *PLoS ONE*, *6*(8), e23254. https://doi.org/10.1371/journal.pone.0023254

Schuster, R. (2014). *Systematic conservation planning in human-dominated landscapes: Maximizing efficiency in biodiversity conservation via carbon sequestration and land management* [Doctoral dissertation]. University of British Columbia. https://doi.library.ubc.ca/10.14288/1.0167515

Schuster, R. (2020, May 1). *Literature Review* [Personal communication].

Sedell, J. R., Reeves, G. H., Hauer, F. R., Stanford, J. A., & Hawkins, C. P. (1990). Role of refugia in recovery from disturbances: Modern fragmented and disconnected river systems. *Environmental Management*, *14*(5), 711–724. https://doi.org/10.1007/BF02394720

Sims, D. (2017). *Dam Bennett: The impacts of the W.A.C. Bennett Dam and Williston Lake Reservoir on the Tsek'ehne of Northern British Columbia* [Doctoral dissertation]. University of Alberta.

Smith, R. J., Bennun, L., Brooks, T. M., Butchart, S. H. M., Cuttelod, A., Marco, M. D., Ferrier, S., Fishpool, L. D. C., Joppa, L., Juffe-Bignoli, D., Knight, A. T., Lamoreux, J. F., Langhammer, P., Possingham, H. P., Rondinini, C., Visconti, P., Watson, J. E. M., Woodley, S., Boitani, L., … Scaramuzza, C. A. de M. (2019). Synergies between

the key biodiversity area and systematic conservation planning approaches. *Conservation Letters*, *12*(1), e12625. https://doi.org/10.1111/conl.12625

Stanley, M. (2010). *Voices from two rivers: Harnessing the power of the Peace and Columbia*. Douglas & McIntyre.

Stewart, F. E. C., Darlington, S., Volpe, J. P., McAdie, M., & Fisher, J. T. (2019). Corridors best facilitate functional connectivity across a protected area network. *Scientific Reports*, *9*. https://doi.org/10.1038/s41598-019-47067-x

Stralberg, D., Matsuoka, S. M., Hamann, A., Bayne, E. M., Sólymos, P., Schmiegelow, F. K. A., Wang, X., Cumming, S. G., & Song, S. J. (2015). Projecting boreal bird responses to climate change: The signal exceeds the noise. *Ecological Applications*, *25*(1), 52–69.

Stralberg, Diana, Carroll, C., & Nielsen, S. E. (2020). Toward a climate-informed North American protected areas network: Incorporating climate-change refugia and corridors in conservation planning. *Conservation Letters*, e12712. https://doi.org/10.1111/conl.12712

Strand, K. J., Cutforth, N., Stoecker, R., Marullo, S., & Donohue, P. (2003). *Community-based research and higher education: Principles and practices*. John Wiley & Sons.

Strona, G., & Bradshaw, C. J. A. (2018). Co-extinctions annihilate planetary life during extreme environmental change. *Scientific Reports*, *8*(1), 16724. https://doi.org/10.1038/s41598-018-35068-1

Suzuki, N., & Parker, K. L. (2016). Potential conflict between future development of natural resources and high-value wildlife habitats in boreal landscapes. *Biodiversity and Conservation*, *25*(14), 3043–3073. https://doi.org/10.1007/s10531-016-1219-2

Tingley, M. W., Darling, E. S., & Wilcove, D. S. (2014). Fine- and coarse-filter conservation strategies in a time of climate change. *Annals of the New York Academy of Sciences*, *1322*(1), 92–109. https://doi.org/10.1111/nyas.12484

Tsay Keh Dene Nation. (2019, September 30). *Preliminary Project Meeting* [In-person meeting].

Tsay Keh Dene Nation. (2020a). *Chu Cho Forestry*. Tsay Keh Dene Nation. http://www.tsaykeh.com/chu-cho-forestry

Tsay Keh Dene Nation. (2020b). *Governance*. Tsay Keh Dene Nation. http://www.tsaykeh.com/governance

Urban, D., & Keitt, T. (2001). Landscape connectivity: A graph-theoretic perspective. *Ecology*, *82*(5), 1205–1218. https://doi.org/10.2307/2679983

Wall Kimmerer, R. (2013). *Braiding sweetgrass: Indigenous wisdom, scientific knowledge, and the teachings of plants*. Milkweed Editions.

Wang, T., Hamann, A., Spittlehouse, D., & Carroll, C. (2016). Locally downscaled and spatially customizable climate data for historical and future periods for North America. *PLOS ONE*, *11*(6), e0156720. https://doi.org/10.1371/journal.pone.0156720

Watson, J. E. M., Grantham, H. S., Wilson, K. A., & Possingham, H. P. (2011). *Conservation biogeography: Systematic conservation planning: Past, present and future* (R. J. Ladle & R. J. Whittaker, Eds.). https://onlinelibrary.wiley.com/doi/abs/10.1002/9781444390001.ch6

Weaver, J. (2019). *The greater Muskwa-Kechika* (No. 13; Conservation Report, p. 172). WCS Canada.

https://www.wcscanada.org/DesktopModules/Bring2mind/DMX/Download.aspx?EntryId=36766&PortalId=96&DownloadMethod=attachment

Weiss, K., Hamann, M., & Marsh, H. (2013). Bridging knowledges: Understanding and applying Indigenous and Western scientific knowledge for marine wildlife management. *Society & Natural Resources*, *26*(3), 285–302. https://doi.org/10.1080/08941920.2012.690065

Wiersma, Y. F. (2008). *Representative reserve design in Canada: The contribution of existing protected areas*. Canadian Parks for Tomorrow: 40th Anniversary Conference, Calgary, AB, Canada. http://prism.ucalgary.ca//handle/1880/46953

Wiersma, Y. F., & Sleep, D. J. H. (2016). A review of applications of the six-step method of systematic conservation planning. *The Forestry Chronicle*, *92*(03), 322–335. https://doi.org/10.5558/tfc2016-059

Williams, J. W., Jackson, S. T., & Kutzbach, J. E. (2007). Projected distributions of novel and disappearing climates by 2100 AD. *Proceedings of the National Academy of Sciences*, *104*(14), 5738–5742. https://doi.org/10.1073/pnas.0606292104

Williams, John W., & Jackson, S. T. (2007). Novel climates, no-analog communities, and ecological surprises. *Frontiers in Ecology and the Environment*, *5*(9), 475–482. https://doi.org/10.1890/070037

Williams, John W., Kharouba, H. M., Veloz, S., Vellend, M., McLachlan, J., Liu, Z., Otto-Bliesner, B., & He, F. (2013). The ice age ecologist: Testing methods for reserve prioritization during the last global warming. *Global Ecology and Biogeography*, *22*(3), 289–301. https://doi.org/10.1111/j.1466-8238.2012.00760.x

Willis, K. J., & Whittaker, R. J. (2000). The refugial debate. *Science*, *287*(5457), 1406–1407. https://doi.org/10.1126/science.287.5457.1406

Wilson, M. W. (2009). Towards a genealogy of qualitative GIS. In M. Cope & S. Elwood (Eds.), *Qualitative GIS* (pp. 156–170). SAGE Publications Ltd. https://doi.org/10.4135/9780857024541.n9

Wineland, S. M., Fovargue, R., Gill, K. C., Rezapour, S., & Neeson, T. M. (2021). Conservation planning in an uncertain climate: Identifying projects that remain valuable and feasible across future scenarios. *People and Nature*, *3*(1), 221–235. https://doi.org/10.1002/pan3.10169

Wright, P. (2016). *Protection and persistence in the Canadian protected areas system: A review of conservation science research and approaches*. 2016 Canadian Parks Summit, Canmore, AB, Canada.

Zurba, M., Beazley, K., English, E., & Buchmann-Duck, J. (2019). Indigenous Protected and Conserved Areas (IPCAs), Aichi Target 11 and Canada's Pathway to Target 1: Focusing conservation on reconciliation. *Land*, *8*(1), 10. https://doi.org/10.3390/land8010010

10.0 APPENDIXES

Appendix A. Federal Species at Risk Act (SARA) Schedule 1 Species in Territory

Darker highlighted species included in analysis

English Name	Scientific Name	Category	SARA Status
Hotwater Physa	Physella wrighti	Invertebrate Animal	Endangered
White Sturgeon	Acipenser transmontanus	Vertebrate Animal	Endangered
Northern Abalone	Haliotis kamtschatkana	Invertebrate Animal	Endangered
Yellow-breasted Chat	Icteria virens	Vertebrate Animal	Endangered
Whitebark Pine	Pinus Albicaulis	Vascular Plant	Endangered
Black Swift	Cypseloides niger	Vertebrate Animal	Endangered
Northern Myotis	Myotis septentrionalis	Vertebrate Animal	Endangered
Little Brown Myotis	Myotis lucifugus	Vertebrate Animal	Endangered
Porsild's bryum	Haplodontium macrocarpum	Nonvascular Plant	Threatened
Crumpled Tarpaper	Collema coniophilum	Fungus	Threatened
Barn Owl	Tyto alba	Vertebrate Animal	Threatened
Lewis's Woodpecker	Melanerpes lewis	Vertebrate Animal	Threatened
Bobolink	Dolichonyx oryzivorus	Vertebrate Animal	Threatened
Marbled Murrelet	Brachyramphus marmoratus	Vertebrate Animal	Threatened
Canada Warbler	Cardellina canadensis	Vertebrate Animal	Threatened
Olive-sided Flycatcher	Contopus cooperi	Vertebrate Animal	Threatened
Barn Swallow	Hirundo rustica	Vertebrate Animal	Threatened
Western Screech-Owl	Megascops kennicottii	Vertebrate Animal	Threatened
Common Nighthawk	Chordeiles minor	Vertebrate Animal	Threatened
Western Grebe	Aechmophorus occidentalis	Vertebrate Animal	Special Concern
Northwest Waterfan	Peltigera gowardii	Fungus	Special Concern
Yellow Rail	Coturnicops noveboracensis	Vertebrate Animal	Special Concern
Green Sturgeon	Acipenser medirostris	Vertebrate Animal	Special Concern
Peregrine Falcon	Falco peregrinus	Vertebrate Animal	Special Concern
Wolverine	Gulo gulo	Vertebrate Animal	Special Concern
Cryptic Paw	Nephroma occultum	Fungus	Special Concern
Grizzly Bear	Ursus arctos	Vertebrate Animal	Special Concern
Long-billed Curlew	Numenius americanus	Vertebrate Animal	Special Concern
Short-eared Owl	Asio flammeus	Vertebrate Animal	Special Concern
Collared Pika	Ochotona collaris	Vertebrate Animal	Special Concern
Band-tailed Pigeon	Patagioenas fasciata	Vertebrate Animal	Special Concern
Rusty Blackbird	Euphagus carolinus	Vertebrate Animal	Special Concern
Red-necked Phalarope	Phalaropus lobatus	Vertebrate Animal	Special Concern
Western Toad	Anaxyrus boreas	Vertebrate Animal	Special Concern
Coastal Tailed Frog	Ascaphus truei	Vertebrate Animal	Special Concern
Evening Grosbeak	Coccothraustes vespertinus	Vertebrate Animal	Special Concern

Appendix B. Conservation Feature Data Sources

Layers by Category	Source(s)	Link (if public)
Cultural		
Sites of Cultural Importance	Tsay Keh Dene Cultural Knowledge Keeper Database	
Cultural/Spiritual Areas	Tsay Keh Dene Cultural Knowledge Keeper Database	
Subsistence Areas	Tsay Keh Dene Cultural Knowledge Keeper Database	
Fine-Filter		
Wetlands	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-wetlands
	Williston Wetland Explorer Tool	https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=5a59fc13b9064cf7b19398f29ceaac9e
Lakes	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-lakes
Karst Deposits	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/reconnaissance-karst-potential-mapping
Grizzly Bear	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/bc-grizzly-bear-habitat-classification-and-rating
Bull Trout/Fish	John Hagen & Associates; Tsay Keh Dene Cultural Knowledge Keeper Database	
Fisher	BC Fisher Habitat Working Group	https://www.bcfisherhabitat.ca/wp-content/uploads/2017/05/Users-guide-to-spatial-data-May-2017.pdf
Caribou (by herd)	Mann (2020); WCS Canada; BC Data Catalogue; Demarchi & Demarchi (2003);	
	Tsay Keh Dene Cultural Knowledge Keeper Database	
Moose	Suzuki & Parker (2016); Demarchi & Demarchi (2003)	http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=1434
Stone Sheep	Round River Conservation Studies; WCS Canada;	
	BC Data Catalogue; Tsay Keh Dene Cultural Knowledge Keeper Database	https://catalogue.data.gov.bc.ca/dataset/ungulate-winter-range-approved
Mountain Goat	Round River Conservation Studies; BC Data Catalogue;	https://catalogue.data.gov.bc.ca/dataset/ungulate-winter-range-approved
	Tsay Keh Dene Cultural Knowledge Keeper Database	
Wolverine	Chu Cho Environmental	
Bank Swallow	Chu Cho Environmental	
Barn Swallow	Chu Cho Environmental	
Western Toad	Chu Cho Environmental	
Horned Grebe	Chu Cho Environmental	
Little Brown Myotis	Chu Cho Environmental	
Northern Myotis	Chu Cho Environmental	
Olive-Sided Flycatcher	Chu Cho Environmental	
Rusty Blackbird	Chu Cho Environmental	
Coarse-Filter		
Forest Pattern & Process	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/bec-map
	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/vri-2019-forest-vegetation-composite-polygons
	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/vri-2019-forest-vegetation-composite-layers-all-layers-
Rare BEC Zones - at variant level	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/bec-map
Elevational Representation	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/digital-elevation-model-for-british-columbia-cded-1-250-000
Ecoregional Representation	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/ecoregions-ecoregion-ecosystem-classification-of-british-columbia
Land Facet Diversity	AdaptWest	https://adaptwest.databasin.org/pages/adaptwest-landfacets
Land Facet Rarity	AdaptWest	https://adaptwest.databasin.org/pages/adaptwest-landfacets
Elevational Diversity	AdaptWest	https://adaptwest.databasin.org/pages/environmental-diversity-north-america
Ecotypic Diversity	AdaptWest	https://adaptwest.databasin.org/pages/environmental-diversity-north-america
Heat Load Index Diversity	AdaptWest	https://adaptwest.databasin.org/pages/environmental-diversity-north-america
BEC Zones 2020	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/bec-map
Climate		
BEC Zones 2050	Climate BC	http://www.climatewna.com/ClimateBC_Map.aspx
BEC Zones 2080	Climate BC	http://www.climatewna.com/ClimateBC_Map.aspx
Climate Corridors (Current-Flow Centrality)	AdaptWest	https://adaptwest.databasin.org/pages/climate-connectivity-north-america
Backward Velocity 2055	AdaptWest	https://adaptwest.databasin.org/pages/adaptwest-velocitywna
Backward Velocity 2085	AdaptWest	https://adaptwest.databasin.org/pages/adaptwest-velocitywna
Forward Velocity 2055	AdaptWest	https://adaptwest.databasin.org/pages/adaptwest-velocitywna
Forward Velocity 2085	AdaptWest	https://adaptwest.databasin.org/pages/adaptwest-velocitywna
Bird Richness (3.0 degrees summer)	AdaptWest	https://adaptwest.databasin.org/pages/audubon-survival-by-degrees
Carbon Storage (above and below ground)	GlobBiomass	https://globbiomass.org/wp-content/uploads/GB_Maps/Globbiomass_global_dataset.html
	ISRIC	https://data.isric.org/geonetwork/srv/eng/catalog.search#/metadata/c02ddf8b-cbfb-4533-a9c3-7bf0790fd041
Cool Headwater Refugia	Climate BC	http://www.climatewna.com/ClimateBC_Map.aspx
Climatic Refugia	AdaptWest	https://adaptwest.databasin.org/pages/climate-informed-priorities
Biotic Refugia	AdaptWest	https://adaptwest.databasin.org/pages/distribution-and-protection-climatic-refugia

Appendix C. Human Footprint Feature Data Sources and Buffers

Footprint by Category	Source(s)	Link (if public)	Buffer	Buffer Source
Permanent				
Dams	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/b-c-dams	1 km large; 0.5 km small	Based on Polfus et al. (2011) approach
Drillsites and Wellsites	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	.25 - 1 km	Polfus et al. (2011)
Active	BC Oil & Gas Commission for status	https://www.bcogc.ca/data-reports/data-centre/?category=60040	1 km	
Orphan			500 m	
Dormant			250 m	
Industrial Uses	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/bc-transmission-lines	1 km	Mann and Wright (2018)
Mines	BC Data Catalogue	http://ftp.maps.canada.ca/pub/nrcan_rncan/publications/ess_sst/299/299660/as_0900A_66.zip	2 km	Polfus et al. (2011)
Pipelines	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	250 m	Mann & Wright (2018)
		https://catalogue.data.gov.bc.ca/dataset/oil-and-gas-commission-pipeline-segment-permits		
Power and Telecom Lines	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/bc-transmission-lines	250 m	Mann & Wright (2018)
		https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures		
Private Land	Mann & Wright (2018)		250 m	Mann & Wright (2018)
Quarries	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	2 km	Based on Polfus et al. (2011) approach
Reservoirs	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/reservoir-permits-over-crown-land#edc-pow	1.5 km	Based on Polfus et al. (2011) approach
Residential Areas	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	250 m	Mann & Wright (2018)
Roads	BC Data Catalogue	ftp://ftp.geobc.gov.bc.ca/sections/outgoing/bmgs/DRA_Public	.5 - 2 km	Province of BC (2015); Polfus et al. (2011)
Outblock Major			2 km	
Outblock Resource Main			1 km	
Outblock Resource Secondary			500 m	
Urban Areas	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/baseline-thematic-mapping-present-land-use-version-1-spatial-layer	1.5 - 8 km	Mann & Wright (2018)
		https://catalogue.data.gov.bc.ca/dataset/vri-2019-forest-vegetation-composite-polygons		
Wind Turbines	NR Can	https://open.canada.ca/data/en/dataset/79fdad93-9025-49ad-ba16-c26d718cc070	2 km	Mann & Wright (2018)
Semi-Permanent				
Agriculture	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/baseline-thematic-mapping-present-land-use-version-1-spatial-layer#edc-pow	1 km	Mann & Wright (2018)
Camps and Cabins	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	1.5 km	Polfus et al. (2011)
Cutblocks	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/results-openings-svw	120 - 240 m	
1940-1980			120 m	Laurance et al. (2007)
1981-2020			240 m	Nation input on younger cutblocks
Roads	BC Data Catalogue	ftp://ftp.geobc.gov.bc.ca/sections/outgoing/bmgs/DRA_Public	.25 - 1 km	Province of BC (2015); Polfus et al. (2011)
Outblock Trails			250 m	
Inblock Resource Main			1 km	
Inblock Resource Secondary			500 m	
Inblock Trails			250 m	
Ephemeral				
Alpine Skiing	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	2 km	Recommended by Ecosystems Branch of FLNRO
Heliskiing	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	2 km	Recommended by Ecosystems Branch of FLNRO
Snowmobiling	Snoriders West destination maps (georeferenced)	https://snoriderswest.com/northernbc	2 km	Seip et al. (2007)
Trail Riding	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures	250 m	Mann & Wright (2018)