COMMUNITY VULNERABILITY TO CHANGING MOUNTAIN SNOWPACKS IN THE ROBSON VALLEY, BRITISH COLUMBIA, CANADA

By

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Abstract

COMMUNITY VULNERABILITY TO CHANGING SNOWPACKS AND WATER SYSTEMS IN A MOUNTAIN REGION

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Mountain regions are experiencing climate change with severe consequences for ecosystems and the human communities that depend on them, necessitating place-based adaptation. This thesis examines community vulnerability to changing mountain snowpack through a mixed-methods case study of McBride and Dunster in the upper Robson Valley, British Columbia, Canada. This thesis is distinct from other mountain climate change studies in that it explores the interactions among multiple environmental and societal forces that influence sensitivity to environmental changes and the capacity to adapt. Local lived experiences were gathered through one focus group and 32 semi-structured interviews with a total of 37 residents and analyzed alongside community documents and plans, local news, and quantitative data on snowpack and streamflow. Latent content analysis revealed that residents are sensitive to decreases in mountain snowpack due to their reliance on melt run-off for freshwater. Low water availability has impacted food security, wildfire suppression, and human health and well-being. Local capacity to adapt has been undermined by the centralization of government services and resulting exodus of residents, and their knowledge and skills. Despite a long history of coping with fluctuations in weather, recent changes, including low precipitation years related to the Southern El Niño Oscillation and heat waves, are considered by many residents to be outside tolerable ranges. Supporting adaptation is rooted in increasing local social capital and cohesion by re-directing financial and human resources, and decision-making power back to northern communities.

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Chapter 1: Introduction

1.1 Research Rationale

Mountain regions globally are experiencing climate change with severe consequences for ecosystems and the human communities who depend on them for their lives and livelihoods. (McDowell *et al.*, 2021). Biophysical changes including changing seasonal weather patterns, rising temperatures, loss of glacier mass, increasing natural hazards, and changes in snowpacks have been recorded, and are expected to accelerate in the future (Campbell & Ryan, 2021; Pomeroy *et al*., 2012; Shea *et al.*, 2021). These changes have affected access to drinking water, damaged infrastructure, and transportation networks, and economic sectors like forestry, farming, and tourism (Hock *et al.*, 2019). Adaptation is unavoidable and necessary to mitigate negative impacts and take advantage of potential new opportunities.

Water is an essential resource, sustaining life for both humans and ecosystems, yet approximately 80% of the world's population is under high risk of water insecurity (Beniston & Stoffel, 2014; Wang *et al.*, 2023). In mountain regions, water availability is often derived from snowpacks that melt continuously in the spring, summer, and fall, then replenish in the winter as part of the hydrological cycle. With rising global temperatures, some mountain regions have experienced 'dry' years when snowpacks are unable to sustain sufficient snow for the melt run-off with implications for ecosystems and human communities (e.g. Beniston & Stoffel, 2014; Campbell & Ryan, 2021).

To date, however, most climate change research in mountain regions has focused on measuring, monitoring, and/or modelling biophysical changes, such as glacier melt, with less attention on how these changes affect peoples' livelihoods and their capacity to adapt to new conditions. Other research in mountain regions has focused on modelling future climate change

and potential impacts (Hock *et al*., 2019) including snowpack depletions (Huss *et al*., 2017). Measuring biophysical changes in mountain regions has advanced our understanding of broad risks associated with dynamic mountain environments, as well as what types of hazards may threaten people living in mountain spaces but is limited in advancing adaptation.

While much climate change research focuses on changes in mountain regions at a large scale, human impacts and responses are highly localized and shaped by factors like local geography and pre-existing societal structures, including economic systems, government practices and policies, and past experiences and knowledge of change (Duerden, 2004; McDowell *et al.,* 2023). To initiate adaptation actions, decision makers need to know the nature of vulnerability, in terms of who and what are vulnerable, to what stresses, and in what way, and also what is the capacity of the community to adapt to changing conditions (Smit and Wandel, 2006). Furthermore, it is now widely accepted that adaptation initiatives are most effective when they are integrated, or mainstreamed, into other resource management, disaster preparedness, and/or community planning programmes and institutions (Adger, 2022). This integration requires knowledge of local governance structures, institutions, and policies, as well as the forces that influence vulnerability and the factors that facilitate or constrain adaptation (Adger, 2006). Adapting to climate change thus requires integrated, culturally relevant approaches that consider the social mechanisms behind traditional and local practices, and mutual dependencies between people and the environment (Fraser, 2003).

This research responds to these knowledge gaps and examines community vulnerability and adaptation to changing snowpacks in mountain regions through a case study of the communities of McBride and Dunster, located in the upper Robson Valley area of British Columbia, Canada. The aim is achieved through four objectives:

1) describe the local water system and its ecological and social components;
2) document the ways in which changing snowpack, in the context of other climatic and non-climatic stressors, is affecting the local water system;
3) characterize the adaptive strategies employed to manage and cope with these conditions; and
4) describe factors that aid or constrain adaptation.

This research is novel in that it (i) assesses vulnerability at the local scale and does so in the context of multiple climate and non-climatic stressors; (ii) considers the role that human agency plays in how people experience and respond to climate change; and (iii) focuses on a geographically remote region in Northern B.C.

1.2 Thesis Organization

This thesis is organized into seven chapters, starting with chapter one, the *Introduction*. Chapter two, *Literature Review*, provides a summary of relevant literature to situate this research within relevant bodies of scholarship, as well as highlights knowledge gaps. *Case Study* is Chapter three, which provides the local and regional context for the research. Chapter four, *Research Methodology*, establishes the research design and approach, as well as describes which methods were employed, as well as data analysis and storage methods. Chapter five is the *Results*, which shares the findings from the data collection process, and is organized into seven sections to categorize the results. Chapter six, *Discussion*, highlights the significance of the research findings as well as connects the findings to the greater bodies of scholarship. Chapter seven, *Conclusion*, closes the thesis, providing a summary of the key findings, a section on practical and scholarly contributions, and future research opportunities.

Chapter 2: Literature Review

This research engages with climate change impacts and adaptation in mountain regions , the concepts and operationalization of vulnerability and adaptation, the role of local knowledge in climate change research, and participatory mapping. These bodies of scholarships are reviewed and critiqued to identify knowledge gaps and opportunities for future research.

2.1 Biophysical Changes in Mountain Regions

Mountain regions are at the forefront of climate change, where warming rates are higher than the global average and contribute to multiple stressors in mountain ecosystems (Chakraborty, 2021; McDowell *et al.*, 2021). Climate change in mountain environments is manifested through various negative impacts that include glacier loss, slope instability, snowpack depletion, flooding, drought, landslides, rockslides, and mudslides (Beniston, 2003; IPCC, 2023; McDowell *et al.*, 2021; Stoffel & Huggel, 2012). These physical responses to climate change present as natural hazards to humans and mountain communities, impacting water security, resource extractive industries, tourism, and recreation, and even causing loss of life and property (McDowell *et al.*, 2021; Hock *et al.*, 2019).

Climate change impacts in mountain environments are often sudden and substantial (Hock *et al.*, 2019, McDowell *et al.*, 2023). The initial concern of physical changes in mountain environments is that of temperature and heavy precipitation events such as heavy rainfall or storms (Stoffel & Huggel, 2012). Changes in precipitation and temperature have various secondary effects, including the extent of glaciers (Beniston, 2003), alpine permafrost (Stoffel & Huggel, 2012), and the distribution and replenishment of snowpacks (Campbell & Ryan, 2021). Increased glacial melt may also lead to glacial lake formation and growth which can result in large outburst floods (Hock *et al.*, 2019; Shea *et al.*, 2021; Stoffel & Huggel, 2012).

Additionally, a decrease in glacier mass, and even the complete depletion of glaciers, will result in decreased biodiversity to glacier-fed rivers and lakes. These changes in biogeochemistry of rivers and proglacial lakes will have significant impacts on aquatic habitat, biotic communities, and water quality for both ecosystems and humans who depend on the hydrological system (Huss *et al.*, 2017).

Snowpacks in mountain basins are a vital part of water resources and mountain environments, where winter snowpacks are the dominant component of stream flows in the warmer seasons (Campbell & Ryan, 2021; Huss *et al.*, 2017; Shea *et al.*, 2021). For many lowland areas, snowpack melt in the summertime supplies reservoirs that are imperative for supplying ecosystem and human demands (Campbell & Ryan, 2021; Huss *et al.*, 2017; Pomeroy *et al*., 2012; Shea *et al.*, 2021; Stewart, 2008). Snowpacks are the cumulative effects of snow ablation and accumulation, with snow cover serving as a control on summer soil-water storage and on the global heat budget (Huss *et al.*, 2017; Stewart, 2008). Furthermore, mountainous seasonal snow cover plays an important role in the hydroclimatic system due to its large spatial extent, latitudinal variation, and seasonal breadth (Stewart, 2008). Similar to glacier melt as discussed above, precipitation as rain, coupled with warmer temperatures quickly diminishes snowpacks, causing the initial spring freshet and runoff to begin earlier in the season, and reducing the amount of fall and summer water flows (Campbell & Ryan, 2021; Huss *et al.*, 2017; Pomeroy *et al*., 2012; Shea *et al.*, 2021; Stewart, 2008; Stoffel & Huggel, 2012).

Snowpack replenishment and density is also related to snow water equivalent (SWE), a useful method to measure the amount of liquid that is stored in the snowpack. SWE essentially indicates how much water would be in the water column, that would result in theory, from the instantaneous melt of a snowpack (Stewart, 2008). The changing climate impacts the SWE, and

consequently, impacts the water supply that is derived from snowpack run-off (Huss *et al.*, 2017; Stewart, 2008). However, elevation plays a crucial role in snowpack accumulation and depletion, SWE, and mountain streamflow responses to climate change (Shea *et al.*, 2021). It is important to understand the physical processes of snow, to understand how to monitor snowpack and environmental changes, and adapt to them.

2.2 Vulnerability and Adaptation

Vulnerability, in the context of climate change can be broadly defined as the potential for loss (Cutter, 1996). However, the meanings and discrepancies behind the term vulnerability arise from various epistemologies, such as human ecology, physical sciences, political ecology, technology, and hazards, creating confusion for the application of the theory (Cutter, 1996). With regards to clarity and this project, vulnerability can be largely categorized by its parameters as the exposure of a system to stress, its degree of sensitivity to said stress, and the adaptive capacity of that system (Adger, 2006; Adger, 2003; Adger & Kelly, 1999; Berkes, 2007; Watts & Bohle, 1993). Additionally, this definition also includes understanding the nature of vulnerability with the inclusion of a social response (both individual and collective) to vulnerability, vulnerabilities of space and place, and vulnerability as an exposure (Cutter, 1996; Smit & Wandel, 2006; Watts & Bohle, 1993). The most functional and overarching definition of vulnerability in this context is the "state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt" (Adger, p. 268, 2006), thus creating space for the consideration of the environmental and social relationship of vulnerability, and its relationship to resilience and adaptation development (Adger, 2006; Adger & Kelly, 1999; Berkes *et al.*, 1998; Watts & Bohle, 1993).

2.2.1 Approaches to Adaptation and Vulnerability Assessments

There are numerous assessment models that can be used to determine the vulnerability of a system. The first research framework for vulnerability analysis I describe here is outlined by Ford and Smit (2004). This framework begins by first assessing the current vulnerability of a community by detailing the exposures to the system, and the current adaptive strategies (Figure 2.1). The second stage assesses the future vulnerability through the estimation, rather than assumption, of directional changes regarding the exposure, and uses that to predict the adaptive capacity in the future, based on the knowledge of past behavior (Ford & Smit, 2004).

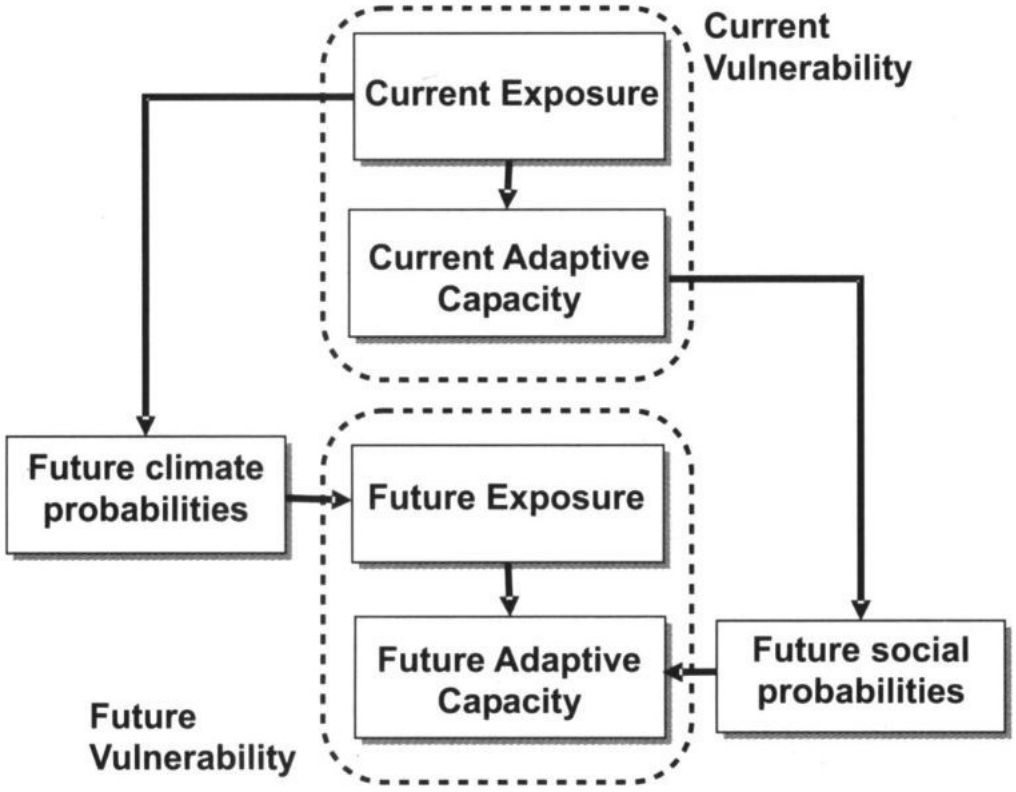

Figure 2.1: Analytical framework for vulnerability assessment (Ford and Smit 2004).

This method is therefore used to assess the vulnerability of a community empirically, while taking into consideration future constraints to adaptive measures (Burton *et al.*, 2002; Ford &

Smit, 2004). The vulnerability approach is useful in assessing the conditions that affect the system.

The vulnerability assessment does not include place-based considerations in the model. Therefore, Cutter's (1996) hazards of place model was also employed to gain further understanding of vulnerability as it relates to locality (Figure 2.2). The combination of the two assessment models as well as employing a case study framework allowed the research to be conducted in a bottom-up, place-based way. The vulnerability assessment in a place-specific context has been done successfully by others (e.g. McCubbin *et al.*, 2015; Pearce *et al.*, 2018; Pearce *et al.*, 2010) to reveal and address underlying impacts of politics, social change, economics, health, and how these factors consequently shape the communities' understanding, vulnerability, and adaptive capacity to the onset of climate change and natural hazards.

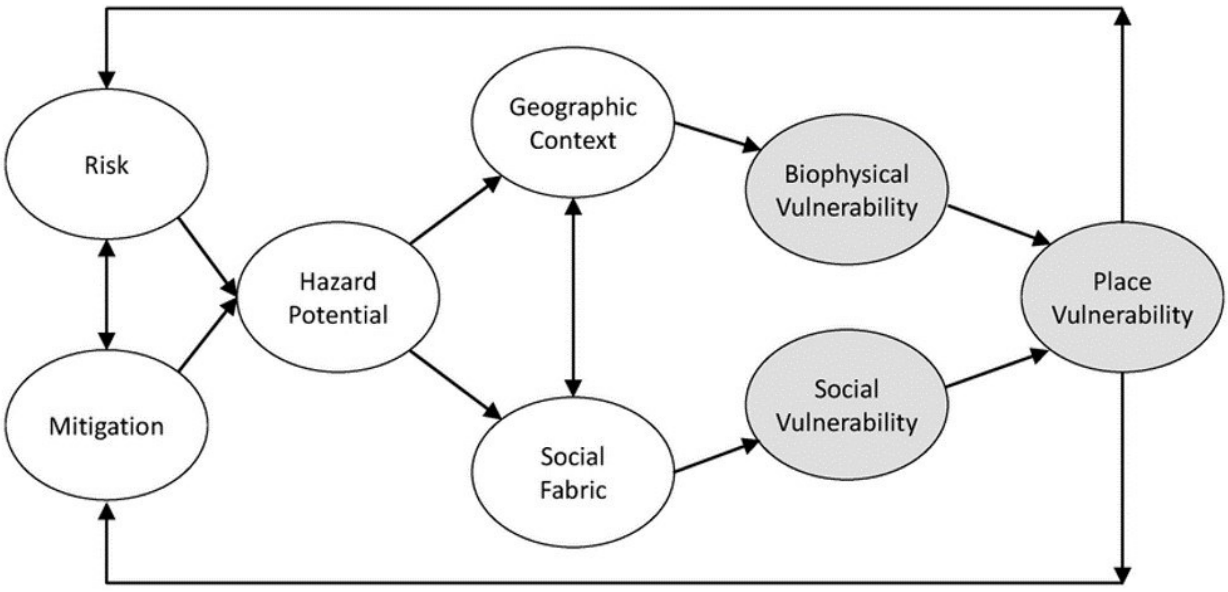

Figure 2.2: Hazards of place model (Cutter, 1996).

The Pressure and release model (PAR), developed by Blaikie *et al.*, (2014), is an organizing framework that outlines a down-stream effect of causal incidents, that together create the sum of the pre-conditions for a disaster (Blaikie *et al.*, 2014). This model also considers that

in order for the "release" aspect of the model to work, the chain of causation needs to be addressed back to the root causes, rather than just the hazard or circumstances of vulnerability. However, this model contains gaps regarding its fixed nature, and therefore does not contain an analysis of where and when the hazards begin to unfold. For example, this model does not account for socio-political or marginalized groups at the point of disaster, thus unable to truly assess fitting adaptation strategies (Blaikie *et al.*, 2014; Burton *et al.*, 2002).

The PAR model differs from the vulnerability approach in that the focus of the PAR model is how a disaster might impact a system, and the vulnerability model focuses on pre-existing conditions prior to disaster. Both models, while hold their own implementation gaps respectively, are also able to complement each other when considered synergistically. PAR does not consider socio-political factors prior to a disaster, therefore on its own is unable to accurately measure adaptive strategies. However, the vulnerability method focuses on the potential capacity of the system, and any elements that may impact the system and its ability to cope, beyond one specific instance.

Blaikie *et al.*, (2014), also introduces the Access model, an expanded analysis of the principles in the PAR model, designed to understand the complexities and varied arrays of environmental and social events, as well as the long-term processes that may be associated with a disaster at the micro-level. The Access model takes a more detailed approach to understanding how conditions need to change to reduce human vulnerability and exposure to physical hazards while still guided by PAR principles (Blaikie *et al*., 2014). Arguably, the Access model is the application of vulnerability assessment after the PAR model, where the site of disaster and the socio-cultural-political facets are considered in the capacity for a community to cope (Blaikie *et al.*, 2014).

A third consideration for vulnerability assessments is what Fraser *et al.*, (2003) describes as mutual vulnerability and mutual dependence. The idea of mutual vulnerability and dependence is that due to the reflexive nature of society and the environment, factors such as human-induced climate change are cause for concern, but the environment has and will always continue to be a powerful constraint and shaper of human society (Fraser *et al.*, 2003). Additionally, environmental response to change may go unfelt and unseen for many years, and a population that caused environmental degradation may not be the same population that is affected by the change (Fraser *et al.*, 2003).

A fourth consideration for vulnerability assessments is that adaptive strategies must go beyond cause-and-consequence because the human-environmental relationship is more complicated. Therefore, composing a human-environment analytical equation to better understand policy-making and resource availability too often misses the dynamics of such issues. Instead, addressing vulnerability as a balance is more comprehensive (Adger & Kelly, 1999; Berkes & Folke, 1998; Fraser *et al.*, 2003).

2.2.2 Adaptive Capacity

Adaptation is the actions or strategies that a system enacts to be able to address change successfully and identify possible opportunities within the change. Adaptive capacity, however, refers to the potential that the system has to be able to enact adaptive strategies. Weaving vulnerability and adaptive capacity together, the latter is situated within a community's 'state' of vulnerability. For example, Ford and Smit outline vulnerability as a "pre-existing" condition, shaped by social, economic, and political structures (Ford & Smit, 2004). However, these same pre-existing conditions define the capacity of a community to cope with hazardous conditions, and recover from the effects (Adger & Kelly, 1999; Cutter, 2020; Smit & Wandel, 2006).

Therefore, adaptation initiatives are manifestations of the conceived adaptive capacity of the system (Adger & Kelly, 1999; Smit & Wandel, 2006).

Understanding adaptive capacity is context and location specific. For example, the scales of adaptive capacity are reflective on each other: the capacity of a community to respond is dependent on the governmental structure and processes of a region and the resources allotted, and the capacity of a family to adapt can be influenced by the drive of the community (Adger & Kelly, 1999; Smit & Wandel, 2006). However, woven through these considerations are determinants or drivers of adaptive capacity (Adger, 2003; Smit & Wandel, 2006; Watts & Bohle, 1993). These determinants include technology, access to financial and informative resources, infrastructure, managerial and governmental systems, kinship networks, and political influence (Smit & Wandel, 2006).

Much literature discusses the idea of a coping range when discussing adaptive capacity. The coping range of a system refers to the time specificity and response to changes and conditions. For example, current political structure, populations size, economic condition, and resource depletion may decrease adaptive capacity at a certain period, while improvements in other sectors may facilitate an increase in adaptive capacity (Adger & Kelly, 1999; Smit & Wandel, 2006). Additionally, cumulative impacts of changes or increased frequency of events can also result in a narrower coping range and may even result in the complete eradication of a system to cope or adapt at all (Smit & Wandel, 2006).

2.3 Human Dimensions of Climate Change in Mountain Regions

Mountain regions are responsible for sustaining and supporting over 1 billion people, both directly and indirectly through water systems, resources, tourism, and ecosystem services (Beniston, 2003; McDowell *et al.*, 2021). Furthermore, mountains are home to endangered

species, are hotspots for biodiversity, and spaces for energy, forestry, and agricultural industries (Beniston, 2003; Chakraborty, 2021; McDowell *et al.,* 2023). Mountain environments are highly ecologically sensitive and are relied on to support large populations, further portraying the urgency of addressing climate change and natural hazards in the mountains. The first concern with mountain climate change is the immediate risk to human life. Natural hazards, geohazards, or mountain hazards consist of the physical processes that are discussed in the biophysical section. What makes a natural hazard a 'hazard,' is the risk to humans that share the mountain space. Landslides, rockslides, mudslides, avalanches, floods, and droughts claim lives across the globe every year. Furthermore, natural hazards hold severe impacts to lives and livelihoods that can persist with long-lasting effects (Halofsky *et al.*, 2017; Hock *et al.*, 2019; McDowell *et al.*, 2021). These impacts include destruction to economic industries such as farming, agriculture, forestry, tourism, and recreation. Additionally, natural hazards in mountain regions impact communication and transportation networks, cultural practices, health and resource accessibility, and water security.

Understanding the impacts of natural hazards on communities can be established by categorizing the incidence of a hazard, and the distribution of damage to communities thereafter (Hewitt, 1992). The initial disaster of a hazard, such as a rockslide, landslide, or flood can have grave impacts to human life, property, and infrastructure (Halofsky *et al.*, 2017; Hock *et al.*, 2019; McDowell *et al.*, 2021). Additionally, small and rural mountain communities are often isolated, decreasing the effectiveness of emergency responses and allocation of resources (Hewitt, 1992; Klein *et al.*, 2019). The lasting impacts to natural hazards include being cut-off from power grids, damage to agriculture and industrial infrastructure, health impacts from lack

of sanitation and damage to water systems, and the cost allocated to 'regrouping' a community after a catastrophic event (Klein *et al.*, 2019).

The degree of negative impact from mountain hazards to communities is intersectional, with initial change or damage from hazards causing long-lasting impacts to economy, livelihoods, and sense of place. The primary focus for this literature review is water security in mountain regions. Snow is a vital component of mountain hydrological systems; any changes in the timing, amount, and extent of the snowpack can have far reaching effects (Beniston, 2012). The change in snowpacks will cause earlier melt, causing earlier stream run-off and decreased summer stream flows, altering timing and thus shortage of surface water in communities where the summer water demand is high (Beniston, 2012; Halofsky *et al.*, 2017). Additionally, extreme weather events and higher rain precipitation may increase run-off from agricultural fields and roads, leaching fertilizers, pesticides, and other contaminants into fresh-water systems (Halofsky *et al.*, 2017; ICIMOD, 2023).

2.3.1 Water Security

Drought is a large water security concern for mountain and lowland communities that rely on snowpack melt for fresh water, particularly for agriculture (Adhikari, 2018; Beniston & Stoffel, 2014). Drought in agriculture-based regions has cascading impacts to food production and food security, crop success, and soil moisture (Adhikari, 2018; Beniston and Stoffel, 2014; Briner *et al.*, 2012; Fuhrer *et al.*, 2014; Vivrioli *et al.*, 2011). Impacts on agriculture from drought also hold severe socioeconomic impacts. The uncertainty of food production can cause push factors, and thus the outmigration of residents, and social conflict with regards to water use (Adhikari, 2018; Beniston & Stoffel, 2014; ICIMOD, 2023). Drought in mountain regions is an

urgent issue that has potential detrimental impacts to other industries, security of communities, and future implications to hydrological systems, and their ability to replenish.

Water security does not just impact agriculture as an industry but also affects the ability for flexibility and change in land-use planning (Beniston, 2012). For example, a community seeking to implement forestry, mining, and other extractive industries as a part of the economy will be hard-pressed with risk of erosion and seasonal water demands (Beniston, 2012). Furthermore, changing social patterns, changing economic industries and incentives, and constant efforts to maintain irrigation systems and develop new ones have shaped land-use planning to incur more risk to geohazards, and excessive consumption of depleting water resources (Aggarwal *et al.*, 2021; Beniston, 2012). Additionally, it is not just the high or mid-mountain communities that are facing increased water security risk due to changes in mountain snowpacks. Downstream communities are facing increased vulnerability as communities in higher elevations redirect water sources for resource extraction or agriculture and as water insecurity accelerates across mountain ranges (Aggarwal *et al.*, 2021; McDowell *et al.*, 2013; Vivrioli *et al.*, 2020). As lowland areas become increasingly more dependent on run-off from mountain water systems and as higher communities construct reservoirs and redirect irrigation systems, water scarcity grows more severe and the options to adapt to more sustainable methods of water consumption decrease (Aggarwal *et al.*, 2021; Vivrioli *et al.*, 2020).

One example of addressing and characterizing vulnerability to water security is the investigation of water security issues in the Elqui Valley, Chile, and the community's adaptive capacity to these water stressors (Young *et al.*, 2010). In this article, Young *et al*. (2010) identify that adaptation usually represents modifications of existing resource management, sustainable development initiatives, and risk management approaches, which are often used to address

immediate vulnerabilities (Young *et al.*, 2010). The Elqui Valley is comprised of extremely steep slopes with dry, sandy soils. All water availability is derived from snow and ice accumulation in the high mountains which feeds the basin's rivers (Young *et al.*, 2010). Additionally, the stress of water insecurity is exacerbated by economic and institutional conditions, and large changes in the agriculture industry (Young *et al.*, 2010). Lastly, water rights are often granted under a market-oriented structure, which comes with issues of large, monocrop farms purchasing water rights instead of small, local farms (Young *et al.*, 2010). The example of Elqui Valley shows how water insecurity in mountain regions is not only related to water availability, but is also tied to debris flow and flooding, drought, socio-economic exposure sensitivities, and barriers to adapting to future risk (Young *et al.*, 2010). Future temperature changes are expected to cause hydrological changes in the Elqui Valley, with projections that water availability for potable, agricultural, and economic water will be unable to meet the needs of the Valley (Young *et al.*, 2010).

Similarly to the Elqui Valley, McDowell *et al*., (2013) discuss the case study investigation of the Khumbu region in Nepal, a unique geographic region that contains several communities who depend on the Indian monsoon season, and the redistribution effects of glacier and snowpack melt. Like numerous other mountain communities, Khumbu livelihoods are primarily based on agriculture, pastoralism, and more recently, tourism (McDowell *et al*., 2013). The study states that respondents indicated being sensitive to changing hydrological systems. Similarly to the Robson Valley, the residents receive their water from small surface water creeks that flow near the communities that they use for household purposes. However, respondents also identified feeling impacts to hydro-electricity production, agricultural yields, and decreased water availability to meet the needs of tourists (McDowell *et al*., 2013). Both Khumbu and the

Elqui Valley demonstrate how biophysical changes in mountain regions shape human vulnerability.

In recent years, tourism has become an opportunity to supplement economic diversity in isolated mountain regions, where economic diversification can be otherwise difficult to implement. Mountain tourism is among the most sensitive forms of tourism, as weather can be both productive for, and limiting to tourism, leisure, and recreational activities (Steiger *et al.*, 2022). Changing climate and weather conditions may increase the unpredictability of an already unpredictable landscape, thus impacting recreationists/tourist satisfaction, safety, and destination suitability for specific activities (Duerden, 2004; ICIMOD, 2023; K C and Thapa Parajuli, 2015; Steiger *et al.*, 2022).

Mountain tourism in both summer and winter visiting seasons is already affected by increasing risk of mountain geohazards, with rockslides, landslides, and glacial lake outbursts floods carrying drastic consequences to mountain tourism industries (K C & Thapa Parajuli, 2015; Steiger *et al.*, 2022; Wilhelmi *et al.*, 2008). Rock climbing, mountaineering, and backcountry activities are undertaken at an increased risk, and significant tourism infrastructure such as access roads and hiking trails are at risk of being damaged or destroyed (ICIMOD, 2023; Steiger *et al.*, 2022). Water security poses a large risk to mountain tourism industries under the weight of climate change. Aside from the potential risk to infrastructure from natural hazards, basic tourism operations place tremendous pressure on existing and already stressed water systems in mountain regions (Steiger *et al.*, 2022; Wilhelmi *et al.*, 2008). The largest stressor to water systems is consumption by tourists (hotels, drinking, showers, pools, etc.). In addition, the limited water availability and water-use conflict is exacerbated by snowmaking, which many mountain tourism industries are becoming dependent on to maintain tourism numbers in ski

destinations (Steiger *et al.*, 2022). It is important to note that research found that placing a 'cap' on water-use in tourism industries showed an up to 60% decrease in tourism-based visits and stays (Steiger *et al.*, 2022). As shifts in the economy, mountain landscapes, climate, weather systems, and in society persist, there are increased pressures to both the natural environment and communities that reside in the mountains.

Mountains are remarkable landscapes, housing a wide range of species, varying ecosystems, and different cultures, customs, and communities. Mountains are also highly fragile environments, being exceedingly susceptible to climate change and shifts in ecosystems. Humans are widely dependent on mountains across the globe for agriculture and hunting, water, natural resources, livelihoods, tourism, and recreation, and as homes. Unfortunately, increased natural hazards, snowpack depletion, environmental degradation, and increased need for resources jeopardize the integrity of mountain environments to support mountain communities and ecosystems. Therefore, there is a need for creative and sustainable methods of adaptation to a changing world.

2.4 Local Knowledge and Environmental Change

Knowledge can be explained as skills and information we gain through experience and education known as scientific knowledge. In western education systems, this is predominantly how knowledge is viewed. However, knowledge is also the awareness or familiarity acquired through an accumulation of experience from a situation, further known as local knowledge, traditional ecological knowledge, or Indigenous knowledge (Mercer, 2010; Wenzel, 1999). Both of the described ways of knowing house their own dynamics of human and power relationships, intertwined with political, social, and economical elements (Berkes, 2009; Mercer, 2010). Since the 1970s, there has been increased implementation and literature on the theory of knowledge co-

production, which is the creation of knowledge through a shared research process that involves people from different backgrounds, knowledge systems, and skill sets (Berkes, 2009; Mercer, 2010; Usher, 2000; Wenzel, 1999). Scientific knowledge systems have been the predominant knowledge that is sought for policy-making, governing decisions, and for problem solving. Unfortunately, the lack of validation and recognition for alternative knowledge systems, and the power of 'institutional knowledge' has resulted in the suppression of key perspectives, and exclusion of pertinent and important knowledge.

In the context of a changing environment, traditional knowledge is a dynamic process of knowledge accumulation, shaped and changed over time with the changing of ecological systems, migration of species, and with environmental stressors (Berkes, 2009). Traditional knowledge is accustomed to acknowledging and adapting to environmental changes. However, the rate of climate change, frequency of natural hazards, and contestation of resource management has proven unprecedented in adaptability. Therefore, the idea of knowledge co-production between traditional knowledge systems and scientific knowledge systems is the best option to navigate adaptation to hazards and disasters, and equitable and adequate environmental governance. There needs to be an integration between scientific 'western' knowledge and Indigenous/traditional/local knowledge, necessitating mutual understanding and recognition of strengths from each knowledge system while also offering respect to cultural, epistemological, and dynamics of each (Berkes, 2009; Mercer, 2010; Usher, 2000; Wenzel, 1999).

2.5.1 Knowledge Co-Production

The occurrence of natural disasters and the risk of hazards is on the rise, especially in locations with limited governmental support, aid relief, or resources to respond to such grave environmental impacts. Furthermore, national and international aid is often provided to

communities' post-disaster, yet only after the population themselves have ensured their survival immediately after the disaster. Residents and/or Indigenous populations may also know what is critical for livelihood security post-disaster (Lejano *et al.*, 2021). Communities come together in the absence of government, which is where local, traditional, and Indigenous knowledge informs the immediate response to a crisis that protects a community. But as climate change, decreased traditional knowledge transmission, increased hazards, and human-interrelated factors further drive vulnerability, communities lose capacity to address destructive crisis, nor should they bear full responsibility to react (Lejano *et al.*, 2021; Mercer, 2010; Flailing *et al*, 2007).

Natural hazard vulnerability is comprised of societal, economic, cultural, and human-interrelated factors that shape a community's capacity and ability to adapt to the changing global context (Flailing *et al.*, 2007). People's behaviour within a space, experiences of place, and value-based knowledge claims shape community perceptions of hazards as they manifest within their environment. (Flailing *et al.*, 2007). In contrast, government policies in response to hazards are claims of fact-based knowledge (Flailing *et al.*, 2007; Mercer, 2010). Fact-based scientific knowledge has shown to not be adequate in responding to place-specific hazards in isolation; however, local knowledge in risk reduction is able to reduce potential environmental hazards as it is attributed to a location, not as a category, allowing for place-based initiatives coupled with scientific data and knowledge.

The key consideration for facilitating knowledge co-production in Disaster Risk Reduction (DRR) is not to identify new knowledge, but to enhance knowledge as a tool that can be implemented by Indigenous and/or rural communities to reduce vulnerability to environmental hazards (Mercer, 2010). Disaster risk reduction is aimed at mitigating new and reducing disaster risk, as well as managing residual risk (Lejano *et al*., 2021; Mercer, 2010;

Furthermore, knowledge co-production should not just be viewed as a method to identify levels of capacity and vulnerability within a community, but as a solution-seeking process that engages residents, researchers, local governments, and stakeholders (Berkes, 2009; Mercer, 2010). In the context of integrated strategy, knowledge for the benefit of knowledge's sake is not an action-oriented method of knowledge co-production and can be considered a harmful waste of time by the community that seeks to address environmental disasters (Mercer, 2010).

After the framework for knowledge co-production is established, the project must collectively address and understand the role of extrinsic factors such as globalization, and how they shape intrinsic impacts such as farming, harm to native soil, and property development in unsafe locations with respect to hazards (Mercer, 2010) and address priorities to contribute to adaptive methods. Flexible and bottom-up as environment and contexts change, what used to work as an adaptive measure to natural hazards in one community may not work or may clash with cultural perspectives in another.

As the world scrambles to address changing environment systems, the demand for resources and instances of destructive natural hazards increases, and national and international governments develop blanket policies to mitigate the impacts (Ingty, 2017; Lejano *et al.*, 2021). However, there is not enough support for local, adaptive measures to address the same issues, leaving the bulk of responsibility to communities to adapt to unprecedented changes. Indigenous and rural communities have been continuously adapting to natural stressors and environmental changes for generations, with many adaptive strategies and practice being passed orally down generations (Ingty, 2017; Lejano *et al.*, 2021; Makondo & Thomas, 2018; Stevenson, 1996). With an already limited understanding of vulnerability to communities from climate change, the implementation of local, traditional ecological knowledge, and Indigenous knowledge into place-

based adaptation policies may serve as a solution (Corburn, 2003; Ingty, 2017; Makondo & Thomas, 2018; Lejano *et al.*, 2021).

Rural communities, particularly mountain or rural coastal communities, are reliant on environmental services and biodiversity for livelihoods (Ingty, 2017; Makondo & Thomas, 2018). However, they are also often located in ecologically sensitive areas and are at the greatest risk to quickly changing environments (Ingty, 2017; Makondo & Thomas, 2018). Adaptation strategies that are co-designed from different knowledge systems are proven to be beneficial. For example, using science to forecast upcoming weather changes can provide the community with time to implement decreased water usage, ration certain resources to revive population numbers, change irrigation practices, or move herds to different areas (Berkes *et al.*, 2000; Ingty, 2017). Due to the rapid onset of environmental changes, many adaptive strategies require institutional funding, governance structures, and changes in economic systems, which is often done in a top-down way (Ingty, 2017). Therefore, co-production of knowledge and solution seeking projects require collaboration among different knowledge systems at the community, governmental, and institutional level.

Well-informed government arrangements are required to enable adequate mobilization of policies, strategies, and environmental management (Van der Molen, 2018). However, the knowledge required to develop environmental decision-making capacity must be done in conjunction with both scientific knowledge, and local/traditional knowledge. In order to develop governing strategies and systems under climate change, it is imperative that there are considerations for diverging perspectives, dynamic environments, power relations and skill sets, and that governance arrangements are adaptive to ensure effectiveness (Taylor & de Loë, 2012; Van der Molen, 2018; Usher, 2000).

Adaptive governance is learning as a multi-actor process, where the government structure has the integrative capacity to gain insight in different knowledge systems, and normative, social perspectives (Van der Molen, 2018). Having an adaptive governance structure in a centralised position allows for immediate responses to environmental management issues, that has resources to support the concern. For example, Van der Molen (2018) described the mussel fishing industry as a way to build and apply regulatory capacity. The government collaborated with local fishers and residents to reach a shared sustainability goal based on ecological knowledge that the local people had on the species. The government then developed a legal permit system to ensure the regulation of the species (Van der Molen, 2018).

Natural resource governance and projects, such as the mussel project, can be designed based on knowledge that is incomplete, primarily when they fail to draw on local ecological knowledge, monitoring, and local stewardship (Ballard *et al.*, 2008; Stevenson, 1996). However, co-production of knowledge for governance does not mean that various knowledge systems are simply providing insight and data to inform other knowledge holders, but are equally involved, or are lead researchers in collective decision-making surrounding environmental governance, including local knowledge holders, Indigenous knowledge holders, and traditional ecological knowledge holders (Ballard, *et al*, 2008; Latulippe & Klenk, 2020; Stevenson, 1996; Taylor & de Loë, 2012; Usher, 2000). Maintaining the co-production knowledge system as collaborative and not extractive ensures considerations across governing bodies and local communities that are grounding, applicable, and more likely to be supported and accepted by the public (Taylor & de Loë, 2012).

It is imperative that communities, research institutions, and governments work to develop adaptive strategies and sufficient DRR strategies in the wake of cumulative environmental

impacts, societal changes, and global pressures. However, it is far more conducive to the success of environmental management and community health if knowledge for implementation is produced collaboratively. While there are still discrepancies and power-relations that hinder the successful implementation of co-produced knowledge at the global scale, understanding the importance of diversity of perspectives, experiences, and skillsets can best equip communities for change.

2.5 Participatory Mapping

Participatory mapping is a qualitative research method that uses community knowledge and understandings of space and place through cartographic practices (Cope & Elwood, 2009). The result is a map that reflects the perspectives, knowledge and/or concerns of the community within their known and lived environment. In the field of climate change adaptation research, participatory mapping creates a visual that is useful for both communities, decision-makers, and emergency response teams to spatially and socially understand the environment, and how to address changes within it. In order to develop participatory mapping methods, it is important to first understand mapping and geographical information systems (GIS). GIS is a computer system designed to analyze, edit, manage, store, and visualize geographic-based information (Crampton, 2010). GIS is a tool rooted in geography, traditionally quantitative and science-based, that integrates different types of data to visualize layers of information based on location using maps or three-dimensional (3D) scenes (Crampton, 2010). Maps are then used to share information, communicate, and work to solve complex spatial problems. However, GIS can fail to include perceptions of space, borders, boundaries, and locations; it is a tool that reflects social norms, so it can be used in a way that marginalizes certain demographics or leaves out key voices. Therefore, it is critical to inquire how to communicate information of a physical space, while

also ensuring that diverse perspectives, groups, and knowledge are adequately involved in the process.

Responding to critiques of a positivist epistemology to the mapping of space in the mid-1990s, GIS and mapping has grown from being designed as a tool to share information about a location, to being used to communicate the relationship between people and the environment. Often containing cultural/spiritual/traditional perceptions of space, participatory mapping, or participatory GIS (PGIS), is thus a tool used to incorporate differing knowledge systems, quantitative data, and illustrate community-based research epistemologies (Cope & Elwood, 2009; Reichel & Frömming, 2014). In the context of this research project, participatory mapping was used to understand perceptions of natural hazard risk from members of mountain communities.

2.5.1 Implementation of Participatory Mapping

To engage in participatory mapping is to integrate mixed research methods that display multiple forms of knowledge, findings, techniques, and truths, all situated within the region where the research is taking place (Cope & Elwood, 2009). Participatory mapping is not only done through traditional mapping methods, but also through mixed-media representation. Therefore, GIS-based maps are woven together with 3D models, paintings, sketch maps, photographs, and sticky notes (Cadag & Gaillard, 2012; Cope & Elwood, 2009). These different representations of space are decided and created through an integrated process, where research participants explain, communicate, share knowledge, examine, debate, and describe experiences within their environment to share with researchers (Cadag & Gaillard, 2012; Cope & Elwood, 2009).

Coupling participants' perceptions and experiences of their environment with scientific data and information allows for the integration of differences, contestations, significant regions, and multiple ways of knowing into a tangible map (Cope & Elwood, 2009). The integration of multiple forms of spatial knowledge and data then generates greater insights that can be used to solve social, political, environmental, institutional, and economic problems and inform decision-makers. Furthermore, and arguably most importantly, participatory mapping engages decision-makers to legitimize and validate local knowledge into policy-making that influences responses to community aspects such as natural hazards and spatial planning initiatives (Cope & Elwood, 2009; McCall & Dunn, 2012). However, maps hold incredible power in shaping borders, segregating spaces, influencing our understandings of regions and who resides in them, and transforming representations of reality. It is not necessarily ethical or applicable to maintain traditional methods of boundary making when facilitating participatory mapping. Therefore, recognizing one's own position in the participatory process and remembering that maps are selective representations, is imperative to developing a truly beneficial map (Cruikshank, 2007; Heesen *et al.*, 2014; Lowan-Trudeau, 2021; Reichel & Frömming, 2014).

2.5.2 Risk and Resilience Mapping

Participatory mapping has proven successful in planning farming plots and activities, resolving territorial disputes, implementing social initiatives and activities, and managing natural resources (Cadag & Gaillard, 2012). However, there has been limited use of participatory mapping for community-based disaster risk reduction (DRR). Recognizing that local knowledge is an incredible value to understanding a changing environment, it is also important to recognize that the same local knowledge holders are also the first to respond or be impacted by a natural hazard. Therefore, participatory mapping can be implemented to delineate regions or areas that

are perceived by community-members as hazardous or prone to vulnerability (Cadag & Gaillard, 2012; Klonner *et al.*, 2021; Smith *et al.*, 2000; Yen *et al.*, 2019).

In the context of natural hazards and climate change, governments will often respond to disastrous hazard events (i.e. flooding, storms, forest fires) as being solely attributed to climate change. However, it is imperative in DRR to look at potential cumulative impacts or causes that exacerbate hazards and vulnerability within a community (Cadag & Gaillard, 2012; Smith *et al.*, 2000; Yen *et al.*, 2011). A method to demonstrate both scientific and local knowledge in a DRR assessment is to overlay the local knowledge over top of the hazard map designed by scientific knowledge (Cadag & Gaillard, 2012; Klonner, 2021). This allows residents to critically assess disaster risk and/or possible improvements within their immediate spaces, including developing evacuation and warning systems as well as preparedness initiatives (Cadag & Gaillard, 2012; Klonner *et al.*, 2021; Yen *et al.*, 2019). Additionally, participatory mapping in DRR provides an opportunity to consider underrecognized concerns such as the risk of disease epidemics due to a hazard, potential border closures, impacts to agriculture and livestock, and restricted mobility (Smith *et al.*, 2000).

After residents, stakeholders, and researchers have developed a participatory map to understand risk within an environment, the produced map can be used to develop adaptation and resilience methods against hazards and risk. Participatory mapping creates knowledge that enhances perceptions and understandings of complex issues at local and global scales (Rawat *et al.*, 2021). With regards to environmental issues, the development of co-produced participatory maps creates usable data in a timely manner, allowing for adequate resources to address dynamic issues. Imperative in the discussion of adaptation and resilience to a changing environment is the changes to experiential or traditional knowledge (Reichel & Frömming, 2014). A quickly

changing space means that strategies shared over generations to cope may no longer be applicable, therefore, the coalition of different ways of knowing can create new adaptation initiatives (Klonner *et al.*, 2021; Rawat *et al.*, 2021; Reichel & Frömming, 2014). For example, implementing more sustainable methods of forestry on steep hillslopes instead of commonly used practices can prevent the ground from sloughing, protecting both land from landslides and the maintenance of biodiversity and traditional harvesting practices (Rawat *et al.*, 2021; Reichel & Frömming, 2014). Additionally, implementing spiritual beliefs such as forest or mountain spirits into participatory mapping aids in understanding why/how residents avoid areas of risk, ultimately protecting farmland, property and life (Cruikshank, 2007; Reichel & Frömming, 2014).

Participatory mapping is being increasingly used to address DRR and develop adaptive and resilience methods to changing environments. The implementation of cultural, spiritual and local knowledge allows for an increased understanding of the depth of risk and how communities perceive and respond to environmental risk. Furthermore, the co-production of knowledge with residents, stakeholders, and researchers allows for tangible, implementable knowledge that can be shared and stored in various ways, including outside of academic institutions. Therefore, adaptation and vulnerability can be assessed with imperative input from the community, and enacted in a way that truly benefits the community.

2.6 Knowledge Gaps and Research Opportunities

Several knowledge gaps in our understanding of climate change impacts, vulnerability and adaptation in mountain region are evident in the reviewed scholarship. ***First,*** climate change impacts in mountain regions is highly localized with impacts being felt uniquely in differing geographical locations, with most research having been conducted at broad scales where human

adaptation and vulnerability is based on assumption rather than empirical evidence. ***Second,*** most research in Canadian mountain environments is focused on measuring biophysical changes including glacier melt (Beniston, 2003), natural hazards (Hock *et al*., 2019), and snowpack depletion (Huss *et al*., 2017) with less attention given to the cascading impacts on human lives, and how to adapt (McDowell & Hanly, 2022). ***Third***, the amount of water contained within a snowpack is also difficult to accurately measure due to factors including the large spatial variations in mountain landscapes, and the use of multiple measuring techniques including remoting sensing, ground observations, and regional climate models (Shea *et al*., 2023). Therefore, estimating SWE in a snowpack may not accurately provide a clear picture of the amount of water available from snow run-off that a community is dependent on.

Themes in vulnerability research showcase that while a system can be ecological, social, and structural, the functions of determining vulnerability are similar – how does the system respond to changes, what capacity do they have to adapt, and how does the system recover and mitigate further effects. Addressing vulnerability is then a function of adaptation, and what considerations, behaviour, resources, and power systems are in place that shape adaptive capacity. While we know how to investigate determinants of adaptive capacity and conduct vulnerability assessments in a theoretical sense based on scenario-based approaches, how to implement these frameworks in a place-based scenario calls for more deliberation. For example, understanding past hazards in the Robson Valley, the recent and past changes in the environment, the current dominant industries, and the resources of the local government allows us to determine the adaptive capacity of the community, and how susceptible they are to climate change (Adger & Kelly, 1999; Adger, 2003). Currently, information on vulnerability and adaptive initiatives in the Robson Valley are derived from theoretical, general models that are

based on future climate projections. However, these models provide little information on impacts to place-specific economic situations, and do not consider the strength within community and neighbour relationships. This research sought to address the above knowledge gaps by employing a bottom-up, community-based approach to identify and characterize how climate and non-climate risks and changes are being experienced and responded to in the Robson Valley.

Chapter 3: Robson Valley Case Study

The Robson Valley is located in east-central British Columbia, stretching roughly 230 kilometres between The B.C. Alberta border in the east and Dome Creek in the west. The Robson Valley occupies the northern portion of the Rocky Mountain Trench and is set between the Canadian Rocky Mountains to the north-east and the Cariboo Mountains to the south-west (Figure 3.1), with the Valley bottom divided by the Fraser River (Wheeler, 2008). Historically, the area has been inhabited by the Simpcw First Nation, and Lheidli T'enneh First Nation, who still hold invaluable knowledge, spiritual, and physical connections to the Valley. The Fraser River was used for travelling, the Yellowhead Pass used for trading, and the abundance of wildlife adequate for hunting and trapping practices (Wheeler, 2008). The relatively recent arrival of settlers to the Valley began with the construction of the Grand Trunk Pacific Railway and the Canadian Northern Railways, which radically changed the Robson Valley (Bradley, 2003; Wheeler, 2008). The Robson Valley developed through extensive forestry practices, railway and development settlements, and a bit later, a successful agriculture region (Wheeler, 2008).

Today the Yellowhead Highway, also known as Highway 16, runs through the Valley where it connects to Kamloops by Highway 5 heading south, and connects to Prince George heading west. The two largest communities in the Robson Valley are Valemount with a

population of 1052 residents, and McBride with 588 (Government of Canada, 2021). There are smaller settlements throughout the Valley, including Tête Jaune Cache, Dome Creek, Crescent Spur, and Dunster, making the total population of the Valley 1589 residents spread over 15,000 km^2 (Government of Canada, 2021). The Village councils of McBride and Valemount politically represent the Valley, and the region as a whole is governed by the Fraser-Fort George Regional District Electoral District H (Robson Valley-Canoe) (RDFFG, n.d.). Since the 2021 Census, McBride has seen a population decrease of 4.5%. The average population age is 45.5 years, with the average total income per year in McBride being $39,600 (Government of Canada, 2021).

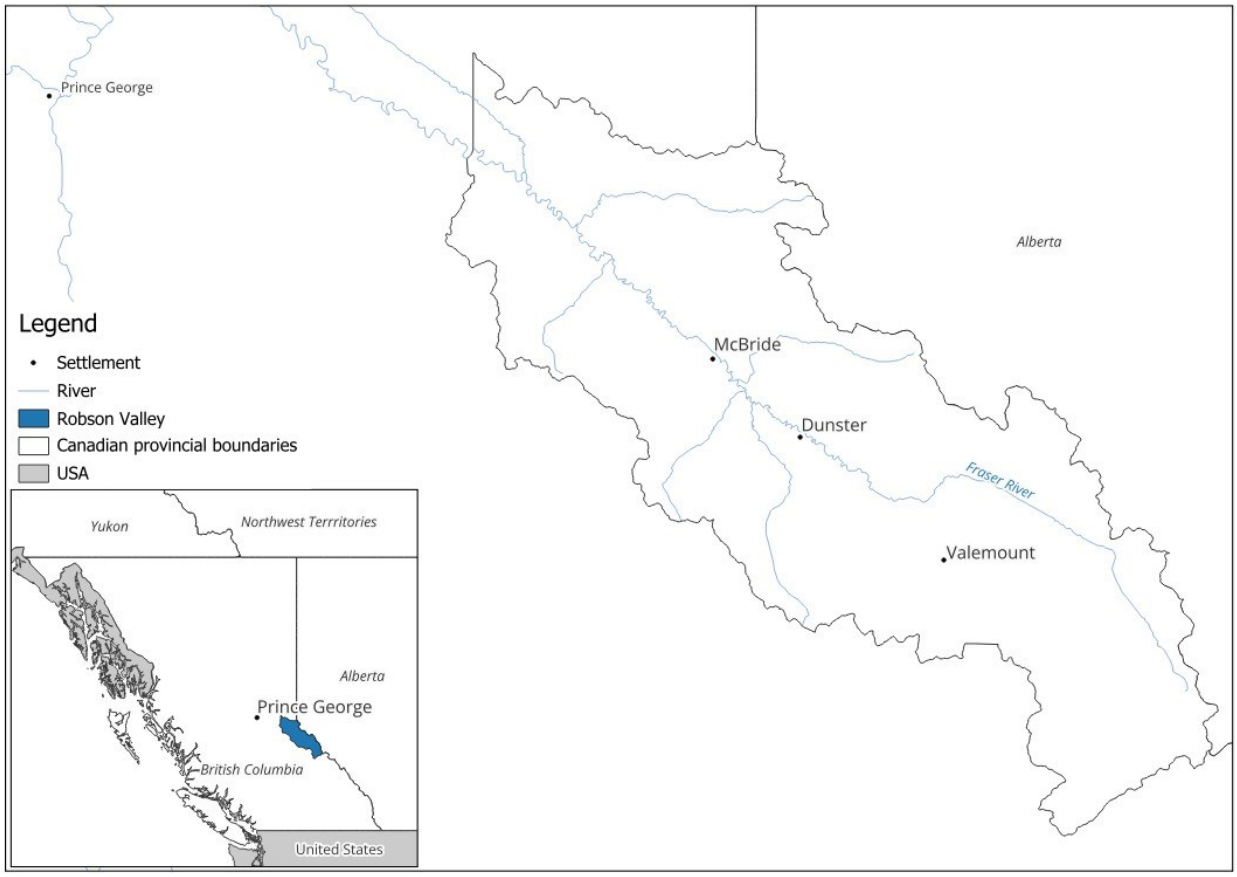

Figure 3.1: Location of study communities in the Robson Valley, B.C, Canada

The Robson Valley has a history of mountain geohazards that have impacted the communities. Since the early 1900s, there have been numerous landslides/mudslides, which have

wiped out the railway, destroyed homes, and resulted in deaths (Wheeler, 2008). Wildfires have also been common in the Valley; many started by various industry and the railway during dry seasons, or many that continued burning under the snow in the winter, only to erupt again in the spring (Wheeler, 2008). Avalanches and floods from rapid snowpack melt throughout the mountain regions have also threatened the community throughout the last century, resulting in significant damages and expenses (Wheeler, 2008). Currently, these hazards still remain a risk to the communities within the Robson Valley. Recently, the Valley has experienced mass movement events that include the evacuation of properties along Mountainview road in July 2020 due to a debris flow, the Swift Creek landslide of July 2021, and continuous mudslides on the East Canoe Forest Service Road (RDFFG, n.d.). Now with increased rapidity of snowmelt and lack of snowfall in the winters, drought has joined the list of hazards in the Valley.

The community of McBride fluctuated between a level four and level five drought, classified as having adverse impacts to socio-economic or ecosystem values where an emergency response is likely/needed, from September 2023 to May 2024 ([Village of McBride] Personal Communication, October 12th, 2023). McBride receives the majority of their water from Dominion Creek, located on Lucille Mountain and accessible by the Lucille Mountain Forest Service Road. The waters from Dominion Creek provide drinking water, sanitary service, and fire protection ([Village of McBride] Personal Communication, October 12th, 2023). Other avenues for water accessibility are limited due to the soil composition of McBride, which is primarily comprised of clay. Clay-based soils allow for changing water table depths, making it difficult to find a sustainable underground aquifer ([Village of McBride] Personal Communication, October 12th, 2023). Lastly, the community of McBride has a history of water

boil advisories that last up to two weeks at a time, increasing water insecurity ([Village of McBride] Personal Communication, October 12th, 2023).

The Official Community Plan and the Water Bylaw of McBride discuss the potential for hazards and water insecurity throughout their region. However, the issues are introduced but not discussed and no resolutions are provided. McBride also has an emergency plan that was most recently amended in 2021. This emergency plan contains plans of evacuation, stages of evacuation, and outlines the requirements of when it is safe to return to the community. This plan also states that Robson Valley often experiences long power outages (Village of McBride, 2019). The emergency plan states that wildfires rank as one of the highest concerns for the Village of McBride, facing serious threat from May to October each year (Village of McBride, 2019). The Village of McBride also states in their emergency plan that the community is susceptible to extreme weather and storms, including, blizzards, drought, fog-reduced visibility, hail, heavy snowfall, heavy precipitation, high winds, ice storms, extreme temperatures, and thunder and lightning storms. The plan also lists earthquakes and cascading hazards such as landslides, flooding, and dangers to public health. Additionally, each hazard or emergency is listed with the possible effects, policies, and responses to these hazards (Village of McBride, 2019).

Rural and small towns across Canada have experienced significant economic restructuring since the late 1990s which has impacted the availability of local services including government, social, education, and health services (Halseth & Ryser, 2006; Halseth *et al.,* 2019). Access to service provisions provide communities with a higher quality of life, economic base, and activities for community members (Halseth & Ryser, 2006; Halseth *et al.,* 2019). Access to local services in rural areas also provide a foundation for social capital and cohesion (Halseth & Ryser, 2006). In Northern B.C., including the Robson Valley, this economic restructuring has

impacted rural communities' ability to rely on these services, and in turn has changed volunteer networks, has caused the out-migration of young professionals and youth, impacted local economies and industries, and has left many rural communities with limited resources that are necessary to maintain a certain quality of life (Halseth & Ryser, 2006). Residents of McBride and Dunster discussed their experience with these changes, including the change in local industry when the sawmills closed, the difficulty in retaining work-age families, and the struggle to keep rural services and amenities. The Robson Valley's experience with centralization and policy changes is telling of a greater Northern B.C. story.

The Robson Valley, specifically McBride and Dunster, provides a unique case study to investigate the impacts of drought and water security to the communities, as well as community vulnerability and adaptation to multiple stressors due to the nature of drought impacting this community, and how they are able to respond to other changes, and other global pressures such as climate change, changing markets, and wildfires (see Figure 3.2). This project has many moving parts and is dedicated to the co-collaboration and knowledge co-production with residents, local knowledge holders, and local governance. It employs a case study approach in order to combine social perceptions of mountain hazards, community knowledge on the environment, and quantitative data and work toward developing place-based solutions that are both relevant and implementable for the community.

Figure 3.2: Aerial view of the Robson Valley

Chapter 4: Methodology

4.1 Research Approach

The research was undertaken with community members in McBride and Dunster using a community-based, bottom-up approach to study climate change impacts, vulnerability and adaptation described by Ford and Smit (2004) (Figure 2.1) and consistent with Cutter (1996) (Figure 2.2). The approach is distinct from other climate change assessments in that it starts by having community members identify conditions, societal and environmental, that are relevant and important to them, beyond those readily captured in climate models (e.g. temperature, precipitation). Here, climatic exposures are considered in the context of multiple climatic and non-climatic stressors, which influence how people experience and respond to risk.

Information on vulnerabilities was obtained primarily from semi-structured interviews and a focus group with residents, participant observation, and analysis of secondary sources. The inclusion of community members in vulnerability assessments has proven to deliver in-depth accounts and real-life areas of concern from a grassroots approach (McDowell *et al*., 2013; Pearce *et al*., 2018). To accomplish this, the research was guided by key considerations for conducting community-based participatory research (CBPR) described by Eriksen (2021) and Halseth et al. (2016). This involves (1) community relationship building; (2) building and maintaining community-academic partnerships; (3) empowerment of communities to address topics of importance to them in a culturally relevant way; (4) trust and reciprocity; (5) long-term processes and commitments of sustainability; and (6) the mutual benefit and co-learning of all partners (Eriksen, 2021, p. 1223). I adhered to cultural and social norms within the Village of McBride and Dunster and aimed to remain as consistent as possible within the community, maintaining open communication, transparency, and availability.

This research was initiated by representatives from the Robson Valley who approached the university in May 2021 about conducting research to learn more about climate change impacts, vulnerabilities, and adaptations in the region. The first research activities focused on community vulnerability to wildfire risk in the upper (Whitehead, 2023) and lower (Canosa *et al*., 2024) Robson Valley. This research identified gaps in our understanding of changes in mountain snowpack and geohazards, which became the focus of the next phase of research.

I first met with community partners in McBride and Dunster in September 2023 when I visited in the Valley together with other research team members to discuss the next phase of the research. We held an information session in the McBride Museum where people could come and discuss resident's viewpoints on what research is needed to better understand changes in snowpack and geohazards. It was decided that some members of the team would focus on specific locations of high concern for geohazard risks and changes in snowpack, and that I would work with residents to document their knowledge and experience of living with these risks.

I returned to McBride again in October 2023 and February 2024 to discuss research priorities with community members. From these discussions, water security emerged as a significant concern to the community. These visits helped shape the research approach and methods and determine the timing of data collection.

4.2 Ethics

There are numerous approaches of ethical accountability within the research process. Catungal and Dowling (2021), discuss that qualitative research often involves observing people and asking personal questions, and therefore includes knowledge that is not readily available to the public. Another important step to maintaining ethics is informed and on-going consent from participants. This project ensured on-going and informed consent to allow the participant to be

able to retract consent at anytime up until publication, ensuring comfortability and autonomy in the process (Catungal & Dowling, 2021; Halseth *et al.*, 2016).

In order to ensure ethical rigour throughout the research, I obtained my certificate of the 'Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans' training. All research activities were in accordance with UNBC's Research Ethics Board requirements (6009506). Additionally, confidentiality and privacy of the participants was safeguarded with the utmost vigilance to prevent unwanted participant exposure. Ensuring ethical considerations contributed to overall trustworthiness of this research project through the building of relationships and trust within the Robson Valley. Additionally, ethical considerations mitigate any inadvertent harm or discomfort to the community while also ensuring that the communities needs are addressed safely, comfortably, and with their best interest in mind. Contacts for counselling were made available in case any discomfort were to occur in the interview process. Additionally, if participants expressed discomfort during the interview, they were reminded that the interview can stop at anytime, breaks could be taken, or we could move onto a different question.

4.3 Data Collection

This research adopted a mixed-methods approach that included semi-structured interviews, a focus group interview, participatory mapping, secondary sources, and community observation and field notes from 10 weeks spent in the Robson Valley. I conducted 25 semi-structured interviews with 32 participants. Eighteen of these were one-to-one conversations between me and a participant, and seven with two participants at once at their request. I also conducted one focus group with seven participants, two of whom had participated in the semi-structured interviews, bringing the total number of study participants to 37 (Table 4.1).

Table 4.1: *Demographic Characteristics of Participants*

Age	Male	Female	No Data	Total
18-34	1	0		
35-54	4	3		
55-74	8	4		
75+	10	5		
ND			2	
Total	23	12		37

From May to October 2024, I spent a total of 10 weeks conducting interviews and fieldwork in McBride and Dunster, and participated in the social life of the Robson Valley.

4.3.1 Sampling and Recruitment

Using a purposive sampling approach, I sought to speak with those experiencing water changes who would like to discuss their experiences. Additionally, I sought participants who have lived in the Robson Valley for at least one year, and every season of the year, so that changing conditions could be quantified and described over a one-year time period. Equal representation of men and women above the age of consent (16 years of age) was aimed for. Participants were recruited primarily through posters that I placed in the local grocery stores, train museum, and library. Connections between the local government, the PICS project, and local research partners and stakeholders also aided in participant recruitment. Participants were also recruited using a snowball method, in which existing participants identified potential candidates who were then provided with my contact information so that they could reach out to me if interested (Longhurst, 2010; Scott, 2021).

4.3.2 Semi-Structured Interviews

Semi-structured interviews are common in vulnerability and adaptation research in the

environmental change and geography disciplines because of their inherent flexibility and space for agency of the participants (Longhurst, 2010; Pearce *et al.*, 2018; Pearce *et al.*, 2010). Additionally, this method allows for the interviewer and interviewee to pick-up on non-verbal cues and possibly press for more information or use follow-up questions that may not be initially included in the base-line questionnaire (Longhurst, 2010). Semi-structured interviews also allow the researcher to see what is relevant to the interviewee, possibly changing the course of conversation and knowledge sharing (Dunn, 2021). I established rapport with interviewees through preliminary relationship building and work in the community, as well as 'warm-up' periods such as light conversation prior to the interview process which increased the level of understanding between the interviewee(s) and I (Dunn, 2021).

Semi-structured interviews with residents were used to document community perspectives and experiences with snowpack and water system change in mountain environments and identify potential avenues for adaptation. I used participatory mapping as part of the semi-structured interviews to gain an understanding of participants' perception of water insecurity, where they think other water resources may or may not be accessible, other potential hazards or spaces of importance, and how they have been impacted. Interviews ranged from 25 minutes to an hour in length, with an average length of 45 minutes, and were held when and where participants chose (Halseth *et al.*, 2016).

Interviews focused on participant concerns, perceptions, and personal experiences with drought and snowpack change. Each interview was both audio-recorded verbatim and transcribed, with the exception of seven interviews which were recorded by hand in a notebook and typed up on a computer in accordance with participants preferences. All interviews were facilitated by an interview guide (see example questions Table 4.2), which was used to identify

common and key themes through open-ended questions.

To ensure rigour and participant comfortability, all interviewees had access to their transcript at any time and were able to withdraw consent up until the publication process. Additionally, participants were given the option to review their transcripts as part of the member-checking process to ensure that it was accurate. Two of the 32 interview participants requested to review their transcripts, and the remainder of the interview and focus group participants requested an overview of the preliminary findings in general, or did not wish to member check at all. Participants were also able to see the interview question guide in advance, if they so chose, which two participants requested.

Table 4.2: *Interview Guide Example Interview Questions*

Themes	Example Questions
Background Information	How long have you lived in the Robson Valley? Where do you receive water from?
Environmental Observations	Do you have concerns about your water supply? What is your biggest concern? Have you observed changes in the snowpack?
Barriers to coping with snowpack and water change	Do you have any concern about your ability to access water? What makes it difficult to access water? What makes it easier to access water?
Adaptation responses	Have you dealt with these issues in the past, and if so, how?
Concluding Questions	Is there anything else you would like to add to this discussion?

4.3.3 Focus Groups

Similar to semi-structured interviews, focus groups are conversation-based activities between six to 12 people that allow for open responses and discussions of a topic set by the researcher (Dunn, 2021). The moderator or researcher of the focus group will ensure that the group remains on topic. However, focus group discussions are non-directive in nature, which

fosters different perspectives and angles of discussion (Dunn, 2021; Longhurst, 2010).

A focus group with farmers was employed to address the issue of water security as well as other topics regarding snowpack change and consequent impacts. The focus group differed from the semi-structured interviews in that it specifically sought out the agricultural sector. Focus group participants were all members of the McBride Farmer's Institute, an institution established in 1915 to address the needs of local farmers, increase agricultural knowledge, and professional development opportunities, who were experiencing impacts from drought and snowpack, and expressed concern about their agricultural-based livelihoods moving into the future. A focus group was conducted in June and followed up with a discussion with the same participants in October. Focus group discussions centred on community perceptions of drought, how it has or has not impacted their respective industry and community, as well as avenues on community adaptation and capacity building. The questions in the focus groups were the same as those in the semi-structured interviews but were adjusted to the specifics of farming. Additionally, the focus groups discussed other mountain hazard topics, including avalanches and landslides, as well as social issues/changes in their communities and how it has or has not impacted their industry. Prompts and follow-up questions were asked based on the flow of conversation.

4.3.4 Participatory Mapping

During semi-structured interviews, a topographic map (scale of 1:250 000) of the Robson Valley from McBride to Dunster was shown to residents, where they were able to annotate or 'mark-up' the map to show where they think there are areas that are 'high hazard' from the melting snowpacks, and how these hazards are, have, or may impact the community, specifically with regards to water availability in the Valley. However, within the first few interviews,

participants expressed that they were uncomfortable with displaying on the map where they received water due to either themselves not having water licenses on the source, having multiple water licenses on the source, or knowing neighbours that did not have water licenses on the source.

To ensure privacy and comfortability, the participatory mapping activity pivoted to focusing on areas that the participants shared were important to them, such as changing glaciers, snowmobiling areas, landslide areas, flood regions, and favourite recreational spots. While this data was not part of the formal analysis process, it increased my own understanding of the region and community perceptions of their mountain space.

4.3.5 Secondary Sources

Historical documents including newspapers, articles, and books were reviewed to understand the historical context of both biophysical changes and socio-economic-political information in the Robson Valley. Additionally, current local, municipal, and federal government documents, procedures, and policies regarding drought, natural hazards, and emergency planning that impacts the ability of the communities to adapt or respond to biophysical mountain changes were included. Some of the secondary sources I used include the Village of McBride's Emergency Plan (Village of McBride, 2019), the local newspaper the Rocky Mountain Goat, and the public library for archived newspapers and reports. Other research projects that have taken place in the Robson Valley regarding natural hazards, changing snowpacks, or important industry information were also reviewed. Lenworth Reckford, a research associate to the project, and I reviewed archival newspaper starting in 1972 up until the early 2000s, recording information that was related to snowpack and water change, water quality, wildfire, and mountain geohazards.

4.3.6 Community Observation and Field Notes

Used in a multitude of disciplines for its simplicity, participant observation is a way of engaging with, participating in, and understanding the environment around the researcher (Laurier, 2010). While in the Robson Valley, I participated in the social life of the community, building rapport and trust with community members (Watson, 2021).

My observations informed my approach, aiding me in knowing who, how, when and where to engage with residents. Data was recorded through journals and field notes written in a field notebook. I took care to ensure that my field notes were rich in detail to accurately capture my experiences (Jackson, 1990). I described the setting, the observed behaviour of the participant, how I was feeling during the process, and any other relevant details. Journals and fieldnotes were done as subtlety as possible as to mitigate residents feeling uncomfortable (Watson, 2021).

4.4 Research Dissemination

In the last week of June 2024, fellow PICS members Dr. Tristan Pearce, Dr. Joe Shea, Sami Sofizada, Lenworth Reckford, and I visited the Robson Valley. We presented to the Village council about a weather station installation on Lucille Mountain, hiked up Mount Lucille to conduct a drone survey of potential installation locations for the weather station, and hosted a community engagement event at the Dunster schoolhouse where we discussed the progress of the PICS research projects, discussed mountain geohazards and water insecurity, snowpack changes, land-use issues, and rural living issues. This event was also an opportunity to build further relationships with residents and find opportunities to reach out to other professors and projects at UNBC about addressing these additional concerns.

This research project is committed to disseminating results of the researcher in a timely manner to the community. The preliminary findings were presented to McBride and Dunster in the fall of 2024 through community meetings, a follow-up discussion with the focus group, and in the member checking process. The final presentation of findings will be done in a manner that is most digestible and desirable for the community (visuals and verbal discussion) and will be open to all members of the community such as at a townhall meeting. A physical copy of the report will also be made available online and shared to community leaders to disperse as they see fit. The thesis will also be made available in the McBride Public Library and the Dunster museum for community accessibility.

4.5 Data Analysis and Storage

Notes and transcriptions from audio recordings of interviews and focus groups were analyzed using latent content analysis, which involves searching the data for underlying meanings as a form of coding (Dunn, 2021). Latent content analysis provokes a deeper analysis to the meanings of words or statements as well as what was explicitly stated. This method of analysis fit with the research objectives because it highlights the lived experiences of residents and bridges common experiences to determine the most prevalent issues.

All data was analyzed using the computer-aided qualitative data analysis software NVivo. Using a combination of inductive and deductive reasoning, I initially sorted data into predetermined themes identified from my research question before additional themes emerged during the coding process. My analysis was done over multiple rounds, during which data was reorganised and sorted as new themes were identified (Bingham & Witkowksy, 2022). After the initial analysis using my themes and sub-themes, the code list was amended based on what information was present in the data through inductive coding and which data needed to be

combined with other themes and deleted. In the next round of coding, I split into two groups; data that discussed water on the McBride Village water system, and data that discussed individual water licenses, due to the nature of responses from participants and differing answers and experiences. Throughout this process, additional sub-themes were created to address nuances throughout the data. The themes were ranked following the dominance demonstrated in the data, which was not only according to prevalence, but also perceived significance.

To ensure comfortability, trust, and rigour in the protection process, all data from interviews was encrypted and uploaded onto an external hard drive and uploaded onto encrypted online storage (Microsoft Onedrive). All participants were assigned a number in place of their name to protect those who chose to remain anonymous. All participant names and participant numbers were stored in a participant masters list which is kept in encrypted online storage. All data will be kept until after the publication period, where afterwards it will be destroyed to ensure anonymity among the community. All hand-written notes are stored in a binder and locked in an office at UNBC until after the publication process, where they will then be destroyed.

4.6 Researcher Positionality

Researcher positionality inherently contains politics, biases, and power imbalances (Rose, 1997). However, reflexivity and trustworthiness urge us as researchers to acknowledge these biases and our embedded ways of knowing rather than aiming to achieve objectivity. As feminist scholars Rose (1997) and Haraway (1988) identify, knowledge is shaped by specific experiences, environments, and circumstances; therefore, knowledge is situated and partial in perspective. It was imperative to do my best to understand my knowledge and introspectively reflect on its role among the large world setting.

I am a Canadian woman from Northern BC, who is of Swiss and Nordic descent. I have experience with the rural and northern context, as well as formal schooling, both of which form my knowledge system. I grew up on a small farm in rural Prince George and I was raised by a family that has always worked in resource extractive industries, so I do share many of the same perceptions of the northern context as well as lived northern experiences with the Robson Valley. Even with this commonality, it is important to remember that I remained an outsider among the research process. Addressing reflexivity and positionality as an outside researcher helps to situate knowledge (Rose, 1997). As a researcher it is important to take into account how my past experiences, education, and current situation shaped how I perceived responses to interview questions, while also accounting for the same process with research participants and how they perceive myself and the interview questions (Rose, 1997). Therefore, remaining transparent with residents that I am a student in the midst of learning, and also do not share the same fears or impacts from drought, helped to alleviate misinterpretations. Addressing my reflexivity also aided in understanding potential power imbalances, and the historical issues of institutional extractive research (Rose, 1997). Pulling from my experiences with horses, hay quality, backcountry hiking, and from growing up in an area that was under the jurisdiction of the RDFFG, I believe opened many doors in the research process. I was invited to go on multiple excursions due to my previous experiences. This included a trail ride up Lucille Mountain where casual conversation revealed concerns about changing landscapes and extractive practices, a fly-in helicopter trail maintenance trip on the Goat River Historic Trail where discussions of aging and concerns about passing responsibility and knowledge on to younger generations took place, and circle dancing evenings where locals shared intimate experiences, feelings of grief, and open arms.

4.7 Methodological Trustworthiness

4.7.2 Reliability

Reliability refers to the ability of a project to be replicable, the ability of a project to produce consistent results over time, and to what extent the findings are true. Reliability refers to the stability of the researcher's claim within an always-changing research context (Guion *et al*, 2011). While replicability is difficult to obtain in this qualitative, case study-based research, transparency was implemented to increase reliability. Transparency was achieved through comprehensive documentation of the data collection, analysis, and fieldwork process (Yin, 2009; Guion *et al.*, 2011). Additionally, participants checked their interviews and verified initial findings to increase the reliability of the research data (Stratford & Bradshaw, 2011).

4.7.3 Validity

Validity refers to whether the research measured what it was designed to and if the means of such measurement were precise (Golafshani, 2003; Guion *et al.*, 2011). Overall, Golafshani (2003) describes validity to be conceptualized by trustworthiness, rigour, and quality in the qualitative paradigm, and that achieving validity is affected from the researchers' perspective of aiming to eliminate bias. In this qualitative study, I (the researcher) was the primary data collector and analyzer, and therefore validity was a consistent conversation throughout the research process. Participant checking and data reviews by my supervisor and committee aided in enhancing validity in this research.

4.7.4 Rigour

As a qualitative researcher, there is great responsibility that comes with the interpretation of shared knowledge in a way that allows for the research to be evaluated, and that the research has been conducted reliably (Stratford & Bradshaw, 2021). Therefore, the first step in ensuring

rigour means establishing trustworthiness in the research (Stratford & Bradshaw, 2021). Stratford and Bradshaw (2021) outline numerous examples of establishing trustworthiness of a research process. First, documenting each stage of research is necessary so that it can be adequately checked by the community that is involved in the research process, and that participant or member checking, where the researcher returns their findings, transcripts, and other research outputs to the community so that they can validate the information, is evident in every-step of the process. When I returned to the community in September to October 2024, I summarized my initial findings in several community meetings as well as met with participants who wanted to review and revise their transcripts to ensure the data reflected what they wanted to share. Second, triangulation was implemented to enhance trustworthiness. Third, reflexivity, which is the critical self-review of one's researcher positionality and ethics, was utilized to ensure rigour. Member checking throughout the project, as well as writing in my personal journal how I felt and how I may have perceived information or conversations with participants, aided in establishing rigour. Additionally, writing into my field note journal about how I was taking in the information, the setting of the conversation, and critically reflecting on my own experiences when conducting research was another tool to ensure rigour

Chapter 5: Results

In both McBride and Dunster, shifts in weather and socio-economic conditions are impacting the lives of residents. The presentation of results in this chapter is structured by the vulnerability approach outlined by Ford and Smit (2004) and the Intergovernmental Panel on Climate Change (IPCC) (2017). First, the water system in the study area is described as a linked social-ecological system, after which factors affecting the water system are discussed, first environmental and then societal. The next section discusses how changes in the water system are impacting residents' lives and livelihoods. Lastly, what residents are doing to cope with, and in some instances, adapt to these changes are outlined, including a discussion of opportunities and barriers to adaptation.

5.1 McBride and Dunster Water Systems

While roughly 35 km apart, the municipal Village of McBride, surrounding properties outside of McBride, and Dunster are all dependent on a similar water system of predominantly gravity-fed water derived from snowpack melt in the high-alpine of the Cariboo and Rocky Mountains. Freshwater availability for the residents of McBride and Dunster comes from surface water (rivers and creeks with intakes) and groundwater (wells); however, surface water is more accessible as it does not require well-drilling, and the Robson Valley experiences fluctuating water table depths. The Fraser River contains freshwater, which is used for wildfire fighting, in some cases drinking water for livestock and irrigation, and even domestic use for some license holders for withdrawal, given its convenient location in the center of the Valley. However, it is seldom used for drinking water due to its turbidity and unreliability. The majority of private residents are dependent on surface water (i.e. creeks, rivers, streams) for their freshwater supply. These surface water sources in most cases are used for households (e.g. hygiene, drinking,

cooking), agriculture (e.g. livestock, crops, farms), fire protection, and garden/local growing purposes. Some private residents, who are located closer to the Valley bottom and along the Fraser River, are dependent on wells for their water source, or use a mix of both surface water and wells to meet their needs. The Village of McBride, including residential, commercial (e.g. restaurants, hotels), and Village infrastructure (e.g. fire department, museum, library), and activities get their freshwater from nearby Dominion Creek located at the Valley bottom near the Village. The Village of McBride is thus responsible for the storage, purification, and distribution of the water from Dominion Creek to multiple dwellings. Those who are supplied by what locals describe as "side creeks" hold water licenses on a creek, which grants them legal permission to take a certain supply of water (see Figures 5.1 and 5.2). The most common way to transport water from a side creek to a dwelling or property is through an intake that is often installed by the license holder and is diverted to a cistern or other storage tank on their property. License holders are responsible for maintaining their intake system and for identifying alternative sources of water if their supply is compromised, unlike residents who live within the McBride Village boundaries, where the Village is responsible for the water supply. In addition to the consumption of water in the residential, commercial, and Village sectors, the B.C. Wildfire service also draws on local water sources for wildfire suppression.

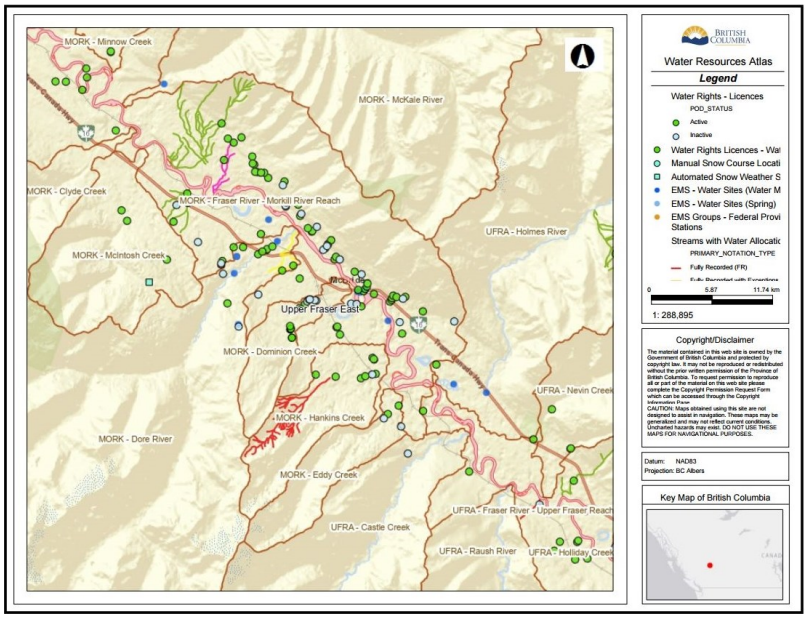

Figure 5.1: Map demonstrating where residents receive water (water rights licences) surrounding the Village of McBride. *Retrieved from the Government of B.C. (2025). B.C. Water Resource Atlas. https://maps.gov.bc.ca/ess/hm/wrbc/*

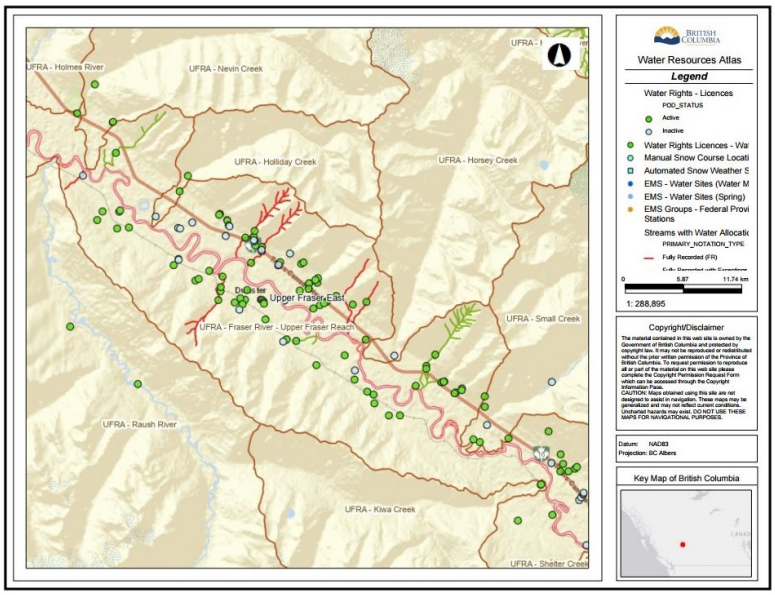

Figure 5.2: Map demonstrating where residents receive water (water rights licenses) surrounding the Dunster area. *Retrieved from the Government of B.C. (2025). B.C. Water Resource Atlas. https://maps.gov.bc.ca/ess/hm/wrbc/*

Much of the freshwater resources in the Robson Valley are fed by melting snowpack in the spring and summer. A 'healthy' snowpack is described by residents as a snowpack that can continue to provide a reliable water source for both ecosystems and humans, as well as reduce

wildfire risk, and support recreation. Snowpack not only insulates creeks and streams to prevent them from freezing, but snow also protects the ground, crops, gardens, and trees from freeze and frost damage. A 'healthy' snowpack also keeps the ground moist, mitigating severe wildfire conditions. Many residents also rely on the snowpack for recreational well-being and livelihoods, including snowmobiling tourism, skiing (i.e. downhill and cross-country), snowshoeing, and trapping.

5.2 Changing Environmental Conditions

During interviews and informal conversations, several participants shared that the fall freeze or "first killing frost" arrives much later in the fall over the past five years, and that the ground now remains frozen later into the spring. Other observed changes include a trend towards less precipitation, hotter temperatures in the summer months, and less snowfall throughout the winter season. Descriptions of these conditions over the past year correspond with the recent El Niño Oscillation of 2023-2024, contributing to the drought conditions throughout B.C. Some participants who are active hikers, trappers, and gardeners noted the disappearance of "permanent snowbanks" or "snow pillows" in the surrounding mountains. Majority of participants, namely farmers, noted an overall increase in the occurrence and severity of extreme weather events (see Table 5.1) like:

> "the worst thing that happened here was the heat dome of 2021. I think that started our apple trees on the steep decline. And two years ago, it rained into December and then got into 25 below right away and the trees split" (Archie Mclean, Dunster).

Residents are acutely exposed to drought as their water system is derived from snowpack melt in the Cariboo and Rocky Mountains. The Province of B.C. has been in a province wide drought since the Spring/Summer of 2022. In 2023, more than 80% of B.C.'s water basins were in drought level 4 or 5, including the Upper Fraser East Water Basin where the Robson Valley is

located. Additionally, the Upper Fraser East Water Basin at its lowest in May was only at 47% of its normal snowpack (Government of B.C., 2024). In addition to the limited snowpack in the alpine, a few participants identified overall changes in the amount of precipitation. The Robson Valley is characteristically a wet environment due to its close proximity to the inland temperate rainforest; however, in the last two years (2022-2024) there has not only been decreased snowfall and rainfall, which is likely a result of the El Niño Oscillation, but also what participants described as 'dry snow,' where the snow itself holds little moisture.

Observations of decreased snowpack began as early as the heat dome event of 2021, where rapid melting of mountain snowpacks caused flooding throughout the Valley and rerouted existing water channels. The summer of 2023 is when the water insecurity issues across the Robson Valley became prevalent for many individuals, and when the Village of McBride began enforcing restrictions on water use in the community. As one interviewee stated,

> "We didn't notice until the restrictions came on. I mean, we turn on the taps, there's always water and there was no reduction. There was no unavailability in certain periods, it was just all of a sudden one day that we got this news that it was a problem, which was not surprising, but it was well, it was surprising. It was surprising because again, we figured this would be one of the last places where this kind of thing would occur. But no, we didn't have any warning personally until the Village placed the restrictions." (Al Birnie, McBride)

The Village of McBride spent a total of 8 months in a state of local emergency, fluctuating between level 4 and 5 of drought conditions. May 17th of 2024 is when the water-use restrictions were lifted.

The onset of drought is characteristically a slow hazard, with dry conditions being experienced over several months if not years; but there are times of the year when the impacts of drought are more pronounced than others. Most participants noted that prior to the drought, access to fresh water was often a concern moving into September: the snowpack had been

melting throughout the summer, less precipitation limits snow accumulation in the mountains, and snowfall had not yet started. Participants noted that this period of the year when water was more scarce has been further exacerbated by drought conditions. Another time of the year when the availability of freshwater is stressed is during the cold months of January and February when it can be difficult to maintain the water system if something goes wrong, and there is a greater risk of creeks with decreased winter flow to freeze. Most recently, water availability was stressed during July and August of 2024 as the hot temperatures coupled with the decreased snowpack from the winter caused decreased streamflow throughout the summer.

Table 5.1: *Observed Environmental Changes*

Conditions	Description of Observed Change	Supporting Quote
Later Killing Frost	• Ability to grow gardens later into the fall – the first frost of the year arriving later in the year • Warmer August and September months	"it's early October or something, and we still hadn't had a killing frost last year. So, I mean, that's unusual. We used to have a killing frost in August" (Nancy Taylor, Dunster).
Decreased and inconsistent snowfall amounts	• Decreased snow in the Valley throughout the winter over the last two years, which is likely due to the cyclical Southern El Niño Oscillation. • Later snowfall in the mountains	"We generally get about two meters of snowfall, and the exception was last year, and the year before. Even when we got more snowfall, it was dry snow, it did not have any moisture in it. Sometimes it comes at varying times of the year, so the one thing that is noticeable in this geography is that its very inconsistent. We get lots of change" (Ray Thiessen, McBride).
Unpredictability of Climate	• Indicators of when to harvest no longer reliable	"If it is dry this time of year [May], usually it means look out for flooding, if creeks stop running you better start, but not now" (Dave Marsh, McBride).
Drier Conditions	• Drier ground • Drier forest • Less precipitation throughout the year and longer periods without rain, which	"Another thing that I really noticed is it's so dry in the bush, and there's so much deadfall. We live in the rainforest, but it doesn't seem like a rainforest anymore" (Nancy Taylor, Dunster).

	may be due to the Southern El Niño Oscillation • Hotter temperatures	
Increased Temperatures	• Hotter summers and winters. • Longer periods of increased temperatures	"You get some periods of 35 below. For more extended periods, but I think it was 35 below here for a couple of days, but the severe low temperatures abated quite significantly and the overall temperature in the winter is higher, you know, 10 or 15 below is as cold as its going to get most of the time" (Al Birnie, McBride).
Weather Extremes	• Heat dome events • Several days or weeks without precipitation during the Southern El Niño Oscillation • Intense snow or ice storms in the wintertime • Longer 'cold snaps' in the wintertime • Unpredictability in the climate	"One thing I've noticed is that the weather patterns seem to get stuck in one way for a long time. And then it will switch to another extreme and stay that way for a while. It used to be every few days, the weather kind of changed. So, if you had really cold weather, it would only last for a few days, and then it would mild up and that would only last for a few days, you know. Now, like last winter it stayed mild forever just about. We had one week of cold weather. And in May it was cloudy pretty much all the time" (Larry Stamm, Dunster).
Decreased Streamflow	• Low mountainside creeks and streams • Decreased availability of water on individual licensed intakes • Fraser river is lower than normal • Streams, creeks, and rivers did not rise with the typical spring freshet period	"This is the lowest I've ever seen it [creek]. I've been up a couple of times. And it was kind of scary before we had this week of rain. I thought, are we going to make it through the summer? And we've never had that issue before." (Bob Thompson, Dunster).
Receding Mountain Snowpacks	• Snowpacks that usually remain all year in the mountains have melted in the summer • Mountain snowpacks do not last as long into the summer as they used to, and do not start accumulating until later • Smaller snowpacks in the summer and winter	"You can't really see glaciers from my place, but you can see permanent snow banks. And some of those have certainly changed. And in fact, last year [June, 2023], on what is known as Big Belle [mountain in the Cariboo range], there wasn't even a sign of what we thought was a permanent snowbank. It was always there." (Bryan Munroe, McBride).

5.3 Societal Change

Residents are experiencing changes in society that are disrupting lives and livelihoods including, in some instances, the capacity to cope with environmental changes affecting the water system. Some societal changes are not unique to the Robson Valley, but are common struggles experienced by many rural communities in Northern B.C.— e.g. the centralization of many services, the turbulent nature of the natural resources industry, healthcare shortages, and land-use issues (Halseth *et al*., 2014).

5.3.1 Centralization

Participants shared in the last 20 years the dynamic of the community has completely changed. In 2003, the Robson Valley experienced shifts in forestry harvesting policies to process logs outside of the region in which they were harvested. As a result of these decisions, sawmills in McBride and Dunster closed, the Ministry of Forests moved out of the Valley and with it, government employees and their families, with impacts on schools, local businesses, and community dynamics.

> "...up until 2003, logs that were cut in the area had to be processed in that area. We lost all local mills and everything, just with a change of government, another stroke of the pen. We had 28 people working for the ministry of highways, and 40 in forestry. We had 400 kids in 1994 in the schools, dwindled to 100 after shutting down those ministries and the centralization of forestry. It really devastated the local population and economy. We had more entertainment and restaurants, the Elks club was strong. Shutting down those ministries affects everything; it changed the whole dynamic [of McBride]." (Darrell Roth, McBride)

Recent acts of centralization include the closure of the Scotiabank branch in McBride, the Village's only financial institution that also served the surrounding communities of Dome Creek, Crescent Spur, and Dunster. Participants also described the impacts of recent changes to the B.C. Vegetable Marketing Commission (BCVMC), the sole provincial instance regulator for the vegetable market: proposed that there must be an agent representing northern markets for anyone

who produces over 1 tonne/$5000 worth of produce, restricting the ability of northern growers to sell their produce. Participants described this as yet another example of how government bureaucracy is hindering their ability to make a living. The spring of 2024 brought more policy change to McBride when the Ministry of Forests made the decision to close the only access to the Renshaw, a popular snowmobiling area that is used by local recreationists and also attracts tourism in the winter. Many residents are concerned about the impact this closure will have on the tourism sector, especially with regards to job losses and decreased tourism revenue. The lack of snowpack the last two snowmobiling seasons has already impacted the local tourism industry, with snowmobiling pass sales dropping by 70%, ([Mark Froese] Personal Communication, June 6th, 2024) and the closing of the Renshaw is yet another blow to a struggling winter tourism sector.

5.3.2 Zombie Farms

Several farms that are located in the Agricultural Land Reserve (ALR) in Dunster and McBride have been sold far above asking price to absentee landowner(s), who many participants stated are left to sit empty. Approximately 25 farms in the area, many along the Fraser River, have been purchased and coined as “zombie farms” by locals due to the absence of any residents and minimal agricultural activity. Many of these properties were purchased before the land was listed on the public market, blocking any opportunities for locals to buy the farms, or for new and/or younger families to move into the Valley and begin farming. Majority of the participants in Dunster as well as other Dunster residents stated that the “zombie farms” have caused the erosion of the social fabric of the community. Participants described the feeling of isolation due to no longer having neighbours to rely on, especially as the population ages, and while coping with drought and other environmental pressures:

> "The biggest problem is they're buying lots of land, which is limiting up land that people could use and they haven't done much. They haven't done anything to interact with the community like being a positive influence. They haven't interacted at all. Matter of fact, they've been quite the opposite. The community would like people to own the land or be there so they could interact and bring something positive to the community. I don't think you can do anything legally, but they're looking at it. And there's some that are quite irate, quite angry." (Roy Howard, Dunster)

Residents are faced with limited options to legally address the commodification of farmland and expressed frustration with the number of livable homes that remain empty and unmaintained. Societal changes compound to make it difficult, if not impossible, for young people to make a living in the Valley:

> "We're all aging and this whole issue around land use that we've talked about, and about how young people can't settle here because there's nowhere for them to live. There's no land for them to buy that they can afford. If they get a mortgage, there's very few jobs they can work, to have steady work and secure employment so they can pay off a mortgage. I mean, it used to be that there were jobs in forestry that paid well. And there used to be jobs everywhere, in education and healthcare in the Valley, but the population has decreased. And so, we've lost a lot of those jobs. And it's just harder for young people to make it here. Most of the young farmers in Dunster, there's a handful of young families that are farming, they inherited their places, or they have been supported by elders that want to give them a chance, but to go and buy a farm for $700,000 or $800,000 and get a mortgage, like forget it. Not going to happen. It's too hard. It's too hard." (Nancy Taylor, Dunster)

5.4 Exposure-Sensitivities

This section discusses how environmental changes affecting the water system are impacting resident's lives and livelihoods. I describe what aspects of the human system are sensitive to decreased snowpack, drought, and reduced availability of freshwater.

5.4.1 Agriculture

Agriculture has been a steady and predominant industry in the Robson Valley for over 100 years (Wheeler, 2008). Agriculture in this region is dependent on snowmelt runoff or aquifers and springs, which are also dependent on snowmelt. The two-year drought period has caused multiple impacts to this sector. The decreased snowpack and consequently decreased

water availability increases the susceptibility of freezing creeks. When the creeks were running low, especially in the mid-winter months, there was not enough snow to insulate the creeks and prevent freezing during cold-snaps. When the creeks begin to develop ice, it diverts water out of its channel, where it will spread across the surface of the ground and will freeze, as a farmer shared, "I was worried the past year about finding money for alternative water supply. The water is frozen to the creek bed; with the low flow it's too easy to freeze up. We had very low water and we were worried it wouldn't sustain us" (Chris Roberts, McBride Farmer).

The decrease in water availability as well as lack of snow cover also negatively impacted the crops farmers were growing. Majority of the focus group participants stated that they were unable to practice irrigation techniques due to the lack of supply to battle the dry ground conditions. Additionally, the lack of spring moisture from precipitation and spring snowmelt also meant that the 2023 grow season was very dry. Several hay farmers specifically mentioned experiencing a poor crop that did not grow an adequate amount for both their own farm, and for selling. The dry ground also makes it difficult to plow fields, as the plow is unable to penetrate the ground adequately. The dry ground also results in large cracks in the field, and farmers are forced to use fertilizers and chemicals to ensure their crops survive. The lack of snow cover also damaged perennial crops and fruit trees due to the lack of insulation to mitigate damage from severe cold snaps, causing many farmers to either lose certain plants entirely, or have a poor harvest the following year, as expressed by a local farmer,

> "I used to sell a lot of hay in a year, but last year didn't sell, and this year I am not going to sell. But expenses are going up and I'm getting less hay. For as many acres as we have, we should have had a surplus of pasture, but it's too dry. We did not recover from the initial graze, so we were cutting into the winter feed in September instead of November" (Interviewee #29).

Two of the seven focus group participants own farms that are on the Dominion Creek water system, meaning that any restrictions put in place by the Village also applied to their farms, increasing the stress of water use. Several farmers experienced forced downsizing of their farms, as they were unable to grow the hay to feed their livestock. Therefore, several people resorted to selling some of their sheep and cows. The financial stress of agriculture due to drought is another experience of majority of the participants. Several participants are hesitant to plant seeds after spending thousands of dollars on them, because they are not sure there will be enough water to support the crop. Therefore, local farmers shared that many farmers in the Robson Valley are not planting their usual crops, and not generating their usual income.

Lastly, participants reported that they felt the effects of unpredictability in local weather patterns. Historically, many farmers, particularly hay farmers, plant seeds in the fall, they survive the winter due to snow cover, then are ready to grow come spring due to all the moisture from melt. Peak precipitation in the Robson Valley is in the middle of June, and a local farmer identified that "June 21st is when hay is at premium for food value" (Harold Edwards, McBride Farmer). However, drought conditions change typical harvesting times and patterns. One participant stated that unpredictability in weather and moisture is impacting their ability to teach 'newcomers' how to farm,

> "With the climate changing it is harder to predict the weather, harder to know when to cut hay. I am trying to pass on pieces of my land to young new farmers to work the land, but it is harder to pass on knowledge of how to do it when the environment is changing and no longer consistent" (Terri Jensen, McBride Farmer).

5.4.2 Gardens and Foraging

It is common for residents in both McBride and Dunster to grow their own gardens and harvest wild foods such as blueberries, huckleberries, thimbleberries, high bush cranberries, and various mushrooms. Private water license holders experienced significant impacts due to

snowpack changes and drought conditions in their area. Similar to what the farmers reported, freezing of surface water creeks and intake pipes also occurred, causing several participants to not have running water for several months. Consequently, this caused repairing the water intake to be quite labour intensive in the winter months to either dig out the channel, constantly move the water intake up the mountain to increase the flow rate, divert creeks, or haul freshwater. One participant described their experience with low-flow freeze, and its relation to snowpack,

> "This year the creek was so low in the winter it froze straight to the bottom and blew out the banks. The flow is still there even though the ice formed on the bottom and formed on the sides, constricted it, and then the water pushes on top of the ice and then does whatever it wants. So there is the potential if the water level is low, it could freeze to the bottom, especially on a year that we did not have much snow, which was the case this year. We had both low water and no snow cover to insulate the creek." (Rob Mercereau, Dunster and McBride).

A decrease in water availability in the growing season and snowpack protection was also a stressor that many participants faced. Majority of participants referred to the decrease in water availability and snowpack as a matter of food security. With the increased costs of groceries and the nature of rural living, many people depend on their own subsistence gardens to feed themselves, their families, and their neighbours – especially participants who live in Dunster, and do not have an easily accessible grocery store. However, participants on the Village of McBride water system also expressed their concern of food security. When the drought restrictions were placed in 2023, one of those restrictions included ceasing the watering of gardens. Many residents felt that this was an issue of food security, and felt frustrated by the Village's decision to do so as expressed by the following participants,

> "Do not tell a farming community that they can't grow food." (Interviewee ID# 25)

> "They basically said that there's no watering your garden at all. To not have that, it severely limits the food security potential of the Valley, and particularly the Village of McBride, and it just doesn't feel right to me." (Rob Mercereau, McBride and Dunster).

Wild foods were also impacted by the drought conditions. Locals identified a decrease in huckleberry and blueberry patches in the summer of 2023, especially in areas that have been reliable to have a sufficient harvest every year due to the hot and dry conditions. Participants also noted that beyond the impact to food security, barriers to growing food also impact the well-being of residents. Growing and sharing food is a way that residents care for each other, for instance, through having community harvest celebrations in Dunster, sharing food at the farmers' markets, and simply having neighbours over for dinner and trading different items if someone grew too much. The act of growing food is not only part of the health of the community but is a part of many participants' identity, as shared by one interviewee,

> "I garden but it's not my hobby. It is what I do. I try and grow as much as I can, so snowpack is important to me. Because if I can't grow my food than what do I have?" (Stephi Mclean, Dunster)

5.4.3 Fire Suppression

Both B.C. wildfire and residential fire services are dependent on local water sources to combat fires. The Village of McBride Fire Department uses water from the Dominion Creek water system to fight local fires; therefore, the drought impacted the amount of water they could allocate to a fire. The Fire Department and the Public Works Manager were required throughout the drought period and during restrictions to communicate and ensure that there was an adequate supply of water to fight a fire. However, the Public Works Manager and The Fire Department discussed the process of acceptable losses, where in some cases the focus is on protecting nearby structures rather than to put out a fire to ensure the efficacy of water use. This is dependent on the severity of the fire, as shared by an interviewee,

> "The Fire Chief and I work hand in hand. If there is a fire, his dispatch phones me immediately and we know exactly what we have for water. We know exactly when we're going to start running short. So, we communicate back and forth, but it's status quo until

> I tell them no, there's not enough water" (Brian Taphorn, Public Works Manager, Village of McBride)

Outside of the Village water system, many residents have small water holding ponds near their houses that they rely on for emergency fire protection, primarily in Dunster where there is no fire brigade. Residents experienced many of these ponds drying up with the decrease in stream flow of nearby water sources, and they did not have the water capacity to place water pumps in the nearby streams. The B.C. wildfire service also had trouble the past two fire seasons, as they were unable to obtain water with water bombers within the closest proximity to a wildfire. Instead, helicopters and trucks would need to travel farther to the Fraser River, or other large rivers ([Dave Hruby] Personal Communication, September 21st, 2023). Additionally, many participants found that the FireSmart sprinkler program that was implemented in 2023 by the RDFFG to mitigate fire stress has been greatly impacted by water availability. Many residents feel that they do not have enough water to operate the sprinklers, even with the looming threat of wildfires. The representative for FireSmart in the Robson Valley discussed the difficulty in implementing the sprinklers currently,

> "I know through my FireSmart that I've been doing, there's a lot of people that have sprinklers that haven't been able to set them up because they don't have the water supply to run them. They're still in a box in the garage or in the house. In the last couple of years, it's been so dry, and I was giving residents trouble because they are no good to you in the box. They said they could set them up, but there is not water to run them so it's just a waste of time." (Dave Hruby, McBride).

Water availability exacerbated the stress of other environmental hazards and has impacted the ability of residents to implement existing mitigation strategies.

5.4.5 Human Health and Well-Being

Drought and snowpack changes have also caused significant emotional stress to residents. Throughout the interviews, a few participants mentioned feelings of uncertainty, vulnerability,

and concern for future generations. Additionally, many participants have been struggling with the inability to engage in recreational activities that they normally would throughout the winter including snowmobiling, skiing, and snowshoeing. Many participants identified that getting outside and being active is important for their mental health, but the increased weather extremes and lack of snow has made it more difficult. For community seniors who still hope to enjoy recreation outdoors, it is imperative that the conditions are safe, such as a sturdy snowpack for skiing, roads free from black ice, and even walkways free from ice. However, with more rain-on-snow (ROS) events in the winter and consequent freezing, many elders stated that getting around in the winter is becoming more hazardous.

Many residents noted feelings of uncertainty for the future, not knowing what the long-term effects will be on their farms and their ability to continue to engage with the environment the same way. Other participants mentioned feeling helpless, that they feel compelled to do something about the changes they are witnessing but are unsure how. Additionally, other participants who work in hydropower and forestry feel vulnerable due to the uncertainty of their future industries. For instance, one interviewee spoke about which decisions to make now to ensure the health and longevity of the industry and environment in the future,

> "We've been talking about this because the community watershed has had a lot less volume than it has in the past. They almost ran out of water last winter, which has never happened before. So there has been lots of talk about things like if you clear cut, how does that affect snowpack and snowmelt? If you partial cut, how does that affect it? Or, if it's a big solid forest where the snow never reaches the ground, how does that affect it? How should the community forest try to help, and not mess things up completely and hurt it, or make it worse? (Craig Pryor, McBride Community Forest General Manager)

Because majority of the water that participants depend on is surface water, water quality is of concern. Residents identified several indicators of 'good' quality water: if the water is clean from bacteria and pollutants; if the water is clean from silt and turbidity; and if the water does

not have a strong mineral taste. However, several other participants identified that even though the chlorination system helps keep their water clean, that they do not prefer the taste of chlorine in their water. The Village of McBride has a history of contending with water quality mostly due to bacteria, E. coli, and turbidity. Many participants recalled several water boil advisories throughout their lifetimes, or being told to go to a community center to pick up potable water in the form of water jugs or plastic water bottles. However, the Village of McBride has continuously updated their water system and now uses a chlorination system to ensure the water is sanitary. The majority of study participants who are not on the Dominion Creek water system and rely on surface water creeks from their own water licenses do not have concerns for bacteria, silt, or minerals in their water. Many people do not filter or sanitize their water at all and claim that they have 'perfect' alpine water that they hold in very high regard. However, several participants expressed water quality concerns due to fire retardant over the years, as well as the lack of response from government officials, and lack of transparency from the companies that manufacture it. Some participants reported instances of their water 'fizzing' for a few weeks after fire retardant was sprayed above or near their water source, which sparked alarm throughout the community of whether it is safe to drink, cook with, or water their gardens with, which was shared by the following interviewees,

> "I had the most amazing water that I relied on everyday, and then after the retardant it was like I was holding poison. I understand why fire retardant is used, that might be what saved my house from burning, but I think it's important to understand what is in it, and what the effects are. I wanted to get my water tested, to ensure it was safe to drink. I called the fire retardant company, Perimeter Solutions, and he said "we told you what the primary ingredients are" and I said I need all ingredients because they will only test for the chemicals that I list, and he said "well, I can't give you that, they won't let me give you that" (Participant #25)

> "A lot of fire retardants have been used in the Valley, and there is no transparency about that. I've called them about that, and they say that the company has proprietary

> knowledge with their chemical formula that they're utilizing. But in the context of people's water systems, I think it is a real travesty that the information is not made public" (Rob Mercereau, McBride and Dunster)

5.5 Current Adaptive Strategies

Residents of the Robson Valley are not strangers to dry weather, heat events, wildfires, and drought stretches, according to many elders and stories from generational farmers. Many elders stated that strategies they were taught as children in the 40s, 50s, and 60s, to conserve and collect water such as rain barrels, 'toughing through it,' and only watering in the morning and night are the same strategies that they practice living in the Village of McBride today. However, the frequency and intensity of the dry periods, many participants stated, is different than what they have previously endured. Several residents and participants stated that the Fraser River was the lowest they had ever seen, and even drilling and digging for new wells is proving insufficient due to the inconsistent water table. There are a number of adaptive strategies that members of Dunster and McBride are currently undertaking for agriculture, subsistence, and well-being.

5.5.1 Water Conservation

Water conservation is the first strategy that many participants discussed to cope with drought and limited snowpack. The Village of McBride required residents on the Dominion Creek system to restrict water use, which entailed no watering of lawns, no washing vehicles, no filling pools/hot tubs, no washing driveways, no lawn and gardening sprinkling, no outdoor hand watering, and no drip irrigation. While there was no enforcement of the water restrictions, many of the participants abided by them as well as they could. Other participants on the Village system said they took additional measures to conserve water, including not running the tap while brushing their teeth, changed how they washed dishes, laundry, and took showers.

Participants outside of the Village water system, especially farmers, also practiced water conservation with many of the same strategies. Many farmers practiced soaking irrigation or drip irrigation (a hose with holes in it) to water but limit the amount of water being used. Other subsistence food growers described having reducers on water barrels to limit the amount of water being allotted into the water system at a given time. Another strategy that coincides with water conservation is using mulch, a type of ground cover such as straw, glass clippings, or straw to place around plants to hold moisture after they have been watered.

5.5.2 Water Storage

When water availability decreases, especially in the growing season, or water has high turbidity from spring melt runoff, participants reported finding alternatives for storing water. The most common, which many people had prior to the drought, is rain barrels. Many people fasten taps at the bottom of the barrels and set them below their eavestroughs to catch rainwater. This water is commonly used for watering gardens and is not potable for drinking. For potable water, many participants have water jugs that they fill with potable water and will store in/near their homes. Filling and hauling water jugs are quite labour intensive and requires several trips a week, and depending on the household and property needs, water hauling may be required every day. Large water totes of approximately 1000L are also commonly used for water storage, and some homes have two or three to store water. They cost approximately $150-$300 per tote and can be purchased to be 'food grade.' Several participants depend on the water totes for watering gardens, but many also use them for back-up domestic water use, including cooking, hygiene, and drinking. To fill these totes, many participants get water from friends or family throughout the Valley who are willing to share extra water they may have. However, many participants also pay to fill their totes. The costs range from $50-$150 to fill a large tote, and around $100-$250

for 3600 gallons. McBride local and owner of Robson Valley Septic and Water Hauling, Darrell Roth (a McBride participant), noticed a gap in the ability of locals to obtain water for gardening and other services after the Village of McBride water restrictions began. Darrell obtained a water license for the Fraser River, which cost approximately $1000. With his already existing equipment to haul water, and in conjunction with Home Hardware and a water tank company from Edmonton, Robson Valley Septic and Water Hauling then filled people's water totes with non-potable Fraser River water for their crops.

5.5.3 Retention Ponds and Dug-Outs

In addition to water tanks and rain barrels, other participants, namely in the agricultural sector, also rely on lined retention ponds for watering gardens, as well as dug-outs for livestock. Several participants began digging dug-outs, which are usually large and sometimes narrow ponds that collect water from which livestock can drink. Sometimes the water from dug-outs can be pumped out for larger crops. Many participants required the use of machinery to dig large dug-outs or make existing dug-outs deeper, and with less debris. Other participants who had not physically dug for increased water retention stated that they were considering it.

The Village of McBride Fire Department also had concerns with water availability. To cope with the limited volume of water in Dominion Creek, the Village purchased a 20,000-gallon tank to hold extra water in case Dominion Creek is unable to supply enough water to fight fires. The now retired Fire Chief, Dave Hruby, stated that in his 43 years as Fire Chief in McBride, he has never worried about water supply until the recent drought. Now, the Fire Department is focused on the diversification of water sources, as they cannot drain the Dominion Creek source beyond a certain level otherwise the system may become waterlogged, and the pressure in the tank may stop it from working.

5.5.4 Well Drilling

Drilling wells is a coping strategy that both the Village of McBride and other properties, mostly in the ALR, are employing to find more water. In February of 2024, the Village of McBride drilled two test wells to try and find water, which unfortunately came up empty (Brian Taphorn, Village of McBride). Other participants are resorting to well drilling either due to no longer having a reliable surface water source, or due to having concerns about the longevity of their surface water source. There has been a range of well depths from 300 feet to over 500 feet, which is costly, and water is not guaranteed because "McBride and Dunster area are clay based from approximately 900 meters elevation and down" (Craig Pryor, McBride Community Forest General Manager), allowing for changing water table depths.

5.5.5 Water Licenses

Legally, all people require water licenses to be able to have rights to take water from stream and groundwater. A water license allows people to be able to legally divert, store and use water for their specific needs, and to ensure that the water is being used efficiently and equitably (Government of B.C., 2024). Additionally, a few participants said the motivation to obtain a water license is because of the protection of the water source it can offer. When asked about the cost and maintenance of a water source and license, a participant stated,

> "it is worth whatever we have to pay for it because then we can have a say on what happens on our water system. So if they're logging we can say to them "this is our water source" so they will look after it" (Archie Mclean, Dunster).

Other participants stated that having a water license on a source, especially in areas with high natural resource extraction, can make you a stakeholder in decisions that happen in the surrounding area. Additionally, some participants stated that they are looking into other licenses

including placer licenses to have as much say over what happens around their water source as possible.

5.5.6 Social Cohesion

Many participants described relying on relationships and sharing networks to cope with environmental changes and with drought. This includes sharing water, even though almost everyone struggled with supply, sharing farming equipment and skills, helping neighbours evacuate during the 2023 and 2024 wildfires and offering evacuees places to stay, sharing food, and emotional support for fears about the future with regards to weather extremes. One interviewee provides insight into the support system in the Robson Valley,

> "Every property around here has some crops that do better than others. And there is a lot of bartering that goes on. Neighbours will come over sometimes and pick raspberries, we will have more raspberries than we can eat. So, they will come over and help themselves to that and they will bring over some kind of plants or vegetables that we didn't get this year. Some years you don't have onions, but your neighbor has a ton, and we have a ton of garlic so we will share. It is very much like a family, like a real old-fashioned community. That's just the way of it. If we ran out of water and our neighbors had some, they would give us some." (Bob Thompson, Dunster)

Seniors in the community discussed that over the years, social capital and working together as a community has been what protects people in the Robson Valley. Social capital is creating social assets, which include levels of trust and the ability to organize for collective action (Markey *et al*., 2008). Several participants shared multiple stories about working with other residents to help clear a road after a landslide, help protect homes in a flood, help fight wildfires, and help harvest hay when conditions allow. According to one interviewee,

> "I have a relationship with the Mennonites. So, I worked their land with their equipment when it was time to harvest hay and they needed help, and in exchange they gave me hay. Because with the drought I was unable to supply enough for my farm. Without that relationship I would have had to downsize*"* (Drazen Bucan, Dunster Farmer).

When asked about strengths within their community, participants from both Dunster and McBride described the relationships amongst each other as being the biggest community strength. Almost every participant identified how the community can pull together in times of crisis, even if in between crises there is community divergence in many facets. Another prevalent strength is the plethora of local knowledge within the mountain environment. Many residents of McBride and Dunster are second or third generation farmers and have experience with natural hazards such as flooding, avalanches, landslides, and wildfires. Additionally, there are many skills such as being able to operate heavy machinery and owning heavy equipment and farm equipment that are applicable to living in this mountain environment. Livelihood activities and hobbies, as well as needing to maintain their own water systems cause many residents to have a certain intimacy with the snowpack, water systems, and mountains, as expressed by the following interviewee,

> "It all depends on snow, really. And for us, it's very direct. We know exactly where the water comes from. But it's a different thing for people who live in the city. They don't look up at their water source on a daily basis, it just comes" (Stefi McLean, Dunster).

Many of the female participants spoke about passing on knowledge about farming, food, and water systems to other young women who were new to the Valley. Many of these same participants said that these skills and networks between women is what helped maintain community cohesion and are skills that are used today to navigate the changing environment and drought conditions. In Dunster, many women speak to the back-to-the-land movement in the 1960s and 1970s, where many families moved to the Valley, especially Dunster, yet were missing the knowledge on how to survive there. They called this the lives of the Dunster women, where other women taught newcomers how to milk cows, what food to grow, and how to harvest food.

5.6 Barriers to Adaptation

There are several barriers identified that make it more difficult to cope with and adapt to changes in the environment. The primary barriers that participants described are government policies, finances, location on a water system, and preference of water. The following section identifies not only barriers to coping with snowpack and water system changes, but also factors that either do, or could, make it easier to navigate them.

5.6.1 Governance

Majority of participants described that with the changes in government and the centralization of services, it has become increasingly difficult to find support from government, and that there is a lack of transparency and lack of consultation before decision-making at the provincial, regional, and community level that profoundly impacts rural industries and livelihoods in the Valley. Participants described that with the decrease in water availability, it is incredibly difficult to obtain a new or additional water license for a different water source, impacting water security. Many residents have resorted to taking water from friends and family, and there have been instances where residents obtain water from other sources without a license.

Participants also discussed that due to centralization, there are no longer government officials in the community that have a context or understanding of the way of life in the Valley, and how to navigate the surrounding environment. Locals expressed frustration that they will be given instructions or answers that are not conducive to fixing their water system, and that no one ever comes to the Valley to look at people's water systems before telling them what to do. Many solutions are prescriptive without consultation, falling short of meeting the needs of locals. Additionally, many participants spoke about tight regulations, making it difficult or impossible to repair or change one's own water system in a timely manner. A few participants stated that many

environmental regulations are too severe, and limit the ability of farmers, especially, to sustain themselves, as expressed by an interviewee,

> "They [provincial decision-makers] just complicate things. It's the people that are trying to officiate it [snow and water] that don't know what they are doing, that don't have an understanding or even compassion for the people that are trying to look after it and manage it. They turn their tap on in the city and figure everybody's water is that easy to get, but it doesn't work that way out here…They all have a job, but what about the rest of us that need to make a living? They're not taking that into consideration, the bigger centers don't. A lot of those people don't realize that if we don't work out here and supply them with wood and with beef and with grain and with vegetables, two days in the cities and no trucks coming in, there's no food on the shelves there." (Ron Weslon, McBride Farmer)

Many participants stated that federal and/or provincial government support would make it easier to deal with drought, but that government support needs to be done in a way where they are consistently interacting with residents and listening and responding to their needs instead of prescribing solutions from a different point of understanding.

5.6.2 Financial Barriers

The cost of a water license application is a minimum of $250, with an annual payment that ranges from $50-$150 depending on the amount of water that license holder requires, and often more for agricultural or hydroelectric use. According to the Government of B.C., B.C. owns all water in the province on behalf of its residents (Government of B.C., 2024). In addition to the primary water license costs, many participants required a secondary water source to meet their needs, which was often storing water in tanks. However, participants described that many residents face economic constraints to cope with drought. Many participants stated that after purchasing the tank, it costs them approximately $150 per fill for a 200-gallon tank on top of already paying their regular water licenses, and that it is still non-potable Fraser River water. While storing water in tanks is a coping strategy that almost every participant is doing, many participants also emphasized the difficulty in sanitizing water jugs, and that it is often not-

preferred water that they resort to using. Additionally, if participants would like to store water for fire protection or to anticipate dry weather, they have to purchase a water pump which can be expensive and requires skills to use. Some residents that were unable to obtain sufficient water volume from surface water sources resorted to well-drilling. The cost of well-drilling across participants and the Village ranged from $40,000 to $60,000 not including ground water licenses. Additionally, some participants discussed that they would like to have efficient grey water systems, better fire protection, or other back-up water systems but are unable to due to financial restriction.

5.6.3 Location

The location of a resident on a water system can impact their ability to cope with drought and snowpack change. Water insecurity is often heightened for participants who are the 'last' on the creek towards the middle of the valley. This is because the higher up the mountain a stream or creek is, the steeper it is and thus the channel is more defined, and the rate of flow is increased. Additionally, certain amounts of surface water will naturally leach into the ground. Once the surface water runs to the last 'user' on the water system, especially if there are several farms or large gardens who are using it, there is often decreased availability. These factors in combination with low-flow freezing, lack of precipitation, and fire protection stress have caused many participants at the bottom of a stream to lose water, shared by an interviewee,

> "It is a combination of everything, one being the last person on the list, and then two being the furthest away from the source because the ground absorbs a certain amount of the water. The loss into the ground isn't a big deal when we have regular flow levels, but when there is a low flow then that loss is a big deal. That's why there is water up there [other water users farther up the same creek] but none down here, because it is another 300 yards to get here, and then there is the regular leaching loss" (Drazen Bucan, Dunster Farmer).

It is not only the location on a specific water source that can increase vulnerability to change. Many participants identified that while having a water license on an independent water source from the Village increases the freedom to use the water in a way that meets their own needs, and not having restrictions, maintaining an independent source is a lot of work. Many of the residents in rural McBride and Dunster are aging, and as discussed above, there are not enough young people moving into the Valley with skills to maintain water systems, operate equipment, or to help the aging rural population. Several participants identified that while lack of water is difficult for everybody, it is especially tolling on the seniors in the community.

5.7 Adaptation Planning

There are several adaptation initiatives that the Village of McBride, and surrounding residents have been instating. In addition to trying to drill for wells, the Village of McBride and the McBride Community Forest are in the process of expanding the size of the current water reservoir to store more water in case of a drought emergency. The plan is to increase the storage by 10 times, so that there will be enough water to provide the Village for 5 days of regular usage, if Dominion Creek were to run dry. The Village of McBride will then purchase and truck water from Valemount until they find an alternative source. However, the Village is still waiting on the provincial government to grant permission to begin construction on expanding the reservoir. Additionally, the Village of McBride received $146,000 in provincial funding for an alternate water source feasibility study on October 2nd, 2024. The funding comes from a Disaster Risk Reduction-Climate Adaptation stream of the Community Emergency Preparedness Fund, a grant funded by B.C.

Some participants that work in the agricultural sector spoke about transitioning to drought resistant crops, and growing blend crops that grow with minimal water. Additionally, one

participant mentioned that the transition from growing hay to growing a specific cover crop blend has helped to retain moisture in the soil. Lastly, bale grazing is another practice that many farmers have adapted to, where hay bales are set in a grid pattern. The cows eat, move, and defecate around the bale(s), then the pattern moves throughout the fields, never having the cows eat in the same spot. It is a cost-effective method of fertilizing the fields and decreasing dependency on chemical fertilizer.

Chapter 6: Discussion

The general scientific consensus is that since the 1950s mountain snowpacks in North America have significantly declined and these changes can affect water security for downstream communities and ecosystems (Beniston & Stoffel, 2014; Environment and Climate Change Canada, n.d.; Hock *et al.,* 2019; Wang *et al.,* 2023). As the Earth's climate continues to warm due to human-caused climate change, these changes are expected to continue and even exacerbate in the future (Beniston & Stoffel, 2014; Hock *et al.,* 2019; Wang *et al.,* 2023). The findings of this research support this broad understanding and give new insights into the human consequences of changing mountain snowpack through the lived experiences of people living in the Robson Valley, B.C. At the onset of this research in 2023, we knew that the Village of McBride was experiencing drought conditions from a decreased mountain snowpack and quickly learned that the situation was not unique to McBride but extended throughout the upper Valley. The findings showed that not only were water sources compromised for human use by snowpack changes, which is commonly represented in the literature, but other stresses including centralization, policy changes, and 'zombie farms' in conjunction with these environmental changes are drastically impacting the well-being and adaptive capacity of Dunster and McBride. This project is unique from the dominant literature in B.C. mountain spaces due to the focus on the lived experiences of Robson Valley residents.

6.1 Changing Mountain Snowpack and Water Availability

The Robson Valley has recently experienced rapid shifts in local weather, including unpredictability of the climate, overall drier conditions, a later killing frost, increased weather extremes, increased temperatures, decreased precipitation, drought, and decreased snowpack, and these shifts are not surprising given recorded climate change trends and timing of the El Niño

Southern Oscillation (ENSO) (Meyn *et al*., 2010; Young *et al.,* 2010). Historical data shows that the Valley has experienced drought and decreased snowpack in previous El Niño seasons. The Robson Valley Courier reported the winter of 1982-1983 to be noteworthy as the Robson Valley experienced near-record mild temperatures, as well as other parts of western Canada (What Happened to our Winter?, 1983). While seasonal weather in the Valley is known to be variable (e.g. Yusa *et al*., 2015), the severity and duration of the changes being experienced today are outside the normal operating environment for most residents. Recent instrumental measurements confirm that the low stream flows and decreased precipitation are unique to the last 100 years of record keeping, permanent snowbanks have disappeared for the first time, and the fastest spring snowpack melt on record was in May 2022 (Government of British Columbia, n.d.).

It was to be expected that decreased water availability would affect human activities in the Valley, including agriculture and animal husbandry. Much has been written about the effects of changing mountain snowpacks on human and environmental health including food security, agricultural industry, and sanitation (Huss *et al*., 2017; Shea *et al*., 2021; Stewart, 2008). However, this research showed that there are many nuanced impacts of climate change in the Robson Valley, such as impacts from lack of snow cover on crops and wild foods, and freezing of low-flow water sources. Farmers in the Valley have depended on reliable environmental indicators to grow and harvest food crops and hay in what is normally considered a 'wet' region due to high precipitation and substantial mountain snowpack. The changes being experienced today are challenging conventional farming knowledge and practices, raising the question of *"if and how farmers will adapt to longer-term changes?"* Questions of knowledge transmission were apparent among farmers, who were concerned that younger generations would not learn how to farm due to repeated poor growing seasons, and thought that their knowledge might not

be applicable to new climatic conditions. Similar concerns have been documented elsewhere in the context of climate change impacts and subsistence harvesting (Pearce *et al*., 2010; Pearce *et al*., 2018; Willox *et al*., 2012).

Decreased water availability has implications for wildfire suppression in the Valley, not only with regards to increasingly dry conditions ecologically, but also the quantity of water available for fire suppression. Other research has discussed the relationship between drought and wildfire, mostly from an ecological perspective (Hessl *et al*., 2004; Littell *et al*., 2016; Riley *et al*., 2013) with less attention given to wildfire suppression capabilities. While wildfire suppression is not the focus of this research, it is a future research question that should be investigated to uncover the connection between snowpack change, water availability, and wildfire risk.

6.2 Social and Political Pressures

The capacity to adapt to changes in water availability were hindered by politically driven socio-economic policies and procedures. The centralization of government and industry in Northern B.C. has eroded local capacities and resources (Halseth & Booth, 2003; Halseth *et al*., 2014; Markey *et al*., 2008). Additionally, residents spoke about the exodus of knowledge and skills due to the centralization of services and decision-making. Due to this relocation of power, decisions are made without consultation of Northern B.C. communities. These changes have manifested through the Robson Valley as proposed changes in the BCVMC, 'zombie farms,' and the lack of local accessibility to branches of government.

The closure of local sawmills and government offices, and the centralization of health care services led to the exodus of many skilled individuals and their families, according to residents. The exodus of these families and skills have impacted local capacity to cope with changes in

water availability, for example, the loss of government officials in the community causing a loss of contextual understanding about water security issues in the Robson Valley. Additionally, many individuals who worked for the Ministry of Forests, or who worked for local sawmills and had heavy equipment operating skills left the Robson Valley, decreasing the amount of people to not only aid in repairing water systems, but also in hazard response. The region also saw the loss of fire-fighting equipment with the closure of the Ministry of Forests office in McBride, shrinking the local capacity to fight wildfire.

The Robson Valley is known as an agricultural region, but provincial government policies are making it difficult, if not impossible, for some farmers to get their produce to market. The BC Vegetable Marketing Commission (BCVMC) has proposed a policy that requires an agent to represent northern markets for anyone who produces over 1 tonne/$5000 worth of produce. However, this policy does not meet the needs or fit the model of produce production in the north. This policy impacts agricultural activities in the region that have already been impacted by decreased water availability. While factors such as inflation, rural living, and low-income have been shown to impact food security in Canada, B.C. has experienced increased food insecurity due to provincial level social policy changes before (Li *et al.,* 2016; Tarasuk *et al.,* 2019).

As of the Fall of 2024, the BCVMC has opted to delay the implementation of the agent expansion until January 1st of 2026, as well as increase consultation during that time (Popple, 2024). It is unfortunate that the consultation process did not take place prior to push-back and concerns from the community. However, this provides an opportunity for northern growers to establish a northern marketing agency to continue to keep the cost of licensing at an affordable rate, as well as create space for conversations surrounding food security, climate change, and policies in Northern B.C. There have been connections made between the Robson Valley and

other Northern communities around Prince George. This research demonstrates the urgent need for increased consultation by the provincial government in rural regions, increased competency of rural regions by larger urban centers to mitigate harmful policy integration, and a mitigation of unhelpful responses by government officials when rural communities are faced with climate challenges exacerbated by sweeping provincial-wide policies.

The rise of absentee land ownership, or 'zombie farms' are an additional cause for concern, as they alter community and agricultural dynamics. Residents stated that absentee land ownership is impacting the social fabric of the community and contributing to feelings of isolation due to no longer having close-by neighbours in the face of snowpack and water changes. There is limited literature on absentee land ownership. In the literature on Saskatchewan farmland, however, several scholars discuss similar experiences to that of the farmers in the Robson Valley, including complicated legal options, degradation of local trust, impacts to local food security and sovereignty, and disintegration of community values (Cotula, 2012; Desmarais *et al*., 2017; Edelman, 2013). The experience of feeling isolated and without neighbours in a usually close community is a significant result because it shapes community capacity to adapt to environmental changes, due to the decreased ability to depend on neighbours in crisis. This finding is not reflected in the literature, demonstrating a gap in our understanding of how the increase of absentee land ownership will impact climate change adaptability in the future.

The absent land owner(s) literature predominantly focuses on the relationship between rural poverty, food price volatility, and overall, placing the power of land sovereignty in the hands of financial actors at the expense of local farmers and rural communities (Desmarais *et al*., 2017; Gunnoe, 2014). The Robson Valley is unique as the communities' concerns are not centered on

the use of farmland, rather the potential for loss of local connection and community health. However, residents shared that it is difficult to pursue legal action. Therefore, the implementation of a 'land sovereignty' framework outlined by Borras and Franco (2012) into progressive land politics discourse to aid in informing local resistance to land grabbing may be a tangible approach. This framework is defined as "the right of working peoples to have effective access to, use of, and control over land and the benefits of its use and occupation, where land is understood as a resource, territory, and landscape" (Borras & Franco, 2012. P. 6). This framework highlights values that the several residents of the western portion of the Robson Valley identified, including the deeply intimate connection between livelihoods, identity, and nature. Residents shared that the loss of social cohesion directly impacts their capacity to respond to changing conditions in the environment. For example, residents rely on their neighbours for water if their source becomes compromised, but with the exodus of many families from the Valley leaving farmland sitting empty, there are less people to rely on, and less available water sources.

It is unsurprising that financial constraints and being located at the bottom of a water system presents barriers to adaptation, as experienced in other mountain regions (Archie, 2013). It is also unsurprising that changes in governance and centralization of services in Northern B.C. pose as one of the largest constraints to adaptation, as noted by residents and participants. Residents are constrained in their ability to obtain a water license on additional water sources if their own were to become compromised, due to the restrictive and untimely nature of water license applications. Centralization has caused many residents to speak to decision-makers no longer having a baseline understanding of water systems work in the Robson Valley, or the history of self-determination and resiliency to changes. Instead, residents are obliged to follow the long

bureaucratic process of obtaining permission to alter their water source, when facing an issue that instead requires immediate action. Barriers presented by governance in drought adaptation have been presented widely in the United States, however, this issue is novel with regards to drought and snowpack changes in B.C. (Sullivan *et al*., 2019).

In addition to difficulty in obtaining information or water licenses, residents discuss lasting impacts from changes in industry, which are often done with lack of consultation beforehand, and lack of support after. This result is unsurprising, and while not directly related to water, has been reported on extensively (Halseth & Booth, 2003; Halseth *et al*., 2014; Markey *et al*., 2008). Many residents also found that environmental regulations are too severe and are designed with limited knowledge of the Robson Valley. The BCVMC, 'zombie farms', and the centralization of services, while all different, they all can be attributed to changes in policy that directly impacts not only adaptive efforts, but resiliency as well.

Similar issues of government interference are evident in the literature, providing examples of policies that undermine long-term resilience, and restrict the ability of rural communities to innovate and change within the system as it exists (Adger *et al*., 2011; Sidle *et al*., 2013). In the Robson Valley, these instances of policies inhibiting the adaptive capacity of communities are evident in the industrial changes, pressures on the food and water systems, and pressures on tourism. For example, the Renshaw snowmobiling area was closed in January 2024 without community consultation when the access bridges were decommissioned by the Ministry of Forests. The Renshaw snowmobile area brings significant income into the McBride area, and with the decrease in forestry and lack of other industries in the area, provided an economic base in tourism. The closure now forces the community to face another sudden change in economic reliability without consultation on how best to cope with the change. The impacts that decreased

snowpack has on snowmobiling tourism in mountain areas is not included in the literature, as most studies explore the impacts of climate change on resort skiing (Steiger *et al*., 2022). Therefore, this issue requires further research with respect to how both policy changes and climate change impact snowmobiling tourism in mountain regions.

6.3 Resiliency and Adaptability

The above issues impact residents on an individual scale. Similar feelings of uncertainty for the future of agriculture, local industry, and community health and feelings of helplessness have been found across multiple regions facing climate change (Clayton, 2020; Pearce *et al*., 2009). Residents are adapting to changes in water availability by drilling wells, digging retention ponds, obtaining new water licenses, and increasing water storage. The ability to adapt is often underpinned by social networks, including sharing food and water with neighbours, sharing farming equipment and skills, and providing places to stay in the face of a wildfire evacuation. Residents have also demonstrated adaptability to these factors through social strengths, ingenuity, and knowledge gained through working in this region. Many of the adaptive initiatives by residents and the Village of McBride were centered around increasing water storage both in tanks and through dug-outs, as well as drilling wells. These methods appear in the literature and are practiced globally to help cope with water insecurity (Young *et al*., 2010).

Social cohesion and local knowledge are imperative community strengths that aided McBride and Dunster in their adaptation initiatives. Sharing networks and strong social cohesion is common in communities coping with environmental changes (Skinner *et al*., 2014), especially given the remote location and isolated nature of the Robson Valley. Social capital and volunteerism are part of the Robson Valley's social cohesion, a common characteristic of rural

communities as they are often dependent on services being volunteer based to be able to meet the needs of the community (Halseth & Ryser, 2007; Joseph & Skinner, 2012; Skinner *et al*., 2014).

Having local knowledge that is specific to the region is another unsurprising adaptive tool on which the Robson Valley depends. According to literature, local knowledge not only helps provide a baseline for understanding environmental changes, but also provides skills to help with mountain geohazards, and other climate-related disasters (Berkes *et al*., 2000; Berkes, 2009; Sidle *et al*., 2013; Taylor & de Loe, 2012; Van der Molen, 2018). Many locals shared not only stories of their experiences helping the community in the face of landslides, avalanches, and wildfire, but also how their local perceptions differed from the provincial or governmental responders. This is a significant finding because it shows the need to provide more consultation, and collaborative work with rural mountain communities in B.C. where geohazards are part of their lived experience. While this strategy is being seen more in wildfire suppression and response (Whitehead, 2023), more work is needed to understand how to best support a mountain community facing these changes by working with their integral and intimate place-based knowledge, rather than a prescriptive response. However, it is not just knowledge on how to endure natural hazard events that is passed down through generations, but skills on how to grow food, store water, catch water and use it appropriately for agriculture, and how to care for livestock. Additionally, the passing of knowledge through generations is not only imperative for one's individual health and success in mountain environments, but is also an important part of community health, relationships amongst women, and social cohesion, which is unsurprising and seen both in the Robson Valley and across the literature (Adger, 2003; Berkes, 2009; Taylor & de Loe, 2012; Townshend *et al*., 2014; Van der Molen, 2018).

Chapter 7: Conclusion

The aim of this thesis was to characterize the vulnerability of a mountain community's water system to changing snowpack and other climatic and non-climatic stressors through a case study of the Robson Valley, B.C. This involved: 1) understanding elements of the local water system as a social-ecological system; 2) documenting the ways in which changing snowpack and other climatic and non-climatic stressors affect the water system and security; 3) documenting current adaptive strategies employed to cope with or manage stressors affecting the water system; 4) identifying barriers and opportunities to enhancing adaptive capacity and reducing vulnerabilities in the water system. This was accomplished through discussions and interviews with residents in McBride and Dunster and the surrounding area who are dependent on municipal water services and individual water licenses for their freshwater needs. This thesis showcases how physical changes in the environment affect human lives and livelihoods, and the forces which condition who is sensitive, in which ways and how, and their capacity to adapt. It does so by drawing upon the lived experiences of some people living in the Valley and who are representative of the broader population.

Changes in mountain snowpack in the Robson Valley have negatively impacted freshwater availability with a range of impacts on the lives and livelihoods of residents. Observed declines in mountain snowpack volume over the last 75 years (Environment and Climate Change Canada, n.d.; Hock *et al.,* 2019) and in particular in the last three years have resulted in low water flow levels in the spring and subsequently less water in the municipal reservoir and area streams. These changes have resulted in increased forest fire risk, drier ground conditions, and decreased plant health, and less fresh water for residents, with a host of impacts on human health and well-being and the local economy.

Social capital and cohesion are central to the capacity of residents to adapt to changing mountain snowpack and water systems. Rural communities in Northern B.C. are reliant on social capital and cohesion to cope with limited services and to support general well-being. Many residents also identified that these same networks are needed in the face of mountain hazards, including drought, because local knowledge, skills, and social networks are the only reliable sources of adaptation. Additionally, many residents who have extensive experience in forestry, logging, and trapping hold unique knowledge about the mountain environments, and often have access to capital resources such as heavy machinery, water pumps, and hoses, that are needed to suppress wildfires. Climate change adaptation initiatives must go beyond addressing direct climate change impacts to include fostering efforts to strengthen social capital and cohesion, which inadvertently enhances the capacity of the community to deal with current and potential future climate risks.

Government policies of centralization have led to outmigration of local skills, knowledge, and services from the Robson Valley and other northern communities, which are critical sources of adaptive capacity. For example, residents must speak to representatives from the Government of B.C. or commute to Prince George to apply for a water license, leaving many residents feeling that decision makers do not have a local understanding of the area, and therefore are unable to provide adequate support when struggling with water issues. The lack of consultation before changing policies (the BCVMC, closure of Scotiabank branch) have also proven to be frustrating for residents of the Valley, depleting place-based services and undermining local food security. Overall, the results showed how sweeping provincial policies have hindered the abilities of northern and rural residents, and in the Robson Valley, these policies have altered the ability of locals to adapt to snowpack and water changes.

The results show that research on vulnerability and adaptive strategies to changing snowpack and water systems revealed more than stresses from lack of precipitation. This research highlighted the interconnected relationship between a farming community and water, the incredible, resilient nature of mountain communities dependent on snowmelt, and the intimate knowledge and skills acquired through generations of farming, logging, trapping, and backcountry activities. This research also highlights the complicated relationship between rural communities in a province that has undergone sweeping centralization that has shaped the vulnerability of the Valley today. The Robson Valley provides a local story of the greater global issue of climate change, and the lived experiences of the residents of McBride and Dunster provide valuable knowledge to address and adapt to changing mountain environments.

7.1 Practical Contributions

There are several practical contributions that can be derived from this research. ***First,*** the research shares the importance of a bottom-up approach to vulnerability assessments in order to identify and support adaptation initiatives at the community level. ***Second,*** this research can be included in community, regional, and provincial decision-making with regards to climate change policies and hazard risk, as well as understanding how policies created in urban centers impact rural communities. ***Third,*** this research can be used by industries including wildfire suppression and agriculture to better understand climate change impacts and vulnerabilities, and potential sources of adaptation. ***Finally,*** residents of the Robson Valley can use the findings to bring attention to the urgency of changing mountain snowpacks and freshwater availability. In doing so, residents can reinforce to government, the consequences that centralization have had on the capacity of the communities to manage climate change and lobby for a greater role in climate change planning.

7.2 Scholarly Contributions

The findings of this research expand the current scholarly narrative of climate change impacts, vulnerability, and adaptation in the Robson Valley, and in mountain areas elsewhere, to include the role of human agency in the face of change. This is the first research to be conducted on vulnerability to changing snowpack and water availability in the Robson Valley and in a rural mountain community in B.C. The research also contributes to our understanding of the role of multiple stressors in climate change adaptation research and points to the importance of addressing non-climatic factors in enhancing capacity to deal with climate change.

7.3 Future Research Opportunities

The research raises some important questions: *how have drought conditions affected wildfire suppression efforts? How has decreased spring run-off affected hydroelectric power generation? What are the short-term and long-term effects of fire retardant on environment and human health? How is food security impacted by changing climatic conditions? How can we better support ageing rural populations? How can we retain adequate healthcare and education in communities in transition?* After the 2024 wildfire season, it became apparent that more research is needed to understand how wildfire risk in the Robson Valley will change in the future, given projections of decreased winter precipitation and increased temperatures, and how decreased water availability could affect fire suppression. Some residents mentioned being concerned about water availability to source private hydropower projects that the provincial government sources from in the Robson Valley. While hydropower was out of the scope of this research project, future research opportunities investigating projected impacts could benefit the entire Province of British Columbia, as it is heavily dependent on hydropower for energy. The Robson Valley would also benefit from research that focuses specifically on agriculture and food

security in a changing climate. Several residents expressed concern for growing ability, drought conditions, and damage to crops from lack of snow cover. A more focused project that assesses vulnerability and adaptive capacity as well as identifying nature-based solutions to adapt to changing environmental conditions with regards to agriculture would be beneficial. Lastly, residents expressed concerns about the use of fire retardant on surrounding forests, and the implications of these chemicals to water security, vegetation health, and river run-off. The Valley would benefit from research on these uses and impacts, as well as transparency of use.

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Appendix 1: Interview Guide

Community Vulnerability to Changing Snowpacks and Water Systems in the Robson Valley, British Columbia, Canada

The following is a set of questions about perceived water security and changes to the water system in the Spring/Summer of 2024. Because it is a semi-structured interview, the responses are expected to be open-ended, and we may ask additional but related questions as part of probing or following up on what our respondents may say. The interview should take about an hour.

This part of the interview generates some basic information about individual and household economics and income, dependents, and other relevant information.

Sociodemographic Questions for Both Interviews and Focus Groups			
1.	ID# Interview #		
2.	Gender		
3.	Age		
4.	Education		
5.	Occupation		
6.	Marital Status		

7.	# Children		
8.	# Children at home		
9.	Do you own property?	**(Y/N)**	
10.	How long have you lived in The Robson Valley		
11.	Do you engage in any hobbies/livelihood activities in the Robson Valley?		

Semi-Structured Interview Guide

1. Where do you get your water from? Can you show me on this map? Do others in your area also receive water from this source?
2. Do you have concerns about your water supply? What is your biggest concern affecting your water supply?
3. Have you seen changes in the snowpack? What do you think is causing these changes to your water system?
4. What do you consider to be good water?
5. Do you have any concerns about your ability to access water? If so, what is affecting your ability to access water?
6. How long have you dealt with water issues?

7. Is the water issue always a problem or are there certain times of the year when it is a larger problem? Can you tell me more about that?
8. Have you dealt with these issues in the past? And if so, how?

Snowball Sampling: If there is anyone else you think I should talk to, please give them my contact information and tell them to reach out at anytime if they would like to chat.

Appendix 2: Focus Group Guide

Activity

1. Participatory Mapping – place a map of the Valley, including local water systems, to identify water insecurity and/or other hazard risks.

Questions

1. Where do you get your water from? Can you show me on this map? Do others in your area also receive water from this source?
2. What is your biggest concern affecting your water supply?
3. Have you seen changes in the snowpack? What do you think is causing these changes to your water system?
4. What do you consider to be good water?
5. If so, what is affecting your ability to access water?
6. How long have you dealt with water issues?
7. Is the water issue always a problem or are there certain times of the year when it is a larger problem? Can you tell me more about that?
8. Have you dealt with these issues in the past? And if so, how?

Snowball Sampling: If there is anyone else you think I should talk to, please give them my contact information and tell them to reach out at anytime if they would like to chat.

Appendix 3: List of Interviewees

List of Interviewees in the Robson Valley

Interviewee #	Name	Gender (M/F)	Age Category	Residing Community
1	Andy Keim	M	Senior (75+)	McBride
2	Dave Marsh	M	Senior (75+)	McBride
3	Ray Thiessen	M	Senior (55-74)	McBride
4	Bob Thompson	M	Senior (55-74)	Dunster
5	Glenda Thompson	F	Senior (55-74)	Dunster
6	Dave Hruby (Focus Group and Interview)	M	Senior (75+)	McBride
7	Bryan Monroe	M	Senior (55-74)	McBride
8	Mark Froese (Focus Group)	M	N/D	McBride
9	Aeron Williamson (Focus Group)	F	Adult (35-54)	McBride
10	Ron Weslon (Focus Group)	M	Adult (35-54)	McBride
11	Jackie Edwards (Focus Group and Interview)	F	Senior (55-74)	McBride
12	Chris Roberts (Focus Group)	M	N/D	McBride
13	Aaron Ford (Focus Group)	M	Adult (35-54)	McBride
14	Richard Chambers	M	Senior (75+)	Dunster
15	Petra Herstikova	F	Adult (35-54)	Dunster
16	Nancy Taylor	F	Senior (75+)	Dunster
17	Larry Stamm	M	Senior (55-74)	Dunster
18	Pete Amyooney	M	Senior (75+)	Dunster
19	Harold Edwards	M	Senior (75+)	McBride
20	Archie Mclean	M	Senior (75+)	Dunster
21	Stefi Mclean	F	Senior (75+)	Dunster
22	Jill Howard	F	Senior (75+)	Dunster
23	Roy Howard	M	Senior (75+)	Dunster
24	Al Birnie	M	Senior (75+)	McBride
25	Anonymous	F	Senior (55-74)	McBride
26	Anonymous	F	Senior (75+)	McBride
27	Rob Mercereau	M	Adult (35-54)	McBride/Dunster
28	Ingrid Heise	F	Senior (55-74)	McBride
29	Anonymous	M	Young Adult (18-34)	McBride

30	Terri Jensen	F	Adult (35-54)	McBride
31	John Wheeler	M	Senior (55-74)	Grand Forks
32	Brian Taphorn	M	Senior (55-74)	McBride
33	Craig Pryor	M	Adult (35-54)	McBride
34	Drazen Bucan	M	Senior (55-74)	Dunster
35	Barbera Jackson	F	Senior (75+)	McBride
36	Michael Jackson	M	Senior (75+)	McBride
37	Darrell Roth	M	Senior (55-74)	McBride

Appendix 4: Information Letter and Consent Form

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

Information Letter / Consent Form

Community Vulnerability to Changing Snowpacks and Water Systems in the Robson Valley, British Columbia, Canada

Who is Conducting the Study?

Mackenzie Ostberg
MA Student in Natural Resources and Environmental Studies, UNBC
University of Northern British Columbia
Prince George, BC V2N 4Z9
Ostberg@unbc.ca
250-981-4113

Supervisor: Dr. Tristan Pearce
250-960-5766
Tristan.Pearce@unbc.ca

Project Sponsor

This research project is funded by the Pacific Institute for Climate Solutions (PICS) as part of the PICS Opportunity Grant that seeks to address Community Resilience and Adaptation to Changing Mountain Snowpacks and Geohazards in the Robson Valley, British Columbia.
https://pics.uvic.ca/

Purpose of Project

This research project is for a Master of Arts thesis, that aims to understand how the Robson Valley is vulnerable to changing snowpack and water systems, specifically drought and how the community understands this hazard. The goal of the research is to understand both current and

future vulnerabilities to hazards, while also investigating avenues for adaptive potential and resilience building. The research question is to characterize the vulnerability of a mountain community's water system to changing snowpack and other climatic and non-climatic stressors through a case study of the village of McBride, Robson Valley, BC, Canada.

Invitation Statement

We invite you to participate in this research study. Anyone over the age of 16 who has lived in the Robson Valley for at least one year and is proficient in communicating in English is invited to participate. Your contact information was either sourced from the Regional District or the Village of McBride, or, from contact with Mackenzie directly. You are being asked to participate due to your experience living in the Robson Valley, this project is appreciative of your time and commitment to this study.

What Will Happen During the Project?

The interview will be conducted by Mackenzie Ostberg, and will include a participatory mapping activity where research participants are able to show on a map their areas of concern in their environment. The interview will consist of a series of questions that focus on the following themes;

- role in the community and involvement in planning for drought and subsequent hazards
- your perceptions of drought risk to yourself and your community
- in what ways drought would affect you personally and your community.
- Your role in drought management
- Your opinions for what can or should be done to enhance resilience at the community level.

Your opinions for what can or should be done to enhance resilience at the community level.

The interview will be conducted in English in person at the McBride Museum. Mackenzie will take notes throughout the interview, and if your consent is given, will also use an audio recording device to for data collection. The interview includes a participatory mapping activity, where the participant is asked to draw on a map of the local area where they get their water from as well as other regions of significance to the participant. All researchers will have signed a confidentiality agreement to ensure that your information is kept confidential unless you give permission to

share it. You have the right to withdraw consent and request anonymity at any point before, during and after the interview, up until the point of publication

Depending on the first interview, you may be re-contacted for a follow up interview to clarify any information from the first interview. The follow-up interview should not take longer than 30 minutes. The maximum amount of time the interview will take is 60 minutes. This study also requests participants to validate their transcripts and the interview data which will take a maximum of 60 minutes. The total amount of time required to participate in this study is 3 hours, and the last point in the year you will be contacted from the interviewer is the Fall of 2024.

Risks to Participating in the Project

While answering some of the questions during the interview you may be asked to envision and discuss a potentially traumatic scenario (i.e stress from drought or other catastrophic natural hazards), which may bring up strong emotions. This is more likely if you have been exposed to similar events in the past. You can stop the interview, skip a question, or withdraw your participation at any time without giving a reason or any consequences.

In the unlikely case of data privacy being breached or released, there may be risk that other in the community may disagree with your opinions on certain questions. To avoid this risk, it is best to share only what you would feel comfortable sharing in a public setting.

If you require support after the interview, please reach out to the following services;

Robson Valley Community Services
250-569-2266
https://robsonvalleycommunityservices.org/

For Immediate Help in Northern BC Through Northern Health
Mental Health Support at 310-6789
For Feelings of Distress or Despair;
1-800-784-2433

McBride and District Hospital and Health Centre
250-569-2251

www.northernhealth.ca

Benefits to Participating in the Project

Your contribution to this study will help generate information to guide community adaptation to drought and natural mountain hazards in the Robson Valley and potentially other rural communities in BC. Some of your ideas and suggestions may be highlighted (with attribution if requested) in outputs from this research including community presentations and academic literature.

Confidentiality and Anonymity

If you choose to keep your identity confidential, all personal identifiers (your name, for example) will be removed from the data and replaced with a code (random letters and numbers). This will connect to a master list that will be stored separately from the information you provide in the interview. All data, including confidential information in the master list, will only be accessed by the research team members (Mackenzie Ostberg and Tristan Pearce).

The research team will keep your identity confidential and will not connect it to anything you say unless you give permission to do so. Your identity will remain confidential to the extent allowed by law. The researcher has a duty to report to authorities any information about a child at risk of abuse under Child Protection laws in British Columbia. The researcher may be required by subpoena (required by government or a court as evidence) to release information gathered during this project.

Data Management

During the project, the master list of confidential personal identifiers will be stored on the research teams' encrypted computers and external hard-drives. At the end of the project the confidential list linking your information to your personal identifiers will be deleted. All data (voice recordings or interview transcripts, and personal identifiers you don't want kept confidential) will be stored on the research teams' encrypted laptop computers, encrypted external hard-drives and encrypted cloud storage until the end of the project, and on Mackenzie Ostberg's encrypted external hard drive for up to 5 years. These computers and external hard-

drives are locked and encrypted to make sure that all data remains secure. Finally, because of the size of your community, if the interview is taking place at your workplace or other public location there is a chance that others in the community may know that you have participated or are connected to this study.

Study Results

Research findings will be shared in the community through a plain-language summary report and community presentation. If there are other study result dissemination methods that you would prefer, please let Mackenzie know during the interview process. The findings will also be prepared as a manuscript and submitted to a peer-reviewed journal. Aggregate data (overall key themes and findings) will be reported in research findings. However, some direct quotations may also be used to highlight key points. Your own direct quotations will only be used if you give permission to use them. If one of your direct quotations is used, names or other information that may identify you will only be included if you give consent to use your name in connection with the information you provide.

Questions, Concerns or Complaints about the project

If you have any questions about what we are asking of you, you are free to contact Dr. Tristan Pearce or Mackenzie Ostberg at the phone number(s) and/or email(s) listed above. If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the UNBC Office of Research at 250-960-6735 or by e-mail at reb@unbc.ca.

Participant Consent and Withdrawal

You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time up until the project report is completed without giving a reason and without any negative impact to you. If you choose to withdraw from the study your information will be withdrawn and securely destroyed.

Consent:

I have read or been described the information presented in the information letter about the project and I have been given a copy of this form.

YES NO

I have had the opportunity to ask questions about my involvement in this project and to receive additional details I requested.

YES NO

I understand that if I agree to participate in this project, I may withdraw from the project at any time up until the publication process, without giving a reason and with no consequences.

YES NO

I agree to be recorded.

YES NO

I agree that my name can be used in association with this project.

YES NO

I give permission for direct quotations that I give to be used in publications/research findings.

YES NO

As a part of this study, the research team may seek to re-contact and/or re-visit you in order to review and clarify your responses. The research team will also return to the community at some point to go through interpretations of the responses, and the research findings.

Do you give your permission to be re-contacted and/or re-visited by the research team in order to review and clarify your interview data, and to go over the results of the study?

YES NO

Signature: _____ Date: _____

NAME (please print): _____

Appendix 5: Timeline

Date	Activities
April 2024	- Preparing for fieldwork and coordinating with McBride for my arrival - Finalizing fieldwork safety plan - Finalizing interview questions, fieldwork protocol, and consent forms
May to July 2024	- Fieldwork in the Robson Valley from May 4th to June 15th - Work on establishing relationships with the community - Complete fieldwork notes, journal entries, and safely store any audio recordings - Conduct both semi-structured and focus group interviews
July – September 2024	- Begin analyzing data from interviews and fieldnotes - Begin utilizing NVivo for latent content analysis - Return end of August/early September to conduct more interviews if needed, present progress, and request any follow-up questions or address any gaps in data
October 2024	- Share preliminary findings with the Robson Valley Communities - Conduct member checking interviews to ensure research is reflective of the communities needs and desires - Begin knowledge transfer process
November 2024	- Formal dissemination of findings - Include any additional input from community into the results section of the thesis
December 2024-March 2025	- Write-up of final discussion and conclusion - Revise any other sections of the thesis

	- Return to the community periodically to visit or participate in any community activities
May 2025	- Defend research to UNBC - Submit Dissertation
May 2025 - Onwards	- Prepare Manuscripts

Appendix 6: Budget

Expense	Estimated Cost	Details
Fuel	$500	Estimation for driving to and from the Robson Valley at beginning, middle, and end of the field season. As well as travel to farms and other regions in the Valley.
Accommodation	$2500	Cost of accommodation for $60/night for 6 weeks.
Food	$1000	Estimated cost of groceries/eating locally for 6 weeks.
Miscellaneous Interview Costs	$70	Estimated cost of coffee, snacks, etc. for focus group interviews.
Total	**$4000**	

Appendix 7: Ethics Approval Form

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

May 24, 2024

Ms. Mackenzie Osterg
Dr. Tristan Pearce
c/o University of Northern British Columbia
Faculty of Environment\Geography, Earth and Environmental Sciences

Dear Ms. Osterg and Dr. Pearce,

File No: 6009506
Project Title: Community Vulnerability to Changing Snowpacks and Water Systems in the Robson Valley, British Columbia, Canada
Approval Date: May 24, 2024
Expiry Date: May 23, 2025

Thank you for submitting the above-noted proposal to the Research Ethics Board ("REB"). Your project has been approved.

We are pleased to issue approval for a period of twelve months from the date of this letter. To continue your proposed research beyond May 23, 2025, you must submit an Annual Renewal and Study Progress form at least one month prior to that date. If your research has been completed before the form is due, please submit a Study Closure form in order to close the REB file.

Throughout the duration of this REB approval, all requests for amendments and renewals, or reporting of unanticipated problems, must be submitted to the REB via the Research Portal.

Please refer to the Chair Bulletins found on the REB webpage for updates on in-person interactions with participants during the COVID-19 pandemic.

If you have any questions or encounter any problems when working in the Research Portal, please contact the REB by email to reb@unbc.ca.

Good luck with your research.

Sincerely,

Dr. Neil Hanlon, Chair,
Research Ethics Board

Appendix 8: Ethical Conduct for Research Involving Humans

PANEL ON RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE 2022

Certificate of Completion

This document certifies that

Mackenzie Ostberg

successfully completed the Course on Research Ethics based on the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2: CORE 2022)

Certificate # 0000926215 **2 December, 2023**