When clean energy is dirty: A geospatial analysis of Canadian hydroelectric dams constructed between 1981 and 2011 and demographic indicators of environmental marginalization

By

Emma I. Taniguchi

Submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Environmental Science

At

Dalhousie University
Halifax, Nova Scotia
August 2022

Supervisors: Drs. Amy Mui & Michelle Adams

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The increasing urgency for climate action has pushed several governments towards investments in long-term, renewable energy sources. With its abundant supply of freshwater rivers, Canada's shift away from oil and gas-generated power has been wholly successful, with almost 80% of all power generation in Canada attributed to hydroelectricity. However, trends in dam placement show a disproportionate number of Indigenous and other marginalized communities displaced or otherwise impacted by the environmental devastation caused by reservoir filling and interrupted water flow. A geospatial regression was conducted on sixteen hydropower dams constructed between the years 1981 and 2011 across Canada to determine if there is a significant spatial trend in constructing hydro projects disproportionately within disadvantaged minority communities. The demographic variables were chosen to align with the Canadian Marginalization Index (CMI), and describe ethnic minority and Indigenous population, dependency, education, and unstable housing. Each variable was applied to the dam location using the most recent census year prior to construction. A generalized linear regression (GLR) conducted in ArcGIS Pro determines if there is a significant relationship between demography in census subdivisions (CSDs) containing dams to those surrounding the dam site. Subdivision areas pre-dating the year 1991 returned inconsistent data due to the large variation in census subdivision size and population. Of the 16 dams analyzed, five returned statistically significant results demonstrating factors representing both higher and lower marginalization factors in dam site areas as compared to those surrounding, depending on the model. Indigenous population dynamics around dam sites return varied outputs, but results are consistent with hydro development political timelines that reveal patterns of historical ignorance to Indigenous land claims and treaty rights. Conversely, dam sites across Canada tend to be in rural and "unorganized" subdivisions, many of which have populations too small for collection or are designated "non-response" zones. These areas contribute largely to the unknowns surrounding community dynamics in the areas, and although the results give indication of the determining factors, finer study areas and more consistent rural data is required to obtain a more representative picture of marginalization in these areas. While lack of demographic data for rural areas of Canada and census years prior to 1981 is a hurdle to this research, greater efforts must occur to ensure the steps we are taking to address climate action do not come at the expense of our most vulnerable communities.

KEYWORDS: Geospatial analysis, Indigenous, Hydroelectricity, Census of Canada, Marginalization index

LIST OF ABBREVIATIONS

IPCC	Intergovernmental Panel on Climate Change
GIS	Geographic Information Systems
PCB	Polychlorinated biphenyls
EJM	The Environmental Justice Movement
CAN-Marg	The Canadian Marginalization Index
EIA	Environmental Impact Assessment
JBNQA	The James Bay and Northern Quebec Agreement
GLM	Generalized Linear Model
GLR	Generalized Linear Regression
OLS	Ordinary Least Squares
GWR	Geographic Weighted Regression
GRanD	Global Reservoir and Dams Database
CSD	Census Subdivision
UTM	Universal Trans Mercator
NAD83	North American Datum 1983
DA	Dissemination Area
VIF	Variance Inflation Factor
AIC	Akaike Information Criterion
EA	Enumeration Area

ACKNOWLEDGEMENTS

First and foremost, I would like to acknowledge that Dalhousie University is located in Mi’kma’ki, the ancestral and unceded territory of the Mi’kmaq. This thesis was conducted with the poignancy of this statement in mind, especially with the emphasis of reconciliation in Canada and the lack of steps currently being taken to right the historical wrongdoings against Indigenous people in the country. We are all treaty people.

I would like to thank my wonderful supervisors, Drs. Amy Mui and Michelle Adams for their diverse experiences and uniquely helpful inputs to the multifaceted nature of this research. For Michelle’s continued support and extensive knowledge of the challenges of Canadian energy development, and for Amy’s comprehensive background in geographic information science and many long sessions with me in the lab, I am eternally grateful.

I would also like to extend my gratitude to Dr. Chris Greene for his experience in analysis on GIS and taking the time to review options most appropriate to my study. His input has allowed for the inclusion of the complex demographic factors comprising the marginalization index and helped my research evolve into a compound analysis of community dynamics and environmental injustice.

A special and poignant thank you to Julie Marcoux for her patience and continued assistance with census data retrieval, operation tutorials on the Canadian Census Analyzer, and broad knowledge of census rules and suppression notices. Julie’s input to this study ensured appropriate scope and access to all data available. This research would not have been nearly as thorough without her contribution.

Lastly, I would like to extend my thanks to the Natural Sciences and Engineering Research Council of Canada (NSERC) and their partnership with Dalhousie for allowing me the honour to participate in the Leaders in Energy Sustainability Program. The opportunity to learn about the development of green energy in the country contributed greatly to my knowledge about the alternatives to hydropower in Canada. The summer research award I was granted allowed for a devotion to this study and an attention to detail that would not have been possible without their support.

CHAPTER I - INTRODUCTION

Over the past several years, climate scientists have observed that the rise in global temperature can been attributed to anthropogenic activity (Hegerl et al. 2007, p. 727; Lovejoy et al. 2016; Stocker et al. 2014). According to the 2013 report from the Intergovernmental Panel on Climate Change (IPCC), 78% of atmospheric carbon was attributed to fossil fuel combustion and industrial activities from the years 2000 to 2010 (Stocker et al. 2014). According to these data, a change in the methods of global energy production is necessary to reduce reliance on fossil fuels and mitigate the warming of global temperature.

As of 2018, 59.6% of energy generation (Terawatt Hours) across Canada is attributed to hydroelectricity, as in the renewable process of generating power by harnessing the energy of a river as it flows through a dam (Government of Canada, 2018). However, many have observed a global trend of developing hydroelectric dam infrastructure on or nearing the borders of Indigenous, non-white, or otherwise marginalized communities (Baird et al. 2021; Pérez-Rincón, Vargas-Morales & Martinez-Alier, 2019; Vélez Torres, 2012). Despite the climate change mitigation benefits, hydroelectric dams are also known to pose threats to biodiversity and human health due to the land cover change and flooding they inevitably cause (Winemiller et al. 2016). While the issue has been studied in several countries (Aung et al., 2021; Baird et al. 2021; Cooke et al., 2017; Ledec & Quintero, 2003; Pérez-Rincón, Vargas-Morales & Martinez-Alier, 2019; Vélez Torres, 2012; Winemiller et al., 2016), there has been little to no significant research that examines this kind of trend in Canada. In this paper, the examination of community demographics surrounding hydroelectric dam sites in Canada using geospatial techniques will elicit a deeper understanding of the factors influencing dam placement.

The debate of the pros and cons of hydroelectric dams has been long-standing for several years with many strong arguments present on both sides. Hydroelectricity is known for being a very economical choice in terms of power generation, offering a relatively inexpensive form of energy to citizens, especially so in cities or other locations with large populations (Ledec & Quintero, 2003). It is also considered by some to be an environmentally responsible choice in terms of power generation, as it is a renewable source of energy and uses fewer carbon-based resources for construction and operation (Meng et al., 2020). However, hydroelectricity has also been criticized for its destructive nature; the dam effectively changes the land cover of a significant area via flooding and river fragmentation, impacting biodiversity and displacing, or otherwise impacting, nearby human populations (Ledec & Quintero, 2003; Zarfl et al., 2014).

Freshwater systems typically impacted by dams are also an essential part of maintaining ecology and local habitats of the areas they run through; they are also heavily depended on for numerous human activities (Aung et al., 2021; Baird et al., 2021; Ledec & Quintero, 2003). Large rivers are often taken advantage of for the abundance of flowing freshwater for drinking, but also as a convenient site for the development of agriculture and fisheries (Aung et al., 2021). In addition, large rivers are essential for commercial viability, as they connect nations to one another and allow for the transport of goods and services (Ansar et al., 2014; Aung et al. 2021). The construction of a hydroelectric dam interrupts the flow of the river, creating an upstream reservoir coupled with the inundation of water on the adjacent lands, and receding and slowing of the downstream flow (Ansar et al., 2014, Ledec & Quintero, 2003).

The subsequent reservoir poses a plethora of potential threats to the surrounding human communities. As the land surrounding the dam becomes flooded, people living in the area are forced to leave and re-settle elsewhere (Ledec & Quintero, 2003). In addition, the water quality of the river is subject to deterioration due to the stagnant nature of the reservoir, creating an anoxic, decaying environment that can lead to the leaching of pollutants from the now-flooded geological formations (Baird et al., 2021; Ledec & Quintero; Meng et al., 2020). This area can also become a health risk, as the shallow and warm reservoir can be a breeding pond for infectious, water-borne diseases and insects that spread quickly and easily, especially in densely populated areas (Ledec & Quintero, 2003). It can also create optimal growth conditions for toxic blue-green algae (Baird et al., 2021).

Downstream, a similar problem regarding water quality is present, as the stagnant water from the reservoir is what is released into the downstream flow (Baird et al., 2021). The flow of the water through the dam is now subject to operator control and is only turned on during specific times for energy generation, which, in many dam operations, creates inconsistency in flow and subsequently accelerates erosion and disrupts sediment transportation downstream (Baird et al., 2021). Furthermore, river fragmentation and dam implementation disrupt fish migration and reproduction patterns (Carter, 2013). For communities depending on fish stocks for their livelihood, this is a severe issue.

Traditionally, Indigenous people have relied more heavily on the land for sustenance and cultural practice and are therefore at greater risk of suffering the negative impacts from hydroelectric dam development and operation (Cooke et al., 2017). Dating back to the 1960s, there have been recognized violations of Canada's treaty rights associated with dam construction, resulting in mass displacement and destruction of Indigenous land (Sheehan, 2020). A recognizable pattern has emerged with hydroelectric dams being disproportionately placed in proximity to Indigenous populations as compared to other communities in Canada (Carver, 2013; Sheehan, 2020; Willow, 2020). One possible explanation for this is environmental injustice, a phenomenon wherein government and industry will locate environmental inconveniences (i.e., landfills, recycling plants, dams, etc.) in or around a marginalized community because they do not have the resources to oppose it (Shultz et al., 2020; Vaz, Anthony & McHenry, 2017).

Notably, environmental injustice is not limited to Indigenous communities. Those most impacted by ecological inequalities are racial or cultural minorities, immigrants, and those suffering from poverty or without access to education (Pellow & Vazin, 2019; Pérez-Rincón, Vargas-Morales & Martinez-Alier, 2019). Historically, those with middle to upper-class status or people who seem to benefit from “white privilege” (the advantages that people with white skin have in society due to its roots in racial injustice (Sullivan, 2017)) have not been subjugated to the threat of environmental hazards in their communities, subjecting a disproportionate number of marginalized communities to the environmental grievances that they cannot afford to avoid (Mascharenhas, 2012, p. 81).

Currently, there are many studies that weigh the benefits and drawbacks of hydroelectric energy generation as a renewable power source and several case studies regarding Indigenous impact post-construction (Aung et al., 2021; Baird et al., 2021; Cooke et al., 2017; Ledec & Quintero, 2003; Sheehan, 2020; Willow, 2020). Despite many studies identifying the pattern of dam site construction around Indigenous communities, there is a noticeable gap in the realm of spatial analyses which would provide measurable geospatial indicators of these trends. Many articles outline the impacts and offer constructive feedback to mitigate potential environmental and social harm moving forward with hydroelectric projects, but none assess the distribution of marginalized communities surrounding dam sites in more than a summary (Ansar et al., 2014; Carver, 2013; Ledec & Quintero, 2003; Stocker et al., 2014). The research to be presented in this thesis will therefore be classified as a pilot study, given there is nothing evident in the literature that outlines any similar project.

The outcome of this work will offer a novel perspective on the correlation between hydroelectric dam sites and marginalized community location using geospatial analysis. The research objectives are to first assess marginalization factors of communities and then compare the results to the proximity of dam sites. With these data, a regression analysis will be applied using geospatial software to determine if there is statistical significance in the marginalization factors in areas containing reservoirs as compared to those surrounding. This research will investigate if the spatial distribution of specific community demographics are being preferentially selected for dam site construction.

Chapter 2 provides a further overview of the existing literature that relates to the general topics of this study. It delves into the history of hydroelectricity in Canada and provides overviews of the positive and negative effects and efficiency of hydropower as a renewable resource. It also reviews the literature surrounding the topic of environmental justice and hydroelectric dams, including trends in marginalized and Indigenous communities as well as an overview of environmental injustice as a topic. It reviews geospatial methods of analysis utilized in studies relating to region-based analysis between demography and physical structures. Finally, it discusses the pertinence of this study by addressing gaps in the literature.

The methodology outlined in Chapter 3 provides a more in-depth overview of how Canadian census data is used to identify community dynamics of census subdivisions surrounding dam sites in the census year prior to dam construction. Key factors of marginalization are determined and applied based on the Canadian Marginalization Index (CAN-Marg) (Matheson et al., 2012). The scope of the study is restricted to dams constructed after the year 1980 due to limitations in the lack of availability and usefulness of census data prior to that year. Mapping techniques are applied to identify geospatial relationships between the census subdivisions and dam sites; the regression analysis determines if there is spatial significance in location. By identifying any spatial patterns in terms of community dynamics surrounding the dam sites, this research gives headway to future studies that will be able to examine possible reasons for why this is, and similar investigations in other countries.

Chapter 4 presents the results of the study in a series of tables and figures, outlining the non-spatial outputs of marginalization proxy variables and the map outputs of running the spatial regression. Significant patterns and trends are outlined in the text and all notable outputs are described. Chapter 5 provides an interpretation of the results as they relate to the research question, giving potential reasoning for the trends identified in Chapter 4. Chapter 6 summarizes the findings and provides recommendations for further research and policy makers. Appendices will contain detailed descriptions of the variables used in the study derived from the census as they apply to each year (Appendix A), a regression output from the GWR run on the Denis-Perron dam to account for a slightly skewed residual deviance (Appendix B), and a screenshot of a map of Quebec's “no data” areas highlighted after joining a dissemination area boundary file with its corresponding demographic data (Appendix C).

CHAPTER II – LITERATURE REVIEW

2.1 INTRODUCTION

To understand the prevalence of hydropower and injustice in Canada, it is necessary to examine the body of academic and related literature. The literature review provides context for the study as well as supports geospatial analysis as appropriate methodology for this research. This review is informed by a variety of sources, including academic journals, personal interviews, and texts. These all serve to inform the reader of three broad sections relating to this study; hydroelectricity in Canada, the intersection between hydropower dams and environmental injustice, and context for the geospatial methods of analysis employed in this study. It summarizes the historical pattern of hydroelectric dam implementation in Canada and addresses its impact on the local communities, providing possible reasoning for the trend in the demography of the affected people. It provides a summary of related studies that employ geospatial methods to analyze data to explain why GIS is selected as the primary investigative tool in this study. This review also identifies knowledge gaps in the available literature that gave rise to this study and emphasize the importance in doing so.

2.2 HYDROELECTRICITY IN CANADA

Hydroelectric development in Canada has been prevalent since the late 1800s, when settlers saw the potential for economic benefit in the land's abundant rivers (Islam, Fartaj & King, 2004; Lee, Cheng & Scheelar, 2012, p. 13). As time progressed, the country was only presented with more reasons to continue hydroelectric development; in the 1960s, technological advances allowed for long-distance transport and sale of hydropower, followed by an oil shortage and public push for climate action in the '70s (Froschauer, 1999, p. 4; Stocker et al., 2014). Since the early 2000s and still a true statistic today, approximately 60% of all electricity in Canada is generated by hydropower, with some provinces (Quebec, Yukon, Newfoundland & Labrador, British Columbia, and Manitoba) well over 90% (Haffner & Burpee, 2017; Islam, Fartaj & King, 2004; Lee, Cheng & Scheelar, 2012, p. 13, Wang et al., 2014). As of the year 2011, 519 reservoirs, 817 dams, and 271 facilities had been constructed across the country and Canada alone was responsible for 25% of the global hydropower output (Lee, Cheng & Scheelar, 2012, p. 14; Lee, Hanneman & Cheng, 2011, p. 29). Emerging as one of

Canada's key solutions to the threat of climate warming, it is important to investigate the benefits and drawbacks of hydroelectricity as a long-term solution.

2.1.1 POSITIVE AND NEGATIVE IMPACTS OF HYDROELECTRIC DAMS

The Canadian government's faith in hydropower is evident by the number of facilities that have been produced over the past century (Lee, Cheng & Scheelar, 2012, p. 14; Lee, Hanneman & Cheng, 2011, p. 29). Unfortunately, hydroelectricity has become a controversial subject in recent years because as many positive outcomes that it elicits, there are just as many negative (Bello, Robescu & Bondrea, 2019; Martin et al., 2020; Solarin & Yen, 2020; Sovacool & Walter, 2018). Hydropower has been revered for being affordable, reliable, efficient, and having low operative costs, making it the obvious low investment, high reward choice in terms of renewable energy (Bello, Solarin & Yen, 2020; Martin et al., 2020; Sovacool & Walter, 2018). Additionally, the reservoirs created by many dams have offered a plethora of societal and economic benefits, such as a consistent source of water for irrigation and drinking, a method for flood control and navigation, and a potential for aquaculture (Bello, Solarin & Yen, 2020; Robescu & Bondrea, 2019). These reservoirs also allow for energy storage, which further increases reliability as water is not quite as fickle as sunlight or wind (Sovacool & Walter, 2018). Furthermore, due to its classification as a renewable energy source, hydropower reduces per capita greenhouse gas emissions and has a relatively low carbon footprint (Martin et al., 2020; Sovacool & Walter, 2018).

As useful and reliable as the reservoirs can be, they can also be a source of ecological devastation heavily scrutinized by environmental activists. While the flooding of the land upstream of the dam can offer many economic and social benefits, the interrupted flow of the river also causes upstream river fragmentation and flow downstream is significantly reduced, sometimes drying out river basins spanning thousands of kilometers (Lee, Cheng & Scheelar, 2012, p. 21, 59; Martin et al., 2020). As the basin fills and the land becomes flooded, the existing local freshwater and terrestrial habitats are degraded or destroyed (Lee, Cheng & Scheelar, 2012, p. 58; Martin et al., 2020). Due to the conditions of the forced flooding, water quality can be reduced, and water chemistry can be altered due to the decomposition of terrestrial plant matter in the stagnant water (Lee, Cheng & Scheelar, 2012, p. 59). This phenomenon also has the potential to pose significant risks to human health, as the stagnant water creates optimal conditions for the spread of water-borne diseases and methylmercury contamination, as well as a reduction in ecosystem services due to decreased biodiversity (Lee, Cheng & Scheelar, 2012, p. 59; Martin et al., 2020; Sovacool & Walter, 2018). Despite its benefits of affordable and renewable energy production, the impacts to human health and the environment are key trade-offs for the reliability of hydroelectric dams. However, as is discussed in the next section, it is probable that hydropower will lose its dependability rapidly in the face of climate change.

2.1.2 HYDROELECTRICITY AS A RENEWABLE RESOURCE

Despite Canadian endeavours, research suggests that hydropower will not be consistent as a viable long-term option for renewable energy as the climate crisis becomes increasingly prevalent (Feng & Beighley, 2020; Harrison & Whittington, 2002; Schaeffer et al., 2012; Wang et al., 2014). In many scenarios, hydropower depends on the consistency of the hydrological cycle to maintain steady energy outputs; as the effects of climate change continue to worsen, hydropower can become less reliable, especially in areas subject to glacier melting (Schaeffer et al., 2012). In addition, changes in precipitation patterns and growing inconsistency of river flows as the hydrological cycle is disrupted can lead to intermittency in energy outputs (Feng & Beighley, 2020; Harrison & Whittington, 2002; Wang et al., 2014). It is expected that as global temperature warms, there will be increased runoff in the spring coupled with decreased runoff in all other months, intensifying river events (Feng & Beighley, 2020). Such changes could cause drastic alterations to the hydrologic cycle, furthering the uncertainties and inconsistency of energy output (Feng & Beighley, 2020). Already, there has been a recognized decrease in the efficiency of hydropower plants over time as the severity of climate change increases, causing a reduction in economic benefits (Bello, Solarin & Yen, 2020; Majumder, Majumder & Saha, 2018). Compelling arguments against future hydropower investments date back several years, however, it is unclear if such arguments are reaching those considering Canada's energy future.

2.2 ENVIRONMENTAL INJUSTICE AND HYDROELECTRIC DAMS

"Neoliberalism," though not frequently discussed, has been quoted to be a pervasive issue in Canada (Mascarenhas, 2012, p. 82). Neoliberalism refers to the idea that a person's right to environmental resources, such as clean air and drinking water, is related to that person’s ability to self-govern, or have the finances to pay one’s way out of environmental catastrophe (Mascarenhas, 2012, p. 82). Mascarehas (2012) uses hydropower as a key example of neoliberalism in Canada in his book, “Where the Waters Divide,” as they are known to provide a solution to climate change by preserving the environment for privileged (and often white) Canadians, while destroying it for the marginalized (p. 83). Mascarenhas (2012) argues that regarding the country’s Indigenous people, neoliberalism has further isolated them from environmental justice, widening the gap of inequality and moving into the territory of environmental racism, a branch of environmental injustice specifically targeted to racial and ethnic minorities (p. 82). Indigenous perspective has been renowned for its efficacy in the climate change movement, and it is important to ensure that Canada is not moving in the wrong direction of resolving one of its most arduous commissions (reconciliation) (Behn & Bakker, 2019; Bernard, 2018).

Indigenous people continue to be one of the most marginalized and oppressed groups in the country (Behn & Bakker, 2019; Bernard, 2018). Aside from enacting the *Truth and Reconciliation Commission* in 2015, there has yet to be any definitive action taken to reconcile the multi-generational trauma endured due to residential schools and white development on unceded Indigenous land (Bernard, 2018). Canada’s “Not in my Backyard” (NIMBY) approach to environmental justice has only served to concentrate pollution and environmental degradation to the “backyards” of low-income, racial minority, and otherwise marginalized people who do not have the means to oppose it (Behn & Bakker, 2019; Mascarenhas, 2012, p. 87). Over time, Canada has moved from blatant acts of racism to a more discreet, but equally harmful ambivalence to Indigenous people and ignorance to the imbalance of resources and environmental “goods” between minorities and white Canadians (Mascarenhas, 2012, p. 87; Powys Whyte, 2018).

2.2.1 DAM PLACEMENT AND INDIGENOUS COMMUNITIES

More often than not, hydropower projects in Canada are met with opposition from Indigenous communities, usually regarding subsequent impacts to the land (Atkinson & Mulrennan, 2009; de Löe, 1999; Dipple, 2015; Gupta, 1992; Martin & Hoffman, 2011, p. 261;

Sheehan, 2020). Most (if not all) settler communities and buildings in Canada are built upon unceded Indigenous land and territory, including the implementation of hydropower dams, often constructed without consent (Sheehan, 2020). The negative impacts of dams are felt by Indigenous communities often more significantly than others, as the land being destroyed is heavily relied on for food security or cultural practice (Sheehan, 2020). Residual impacts have direct negative implications on Indigenous food and water supply including methylmercury contamination, biodiversity extinction, fish migration pattern disruption, polychlorinated biphenyls (PCB) contamination in staple foods, and water quality impediment due to accumulation heavy metals (Baird et al., 2021; Mascarenhas, 2012, p. 84, Sheehan, 2020). While disruption to people living near a dam site is significant, their livelihood is not called into question the way it is for Indigenous people.

Aside from the obvious direct impacts, dam implementation significantly obstructs Indigenous way of life (Baird et al., 2021; de Löe, 1999; Mascarehas, 2012, p. 84; Sheehan, 2020). As an example, Baird et al. (2021) discuss the residual effects of the W.A.C. Bennett Dam in British Columbia on the local Indigenous communities (mainly Sekani, Cree, Dene, and Métis). This dam, constructed on the Peace River, a notable sacred body for Indigenous people, obstructed downstream movement of fish and restricted access to harvest areas, creating significant resource deficiencies (Baird et al., 2021). Furthermore, it thwarted the seasonal migration of Indigenous people to their winter cabins and created hazardous conditions for river travel due to hanging ice caused by constantly fluctuating water levels (Baird et al., 2021). In addition to this, several sources point out that Indigenous people rarely experience the benefits of the dams that infringe on their treaty rights, as most reservations are reliant on diesel energy despite having the capability to be connected to hydroelectric power grids (Cooke et al., 2017; Karanasios & Parker, 2018; Cooke et al., 2017). Dam implementation not only has the capacity to cause physical harm to Indigenous people, but also completely changes their way of life, a clear infringement on their rights of self-governance (Behn & Bakker, 2019).

2.2.2 THE JAMES BAY PROJECT

99% of all energy generated in the province Quebec is attributed to hydropower, largely due to the developments of the James Bay Project, initially proposed in 1971 (Gupta, 1992;

Haffner & Burpee, 2017; Martin & Hoffman, 2011, p. 261). At the time of its completion, it was the largest hydroelectric facility in the world, but it did not come without controversy (Gupta, 1992; Martin & Hoffman, 2011, p. 63). The Cree are an Indigenous group occupying much of north-west Quebec, a largely unpopulated and previously industrially undeveloped part of the province (Morantz, 2002, p. 28). Phase one of the James Bay Project was set to dam La Grande River with eight generating stations and divert a further three to increase flow through the dams, all within Baie-James, an unorganized municipality in north-western Quebec (Martin & Hoffman, 2011, p. 63-64). The Cree to be directly impacted by this project were neither notified nor consulted regarding this project prior to construction, despite the infraction of their land rights under the *Indian Act* (Indian Act, 1985; Martin & Hoffman, 2011, p. 65-66).

Concerned for the fate of their 5000-year-old hunting and fishing territory, the Cree took their claim to court (Gupta, 1992). In 1973, Judge Albert Malouf ruled in favour of the Cree and ordered all project development to stop, however just a week after the decision, the court of appeal overturned the injunction, claiming the interests of Quebec's southern society outweighed the destruction to Indigenous land (Gupta, 1992; Morantz, 2002, p. 252). As a response, the Crees began negotiations with the provincial government and Hydro-Quebec for a treaty, resulting in the first ever comprehensive land claim agreement (modern treaty), the *James Bay and Northern Quebec Agreement* (JBNQA), signed in 1975 (Martin & Hoffman, 2011, p. 261; Morantz, 2002, p. 253). While still allowing the project to proceed, the Crees believed the JBNQA would mitigate some of the damage caused by development and allow them continued and exclusive access to their land (Gupta, 1992).

However, as phase one of the project proceeded, this was realized to be an impossibility due to Hydro-Quebec's failure to adhere to the agreement (Gupta, 1992; Martin & Hoffman, 2011, p. 208). Plans for a second project, the Great Whale Complex, were further concerning to Crees when construction began in 1988 (Martin & Hoffman, 2011, p. 232). However, in 1994, a review of the agreement found Hydro-Quebec to be in violation, and an official environmental impact assessment (EIA) was ordered to be conducted prior to the resuming of the project (Martin & Hoffman, 2011, p. 232). In 2002, a new agreement between the Crees and Hydro-Quebec was enacted to resolve disputes regarding violations of the JBNQA, formally known as the *Paix des Braves* (Martin & Hoffman, 2011, p. 32). This agreement is distinguished from the original as it "recognized First Nations as partners with whom the state must deal nation-to-nation" (Martin & Hoffman, 2011, p. 32). Following the *Paix des Braves,* consultation with Indigenous people in Quebec prior to industrial development (including hydro projects) must transpire and must be economically beneficial to both parties (Martin & Hoffman, 2011, p. 32). However, by the time the *Paix des Braves* came into effect, 11,500 km^2 of Indigenous land had been flooded, thousands of fish and caribou had died as a result of methylmercury poisoning, hunting and trapping land had been severely reduced, and non-native people hunted and fished uncontrolled on the land for which the Indigenous had been granted exclusivity to in the JBNQA (Gupta, 1992; Hornig, 1999, p. 23; Morantz, 2002, p. 253).

2.2.3 ENVIRONMENTAL INJUSTICE AND WHO IT IMPACTS

Research shows that Indigenous people may not be the only marginalized group experiencing the negative impacts of hydropower (Davoudi & Brooks, 2014; McHenry, 2017; Mascarenhas, 2012, p. 87; Vaz, Anthony & McHenry, 2017). Historically, the environmental justice movement (EJM) has fought for equal distribution of environmental "goods" amongst racial minorities but has since evolved to include a range of socially disadvantaged people (Davoudi & Brooks, 2014). The Canadian Marginalization Index (CAN-Marg) gives insight into how these factors of marginalization can determine to what degree a community is at risk of environmental injustice (Matheson et al., 2012).

Possible reasoning for the hydropower prevalence in Canada can be traced back to the root of environmental activism, which historically caters to the "ecological concerns of [the] white middle-class," ostracizing minorities from consideration and contributing to the NIMBY mindset (Davoudi & Brooks, 2014; Mascarenhas, 2012, p. 87). Generally, anyone outside of that umbrella is at risk of being subjected to environmental injustice. Davoudi & Brooks (2014) state that "[t]he political reach of EJM has transcended ethnicity and race to include other social differences such as deprivation, age, gender, health, and disability" as well as "social isolation and lack of access to insurance." Vaz, Anthony & McHenry (2017) explain how low-income and minority communities should also be included as those especially vulnerable to environmental injustice. As is clear from the literature that hydropower projects can assuredly be classified as an environmental “bad” (Mascarenhas, 2012, p. 87), areas representing high volumes of the community dynamics outlined by Davoudi & Brooks (2014) and Vaz, Anthony & McHenry (2014) have the potential to be selected as dam sites.

There are several categories of people who lie outside the classification of “white middle-class,” and thus determining the degree of marginalization is likely to be an arduous task. Davoudi & Brooks (2014) explain how the distribution of environmental “bads” can vary depending on the specific and overlapping vulnerabilities pertaining to a specific community. However, a tool known as the Canadian Marginalization Index (CAN-Marg) can be used to address this. It was created using Canadian census data to ensure close alignment with community dynamics in the country and acts as an “area-based indicator of socio-economic status” (Matheson et al., 2012). CAN-Marg is used as a tool to conceptualize marginalization in Canadian communities based on several contributing factors (Matheson et al., 2012). As environmental injustice is incredibly multi-faceted and difficult to quantify, the use of the Canadian Marginalization Index (CAN-Marg) is the most appropriate method to summarize community deprivation to date.

2.2.4 DAM PLACEMENT AND MARGINALIZED COMMUNITIES

The demands of a hydropower dam in terms of the physical geography of the land are simple, yet absolute; dams cannot exist without a river. For whatever the reason of human settlement patterns, there are very few rivers in Canada that run through populous areas (Sovacool & Walter, 2018). Whether purposeful or by coincidence, the geographic distance separating rural communities impacted by dams from those in control of the hydropower projects serves only to quietly isolate these populations as they suffer the consequences (Sovacool & Walter, 2018). Stakeholders are regarded as key voices in any large-scale project, but Bakker & Hendriks (2019) explain that when it comes down to it, resource regulation is a socio-political process often enacted by groups of people who share similar thought processes. Even when minority voices are among these decision-makers, it is unlikely that they will draw on the perspectives of those who will be directly impacted by the implementation of the project without forced intervention (Bakker & Hendriks, 2019).

Rural and urban areas generally show a large divide in socio-economic status between its inhabitants, the former often facing the extent of environmental burdens (Caner Sayan, 2017). This divide is often attributed to the differences in employment opportunities between the two locations. Whereas urban centers are likely to offer positions pertaining to a wide range of professions, work in rural areas is largely based in agriculture. As this is a main source of income for many people in rural communities, hydropower projects tend to increase levels of poverty by interfering with farming and aquaculture (Sovacool & Walter, 2018). From this research, the geographical divide between the privileged and marginalized is identified as a key factor in environmental injustice, especially as it pertains to hydropower.

2.3 GEOSPATIAL METHODS OF ANALYSIS

2.3.1 GEOSPATIAL ANALYSIS OF HUMAN DEMOGRAPHY

A key aspect of this analysis is the investigation of the geographic relationship between the physical location of the hydroelectric dams as they relate to the demographic features of the communities surrounding them. To accurately analyze the relationships between these attributes, a pertinent method is a geospatial analysis. Several studies investigating the geographic distribution of demographic variables have been conducted using Geographic Information Systems (GIS), suggesting that it is the superior method to employ when studying the relationship between geographic features to demographic attributes (Hurzeler et al., 2021; Johnson et al., 2016; Richards, 2014; Schnell et al., 2016).

A study by Richards (2014) analyzed racial ethnicity by attendance region within school districts to investigate any instances of “natural” segregation; this study did so by using polygon spatial objects to create natural boundaries based on demographic features. Similarly, Hurzeler et al. (2021) used GIS to determine correlation between alcohol-based suicide and factors relating to socioeconomic disadvantage across Australia using density and hotspot cluster analysis. The use of a spatial format for both these analyses strengthens the results and make for easier reader interpretation. When comparing geographic boundaries to demographic attributes, it is clear from this research that using a geospatial software is the most reliable method.

Furthermore, a study by Schnell et al. (2016) investigated “spatiotemporal clusters” of giardiasis cases to determine if environmental factors could be related to case frequency. The analysis implemented for this study is a binomial model applied to a spatial regression, as in the geographic distribution of certain factors as they relate to the allocation of identified spatiotemporal clusters (Schnell et al., 2016). The binary model can be applied when coding the program to identify either the existence or lack of a specific feature (i.e., giardiasis cluster, dam site, etc.). Related, a study conducted by Johnson et al. (2016) applies geospatial methods to detect potential relationships between shrimp farming, salinity intrusion, and levels of poverty in Bangladesh. To do this, researchers identified key drivers for poverty and then used GIS to map the geographic distribution of the drivers (Johnson et al., 2016). Johnson et al. (2016) first used a join-count spatial autocorrelation to identify randomness or significance in the distribution of poverty clusters followed by a regression to identify if the geographic factors (shrimp farming, salinity intrusion) explained cluster patterns. These studies are examples of astute geospatial methodology applied to investigate the relationship between spatial and non-spatial (demographic) data and demonstrate the benefits of conducting an analysis using GIS. From these studies, one can see how the relation of the frequency of a particular variable to the geographic area it is connected to can give valuable insights about the population dynamics within those areas, producing an easily digestible output.

2.3.2 GEOSPATIAL REGRESSION AND GENERALIZED LINEAR MODELLING

The importance in choosing an appropriate geospatial analytical tool cannot be underestimated. A generalized linear model (GLM) is used to investigate the impact a set of explanatory (or independent) variables may have on a dependent variable (Liu, Divani & Petersen, 2022). When a generalized linear regression (GLR) is performed on a spatial software, the same is achieved, yet the variables are compared within a geographic context, investigating the relation between the variables in terms of physical distance relation. Several studies have been conducted that employ geospatial regressions as primary analysis tools to generate predictions regarding demographic variables to geographic distribution (Chen, 2018; Schnell et al., 2016). This research demonstrates the usefulness of applying a geospatial regression as an appropriate method of investigating significance of distribution of demographic variables.

Chen's (2018) study investigates how the geographic clustering of certain socioeconomic variables may influence breast cancer rates. An ordinary least squares (OLS) is first applied to determine the most influential explanatory variables, followed by a geographically weighted regression (GWR) to determine strength of the independent variables on the model (Chen, 2018). This method considers how the explanatory variables may be spatially dependent, which is a necessary component often left out of non-spatial analyses. Another study conducted by Schnell et al. (2016) uses a binary regression model to draw conclusions about relationships between demographic variables in areas where a giardiasis cluster is present. This model can draw significance or insignificance based on the consistency of the explanatory variables in areas where the dependent variable is present. While few studies have been conducted that relate geographic attributes to the distribution of demographic variables, these studies demonstrate that spatial regression is an appropriate technique to employ when investigating this kind of relationship.

2.4 GAPS IN KNOWLEDGE

While research has been conducted regarding hydroelectric dams and environmental injustice regarding Indigenous people and marginalization, there is a noticeable absence of studies investigating their overlap using geospatial tools, and none that have been conducted using Canadian census data. Lee, Hanneman & Cheng (2011) include a map on p. 34 of hydroelectric projects across the country and Indigenous treaty boundaries, but do not include additional marginalization factors. Additionally, several studies discussing the impacts of hydroelectric dams can be identified, but none assess significance in proximity of these marginalized communities to the dam site (Baird et al., 2021; Bakker & Hendriks, 2019; Bello, Solarin & Yen, 2020; Cooke et al., 2017; Lee, Cheung & Scheelar, 2012; Majumder, Majumder & Saha, 2018). This study will attempt to bridge these gaps and promote further investigation into potential areas of environmental injustice in Canada.

2.5 CONCLUSION

In summary, the literature shows that the Canadian government has leaned heavily into hydroelectricity as a long-term and final solution to reliance on fossil fuels and energy dependence in the country (Islam, Fartaj & King, 2004; Lee, Cheng & Scheelar, 2012, p. 13).

Despite the long-term viability of hydropower being called into question and the environmental injustice and destruction caused by their implementation, hydropower continues to hold its monopoly on energy production in the country (Feng & Beighley, 2020; Harrison & Whittington, 2002; Lee, Cheng & Scheelar, 2012, p. 59; Martin et al., 2020; Sovacool & Walter, 2018; Wang et al., 2014). The ecological devastation caused by hydroelectricity classifies it as an environmental “bad,” putting marginalized communities disproportionately at risk of being targeted as dam sites (Davoudi & Brooks, 2014; Mascarenhas, 2012, p. 87). Investigation into a relationship between marginalized areas and dam sites is best carried out using a geospatial regression analysis to determine geographic significance (Johnson et al., 2016; Schnell et al., 2016). Despite numerous studies conducted on hydroelectricity and environmental injustice, there is a clear gap in the study of geospatial relationship between the two. This research aims to fill the gap in the literature, as well as to investigate an important issue regarding reconciliation and the future of renewable energy in Canada.

CHAPTER III – METHODOLOGY

3.1 DATA COLLECTION

Both spatial and non-spatial data used for this study is publicly accessible through Statistics Canada and the Global Reservoir and Dams Database (GRanD). GRaND Version 1.3 was used and gives both point and polygon spatial objects representing dam sites and reservoirs respectively (Lehner et al., 2011). This data was implemented to refine the study area based on year of execution and specific use. Both demographic and digital/cartographic boundary files for provinces and census years of interest (1981 – 2006) were taken from StatsCan and then further refined using Microsoft Excel. The tool *Scholars Geoportal* was used to download geospatial shapefiles for census subdivisions (CSDs) and access metadata. The *Canadian Census Analyzer* database was used to filter and download corresponding census data by subdivision for each census year.

3.2 DETERMINATION OF SCOPE

This study was made possible due to the open-source availability of census data, provided by Statistics Canada. However, vast improvements have been made to both the quality and quantity of data collected by the census in the last few decades. The first year in which census data is consistent and relevant to this study (in terms of the types of data collected) is in the year 1981. Thus, the scope of this research is focused on hydroelectric dams in Canada that began construction sometime after the year 1980.

After establishing the time frame, geographic area limitations were determined by examining the geographic locations of the dams using ArcGIS Pro (Esri Inc., 2021). The following steps are outlined in an overview schematic (Figure 1). The pre-downloaded shapefiles from GRanD were imported into ArcPro and then added as separate layers (dam and reservoir) to the map (Global Dam Watch, 2019). From here, census boundary files were added to the map based on feature attributes to determine an appropriate scope. Naturally, Canadian census data does not extend internationally, and thus limits the study to within national boundaries. In addition, all dams beginning construction in a year earlier than 1981 must be omitted due to lack of corresponding demographic data. It is also important to note that this study is investigating impacts of dams in existence for the purpose of energy production, and thus all dams within the database that exist for purposes outside of hydropower generation are irrelevant.

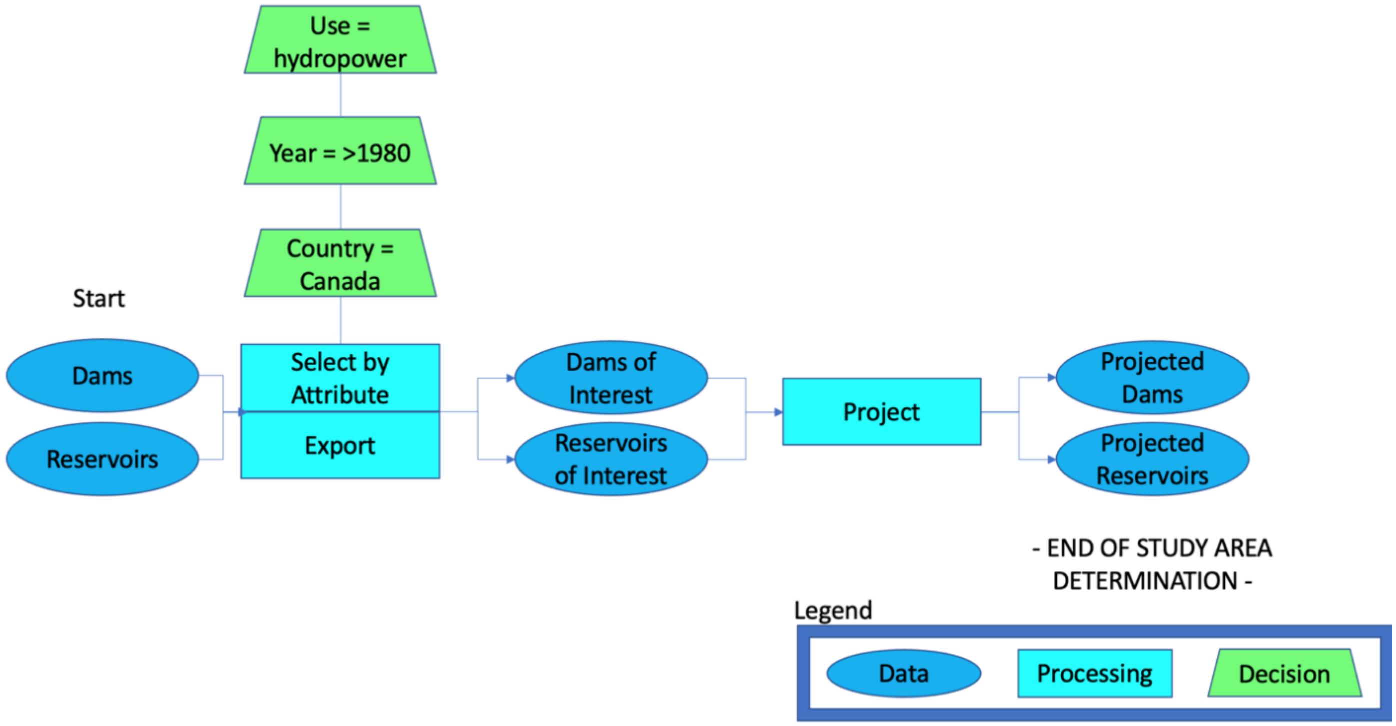


Figure 1. Flow chart outlining the geoprocessing steps of determining the project study area using the data collected from Global Dam Watch (2019). Chart shows data inputs and outputs, processing steps, and any decisions to be made. Created by Emma Taniguchi.

Three conditions were applied to the attribute tables of both feature classes, as can be seen in Fig. 1, using the BOOLEAN operator “OR,” such that only dams applying to all three conditions were selected. Notably, the GRanD database includes a “secondary” option for use and country, and thus all reservoirs overlapping two countries (including Canada) and dams listing hydropower generation as a secondary use are also selected (Global Dam Watch, 2019). Once run, all selected rows from each table were exported into new feature classes and separated as the dams and reservoirs of interest for the study. The new exported layers each contained 18 rows of data, limiting the scope to the dams and associated reservoirs listed in Table 1. All layers were projected to UTM NAD83.

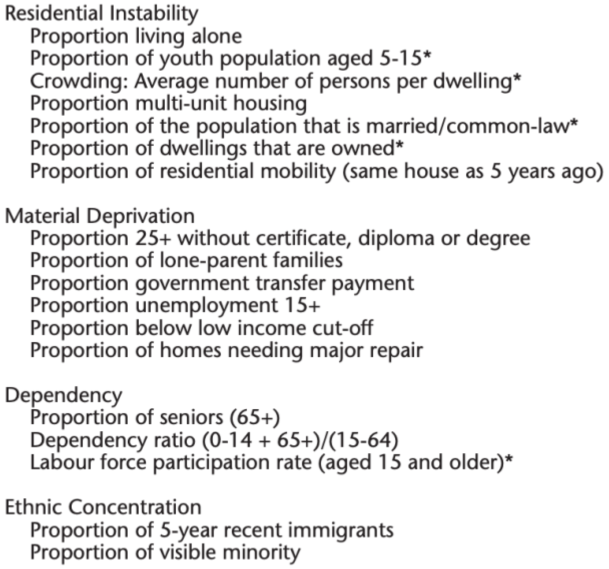
Table 1. Canadian hydropower dams and corresponding reservoirs constructed after the year 1980. The country each reservoir and dam are in is included as well as the corresponding census year (the most recent census of population conducted prior to the dam construction date. Data extracted from Global Dam Watch (2019).

Dams and Reservoirs of Interest to the Study			
Location	Reservoir Name	Dam Name	Census Year
British Columbia	Revelstoke	Revelstoke	1981
Alberta	-	Oldman River Dam	1986
Manitoba	-	Limestone	1986
Quebec	Kipawa	Laniel	2006
Quebec	Rupert	Rupert	2006
Quebec	-	Eastmain-1	2001
Quebec	La Grande 3	La Grande 3	1981
Quebec	La Grande 4	La Grande 4	1981
Quebec	La Forge 1	La Forge 1	1991
Quebec	La Forge 2	La Forge 2	1996
Quebec	Caniapiscau	Caniapiscau Barrage	1981
Quebec	-	Peribonka	2006
Quebec	Lac Portneuf	Itomamo	2001
Quebec	-	Sault-aux-Cochons	2001
Quebec	-	Toulnustouc	2001
Quebec	Lac-Walker	Denis-Perron	1996
Newfoundland	-	Cat Arm Dam West	1981
Newfoundland	-	West Salmon Dam	1981

3.3 NON-SPATIAL REGRESSION TO IDENTIFY PROXY VARIABLES

To determine what constitutes a disadvantaged community, variables were chosen based on those comprising the Canadian Marginalization Index (CAN-Marg) (Matheson et al., 2012). However, including all 18 variables from the CAN-Marg in a geospatial regression analysis makes for a complicated and inconclusive output with the potential for issues regarding overfit (Chen, 2018). Thus, a decidedly more appropriate approach for this study was to determine certain proxy variables that could conglomerate several other variables within them. The CAN-Marg is described as having four “dimensions,” made up of residential instability, material deprivation, dependency, and ethnic concentration (Matheson et al., 2012). To ensure an astute analysis of these dimensions, the goal was to preserve most of the explanatory variables into one that outlines their trends with 60% (adjusted R^2 value of 0.6) accuracy or greater.

Quebec was chosen as a sample study area in which to run a non-spatial regression since it contains most of the dams and reservoirs of interest (ref. Table 1). The year 2006 was selected as the census year in which to run the regression on to ensure congruency in the explanatory variables that align with the indicators of marginalization, as 2006 was the earliest year that all variables included in the CAN-Marg were collected in the census (Matheson et al., 2012). To ensure an adequate sample size was available for the regression, the 2006 census data was sorted by dissemination area (DA) rather than CSD. In the Canadian Census Analyzer, all variables aligning with the CAN-Marg (Figure 2) were selected and exported as a MS Excel-Ready file.



Residential Instability
    Proportion living alone
    Proportion of youth population aged 5-15*
    Crowding: Average number of persons per dwelling*
    Proportion multi-unit housing
    Proportion of the population that is married/common-law*
    Proportion of dwellings that are owned*
    Proportion of residential mobility (same house as 5 years ago)

Material Deprivation
    Proportion 25+ without certificate, diploma or degree
    Proportion of lone-parent families
    Proportion government transfer payment
    Proportion unemployment 15+
    Proportion below low income cut-off
    Proportion of homes needing major repair

Dependency
    Proportion of seniors (65+)
    Dependency ratio (0-14 + 65+)/(15-64)
    Labour force participation rate (aged 15 and older)*

Ethnic Concentration
    Proportion of 5-year recent immigrants
    Proportion of visible minority

Figure 2. The four dimensions of CAN-Marg and their associated variables extracted from the 2006 Census of Population. Image taken from Table 1 of Matheson et al. (2012).

Prior to regression analysis, the output table was tidied by inserting appropriate column titles and converting all raw number values into percentages and ratios according to the total number (i.e., Indigenous population converted to % of total population that are Indigenous; dwellings in need of major repair to % of total dwellings in need of major repair, etc.). Once completed, a regression was run; this process used general stepwise technique, starting with the variables assumed most likely to represent others (ex. DWL_OWN, i.e., percentage of total dwellings that are owned, as the dependent variable and all others as independent). Once the regression was run, the output table was examined and independent variables with insignificant p-values (>0.05) were removed from the model. This procedure was repeated until an adjusted R^2 value > 0.6 was achieved, the decided point at which use of the dependent variable as an explanatory in the spatial regression is justified. The statistical outputs showed high explanatory power for the use of variables POP_DEP, DWL_OWN, EDU_NCERT, and INDIG_POP as proxies, and they were subsequently selected to act as the refined CAN-Marg within the spatial regression. Due to its perceived importance as a factor indicating marginalization, ETH_NWHT was also chosen to be included in the spatial regression, despite not having enough explanatory power to act as a proxy variable (Matheson et al., 2012). A preliminary correlation analysis step was omitted, as correlation between related variables was assumed based on the study by Matheson et al. (2012).

There are some census years wherein the decided proxy variables are not available. In 1981, instead of a comprehensive list of different ethnicities and visible minority identities (ETH_NWHT - given in later years), there are only three categories of single origin: British, French, and Other (Statistics Canada, 1981). British and French are not the only Caucasian ethnicities, meaning the "other" category is not an astute representation of visible minorities. However, the cultural makeup of the country during that time can be a good indication in some cases of a minority population, especially when geographically compared to later years (i.e., "Indian reserve" CSDs in 1981 have populations between 90-100% not of French or British origin, numbers strongly corresponding to Indigenous population of later years) (Statistics Canada, 1981; 2006). To avoid confusion, the ethnicity variable name in 1981 was changed to ETH_NBRFR and used in place of ETH_NWHT. In addition, counts of Indigenous population did not become a demographic variable of the census until 1991, and thus INDIG_POP was removed from analyses prior to this date (Statistics Canada, 1991).

3.4 DATA CLEANING

3.4 1 CENSUS DATA COLLECTION

The tool used in this study to extract, sort, and download census data was the Canadian Census Analyzer database. This tool allows the user to search census' by year, sort by several different geographic units (dissemination areas, census subdivisions, census tracts, etc.), and within those units, select by province or by area/subdivision/tract name alphabetically (CHASS, 2014). To begin the process of extrapolating census data, geographic location of each dam/reservoir was noted. Table 3 outlines the provinces in which each dam is located; note that the final column states a secondary province for each dam. In some cases, census subdivisions surrounding the dam site or the reservoir itself overlap provincial boundaries. For these locations, census subdivisions for both provinces in the corresponding census year were downloaded.

Table 2. Each dam within the study area with its corresponding census year. The primary column indicates the province in which the dam lies. When populated, the secondary column gives the province in which data from census subdivisions is needed in due to overlapping geography. Study area determined with Global Dam Watch (2019) data using ArcGIS Pro (Esri Inc., 2021).

Dams of Interest: Corresponding Provinces and Census Years			
Dam Name	Year	Primary Province	Secondary Province
Revelstoke	1981	British Columbia	Alberta
Caniapiscau		Quebec	Newfoundland & Labrador
La Grande 3		Quebec	Ontario
La Grande 4		Quebec	Ontario
Cat Arm		Newfoundland & Labrador	-
West Salmon		Newfoundland & Labrador	-
Old Man River	1986	Alberta	British Columbia
Limestone		Manitoba	Ontario
La Forge 1	1991	Quebec	Ontario
La Forge 2	1996	Quebec	Ontario
Denis-Perron		Quebec	Newfoundland & Labrador
Eastmain 1	2001	Quebec	Ontario
Itomamo		Quebec	-
Sault aux Cochons		Quebec	-
Toulnustouc		Quebec	Newfoundland & Labrador
Laniel	2006	Quebec	Ontario
Rupert		Quebec	Ontario
Peribonka		Quebec	-

After determining what province data is needed from for each census year, the extrapolation process began using the Canadian Census Analyzer database. Data was filtered by appropriate census year, then by census subdivisions, followed by province(s) associated for each dam (ex. for Revelstoke, data for British Columbia and Alberta was required for the year 1981). Based on the proxy variables selected for analysis in the non-spatial regression, all corresponding demographic attributes were selected to be exported. In the final spreadsheet, all values are presented as ratios and percentages, thus not all variables are given in their final form in the census data. Due to this, all factors relating to the variable of interest needed to be included in the output in order to convert them. Table 4 outlines the variables needed for the formation of each CAN-Marg indicator and the equation utilized to convert them. Demographic attributes are not presented the same in every census year, and thus the required transformations may vary.

Table 3. Variables required to create the final output for each variable, including the format in which it is presented, and the equation required for transformation for census years 2001 and 2006. As demographic attributes vary in collection between census years, alternate methods must be employed for some dams. Data extracted from Statistics Canada (2001; 2006).

Census Data Variable Selections and Conversions			
Variable	Presented as:	Variables Selected	Equation
POP_DEP	Ratio	Male & female population ages 0-14 (POP_YTH), Total senior population 65+ (POP_SEN), Total population (POP_TOT)	POP_DEP = (POP_YTH + POP_SEN)/ (POP_TOT - [POP_YTH + POP_SEN])
DWL_OWN	Percentage	Total number of dwellings (DWL_TOT), number of dwellings owned (DWL_OWN)	(DWL_OWN/DWL_TOT) *100
EDU_NCERT	Percentage	Total population over the age of 15 (POP_15), Total population with an education less than grade 9; total population without a high school diploma (EDU_NCERT)	(EDU_NCERT/POP_15) *100
ETH_NWHT	Percentage	Total population (POP_TOT), Total visible minority population (ETH_NWHT)	(ETH_NWHT/POP_TOT) *100
INDIG_POP	Percentage	Total population (POP_TOT), Total Indigenous population (INDIG_POP)	(INDIG_POP/POP_TOT) *100

Once all necessary variables were selected, CSD Code and CSD Name were included in the output as they are useful for ensuring appropriate tabular joining in the next step. Each variable was downloaded and cleaned in preparation for analysis. Once each table had been downloaded and named correctly, they were cleaned to prepare for import. For some variables, a preliminary transformation was required to conglomerate some census variables prior to converting them. The variable POP_YTH is required to produce POP_DEP (see Table 4), but the census splits this variable into Male population aged 0-4, 5-9, 10-14 and female population 0-4, 5-9, 10-14. Therefore, prior to carrying out the equation, all those values were combined (Statistics Canada, 1981; 1986; 1991; 1996; 2001; 2006). This was carried out by creating a new column using the Excel “SUM” function to combine all related columns (identified based on the reference) into a new POP_YTH column. The “paste values” function was executed into a new column to avoid unreferenced cells, and then all unnecessary cells were deleted. This addition was repeated for the variable EDU_NCERT (see Table 4).

Once the preliminary transformations were complete, all headers were changed in both the reference and data sheet to align appropriately with the data being represented. Appendix A shows the naming technique applied for each census year. Once this was carried out, all variables were converted to their final representation as outlined in Table 4. As with the combination step, the “paste values” function was used to separate the final values from their equation. Once complete, all irrelevant columns were deleted so the only columns that remained were those identifying the CSDs and the final stage variables. The reference sheets were also altered so they described more accurately what each variable was representing (available in Appendix A). This process was repeated for all downloaded spreadsheets.

3.4.2 SPATIAL REGRESSION

Once the cleaning of the non-spatial data was completed, the process of refining the spatial data and combining non-spatial to spatial began. Figure 2 outlines the remaining data-cleaning steps of the spatial data, beginning with importing the shapefiles (Statistics Canada, 1983; 1988; 1992; 1997; 2002; 2007 [ESRI Shape]. The following was conducted on the same map that determination of scope was conducted. The file for 1981 was added to the map, which spans the country. The shapefiles were clipped to the specific study areas by selecting the corresonding by province ID(s) for each study area. The output was exported as a new feature class and named as PrimaryProvince_SecondaryProvince_YY. This process was repeated for all years and associated provinces (as per Table 3). Once complete, all original downloaded files were removed from the map.

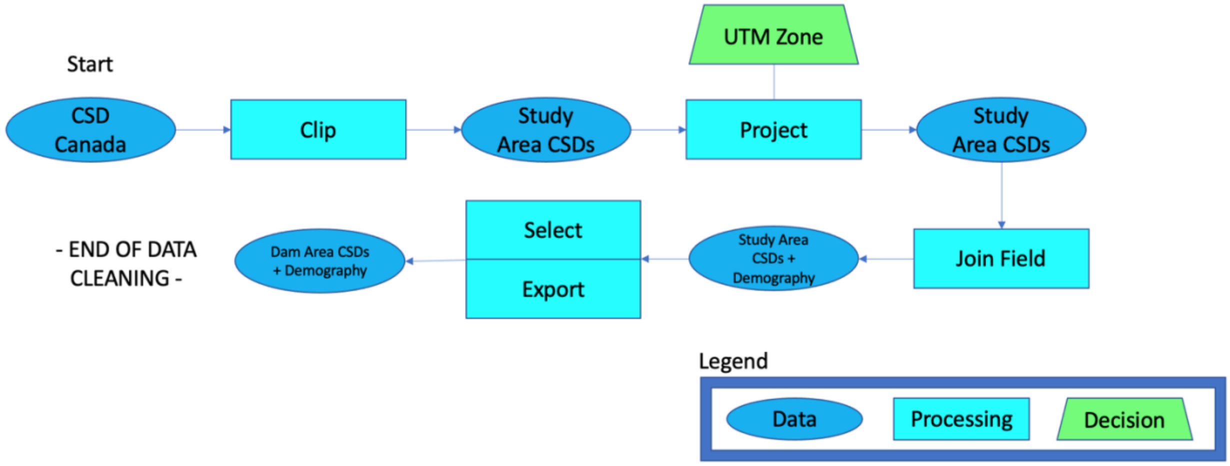


Figure 3. Flow chart schematic outlining an overview of the data cleaning process conducted on ArcGIS Pro (ESRI, 2021). Process completed with census data for all census years between and including 1981 and 2006 from Statistics Canada (1981; 1986; 1991; 1996; 2001; 2006). Chart shows input and output data, processing steps, and any decisions to be made. Created by Emma Taniguchi.

To conduct a successful GLR, it is appropriate for all associated layers to be in a projected coordinate system rather than geographic. The study areas created in the previous step span the country, which also means they exist in several Universal Trans Mercator (UTM Zones) within the NAD83 (North American Datum 1983). Table 5 shows each dam's associated zone that it is projected in and the name of the corresponding layer for each. Dams with the same census year, associated provinces, and UTM zone only exist once within the map. However, in some cases, a layer with the same census year and associated provinces was projected into multiple zones. The resulting projected layers were named as: damname_utm# (i.e., revelstoke_utm11) as each layer is specific to each individual dam. At this point, La Grande 3 and La Grande 4 were combined into a single layer as well as Cat Arm and West Salmon, as they have year, zone, and province(s) in common and are geographically close enough to exist within the same analysis.

Table 4. Each dam's and layer's associated Universal Trans Mercator (UTM) zone in which to be projected based on the geographic location of the dam/reservoir. Associated UTM zones derived from Natural Resources Canada (2021).

Dams of Interest: Associated Layer Names and UTM Zones		
UTM Zone	Dam Name	CSD Layer
11	Revelstoke	BritishColumbia_Alberta_81
	Old Man River	Alberta_BritishColumbia_86
15	Limestone	Manitoba_Ontario_86
17	Laniel	Quebec_Ontario_06
18	La Grande 3	Quebec_Ontario_81
	La Grande 4	Quebec_Ontario_81
	La Forge 1	Quebec_Ontario_91
	Eastmain 1	Quebec_Ontario_01
	Rupert	Quebec_Ontario_06
19	Caniapiscau	Quebec_Newfoundland_81
	La Forge 2	Quebec_Ontario_96
	Denis-Perron	Quebec_Newfoundland_96
	Itomamo	Quebec_01
	Sault aux Cochons	Quebec_01
	Toulnustouc	Quebec_Newfoundland_01
	Peribonka	Quebec_06
21	Cat Arm	Newfoundland_81
	West Salmon	Newfoundland_81

Once all layers were projected, they were joined with the spreadsheets created in the previous step. Using the geoprocessing tool “Join Field,” each projected layer was selected as the input table and matched with its corresponding demographic data by selecting the appropriate Excel spreadsheet as the join table. Using these steps, each projected layer was combined with its corresponding data sheet. Once joined, each layer was examined to ensure the command was executed properly. If successful, each layer was checked for the spatial distribution of null values. Nulls can be seen in areas that did not receive adequate responses, and thus have no data associated with them. In instances for which the CSD that contains the dam is null, the dam was removed from the study. In this case, Itomamo and Sault aux Cochons both exist in no data areas, and thus cannot be analyzed.

All remaining dams were then prepared for regression. The CSDs containing and surrounding each dam were highlighted; the area selected varies based on the geographic size of each census subdivision. Dams situated in larger CSDs have a much wider surrounding area selected than those in smaller CSDs, but always contain at least the dam site CSD and all those touching it. All values with null demographic data were removed, as well as all CSDs with populations equal to 0, or small enough that the demographic values yield inconclusive results (ex. POP_DEP = -5). This was repeated with all projected layers.

3.5 GENERALIZED LINEAR REGRESSION

To determine significance in the relationship between dam placement and marginalization, a Generalized Linear Regression (GLR) was run using a binary (logistic) model. This model type is most appropriate for the study as the differences in demography due to the presence or absence of a dam within a CSD could simply be coded as 1s and 0s. The calculation CSD_Dam = 0 was input and run. Then manually, CSDs containing all or part of the associated reservoir were coded as 1 and the edits were saved. This process was repeated with all projected CSD layers. Figure 4 outlines the process of running the regression once the CSD_Dam column was coded. This process was repeated with all projected CSD layers.

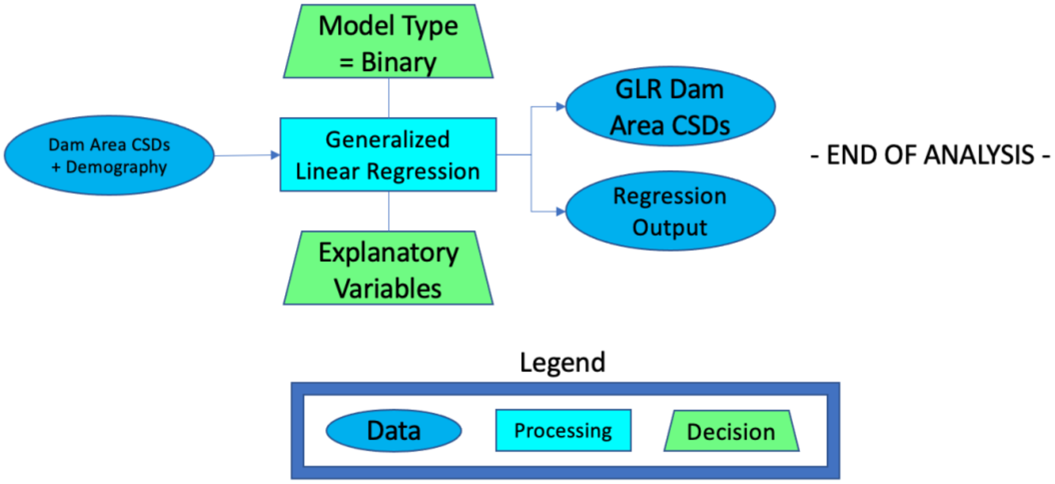


Figure 4. Flow chart outlining the geoprocessing steps for the GLR. Process carried out using census data for all years between 1981 to 2006 from Statistics Canada. All input and output data, processing steps, and decisions made are included. Created by Emma Taniguchi.

Once the regression had been run on each layer with the significance of each noted, six diagnostic checks were conducted on each significant model to ensure they were “properly specified” (ESRI Inc., n.d.). Each regression output’s coefficients were examined for all variables; ensuring none were equal to (or very near) 0 (ESRI Inc., n.d.). All relationships (sign of coefficient) between the dependent and independent variables were inspected, making note of unexpected relationships (ex. a positive relationship was expected for EDU_NCERT, and thus the coefficient sign should be +) (ESRI Inc., n.d.). The Variance Inflation Factor (VIF) values were also checked, ensuring each did not exceed 7.5, which would indicate redundancy between variables (ESRI Inc., n.d.). Next, the distribution of standardized residual histogram was examined, ensuring all models were un-biased. i.e., represent normal distribution (ESRI Inc., n.d.). Finally, the (Akaike Information Criterion) AICc was examined to determine the overall strength of the model as compared to the others, or how well the dependent variable is explained by the independents as compared to the performance of the other models (ESRI Inc., n.d.).

3.6 LIMITATIONS AND DELIMITATIONS

The limitations of this study arise largely due to the absence of adequate or consistent demographic data. Because of the geographic comparisons and relationships being analyzed, smaller polygons are preferred to represent demography as they give a finer and more specific summary of each area. Census subdivisions tend to represent a small geographic area in urban areas, but widen considerably in rural locations, which is where most dam sites tend to be. Dissemination areas (DAs) or enumeration areas (EAs)[1] would have been the most appropriate scale for this study, but geospatial files using polygon spatial objects are not available for census years prior to 2001. Even then, for dams with 2001 and 2006 as associated census years, the DAs encompassing the reservoirs contain only null values after a join field is performed, rendering the analysis for those dam sites impossible.

The prevalence of no data areas seen in both DAs and CSDs proves another challenge. With the scope of the study already reduced so significantly (post 1980), areas populated with

---

[1] DAs and EAs refer to the same grouping within the census. The naming was changed from enumeration to dissemination in the 1996 census.

null values and subsequently removed from analysis leave out essential pieces of the puzzle that render the final outputs somewhat incomplete. While meaning can be derived from the results of this study, there is no way of knowing what impact the redacted information could have had on the outcome. The assumption that areas with no data or null values are unpopulated has been applied to account for this.

In some instances, certain variables do not vary enough between CSDs within study areas to be included in the analysis; the GLR tool in ArcGIS Pro will automatically remove these variables. In cases where this occurs, different explanatory variables are chosen as proxies to those not available for analysis. The assumption that these variables act as proxies in the same way that those removed do is applied for analysis to take place.

A delimitation of this study arises from the reduction of the scope to dams constructed in a year post-1980. The country's most active time of hydroelectric dam construction occurred between the years 1950 and 1970, a period that this study is forced to eclipse due to lack of data (Alfredsen et al., 2021). Due to this, there are hundreds of Canadian dams that are not accounted for within the analysis, and thus all CSDs that do not contain a dam or reservoir constructed in the past 40 years are treated as if they do not have one at all, which is not necessarily the case. Since there is no way to determine how the populations of these areas have been impacted by historic dams, this factor is not considered.

CHAPTER IV – RESULTS

4.1 PROXY VARIABLES

The initial, non-spatial regression was conducted to determine proxy variables that had significant trends with others used in the Canadian Marginalization Index (CAN-Marg). The resulting proxy variables were later used to conduct the spatial regression to determine significant relationships between marginalized communities around dam sites. Table 6. a) displays the regression output given when testing the explanatory strength of 5 variables on the population dependency ratio (POP_DEP). The model reports a high adjusted R^2 value, suggesting strong relationships between each independent variable on the dependent. The coefficients generated in the output suggest that with in increasing population dependency ratio, one can expect there will be an increase in overall youth and senior population (POP_YTH; POP_SEN), an increase in the average number of persons per household (PHH_AVG), an increased number of people living alone (PHH_ALONE), as well as an increase in the labour participation rate (LAB_PART).[2]

Similar results can be seen for the variable DWL_OWN, for which the regression generated a smaller, but still significant adjusted R^2 value (Table 6. b)). This model suggests that as the number of owned dwellings in a dissemination area increase, a decrease in multi-unit housing (DWL_MULT), residential mobility (MOB_RES), homes in need of major repair (REP_MAJ), and single parents (PHH_SING_PAR) can be expected, along with an increase in married population (POP_MAR). Table 6. c) demonstrates the lowest instance of predictive power among the variables, however, still elicits a significant relationship between population with an education below that of a high school graduate (EDU_NCERT) and the corresponding independent variables. The model shows that as the population of people without a high school diploma increases, one can expect a corresponding increase in unemployment rate (LAB_UNEMP), percentage of income among families attributed to government transfer (INC_FAM_GVT), and major repairs on homes needed (REP_MAJ) as well as a decrease in incidence of low income among families (FAM_LOINC), multi-unit housing (DWL_MULT), and married population (POP_MAR).

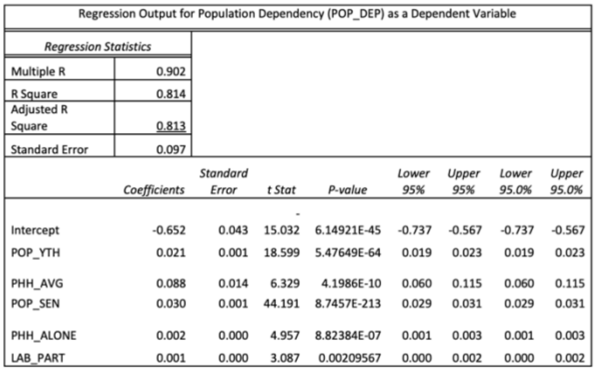
---

[2] See Appendix A for detailed descriptions on each variable for each census year

Table 6. d) demonstrates a strong relationship between the dependent variable INDIG_POP and several corresponding independent variables. The model suggests that with an increase of Indigenous population, one can expect a corresponding increase in homes in need of major repair (REP_MAJ), number of people living alone (PHH_ALONE), average number of people per household (PHH_AVG) and unemployment rate (LAB_UNEMP) as well as a decrease in labour participation rate (LAB_PART) and unattached persons incidence of low income (IND_LOINC).

Table 5. Regression output displaying results of independent variables (shown under "Intercept") explanation for the dependent variable POP_DEP (a)), DWL_OWN (b)), EDU_NCERT (c)), and INDIG_POP (d)). All adjusted R² values show high explanatory power (greater than 0.6). Table generated in Microsoft Excel using data from the 2006 Canadian Census on 771 dissemination areas in the rural Quebec area.

a)

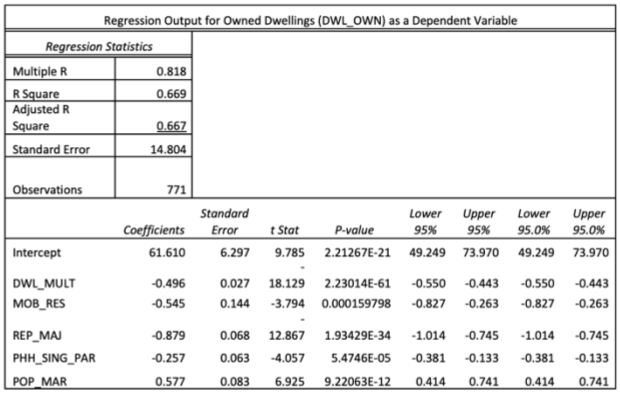


Regression Output for Population Dependency (POP_DEP) as a Dependent Variable

Regression Statistics	
Multiple R	0.902
R Square	0.814
Adjusted R Square	0.813
Standard Error	0.097

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.652	0.043	-15.032	6.14921E-45	-0.737	-0.567	-0.737	-0.567
POP_YTH	0.021	0.001	18.599	5.47649E-64	0.019	0.023	0.019	0.023
PHH_AVG	0.088	0.014	6.329	4.1986E-10	0.060	0.115	0.060	0.115
POP_SEN	0.030	0.001	44.191	8.7457E-213	0.029	0.031	0.029	0.031
PHH_ALONE	0.002	0.000	4.957	8.82384E-07	0.001	0.003	0.001	0.003
LAB_PART	0.001	0.000	3.087	0.00209567	0.000	0.002	0.000	0.002

b)

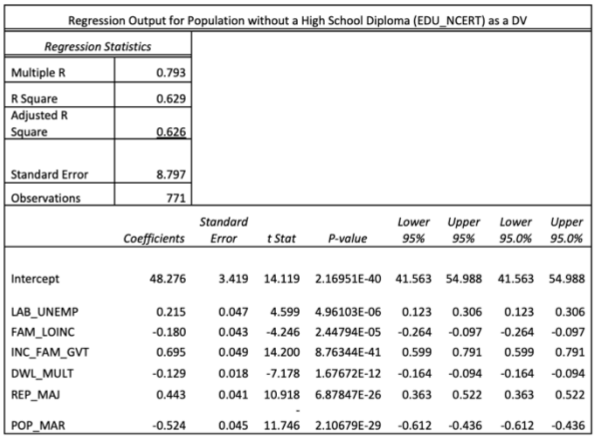


Regression Output for Owned Dwellings (DWL_OWN) as a Dependent Variable

Regression Statistics	
Multiple R	0.818
R Square	0.669
Adjusted R Square	0.667
Standard Error	14.804
Observations	771

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	61.610	6.297	9.785	2.21267E-21	49.249	73.970	49.249	73.970
DWL_MULT	-0.496	0.027	-18.129	2.23014E-61	-0.550	-0.443	-0.550	-0.443
MOB_RES	-0.545	0.144	-3.794	0.000159798	-0.827	-0.263	-0.827	-0.263
REP_MAJ	-0.879	0.068	-12.867	1.93429E-34	-1.014	-0.745	-1.014	-0.745
PHH_SING_PAR	-0.257	0.063	-4.057	5.4746E-05	-0.381	-0.133	-0.381	-0.133
POP_MAR	0.577	0.083	6.925	9.22063E-12	0.414	0.741	0.414	0.741

c)

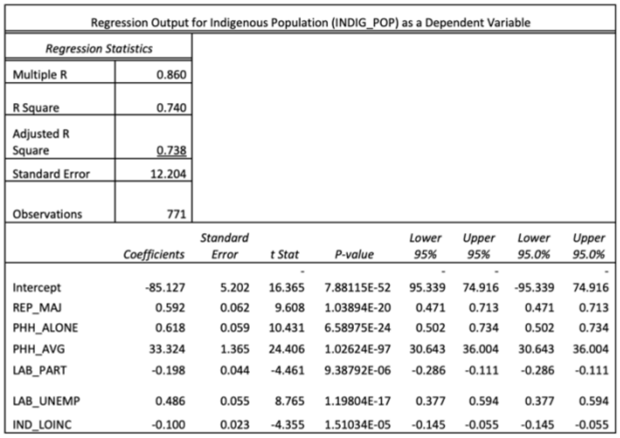


Regression Output for Population without a High School Diploma (EDU_NCERT) as a DV

Regression Statistics	
Multiple R	0.793
R Square	0.629
Adjusted R Square	0.626
Standard Error	8.797
Observations	771

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	48.276	3.419	14.119	2.16951E-40	41.563	54.988	41.563	54.988
LAB_UNEMP	0.215	0.047	4.599	4.96103E-06	0.123	0.306	0.123	0.306
FAM_LOINC	-0.180	0.043	-4.246	2.44794E-05	-0.264	-0.097	-0.264	-0.097
INC_FAM_GVT	0.695	0.049	14.200	8.76344E-41	0.599	0.791	0.599	0.791
DWL_MULT	-0.129	0.018	-7.178	1.67672E-12	-0.164	-0.094	-0.164	-0.094
REP_MAJ	0.443	0.041	10.918	6.87847E-26	0.363	0.522	0.363	0.522
POP_MAR	-0.524	0.045	-11.746	2.10679E-29	-0.612	-0.436	-0.612	-0.436

d)



Regression Output for Indigenous Population (INDIG_POP) as a Dependent Variable

Regression Statistics	
Multiple R	0.860
R Square	0.740
Adjusted R Square	0.738
Standard Error	12.204
Observations	771

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-85.127	5.202	-16.365	7.88115E-52	-95.339	-74.916	-95.339	-74.916
REP_MAJ	0.592	0.062	9.608	1.03894E-20	0.471	0.713	0.471	0.713
PHH_ALONE	0.618	0.059	10.431	6.58975E-24	0.502	0.734	0.502	0.734
PHH_AVG	33.324	1.365	24.406	1.02624E-97	30.643	36.004	30.643	36.004
LAB_PART	-0.198	0.044	-4.461	9.38792E-06	-0.286	-0.111	-0.286	-0.111
LAB_UNEMP	0.486	0.055	8.765	1.19804E-17	0.377	0.594	0.377	0.594
IND_LOINC	-0.100	0.023	-4.355	1.51034E-05	-0.145	-0.055	-0.145	-0.055

4.2 SPATIAL REGRESSION

Table 7 shows a summary of the GLR outputs given for each reservoir. The column "CSDs Selected" shows the study area in terms of the number of subdivisions used in the model. This number varies greatly depending on the geographic size of the subdivisions surrounding the dam site; generally, dams located in rural areas of the province have much larger census subdivisions, and thus a smaller number are selected for analysis.

The column “Explanatory Variables” (Table 7) gives a list of the independent variables selected for analysis. Ideally, these would all be the variables (and proxies) selected for analysis based on the non-spatial regression but in some cases, this is not possible. The GLR geoprocessing tool in ArcPro will remove explanatory variables in which the values are too universally similar, so in the case of Cat Arm, West Salmon, and Limestone dams, different proxy variables are selected for analysis (see Table 7).

The regression output statistics are also given for each dam in Table 7. The ACC, corrected for small sample size (AICc) represents the model strength, where a smaller AICc value means a better model. Apart from Rupert (AICc = 22.99) and La Grande 1 & 2 (AICc = 16.63), all statistically significant models have the smallest AICc values. Out of 16 models, 5 had statistically significant relationships that found the selected variables to be determinate of dam location (Table 7). The significant models are all dams located in Quebec and that began construction after the year 1991. Four of these dams demonstrate normal distribution of the residuals aside from one, Denis-Perron, which has a slight positive skew.

Table 6. Results of running GLR on each dam's associated CSDs. Models demonstrating significant relationships (p-value < 0.05) are highlighted. 5 out of the 14 models (16 dams total) have significant results. Analyses run on ArcGIS Pro using spatial boundary files and census data from Statistics Canada (1981; 1986; 1991; 1996; 2001; 2006).

Generalized Linear Regression (GLR) – Model Output Result Summary											
Dam	Province	Census Year	CSDs Selected	CSDs Containing Dams	Explanatory Variables	AICc	% Deviance Explained	Joint Wald Statistic	P-Value	Degrees of Freedom	Deviance Residuals
Revelstoke	British Columbia	1981	187	2	POP_DEP, DWL_OWN, ETH_NBRFR, EDU_NCERT	30.298	0.098	2.162	0.706	4	Normal
Caniapiscau	Quebec	1981	65	2	POP_DEP, DWL_OWN, ETH_NBRFR, EDU_NCERT	25.368	0.196	3.495	0.479	4	Normal
La Grande (1&2)	Quebec	1981	102	1	POP_DEP, DWL_OWN, ETH_NBRFR, EDU_NCERT	16.633	0.465	5.226	0.265	4	Normal
Cat Arm & West Salmon	Newfoundland	1981	369	3	POP_DEP, PHH_AVG, LAN_OTH, RGN_NCHST	35.748	0.266	9.265	0.055	4	Normal

Oldman River	Alberta	1986	330	3	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT	41.390	0.085	2.917	0.572	4	Normal
Limestone	Manitoba	1986	66	2	POP_DEP, LAB_UNEMP, FAM_LOINC, IND_LOINC	23.691	0.291	5.217	0.266	4	Normal
La Forge 1	Quebec	1991	198	1	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT	10.311	1.000	12.571	0.014	4	Normal
La Forge 2	Quebec	1996	208	1	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	12.416	1.000	12.670	0.027	5	Normal
Denis-Perron	Quebec	1996	269	1	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	12.319	1.000	13.186	0.022	5	Slight positive skew
Eastmain 1	Quebec	2001	137	2	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	26.282	0.347	7.237	0.204	5	Normal
Toulnustouc	Quebec	2001	319	2	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	31.886	0.192	4.658	0.459	5	Normal
Laniel	Quebec	2006	590	5	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	67.041	0.048	2.767	0.736	5	Normal
Rupert	Quebec	2006	171	2	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	22.999	0.518	11.281	0.046	5	Normal
Peribonka	Quebec	2006	303	1	POP_DEP, DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	12.280	1.000	13.444	0.020	5	Normal

Six diagnostic checks were conducted on each significant model. None of the output models have any one variable coefficient that is equal or very close to 0 (see Table 8), which would be indicative that one of the variables used for analysis is unhelpful to the overall model (ESRI Inc., n.d.). Additionally, no significance was detected for the VIF values in any model, which indicates there is no redundancy among the variables; deviance residual histograms show normal distribution for all models except that of Denis-Perron, meaning that with the one exception, all models are un-biased (ESRI Inc., n.d.). All key variables were identified in the original non-spatial regression to ensure the correct explanatory factors were being used and AICc of all significant models are smaller than those of the insignificant. A subsequent GWR was conducted on the CSDs surrounding the Denis-Perron dam site to determine reasoning behind the skewed results. The GWR model was not significantly different from the GLR and thus the skew was likely an artefact or otherwise caused by something other than spatial non-stationarity (see Appendix B).

Table 7. Summary of the diagnostic check outputs conducted for each dam area that's model is significant. The "coefficient of 0" column indicates whether any variables are unhelpful to the model. "Unexpected relationships" lists all variables moving in the opposite direction to what the hypothesis predicted for each model. "Redundant variables" states which variables (if any) showed significance for the VIF statistic. "Biased model" refers to normal or skewed distribution of the residuals.

GLR Diagnostic Check Results for Significant Models

Dams	Coefficient of 0?	Unexpected Relationships?	Redundant Variables?	Biased Model?	Key Variables?	AICc
La Forge 1	No	ETH_NWHT, EDU_NCERT	None	Normal	Yes	10.310885
La Forge 2	No	INDIG_POP	None	Normal	Yes	12.415842
Denis-Perron	No	DWL_OWN, POP_DEP, EDU_NCERT, INDIG_POP	None	Positive Skew	Yes	12.319392
Rupert	No	POP_DEP, ETH_NWHT, EDU_NCERT	None	Normal	Yes	22.998899
Peribonka	No	DWL_OWN, ETH_NWHT, EDU_NCERT, INDIG_POP	None	Normal	Yes	12.28

Variables demonstrating unexpected relationships are listed for each corresponding dam in Table 8, each of which demonstrates at least one trend in the opposite direction that what the hypothesis predicts. With the instance of a dam site within a CSD, the expected result would be an increase in visible minorities (ETH_NWHT), people with an education below a high school graduate (EDU_NCERT), Indigenous population (INDIG_POP), and population dependency ratio (POP_DEP) and a decrease in percentage of dwellings that are owned (DWL_OWN).

The La Forge 1 model shows a smaller visible minority population and a higher percentage of persons with a high school education in areas with dams as compared to the surrounding regions and La Forge 2 has a comparatively lower Indigenous population in the dam site CSD (see Table 8). Most variables in the Denis-Perron, Rupert, and Peribonka models have trends in an unexpected direction. Population dependency has a negative relationship and percentage of dwellings owned has a positive in two of five models (Table 8). Both visible minority population and Indigenous population show negative trends in three of five models, and uneducated population has a negative trend in four of the five models.

Figures 5-9 outline the deviance residuals for each significant model, showing reservoir location, CSDs included in the analysis, and all areas redacted due to lack of data. Number of residual tiers vary based on study area due to the difference in output ranges. Values closest to 0 represent areas that match the model's prediction based on what demography in the area should look like based on the surrounding geography. The higher values (shown in increasingly darker shades of green) represent CSDs with relationships significantly higher than what the model predicts; subsequently, lower values (increasingly darker shades of purple) are CSDs with relationships significantly lower than the mean.

Figure 5 shows the output map of deviance residuals after running a GLR on the La Forge 1 dam area. CSDs in this area are mainly rural, and this tend to have a very large geographic area. The CSDs surrounding that which contains the reservoir are mainly no data regions, thus the analysis is forced mostly south-west of the reservoir. The model reports overall significance of this region (ref. Table 7), yet the residuals all lie quite close to 0. Positive deviance can be seen in only the CSD containing the reservoir, and negative in one small CSD in the south-east area of the map (Fig. 5).

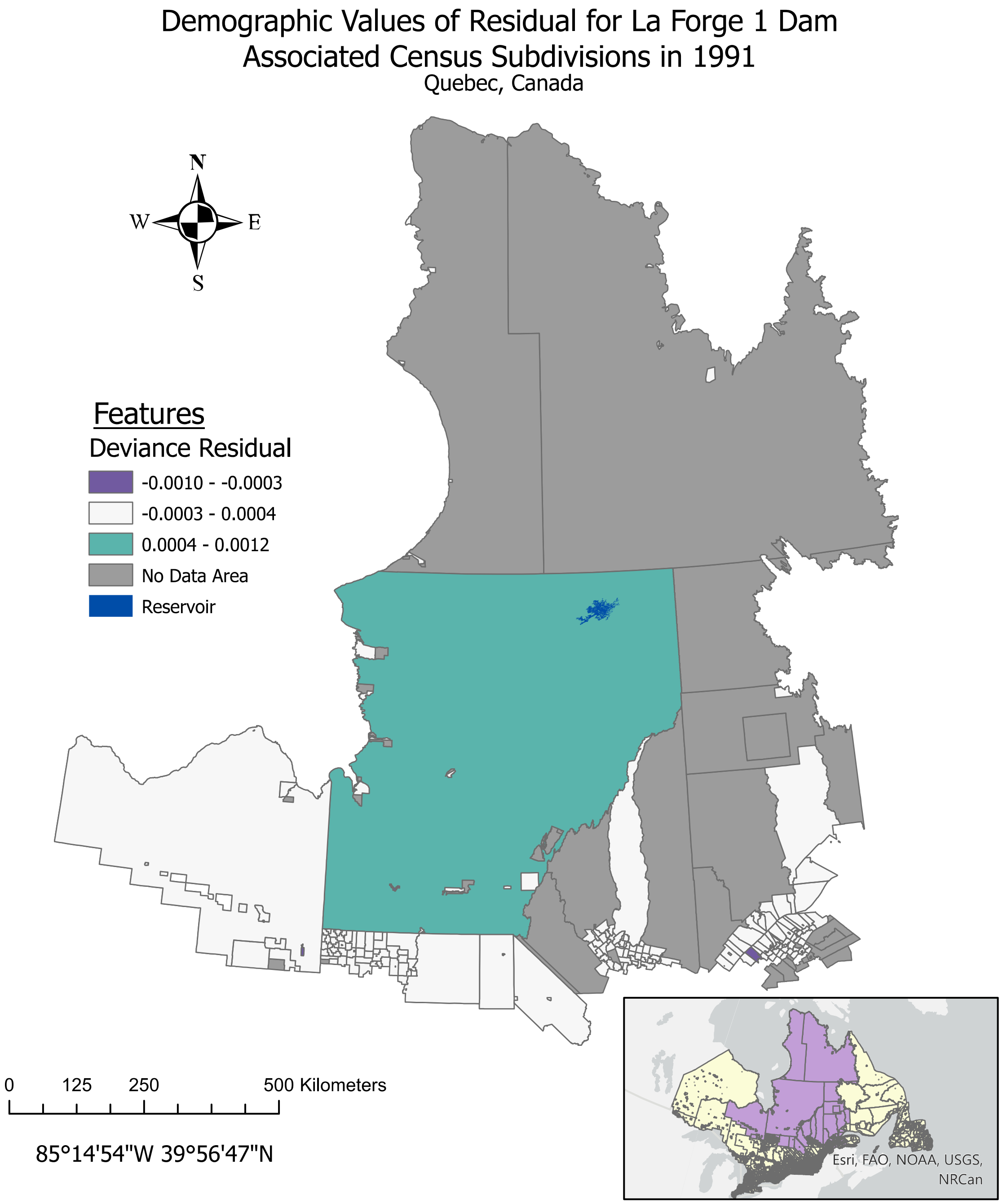


Figure 5. Map showing distribution of deviance residuals and no data regions for census subdivisions associated with La Forge 1 dam and reservoir. Map frame shows the analysis region highlighted within the study area. Residuals are positively deviated in the CSD containing La Forge 1 and nowhere else in the map. A few CSDs are negatively deviated south of the reservoir. Spatial reference: NAD1983 UTM Zone 18. Data Sourced from Global Dam Watch (2019) (dams and reservoirs), Statistics Canada (1991) (CSD data), and Statistics Canada (1992) (boundary file). Output expressed using equal interval classification method

La Forge 2 lies on the same river and in the same census subdivision but creates an entirely new reservoir. Figure 6 shows the deviance residual outputs run on the areas surrounding La Forge 2. While one might expect similar outputs to La Forge 1, several differences can be noted between the two census years. Some of the no data areas surrounding the CSD of interest contain data in the 1996 analysis. The layout of CSDs is also slightly different, as some have been added and some removed. However, the regression output still reports overall model significance. Like Fig. 5, Figure 6 has little residual variance, with all three tiers being very close to 0. The CSD containing La Forge 2 has the highest deviance whereas three smaller CSDs (two south, one west of the dam) have the lowest (Fig. 6).

Figure 7 shows the deviance residual map for the Denis-Perron dam. As is a recurring trend in all significant models, many of the CSDs surrounding the dam have been removed from the study due to lack of data in those areas (Fig. 7). To account for this, a larger study area surrounding the dam has been selected (as seen in the map frame in Figure 7). Deviance from the mean is not wide in this model, as can be seen in Figs. 5 and 6 as well. The CSD containing Denis-Perron shows the largest positive residual (Fig. 7). This model differs from the others in that it has a slight negative skew in distribution of residuals; this is evident in the number of CSDs that deviate from the mean in the negative direction, including many CSDs in the southern region of the study area and most notably, the CSD directly to the left of the one containing Denis-Perron (Fig. 7).

Figure 8 shows the output map of deviance residuals on the CSD containing and surrounding the Peribonka dam. A limitation of this model is that the reservoir lies on the border between two CSDs, one of which contains no data, which is a trend that exists in much of the east quadrant of the study area, skewing the analysis to the south. Also notable is the large discrepancy between size of CSDs in this area. The north is populated with CSDs that span vast geographies, while the subdivisions in the south are much smaller. Similar to the other models (Figs. 5, 6 & 7), residuals do not greatly differ from the mean, and thus are represented in only three tiers (Fig. 8). The CSD containing (part of) the Peribonka reservoir represents the largest positive value seen, while several smaller CSDs in the south-eastern quadrant of the study area have negative residual values (Fig. 8).

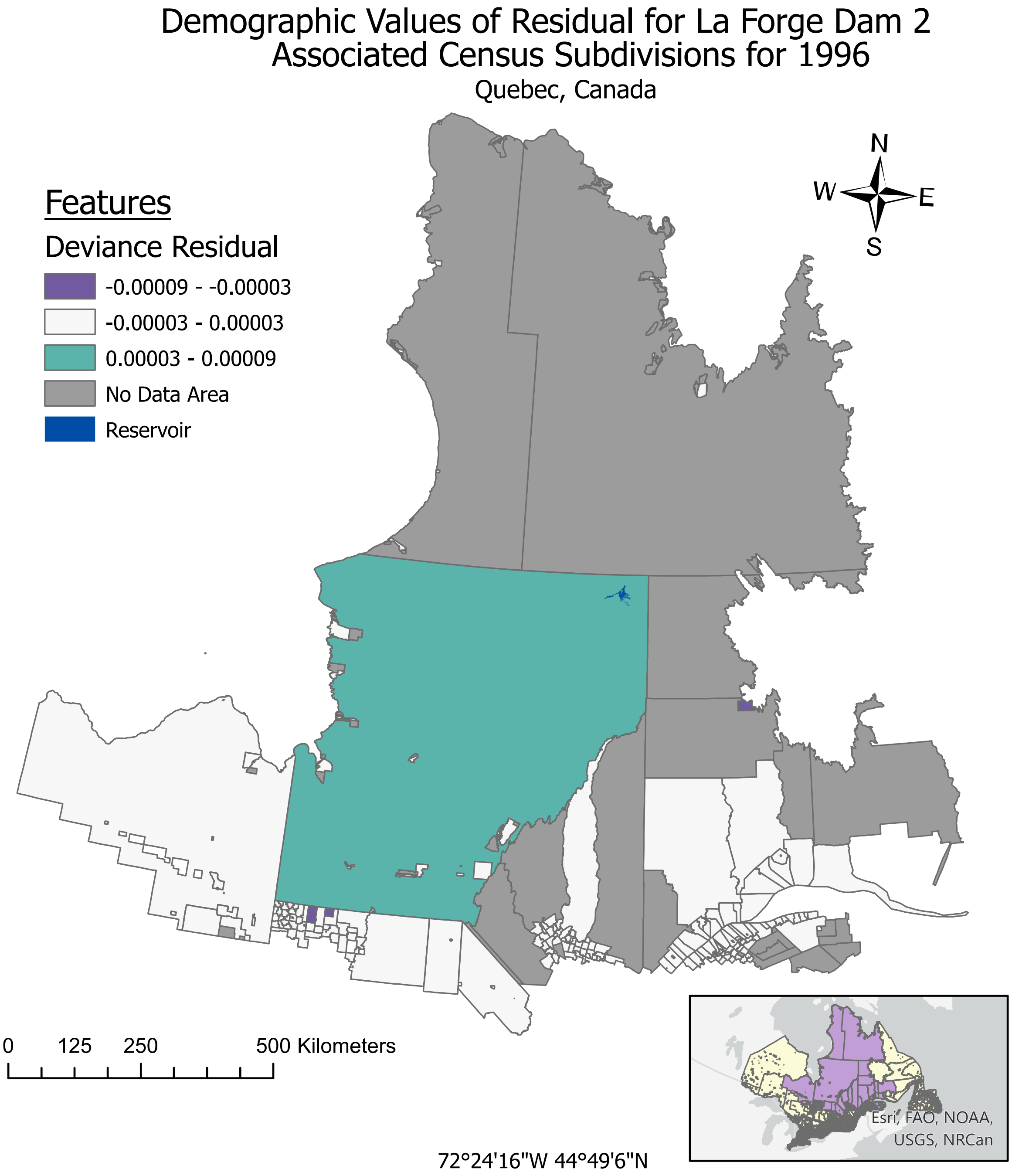


Figure 6. Map showing distribution of deviance residuals and no data regions for CSDs associated with La Forge 2 dam and reservoir. Map frame shows the analysis region highlighted within the study area. The only CSD with a positive deviance residual is that containing the dam. Smaller CSDs with negative residual skews are more populous. Spatial reference: NAD1983 UTM Zone 19. Data Sourced from Global Dam Watch (2019) (dams and reservoirs), Statistics Canada (1996) (CSD data), and Statistics Canada (1997) (boundary file). Output expressed using equal interval classification method.

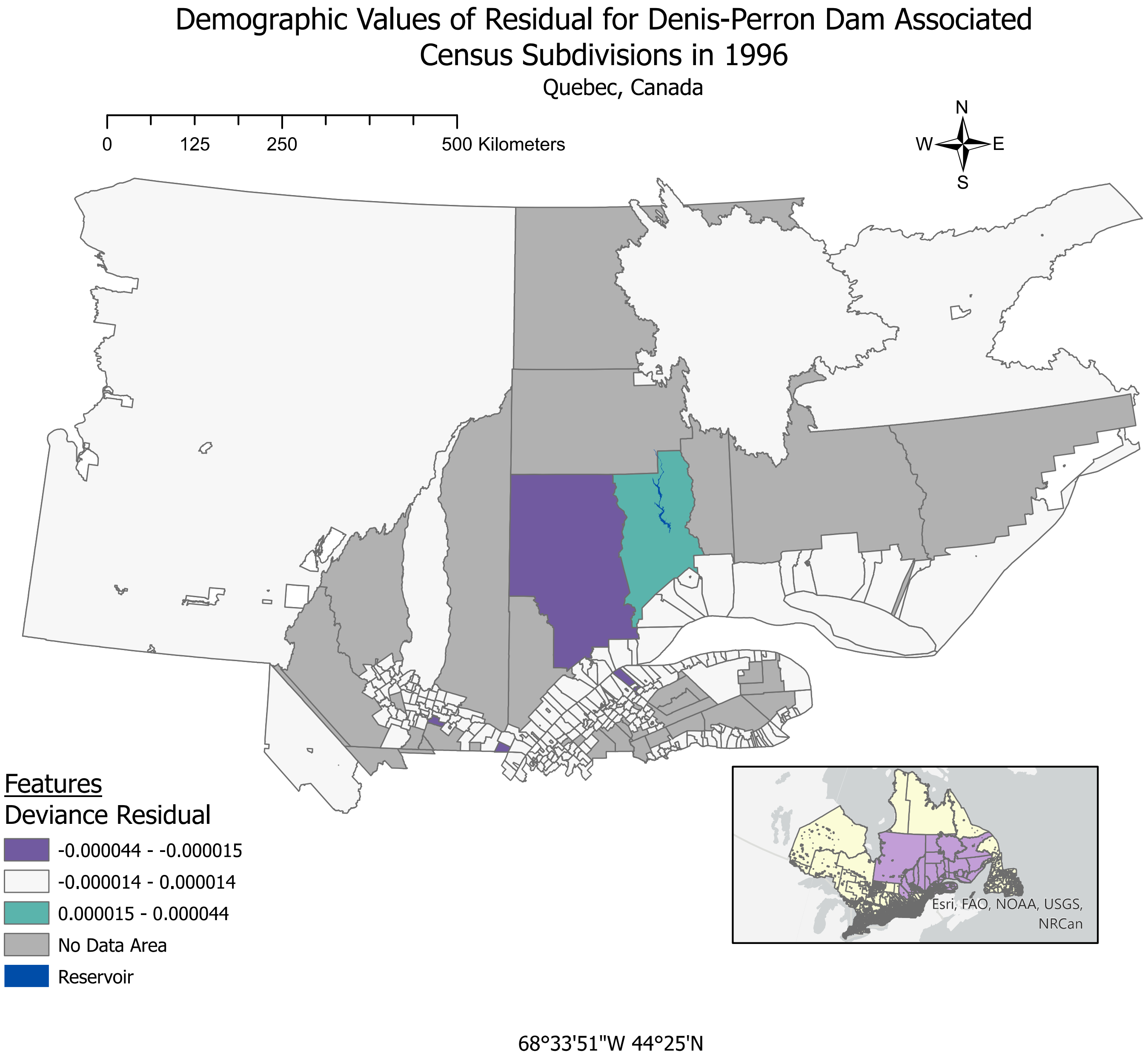


Figure 7. Map showing distribution of deviance residuals and no data regions for CSDs associated with the Denis-Perron dam and Lac-Walker (reservoir). Map frame shows the analysis region highlighted within the study area. CSD containing the reservoir is the only area with a positive deviance residual. Some CSDs with negative deviance residuals can be seen south of the reservoir. Spatial reference: NAD1983 UTM Zone 19. Data Sourced from Global Dam Watch (2019) (dams and reservoirs), Statistics Canada (1996) (CSD data), and Statistics Canada (1997) (boundary file). Output expressed using equal interval classification method.

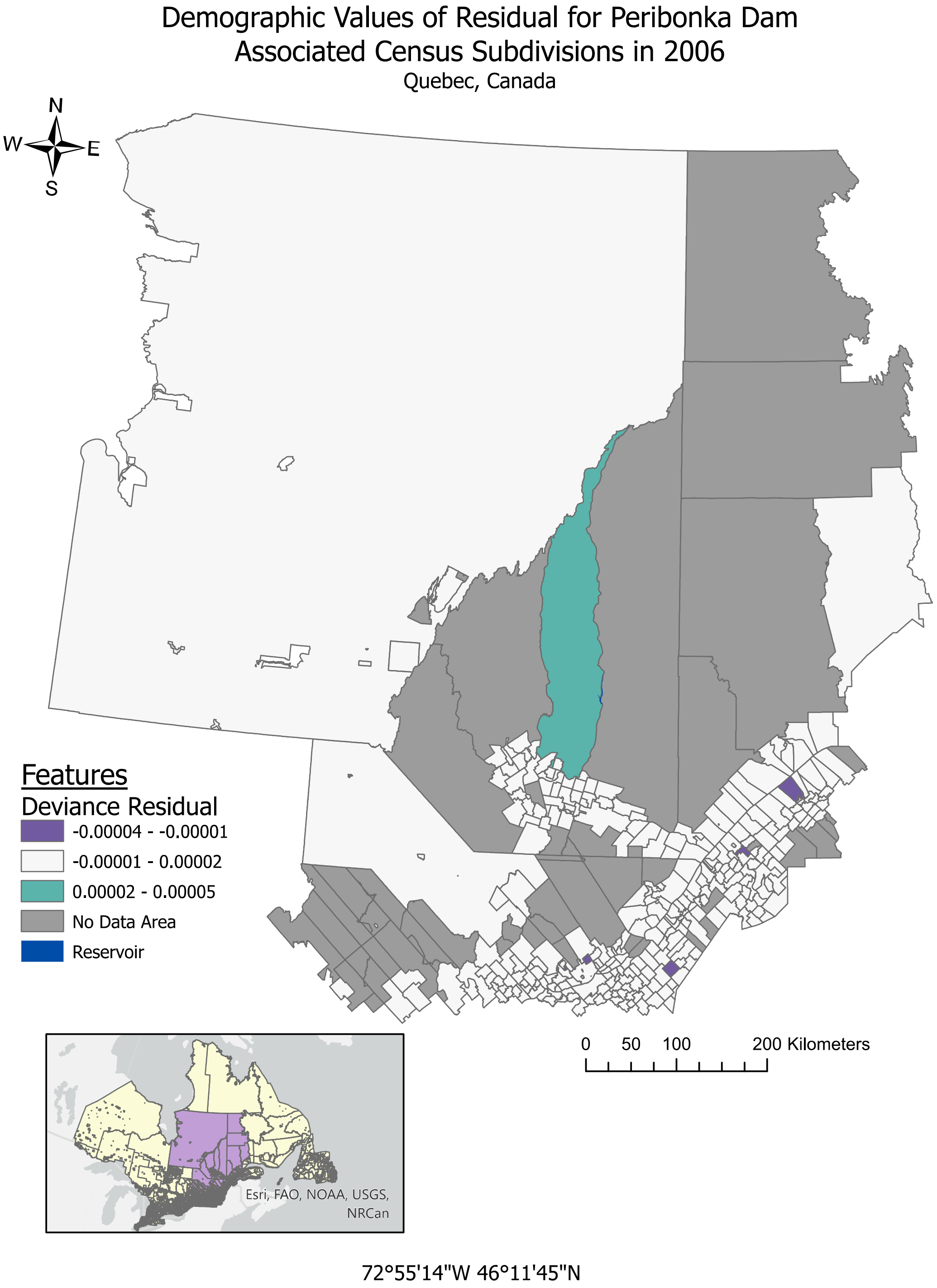


Figure 8. Map showing distribution of deviance residuals and no data regions for CSDs associated with the Peribonka dam and reservoir. Map frame shows the analysis region highlighted within the study area. CSD containing the dam is the only area where a positive deviance residual can be seen. Negative deviance residuals can be noted in some CSDs south of the reservoir. Spatial reference: NAD1983 UTM Zone 19. Data Sourced from Global Dam Watch (2019) (dams and reservoirs), Statistics Canada (2006) (CSD data), and Statistics Canada (2007) (boundary file). Output expressed using equal interval classification method.

Figure 9 is a map of residual deviance for the Rupert dam. As with the other models, no data CSDs comprise much of the area surrounding the dam site (Fig. 9), forcing analysis into mainly the south-west region of the study area map. However, unlike the other modes, the deviance residuals in Fig. 9 do represent a wide range of deviance, and this is represented in five tiers instead of three. The CSD containing the dam deviates from what is predicted by a value of 2.47 (Fig. 9). Negative deviance (purple) is clustered mainly around the southern edge of the study area (Fig. 9).

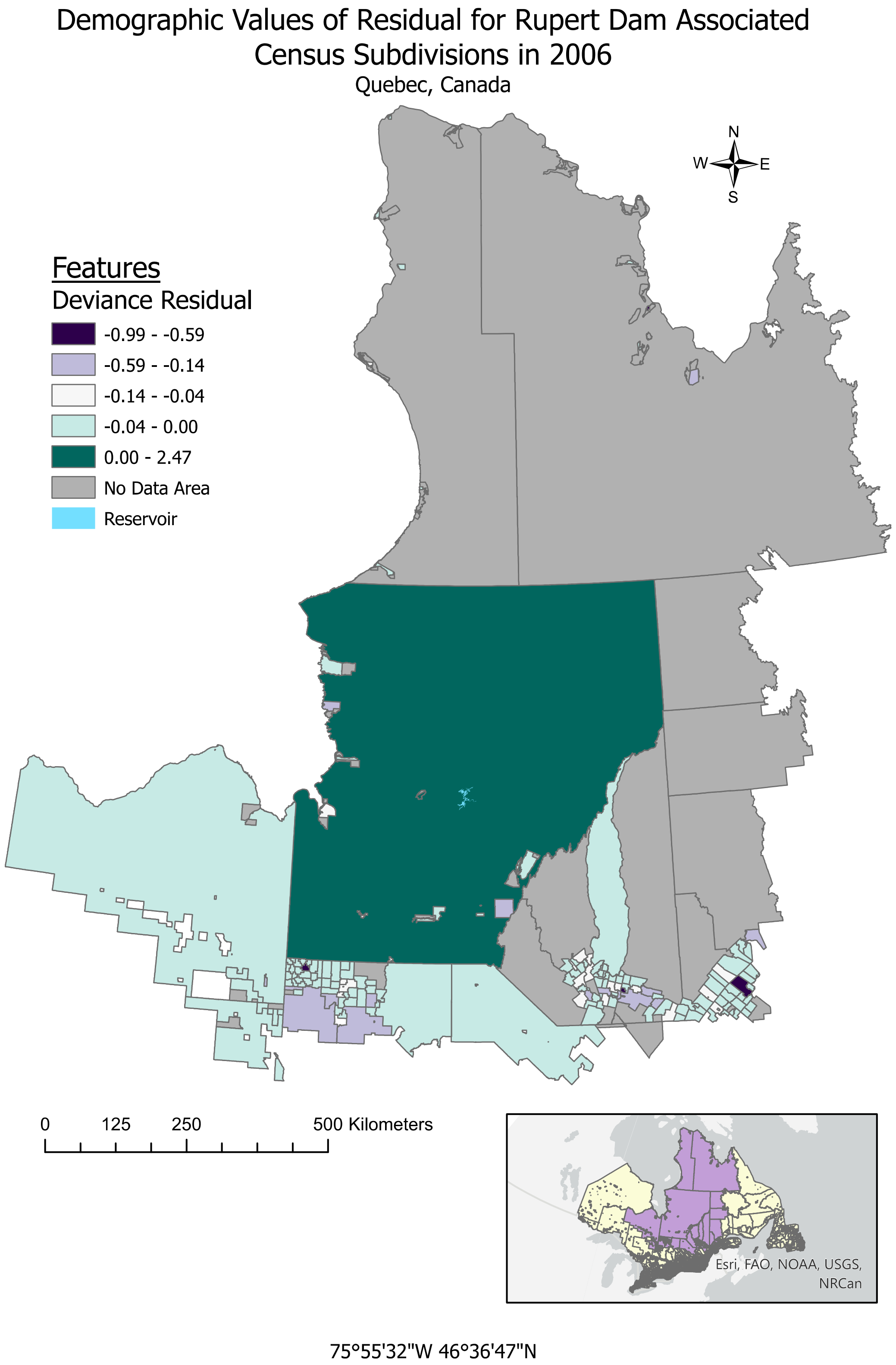


Figure 9. Map showing distribution of deviance residuals and no data regions for CSDs associated with the Rupert dam and reservoir. Map frame shows the analysis region highlighted within the study area. Created by Emma Taniguchi on July 4, 2022. Spatial reference: NAD1983 UTM Zone 18. Data Sourced from Global Dam Watch (2019) (dams and reservoirs), Statistics Canada (2006) (CSD data), and Statistics Canada (2007) (boundary file). Output expressed using Jenks (natural

PART V – DISCUSSION

5.1 NON-SPATIAL REGRESSION

The output statistics from Table 6. a) outline the explanatory strength that the variables have on the proxy POP_DEP (population dependency ratio). The results suggest that with more dependency in a census subdivision, there is an increase of people entering the labour force and a higher number of people living alone, factors for one might expect a negative relationship. However, the increase in participation rate could be attributed to more people having to enter the workforce due to a strain on finances who previously had the option not to work (i.e., teenagers working part-time to support family, stay-at-home parents and/or caretakers, etc.). Related, an increase of people living alone could also be due to young adults moving away from home as their caretaker's dependency increases. Overall, population dependency acts as an astute proxy variable.

Table 6. b) shows 5 explanatory variables, most with negative relationships as they relate to percentage of people who own their own homes (DWL_OWN). It is important to note that percentage of people owning their own homes was chosen as a proxy variable for its potential insight into income statistics regarding a specific area, as those in the position to purchase, rather than rent a home are more likely to be financially stable. Therefore, it makes sense that an increase in people owning their own homes is accompanied by a decrease in percentage of homes in need of major repair, an attribute that can be associated with low-income housing (Table 6. b)). Similarly, an increase in owned homes accompanied by a decrease in percentage of single parents is also logical, as single-income families are less likely to be able to afford a mortgage than those with dual-income. Therefore, DWL_OWN works as an appropriate proxy variable for the more obvious explanatories, as well as a partial proxy for income.

Percentage of the population without a high school diploma (EDU_NCERT) works as a proxy for six explanatory variables, as can be seen in Table 6. c). Several of the explanatories for this variable are palpable; a high school education is a pre-requisite for several careers, thus in areas where there is a large percentage of people without a high school education, it makes sense that unemployment rate would also exist at a higher margin. Related, if there is an increase in unemployment, it is logical that there would be a subsequent increase in the percentage of family income attributed to government wire transfer, as well as an increase in the percentage of dwellings in need of major repair, which as previously discussed, can be representative of low-income housing. More convoluted is a notable decrease in incidence of low income among families with an increase of population without a high school education, a decrease in multi-unit housing, and a decrease in married population. This proxy is interesting because it includes explanatories that can be used as indicators of both high- and low-income. It is pertinent to note that of the four models, EDU_NCERT has the lowest adjusted R^2 value - 0.626 (ref. Table 6. c)). Considering these unexplainable relationships, it is possible that external factors are influencing the outcomes, especially considering the model strength.

Percentage of the population identifying as Indigenous is also a proxy for six variables from CAN-Marg (Table 6. d)). Indigenous people in Canada have a long history of being mistreated by legislators, and thus reservations and other places where their populations are high have gained a reputation of being run-down and having “deplorable” living conditions (Canada Mortgage and Housing Corporation [CMHC], 2009; Patterson & Dyck, 2015). This offers explanation for the positive relationship between Indigenous population and dwellings in need of major repair (Table 6. d)). People living on treaty lands, reserves, or other Indigenous-run communities are typically located in northern and/or rural areas of Canada where employment opportunities are much more difficult to come by, which may explain the decrease in labour force participation rate and increase in unemployment rate associated with a higher Indigenous population (Harding & St-Denis, 2021). An extremely notable trend is the strong relationship between Indigenous population and an increase of average persons per household (coefficient = 33.324, as per Table 6. d)). It is probable that this relationship can be attributed to “multi-generational households,” referring to grandparents living in the same household as their grandchildren, a phenomenon which is more common to see in Indigenous homes (Harding & St-Denis, 2011). One interesting relationship identified is that of an increased percentage of Indigenous population paired with an increase in the percentage of population who lives alone (ref. Table 6. d)). An explanation for this could also be related to multi-generational households; as the elderly vacate their households to live with their children or grandchildren, they may cause a dip in the local housing market, providing opportunity for people in areas with higher Indigenous population to live alone. Lastly, a decrease in incidence of low income among unattached individuals is also an explanatory variable for an increase in Indigenous population, which is inconsistent with existing data (CMHC, 2009; Rotondi et al., 2017). A possible explanation for this from Harding & St-Denis (2021) explains that this is a disparity caused by data suppression that is notably higher for Indigenous reserves, which could result in a biased result and thus produce an inconsistent outcome. This is an important recurring motif that consistently presents itself throughout this analysis.

One variable included in the spatial analysis, yet not used as a proxy is ETH_NWHT, or the percentage of non-Caucasian people/visible minorities present in a census subdivision. This is because significant results could not be obtained when attempting to use it as a proxy or include it as an explanatory variable in any of the instances seen in Table 6. Despite this, research indicating that ethnic minority population is a key factor of marginalization emphasized the pertinence of the inclusion of this variable in the spatial analysis (Matheson et al., 2012). One probable explanation for this can be attributed to the lack of ethnic diversity spanning across all provinces and census years included in this study, especially in Quebec (see Figure 10). Despite the country's reputation of diversity, seeing a census subdivision even 5% visible minority is an anomaly (Statistics Canada, 1996; 2001; 2006). As a result, subdivisions with a visible minority population that comprises more than 10% of the total population may be much more insightful than one might think.

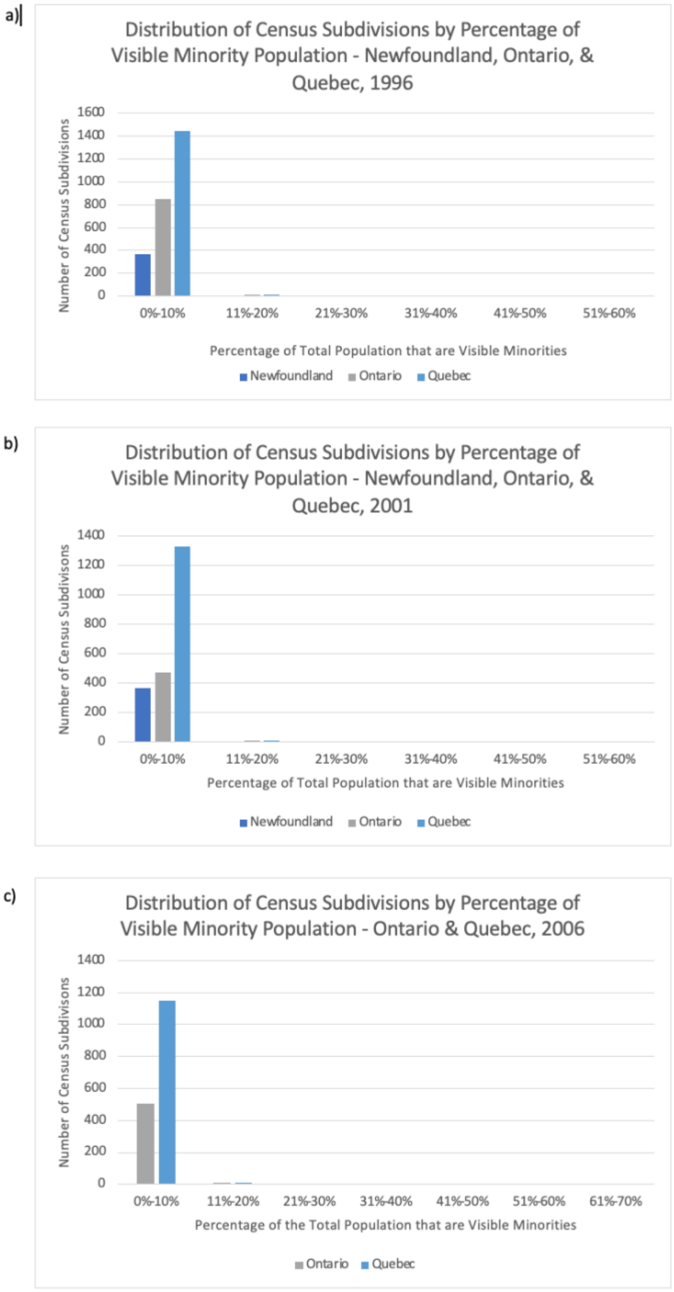


Figure 10. Bar graphs displaying percentage of total population comprised of visible minorities for Newfoundland, Ontario, & Quebec in 1996 (a)) and 2001 (b)) and Ontario & Quebec in 2006 (c)). Each figure shows the corresponding provinces for which CSDs were extracted to conduct analysis. For all shown provinces, the majority of CSDs have ethnic minorities comprising 10% or less of the total population in the vast majority of cases. Created using data from Statistics Canada, 1996; 2001; 2006.

Similarly, percentage of the population having immigrated to Canada within 5 years prior to the census could also not be included as an explanatory variable, as numbers between subdivisions are insignificant. Unlike visible minority population, recent immigration is not regarded as a particularly important variable to include in analysis, and thus was omitted.

5.2 SPATIAL OUTPUT – FACTORS OF MARGINALIZATION

The purpose of including marginalization factors in this study is to determine potential relationships between several demographic factors within geographic locations chosen as dam sites. Out of sixteen models, only five had statistical significance, and of those five, any pattern or trend that would give indication of marginalization is not present. In other words, the variables chosen to represent marginalization render inconsistent within the significant models. In almost every case (excepting La Forge 2), at least one variable represents an opposite relationship that could be expected in representing a marginalized community (Table 8). Specifically related to the applied marginalization factors derived from CAN-Marg, the results indicate that this method is not a reliable way to measure discriminatory practices geographically. One potential reasoning for this is Tobler's first law of geography, which states "everything is related to everything else, but near things are more related than distant things." (Tobler, 1970). The methodology of this research involves conducting a regression on census subdivisions containing, bordering, and otherwise surrounding dam sites for a particular year and region. Based on previous data, and further alluded to with geographic sizes of CSDs, many dams are in rural areas away from city centers. The corresponding spatial analysis detects changes in demographic features based on the specific dam site, however, disparity between certain demographic statistics in rural versus urban communities are acknowledged as an ongoing phenomenon in Canada (Singh, 2002). Statistically, rural areas have higher incidence of low income, have more affordable housing that is less likely to require major repair, and are less likely to have a high percentage of visible minorities contributing to their population (Singh, 2002; Rupnik, Tremblay & Bollman, 2001; Statistics Canada, 2001). As it relates to this study, Tobler's Law would explain how demographic characteristics among neighbouring census subdivisions are more likely to be similar to each other based on the principle of geographic closeness (Tobler, 1970). This may offer some explanation regarding the unexpected relationships seen in variable proxies for marginalization, as the comparative margin is too narrow.

To derive any meaning from the significant output models, they must be individually investigated. La Forge 1 (1991) shows the dam site with a lower percentage of ethnic minorities within the dam site and a lower percentage of people without a high school education as compared to the surrounding CSDs (Table 8). However, the model also finds a higher dependency ratio and a lower percentage of people not owning their own homes within the dam site. La Forge 1 is just one generating station of many comprising James Bay Project, in which development occurred continuously from the years 1971 to 2012 (Gupta, 1992; Atkinson & Mulrennan, 2009). It is one of the dams constructed during the second phase of the project, preceded by three massive generating stations built in phase one (Gupta, 1992). With this in mind, the results depicting the expected relationships are consistent with what one might expect to see following a displacement event: high population dependency as need for additional support from relatives and friends increases, and low percentage of dwellings that are owned, potentially indicative of forced evacuation as once-dry land became flooded. Because these two indicators of marginalization are not paired with higher population percentage of ethnic minorities and people with education below high school, it is unlikely that this model's reports are in fact indicative of marginalization in the area.

La Forge 2 (1996) is the only one of the significant models that indicates consistency in the expected relationships between each marginalization variable (see Table 8). Since it is located in the same CSD as La Forge 1 (a municipality known as Baie-James at the time) and only slightly north-east, it is likely that this model is indicative of environmental marginalization. Considering La Forge 1 demographic trends suggest displacement due to infilling of the reservoir, it is likely that those with the privilege to do so moved away from Baie-James, leaving behind the marginalized population who were not able to do the same. Population change statistics further support this theory, as a -35.6% change in total population within Baie-James can be identified between the years 1991-1996, the census years preceding the La Forge 1 and La Forge 2 dam projects respectively (Fig. 11). Rather than showing preferred selection for this area as a dam site, this model is demonstrating a situation in which marginalized groups are unable to leave a harmful situation due to limitations they face based on their economic and social status.

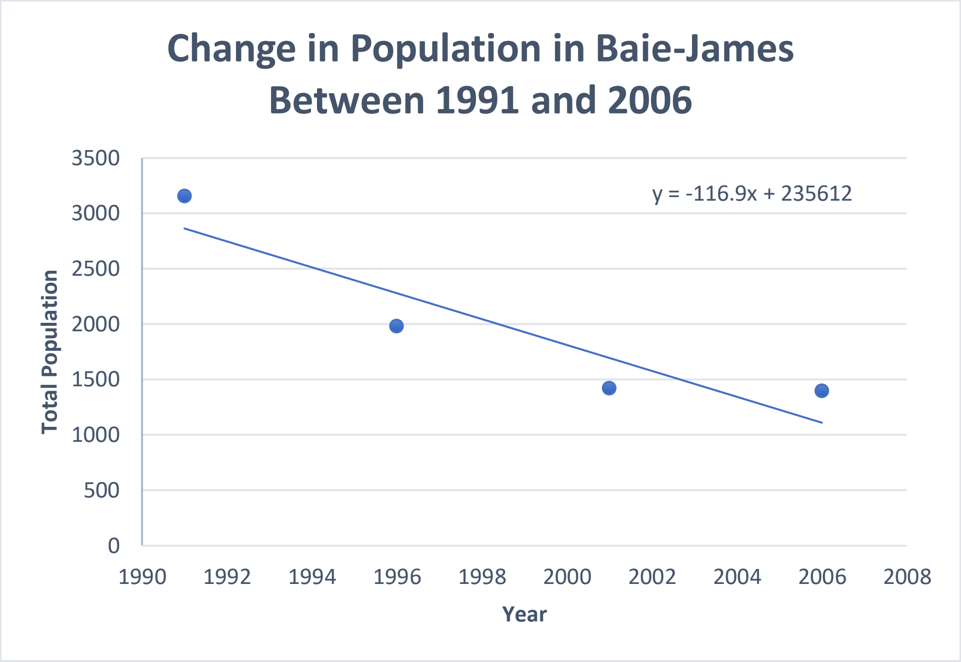


Figure 11. Line graph displaying the change in total population in Baie-James over time. A clear downward trend can be seen with a linear equation included. Notably, the steepest downward slope occurs between 1991 and 1996. Created using data from Statistics Canada, 1996; 2001; 2006.

The Denis-Perron and Peribonka models both show 3/4 marginalization indicators moving in opposite directions than what is expected. Within the CSD containing the Denis-Perron dam, more dwellings are owned, there is a higher percentage of the population with a high school education, and a lower population dependency (see Table 8). However, there are more visible minorities within the dam site as compared to those surrounding. Similarly, the CSD containing Peribonka also has a higher number of dwellings owned and a higher percentage of the population with a high school education, but a lower visible minority population (see Table 8). The only variable consistent with what is expected is a high population dependency. Interpretation of these results are largely hindered by the significant proportion of surrounding CSDs that are non-response/no data areas, and in both cases, this includes CSDs that partly contain the reservoir in question (see Figs. 7 & 8). These models rely heavily on demographic statistics from the urban areas south of the reservoirs since they are forced omit the majority of the rural CSDs within the study area. Due to the data outputs, it can be concluded that neither model alludes to selection of dam site due to demographic indicators of marginalization. However, the no data regions of the study area significantly disadvantage the reliability of these conclusions.

The Rupert Dam (a.k.a. The Rupert Diversion Project) began construction in the modified third phase of the James Bay Project (Atkinson & Mulrennan, 2009). Implementation began following the *Paix des Braves*, for which all development plans were mutually agreed upon by Hydro-Quebec and the local Indigenous people; one notable alteration employed to reduce flooded land by twenty times what had been previously proposed (Atkinson & Mulrennan, 2009). Without the threat of imminent destruction that had been ongoing in Baie-James for years, it is likely that this CSD began to seem like a desirable place to live once again. This may explain the drastic change in marginalization indicators since 1996. Notably, as compared to surrounding CSDs, Baie-James had a lower population dependency ratio, a lower percentage of visible minorities, and a higher percentage of people with a high school education in 2006 (ref. Table 8). The persistence of a lower percentage of people owning their own homes within the CSD is more likely attributed to a residual effect of the persistent flooding in the area from the James Bay Project, rather than a true indicator of low income. Interestingly, after only ten years, the same CSD once overwhelmingly marginalized had become the opposite once again.

5.3 SPATIAL ANALYSIS – INDIGENOUS POPULATION

5.3.1 INSIGNIFICANT MODELS

Although Indigenous population was included as a factor of marginalization within the spatial analysis, it is separated from the other marginalization indicators for interpretation of the models. Indigenous population is not explicitly included as a separate variable in the Canadian Marginalization Index, but malfeasance in Canada, more often than not, has First Nations at the forefront. Of the 16 models, the 11 that report insignificant results allude to the fact that there is no significant spatial relationship that clusters higher instances of Indigenous population specifically around dam sites (ref. Table 7). However, historical patterns in Indigenous community placement around the country as well as insufficient data is a likely cause of this phenomenon.

The Revelstoke Dam in British Columbia is one such example of a non-spatial pattern. British Columbia is known to have had one of the highest instances of urbanized Indigenous communities in the country in 1981, 39% of Indigenous people reporting living within 50 kilometers of an urban center (Cooke, 1987, p. 14). Historically, segregation between Indigenous people and white Canadians was pertinent in British Columbia specifically; the result presenting itself as “more than 1500 small reservations scattered across the province” (Harris, 2002, p. 266). While British Columbia does not have the largest percentage of Indigenous people per total population, the geographic community distribution among communities and reservations is wider than the other provinces, which tend to have communities confined to mainly rural and remote areas (Statistics Canada, 1981; Cooke, 1987, p. 14). Indigenous distribution in the province is likely to have had an impact on the results of this analysis, as the small, isolated communities commonly found elsewhere in Canada are much more likely to represent as discrimination in the analysis software. The same logic can be applied when examining the outputs of Cat Arm and West Salmon dams, both constructed in early 1980s Newfoundland. Due to the small geographic area of the province and relatively few CSDs, these were run in a single analysis, also yielding a non-existent spatial pattern between Indigenous population and dam site. With percentage of Indigenous people among total Newfoundland population under 0.6% in 1981, it is likely that this insignificance is attributed to a lack of overall Indigenous population (Statisitics Canada, 1981).

The Caniapiscau barrage is an interesting anomaly within this analysis. Unlike the other models, Caniapiscau reservoir was not caused directly by the dam with the same name. This reservoir was formed as part of phase one the James Bay Project, in which Caniapiscau, along with two other rivers, was diverted towards James Bay to increase flow rate to the Robert-Bourassa (formerly known as LaGrande 2), LaGrande 3, and LaGrande 4 generating stations (Gupta, 1992). Caniapiscau, LaGrande 3, and LaGrande 4 are all located in the same CSD and have the same corresponding census year preceding their construction (1981). Although both models demonstrate statistical insignificance, LaGrande 3 and 4’s model strength is competitive with the dams that are significant (AICc = 16.633). Notably, La Grande 3 and 4 were the second and third generating stations built in phase one of the James Bay Project, using the diverted flow from several other rivers to correspondingly fill Caniapiscau reservoir (Gupta, 1992; Hornig, 1999, p. 42). Also located in the same CSD are the La Forge 1, 2, and Rupert dams, all part of the James Bay Project and rendering statistically significant outputs (ref. Table 8). This may be a potential reasoning for the model strength output. Regarding the overall model insignificance, 1981 is a poor year for the census. Data outlining specifically Indigenous population is not available and is represented in the ETH_NBRFR variable in the model; in itself, this is not revealing of specific ethnicity. Two CSDs with 70% population that is not of British or French ethnic origin may allude to any range of ethnicity makeup; one may be mostly European and the other African, but the software sees no difference, as it is limited by the constraints of the variable. In later models investigating dams within this CSD, Indigenous population is included as a separate variable, and all rendered significant outputs. This indicates that this is the most viable explanation for the discrepancy.

The Oldman River Dam in Alberta and Limestone Generating Station in Manitoba are more examples of statistical insignificance in a model. Both of these correspond to 1986 as the most recent census year preceding construction, which unfortunately, is the last year that Indigenous identity is not included in data collection of census variables. Without this data, the data regarding specifically Indigenous marginalization cannot be computed geographically within this study. However, it is important to note that while no geographic analysis is possible using this methodology for these dams, the Oldman River Dam controversy remains one of the most well-documented examples of Indigenous injustice at the hands of hydro industry and legislators (Glenn, 1999, p. 6; de Löe, 1999). Limestone, on the other hand, is one of the last generating stations built in by Manitoba Hydro after a series of developments on the major rivers in the northern region of the province (Dipple, 2015). It is generally regarded with mixed opinions, as Manitoba Hydro is outspoken about including Indigenous people in their planning, but this is generally regarded as a surface-level fail-safe to avoid suspicion into unsustainable practices (Dipple, 2015). For these reasons, further investigation into the spatial relationships between Indigenous communities and dam sites for these specific examples have the potential to yield insightful results.

Eastmain-1 is one of the reservoirs built in the second phase of the James Bay Project, along with LaGrande 1, Brisay, Eastmain-2, and LaForge 1 and 2 (Gupta, 1992). Eastmain-1 dam lies south of the projects completed during phase one, but still within Baie-James. Construction plans for this dam were suspended pending the completion of the EIA and signing of the *Paix des Braves,* a result of Hydro-Quebec's failure to uphold the JBNQA (Morantz, 2002, 0. 255-6). With the project activities halted for eight years (1994-2002), it is likely that communities previously displaced by the project felt safe enough to return to Baie-James due to the pause in developments, potentially creating an equal distribution regarding the Indigenous populations in the CSDs surrounding and containing the dam site (Morantz, 2002, p. 255-6). This is further supported by the Indigenous population migration statistics (Fig. 12), as 1996-2001 is the only time period in which positive population growth in Baie-James can be seen. Therefore, it is likely that the statistical insignificance of this model can be attributed to the migration of Indigenous people into the CSD, counterbalancing the demographics within the analysis study area.

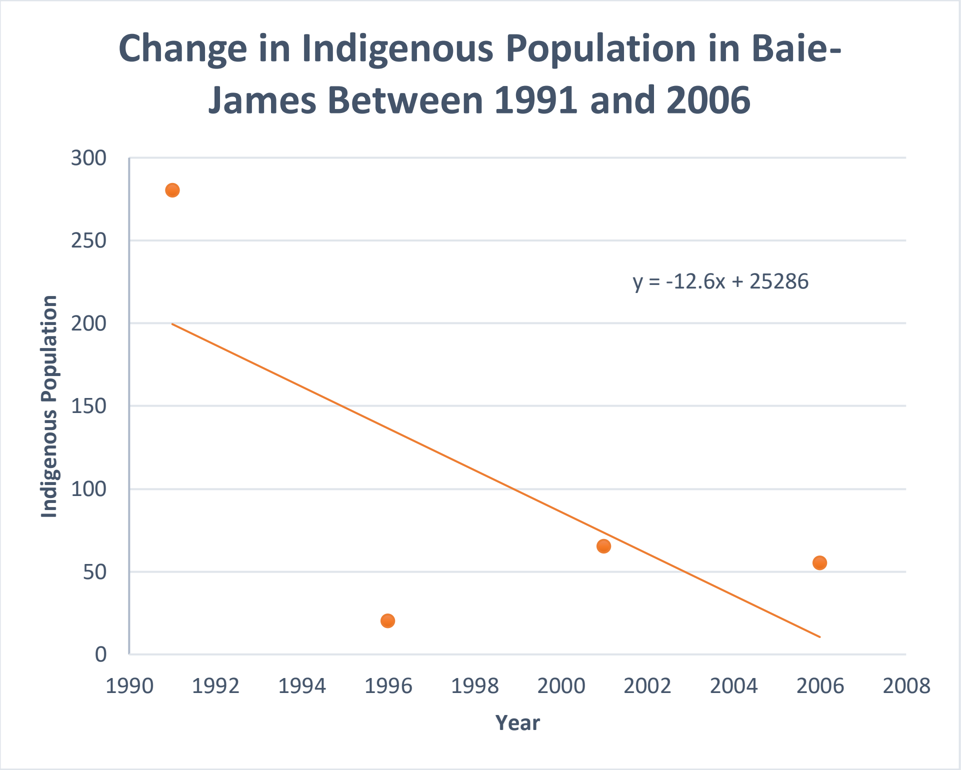


Figure 12. Line graph displaying the change in Indigenous population in Baie-James over time. A clear downward trend can be seen with a linear equation included. The steepest negative slope can be seen between 1991 and 1996. Created using data from Statistics Canada, 1996; 2001; 2006.

Analysis conducted on the Toulnustouc hydro project also yields insignificant results. Based on the geographic distribution of the non-response CSDs surrounding the reservoir, it is likely that insufficient data could be obtained as it relates to Indigenous people in this area. Another potential explanation could be related to Hydro-Quebec's attempt to include Indigenous stakeholders in their projects to avoid a repeat of the James Bay Project. Reports from the construction of this dam comment on how input from the Innu (the Indigenous community occupying north-eastern Quebec and north-western Labrador) was sought in an attempt to reduce impact to land in the area and abide by the new comprehensive land claim agreement (Martin & Hoffman, 2011, p. 261). Although this attempt is still regarded as slightly controversial, the attempt to include the Innu in the planning process does not indicate an attempt to expose the Indigenous community to the hazard unjustly, which would render an insignificant output.

The final insignificant model is the Laniel Dam, located in south-western Quebec bordering Ontario. This dam and associated reservoir were originally constructed in 1911, and then reconstructed in 2006 in the interest of the safety of the local community (Public Works and Government Services Canada, 2005). Subsequently, the reservoir had already been filled and thus any new residual impacts would be minimal. Since the dam had previously existed, it is to be expected than an no significant relationship would be detected in this area.

While these models do not demonstrate significant spatial relationships between dam placement and Indigenous population distribution, in every case, other factors at play indicate that these relationships are far more complex than simply geophysical. In some cases, lack of appropriate Indigenous data prevents adequate analysis from being conducted, concealing any possible significant relationships at play. In others, external variables are suggestive of potential relationships limited by the scope of this study. To thoroughly investigate this, further research is required to determine if these locations are simply insignificant, or if forces outside the realm of this study have altered the outputs.

5.3.2 SIGNIFICANT MODELS

Not every significant model demonstrates a positive (expected) relationship of higher Indigenous populations in dam sites. However, a distinct timeline emerges and provides powerful insight into the historical battle between Canadian hydropower companies and Indigenous people over their unceded territory. To reiterate, the chronologically earliest significant model, La Forge 1, was built in the second phase of the James Bay Project (Gupta, 1992). At this time, statistics on Aboriginal identity had not yet been included as a variable within the census data, and thus Indigenous population s conglomerated into the variable, ETH_NWHT, which conceals information on specific ethnicities. Specific conclusions cannot be drawn regarding Indigenous population as it does not exist as an isolated variable. Despite the lack of geospatial analysis, population change statistics from the 1996 census provide insight into the impact of the first step of phase two. Figure 12 demonstrates Indigenous population change in Baie-James over the span of phase two; between 1991 to 1996, a -1300% drop is seen (Statistics Canada, 1996). Not only does this allow for some interpretation of the impacts of La Forge 1, but also acts as a potential explanation for the La Forge 2 model.

In 1996, the Baie-James CSD had a smaller Indigenous population compared to those surrounding. However, this is to be expected based on Figure 12. Most likely attributed to displacement from La Forge 1, Indigenous people living within Baie-James likely evacuated to neighbouring CSDs, which would explain the significant relationship outlining a higher Indigenous population outside of the dam site. The James Bay Project complicates this analysis as conditions within Baie-James were constantly fluctuating based on the stage and political climate surrounding development. While the data would simply suggest that hydro-developers chose this region as a dam site because of the *lack* of Indigenous population, the complex timeline alters the reliability of that statement.

The complexity of the Baie-James models are further supported with the construction of the Rupert Dam, in which a higher Indigenous population is seen within the CSD as compared the remainder of the study area. In 1994, the project was halted as Hydro-Quebec was found to be in violation of the original agreement that had been enacted between the industry and the Crees (Morantz, 2002, p. 254). During the eight years that construction was stopped, a false sense of security may have been garnered among the Cree people in the area, and those who had evacuated during phase two may have returned. This hypothesis is also supported by the 69.23% increase in Indigenous population between 1996 and 2001 within Baie-James, as seen in Figure 3. Testimonies from Crees living in the area at the time suggest they had confidence that their leadership would not sign an agreement allowing for Hydro-Quebec to further develop the land within the area, and thus felt safe to return (Atkinson & Mulrennan, 2009). However, an agreement was privately signed between the Cree Chief and Quebec officials, allowing a modified version of the Rupert Diversion Project to proceed (Atkinson & Mulrennan, 2009). With the amount of opposition met with this project, it is interesting that Hydro-Quebec would continue with their plans to develop in the north-western region of the province.

As previously mentioned, the Denis-Perron (a.k.a. SM-3) (1996) and Peribonka (2006) models are both disadvantaged due to the number of non-response CSDs surrounding both dam sites see Figs. 7 & 8). Nevertheless, both outputs show a lower Indigenous population within the dam site as compared to the surrounding areas. However, both of these projects began construction after the politics of the James Bay Project had settled, resulting in the JBNQA followed by the *Paix des Braves* (Martin & Hoffman, 2011, p. 261; Morantz, 2002, p. 254). As a result, the Innu were able to reach an agreement with Hydro-Quebec in both cases, ensuring direct benefits to their community in exchange for use of their land (Martin & Hoffman, 2011, p. 277). With potential notice to relocate and/or negotiations to implement the dam in a site that would not directly impact the local Innu, it is logical that a negative relationship between Indigenous population and dam sites would be identified by the model. Despite the drawbacks of the non-response CSDs in these areas, the model output still reports results that align with the historical timeline of hydropower development in the country.

5.4 DATA LIMITATIONS

Although retrieval of results from the spatial regression models was ultimately successful, the scope of analysis and model outputs are severely limited by the inconsistencies and unavailability of census data. The three major data discrepancies acting as roadblocks to this study fall in the range of unavailable data, consistency of data that is available, and quality of available data. Together, these shortcomings contributed to the quality issues pertaining to the output models and provide potential reasoning as to why the results cannot be taken at face value.

As previously mentioned, this study omits the most productive time for hydropower development in Canadian history from analysis (Alfredsen et al., 2021). Census statistics collected prior to 1971 is all but inaccessible, and the data that is available is not digitized and the collection of variables relating to marginalization is very poor. Based on what is presented in the literature, the failure to respect Indigenous rights and various injustices committed against them before the implementation of the JBNQA should present a clear pattern of marginalization and discrimination against Indigenous people throughout the influx of hydro project development in Canada. The absence of data in this respect obstructs any true patterns that may have emerged prior to the JBNQA and subsequently conceals any injustices that may have been committed against vulnerable communities during this time period.

Ultimately, the temporal scope of this study is entirely dependent on the years in which both spatial and sufficient demographic data is available. The inconsistency of CSD cartographic and digital boundary file availability played a large role in narrowing the time frame. As is evident from the output maps (see Figs. 5-9) the variation in geographic size between census subdivisions is significant and as most dams investigated are located within rural zones (larger CSDs), it is pertinent to select the geographic division unit that provides the smallest output area, i.e., EAs/DAs. However, cartographic/digital boundary files using polygon spatial objects are not available for EAs, and the earliest year DA spatial files can be accessed is 2001, encompassing only a small portion of the dams included in the study. Furthermore, even in an attempt to apply the corresponding DA files to the study, the frequency of non-response or no data areas are far more frequent as compared to CSDs (see Appendix C), which transitions into the final category of data discrepancies interfering with the diligence of this study.

Without the option to use EAs/DAs as geographic units for this study, CSDs become the only option. The variability in CSD size is inconvenient as it forces the study to assume equal distribution of population within each subdivision, which is extremely unlikely. Using Baie-James as an example, the CSD is so geographically large that it is impossible to know how much of the population is truly directly impacted by dam implementation; it could be that townships and communities are clustered around the river to be dammed, or that no one lives within 100 kilometers of the dam site. Considering the majority of dams in this study are located within rural areas and geographically massive CSDs, it adds uncertainty into the models; a marginalized community could be clustered around the dam site, but with an area so large, an insignificant output could still be reported. This issue is further complicated with the prevalence of non-response regions.

As is evident from the output maps (Figs. 5-9) several significant (and insignificant) models are surrounded by non-response or no data regions. This phenomenon occurs when the physical boundaries and code for a CSD exists but has no corresponding demographic data, which can occur for two main reasons. Statistics Canada has a variety of methods to ensure confidential information cannot be revealed from census data. The random rounding rule transforms population counts into "randomly rounded" amounts for each category (Statistics Canada, 2017). In other cases, populations in certain areas are too small for data to remain confidential, and thus data from specific categories are removed entirely, i.e., only total population count is released for standard populations less than 40 and non-standard less than 100, income data is only released for populations larger than 250, etc. (Statistics Canada, 2017). However, even with these protocols in place, some CSD data is removed altogether and classified as "not released" when StatsCan believes there is still a chance of a confidentiality breach (Statistics Canada, 2022). Especially in rural areas where populations are small, this is likely to be the case in many situations.

The second reason CSD data may be suppressed is due to an inadequate response rate, for which responses had not been obtained for an appropriate sample size and therefore, have the potential to skew or otherwise compromise the data quality (Statistics Canada, 2022). Over time, StatsCan has refined response-rate determination tools and motivation techniques have been implemented to increase census response rates, including fining non-responders (Statistics Act, 1985). However, there are several factors contributing to under-counts and/or unresponsive populations that contribute to an unfortunate pattern. Changes to the census have been made throughout the years that prevent it from existing as a continuous and reliable data source, including the shift to statistics based on 20% sample data, a symptom of the few years in which the census was not mandatory (Green & Milligan, 2010). When profiling a population of millions, 20% is not likely to give an accurate representation, especially when statistics show there are specific groups that are less likely to respond (Green & Milligan, 2010). Unfortunately for this study, these groups include Indigenous people, those living in remote or rural locations, and high-income households (Green & Milligan, 2010). The census also operates by profiling households, which would provide an obvious misrepresentation of those living in poverty, thus constantly moving around and some without a home address (Rotondi et al., 2017). A study by Rotondi et al. (2017) finds an underestimation of Indigenous population in the city of Toronto by a factor of 2 to 4. Based on this data, the non-response regions from this study could potentially have a substantial Indigenous community and furthermore, the CSDs included in the regression are likely to under-represent the true community demographics.

For the numerous, and valid reasons that Indigenous and other marginalized societal groups choose not to respond to the census, the vitality of accurate demographic data in the census cannot be overstated. Research into environmental justice is largely hindered by these statistical weaknesses, and uncovering spatial patterns is not truly possible without access to unbiased, appropriate statistics. While the results of this study allow for interpretations about spatial patterns and provide insight into the politics surrounding hydro developments from 1981-2011, so much is still unknown, a gap unfortunately caused by the quality and absence of demographic data in Canada.

Furthermore, the results from this study are inconsistent in terms of marginalized communities, some models even showing preference for populations more privileged as dam sites. While inconsistencies are also detected in the case of Indigenous populations, a distinct timeline emerges within the model patterns that align with the political history of hydro developments over time. While this demonstrates that government and industry are not targeting Indigenous communities as dam sites, there is certainly a pattern of inconsideration of adverse impacts on any potential impacts to First Nations, closely coupled with a failure to consider treaty violations and Indigenous land claims. The repetitive destruction of historical and sacred Indigenous land is revered as simply an unavoidable part of the process in every project constructed prior to the JBNQA. Clearly, this is an issue that extends beyond simple dam site proximity to Indigenous populations, as in many of these cases, the destroyed land is not used as community or reservation ground, but rather is heavily depended on by the Indigenous people to maintain their culture through hunting, trapping, gathering, and religious practices that have been maintained for generations.

With the continuous strife caused by hydroelectric projects in Canada, this method to “better Canada’s future” comes at the cost of reconciliation. The crimes against Indigenous people in Canada are kept alive with the continuous dependence on hydropower and contribute to the neoliberalism that separates white Canadians from the marginalized. The James Bay Project is a classic example of the NIMBY approach – regarded as a development the province of Quebec “just can’t do without,” but neither benefits the Indigenous people nor was considered a potentially inappropriate location, especially as the power grid to be connected is entirely south of the generating site (Gupta, 1992). With the number of un-dammed rivers rapidly decreasing as Canada’s energy needs grow, it is time to consider whether the continued investment into hydropower is worth the expense of the continuous alienation of the Indigenous people, who soon may not have any land left to steal.

PART IV – CONCLUSION

Despite what is outlined in the literature, the methodology applied in this study did not render significant results equating a geospatial relationship between marginalized communities. Out of the 16 models analyzed, 11 yielded insignificant results, and the remaining five are largely inconclusive or otherwise demonstrate weak indication of community marginalization as a potential factor for determination of dam site. Indigenous population in the significant models also yields inconclusive results, however, most models align with distinct historical timelines regarding Indigenous movements in response to hydroelectric developments. While a significant geospatial relationship was not detected in this study, this revelation suggests that perhaps a correlation does exist, but the data and methodology applied in this study were not able to reveal this relationship.

A potential reason for the inconclusive and insignificant results of this study is the disparity in publicly accessible demographic data. The Canadian Census is heavily depended on regarding research into environmental justice for the revelations of community dynamics and vast expanse of statistical information. The recent alterations to the census have only served to reduce consistency and further obstruct potential discriminatory relationships from being revealed. Due to years of mistreatment, Indigenous (and other minority) communities have become distrustful of the government, and greater effort and alternate methodology must be employed to encourage census submission by taking steps to educate minority communities on how the collected data serves to benefit them, rather than invade their privacy (Rotondi et al., 2017). Furthermore, it is important to point out the suppression of data is not always due to low response rates, and sometimes to conceal confidential information regarding the residents of low-populated towns (Statistics Canada, 2022). However, if StatsCan were to separate the ‘non-response’ regions from the under-populated in separate categories, insight into community dynamics could be achieved by data analysts while still protecting the privacy of the residents.

The results of this study indicate that dam site is not preferentially selected for marginalized or Indigenous communities, but the models did mirror the timelines of hydropower development in the country and their political climates. To obtain a full picture of the impact of hydroelectric damming in Canada, further research should be conducted on community demographics and Indigenous communities surrounding dam sites prior to the year 1981 to determine if spatial relationships are recognized in areas where significant harm was caused. Additionally, research into Indigenous movements in Canada over time, including years of land claim, reservation, and treaty establishment will give a better understanding into the degree of infringement on Indigenous rights and bridge the gaps in the timeline.

This research reveals an ongoing disdain for Indigenous perspective if it interferes with industrial development. Consistently, mass Indigenous displacement and destruction of unceded land was not considered a problem when the project was in the interest of the urbanized population. With hydropower still Canada's leading energy source, it is important to recognize the implications that come with it. Recent studies show that the country has only dammed half its existing capacity (Haffner & Burpee, 2017); if Canada continues to push forward with long-term plans for hydro development, it may come at the cost of reconciliation.

REFERENCES

Alfredsen, K. Amundesen, P.-A., Hahn, L., Harrison, P. M., Helland, I. P., Martins, E. G., Twadek, W. M. & Power, M. (2021). A synoptic history of the development, production and environmental oversight of hydropower in Brazil, Canada, and Norway. *Hydrobiologia 849*, 269-280. Doi: 10.1007/s10750-021-04709-4

Ansar, A., Flyvbjerg, B., Budzier, A. & Lunn, D. (2014). Should we build more large dams? The actual costs of hydropower megaproject development. *Energy Policy 69*, 43-56. https://doi-org.ezproxy.library.dal.ca/10.1016/j.enpol.2013.10.069

Atkinson, M. & Mulrennan, M. E. (2009). Local protest and resistance to the Rupert Diversion Project, Northern Quebec. *Arctic 62*(4), 468-480. http://www.jstor.org/stable/40513337

Aung, T. S., Fischer, T. B. & Azmi, A. S. (2021). Social impacts of large-scale hydropower project in Myanmar: a social life cycle assessment of Shweli hydropower dam 1. *The International Journal of Life Cycle Assessment, 26*(2021), 417-433. https://doi-org.ezproxy.library.dal.ca/10.1007/s11367-021-01868-3

Baird, I. G., Silvano, R. A. M., Parlee, B., Poesch, M., Maclean, B., Napoleon, A., Lepine, M & Hallwass, G. (2021). The downstream impacts of hydropower dams and Indigenous and local knowledge: Examples from the Peace – Athabasca, Mekong, and Amazon. *Environmental Management 67*(4), 682-696. https://doi.org/10.1007/s00267-020-01418-x

Bakker, K. & Hendriks, R. (2019). Contested knowledge in hydroelectric project assessment: The case of Canada's site C project. *Water 2019 11*(406), 28-45. Doi: 10.3390/w11030406

Behn, C. & Bakker, K. (2019). Rendering technical, rendering sacred: The politics of hydroelectric development on British Columbia's Saaghii Naachii/Peace River. *Global Environmental Politics 19*(3), 98-119. https://doi.org/10.1162/glep_a_00518

Bello, M. O., Solarin, S. A., Yen, Y. Y. (2020). Interfuel substitution, hydroelectricity consumption and CO2 emissions mitigation in Malaysia: evidence from a transcendental logarithm (trans-log) cost function framework. *Environmental Science and Pollution Research, 27* 17162-17174. https://doi.org/10.1007/s11356-020-08251-z

Bernard, D. (2018). Reconciliation and environmental racism in Mi'kma'ki. *Kalfou, 5*(2), 297. Doi: 10.15367/kf.v5i2.214

Canada Mortgage and Housing Corporation. (2009). *Preconditions leading to market housing on reserve.* CID: 20.500.12592/12zcdn. http://canadacommons.ca/artifacts/1205295/preconditions-leading-to-market-housing-on-reserve/1758404/

Caner Sayan, R. (2017). Urban/rural division in environmental justice frameworks: Revealing modernity-urbanisation nexus in Turkey's small-scale hydropower development. *Local Environment 22*(12), 1510-1525. Doi: 10.1080/13549839.2017.1368465

Carver, M. (2013). Impacts of the proposed site C dam on the hydrologic recharge of the Peace-Athabasca delta. *Aqua Environmental Associates.* https://www.ceaaacee.gc.ca/050/documents_staticpost/63919/96375/4-November_25_2013-Impacts_of_the_Proposed_Site_C_Dam_on_the_Hydrologic_Recharge_of_the_Peace-Athabasca_Delta.pdf

CHASS. (2014). *Canadian Census Analyzer.* Faculty of Arts & Science, University of Toronto. http://dc1.chass.utoronto.ca/census/

Chen, X. (2018). A spatial and temporal analysis of the socioeconomic factors associated with breast cancer in Illinois using geographically weighted generalized linear regression. *Journal of Geovisualization and Spatial Analysis 2*(5). Doi: 10.1007/s41651-017-0011-5

Cooke, F. M., Nordensvard, J., Saat, G. B., Urban, F. & Siciliano, G. (2017). The limits of social protection: The case of hydropower dams and Indigenous people's land. *Asia and the Pacific Policy Studies, 4*(3), 437-450. https://doi.org/10.1002/app5.187

Cooke, K. (1987). *An overview of registered Indian conditions in British Columbia*. Indian and Northern Affairs Canada [Press].

Davoudi, S. & Brooks, E. (2014). When does unequal become unfair? Judging claims of environmental justice. *Environment and Planning A 46,* 2686-2702. Doi: 10.1068/a130346p de Löe, R. C. (1999). Dam the news: Newspapers and the Oldman River Dam project in Alberta. *Journal of Envrionmental Management 55*(4), 219-237. https://doi-org.ezproxy.library.dal.ca/10.1006/jema.1999.0258

Dipple, J. (2015). *Implications of hydroelectric partnerships in northern Manitoba: Do partnership agreements provide social licence?* [Unpublished master's thesis]. University of Manitoba. https://mra-mb.ca/wp-content/uploads/dipple_joseph-1-copy-1.pdf

Esri Inc. (2021). *ArcGIS Pro* (Version 2.8). Esri Inc: Redlands, CA, USA. https://pro.arcgis.com/en/pro-app/2.8/get-started/get-started.htm

Esri Inc. (n.d.). *What they don't tell you about regression analysis.* ArcGIS Pro (version 2.8). https://pro.arcgis.com/en/pro-app/2.8/tool-reference/spatial-statistics/what-they-don-t-tell-you-about-regression-analysis.htm

Feng, D & Beighley, E. (2020). Identifying uncertainties in hydrologic fluxes and seasonality from hydrologic model components for climate change impact assessments. *Hydrology and Earth Sytems Sciences, 24*(5) 2253-2267. doi: 10.5194/hess-24-2253-2020

Froschauer, K. (1999). *White gold: Hydroelectric power in Canada.* UBC Press

Glenn, J. (1999). *Once upon an Oldman: Special interest politics and the Oldman River Dam.* UBC Press.

Global Dam Watch. (2019). GRanD (version 1.3) [Data file]. Retrieved from https://globaldamwatch.org/grand/

Government Canada. (2018). Electricity Facts. *Natural Resources Canada*. https://www.nrcan.gc.ca/science-and-data/data-and-analysis/energy-data-and-analysis/energy-facts/electricity-facts/20068

Government of Canada. (2021). *The UTM Grid – Universal Transverse Mercator Projection.* https://www.nrcan.gc.ca/earth-sciences/geography/topographic-information/maps/utm-grid-map-projections/utm-grid-universal-transverse-mercator-projection/9779

Green, D. A. & Milligan, K. (2010). The importance of the long form census to Canada. *Canadian Public Policy 36*(3), 383-388. https://doi.org/10.3138/cpp.36.3.383

Gupta, A. (1992). Canadian hydro-electric project – James Bay: An explosive agenda of politics, money, and the environment. *World Affairs: The Journal of International Issues 1*(1), 40-45. http://www.jstor.org/stable/45064142

Haffner, J. & Burpee, J. (2017). More hydro power in Canada: Tapping our potential. *Canadian Global Affairs Institute.* CID: 20.500.12592/715v1f.

Harding, A. & St-Denis, X. (2021). Low-income statistics for the population living on reserve and in the north using the 2016 census. *Statistics Canada.* CID: 20.500.12592/cpgq4s

Harris, C. (2002). *Making Native space: Colonialism, resistance, and reserves in British Columbia.* UBC Press.

Harrison, G. P. & Whittington, H. W. (2002). Investment in renewable energy: accounting for climate change. *IEEE Power Engineering Society Summer Meeting 1,* 140-144. Doi: 10.1109/PESS.2002.1043199

Hergerl, G. C., Zwiers, F. W., Braconnot, P., Gillett, N. P., Luo, Y., Marengo Orsini, J. A., Nicholls, N., Penner, J. E. & Stott, P. A. (2007). Understanding and Attributing Climate Change. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Avery, K. B., Tignor, M. & Miller, H. L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Hornig, J. F. (Ed.). (1999). *Social and environmental impacts of the James Bay Hydroelectric Project.* McGill-Queens University Press.

Hurzeler, T., Buckley, N. A., Noghrehchi, F., Malouf, P., Page, A., Schumann, J. L. & Chitty, K. M. (2021). Alcohol-related suicide across Australia: a geospatial analysis. *Australian and New Zealand Journal of Public Health, 45*(4) 394-399. https://doi.org/10.1111/1753-6405.13122

Indian Act, RCS 1985, c. I – 5.

Islam, M., Fartaj, A. & King, S.-K. (2004). Current utilization and future prospects of emerging renewable energy applications in Canada. *Renewable and Sustainable Energy Reviews 8*(6), 493-519. https://doi.org/10.1016/j.rser.2003.12.006

Johnson, F. A., Hutton, C. W., Hornby, D., Lázár, A. N. & Mukhopadhyay, A. (2016). Is shrimp farming a successful adaptation to salinity intrusion? A geospatial associative analysis of poverty in the populous Ganges-Brahmaputra-Meghna Delta of Bangladesh. *Sustainability Science 11,* 423-439. https://doi.org/10.1007/s11625-016-0356-6

Karanasios, K & Parker, P. (2018). Tracking the transition to renewable electricity in remote Indigenous communities in Canada. *Energy Policy 118,* 169-181. https://doi.org/10.1016/j.enpol.2018.03.032

Ledec, G. & Quintero, J. D. (2003). Good dams and bad dams: Environmental criteria for site selection of hydroelectric projects. *Latin America and Caribbean Region Sustainable Development Working Paper 16*. https://openknowledge.worldbank.org/bitstream/handle/10986/20226/303600NWP0Good000010Box18600PUBLIC0.pdf?sequence=1&isAllowed=y

Lee, P. G., Cheung, R. & Scheelar, C. (2012). *Hydropower developments in Canada: Greenhouse gas emissions, energy outputs and review of environmental impacts.* Global Forest Watch Canada [Press].

Lee, P. G., Hanneman, M. & Cheng, R. (2011). *Hydropower developments in Canada: Number, size and jurisdictional and ecological distribution.* Global Forest Watch Canada [Press].

Lehner, B., Liermann, C. R., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Döll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J. C., Rodel, R., Sindorf, N. & Wisser, D. (2011). High resolution mapping of the world's reservoirs and dams for sustainable river-flow management. *Fronteirs in Ecology and the Environment 9*(9), 494-502. https://doi.org/10.1890/100125

Liu, X., Divani, A. A. & Petersen, A. (2022). Truncated estimation in functional generalized linear regression models. *Computational Statistics & Data Analysis 169,* 107421. https://doi-org.ezproxy.library.dal.ca/10.1016/j.csda.2022.107421

Lovejoy, S., del Rio Amador, L., Hébert, R. & de Lima, I. (2016). Giant natural fluctuation models and anthropogenic warming. *Geophysical Research Letters 43*(16), 8670-8676. https://doi.org/10.1002/2016GL070428

Majumder, P., Majumder, M & Saha, A. K. (2018). Climate change and urbanization on hydropower plant by network-based decision-making methods: Identification of the most significant parameter. *Water Conservation Science and Engineering 3,* 169-179. https://doi.org/10.1007/s41101-018-0048-4

Martin, D., Anders, A., Gernaat, D. & Verones, F. (2020). Controlling biodiversity impacts of future global hydropower reservoirs by strategic site selection. *Scientific Reports 10*(1). doi: 10.1038/s41598-020-78444-6

Martin, T. & Hoffman, S. M. (2011). *Power struggles: Hydro development and First Nations in Manitoba and Quebec.* University of Manitoba Press.

Mascarenhas, M. (2012). *Where the waters divide: Neoliberalism, white privilege, and environmental racism in Canada*. Lexington Books.

Matheson, F. I., Dunn, J. R., Smith, K. L. W., Moineddin, R. & Glazier, R. H. (2012). Development of the Canadian Marginalization Index: A new tool for the study of inequality. *Canadian Journal of Public Health, suppl. Contemporary Use of Area-based Socio-economic Measures 103*(Suppl. 2), S12-S16A. https://www.proquest.com/docview/1269153593/fulltextPDF/CF1E933CFC644FDPQ/1?accountid=10406

Meng, Y., Liu, J., Leduc, S., Mesfun, S., Kraxner, F., Mao, G., Qi, W. & Wang, Z. (2020). Hydropower production benefits more from 1.5 °C than 2 °C climate scenario. *WaterResources Research 56*(5), 29-37. https://doi-org.ezproxy.library.dal.ca/10.1029/2019WR025519

Morantz, T. (2002). *The white man's gonna getcha: The colonial challenge to the Crees in Quebec.* McGill-Queens University Press.

Patterson, D. & Dyck, L. (2015). Housing on First Nation reserves: Challenges and successes. *Interim Report of the Standing Senate Committee on Aboriginal Peoples.* CID: 20.500.12592/vqnzs3. https://canadacommons.ca/artifacts/1216647/housing-on-first-nation-reserves/1769750

Pellow, D. & Vazin, J. (2019). The Intersection of race, immigration status, and environmental justice. *Sustainability 11*(14), 3942. Doi: 10.3390/su11143942

Pérez-Rincón, M., Vargas-Morales, J. & Martinez-Alier, J. (2019). Mapping and analyzing ecological distribution conflicts in Andean countries. *Ecological Economics 157,* 80-91. https://doi-org.ezproxy.library.dal.ca/10.1016/j.ecolecon.2018.11.004

Richards, M. P. (2014). The gerrymandering of school attendance zones and the segregation of public schools: A Geospatial Analysis. *American Educational Research Journal 51*(6), 1119-1157. http://www.jstor.org/stable/24546713

Powys White, K. (2018). On resilient parasitisms, or why I'm skeptical of Indigenous/settler reconciliation. *Journal of Global Ethics 14*(2), 277-289. https://doi-org.ezproxy.library.dal.ca/10.1080/17449626.2018.1516693

Public Works and Government Services Canada (2005). *$13,406,560 contract awarded to reconstruct the Laniel Dam.* Retrieved from Public Works and Government Services Canada. https://www.canada.ca/en/news/archive/2005/11/13-406-560-contract-awarded-reconstruct-laniel-dam.html

Robescu, L. D. & Bondrea, D. A. (2019). The water footprint from hydroelectricity: a case study for a hydropower plant in Romania. *E3S Web of Conferences 85,* 6012-6019. Doi: 10.1051/e3sconf/20198506012

Rotondi, M. A., O'Campo, P., O'Brien, K., Firestone, M., Wolfe, S. H., Bourgeois, C. & Smylie, J. K. (2017). Our health counts Toronto: Using respondent-driven sampling to unmask census undercounts of an urban indigenous population in Toronto, Canada. *BMJ Open 7.* Doi: 10.1136/bmjopen-2017-018936

Rupnik, C., Tremblay, J. & Bollman, R. D. (2001). Housing conditions in predominately rural regions. *Rural and Small Town Canada Analysis Bulletin 2*(4). (Ottawa: Statistics Canada, Catalogue no. 21-006-XIE). https://www150.statcan.gc.ca/n1/en/pub/21-006-x/21-006-x2000004-eng.pdf?st=80Rddsmd

Schaeffer, R., Szklo, A. S., de Lucena, A. F. P., Borba, B. S. M. C., Nogueira, L. P. P., Fleming, F. P., Troccoli, A., Harrison, M., Boulahya, M. S. (2012). Energy sector vulnerability to climate change: A review. *Energy 38*(1), 1-12. https://doi.org/10.1016/j.energy.2011.11.056

Schnell, K., Collier, S., Derado, G., Yoder, J. & Warner Gargano, J. (2016). Giardiasis in the United States – an epidemiologic and geospatial analysis of county-level drinking water and sanitation data, 1993-2010. *Journal of Water and Health 14*(2), 267-279. Doi: 10.2166/wh.2015.283

Schultz, J. M., Sands, D. E., Kossin, J. P. & Galea, S. (2020). Double environmental injustice – Climate change, Hurricane Dorian, and the Bahamas. *The New England Journal of Medicine 382,* 1-3. Doi: 10.1056/NEJMp1912965

Sheehan, M. (2020). "Something is wrong here:" An interview with Sarah Cox about damming Canadian rivers for hydroelectricity. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy.* https://doi-org.ezproxy.library.dal.ca/10.1177%2F1048291120976645

Singh, V. (2002). Rural income disparities in Canada: A comparison across the provinces. *Rural and Small Town Canada Analysis Bulletin 3*(7). (Ottawa: Statistics Canada, Catalogue no. 21-006-XIE). https://www150.statcan.gc.ca/n1/en/pub/21-006-x/21-006-x2001007-eng.pdf?st=Kbv40wBQ

Sovacool, B. K. & Walter, G. (2018). Internationalizing the political economy of hydroelectricity: security, development, and sustainability in hydropower states. *Review of International Political Economy 26*(1). https://doi.org/10.1080/09692290.2018.1511449

Statistics Act, RSC 1985, c. S – 19.

Statistics Canada. (1981). *Census Profile for Canada, Provinces and Territories, Census Divisions and Census Subdivisions, 1981 Census – Part B* (Table 97-570-X1981005) [Data set]. https://www12.statcan.gc.ca/datasets/Alternative.cfm?PID=113752

Statistics Canada. (1986). *Census Profile for Canada, Provinces and Territories, Census Divisions and Census Subdivisions, 1986 Census – Part A* (Table 97-570-X1986002) [Data set]. https://www12.statcan.gc.ca/datasets/Alternative.cfm?PID=113684

Statistics Canada. (1991). *Profile of Census Divisions and Subdivisions – Part A* (Table 95F0168X) [Data set]. https://www12.statcan.gc.ca/datasets/Alternative.cfm?PID=29

Statistics Canada. (1996). *Profile of Census Divisions and Subdivisions, 1996 Census* (Table 95F0181XDB96001) [Data set]. https://www12.statcan.gc.ca/datasets/Alternative.cfm?PID=35782

Statistics Canada. (2001). *Profile for Canada, Provinces, Territories, Census Divisions and Census Subdivisons, 2001 Census* (Table 95F0495XCB2001001) [Data set]. https://www12.statcan.gc.ca/datasets/Alternative.cfm?PID=68767

Statistics Canada. (2001). *Visible Minorities in Canada – Canadian Centre for Justice Statistics Profile Series.* (No. 85F0033MIE). https://www150.statcan.gc.ca/n1/en/pub/85f0033m/85f0033m2001009-eng.pdf?st=nU--YN00

Statistics Canada. (2006). *Census Profile for Canada, Provinces, Territories, Census Divisions, Census Subdivisions and Dissemination Areas, 2006 Census* (Table 94-581-XCB2006002) [Data table]. https://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/rel/Ap-eng.cfm?LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=0&GK=0&GRP=0&PID=94534&PRID=0&PTYPE=89103&S=0&SHOWALL=0&SUB=0&Temporal=2006&THEME=81&VID=0&VNAMEE=&VNAMEF=

Statistics Canada (2017). *Guide to the Census of Population, 2016.* (No. 98-304-X2016001). https://publications.gc.ca/collections/collection_2017/statcan/98-304-x/98-304-x2016001-eng.pdf

Statistics Canada. (2022). *Boundary files* [Dictionary]. https://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-eng.cfm

Statistics Canada. (2022). *Geographic areas not released, 2021 Census of Population.* https://www12.statcan.gc.ca/census-recensement/2021/ref/sup/index-eng.cfm

Statistics Canada. [ESRI Shape]. *Cartographic Boundary File (CBF), 1986 Census.* Ottawa: Statistics Canada, 1988

Statistics Canada. [ESRI Shape]. *Cartographic Boundary File (CBF), 2001 Census.* Ottawa: Statistics Canada, 2002

Statistics Canada. [ESRI Shape]. *Digital Boundary File (DBF), 1981 Census.* Ottawa: Statistics Canada, 1983

Statistics Canada. [ESRI Shape]. *Digital Boundary File (DBF), 1991 Census.* Ottawa: Statistics Canada, 1992

Statistics Canada. [ESRI Shape]. *Digital Boundary File (DBF), 1996 Census.* Ottawa: Statistics Canada, 1997

Statistics Canada. [ESRI Shape]. *Digital Boundary File (DBF), 2006 Census.* Ottawa: Statistics Canada, 2007

Stocker, T. F., Qin, D., Plattner, G. K., Tignor, M. M. B., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V. & Midgley, P. M. (2014). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of IPCC the Intergovernmental Panel on Climate Change*. Cambridge University Press http://dx.doi.org/10.1017/CBO9781107415324

Sullivan, S. (2017). White privilege. *The Oxford Handbook of Philosophy and Race.* Doi: 10.1093/oxfordhb/9780190236953.013.8

Tobler, W. R. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography 46,* 234-240. https://doi.org/10.2307/143141

Vaz, E., Anthony, A. & McHenry, M. (2017). The geography of environmental injustice. *Habitat International 59,* 118-125. https://doi-org.ezproxy.library.dal.ca/10.1016/j.habitatint.2016.12.001

Vélez Torres, I. (2012). Water grabbing in the Cauca Basin: The capitalist exploitation of water and dispossession of Afro-descendant communities. *Water Alternatives 5*(2), 431-449. https://ezproxy.library.dal.ca/login?url=https://www.proquest.com/scholarly-journals/water-grabbing-cauca-basin-capitalist/docview/1151964193/se-2

Wang, B., Nistor, I., Murty, T. & Wei, Y.-M. (2014). Efficiency assessment of hydroelectric power plants in Canada: A multi criteria decision making approach. *Energy Economics 46,* 112-121. https://doi.org/10.1016/j.eneco.2014.09.001

Willow, A. J. (2020). Destruction and disjuncture: Ironies of apology, exhibition, and ethnography along British Columbia's dammed Peace River. *Ethnohistory 67*(1), 49-74. https://doi-org.ezproxy.library.dal.ca/10.1215/00141801-7888707

Winemiller, K. O., McIntyre, P. B., Sáenz, L. et al. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science 351*(6269), 128-129. https://doi.org/10.1126/science.aac70823

Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L. & Tockner, K. (2014). A global boom in hydropower dam construction. *Aquatic Sciences 77*(2015), 161-170. https://doi-org.ezproxy.library.dal.ca/10.1007/s00027-014-0377-0

APPENDIX A

Variable Descriptions - Census 1981	
Variable Name	Description
POP_DEP	Population dependency ratio
DWL_OWN	Percentage of occupied private dwellings that are owned
ETH_NBRFR	Percentage of the total population describing their ethnic origin to be different than British or French
EDU_NCERT	Percentage of the population 15 years and over without a high school certificate, diploma, or degree
LAN_OTH	Percentage of the total population who cannot speak either official language (English or French)
PHH_AVG	Average number of persons per private household
RGN_NCHST	Percentage of the total population having a religious faith other than Christianity. Catholocism, etc,

Variable Descriptions - Census 1986	
Variable Name	Description
POP_DEP	Population dependency ratio
DWL_OWN	Percentage of occupied private dwellings that are owned
ETH_NWHT	Percentage of the single ethnic origin population who identify as non-caucasian
EDU_NCERT	Percentage of the population 15 years and over without a high school certificate, diploma, or degree
LAB_UNEMP	Unemployment rate
FAM_LOINC	Incidence of low income in economic families
IND_LOINC	Incidence of low income among unattached individuals

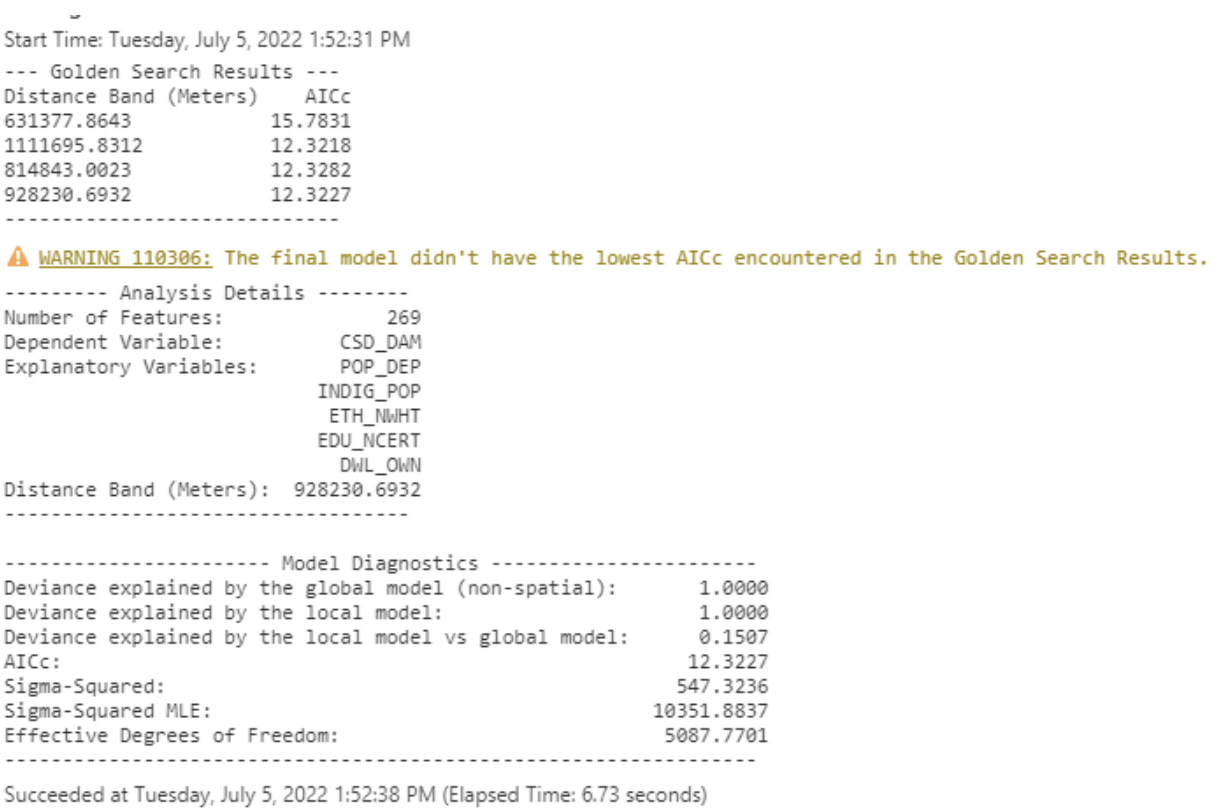
Variable Descriptions - Census 1991	
Variable Name	Description
POP_DEP	Population dependency ratio
DWL_OWN	Percentage of occupied private dwellings that are owned
ETH_NWHT	Percentage of the single ethnic origin population who identify as non-caucasian
EDU_NCERT	Percentage of the population 15 years and over without a high school certificate, diploma, or degree

Variable Descriptions - Census 1996	
Variable Name	Description
POP_DEP	Population dependency ratio
DWL_OWN	Percentage of occupied private dwellings that are owned
ETH_NWHT	Percentage of the total population who identify as a visible minority
EDU_NCERT	Percentage of the population 15 years and over without a high school certificate, diploma, or degree
INDIG_POP	Percentage of the total population who are Indigenous

Variable Descriptions - Census 2001	
Variable Name	Description
POP_DEP	Population dependency ratio
DWL_OWN	Percentage of occupied private dwellings that are owned
ETH_NWHT	Percentage of the total population who identify as a visible minority
EDU_NCERT	Percentage of the population 20 years and over without a high school certificate, diploma, or degree
INDIG_POP	Percentage of the total population who are Indigenous

Variable Descriptions - Census 2006	
Variable Name	Description
POP_DEP	Population dependency ratio
DWL_OWN	Percentage of occupied private dwellings that are owned
ETH_NWHT	Percentage of the total population who identify as a visible minority
EDU_NCERT	Percentage of the population 15 years and over without a high school certificate, diploma, or degree
INDIG_POP	Percentage of the total population who are Indigenous

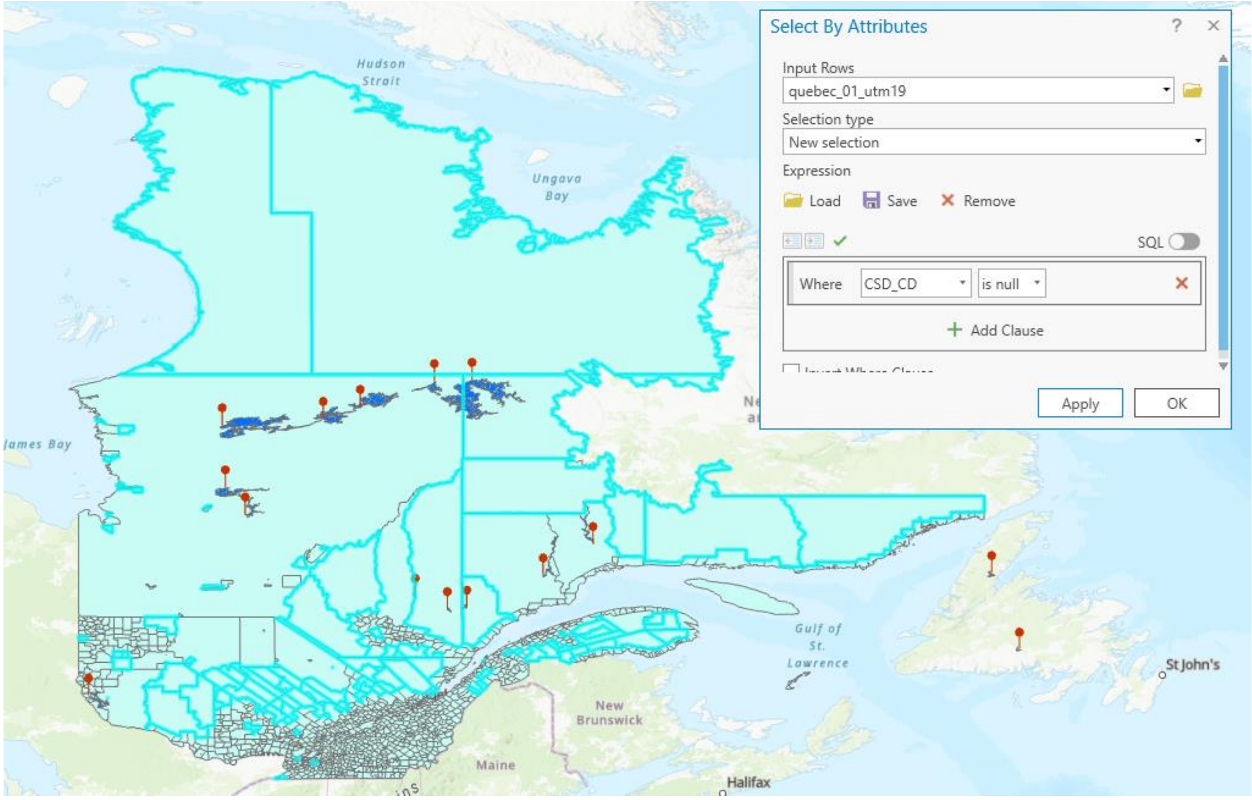
APPENDIX B



```
Start Time: Tuesday, July 5, 2022 1:52:31 PM
--- Golden Search Results ---
Distance Band (Meters)    AICc
631377.8643            15.7831
1111695.8312           12.3218
814843.0023            12.3282
928230.6932            12.3227
-----------------------------
⚠ WARNING 110306: The final model didn't have the lowest AICc encountered in the Golden Search Results.
--------- Analysis Details --------
Number of Features:                269
Dependent Variable:            CSD_DAM
Explanatory Variables:         POP_DEP
                             INDIG_POP
                              ETH_NWHT
                             EDU_NCERT
                               DWL_OWN
Distance Band (Meters):  928230.6932
-----------------------------------

----------------------- Model Diagnostics -----------------------
Deviance explained by the global model (non-spatial):       1.0000
Deviance explained by the local model:                      1.0000
Deviance explained by the local model vs global model:      0.1507
AICc:                                                      12.3227
Sigma-Squared:                                            547.3236
Sigma-Squared MLE:                                      10351.8837
Effective Degrees of Freedom:                            5087.7701
-----------------------------------------------------------------
Succeeded at Tuesday, July 5, 2022 1:52:38 PM (Elapsed Time: 6.73 seconds)
```

APPENDIX C



Select By Attributes

Input Rows
quebec_01_utm19

Selection type
New selection

Expression

Where CSD_CD is null