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Integrated Travel Research & Development
GGR442H5 - Capstone Project

ENHANCING TRANSPORTATION EQUITY IN INDIGENOUS COMMUNITIES

Authored By:

Thadsha Pancharatnam, Vedi Mistry, Sunggu Park, Sze Yui Chan

Research Mentor:

Vern Raincock

Stakeholders:

Remote & Indigenous Communities

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Executive Summary

Transportation access significantly influences the social, economic, and environmental well-being of communities, however, many rural Indigenous populations in Alberta face substantial barriers that limit their mobility and access to essential services such as healthcare and education. This project aims to develop a comprehensive strategy to improve public transportation access for these underserved communities by leveraging GIS. Through the integration of demographic, spatial, and infrastructure data, we will identify key service gaps and propose targeted solutions, including new transit routes and proposed areas for new transportation infrastructure development. Accessibility criteria will focus on public transit availability, proximity to essential services, travel times, and environmental sustainability. The project outcomes include an interactive ArcGIS StoryMap for visualizing findings, along with a comprehensive report detailing the methodology and actionable strategies. By addressing the operational and infrastructural challenges faced by rural and Indigenous communities, this project seeks to foster equity, reduce social isolation, and improve the quality of life for rural and Indigenous populations in Alberta.

Background Information

Transportation access is a critical determinant of social, economic, and environmental well-being in Alberta, especially for Indigenous and rural communities. These communities face significant barriers to accessing vital services such as healthcare, education, and employment, exacerbating geographic isolation and economic inequality. The absence of an integrated public transit system forces a heavy reliance on personal vehicles, significantly increasing living costs and limiting mobility for rural populations (Affordability Action Council, 2024).

The Alberta Transportation Annual Report (2021-2022) underscores the urgency for targeted investment in public transit systems, particularly in smaller rural and remote communities. While programs like the Rural and Northern Communities stream of the Investing in Canada Infrastructure Program (ICIP) have provided funding, their primary focus has been water and wastewater systems rather than transportation (Government of Alberta, 2022). Additionally, smaller municipalities encounter challenges such as inadequate infrastructure funding and limited operational support, further compounding transit accessibility issues.

Our project addresses these gaps by leveraging GIS tools to analyze demographic and transit data. This analysis identifies underserved Indigenous and rural communities and evaluates the proximity of transit infrastructure to essential services, such as hospitals. For example, our service area analysis in cities like Lethbridge and Fort McMurray highlights accessibility gaps for Indigenous communities despite the presence of nearby urban transit systems. Walking distance cutoffs of 3, 5, and 10 minutes were used to evaluate the usability of public transit stops for vulnerable populations.

Building on this analysis, we propose sustainable, community-based solutions to improve transportation equity in these regions. This includes designing a framework for operational funding, better coordination between transportation modes, and prioritizing infrastructure development in high-impact areas.

Our approach integrates land-use and suitability analysis to propose optimal locations for new bus stops and rail stations. Through these efforts, this project seeks to bridge the transportation gap and foster long-term mobility solutions for Alberta's Indigenous and rural populations.

Goals & Objectives

The primary goal of this project is to develop a comprehensive data analysis framework to improve public transportation accessibility for Indigenous and rural communities across Alberta. Utilizing GIS tools and methodologies, the project identifies underserved areas and highlights transit service gaps, particularly in regions with little to no public transit infrastructure. Collaboration with Vern Raincock, our research mentor, ensures the data is accurate and the proposed solutions are practical and grounded in the realities of existing infrastructure.

To achieve this, we employ a SMART-based approach, ensuring our goals are Specific, Measurable, Achievable, Realistic, and Time-bound. The refined project goals include:

1. <u>Pinpointing underserved areas:</u> Using normalized demographic and geographic data, including Indigenous population density and proximity to essential services like healthcare, we will identify regions requiring immediate transit solutions.

2. <u>Proposing sustainable transit solutions:</u> Utilizing GIS-driven service area analysis, we recommend feasible public transit routes and infrastructure development, such as bus stops and rail stations, that align with local needs and resources.

3. <u>Promoting equity in accessibility:</u> Prioritizing solutions that improve access for vulnerable populations, such as those within a 10-minute walking distance of transit stops, to ensure inclusivity and usability.

4. <u>Ensuring practical implementation:</u> Developing solutions that leverage existing local resources and infrastructure, focusing on creating actionable plans within a 4-month timeframe.

Our deliverables will provide actionable recommendations to stakeholders, bridging the transportation gap and fostering greater social, economic, and environmental inclusion for Alberta's rural and Indigenous populations.

Methodology

The methodology is divided into two main components. The first focuses on visualizing the existing public transportation infrastructure to identify areas where equity issues are most prevalent. The second utilizes this analysis to propose potential locations for transit stops or routes, aiming to reduce transportation inaccessibility for Indigenous communities.

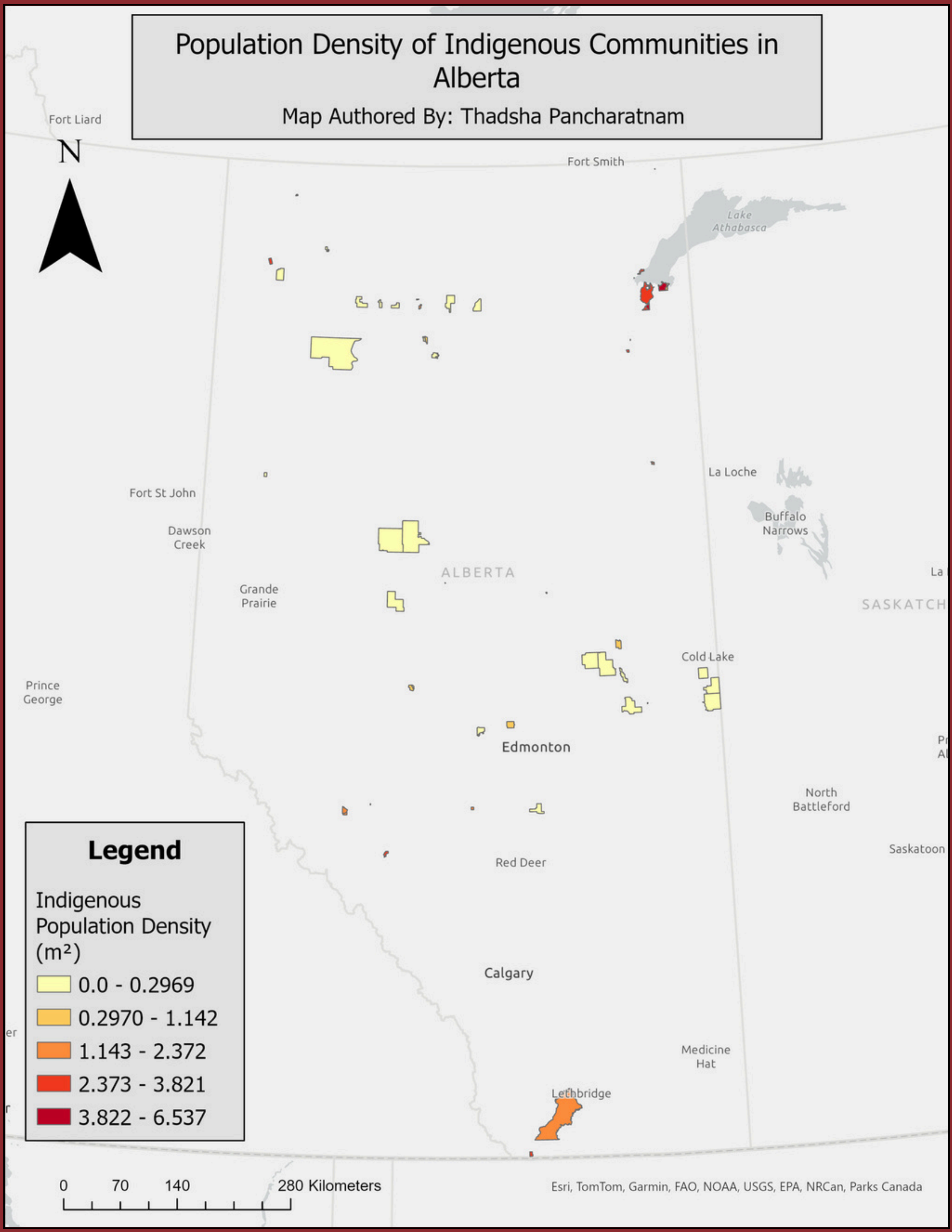

Figure 1: Normalized population density of Indigenous communities in Alberta. This map highlights areas from low (yellow) to high (red) density. Not all Indigenous people reside in the communities.

To address the first component, ArcGIS Pro created a shapefile displaying all officially recognized Indigenous communities across Alberta and calculated their respective population densities. This was achieved by performing a table join in ArcGIS Pro, integrating spatial data on Indigenous communities sourced from the University of Lethbridge (n.d.) with Alberta census data provided by the Government of Alberta (2021). The symbology was adjusted to reflect population density, with particular emphasis on communities with higher population densities, represented by dark orange and red polygons as seen in Figure 1. These high-density areas were prioritized as they signify a greater need for resources, services, and infrastructure.

Subsequent steps involved collecting public transportation data and identifying essential services to visualize the alignment of transportation networks with the distribution of essential services. For this project, a general framework was adopted for accessibility, focusing specifically on hospitals as a primary essential service, with data sourced from the University of Toronto (n.d.).

Once all necessary data were gathered, Network Analysis was conducted in ArcGIS Pro using the Service Area tool. For this analysis, a focus was on two cities: Lethbridge and Fort McMurray; this is due to the availability of bus data and their proximity to densely populated Indigenous communities. GTFS data were obtained from the City of Lethbridge (n.d.) and the Regional Municipality of Wood Buffalo (n.d.). The Service Area Analysis parameters were configured to examine walking times to bus stops, with cutoffs set at 3, 5, and 10 minutes. These intervals were chosen as they represent ideal walking distances for public transit users, particularly for vulnerable populations such as the elderly or individuals with health conditions (Chuang et al., 2023). Figure 2 illustrates the tools utilized in ArcGIS Pro to perform the service area analysis.

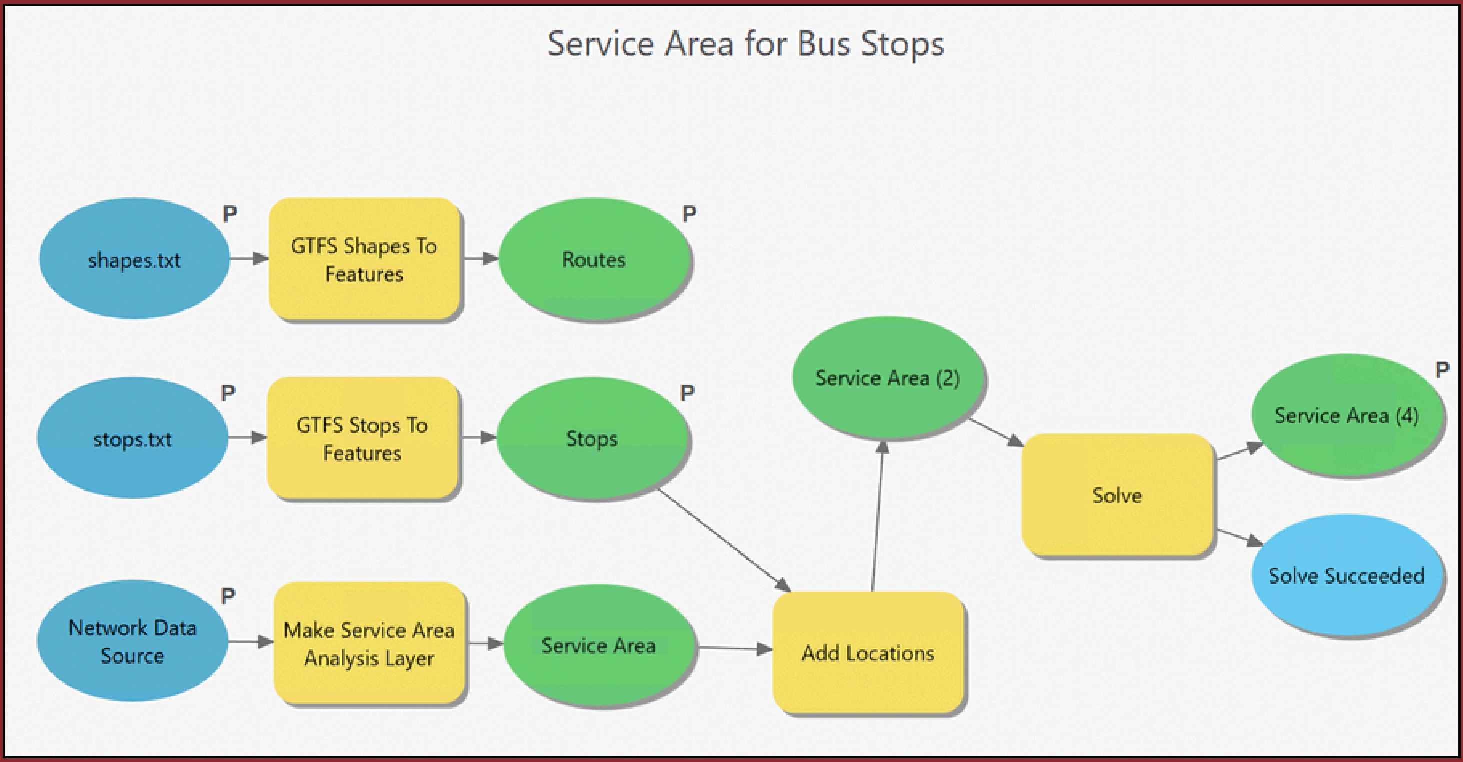

Figure 2: Service Area Analysis Workflow
This diagram illustrates the workflow for analyzing bus stop accessibility using GTFS data. Shapes.txt and stops.txt files are converted into spatial features, incorporated into a service area layer, and analyzed using walking time cutoffs (3, 5, 10 minutes). The process efficiently identifies transit accessibility zones.

Using the “shapes.txt" files from the GTFS datasets, the route data was converted into a shapefile format with the "GTFS Shapes to Features" tool. Similarly, bus stop information from the stops.txt file was converted into a compatible format for analysis. This process ensured that all data were appropriately formatted for use in the Service Area tool. “Make Service Area Analysis Layer" was used to define the walking time cutoff parameters. The “Add Locations" tool was used to input and define the stops shapefile as the main facilities that the walking time would be heading towards. Finally, the “Solve" tool was used to generate the final output of the service area.

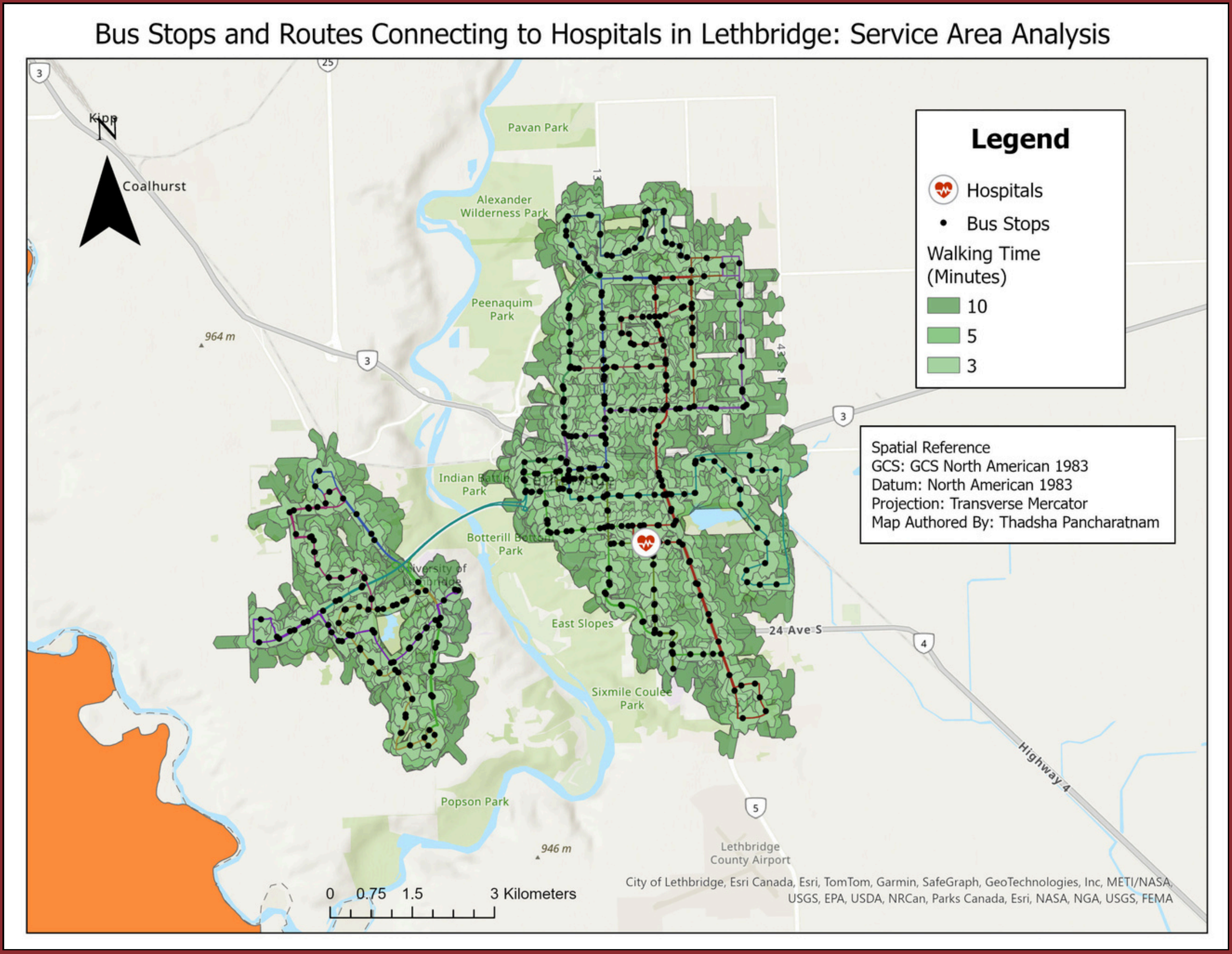

Figure 3: Service Area Analysis of Bus Stops Connecting to Hospitals in Lethbridge
This map depicts the service areas for bus stops in Lethbridge, showing walking time cutoffs of 3, 5, and 10 minutes. The map highlights the proximity of bus stops to hospitals and includes the Indigenous population density, indicating accessibility challenges.

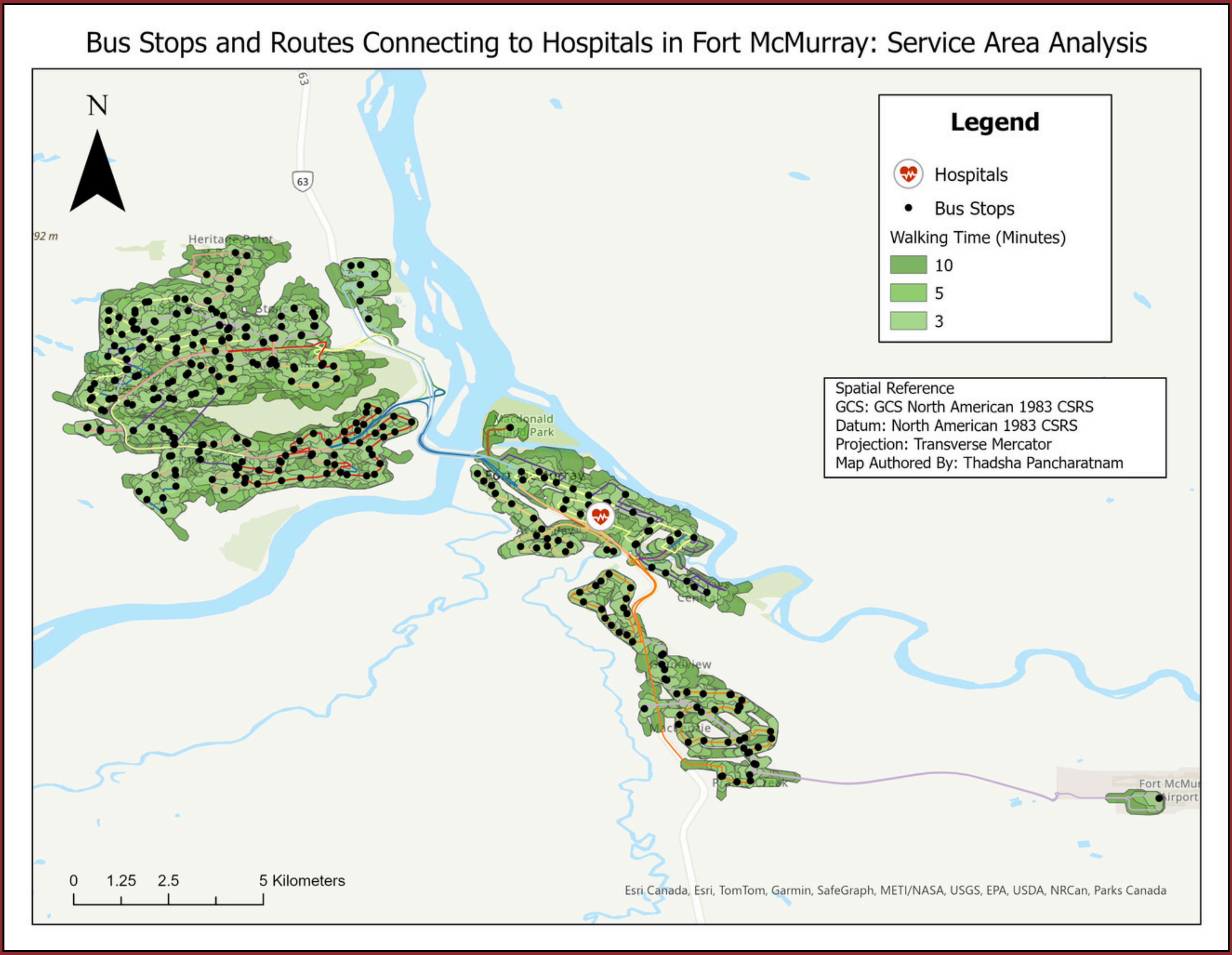

Figure 4: Service Area Analysis of Bus Stops Connecting to Hospitals in Fort McMurray
This map shows the service areas of bus stops in Fort McMurray with walking time cutoffs of 3, 5, and 10 minutes. The analysis is overlaid with Indigenous population density, illustrating the accessibility of public transit to hospitals.

As shown on the maps in Figures 3 and 4 above, the areas outside the cutoff timings indicate inaccessibility to bus stops, with the routes illustrating which buses connect to hospitals. To highlight the underserved areas, the "erase" tool was utilized to subtract the service area layer from the Alberta division boundaries, which include the Indigenous communities and the two cities, to identify these areas. Figure 5 presents the ModelBuilder in ArcGIS Pro used to perform this process with the erase tool. Building ModelBuilder workflows in ArcGIS Pro is essential for this project because it enhances efficiency, consistency, and reproducibility in spatial analysis. Figures 6 and 7 display the maps of underserved areas in Fort McMurray and Lethbridge, respectively.

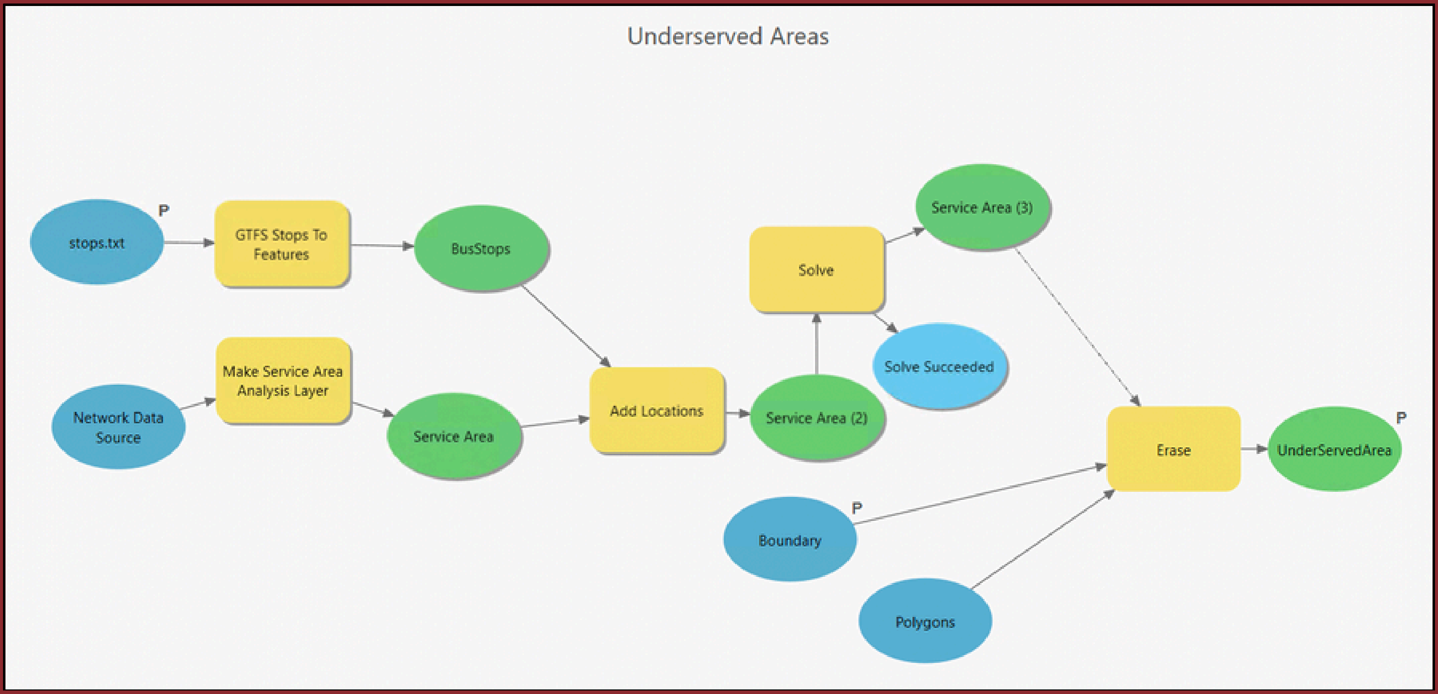

Figure 5: ArcGIS pro Modelbuilder for underserved areas which includes the parameters needed for input and output. This model builder subtracts the service area layer from the boundary using the erase tool.

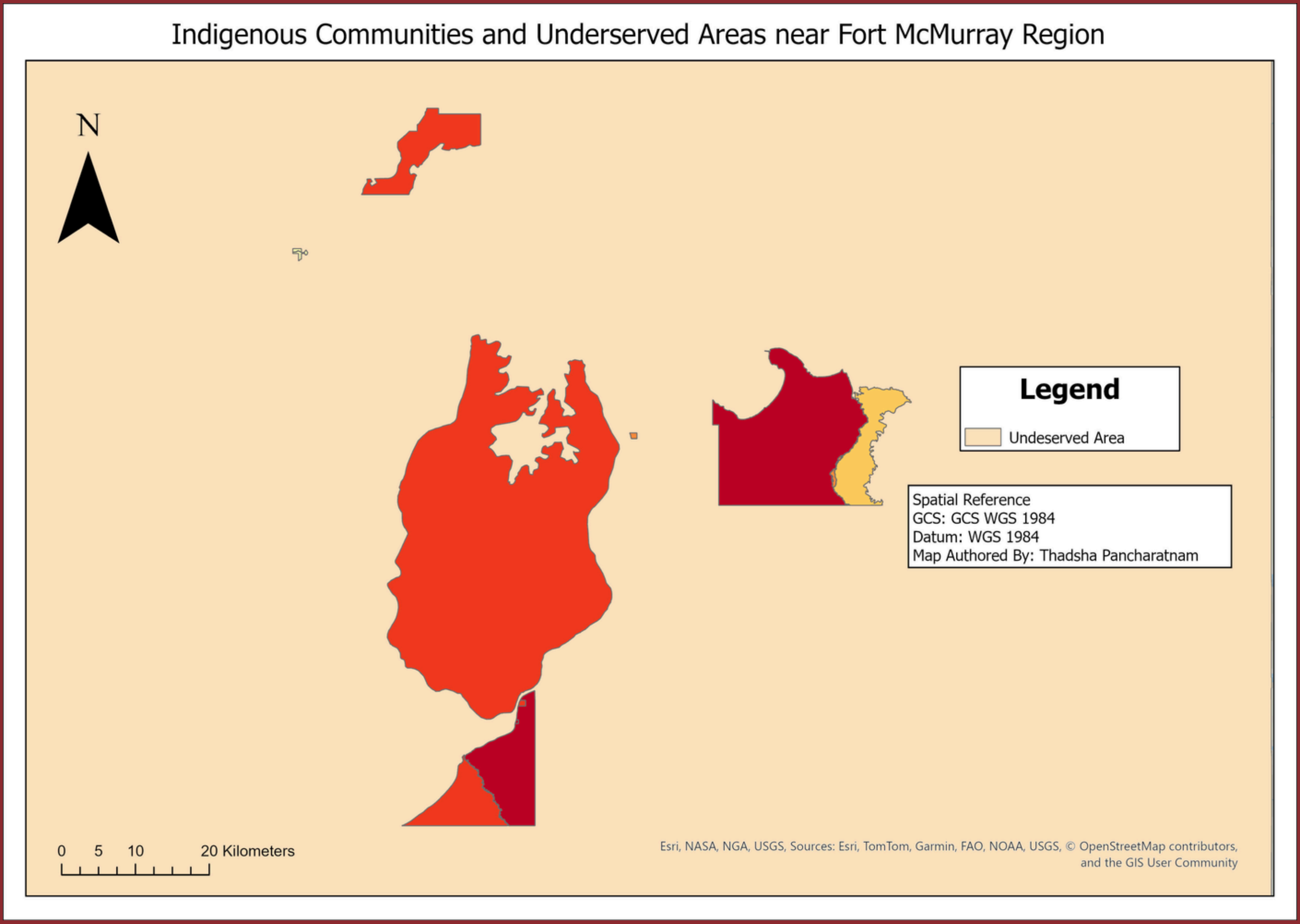

Figure 6: Indigenous Communities and Underserved Areas near Fort McMurray
This map highlights underserved areas within the Fort McMurray region. The shaded regions represent areas with limited access to public transportation infrastructure.

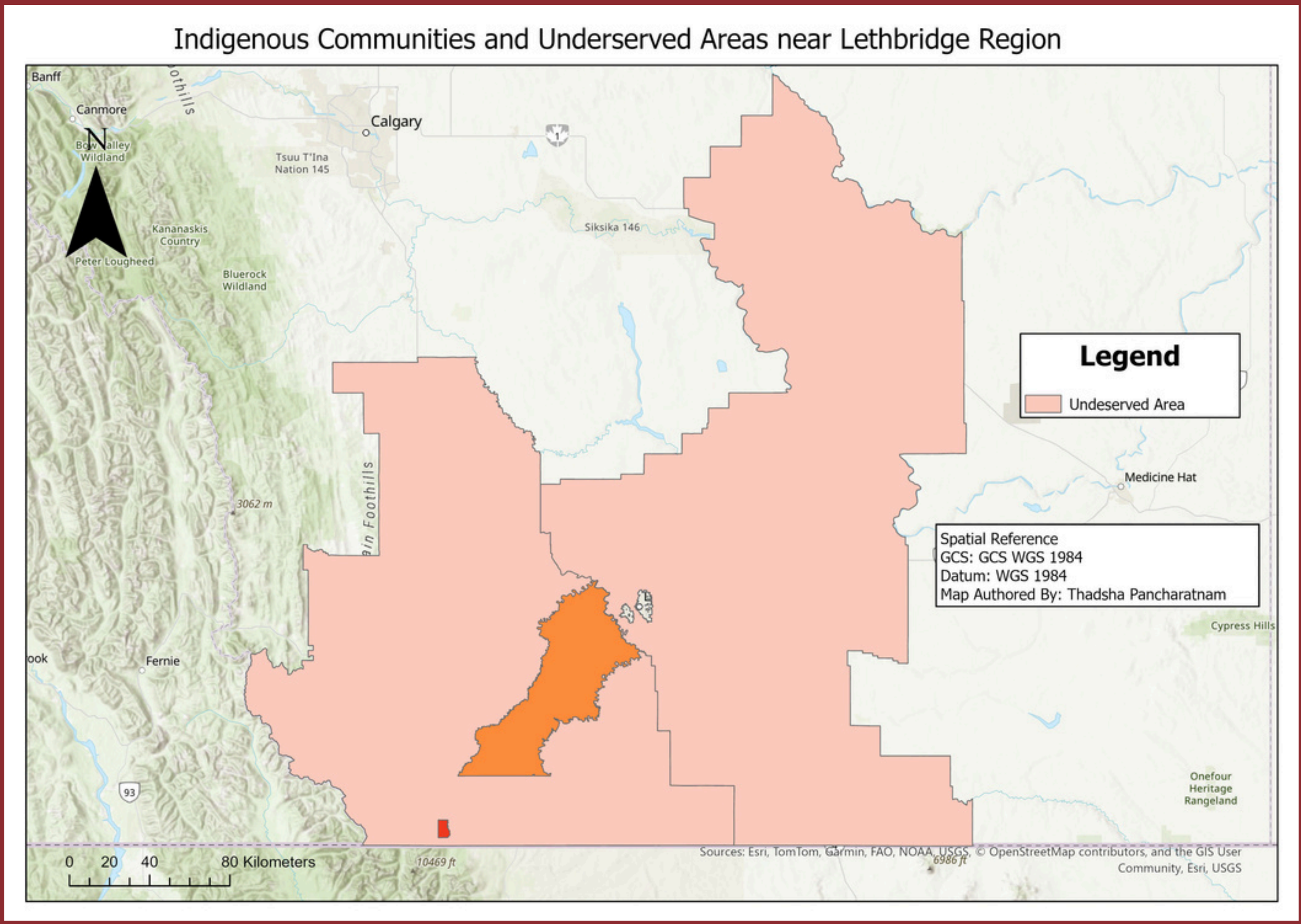

Figure 7: Map of Indigenous communities and underserved areas near the Lethbridge region, Alberta. Highlighted regions in pink represent underserved areas based on accessibility to services and infrastructure.

Now that the transportation equity issues in Alberta can be seen and understood, the next step is to conduct a Suitable Area Analysis. More specifically, the goal was to develop a potential solution to the current inaccessible transportation infrastructure and to do this it was needed to determine what areas would be suitable for building transportation networks. The criteria for finding these ideal spots consisted of two factors:

- Land Cover Data - information about the physical material present on the surface of the Earth. This includes the natural and human-made features that cover the land.
- Elevation Data (DEM) - a digital representation of the Earth's surface topography. It provides information about the elevation (height) of the terrain at specific points relative to a reference, typically sea level.

The suitable area analysis started by gathering Alberta land use and elevation data from the Alberta Energy Regulator (2021) and the Government of Alberta (n.d.) respectively. Then using the extract by mask tool, these two rasters were extracted to the shapefile of the indigenous communities which is displayed in figures 8 and 9.

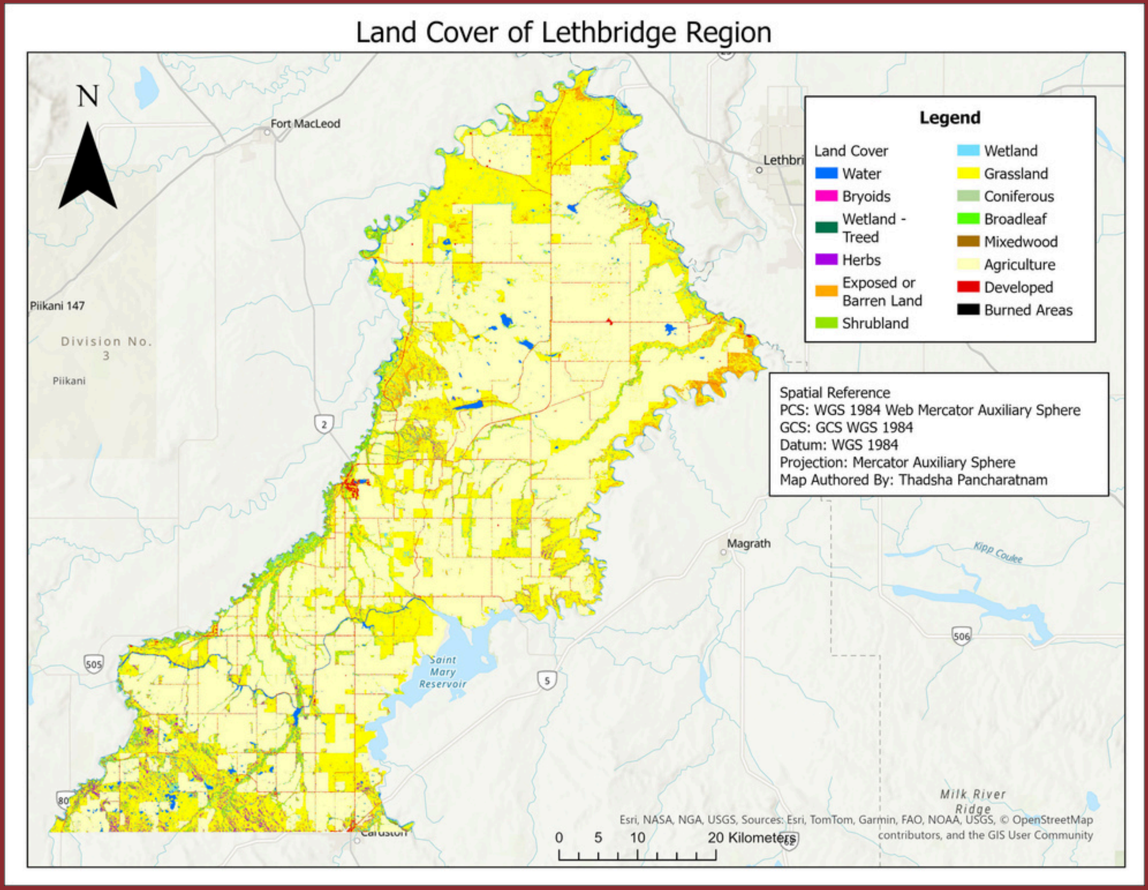

Figure 8: Land cover map of the Lethbridge region, Alberta, showing the distribution of different land cover types. Key features include wetlands (blue and green), grasslands (yellow), agricultural areas (orange), and developed regions (red). Burned areas are highlighted in black.

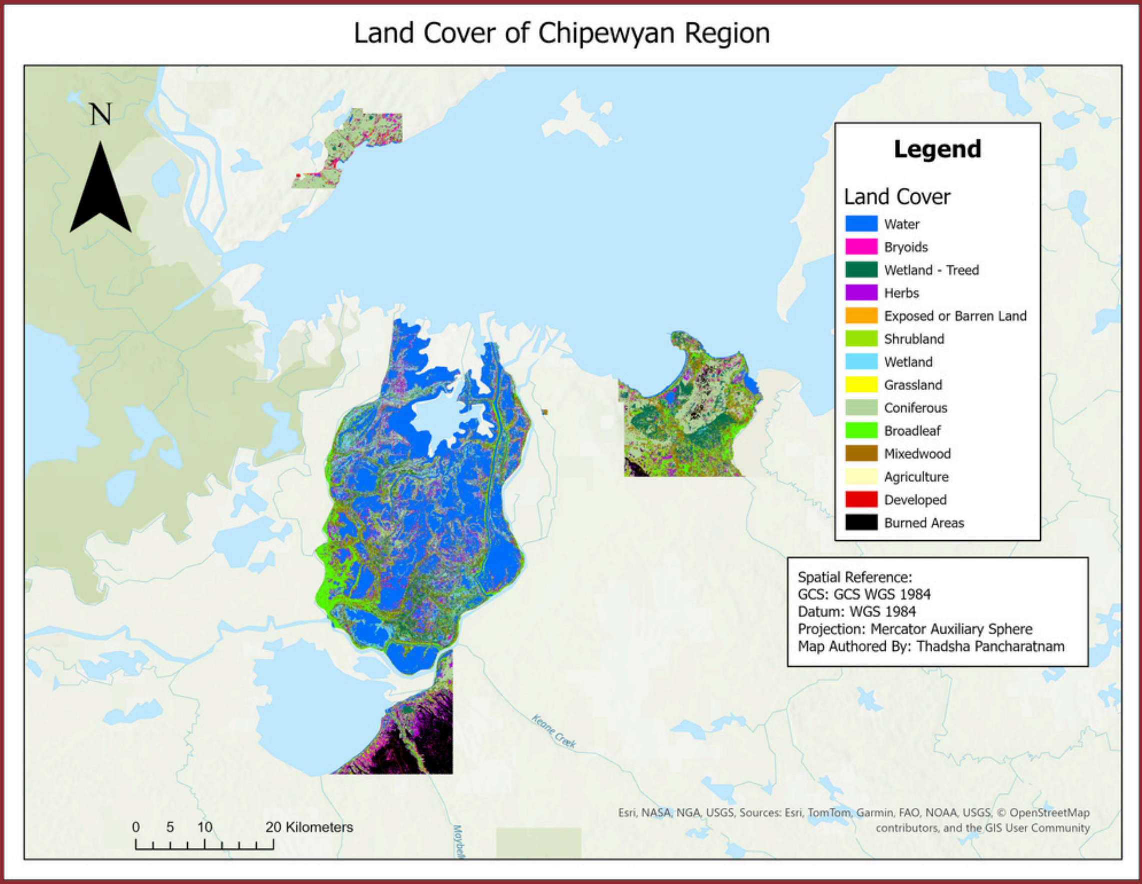

Figure 9: Land cover map of the Chipewyan region, showcasing diverse land cover types such as water bodies (blue), grasslands (yellow), wetlands (green), and developed areas (red). The map highlights the distribution and variety of land cover, providing insights into ecological and development opportunities.

Using research, it was identified that specific land covers and slope ranges would be the most ideal and convenient for building transportation infrastructure. For the land covers, this included Grassland (Hiscock et al., 2021), Agriculture (Lambin & Geist, 2006), and Exposed Land (Hou et al., 2022). These particular land covers are suitable for development due to their lower biodiversity and ecological sensitivity, preserving sustainability compared to more environmentally significant areas such as wetlands and forests, which are critical for ecosystem services and habitat conservation (DeFries et al., 2002).

To identify the ideal slope range, the percentages were computed using the slope tool where the percentages ranged from 0 to infinity and the value 0 represents a flat surface while a 45-degree surface represents 100 percent (Esri, n.d.). As the land becomes more vertical, the percentages increase and tend to infinity (Esri, n.d.). Slopes that fell in a gradient between 4-10% were considered “gentle” in terms of suitability (Singh et al., 2019) therefore slopes ranging under 10% were considered suitable for building on. Figures 10 and 11 show the slope percent rise of the Indigenous communities that were the focus of this study.

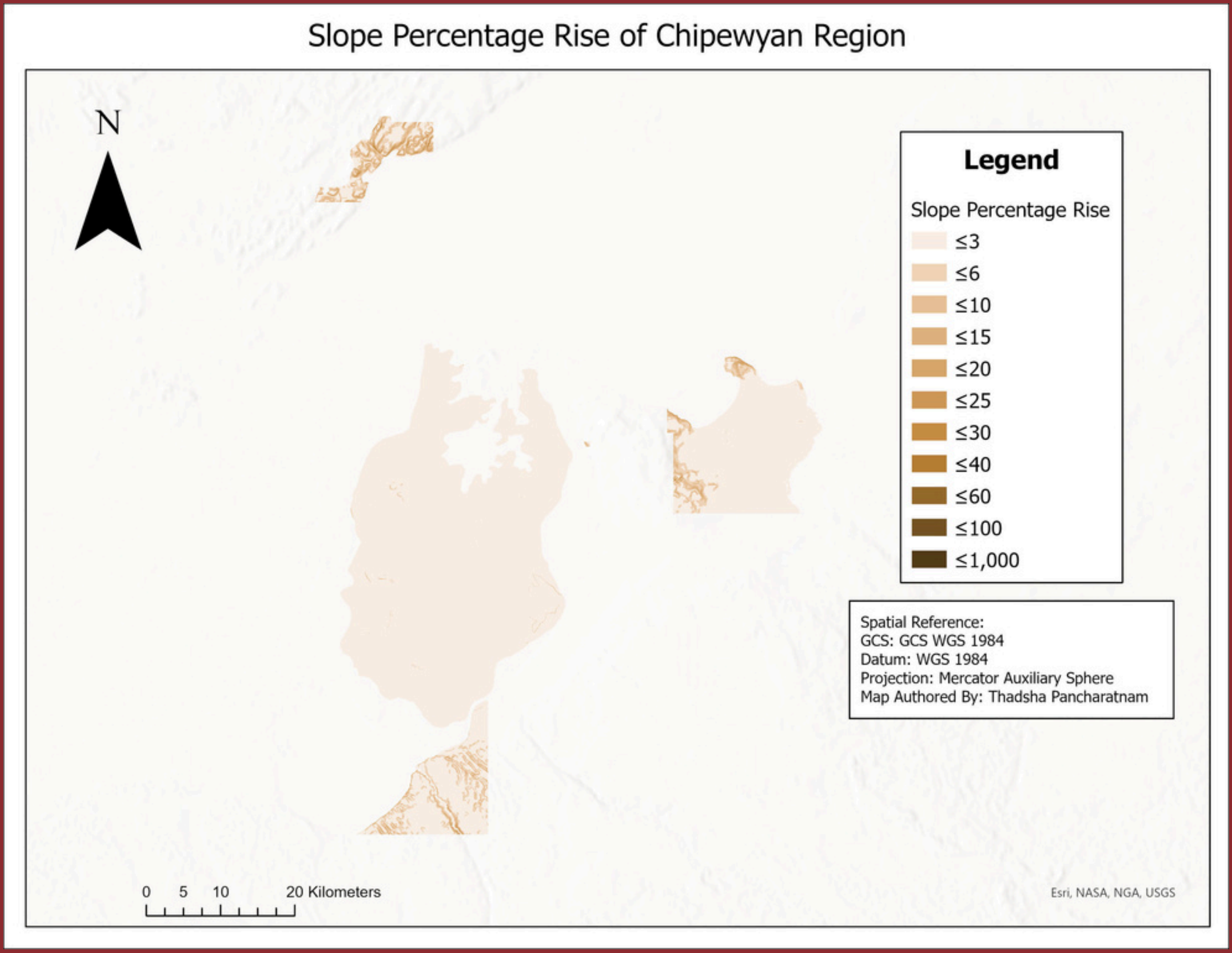

Figure 10: Slope percentage rise map of the Chipewyan region, depicting variations in slope steepness. The gradient ranges from flat areas (≤3%) to extremely steep terrain (≤1,000%), represented by a colour scale from light beige to dark brown.

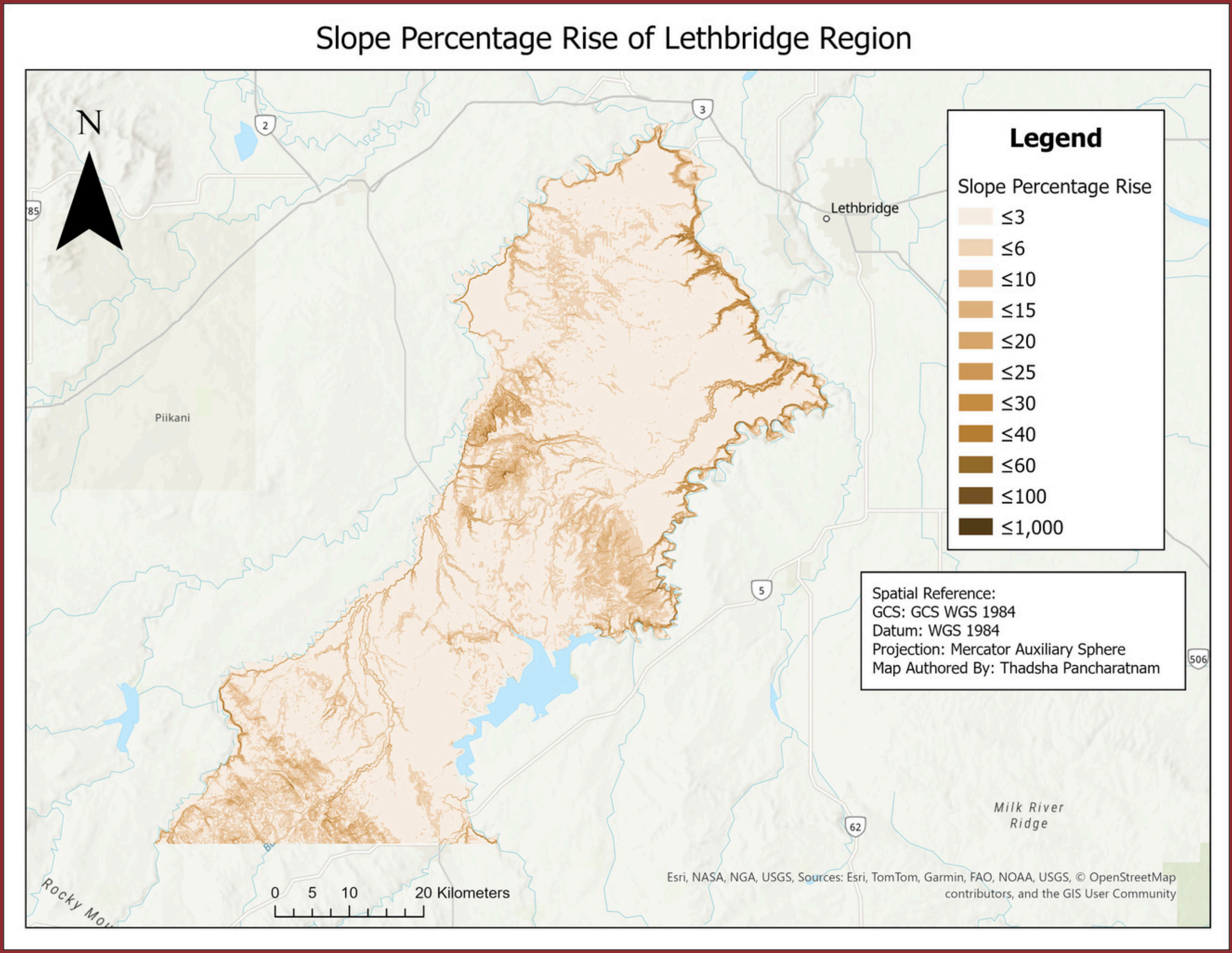

Figure 11: Slope percentage rise map of the Lethbridge region, illustrating the variability in terrain steepness. Slope percentages range from flat areas (⩽3%) to steep terrains (⩽1,000%), with a color gradient from light beige to dark brown. This map is essential for assessing areas suitable for development or conservation purposes.

Finally, the reclassify tool was used to set all the areas unsuitable for building to 0 and suitable areas to 1 in both rasters. Then using the raster calculator, the reclassified rasters were combined into one which showed the final suitable area based on both land usage and elevation. Figure 12 displays the ModelBuilder of all the tools used as previously described to conduct the Suitable Area Analysis.

The creation of the Suitable Area Analysis Modelbuilder was streamlined using ModelBuilder in ArcGIS, as shown in Figure 12 below. The process integrates multiple datasets—land classification, elevation, and community boundaries—by using tools such as Extract by Mask and Reclassify to filter and prioritize areas based on specific criteria. The slope percentage data, calculated from elevation values, was extracted and reclassified to identify areas with slopes under 10%, deemed suitable for construction. Land cover types were similarly reclassified to highlight less ecologically sensitive areas like grasslands and agricultural lands.

These outputs were combined using the Raster Calculator to generate the final map of suitable areas for transit infrastructure development. This automated workflow ensures consistency and reproducibility, enabling future researchers to replicate or expand upon the methodology efficiently.

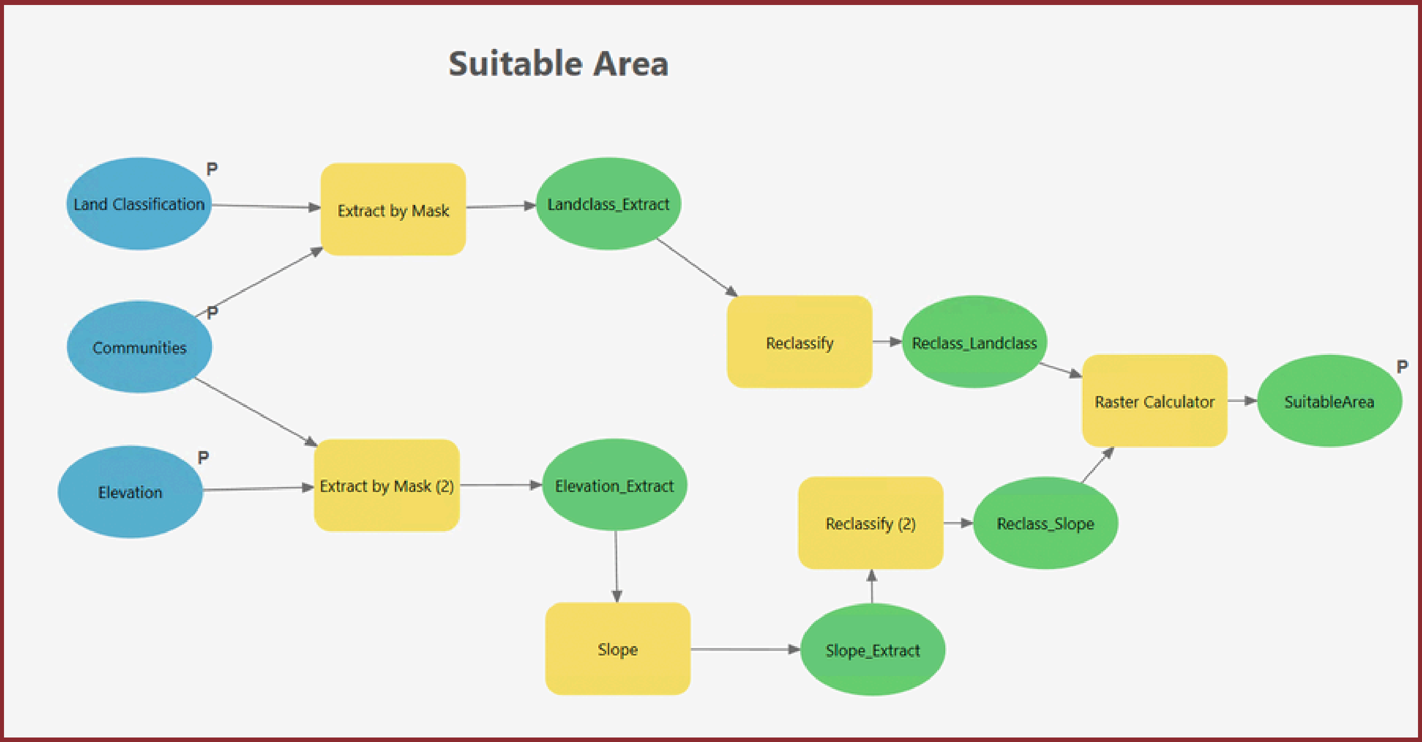

Figure 12: ModelBuilder workflow for identifying suitable areas for public transportation infrastructure. The process integrates datasets such as land classification, communities, and elevation, using tools like Extract by Mask and Reclassify to filter data based on criteria such as slope percentage and land-use type. The final outputs, derived through the Raster Calculator, produce a map highlighting areas suitable for development. This workflow ensures reproducibility and facilitates efficient analysis.

Results & Discussion

This project identifies public transportation inequities in rural and Indigenous communities in Alberta, where limited public transit access exacerbates social isolation and restricts access to essential services such as healthcare. Service Area Analysis reveals that public transit infrastructure is heavily concentrated in urban areas, with accessibility declining rapidly in areas farther from city centers.

Suitable Area Analysis, using criteria like slopes under 10% and land-use types such as grassland, agricultural land, and exposed/barren land, identified green areas in Figure 13 as optimal for new transit infrastructure. Expanding transit networks in these underserved regions would connect communities to essential services, fostering social and economic inclusion while improving quality of life.

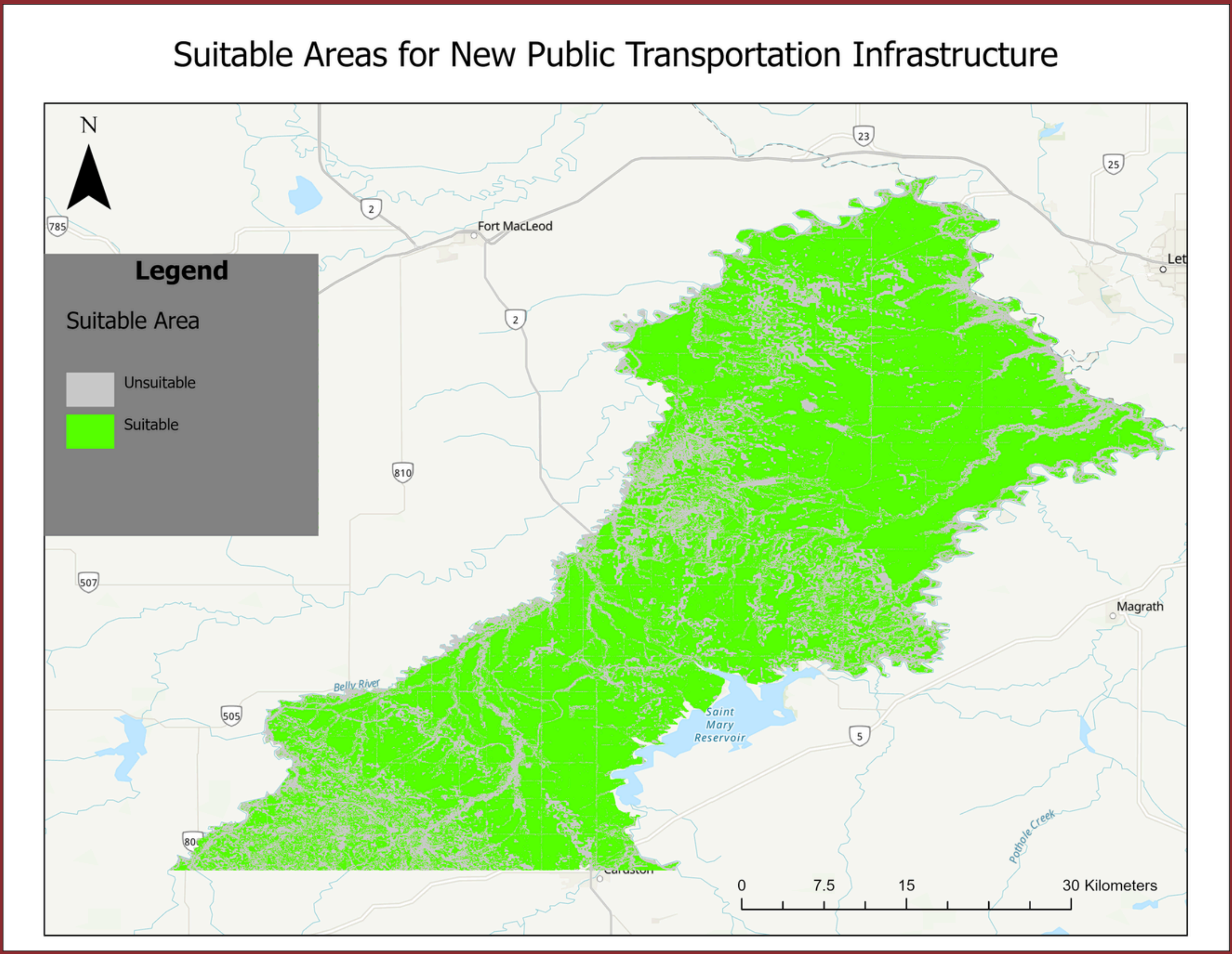

Figure 13: Map of suitable areas for new public transportation infrastructure in the Lethbridge region. Areas identified as suitable are highlighted in green, while unsuitable areas are shown in gray. The suitability analysis is based on factors such as slope gradient and land cover type, ensuring efficient and sustainable infrastructure placement.

However, identifying suitable areas for new public transportation infrastructure requires additional considerations, such as construction costs, legal requirements, and agreements with residents. Additionally, a broader range of land types should be evaluated with appropriate criteria. Time constraints also limited the scope of this project, excluding essential services like education and employment, which are critical for a more comprehensive analysis of accessibility needs.

Despite these limitations, this project provides a strong foundation for future research on public transportation equity. The processes are fully reproducible using ModelBuilder, enabling future researchers to build on this work efficiently and address similar challenges.

Conclusion & Recommendations

This project demonstrates a comprehensive framework for addressing transportation inequities in Alberta's rural and Indigenous communities through GIS-based analyses. The findings reveal significant public transportation accessibility gaps in cities such as Fort McMurray and Lethbridge, disproportionately affecting Indigenous populations who lack reliable transit options to essential services like healthcare. By leveraging Service Area and Suitable Area analyses, the project identified critical underserved areas and optimal locations for transit infrastructure development based on criteria like slope suitability (<10%) and ecologically sustainable land types (grassland, agricultural land, and exposed land). These results provide a clear path for addressing accessibility challenges and improving social, economic, and environmental equity.

Recommendations

1. Infrastructure Development in Underserved Areas: Prioritize the construction of transit stops and routes in the identified green zones from the Suitable Area Analysis to ensure accessibility for rural and Indigenous communities. Emphasizing areas with gentle slopes and low ecological sensitivity will minimize environmental disruption and construction challenges.
2. Expand Essential Services Accessibility: Broaden the analysis to include education and employment centers as additional essential services. Incorporating these into transit planning will provide a more comprehensive approach to improving accessibility and addressing diverse community needs.
3. Collaborative Planning: Engage with local stakeholders, including Indigenous leaders, municipal governments, and community members, to ensure proposed solutions align with cultural, legal, and community-specific requirements. Collaboration can foster trust and encourage the adoption of these initiatives.

By addressing the identified gaps and implementing these recommendations, Alberta can create a more equitable and inclusive transportation system that fosters connectivity, reduces social isolation, and enhances the quality of life for its rural and Indigenous communities.

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