Tide and Seek: A Coastal Adaptation and Vulnerability Assessment (CAVA) Geographic Visualization in Lunenburg, Nova Scotia

by

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Abstract

Sea level rise (SLR) and storm surge events (SSE) due to climate change significantly threaten the sustainability of tourism-reliant coastal communities, such as the Town of Lunenburg, Nova Scotia. Coastal risk assessments exist globally, but rarely address the interrelation between biophysical climate effects, socioeconomic systems, and climate perceptions of stakeholders. In Lunenburg, there is a disconnect in residents' awareness of SLR adaptation plans despite climate-policy participatory processes.

The current study uses GIS methods to create a 3D climate risk visualization to increase the understanding of risks facing Lunenburg. These methods should improve upon the accuracy of previous adaptation planning documents through up-to-date Light Detection and Ranging (LiDAR) elevation sources. Interactive visualization features were incorporated which allow stakeholders to visualize geospatial information relevant to their specific needs or concerns. The visualization can be accessed through this link.

Within the study area, Scenario 1, which investigated a water rise level of 1.75m, resulted in the inundation of 43 civic addresses, 1.207km² of land, and 2.632km of roads. Scenario 2 examined 3.25m of water rise, which resulted in the inundation of 140 civic addresses, 2.070km² of land, and 14.562km of roads. Scenario 3 evaluated 4.15m of water rise, which affected 190 civic addresses, 2.479km² of land, and 18.233km of roads.

3D climate risk visualizations can equalize and increase stakeholder awareness levels, inform policy decisions, and increase the accessibility of open-source geospatial data. Visualizing biophysical, social, and economic indicators simultaneously allows for a holistic understanding of climate risk. Awareness and preparedness of local stakeholders is a prerequisite to formulating climate-adaptation strategies.

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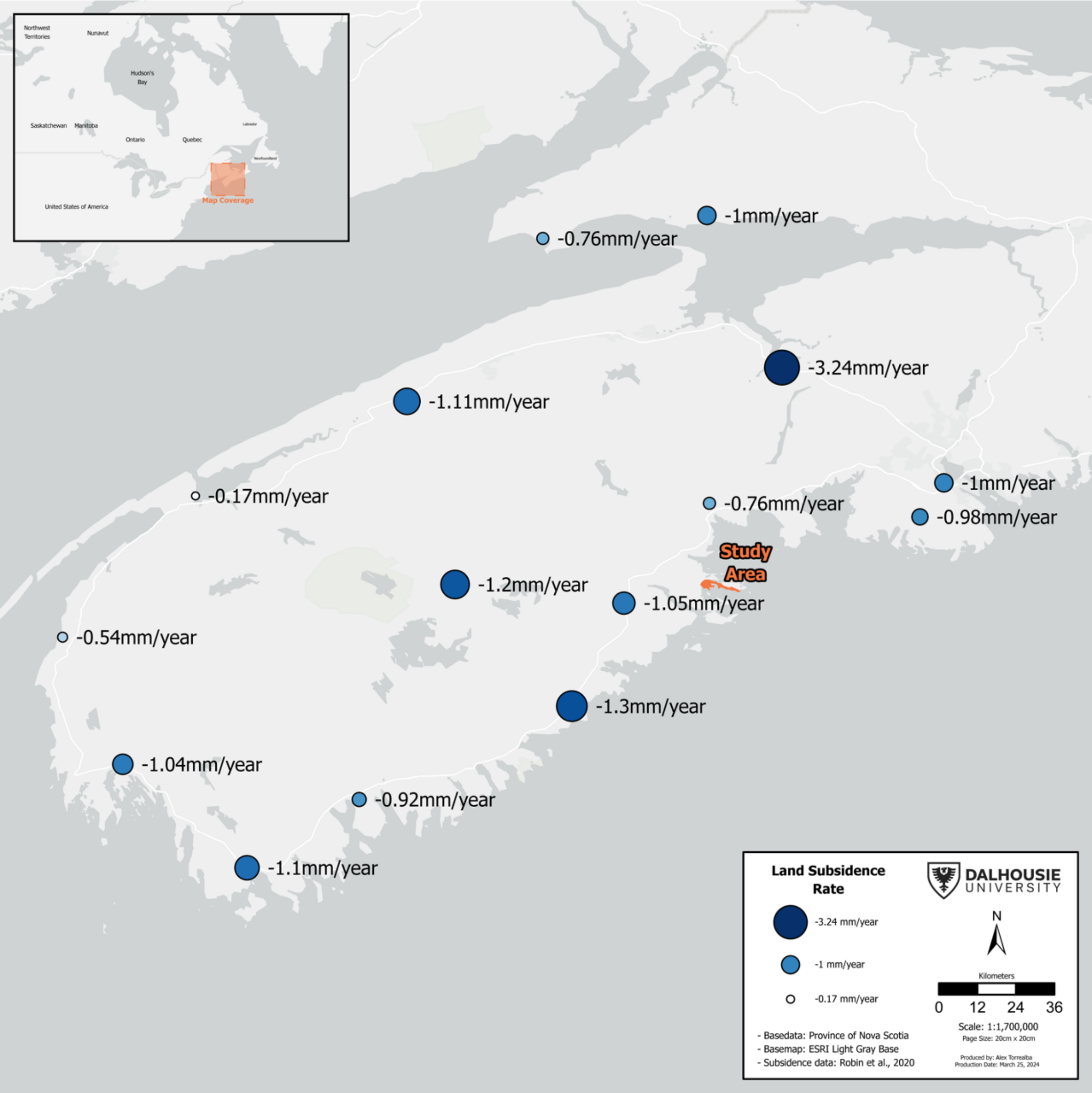
Chapter 1: Background and Introduction

Earth's atmospheric system is currently enduring significant climatic transformations which can be attributed to various environmental factors; notably the release of anthropogenic greenhouse gas (GHG) emissions. Climate change is the subsequent long-term atmospheric effects of such emissions (United Nations, n.d.). Climate change is widely accepted to be intricately connected to the viability of human societies and ecosystems. Considering the naturally occurring regional variability in global climate patterns, the effects felt from climate change differ by geographic location (IPCC, 2023; Wong et al., 2020). Due to their industries and layout, coastal communities such as the Town of Lunenburg, Nova Scotia (the focal town of this paper), are particularly vulnerable to such long-term climatic shifts including rising sea levels and the associated ramifications (CLIMAtlantic, n.d.).

In Atlantic Canada, the three main causes of sea level rise (SLR) include: the melting of glaciers and ice sheets, thermal expansion of the oceans, and localised land subsidence (Greenan et al., 2019). Resulting from temperature increases of the atmosphere and oceans, glaciers and ice sheets around the world are melting, which is now the primary source of global SLR (IPCC, 2022). Thermal expansion is a result of ocean waters absorbing heat from the atmosphere which causes water molecules to expand; responsible for one third of global sea-level rise since 2004 (Wong et al., 2020). Land subsidence, a phenomenon particularly relevant to the Atlantic Canadian context, is the vertical movement of land (Blackwood & Berrick, n.d.). The release in surficial pressure following the most recent ice age is causing the land of Atlantic Canada to sink, causing many communities to experience a relative rate of SLR greater than the global average (CLIMAtlantic, n.d.; Oppenheimer et al., 2022; James et al., 2014). According to Greenan et al. (2019), Nova Scotia is experiencing an average of approximately 2mm/year of land subsidence. Figure 1 illustrates the isostatic adjustment of Atlantic Canadian GPS stations in proximity to the study area. Global mean SLR is projected to increase by 0.43 meters to 0.84 meters by the year 2100 (Oppenheimer et al., 2022). In Atlantic Canada however, considering subsidence, relative SLR is projected to increase between 1.46 meters and 1.75 meters by 2100 (Wade, 2022). It is important to note that the SLR projection of up to 1.75 meters does not account for the potential of storm surge events (SSE), which typically add an additional 1.5 meters on top of the average SLR of 1.75 meters (T. Webster, personal communication, March 13, 2024). In worst case scenarios such as Hurricane Fiona, this SSE can increase water levels by an additional 2.4 meters (T. Webster, personal communication, March 13, 2024). Based on this information, the current thesis investigates three scenarios of total water rise: 1.75m, 3.25m, and 4.15m, as depicted in Figure 2. Supplementary to the temporary flooding caused by SSE, these powerful waves result in higher rates of erosion which can affect the feasibility of beach activities including swimming, kayaking, and fishing; all of which support the tourism industry (Glavovic et al., 2015). The effects of SLR in conjunction with land subsidence, the increasing frequency of SSE, coastal flooding, and erosion of beaches will gravely impact coastal communities in the future (CLIMAtlantic, n.d.).

Figure 1

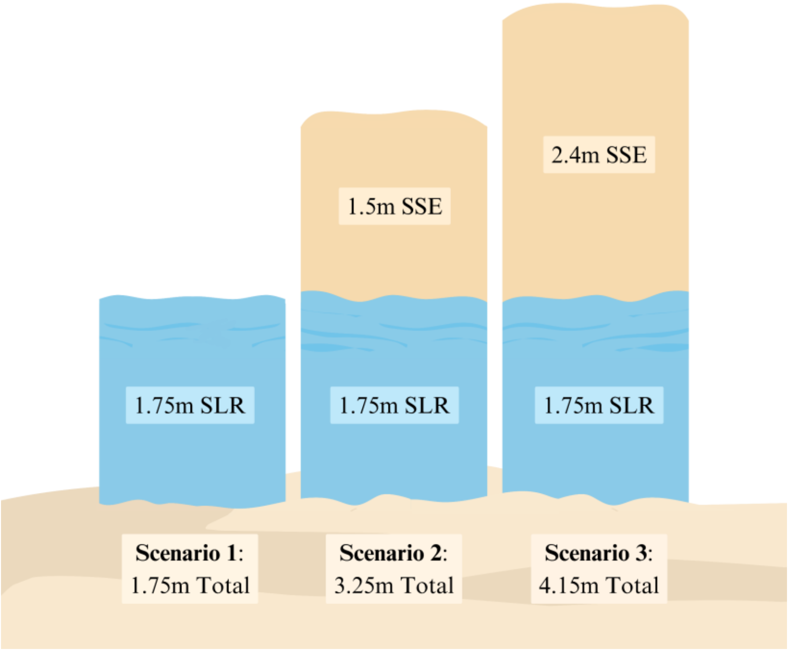
Rate of Land Subsidence at Nova Scotian GPS Locations Proximal to Study Area



Note. Larger and darker circles indicate a higher rate of land subsidence at a GPS point. Lighter and smaller circles indicate a lower rate of land subsidence at a GPS point. Data used to create graph sourced from Robin et al., (2020).

Figure 2

Visualization of Sea Level Rise Scenarios to be Investigated for the Study Area



Note. Blue 'waves' indicate the proportion of each sea level rise (SLR) scenario resulting from SLR. Beige 'sand' indicates the proportion of each SLR scenario because of storm surge events (SSE).

Among almost every other industry, the global tourism industry will need to adapt to the ramifications of climate change, as many tourism activities and destinations are weather and climate-dependent (Scott et al., 2008). In 2019, prior to the effects of the COVID-19 pandemic, the Canadian tourism industry accounted for 2.03% of the national gross domestic product (GDP), which equates to a $43.7 billion industry total (Destination Canada, 2019). Furthermore, meeting the demands of the national tourism industry resulted in the employment of 748,000 Canadians in 2019 (Destination Canada, 2019). Given the employment potential and economic value of this industry, it is evident that this is a crucial industry for many Canadian tourist destinations. Considering Canada has the longest coastline in the world, provincial and municipal scale economic stability will be heavily impacted by disaster response and infrastructure investments that accompany climate change and SLR-related disasters (Smith et al., 2021). In 2019, Hurricane Dorian caused $62.2 million in provincial damages; while in 2022, Hurricane Fiona caused over $385 million in provincial damages, totaling nearly $450 million in damages for Nova Scotia from just two storms over three years (Public Safety Canada, 2019; Insurance Bureau of Canada, 2022). This increasing cost and frequency of extreme storm events underscores the need for risk assessment tools to ensure proper resource allocation and adaptation, and visualization tools to convey this risk to diverse stakeholder audiences.

Lunenburg, the focal town of the current study, is already experiencing increases in relative SLR and SSE that threaten buildings, infrastructure, and the local economy (Forbes & Wightman, 2013; Upland Planning and Design, 2019). As a coastal town and United Nations Educational, Scientific and Cultural Organization (UNESCO) world heritage site, the viability of the Lunenburg economy is tied to the survival of its tourism sector. In 2019, with a population of just 2,500, Lunenburg attracted approximately 415,000 visitors and 176 vessels, making it the second most visited place in the province of Nova Scotia (Tourism Nova Scotia, 2020; Atlantic Canada Opportunities Agency, 2021). Coastal destinations like Lunenburg are reliant on the economic benefits of tourism (Scott et al., 2008; Toubes et al., 2017). By 2030, marine tourism is projected to be the largest value-added segment (26%) of the ocean economy (Brumbaugh & Patil, 2017). This is illustrated by the proportion of the Town's population employed in potentially tourism-relevant occupations shown in Table 1. These employment opportunities may face risk due to flooding, erosion of beaches, and extreme storms, which have been shown to threaten the integrity and accessibility of coastal tourist destinations and heritage sites (Rockman, 2016). Considering the economic value and local employment opportunities generated through tourism, there are significant liabilities currently threatening the future of this industry.

Table 1

Proportion of Population Employed in Tourism-Relevant Occupations

Domain	Number of residents	Percentage of population
Sales and service	270	11.27%
Business, finance, and administrative occupations	130	5.43%
Total tourism relevant occupations	400	16.69%

Note. Retrieved from Statistics Canada (2022).

Additional to the obvious social drivers of climate adaptation, it is understood that adaptation and vulnerability assessments are a clear step towards informed adaptation strategies on local and provincial levels. Such assessments aim to create more resilient communities, with a healthy environment, social justice, and viable economies in mind. The aforementioned geographic variability of climate effects underscores the growing need for adaptation measures which are tailored to a specific geographic location, and the needs of its community, accentuating the demand for local climate adaptation and vulnerability assessment tools.

GIS based risk assessments and visualisations have historically been used for various environmental issues (Kumar & Pramod Krishna, 2020; Li et al., 2022; Tomar et al., 2021). Although, rarely do these studies visualize the interaction between biophysical climate impacts (such a SLR and SSE) and geospatial indicators of social factors (such as emergency services and access to other services). Holistic risk assessments view hazards within the larger socio-ecological systems rather than solely investigating the environmental destruction of an area (Van Westen et al., 2014). The current visualization approaches vulnerability and adaptation assessments through this holistic lens. This will be done by creating a 3D web application to visualize layers of climate risk through three different SLR scenarios, and overlaying spatial information such as the location of beaches and trails, or the location of the UNESCO site boundaries. This tool aims to educate stakeholders on the layered effects of climate stressors and how SLR and SSE will affect different industries or activities practiced within the study area. Moreover, connections between stakeholders' perception of climate risks and geographic indicators of said risks will be made. Survey data from various stakeholders in Lunenburg will be investigated through this process.

1.1 Significance of Study

Climate adaptation measures are not regionally consistent, as the effects of this wicked challenge are unequally distributed across the world. These disparities support the necessity to understand the different layers of vulnerabilities, as well as their cumulative effects on a geographic area as a precursor to addressing complex societal issues. A 3D climate visualization tool will be created to assess biophysical, social, and economic risks to the Town of Lunenburg. The study contributes to and builds off the existing research project titled: Towards a Coastal Adaptation and Vulnerability Assessment Model for Tourism in Small Coastal Communities (CAVA) (SSHRC-IDG-430-2020-01263). The aim of the CAVA project is to develop a vulnerability assessment model for coastal communities to build climate adaptability, community resilience, and inform development. The CAVA process bridges scientific, social, and economic dimensions of research through quantitative measures of climate change with a qualitative assessment of the awareness and management capacity on the tourism industry in Lunenburg. Through their data collection, the CAVA project conducted key informant interviews with 26 tourism-related businesses and organisations, in addition to surveys of 54 business and organisations, as well as tourism stakeholders and local residents. The results show a lack of risk awareness and knowledge of risk and adaptation strategies, despite existing resources within the Municipality of the District of Lunenburg's (MODL) Local Climate Change Action Plan, and its associated participatory processes. This lack of awareness impacts the ability for various levels of government (and other decision-making entities) to provide adequate adaptation strategies. This 3D map aims to decrease these knowledge gaps by creating a visualization tool that is accessible to various stakeholder groups and links climate data with community-relevant spatial information.

1.2 Research Objectives

The current study aims to address the following research objectives:

- Visualize the cumulative effects of climate-related stressors and vulnerabilities facing the study area.
- Increase climate education and inform stakeholders and policy makers of the vulnerabilities facing the study area.
- Use GIS tools to visualize and support the existing survey findings of the CAVA project.
- Assess connections between CAVA survey findings on stakeholder risk perception and awareness with biophysical indicators of change.

Chapter 2: Literature Review

This chapter will serve as a review of the context and existing literature that helped shape the CAVA project and this visualization. Beginning with a brief review of the colonial history of Lunenburg which supports the town's cultural heritage and tourism sectors, followed by the current coastal policy implications for the study area. Finally, further examples of GIS based coastal vulnerability assessments will be explored.

2.1 History of The Town of Lunenburg

Lunenburg's location is known by the Mi'kmaq as E'se'katik, which means 'place of clams', in reference to the region's long-standing fishing potential (McCann, 2022). Given the seasonality of activities practised by the Mi'kmaq in the location of Lunenburg, the annual population significantly varied, reaching up to 300 inhabitants at some times of year prior to European contact (Wicken, 1993). In the wake of early examples of French settlement, Mi'kmaq and Acadian peoples cohabitated at the site of Lunenburg for over 100 years; with Acadians referring to this region as Merliguesche (McCann, 2022). Once Canada fell under British rule, the area was named Lunenburg (McCann, 2022). To force out the Mi'kmaq and Acadians, in 1753, the British government granted land to and settled 1453 protestants from various regions of Europe (McCann, 2022). Shortly after this settlement, the British government forcefully deported all remaining Acadians as part of Le Grand Dérangement (McCann, 2022). This expulsion, paired with the ongoing genocidal tactics of settler colonialism on Indigenous peoples, swiftly and drastically altered the demographics of this region. Today, some examples of early British architecture in Lunenburg are still standing (McCann, 2022). Like a palimpsest, well maintained examples of the Town's heritage architecture tell stories of the colonial history of Lunenburg, exemplifying multiple reasons why a portion of this town has been designated a UNESCO world heritage site. Approximately 70% of the original colonial buildings from the 18th and 19th century are still standing, a rarity that speaks to the cultural and historical significance of the Old Town Lunenburg (Parks Canada, 2023). See Appendix A for images of the Old Town Lunenburg.

2.2 An Analysis of Contemporary Climate Adaptation Policies in Lunenburg

The Municipality of the District of Lunenburg's [MODL] (2022a), Local Climate Change Action Plan summarises the municipality's 10-year strategic action plan for emissions reductions and climate change adaptation plans. While the MODLs Local Climate Change Action Plan encompasses the entire Lunenburg Municipality, this document's lack of coastal specific planning will evidently have negative ramifications for the Town of Lunenburg. This plan outlines how the Municipality is working towards 30% emissions reduction by the year 2030 from 2019 levels and achieve net zero-emissions by 2050. However, there is little mention of the risks to coastal communities and tourism. The plan does not attempt to address coastal erosion, SLR, or saltwater intrusion. There is no mention of SLR impacts, or protective SLR infrastructure/municipal regulations. The 3D visualization will attempt to increase the accessibility of such information through an interactive application (MODL, 2022a).

From a more local perspective, in 2015 the Town of Lunenburg commissioned CBCL Limited to create a climate change action plan for the Town (CBCL Limited, 2015). This document provided an extensive outline of how the Town will be impacted by SLR and SSE. This action plan, however, is limited in the fact that it is based off data from the early 2010s and only provides static maps to visualize SLR and SSE effects in isolation. The current 3D visualization attempts to create more accessible SLR and SSE data by enabling diverse stakeholder groups to access this data and interact with it in ways that fit their needs or concerns. As demonstrated by Duarte et al. (2022), interactive maps have been determined to increase the accessibility and active learning of science communication materials, particularly for audiences who may not specialize within climate-relevant domains. The 3D visualization encompasses a larger study area than the CBCL (2015) action plan, adding relevant industries and tourism hotspots which are outside the Town boundaries, yet still interconnected with the Town's economy, residents, and culture.

The MODL, like many regions in Canada have experienced community pushback and frustration surrounding flood zone/SLR mapping (MODL, 2022b; CTV Montreal, 2019). The MODL set out (in accordance with the Province of Nova Scotia's Statement of Interest on Flood Risk) to create flood risk maps for the entire municipality (MODL, 2022b). Shortly after the release of these mapping applications, the Municipal Council decided to have them taken down due to pushback by the community for concerns about this information's accuracy, effect on property values, and impacts on insurance rates (MODL, 2022b).

2.3 Canadian Tourism Industry

SLR, SSE, and other climate ramifications will affect coastal areas, where tourism often dominates the local economy. This threatens the integrity and accessibility of coastal tourist destinations and heritage sites (Rockman, 2016). Given the share of the Canadian GDP generated through the tourism industry discussed in Chapter 1, it is evident that there are significant liabilities for this industry. This is supported by the fact that in 2021, the tourism industry accounted for $1 billion of the Nova Scotian GDP, a major economic sector even with the productivity decrease because of the COVID-19 pandemic (Tourism Nova Scotia, n.d.). SLR, erosion of beaches, and the increasing risk of SSE all contribute to the vulnerability of coastal regions, exacerbating concerns about the sustainability of their local tourism sectors. To gain a holistic understanding of the risks facing Lunenburg, it is necessary to investigate beyond sources of environmental strain that result from the climate crisis, as no elements of a community nor drivers of climate change can operate in isolation from one another. SLR and SSE scenarios will therefore be investigated in conjunction with impacts on social and economic indicative layers.

2.4 Relative Sea Level Rise, Land Subsidence, and Storm Surges

Absolute SLR refers to the change in sea level relative to the Earth's centre of mass, whereas relative SLR refers to the change in sea level in reference to land (Mazzotti et al., 2008). Relative SLR therefore accounts for the effects of vertical land movements such as subsidence. Both forms of SLR result in coastal inundation as land is lost to the sea, but also increase vulnerability to SSE and erosion (James et al., 2014). All scenarios and discussions of SLR in Lunenburg for the current study will refer to relative SLR which factors in land subsidence effects.

During the peak of the most recent glacial period, the Laurentide ice sheet, situated above the Hudson Bay, was up to 4km thick (Simon et al., 2016). Due to the extremely viscous, yet liquid nature of the Earth's mantle, the weight of the Laurentide ice sheet caused the Earth’s crust below Northern Quebec to compress and the crust below Atlantic Canada to lift over many years (Simon et al., 2016). Given that the

Laurentide ice sheet no longer exists, Atlantic Canada is currently experiencing a phenomenon known as subsidence (James et al., 2014). This means that the expansion of the mantle below Atlantic Canada during the last glacial period is currently causing the land of Atlantic Canada to sink back into its original place. This is the main reason why much of Atlantic Canada is experiencing a relative SLR higher than the global average. As discussed in Chapter 1, it is common for locations across NS to experience up to 2mm/year of subsidence, with some regions (Sydney) sinking by up to 4.54 mm/year (Greenan et al., 2019; Robin et al., 2020).

2.5 Current State of Coastal Adaptation and Vulnerability Assessments

Dube et al. (2021) describe a vulnerability assessment of Cape Town very similar to that of the current study. Cape Town is a popular destination for tourists, located on the coast of South Africa threatened by rising sea levels, erosion, and flooding. The authors examine the implications of climate change on the tourism industry in Cape Town and use this information to recommend adaptation strategies for the industry. Furthermore, the medium used to assess sea-level rise impacts was Digital Elevation Models (DEMs) created through the NASA shuttle-radar-topography mission (SRTM), which is a methodology that will inform aspects of the SLR visualization. The authors used a mixed-method approach to collect various data points of biophysical indicators both remotely and in the field; this data was then supported by informant interviews. The current 3D map aims to address a key limitation of Dube and colleagues (2021) by visualizing the relation between increasing SLR and SSE, with various social and economic geospatial indicators simultaneously, so stakeholders can gain a better understanding of what elements of their community will be impacted by climate change.

Building on the static maps and figures created in the study by Dube and colleagues (2021), the current study aims to increase climate awareness and education by making coastal vulnerability assessments more accessible using a dynamic and interactive GIS web application that maps vulnerabilities. This application will then be used to compare the risks facing Lunenburg through the lens of the CAVA projects existing survey findings on risk perception and awareness.

2.6 Community Engagement Studies

Rulleau & Rey-Valette (2017) investigated community-based measures for tackling climate change in coastal areas of Southeast France following a major storm event. In a location tied to the tourism industry, the researchers created a survey to study the perceptions of residents on the effectiveness of climate adaptation strategies and their willingness to support and contribute to these efforts. The survey particularly assessed attitudes towards shoreline hardening infrastructure including sea walls and adaptation projects such as managed retreat and relocation. Overall, the authors found that individuals were in support of these types of infrastructure changes, provided there is not a cap on compensation. Results suggested attitudes were heavily influenced by an individual's perceptions of government policy effectiveness and the benefits of tourism, highlighting the potential impact of increasing climate education within Lunenburg. The authors concluded that while these infrastructure-supporting attitudes may exist, there is a need for improved coordination between different actors to enable long-term forward adaptation planning, underlining the need for increased climate education and effective participatory processes (Rulleau & Rey-Valette, 2017).

Studies like Rulleau & Rey-Valette (2017) and Dube et al. (2021) highlight how there are few coastal adaptation and vulnerability assessments that investigate the overlapping risks associated with biophysical and social impacts of climate change, and survey data to gauge residents' awareness of climate-related issues. The 3D climate visualization tool aims to address these gaps by investigating the biophysical impacts threatening Lunenburg including sea-level rise; while simultaneously investigating how these impacts are related to residents' perceptions and attitudes toward climate adaptation, and how this visualization can be used to increase effective participatory processes and risk awareness. By combining these elements, a stronger understanding of how these complex issues are interconnected, and an increase in climate education can be gained.

Chapter 3: Methods

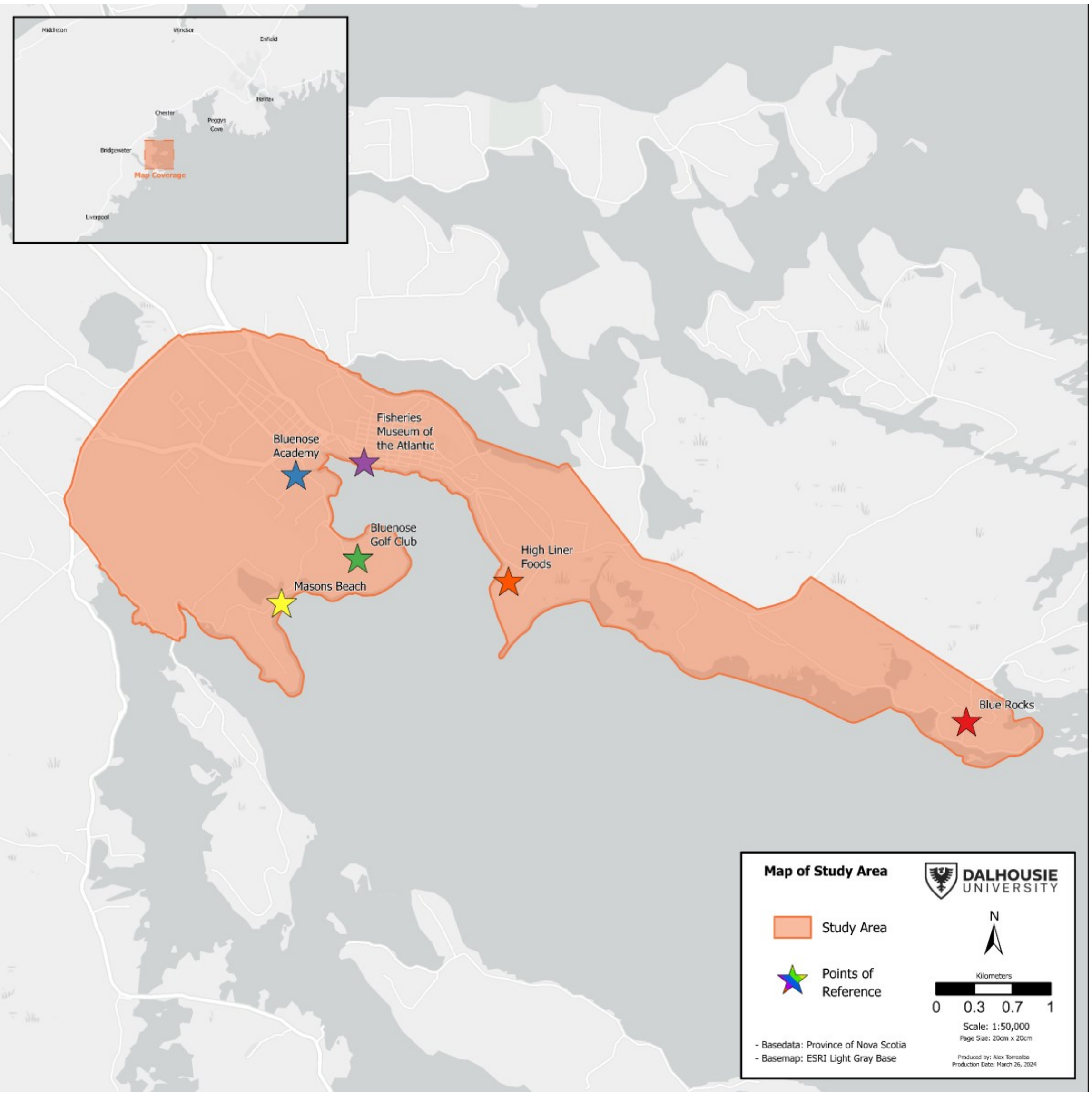
This study uses GIS methods to analyse and visualize climate vulnerabilities, aiming to assess the projected impacts of climate change on the Town of Lunenburg and its tourism industry. Given Lunenburg's geographic location and economic significance, the Town will be increasingly at risk of issues related to climate change. The impacts will be visualized through GIS methods, including a custom interactive ArcGIS Web Experience with a variety of open data sources. Various types of geospatial data, such as Light Detection and Ranging (LiDAR), Digital Elevation Models (DEMs), raster data, and geometric fields, will be utilized, incorporating economic, social, and biophysical points, lines, and polygons. The current study will adopt a form of grounded theory to identify areas for geospatial analysis and qualitative connections based on the findings of the visualisation and any notable patterns with the CAVA project survey data.

3.1 Study Area

The first step in the GIS visualization was to determine and create the study area polygon, demonstrated in Figure 3. A polygon was drawn that included the entire Town of Lunenburg, but also included areas important to its tourism industry that are not within the Town's boundary such as Mason's Beach and the Highliner Foods Fish Processing plant. Additional to the Town of Lunenburg, it was decided that the nearby town of Blue Rocks should also be included due to its connection to the Lunenburg tourism industry with the presence of boat tour businesses, art galleries, and trails.

Figure 3

Study Area used for GIS Visualization and SLR Scenario Bands



Note. Reference points can be seen in different coloured star shapes.

3.2 Climate Relevant Data Acquisition

The predominate sources for geographic data in this study were open government databases. Tables 2-3 outline the dataset sources and layers used for this study from the Nova Scotia Geographic Data Directory, and the Town of Lunenburg ArcGIS Online Profile, respectively.

Table 2

Sources of Adapted Visualisation Layers from Nova Scotia Geographic Data Directory

Dataset Title	Visualisation Title	Original Data Type	Adapted Data Type	Date Published (YYYY-MM-DD)
Nova Scotia Civic Address File (NSCAF)	N/A*	Point	Point	2023-12-08
The Nova Scotia Protected Area System	N/A*	Polygon	Polygon	2020-05-27
Nova Scotia Topographic Database - Water Features	Wet Features	Polygon	Polygon	2020-12-18
Nova Scotia Topographic Database - Roads, Trails and Rails	Roads	Line	Line	2020-12-18
	Trails and Tracks	Line	Line	2020-12-18
Nova Scotia Topographic Database - Digital Elevation Model (DEM)	Lunenburg Ground	Vector points	ArcGIS Tiled Elevation Service	2019-01-01
Nova Scotia LiDAR Data DataLocator	Sea Level Rise Scenarios	Point Cloud	Elevation Bands	2019-05-25

Note. Visualization titles listed as "N/A*" indicate a layer that was used for analysis purposes only and not included on the visualization itself. All these data characteristics are retrieved from the Government of Nova Scotia. (n.d.). Geographic Data Directory [Database]. https://nsgi.novascotia.ca/gdd/

Table 3

Sources of Adapted Visualisation Layers from the Town of Lunenburg's ArcGIS Online Profile

Dataset Title	**Visualization Title**	**Original Data Type**	**Adapted Data Type**	**Date Published (YYYY-MM-DD)**
Town of Lunenburg Limits	Town of Lunenburg Limits	Polygon	Polygon	2021-11-22
TOL Registered Heritage Properties	Heritage Properties	Polygon	3D Polygon	2021-12-17
UNESO World Heritage Site and National Historic Site of Canada	UNESCO Heritage Site	Polygon	Polygon	2021-12-17

Note. All of these data characteristics are retrieved from the Town of Lunenburg. (n.d.). ArcGIS Online Content. https://maps.arcgis.com/home/search.html?searchTerm=owner%3A%22Lunenburg%22#content

Additionally, other layers were plotted by hand for data that did not exist through open geospatial data. This includes plotting businesses in the study area from an existing dataset created by the CAVA project. Furthermore, layers identifying notable tourism indicators such as beaches, trails, museums, and parks were plotted by hand. Beaches were plotted by creating a 'Pairwise Buffer' of 0m elevation contours that overlapped beach areas. Additionally, town services were plotted, including the Lunenburg Fire Department, the Fishermen's Memorial Hospital, the Lunenburg EHS Base, and the Lunenburg RCMP Office. This plotting by hand employed several different methods. For the CAVA dataset of businesses within the study area, a comma separated values (.csv) file of addresses were created. Using the 'Geocode Table' feature within ArcGIS Desktop, all addresses were converted into geospatial points, this data was then exported to a shapefile to be uploaded to ArcGIS Online. Other information such as single point structures including the emergency services layer were all plotted by searching for these locations on Google Maps, then inputting these coordinates into a .csv file. This file was converted into geospatial point data through the ‘XY Table to Point’ feature in ArcGIS Pro, which was then exported into a shapefile to be uploaded to ArcGIS Online.

Other layers such as provincially protected areas were initially considered for the visualization tool, yet it was later determined that the addition of such layers did not contribute to the overall thesis and its objectives. For the example of protected areas, this was excluded since the nearest protected area (Second Peninsula Provincial Park) was greater than 2km from the study area boundaries (Open Government Canada, 2022). Furthermore, while civic addresses were used for analysis purposes to quantify risk, this layer was not selected to be included in the visualization.

3.3 Data Translation and Storage

The data in Tables 2-4 exist in various file formats including shapefiles, hosted feature layers, and tagged image file formats (.tiff). To keep data consistent and organised, all other file formats were converted into hosted feature layers. This was done by placing all different supported data files into a project on ArcGIS Pro and exporting each layer as a zipped shapefile. This data was then uploaded into an ArcGIS Online content folder. Hosted feature layers were selected for this study as they are compatible with web scenes, and support fast visualisation of 2D and 3D data, while being optimised for online visualisation and use.

3.4 Sea Level Rise Elevation Bands

SLR elevation bands were created to visualize impacted areas at various flooding heights using a DEM created from the Government of Nova Scotia's raw LiDAR data described in Table 2. Extracting a DEM from this LiDAR data was chosen for this task as opposed to a Digital Terrain Model (DTM) as DTMs map the terrain inclusive of its anthropogenic structures. In the event of extreme storms or future erosion, human-made structures may fail and therefore the DEM (bare-earth only) provides a more accurate worst-case scenario for this purpose. That being said, seawalls or other hard engineering climate solutions could be employed and change the accuracy of this flood map as coastal protective infrastructure in the Town of Lunenburg develops. These SLR bands were created by opening all LiDAR files within a LAS dataset on ArcGIS Pro and setting the ground classified points as the project's elevation source. This was done as the provincial LiDAR has a resolution of 1m ^{2}, which is more consistent and accurate than the WorldElevation3D elevation source automatically added to ArcGIS Pro projects. These ground classified points were then converted into a DEM using the LAS Dataset to Raster feature.

Assumedly due to the presence of boats within the Town of Lunenburg's Harbour, when elevation contours were created through ArcGIS Pro's 'Surface Contour (Spatial Analyst)' function, this would result in jagged edges that do not match the satellite imagery or natural Nova Scotian topography (see Appendix B). Due to these inconsistencies and the raster data type of these contours, it was decided that exporting vector type elevation contour lines from Global Mapper would be more appropriate for this purpose. Upon loading the DEM created from the NS LiDAR data within a Global

Mapper project, using the 'Contour Generation' feature and a simplification rate of 0.5, contours were generated at: 0m, 1.75m, 3.25m, and 4.15m. These contours were then exported as line-type shapefiles and added to this project's ArcGIS workspace. These contours were then turned into elevations bands within ArcGIS Pro's 'Generate Elevation Bands from Features' topographic production geoprocessing tool to show the difference between each elevation height and current average sea-level. This was done to display the impact of SLR in an intuitive way, where layer visibility can be easily toggled with just one polygon for each scenario. There were however instances where elevation contour lines did not connect which would mean that no polygon would be formed for the affected area. In this case a polygon would be plotted using the trace function of the create features tool.

The heights selected for these scenarios were based off the 3 possible scenarios investigated through this thesis. The first SLR rise scenario of 1.75m was selected based on the subsidence inclusive relative SLR prediction of up to 1.75m by 2100 by Wade (2022). For the other scenarios in this study, we aimed to visualize the potential impact of SSE in conjunction with the projected SLR baseline of 1.75m by 2100. The second scenario represents the combined effect of a 1.75m SLR and an additional 1.5m water level increase from a typical SSE in Atlantic Canada, resulting in a total elevation of 3.25m. Scenario 3 visualizes the combined impact of a 1.75m SLR and a worst-case scenario SSE of 2.4m, resulting in a total elevation of 4.15m. This 2.4m of SSE was selected for this worst-case scenario as this was the highest surge recorded during Hurricane Fiona in Atlantic Canada along the Northumberland Strait. The selection of these SSE levels were informed by personal communications with Dr. Tim Webster, who is an expert in the field of coastal flood risk research (Webster, T., personal communication, March 13, 2024).

3.5 Creation of Web Scene/Layer Compilation

A local web scene was created to begin the creation of the risk awareness visualisation. A web scene was selected over a web map to enable the application of 3D data files and terrain information. Esri's Satellite Imagery basemap was selected for this project to act as a realistic backdrop to this visualisation. Individual layers described in Section 3.2 of this study were organized by thematic groups. The tourism grouping included heritage properties, the UNESCO site, museums, and galleries. The environmental grouping consisted of beaches, parks, wet features, trails, and tracks. The town services grouping consisted of emergency services, essential services (i.e. gasoline and groceries), and the Town of Lunenburg limits. Finally, sea-level rise layers were grouped together for ease of access so users can adjust through different sea-level heights in one location.

3.6 Creation of Web Experience

Within ArcGIS Online, a custom web experience was created in the ArcGIS Experience builder, the web scene described in Section 3.5 of this study was added as the embedded scene. The design of this Web Experience prioritised interactive widgets that support dynamic map elements. A map layers widget was created to allow individuals to choose which layers are visible. Other widgets included a basemap selection widget, a legend widget, a location search widget, and a drawing widget. The layouts of these widgets and the 3D visualization itself was changed based on the device type of users to ensure readability and clarity. Furthermore, a description of how to use the map was included below each widget. This type of 3D interactive data visualization was selected for this project as theories of effective communication highlight the benefits of spatial data representation, interaction, and colour (Duarte et al., 2022). Spatial representation of data increases the accessibility of science communication over numbers alone, particularly with respect to phenomena such as SLR which can be challenging to quantify without spatial representation (Duarte et al., 2022). The visualization itself can be accessed through this link.

3.7 Numerical Quantification of Risk and Traffic Light Symbology

Civic addresses were excluded from the visualization to retain anonymity for residents. To best quantify the level of risk to Lunenburg's civic addresses in an ethical manner, a numerical figure of how many civic addresses would be inundated under each of the SLR scenarios is presented. This was calculated by adding the provincial Civic Address file discussed in Table 2 to an ArcGIS Pro workspace and creating a 'Pairwise Clip' of this layer through the three SLR scenarios. In each case, the civic addresses would be the input features, and the SLR scenarios would be the clip features. The number of attributes within each layer was then calculated and used within the analysis of this report to avoid identifying which houses specifically would be affected by a SLR scenario.

This methodology was also used to create the traffic light symbology for the roads and trails layer within the visualization. Data such as roads and trails were best visualized by creating a unique symbology that assigns colours based on the elevation of line segments. This was done through putting road and trail features through a 'Pairwise Clip' of each of the three SLR scenarios, then merging these clipped files once again so each segment could be coloured based upon its intersection (or lack thereof) with each of the SLR elevation bands. Upon being uploaded to the Web Scene, all roads/trails within the 1.75m SLR elevation band were coloured red, those within the 3.25m SLR elevation band were coloured orange, those within the 4.15m SLR elevation band were coloured yellow, and finally those that do not intersect any scenarios discussed in the current thesis were coloured green. This was done to make this visualization as intuitive as possible as this colouring method mimics that of a traffic light.

3.8 Comparison Between Survey Results and GIS data

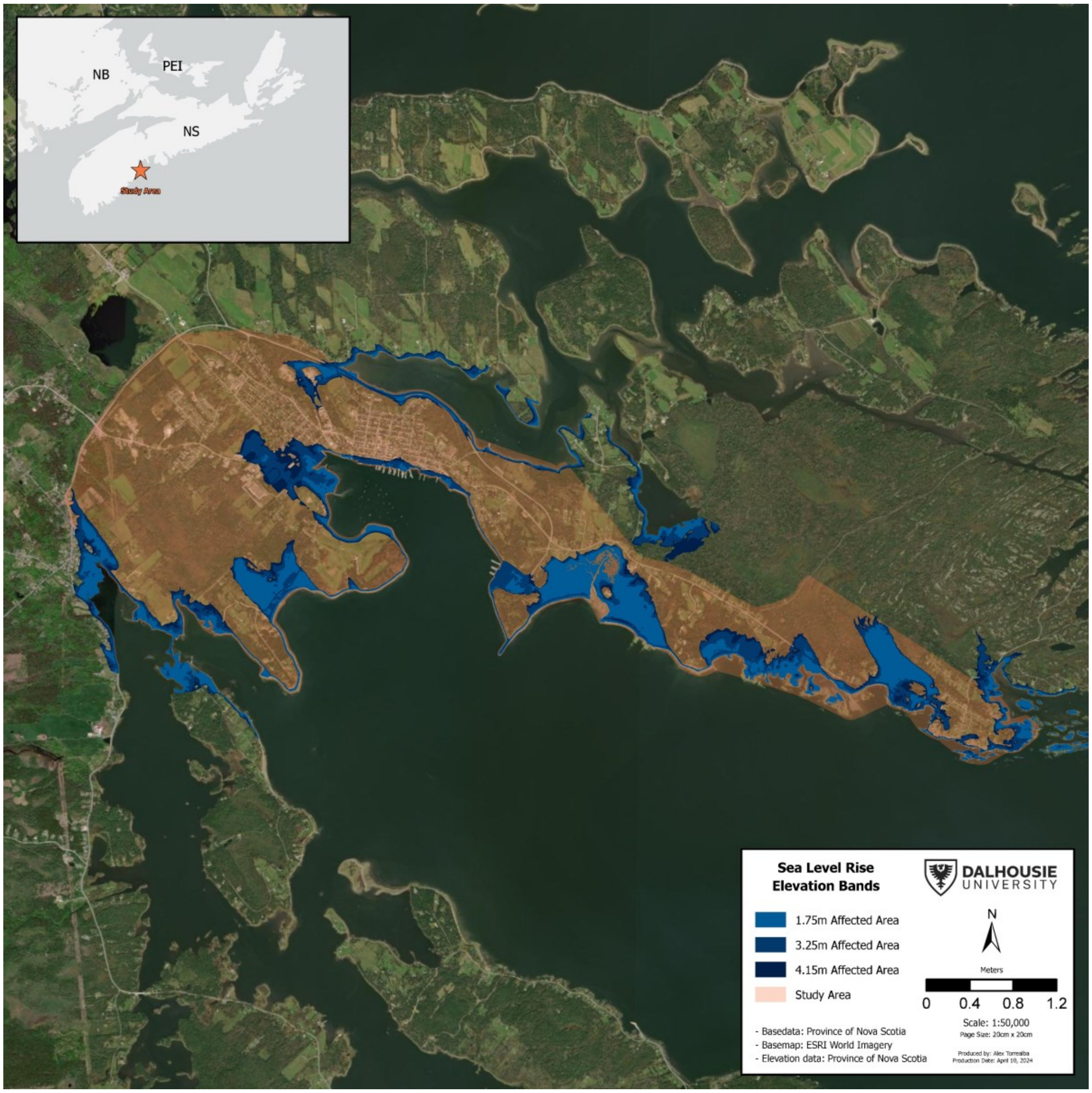
Correlations between results from the CAVA project's survey data and biophysical data were explored over the course of this study. Inspired by grounded theory, the method employed for these observations was inductive and evolved as patterns emerged through the creation of the visualisation tool. As layers and spatial data populated the visualisation tool, an effort was made to note any trends in this data and the survey results. For instance, when a trend of geospatial indicators led to areas of high predicted vulnerability, a comparison was made between the geometric attributes (ex: percentage of study area flooded under 3.25m sea-level rise scenario and survey results and or perceptions of an associated issue). The analysis particularly compared stakeholder risk perception with the quantifiable: number of civic addresses, length of road, and the land area affected.

Chapter 4: Results

The results of the SLR visualization polygons can also be used to quantify to risk facing Lunenburg under each scenario investigated. Figure 4 illustrates the SLR elevation bands discussed in Section 3.4.

Figure 4

SLR Elevation Bands within the Study Area



Note. The study area is represented by an orange polygon. Sea level rise elevation bands are represented by polygons of three shades blue, with 1.75m, 3.25m, and 4.15m denoted by light, medium, and dark blue respectively.

Through the creation of the SLR bands, quantifiable risk indicators were calculated such as the percent of the Town's land area, roads, and civic addresses lost due to each of the SLR scenarios; Tables 4-5 illustrate this data.

Table 4

Impact of SLR Scenarios on Civic Addresses, Roads, and Land Area Within Town Boundary

SLR Scenario	Civic address		Roads		Land area	
	Number affected	Proportion of town affected (%)	Length affected (km)	Proportion of town affected (%)	Area affected (km²)	Proportion of town affected (%)
1.75m	18	1.268	0.934	2.101	0.173	4.437
3.25m	83	5.849	6.789	15.272	0.471	12.047
4.15m	126	8.879	8.883	19.985	0.637	16.307

Table 5

Impact of SLR Scenarios on Civic Addresses, Roads, and Land Area Within Study Area

SLR Scenario	Civic address		Roads		Land area	
	Number affected	Proportion of study area affected (%)	Length affected (km)	Proportion of study area affected (%)	Area affected (km²)	Proportion of study area affected (%)
1.75m	43	2.312	2.632	3.102	1.207	10.903
3.25m	140	7.527	14.562	17.162	2.070	18.698
4.15m	190	10.215	18.233	21.489	2.479	22.393

Scenario 1 (1.75m SLR, 0m SSE) resulted in the inundation of 18 civic addresses within Lunenburg, accounting for 1.268% of all civic addresses within the town, and 43 addresses within the study area, representing 2.312% of the total. Scenario 2 (1.75m SLR, 1.5m SSE) resulted in the flooding of 83 civic addresses within Lunenburg, accounting for 5.849% of all civic addresses within the town, and 140 addresses within the study area, representing 7.527% of the total. Scenario 3 (1.75m SLR, 2.4m SSE) resulted in the inundation of 126 civic addresses within Lunenburg, accounting for 8.879% of all civic addresses within the town, and 190 addresses within the study area, representing 10.215% of the total.

Scenario 1 (1.75m SLR, 0m SSE) resulted in the inundation of 0.934km of roads within Lunenburg, accounting for 2.101% of the town's total road length, and 2.632km of roads within the study area, representing 3.102% of the total. Scenario 2 (1.75m SLR, 1.5m SSE) resulted in the inundation of 6.789km of roads within Lunenburg, accounting for 15.272% of the town's total road length, and 14.562km of roads within the study area, representing 17.162% of the total. Scenario 3 (1.75m SLR, 2.4m SSE) resulted in the flooding of 8.883km of roads within Lunenburg, accounting for 19.985% of the town's total road length, and 18.233km of roads within the study area, representing 21.489% of the total.

Scenario 1 (1.75m SLR, 0m SSE) resulted in the inundation of 0.173km² of town land, which is 4.437% of the total, and 1.207km² of the study area which composes 10.903% of the total. Scenario 2 (1.75m SLR, 1.5m SSE) resulted in the inundation of 0.471km² of town land, which is 12.047% of the total, and 2.070km² of the study area which constitutes 18.698% of the total. Scenario 3 (1.75m SLR, 2.4m SSE) resulted in the flooding of 0.637km² of town land, which is 16.307% of the total, and 2.479km² of the study area which comprises 22.393% of the total.

Chapter 5: Analysis and Discussion

While there is an extensive body of research that exists with respect to biophysical mapping of SLR, further research is required that investigates the impacts of SSE and climate vulnerabilities on a community scale, considering the interconnected effects on socioeconomic factors. The variable and wicked nature of the climate crisis exemplifies the need for local scale mapping tools to accurately assess broad climate vulnerabilities of communities, particularly those reliant on climate-dependant industries such as Lunenburg. In Atlantic Canada, this need is particularly important given the increased rate of relative SLR due to the ongoing effects of land subsidence and the wave heights of increasingly powerful SSE combined. Physical mapping of risk is a crucial precursor to developing climate adaptation plans which minimize the economic impact of climate change and increase resilience and economic preparedness within the study area. Given Lunenburg's status as the second most visited place in the province, and its proportion of the population employed in potentially climate-dependant industries, a better understanding of these climate risks is crucial to ensuring an equitable transition and job retention for residents. This methodology allows for a more holistic understanding of how a diverse range of community characteristics will be affected as climate change is not an isolated cascade of events.

Additional to a holistic visualization of climate risks and vulnerabilities, the current study builds off survey data which demonstrate the current risk awareness gap within Lunenburg stakeholders. Effective management of adaptation strategies in Lunenburg should incorporate perspectives from diverse stakeholder groups including business owners, tourism stakeholders, and residents. Yet numerous representatives of these stakeholder groups are not aware of the climate-related risks facing Lunenburg as results from the CAVA study show: for instance, 45% of tourism stakeholders were not aware of the climate risks facing Lunenburg. Effective participatory processes within the adoption of climate policy are not possible unless all stakeholder groups are well-informed of the issues facing Lunenburg. Even with the Town's approval of the MODL Climate Action plan described in Section 2.2 and its associated participatory processes and the publication of the Town's Climate Action Plan, 80% of interviewed residents were not aware of steps the town is taking in response to climate change. With this gap in policy awareness in mind, it is possible the participatory process that effectuated the adoption of the MODL plan did not meet the holistic needs of the community. Preparedness and awareness among different stakeholder groups is a necessary precursor for community-led adaptation strategies. The current visualization can act as a tool to equalize awareness levels across stakeholder groups. All these elements work together to develop climate education within Lunenburg and heighten the risk awareness levels to inform the enactment of stronger coastal legislation at the local or municipal levels.

In a coastal community such as the study area, adaptation measures should be informed by tourism, community, business, resident, and organizational stakeholders combined. Reiterating the findings of Rulleau & Rey-Valette (2017), support for infrastructure investments following major storm events were heavily influenced by an individual's perception of government policy effectiveness and tourism industry appraisal. Without adequate perceptions of risk, individuals are less likely to accept adaptation policies (Rulleau & Rey-Valette, 2017). These findings were used to attempt to increase risk awareness in a way that reduces community-pushback seen through the

MODL flood plain maps described in Section 2.2 (MODL, 2022b). Most notably, while civic addresses were used to quantify risk to the study area and town, this layer was excluded from the visualization to retain individual resident anonymity regarding concerns for property values or insurance rates.

5.1 Assessment of Geometric Risk Indicators

Through the 3D visualization and inundated address counts, roads, and land, the current study identifies several ways in which the study area may be affected in the coming years due to climate change. Contrasting this level of risk, of the tourism and business stakeholders interviewed through the CAVA project, 50% are not concerned about the threat of climate change to their business, and 74% are not taking steps to mitigate climate risks to their business. This discrepancy demonstrates a lack of risk awareness and knowledge of mitigation strategies. While the CBCL report discussed in Section 2.2 outlines the risk to Lunenburg with respect to SLR and SSE, there is evidently a disconnect between the current data available, and stakeholders' perception of risk. The visualization can act as a tool to bridge this gap, by making this type of data easier to understand and learn through interactive visualization elements.

The risk awareness map attempts to address the climate knowledge gaps in Lunenburg; and as Duarte et al. (2022) point out, through a medium that is accessible to individuals who may not have a background in the earth sciences. To increase the effectiveness of participatory processes, government stakeholders could implement visualizations with broad categorical data to enable different stakeholders to glean more useful insights from existing sources. While much of the data used for the visualization is open governmental data, most stakeholders do not have access to the software required to analyze and visualize this data, or the knowledge of how to work with such proprietary software. The increased deployment of public GIS visualizations would give new meaning and potential to existing data sources.

The use of layer grouping categories such as environmental, tourism, and town services allows for individual stakeholder groups to isolate data that is specific to their populace or fits their needs. The SLR rise scenario layers were created specifically for this visualization, as this is not data that is available within current open government data sources. These layers were selected to visually show what pieces of infrastructure may be affected by flooding in the coming years. While it would have been simple to create tables that show the elevation heights of individual buildings or landmarks, this does not display risk in such a tangible way and would likely result in community pushback as it associated a level of risk with a specific address of building.

The current study uses 3D maps to offer an accurate representation of real-world environments, modelling human vision and spatial perception closer than non-spatial methods of displaying data. Roads, trails, and track layers were included to visualize community features that would affect the accessibility of community services and travel if they were destroyed by a SLR scenario. A viable economy enables stakeholders to participate in coastal activities such as fishing, kayaking, hiking, and swimming. Damaged roads would have detrimental effects if flooded as this is the main way of transporting goods and services and the primary mode of transport used by tourists to enter the study area (Atlantic Canada Opportunities Agency, 2021). The capital cost of each kilometer of a 100 series (non-divided) highway in Nova Scotia is $3.5 million, underscoring the financial liability associated with each of the scenario’s road length lost described in Table 4-5 (Nova Scotia Department of Public Works, 2021). Layers such as beaches, wet features (i.e. wetland, lakes, ponds, etc.), museums and galleries, and parks were included as these layers are features that impact the quality of tourism visitors' experiences. Ensuring economic stability is integral to addressing the climate crisis, as adaptation measures are at times associated with high capital investments such as road construction. As tourism has been determined a "climate-dependant industry", the level of impact these layers will experience could affect the livelihoods of 16.69% of the Town's population (Scott et al., 2008).

Business layers were also included within this visualization to demonstrate other industry vulnerabilities, notably the High Liner Foods fish processing plant. Roughly 1km from the Lunenburg Waterfront is the High Liner Foods fish-processing plant, one of Canada's largest fish-processing plants (McCann, 2022). In addition to the revenue this plant contributes to the local economy, this plant employs many residents, and directly supports the tourism industry as Lunenburg is known for its seafood. In 2016, High Liner Foods invested $13 million dollars to upgrade this plant and create 70 new union jobs, underscoring the continued growth and importance of this industry for the Town of Lunenburg (Withers, 2016). The effects of climate change such as flooding, erosion, and extreme storms threaten the integrity and accessibility of Highliner Food's coastal infrastructure and ability to function (Rockman, 2016). In addition to its direct employment of Lunenburg residents, this plant indirectly supports local fishers and businesses who rely on their products.

5.2 Limitations and Future Directions

One of the main limitations of this visualization is the potential exclusion of populations who do not have access to the internet. This could be due to a lack of computer literacy, or a lack of physical access to the internet for financial or social reasons. This could be minimally rectified through the creation of paper maps for individuals who may prefer or require such an alternative means of data access. To get the best chance of fully equalizing climate risk awareness levels across stakeholder groups, accessible data for all is required. However, this alternative paper format would greatly decrease the intuitive nature, and active learning fostered by interactive 3D maps. As paper maps would not be able to effectively visualize this amount of data at once, nor would this support the benefits of layer groupings to allow stakeholders to isolate data that fits their needs.

The size of the study area is a potential limitation for the 3D climate visualization. Other projects may assess more settlements and residential areas next to a specification of tourism-dependent operations or businesses, yet this would require more time than the current study allows. However, increasing the study area may also result in the overgeneralization of findings as climate ramifications are geographically variable. Additionally, a larger study area may require the assessment of multiple jurisdictions of local climate mitigation documents, therefore preparedness and policy awareness across stakeholder groups may differ geographically. The policy awareness gap among different stakeholder groups identified through the CAVA project surveys could be improved within the 3D visualization itself, by informing viewers of relevant policy information to the layers currently selected.

Another limitation of the visualization tool is the exclusion of data to demonstrate the impact of precipitation-based flooding events and risk. From 1948 to 2016, average annual precipitation increased in Atlantic Canada by 11% (Zhang et al., 2019). On July 21, 2023, the province of Nova Scotia was hit by torrential rains with some regions of the province recording 250 mm of rainfall in a very short period (Public Safety Canada, 2023). Significant precipitation events are causing an increase in the occurrence of flooding-related infrastructure damages, damages to ecosystems and biodiversity, and an increase in the spread of waterborne diseases (CLIMAtlantic, n.d.). As precipitation-based flooding events are becoming more severe due to climate change, future research should attempt to address this by investigating the combined effects of SLR and SSE flood risk and precipitation flood risk.

Finally, the accuracy of the current study may be limited through human and software-based errors. When working with large datasets and various elevation heights, there were instances where polygons were formed from elevation contour lines when this was not meant to be (due to the presence of obstructions to the LiDAR data from things like boats or mislabeled point cloud data). Moreover, when a selection of contour lines had small gaps between vertices, this would not form a complete SLR elevation band polygon. Such instances were addressed through the creation or deletion of polygons using the trace feature to mimic as close as possible the original features of the contour lines. Moreover, the geospatial information obtained from open governmental sources may have contained inaccuracies that were consequently incorporated into the 3D visualization.

Chapter 6: Conclusion

The current study explores the climate awareness and preparedness gaps among different stakeholder groups and explored the uses of local scale risk visualization tools. The use of GIS tools to assess SLR scenarios demonstrates the varying and interconnected effects of climate change impacts on a variety of community characteristics such as the tourism industry in Lunenburg. Through the integration of a diverse range of layer content, and interactive geospatial visualization tools, this study will increase the accessibility and active learning of open geospatial data. This methodology of visualization can act as a tool to equalize different levels of risk awareness and perceptions among different stakeholder groups and increase climate education, while providing stakeholders with the opportunity to select layers based on their interests or concerns. Increases in climate education are a necessary precursor to effective participatory processes and informed decision making. The current study can act as a guiding document for future policy decisions, infrastructure investments, and foreword adaptation planning; allowing us all to work towards a more sustainable, and resilient society.

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Appendix A

Images of Old Town Lunenburg Heritage Buildings and Surrounding Areas

Figure A1

Buildings Within Commercial Zone 1 on 116-128 Montague Street

Figure A2

View of High Liner Foods Fish Processing Plant from Waterfront

Figure A3

Buildings Within Commercial Zone 1 on 56-82 Montague Street

Figure A4

Docks Abutting 240 Montague Street within Marine Industrial Zone 4

Figure A5

Residential Zone 1 Buildings Near the Intersection of Montague Street and Kempt Street

Figure A6

Buildings Within Commercial Zone 1 on South End of King Street

Appendix B

Figure B1

Jagged Elevation Contour Lines Resulting from Boat Presence within Lunenburg Harbour

Note. Jagged elevation contour generation errors can be seen in a red solid line.

Appendix C

Sectioned Sea Level Rise Elevation Band Maps

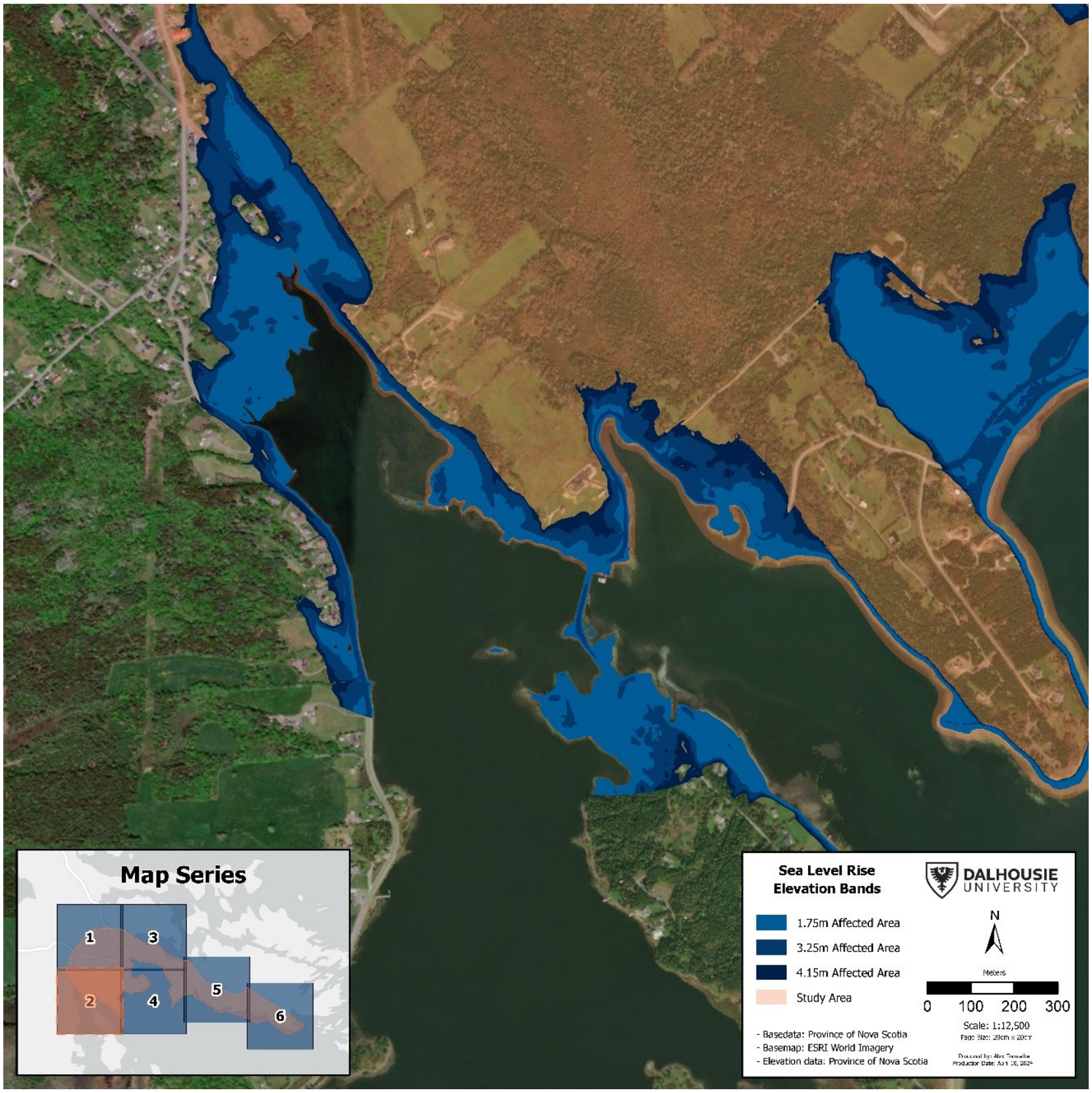
Figure C1

Map 1 of Sea Level Rise Elevation Band Map Series

Note. The study area is represented by an orange polygon. Sea level rise elevation bands are represented by polygons of three shades blue, with 1.75m, 3.25m, and 4.15m denoted by light, medium, and dark blue respectively.

Figure C2

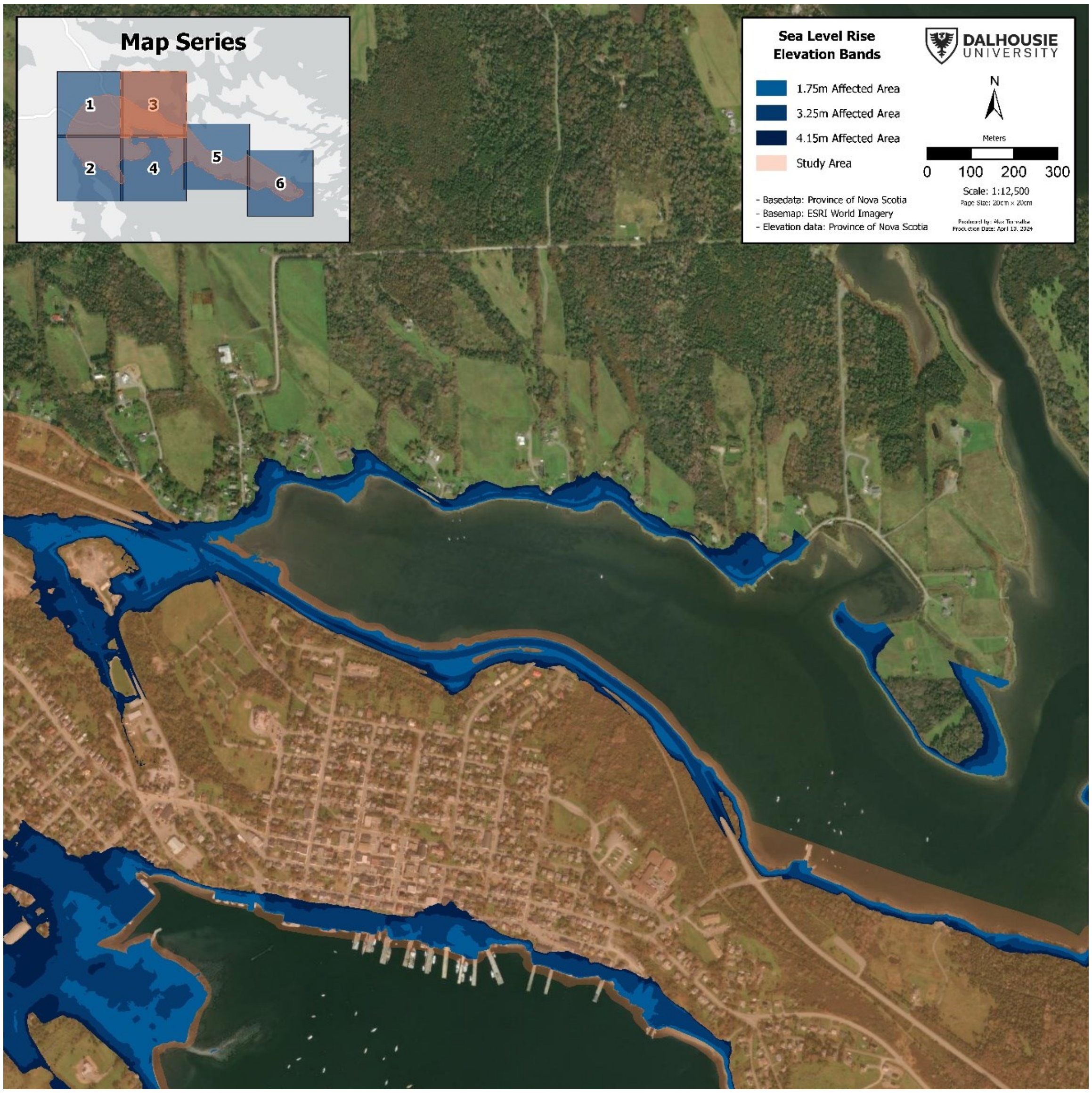
Map 2 of Sea Level Rise Elevation Band Map Series



Note. The study area is represented by an orange polygon. Sea level rise elevation bands are represented by polygons of three shades blue, with 1.75m, 3.25m, and 4.15m denoted by light, medium, and dark blue respectively.

Figure C3

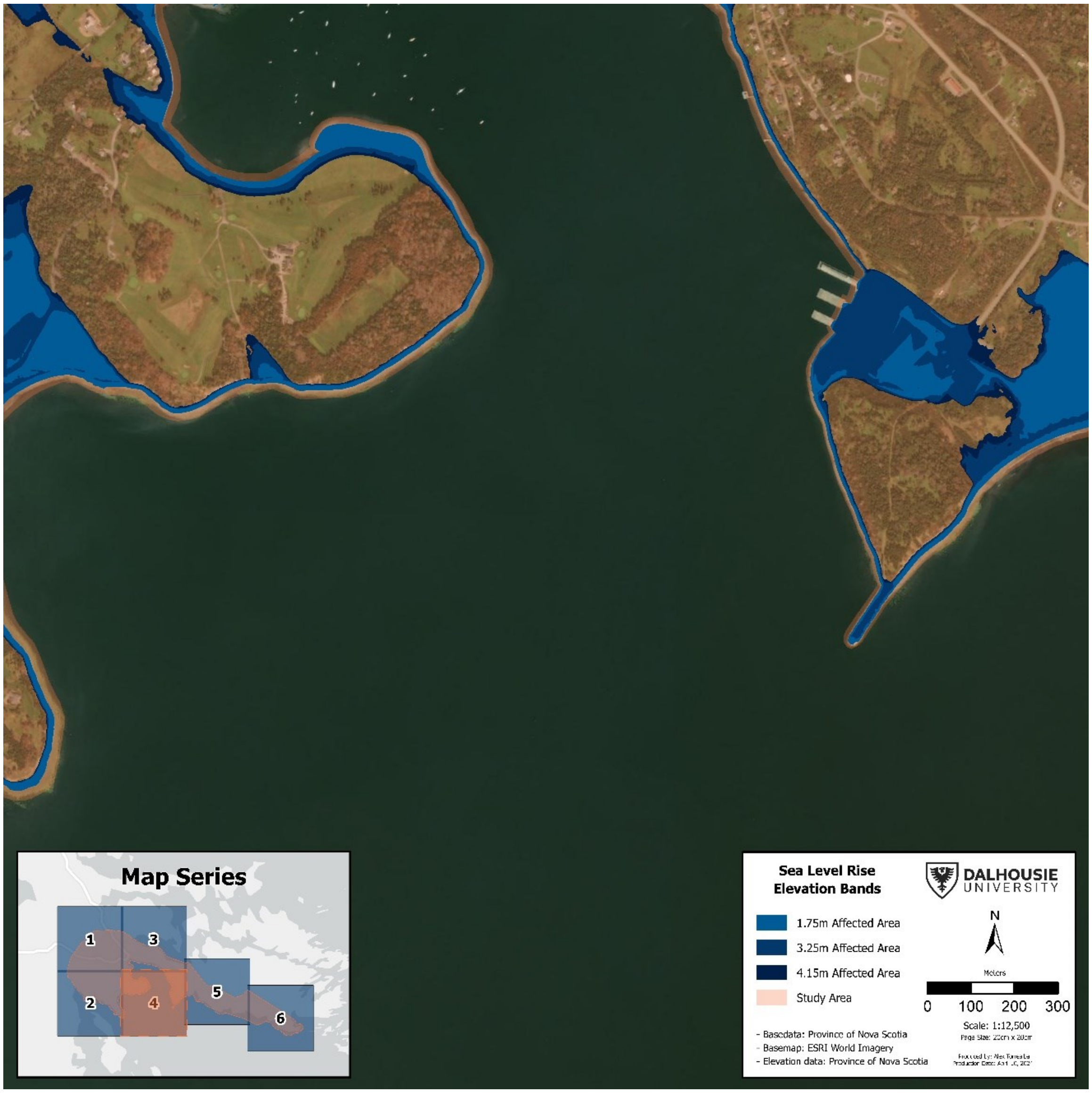
Map 3 of Sea Level Rise Elevation Band Map Series



Note. The study area is represented by an orange polygon. Sea level rise elevation bands are represented by polygons of three shades blue, with 1.75m, 3.25m, and 4.15m denoted by light, medium, and dark blue respectively.

Figure C4

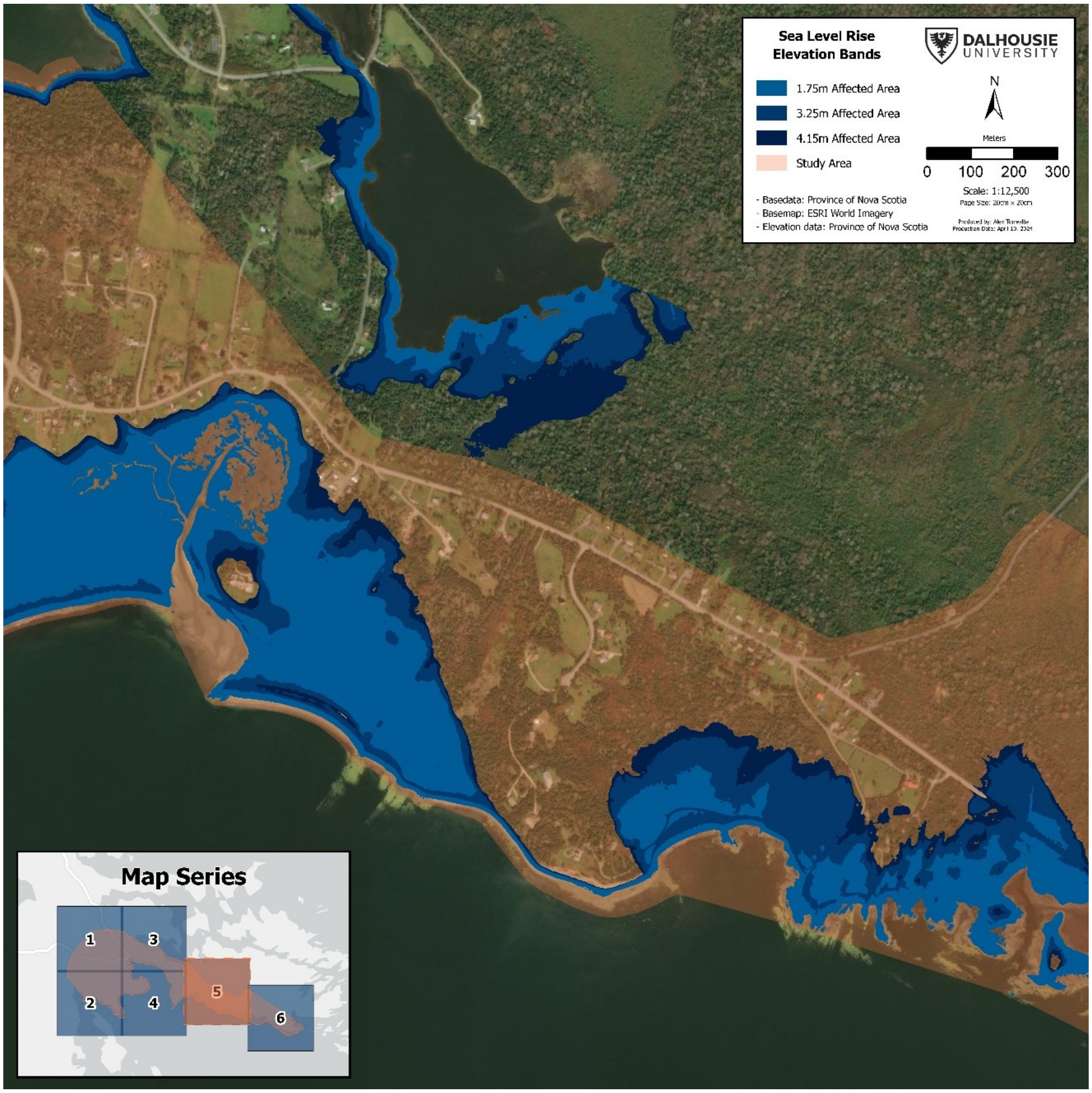
Map 4 of Sea Level Rise Elevation Band Map Series



Note. The study area is represented by an orange polygon. Sea level rise elevation bands are represented by polygons of three shades blue, with 1.75m, 3.25m, and 4.15m denoted by light, medium, and dark blue respectively.

Figure C5

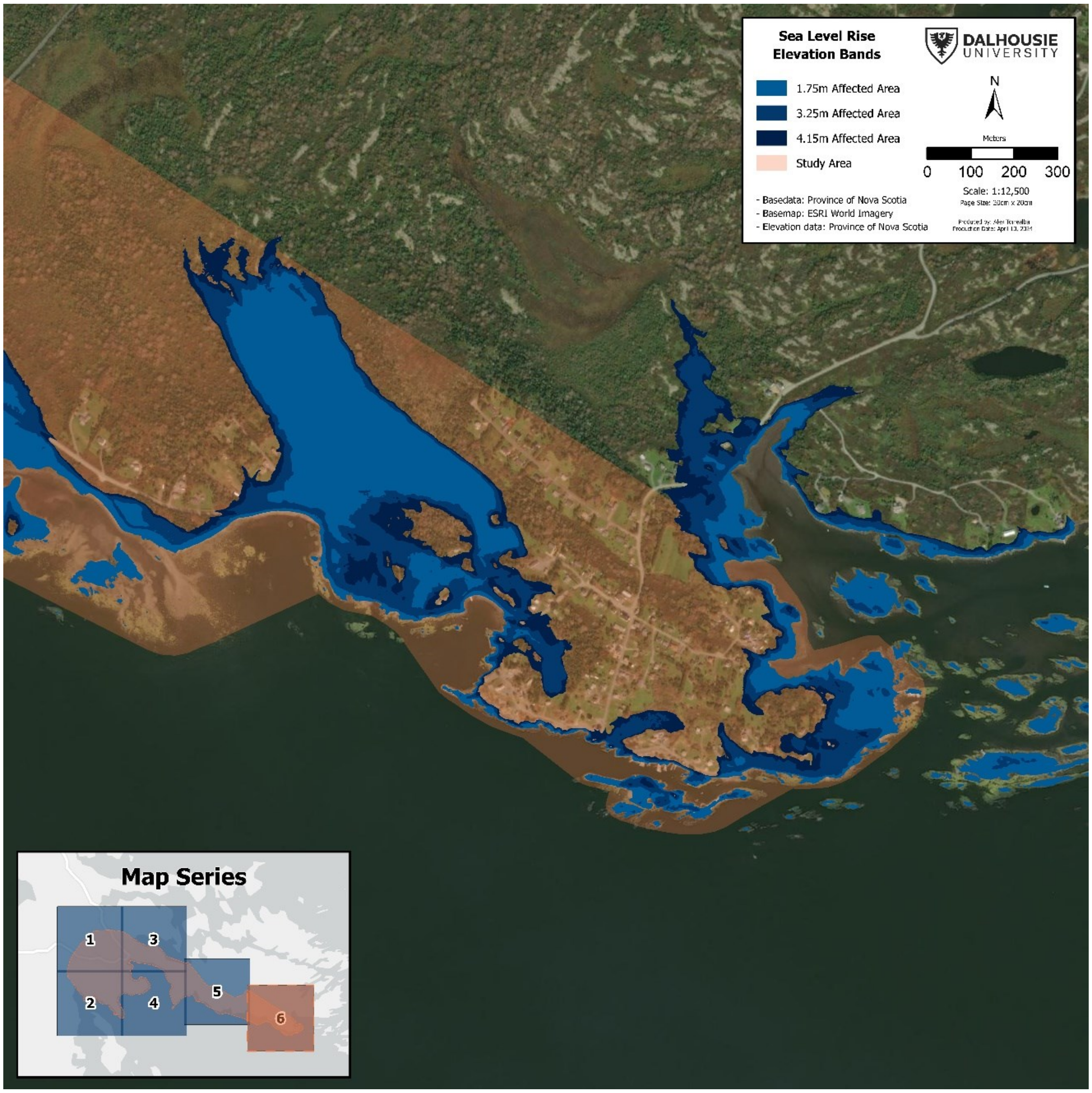
Map 5 of Sea Level Rise Elevation Band Map Series



Note. The study area is represented by an orange polygon. Sea level rise elevation bands are represented by polygons of three shades blue, with 1.75m, 3.25m, and 4.15m denoted by light, medium, and dark blue respectively.

Figure C6

Map 6 of Sea Level Rise Elevation Band Map Series



Note. The study area is represented by an orange polygon. Sea level rise elevation bands are represented by polygons of three shades blue, with 1.75m, 3.25m, and 4.15m denoted by light, medium, and dark blue respectively.