A Systems Analysis of Policymaking for Climate Adaptation in Coastal Virginia

by

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A dissertation submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Systems Engineering

[April 15, 2022]

Signature of the Author _____

Certified by _____
PhD Program Director Date

Ph.D. IN SYSTEMS ENGINEERING

UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VIRGINIA

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Submitted to the
Engineering Systems and Environment Department
Ph.D. Program in Systems Engineering
in partial fulfillment of the requirements for the
Doctor of Philosophy Degree
at the UNIVERSITY OF VIRGINIA

Abstract

The impacts of climate change have sparked policy responses at different governance levels. Studying the central adaptation policies and understanding the interactions and complexities of governmental and non-governmental stakeholders is essential in guiding local, regional, and state stakeholders to formulate policies and make investment decisions. With strategic and economic significance on the national level, Coastal Virginia has one of the highest rates of sea-level rise in the United States, instigating intensified and more frequent climate hazards such as flooding and storms. This research strives to characterize the status of adaptation policymaking and discover the challenges and governance gaps in this region to provide insights for effective adaptation policies in the future. Moreover, it provides a spatial understanding of climate risk and its associations with socioeconomic vulnerabilities, raising questions about the underlying roots of such associations and arguing for an emphasis on vulnerabilities for equitable adaptation policymaking. Moreover, it proposes a policy framework for local adaptation to analyze and introduce successful and sustainable policy measures through collective decision-making informed by a policy analysis tool. Eventually, the managed retreat is analyzed as an inevitable policy for areas with high climate risk. With an emphasis on Coastal Virginia, this research has several theoretical and empirical outcomes illuminating the status quo and future of adaptation policymaking that would be adjustable to other geographic, economic, and environmental conditions.

Acknowledgment

This dissertation concludes my delightful journey as a Ph.D. student in systems engineering at the University of Virginia. I want to thank my advisor, Dr. Garrick Louis, who has been a true friend during my journey. I have learned from him beyond the usual advisor-advisee relationship, as he has most importantly taught me to be a better person who ultimately cares about the impact of their work on individuals more than anything else. I would like to express my gratitude to Dr. William T. Scherer, whose systems thinking and critical perspective have taught me a lot during the past few years. I am very thankful to Dr. Rider W. Foley, who has kindly supported me in every setting. I am grateful for the opportunity to have Dr. Carlton H. Hershner and Dr. Andrew M. Scheld on my committee; they have been wonderful, patient, and instrumental in my growth as a Ph.D. student. I would like to thank Dr. James H. Lambert for his presence and guidance from the beginning. I appreciate having Dr. Majid Shafiee-Jood on my committee for his kind and scrupulous feedback throughout my research, which has tremendously improved my work.

I am lucky to have Dr. Faraz Dadgostari and Neda Nazemi as friends with whom I initiated this journey. This journey would not have been possible without the utmost support of Rose, my lovely wife. She has been my source of hope and motivation within the last year. Last, yet most important, I am deeply owed to my parents. My mother, with all the love embodied in her tearful eyes, being that she is far from me, and my father, with his genuine belief in me, have given me the courage to succeed in this journey and every other journey in life.

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Chapter 1
Introduction

This chapter serves as the opening to the research agenda for this dissertation. It starts by broadly providing background information on climate risks and challenges, specifically in coastal Virginia. It states the motivation for doing this research, the goals and research questions, and the methodologies implemented to achieve the goals. It also provides an overview of the subsequent chapters explaining how they are related to the research goals and questions.

1.1. Motivation and Background

Anthropogenic climate change is a reality that will affect us on global and local scales for decades to millennia (Hansen and Stone, 2016). Self-reinforcing climate systems could accelerate human-induced changes and move the climate to situations different from the past (Hayhoe et al., 2018). Sea levels are expected to rise by 1-4 feet from today's levels by 2100. Sea-level rise (SLR) will be higher than the global average on the east and gulf coasts of the United States (U.S. Global Change Research Program, 2018). This phenomenon will increase the frequency, depth, and extent of extreme flooding associated with coastal storms, such as hurricanes and nor'easters. The United States has sustained 310 extreme weather and climate disasters since 1980, with costs exceeding $2.155 trillion (NOAA, 2022a). The annual average number of such disasters is 7.4 events from 1980 to 2021. However, this number rose to 17.2 events per year within the last five years, i.e., 2017 – 2021, indicating a 230% increase.

Coastal areas are a critical part of the U.S. economy as coastal counties embrace 42% of population and employment, 48% of GDP, and 20% of land area (USGCRP, 2020). Coastal areas are one of the most vulnerable locations for climate-related natural disasters. For example, flooding is estimated to be from 300% to 900% more frequent in U.S. coastal communities than just 50 years ago. At the same time, almost 40 percent of the U.S. population lives in high-population-density coastal areas, exposing them to the increased risks of SLR, flooding, shoreline erosion, and other climate hazards (NOAA, 2021). According to climate risk assessments, approximately $86 billion of U.S. coastal property will be below sea level by 2050. This figure will go up to more than $370 billion by 2100, assuming the same climate pattern. SLR could increase the annual damages from coastal storms and hurricanes at the eastern coast and the Gulf of Mexico by $108 billion. Property losses from SLR mostly happen in particular regions of the U.S., especially on the Southeast and Atlantic coasts, where the rise is higher than average, and the losses are far more significant than the national average (Gordon, Lewis and Rogers, 2014). In addition to private property risks, potential damages to coastal infrastructure, e.g., roads, bridges, tunnels, and pipelines, will result in cascading costs and national impacts (USGCRP, 2020).

Coastal Virginia, the eastern side of Virginia as shown in Figure 1, has the highest relative SLR rates on the Atlantic coast of the U.S. Virginia's coastal region covers one-quarter of the state and more than 70 percent of the Commonwealth's population. Recent estimates show that 250,000 acres of land, 1,469 miles of roads, and property valued at $17.4 billion lie less than five feet above the high tide line in Virginia. The

combination of relative SLR, increases in frequency and duration of rainfall events, rising regional water tables, and storm surges from more frequent and severe weather systems will exacerbate flooding in coastal Virginia (Commonwealth of Virginia - Office of the Governor, 2020b).

Figure 1. Map of Virginia
Source: (iStock, 2022)

There are two general approaches to tackle climate risk: mitigation and adaptation. Mitigation is "a human intervention to reduce the sources or enhance the sinks of greenhouse gases" (Edenhofer, 2015). Adaptation, however, is "the process of adjustment to actual or expected climate and its effects. Adaptation seeks to moderate or avoid harm or exploit beneficial opportunities in human systems. Human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014). Indeed, mitigation tackles the risk through the causes of climate risk, while adaptation addresses how to reduce the adverse effects by taking advantage of any opportunity. Here, our focus is on climate adaptation, which is conceptually close to resilience, defined as "the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a threat" (Cutter *et al.*, 2008).

Both public and private sectors engage in developing and executing adaptation measures. However, empirical studies and economic theory tell us that private-derived adaptation, a.k.a. autonomous adaptation, will often not be desirable as it does not undertake specific actions because of a misunderstanding of actual risk, costs, and lack of incentives. Thus, the public sector will need to play a crucial role (Chambwera *et al.*, 2015). The public sector has three main reasons to intervene in adaptation to climate risk (Fankhauser and Soare, 2013), namely:

- To provide climate adaptation public goods such as sea defenses
- To remove adaptation barriers such as market imperfections and behavioral barriers

- To assist vulnerable populations, those who cannot sufficiently adapt on their own

Policymakers can encourage autonomous adaptation by taxes, subsidies, and interventions from an economic perspective. However, such policies should be designed in a way that causes efficient outcomes and avoids perverse results. The policy needs to affect stakeholders' decision-making, triggering voluntary actions based on their incentives. Moreover, the policy should be cost-effective to enable the public sector to use its resources efficiently. Measuring the net effects of a policy is challenging, as it is hard to project the outcomes of the proposed policy (Fankhauser, 2017). There is also a chance that the effects of a poorly designed policy will be contrary to the policymaker's intentions. For example, subsidizing irrigation water conservation has increased total water use by farmers as it encourages them to increase the land under irrigation (Pfeiffer, 2010). For these reasons, a policy analysis framework is required to assess and find the expected positive and negative outcomes of climate risk management policies.

Adaptation is context-specific and local (Mullan *et al.*, 2013; Preston, Mustelin and Maloney, 2013; Fünfgeld, 2015). This translates to local stakeholders as the adaptation leaders in a policymaking framework. However, institutions and government hierarchies' structures and interactions can limit local actors (Keskitalo and Kulyasova, 2009). Therefore, it is essential to model local adaptation by including the government system and interactions in the model's assumptions and dynamics. Policymakers find the involvement of multiple stakeholders in policy design to improve policymaking quality and increase awareness among critical participants and players (Mullan *et al.*, 2013). Therefore, understanding adaptation policies in Coastal Virginia is essential for further policy analysis, a task we pursue as the first step in this research.

Vulnerability is a reason for government intervention in climate adaptation. Vulnerability is "the inherent characteristics of social systems creating the susceptibility to harm from exposure to stresses associated with environmental and social change. Vulnerability is derived by the absence of capacity to adapt and determined by the exposure to climate risk and the possible harm from exposure" (Adger, 2006; Cutter *et al.*, 2008). Climate risk assessment studies should include physical and social vulnerability. Physical vulnerability helps policymakers target interventions to risk-reducing strategies for specific assets. Social vulnerability helps policymakers customize their strategies based on local differences in needs and capacities within and across groups (Koks *et al.*, 2015). The importance of social vulnerability in adaptation requires us to explore it in Coastal Virginia, a task we do, as explained later in this chapter.

1.2. Dissertation Structure

Building on the literature and issues discussed earlier, this research pursues adaptation policymaking on a local level. This research is inspired by the fellowship I had in summer 2019 from the Environmental Resilience Institute (ERI) and my internship in the Center for Coastal Resources Management (CCRM) in summer 2020. The research focuses on Coastal Virginia when specific geographic, economic, and environmental conditions must be considered; however, we could extend the frameworks and models to other localities. The main goals of this research are the followings:

- To characterize the status of adaptation policymaking in Coastal Virginia
- To identify main challenges and gaps in adaptation policymaking in Coastal Virginia
- To assess socioeconomic vulnerability and how it relates to climate risk in Coastal Virginia

- To propose an analytical framework for local adaptation policymaking and use the framework to model and compare alternative policy measures for managed retreat

Table 1. Research goals, questions, methods, and associated chapters

	Research Goals	Research Questions	Methods	Dissertation Chapter
1	To characterize the status of adaptation policymaking in Coastal Virginia	• How are the climate risks perceived and addressed by the main stakeholders? • What are the main introduced policies at the local, regional, state, and federal levels? • Who are the major players in coastal adaptation policymaking, either inside or outside the formal governance levels?	• Qualitative research through interviews with stakeholders • Review of policy documents • Keyword analysis • Thematic analysis	Chapter 2
2	To identify main challenges and gaps in adaptation policymaking in Coastal Virginia	• What are the main overarching challenges and gaps specific to each governance level? • How could these gaps influence policies moving forward?		Chapter 3
3	To assess socioeconomic vulnerability and how it relates to climate risk	• How is social vulnerability spatially distributed? • How is vulnerability associated with climate risk? • Is vulnerability playing a different role in different areas?	• GIS data analysis • Statistical and regression techniques	Chapter 4
4	To propose an analytical framework for local adaptation policymaking; to model and compare policy measures for managed retreat	• What is a suitable policy analysis framework for adaptation policymaking? • How to model and compare different retreat policies? • What retreat policy is the most successful for a locality?	• System analysis • General equilibrium economic modeling using micro-level decision-making • Optimization • Computer simulation	Chapter 5

Table 1 displays the research goals, questions, and methods used to achieve each goal, while each goal is addressed through a chapter of the dissertation. The Chapters have their individual scope, contributions, and methodology as each chapter is published as a journal or conference paper, collectively forming a research framework for more efficient and equitable adaptation policymaking in Coastal Virginia. We take a qualitative approach in addressing the first two goals in chapters 2 and 3. We leverage semi-structured interviews with adaptation stakeholders in Coastal Virginia to analyze the policies and stakeholders on the local, regional, state, and federal levels in Chapter 2. Chapter 3 uses a similar methodology to find the most significant challenges in adaptation policymaking on each governance level and discuss the path forward. We then use geographic and statistical analysis to map and correlate climate risk and socioeconomic vulnerability on a spatial basis, as presented in Chapter 4. Chapter 5 offers a policy framework to analyze local adaptation policies and help the policymakers in their adaptation efforts. We use "managed retreat," a challenging subject among stakeholders, as a case study to model and compare several retreat policies using general equilibrium economic modeling. The findings are summarized in Chapter 6, accompanied by suggestions for future research and my career after this Ph.D. program. Five appendices help to clarify the analyses of chapters 2-5 as they are explained within each chapter.

Chapter 2

An overview of existing policies and stakeholders

Impacts of climate change have sparked policy responses at different governance levels. Studying the central adaptation policies and understanding the interactions and complexities of governmental and non-governmental stakeholders is essential in guiding local, regional, and state stakeholders to formulate policies and make investment decisions. With strategic and economic significance on the national level, Coastal Virginia has one of the highest rates of SLR in the United States, instigating intensified and more frequent climate hazards such as flooding and storms. This chapter strives to characterize the status of adaptation policymaking in this region through a novel keyword analysis method and a thematic analysis of interviews with the main adaptation decision-makers and stakeholders. We discover the central adaptation policies and programs at the local, regional, and state, and federal level, accompanied by the identification of major players. This provides us with a comprehensible narrative of adaptation policymaking, which could be exploited to analyze governance gaps and adaptation challenges further. The approach and methodologies of this research could be implemented in similar studies for other areas of the United States that are at high climate risk paving the way for an informed national adaptation policy, a long-missing and indispensable practice to be pursued at the federal government.

2.1. Introduction

Anthropogenic climate change is a reality that will affect us on global and local scales for decades to millennia (Hansen and Stone, 2016). Self-reinforcing climate systems could accelerate human-induced changes and move the climate to situations that are different from the past (Hayhoe *et al.*, 2018). Sea levels are expected to rise by 1-4 feet from today's levels by 2100. Sea level rise (SLR) will be higher than the global average on the east and gulf coasts of the United States (U.S. Global Change Research Program, 2018). This phenomenon will increase the frequency, depth, and extent of extreme flooding associated with coastal storms, such as hurricanes and nor'easters. Coastal areas are a critical part of the U.S. economy, as coastal counties embrace 42% of population and employment, 48% of GDP, and 20% of the land area (USGCRP, 2020). According to climate risk assessments, $86 billion of U.S. coastal property (on average) will be below sea level by 2050. Assuming the same climate pattern, this figure will increase to more than $370 billion by 2100. SLR could increase the annual damages from coastal storms and hurricanes at the eastern coast and the Gulf of Mexico by $108 billion. Property losses from SLR mostly happen in particular regions of the U.S., especially on the Southeast and Atlantic coasts, where the rise is higher than average, and the losses are far more significant than the national average (Gordon, Lewis and Rogers, 2014). In addition to private property risks, potential damages to coastal infrastructure, e.g., roads, bridges, tunnels, and pipelines, will result in cascading costs and national impacts (USGCRP, 2020). Coastal Virginia, home to 6 million people or 70% of the state’s population, has one of the highest rates of SLR in the United States,

as sea-level in some coastal areas of the state is 14 inches higher than what it was in 1950 (Boon, 2012; Kopp, 2013; NOAA, 2022b). Partly caused by extensive land subsidence, Hampton Roads is the second-largest population at risk of SLR in the US, after New Orleans (Eggleston and Pope, 2013).

Impacts of climate change have sparked policy responses on different governance levels. Studying these policy responses and their implementation is vital to understanding their effectiveness in responding to climate change impacts. It is critical to understand the adaptation practice specific to an area by including the government systems, interactions, and dynamics, as adaptation is primarily context-specific and local (Mullan *et al.*, 2013; Preston, Mustelin and Maloney, 2013; Fünfgeld, 2015). Such a study to identify the central policies, stakeholders, and barriers to adaptation is missing for Coastal Virginia, and our study was initiated to address this gap. Our research has two main objectives, each followed by specific research questions:

1. To characterize the status of climate adaptation policymaking in Coastal Virginia
    a. Who are the major players in coastal adaptation policymaking, either inside or outside the formal governance levels?
    b. How are the climate risks perceived and addressed by the main stakeholders?
    c. What are the main introduced policies at the local, regional, state, and federal levels?
2. To identify main challenges and gaps in climate adaptation policymaking in Coastal Virginia
    a. What are the main overarching challenges and gaps specific to each governance level?
    b. How could these gaps influence policies moving forward?

The second objective is to understand the challenges and identify climate adaptation policy pathways, which requires understanding and disentangling complexities in policymaking processes and stakeholders' interactions. Characterizing the adaptation policymaking and having a comprehensive look into the governing policies and programs in this area is essential in guiding local, regional, and state stakeholders to formulate policies and make investment decisions; however, there is a dearth of the empirical literature on current risk and adaptation policies (Gussmann and Hinkel, 2021). Hence, this chapter contributes to the literature by addressing the first objective paving the way for accomplishing the second objective, which would be addressed in Chapter 3.

Our literature review identifies several studies that have addressed the barriers and challenges of coastal adaptation on national, regional, and local levels, usually done through literature review, document analysis, surveys, and interviews (Baker *et al.*, 2012; Shi, Chu and Debats, 2015; Lin *et al.*, 2017; Lubell, 2017; Yusuf and St. John, 2017; Molenveld, van Buuren and Ellen, 2020; Valente and Veloso-Gomes, 2020; Larsen *et al.*, 2021). We also find scholars that study the current adaptation policies and influential stakeholders, in case studies within and outside of the U.S., to understand the scope of adaptation, derive barriers and challenges, and provide guidelines and insights for a successful adaptation in the future (Blázquez, García and Bodoque, 2021; Rasmussen *et al.*, 2021; Hürlimann *et al.*, 2022). For example, Hughes (2020) studies the adaptation policies and documents in Detroit, Michigan, and Cleveland, Ohio, as the only major cities in the Great Lake Region of the U.S. that have developed formal adaptation plans (Hughes, 2020). With an emphasis on justice and social equity, it reveals notions of equity being addressed in the planning efforts and policy tools as the outcome of growing poverty and inequality and extensive grassroots work. It also recognizes that adaptation is not a top priority for local leaders, and there is a

significant need for collaboration and partnerships in adaptation implementation. In another relevant study, Morris (2020) reviews the literature on climate adaptation approaches of coastal ports, arguing for the necessity of collaboration among stakeholders to facilitate adaptation on a regional level (Morris, 2020). Hampton Roads, Virginia, is introduced as an example of stakeholder engagement in shaping an understanding of climate risk that benefits successful climate adaptation.

Hernandez et al. (2018) analyze the status of climate adaptation efforts as the response to more frequent and intense heatwaves and dust breaks in the Canary Islands (Hernandez *et al.*, 2018). Interviewing with the main actors, e.g., regional and local governments, environmental NGOs, local universities, and trade unions, they discover the central policies and stakeholders leading to the identification of climate adaptation barriers. Uncertainties in climate modeling, divergent opinions on the hazards and adaptation implementation, absence of epidemiological data, and lack of participation are the discovered barriers. In a recent study, Gussmann and Hinkel (2021) assess the SLR and coastal policy effectiveness in the Maldives, leveraging a study of policy documents and semi-structured interviews with coastal policy experts and stakeholders (Gussmann and Hinkel, 2021). Evaluating the integration of climate change considerations into policy objectives, coherence of policy objectives, and compliance with the policies, they conclude that existing coastal policies are not structured to consider rising sea levels effectively.

In this chapter, we pursued a qualitative approach, mainly informed by interviews with the involved stakeholders of coastal adaptation practice in Virginia and analysis of the available documents, plans, and policies. The City of Norfolk and Hampton Roads have been our local and regional focus due to their pioneering role in Virginia's coastal climate adaptation policy and their national strategic significance. We used two distinct methodologies to answer our research questions. First, we develop a keyword analysis method, using natural language processing algorithms to inform our research questions and extract the main themes. Secondly, we dig deeper into our data and refine the ongoing themes in the practice of coastal adaptation policymaking. This methodology provides a clear and comprehensive narrative about the evolution of policies and programs and various stakeholders' roles. That is our most significant contribution in this chapter, as we believe having such a narrative is essential for any further gap analysis and thinking about the future of this practice. Our general approach is crafted as a model, which can be adapted to inform policy analysis in the context of the dynamics and interrelationships in other coastal communities. Such local and regional studies can contribute to well-informed national-level climate adaptation policy analysis based on comparative studies between different areas.

2.2. Methodology

We started our sampling by interviewing adaptation decision-makers in the City of Norfolk and expanded it to the regional and state governments through snowball sampling. During data collection, we were introduced to stakeholders from environmental NGOs, academia, and economic development nonprofits who have been involved in climate adaptation in Coastal Virginia. To have a comprehensive understanding of adaptation practice, we also contacted a few stakeholders from the federal government who are locally present in this region, e.g., Army Corps and Military installations. We used two indicators to stop sampling. The first indicator was when the answers we were hearing from interviewees did not have significant new information. The second indicator was when the suggestions we were receiving from interviewees for the next person to talk to were all people and organizations we had already contacted. These two events indicated a saturation point (Guest, Bunce and Johnson, 2006). Email addresses, either publicly available or attained from other interviewees, were used to contact stakeholders. Overall, we contacted 110 people

within the stakeholder groups resulting in 42 interviews conducted from August 2021 to January 2022, as shown in Table 2. Interviews were conducted virtually and recorded through Zoom. We acknowledge the fact that this is not a comprehensive list of stakeholders. Notably, property owners (residential, commercial, and industrial) and property insurers were not included. Our IRB (Institutional Review Board) protocol allowed us to interview representatives of relevant organizations and not unaffiliated individual property owners and insurance agents. Thus, the closest we could get to the perspectives of these stakeholders was the economic development nonprofits.

We transcribed interviews using an artificial intelligence platform; they were later individually reviewed and edited (*Otter*, 2022). We used two distinct methodologies to analyze our data; keyword analysis through Natural Language Processing (NLP) and thematic analysis through conventional content analysis introduced by Hsieh and Shannon (Singh, 2018), (Hsieh and Shannon, 2005).

Table 2. Summary of conducted interviews

Organization Group	People Contacted (#)	Interviews (#)
Local government	32	9
Regional Government	5	2
State Government	22	8
Federal Government (locally present)	10	2
Environmental Nonprofit	28	12
Academia	8	6
Economic Development Nonprofit	5	3
Total	**110**	**42**

We first performed a keyword analysis to obtain a general understanding of our data, as presented in section 2.3. To do so, we developed a two-step method through which we were able to extract what concepts regarding coastal adaptation were discussed in our data. In the first step, we extracted keywords using the Scikit-learn machine learning library in Python and categorized the extracted keywords based on their similarity, ending up with four categories: climate risks and response, policy-related topics, stakeholders, and locations. Scikit-learn uses a variety of linear algebra, vector machines, and logistic regressions to process text, extract, and modify keywords (Pedregosa *et al.*, 2011). Afterward, we interpreted the keywords in each category using our knowledge from the study to inform the research questions. As the next step, we divided our data set into subsets based on the stakeholder groups and performed the keyword analysis for four stakeholder groups: local government, state government, environmental nonprofits, and academia. We could not do it for three other groups as the sample size was insufficient for such analysis. The keywords specific to each stakeholder group were also analyzed to inform us about the point of view of the specific stakeholder group in the story.

Thematic analysis was built on Hsieh and Shannon's process for conventional content analysis to acquire an overall understanding of the data and employ an iterative process of drawing themes (Hsieh and Shannon, 2005). It was performed by first reaching a preliminary codebook through consensus building after two interviews were individually analyzed (Saldaña, 2013; Roberts, Dowell and Nie, 2019). Then the interviews were individually coded. We modified the codebook two additional times during the coding process as new codes had come to the scene. We used Dedoose as the software for implementing the codes (*Dedoose*, 2022). Writing the findings of thematic analysis, presented in 2.4, we also used the reports,

documents, and legislations, as much as needed, to confirm the specifics about policies and programs, e.g., numbers, dates, and maps.

2.3. Keyword Analysis

This section provides an analysis of discussed topics using our first methodology. It will show how the participants in this study perceive climate risks, policies, and primary stakeholders. Looking at the keywords related to climate risks and response (Figure 2), flooding, either initiated by storm surge or precipitation, is perceived as the top climate risk for coastal Virginia. SLR is the second challenge, while it is frequently mentioned with flooding (flooding & SLR as a keyword together). People also talk about climate change as a risk while having a lower frequency in our data. The interesting observation is that hurricanes, nor'easters, and extreme heat are not existent in the keywords.

Resilience is the most used phrase addressing the response to climate risks. It is particularly noticeable because the interview questions used "climate adaptation" to refer to the efforts, policies, and programs designed to combat the climate change impacts. People address all the efforts, policies, programs, and projects to fight climate impacts under "resilience." Coastal resilience is another phrase that is being used frequently, as this issue was first raised by coastal Virginia, mainly in Hampton Roads. Climate adaptation and coastal adaptation are the other phrases addressing such response that we mainly observe in environmental organizations and local government language.

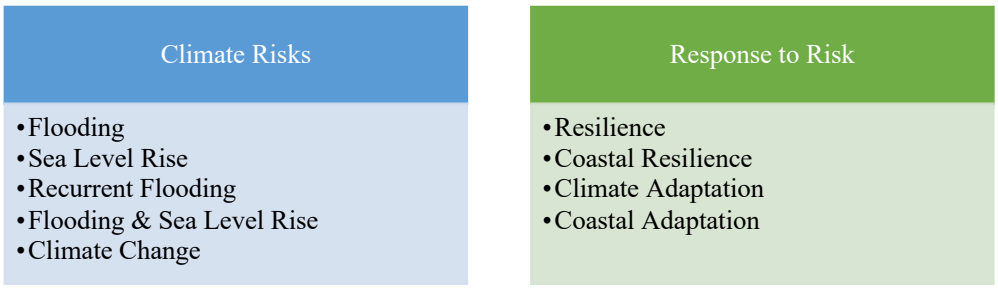

Figure 2. Keyword analysis: climate risks and response

Regarding the timeline and challenges of policymaking, in Figure 3, people refer to "10 years ago" as a time when discussion on climate impacts was not as common as today. In their language, ten years ago was the time you did not see any effort, nor discussion, on climate impact in different layers of government, but today the impacts of climate change have come to the scene, and there is a general awareness of the problem between different stakeholders, with an agreement that something should be done to combat the impacts of climate change. There is a high emphasis on funding as a significant challenge in this practice, and most stakeholders refer to it as the biggest challenge. Funding is also emphasized because local governments do not have the potential to raise enough money and have been chiefly relying on federal dollars to tackle this issue within the last few years. However, access to federal money and its sufficiency is a problem since federal dollars may need to be matched by local/state funds, and the state of Virginia has not allocated enough money to this issue. Data comes as the second obstacle in planning and decision-making for climate adaptation, as knowing the extent of the risks and accurate projections of them in the future are essential to understanding what geographies, communities, and assets will be at risk. Virginia is not perceived to have the required data and models for effectively planning the future. People also compare Virginia with other locations, such as New Orleans and North Carolina, with more advanced data and modeling tools for flooding and SLR (Figure 5). Finally, there is an emphasis on the long-term nature of climate change

impacts as a challenge. Because this is viewed as a long-term effect, this issue becomes lost among other pressing public policy issues at different levels of government and in political cycles.

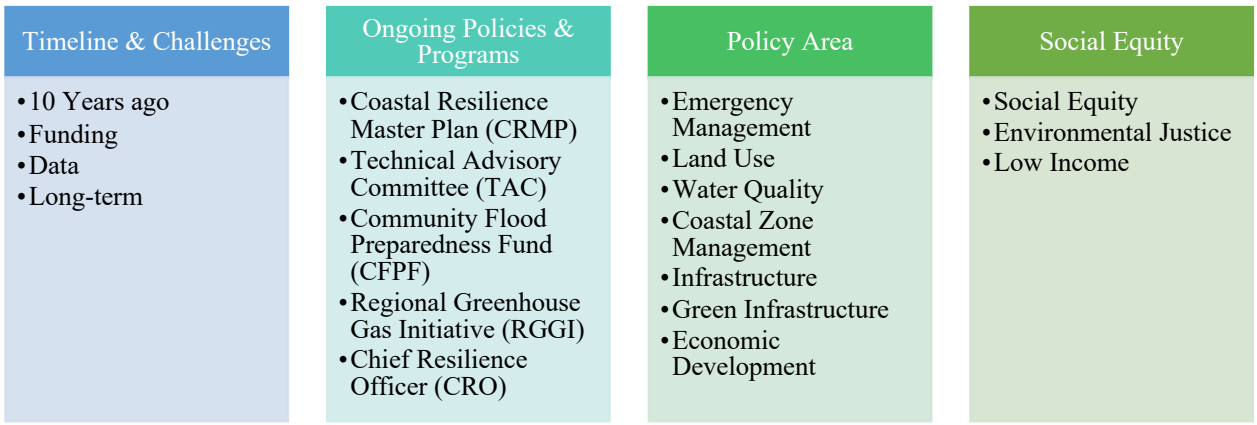

Figure 3. Keyword analysis: policy-related topics

Ongoing policies and programs that the stakeholders cite the most are related to the state-level efforts within Governor Northam's administration. The most emphasized policy is the recently released coastal resilience master plan. This was initiated in November 2018 as an executive order (Executive Order 24) by the governor of Virginia, and the first version was released in December 2021. The process of drafting the master plan was overseen by a Technical Advisory Committee (TAC) appointed by the governor through Executive Order 71 in 2020. The Community Flood Preparedness Fund (CFPF) allocated money through legislation in the General Assembly in 2021 to fight flooding within the Commonwealth of Virginia. The funding of CFPF is supplied through the revenue that Virginia obtains from the Regional Greenhouse Gas Initiative (RGGI). The participating RGGI states include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia (RGGI, 2022). Most of the participants in our survey perceived CFPF as the first time the Commonwealth allocated money to flooding as the most pressing climate issue. The Chief Resilience Officer (CRO) was created by legislation in the General Assembly in 2020 to be the primary coordinator of resilience and adaptation initiatives in the Commonwealth. The fact that all the policies in our keywords are at the state level speaks to the importance of state-initiated programs and policies in the eyes of stakeholders. It is also partly because they have been perceived as new and progressive efforts in Virginia, bringing the state to the front of the adaptation policymaking area, as it was viewed as lagging before the Northam administration.

Figure 3 shows participants' emphasis on relevant policy areas to climate adaptation, indicating how diverse and complex climate adaptation could be. This list could potentially be broader, as climate issues like extreme heat are directly relevant to health, and this list does not consider the health impacts of climate change. An interesting observation is the presence of green infrastructure in this set, showing significant emphasis on green infrastructure among the stakeholders, primarily environmental organizations. Another interesting item here is "economic development." This happens to a great degree because, at the local level, economic development is perceived as the most critical issue on elected officials' agenda, absorbing their attention the most. It also speaks to the involvement of regional economic development nonprofits stepping to this area as they are worried about prospects of business and economy being negatively affected by climate risks.

Concern on social equity is also present amongst stakeholders, mostly observable in environmental organizations. The disadvantage of low-income communities in this process is perceived to be multifaceted. They have limited means to tackle the same problems as more affluent communities; their problem is more significant as they face greater levels of climate risk, and more importantly, the current status of allocation of government funding disproportionately goes to more affluent communities as they have higher housing values and get a better cost-benefit ratio when it comes to the feasibility study of a resilience project. This issue is also frequently raised by different stakeholder groups in the form of insufficient capacities and abilities of some localities, notably smaller and rural communities, to deal with climate impacts. Some localities like Virginia Beach are known to have the financial and technical capacity to address the climate problems appropriately, while smaller and rural areas lack that capacity to even apply for specific grants and funding sources.

Figure 4. Keyword analysis: stakeholders

Climate adaptation stakeholders identified with keyword analysis are portrayed in Figure 4 within six groups. The local government is perceived as a leading stakeholder, reflecting that this fight has to be fought locally. Within the local government, the city council and elected officials are perceived to be the most influential since the local decisions and allocations of the budget happen through locally elected individuals. They have a significant role in leading the policies and programs at that level of government. On the other hand, communities are the stakeholders facing the challenges and climate impacts most presently. At a regional level, the planning district commissions play a significant role in influencing the decisions, although they primarily represent localities and do not have any authority over them. Hampton Roads Planning District Commission (HRPDC) is perceived to be the most advanced regional entity, as they have been leading this effort to bring synergy on the issue in Hampton Roads and convey the challenges of coastal Virginia to state and federal legislators and decision-makers.

The state government is perceived as a significant stakeholder since the state leadership has an enormous potential for impact through legislation within General Assembly, allocation of funding, e.g., CFPF, and initiating a broad conversation among different stakeholder groups, including state agencies, that do not interact very often as needed for tackling climate change impacts. Ann Phillips, the Special Assistant to the Governor for Coastal Adaptation and Protection (SACAP), and the Secretary of Natural Resources are perceived to be significant stakeholders who have been leading the process of crafting the Coastal Resilience Master Plan (CRMP) with the participation of different stakeholder groups and support from TAC. State agencies are also present in this figure as they have a big say in regulations and permitting of

adaptation projects. They mediate the allocation of federal funding and grants and the recently introduced state funding, CFPF.

The federal government is among the emphasized stakeholders as they manage funding resources, e.g., FEMA, DOD, NOAA, OMB, and Congress, and provide high-level regulations, modeling, and data, e.g., FEMA, EPA, and NOAA. We will discuss this further in section 2.4.4. The U.S. Army Corps of Engineers is a highlighted federal entity, as they can provide technical and financial resources through their Civic Works program by doing studies and designs for coastal areas, e.g., Norfolk coastal storm risk management study. They also have regulatory authority in the design and implementation of infrastructure adjacent to bodies of water.

Environmental nonprofits are identified as another stakeholder group emphasizing Wetlands Watch, Chesapeake Bay Foundation (CBF), and Elizabeth River Project (ERP). Their existence here stems from their influence on legislature and policymaking on environment-related issues, and their activities influencing policies at the state level. Skip Stiles is the executive director of Wetlands Watch, who is perceived to be a champion for climate adaptation even beyond the state of Virginia. The private sector is identified as another significant stakeholder mainly because there is an emphasis on the potential role of the private sector in making progress in adaptation policymaking due to their financial resources and influence over policymakers. The private sector is generally referred to as a big missing player in this issue, with efforts going on to include them within the ongoing discussions, although some economic development nonprofits also play a role.

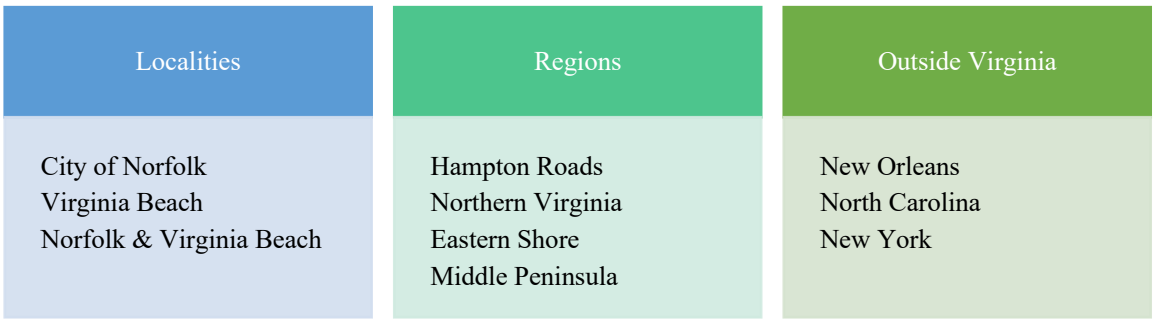

Figure 5. Keyword analysis: locations

The cities of Norfolk and Virginia Beach are perceived to be the leading localities in climate adaptation as they are frequently mentioned together by the stakeholders in our study (Figure 5). The City of Norfolk has been the first to start this conversation, being able to acquire funding for some studies and projects due to its importance on the state and national levels. Virginia Beach has started this later, mainly after Hurricane Matthew, and has been able to do a city-side study, find its flooding vulnerabilities, and raise money through a bond referendum passed in November 2021, to execute projects addressing its main climate risks. Other than Hampton Roads as the lead on fighting flooding and SLR, Northern Virginia is perceived as significant because of an appealing political environment to climate issues, financial resources, and influence on state-level policymaking. Eastern Shore and Middle Peninsula are perceived as primarily rural areas facing climate risks while having lower capacities for addressing this issue than a region like Hampton Roads. Besides, the Middle Peninsula is perceived as an active player in state-level efforts addressing climate impact issues as their delegation has been trying to address the flooding of that region.

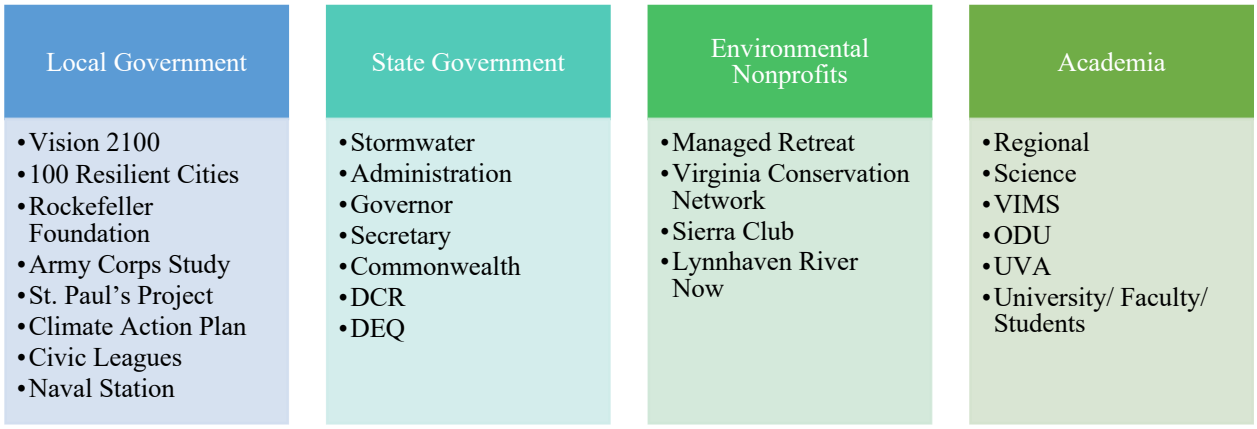

Figure 6. Keyword analysis: specific to main stakeholder groups

Running the keyword analysis for local government interviews, Figure 6, we derive the specific policies, programs, and projects that have been introduced in the City of Norfolk, i.e., Vision 2100, 100 Resilient Cities by Rockefeller Foundation, coastal storm risk management study by Army Corps of Engineers, St. Paul's renovation project, and the Climate Action Plan. These are the primary relevant initiatives in Norfolk within the last decade for addressing climate adaptation. This will be discussed further in section 2.4.2.1. Moreover, civic leagues and the naval station are emphasized as they have a significant presence in how their host local government identifies with the City of Norfolk.

Doing the same analysis for state government interviews, Figure 6, we find stormwater to be a new keyword as there is an emphasis on the state level that flooding across the state is not limited to SLR. Indeed, in non-coastal parts of the state, stormwater and pluvial flooding are critical issues. It is also argued that within the outreach efforts of the master plan process, stormwater flooding has been more significant in coastal areas of the state. The other revealed keywords mainly speak to the importance of state administration in the eyes of state government interviewees.

Environmental nonprofits emphasize managed retreat as a new keyword, an interesting observation (Figure 6). This happens because they generally advocate for the environment, e.g., water quality and wetlands conservation, and believe people and installations should move out of the way of the environment. Besides, they argue that managed retreat will be inevitable as projections of SLR on a regional basis will require some communities to move out of the floodplain. This is in sharp contrast to the attitude of local governments, who refrain from mentioning this issue because they believe it does not convey a positive impression of their locality and that it is not financially appealing to them. Some other environmental organizations are also revealed as partner organizations pursuing similar agendas.

The analysis of academic interviews brings "regional" as a new keyword as they highly emphasize the necessity for regional planning and decision-making for climate adaptation. They mainly argue for regional collaboration as they believe that water does not respect political boundaries, and optimum planning to tackle issues of flooding and SLR can be realized through a planning effort that is regional and comprehensive. They also emphasize particular academic institutions, as they explain their efforts within the realm of climate adaptation, e.g., Virginia Institute of Marine Science (VIMS), Old Dominion University (ODU), and University of Virginia (UVA). VIMS has the highest recognition as an influential stakeholder among these three, as shown in 2.4.4.

2.4. Thematic Analysis

This section uses thematic analysis to dig deeper into the existing policies at different governance levels. We first report how the stakeholders perceive climate risks and challenges, then we provide an overview of ongoing policies and programs for coastal adaptation. To do so, we first look at local governments, particularly the City of Norfolk, as the local focus of our study and review the ongoing policies and programs within their jurisdiction. Then, we look at regional governments, planning district commissions, and provide an overview of ongoing regional efforts, specifically in Hampton Roads, as our regional focus. Then, we expand our lens by looking at the efforts in the Commonwealth of Virginia. Even though the scope of our study did not include the federal government, we spoke to the Army Corps of Engineers, Norfolk District, the local representation of the US Army Corps of Engineers. Thus, we briefly discuss our findings of the federal government's role in this story. After this, we look at three main non-governmental stakeholder groups, i.e., environmental nonprofits, academia, and the private sector. We close this section by identifying the most influential stakeholders based on interviewees' responses at the end of the interview.

2.4.1. Perceptions of Climate Risks

Flooding seems to be the most observable and pressing climate risk in coastal Virginia, which could be caused by SLR or precipitation. Within the last decade, the intensity and frequency of flooding have been increasing, igniting certain calls for action. Extreme heat is another climate challenge, but it has not gotten as much attention in planning and response because it is not as observable as flooding. Moreover, there is little emphasis on hurricanes and nor'easters since there have not been many intense hurricanes.

Regarding awareness and response to climate risks, it is challenging to attract attention to climate impacts such as flooding and SLR, particularly if the public is not directly exposed to this problem. It is also the case that impacts of climate change are long-term and can be easily lost in the short-term political cycles and among other pressing issues. Resilience is the most used phrase addressing impacts of climate change versus climate adaptation; some even use flooding resilience. However, what it means can be very different depending on the stakeholder groups. For example, resilience for rural localities in the Middle peninsula generally means fighting the flooding and SLR to save their properties. In contrast, for the environmental nonprofits, those properties should be retreated from as keeping their status has negative consequences for water quality and nature conservation.

Phrases addressing climate adaptation have changed through time. For example, recurrent flooding was the common phrase before SLR became politically acceptable in Virginia. Some individuals are still cautious about using climate change in their discussions as it might be detrimental in their conversations with politicians of particular political beliefs. As another example, some environmental organizations prefer to use flooding instead of SLR, as it receives statewide attention, while SLR is mainly perceived as an issue for coastal areas. Figure 7 provides a summary of perceptions regarding climate risks and the response to them.

Perceptions of Climate Risks	Response to Climate Risks
• Flooding is the most observable climate risk • Flooding and SLR are the most recognized risks • There has been increased frequency and intensity of flooding • Tidal flooding was the main risk, and it is still a big challenge in Hampton Roads • Precipitation flooding has grown to become a big concern in coastal Virginia • Heat is perceived as the third most crucial risk • There is less focus and planning on intense heat as it is not as observable as flooding • There is mention of hurricanes and nor'easter as risk, but it is not much emphasized	• SLR is a slow and long-term phenomenon, and it is hard to get the public's attention to it • People ignore the issue if it is not directly impacting them • It can be lost in political cycles and amongst other pressing issues • Resilience is the most used phrase addressing the response to climate risks • Recurrent flooding was used before SLR became politically acceptable • Some people are cautious in using climate change in specific political environments • Flooding receives statewide attention, whereas SLR is mainly perceived to be coastal

Figure 7. Perceptions and response to climate risks

2.4.2. Ongoing Policies at Different Governance Levels

This section provides a narrative of coastal adaptation practice in Virginia by explaining the efforts at different governance levels.

2.4.2.1. Local Government

The City of Norfolk receives considerable national recognition on the issues of flooding and SLR because it has the highest population at risk of SLR, second to New Orleans, and has strategic significance on a state and national level, i.e., the presence of Norfolk Naval base and Port of Virginia. The city has been a pioneer in this region in recognizing its climate challenges and pursuing solutions and funding to tackle them. Norfolk aspires to be an example and laboratory for coastal resilience in the nation, focusing on multi-level partnerships and community-based approaches. This section summarizes climate adaptation policies, studies, programs, and projects of Norfolk. We, first, discuss the high-level policies, documents, and studies that shape the foundation of Norfolk's approach to resilience and then discuss the ongoing programs and projects.

2.4.2.1.1. Policies and Studies

The first systematic effort to address the impacts of climate change in the City of Norfolk dates back to the late 2000s, in which the observed problem was more frequent and intense flooding. This observation led to the City Council approaching the city manager to develop a strategy to address the issue. This led to establishing a cross-departmental committee in the city, leading to two studies; one for stormwater and one for tidal flooding, which eventually became the foundation for Norfolk's Coastal Resilience Strategy (City of Norfolk, 2014). Within these studies, for the first time, it became apparent that there was an acceleration of SLR, accompanied and exacerbated by land subsidence. The strategy is based on four pillars: Plan, Prepare, Mitigate, and Communicate. "Plan" refers to the necessity of understanding the scope of the flooding challenge, while "Prepare" is mainly related to emergency management and having the required transportation and evacuation at the time of a natural disaster. "Mitigate" regards the vulnerabilities of Norfolk to storm and flooding caused by relative SLR. It resulted in a series of short and long-term infrastructure solutions to improve water drainage and reroute and deflect water, called a billion-dollar plan.

The plan recommends several infrastructure projects along different watersheds in the city (City of Norfolk, 2014). The final pillar is to make sure that the climate risks and efforts by the city are effectively communicated to citizens to prepare them to take action as the climate risks are heavily impacting residential and single-family homes.

The next significant step for Norfolk was its selection to be among the first cohort of 100 Resilient Cities (100RC) by the Rockefeller Foundation in 2013. The 100 Resilient cities initiative was designed to help the participant cities develop a strategy for guiding each city through the challenges of the 21st century (Rockefeller Foundation, 2022). In 2014, this led to the formation of the Chief Resilience Officer (CRO) as a position directly reporting to the city manager. From that point, "Resilience" plays a substantial role in the planning of Norfolk with the broad definition suggested through the initiative, which is "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience". So, the city designed a resilience strategy with three main goals, as shown in Table 3. Being part of the 100 Resilient Cities has provided Norfolk with several resources, financial and technical, to have a comprehensive approach toward resilience and the ability to share and exchange thoughts and experiences with several other cities in and outside of the United States. Individuals within the local government speak of this as one of the most rewarding and professional relationships they have experienced while the impacts are still ingrained within the community, making Norfolk a climate resilience leader in this region.

Table 3. Resilience strategies of City of Norfolk

Goals	Strategies
Goal 1: Design the Coastal Community of the Future	• Collectively create a vision for the city's future • Identify and implement innovative infrastructure for water management • Redesign tools and regulations to achieve our vision for the future
Goal 2: Create Economic Opportunity by Advancing Efforts to Grow Existing & New Industry Sectors	• Create a multi-pronged economic development strategy • Nurture the city's entrepreneurial ecosystem • Strengthen the workforce development pipeline • Reinvest in and revitalize neighborhoods
Goal 3: Advance Initiatives to Connect Communities, Deconcentrate Poverty & Strengthen Neighborhoods	• Improve citizen access to information and services • Use technology to support and enhance community-building efforts • Connect people and facilitate dialogue that advances community-building efforts

As part of Norfolk's commitments in the 100 Resilience Cities program, the city made "Norfolk Vision 2100" a long-term strategic vision for the city's future (1st strategy of Goal 1). This happened as a result of a 1.5-year effort, which started in mid-2015 and was adopted in November of 2016 by the City Council. The process involved extensive citizen and city leadership participation through three distinct phases: Awareness, Asset mapping, and Vision development (City of Norfolk, 2016). More than 500 citizens directly participated in the process while city staff led them through the process, resulting in the division of Norfolk into four areas based on the exposure to natural risks and existence of significant assets (Figure 29):

- Red areas: identified as being rich in assets at higher natural risk that needs design and implementation of flood protection systems
- Yellow areas: identified as having fewer critical assets at higher risk, that have a lower priority for flood protection investment, but there is a need to educate residents about the risk of recurrent flooding

- Green areas: identified as lower risk locations with great potential for transformation – a potential home for many new assets
- Purple areas: identified as lower risk locations without many critical assets

Vision 2100 is now part of the Norfolk Comprehensive Plan, plaNorfolk 2030 as a guide for zoning, land use planning, and investment decision-making in the city (City of Norfolk, 2021a). It is perceived as the most successful among resilience efforts. It was realized through the collaboration of several city entities, e.g., City Planning, Neighborhood Development, Communications and Technology, and the Resilience Office, with the participation and input from the citizens and communities. It also makes Norfolk the only locality in the region to have done such long-term strategic planning, and it has been receiving significant positive recognition.

Dutch dialogues have been another significant initiative for climate adaptation in the City of Norfolk (City of Norfolk, 2015). It was an effort initiated by Norfolk in 2012 and was broadened to include the Hampton Roads region by the involvement of HRPDC in 2014. Historically, Dutch Dialogues were workshops initiated by Netherlands' embassy to teach about the Dutch approach to integrated water management in American cities facing flooding and SLR; this was initiated with three rounds of workshops in New Orleans, 2008 and 2010 (Waggonner *et al.*, 2014). Different localities were asked to submit their resilience-related challenges. Eventually, the Tidewater District of Norfolk and the Newmarket Creek watershed in Hampton and Newport News were selected as the target study sites for the Hampton Roads Dutch dialogues. Then, within a 5-day event in June 2015, Dutch designers, engineers, planners, architects, and counterparts from Norfolk, Hampton, and Newport News analyzed and recommended several practical strategies for resilience and integrated water management for resilience at the target sites. Dutch philosophy and experience of "living with water" rather than "fighting the water" accompanied by a collaborative multidisciplinary design and focus on multi-purpose infrastructure have been the most important outcomes of these events, which are still present in the language and endeavors of city staff in Norfolk. Dutch Dialogues are perceived as a success story when different stakeholders speak of Norfolk's experience with adaptation policymaking.

The *Coastal Storm Risk Management Study* was another climate adaptation study that has been done in Norfolk by the US Army Corps of Engineers (USACE). After Hurricane Sandy, USACE performed a North Atlantic Coast Comprehensive Study (NACCS) to address the flood risks of vulnerable coastal populations within the USACE North Atlantic Division (Simm *et al.*, 2015). The study was concluded in 2015 and identified nine high-risk areas along the Atlantic coast for further studies. Norfolk was one of the nine, and luckily, one of three, which was authorized and funded afterward. The study, called Norfolk Coastal Storm Risk Management Study, was concluded in 2018 recommending a $1.4 billion project, including storm-surge barriers, nearly 8 miles of floodwall, a 1-mile levee, 11 tide gates, and seven pump and power stations, as shown in Figure 30 (USACE, 2018). Then, in 2019, Congress authorized the study to go further to the Preconstruction Engineering and Design (PED) phase, an $8 million design effort for a couple of years. The City of Norfolk has to pay 35% of the costs, and the Army Corps covers the rest through their federal appropriations. Parts of the project are included in the Infrastructure Bill passed in November 2021, and the City of Norfolk is waiting to see the amount of funding that will be allocated to their project within this bill. If the city receives funding, their priority is to work on the Downtown area of the city, and there is an ongoing conversation about technical designs of that project which are to be a berm, a levee, or seawall.

All budget allocation to the Army Corps' projects has to be approved by the Congress and Office of Management and Budget (OMB) in the White House. So, the city of Norfolk has been trying to leverage its national importance through its congressional representatives due to the Naval Base, which is the largest naval base in the world, and the Virginia Port, which is the third-largest port on the East Coast. The Army Corps' studies are in high demand from localities but in low supply, as there could only be ten studies on a national level each year, including environmental issues other than flooding. Therefore, this leaves room for only a few flooding studies across 41 Districts of the Army Corps. At this point, Virginia Beach and the Southern Peninsula are other localities in Virginia that are waiting to receive approval for the Army Corps' study.

"*Resilience quotient*" is a resilience policy that Norfolk adopted into its zoning ordinance in 2018 (City of Norfolk, 2021b). The main idea is to produce market-based incentives for construction in safer areas in the city. To do so, the city land is divided into two areas: coastal resilience overlay, which is the 500-year flood zones, and upland resilience overlay, which is the rest of the city. A developer would need certain resilient quotients, based on the size of their construction, which can be acquired by specific flood and stormwater mitigation activities or conservation easements for the high-risk properties. For example, a developer could apply a conservation easement, take that property offline, and then use the resilience quotient for building in less risky areas. People in the local government believe the zoning code of Norfolk is one of the most resilient ones in the United States.

"*Resilience Penny*" is a recent allocation of one cent, from a 10-cent increase of property tax for $100 assessed property value, to resilience endeavors in the City of Norfolk (Commonwealth of Virginia - Office of the Governor, 2021). It generates about $2 million annually that the city uses for small-scale resilience projects, e.g., green infrastructures along the shoreline, to fight flooding. This is the city's first effort to raise funding to specifically address and pay for resilience projects. Norfolk has traditionally relied on federal money to pay for their resilience projects, e.g., HUD for the Ohio Creek Watershed and Army Corps of Engineers for Coastal Storm Risk Management Study, arguing raising the local tax to pay for adaptation is not feasible; however, this small tax levy, accompanied with the recent bond referendum in Virginia Beach, to be discussed in 2.4.2.1.3, could indicate that using local financial resources is going to be possible in the future.

"*A Green Infrastructure Plan for the City of Norfolk*" is a strategic document mapping and planning green infrastructure in the city to help its resilience goals (Green Infrastructure Center, 2018). Released in 2018 as the culmination of a 2-year effort by the Green Infrastructure Center, a nonprofit, Old Dominion University and the City of Norfolk, to propose strategies for the city to use green infrastructure to retain stormwater, support wildlife and habitat, and improve water quality, and promote health and beauty in the city (Green Infrastructure Center, 2018). Using green infrastructure and designing SLR and flooding infrastructure to address the climate risks and add to the city's beauty, recreation, and life is observable throughout different resilience efforts in the city. This, along with referral to the strategic plan of the city, Vision 2100, shows the continuity of impacts of programs like 100 Resilient Cities and Dutch Dialogues in the city of Norfolk.

In contrast to Norfolk's lead in climate adaptation, the city was not very active in climate mitigation until 2017, when the mayor of Norfolk signed the *Global Covenant of Mayors for Climate and Energy* agreeing to address climate mitigation and adaptation. This led to the formation of the *Mayor's Advisory Commission on Climate Change Mitigation and Adaptation* that was comprised of citizens and co-chaired by a city council member in 2018. The commission came up with a strategic document, "Climate Action Plan," in

2019. The Action Plan addresses mitigation solely as adaptation has been addressed through other city endeavors. It recommends 63 strategies in six areas, i.e., renewable energy production, buildings & energy efficiency, transportation, consumption & waste, food & agriculture, engagement, outreach, & education (Mayor's Advisory Commission on Climate Change Mitigation and Adaptation, 2019). The commission also recommends that the city hire staff to implement the suggested strategies in the Action Plan, which has led to hiring the first environmental sustainability manager in Norfolk in 2020.

2.4.2.1.2. Programs and Projects

The *Ohio Creek Watershed Project* is an iconic resilience project that Norfolk designed and is building as the outcome of the $120 million federal award that Norfolk received, in 2016, through the National Disaster Resilience Competition (NDRC) in collaboration with the Commonwealth of Virginia, as shown in Figure 31 (City of Norfolk, 2019). This funding was awarded for building the project and a coastal resilience accelerator center. The Ohio Creek Watershed, located southeast of Norfolk – an "R" labeled area in Vision 2100, includes two residential, predominantly African American, neighborhoods, i.e., Chesterfield Heights Historic District (with Civic Leagues and a strong community identity) and Grandy Village (a public housing community with more than 300 units). The project has three main components:

- Coastal defense to keep storm surge out of neighborhood: green berms, living shorelines, and floodwall
- Stormwater retention for rainwater runoff: stormwater parks and rain gardens, bioswales and bump-outs, pervious pavement, and expansion of underground pipelines
- Connectivity for easy access and amenities connected to water: public pier, playing field, walking & fitness trail, interactive playground

The preliminary designs of this project were done by a collaboration between Hampton University, Old Dominion University, Chesterfield Heights Civic League, Wetlands Watch, and Virginia Sea Grant (funding source) as the primary input to the Dutch Dialogues event in 2015. Then, with the strategies and designs introduced in the dialogues, the City of Norfolk was able to win the NRDC grant from the Department of Housing and Urban Development (HUD) in conjunction with the Virginia Department of Housing and Community Development (DHCD). The project's construction phase was started in 2020 and is planned to be completed by 2023. Norfolk's Office of Resilience is primarily in charge of the project, and the project has been taking tremendous time and energy from this office.

St. Paul's Tidewater Gardens is another significant project of Norfolk in resilience, which is the redevelopment of a public housing community at significant flood risk (City of Norfolk, 2022). They were built over an old creek bed that was filled for redevelopment in the 1950s. This community has been isolated and walled off by a series of urban highways that disconnected it from the rest of the city. The city is putting in efforts in deconcentrating poverty and developing a high-quality mixed-income community. Besides the socioeconomic component, the city would also build a resilient park to treat and store the stormwater runoff and provide a significant recreational amenity to the community. This project is mainly financed by a $30 million Choice Neighborhood Initiative (CNI) grant from HUD and a $14.4 million grant from the Virginia Department of Transportation (VDOT) to rebuild the road infrastructure in Tidewater gardens. Besides, the city has also committed to a $3 million annual budget to help and support families through this transformation project. This project has been managed by the Office of St. Paul's Transformation, which

was recently transferred to the newly formed Department of Housing and Community Development in Norfolk.

There has been a focus on improving Norfolk's class in the Community Rating System (CRS) introduced by FEMA under the National Flood Insurance Program (NFIP) within the last decade. They have recently moved to Class 5, qualifying for a 25% discount on insurance rates, effective April 2022. It is believed that Norfolk is the second locality in Virginia to reach Class 5 so far, after James City County. CRS is a point-based FEMA program designed to incentivize floodplain management practices beyond NFIP minimum requirements on a local level. Classes range from Class 10, the lowest with no discount on insurance rates, to Class 1, the highest with 45% discount on insurance rates. This has happened partly by adopting higher regulatory standards for new constructions. For example, minimum freeboard requirements, a mandate for the elevation of new construction in flood zones, was increased to three feet above base flood elevation, while FEMA's minimum policy is to build one foot above the base. Expanding the outreach for the flood insurance program to the neighborhoods and communities with low flood insurance uptake rates has been another effort to improve Norfolk's position in the CRS program. Citywide improvement in stormwater systems has been the other driving force to improve Norfolk's class. For instance, they developed a system to improve inspections and problem tracking of stormwater infrastructure before and after a storm event. The city has ideas to upgrade themselves to Class 3, qualifying for a 35% discount, which requires specific actions by the planning department and the resilience office. That is what they hope to achieve in the near future.

Table 4. Strategic policies and studies for resilience in the City of Norfolk

Policy/Study	Main Involved Stakeholders		Timeline	Funding sources
	Local government	Outside local government		
Coastal Resilience Strategy	• City Council • City Manager • Deputy City Manager • City Departments	-	2011-13	-
100 Resilient Cities & creation of Resilience Office	• City Council • City Manager • Deputy City Manager	• Rockefeller Foundation • Several Resilient Cities (100RC) • National/International Consulting Firms	2013-present	Rockefeller Foundation
Norfolk Vision 2100	• Resilience Office • Planning Dep. • Neighborhood development Dep. • Communications and Technology Dep.	• Citizens & Civic Leagues	2015-16	-
Dutch Dialogues	• Mayor of Norfolk • Resilience Office • Deputy City Manager • City Departments	• Netherland embassy • Waggonner & Ball Architects • HRPDC • City of Hampton • City of Newport News • Army Corps of Engineers • Environmental organizations (Norfolk District)	2012-15	• Netherland embassy • City of Norfolk
Coastal Storm Risk	• City Manager • Resilience Office • Planning Dep.	• Army Corps of Engineers • Congress & congressional representatives	2016-present	• Congress

Policy/Study	Main Involved Stakeholders		Timeline	Funding sources
	Local government	Outside local government		
Management Study	• City Council	• Office of Management & Budget		• Office of Management & Budget
Zoning Ordinance & Resilient quotient	• Planning Dep. • City Planning Commission • City Attorney • City Manager • City Council	-	2018	-
Resilience Penny	• City Council • Resilience Office	• Environmental organizations	2019	Property tax
Green Infrastructure Plan	• City Manager • City's Watershed Management Task Force • Department of Public Works	• Green Infrastructure Center	2016-18	• National Fish and Wildlife Foundation • Department of the Interior • City of Norfolk
Climate Action Plan	• City Council • City Departments	• Citizens & Civic Leagues	2017-19	-

Table 4 and Table 5 portray a summary of the strategic policies, studies, programs, and projects, including the main involved stakeholders in and outside the local government. The extent and variety of involved stakeholders indicate that the practice of climate adaptation policymaking in the City of Norfolk has been mainly a bottom-up process initiated by the local government, while highly influenced by practices and expertise outside of formal governance hierarchy, with an emphasis to take advantage of federal financial resources by leveraging the national recognition of Norfolk.

Table 5. Programs and projects for resilience in the City of Norfolk

Program/Project	Influential Stakeholders		Timeline	Funding sources
	Local government	Outside local government		
Ohio Creek Watershed Project	• Resilience Office • City Manager • City Council • City Departments	• Dutch Dialogues • Old Dominion University • Hampton University • Wetlands Watch • Civic League • DHCD	2016-present	Department of Housing and Urban Development (HUD)
St. Paul's Tidewater Gardens	• City Council • Department of Housing & Community Development • Resilience Office • Norfolk Redevelopment and Housing Authority • City Departments	• People First • Urban Strategies, Inc • HUD • VDOT	2017-present	• HUD • VDOT • City of Norfolk
CRS improvement	• Planning Dep.	• FEMA • Environmental Organizations	2011-present	FEMA
Small scale projects Examples: River Star Homes, Retain Your Rain,	• Resilience office • City departments	• Elizabeth River Project • Wetlands Watch • Chesapeake Bay foundation • Other Environmental Organizations	Ongoing	• City of Norfolk • EPA

Program/Project	Influential Stakeholders		Timeline	Funding sources
	Local government	Outside local government		
(Bioswales, Green roofs, Nature-based shorelines)				

2.4.2.1.3. Other Localities

Although Norfolk has been our focal locality within this study, speaking to different stakeholder groups, we heard stories of adaptation policymaking in other localities along Hampton Roads. Some other localities, i.e., Virginia Beach, City of Hampton, Portsmouth, also have municipal plans to deal with SLR, while a few others, e.g., Newport News, are developing a citywide plan. Some of the plans include flooding, a growing piece related to rainfall flooding, but none include other issues such as intense heat. Besides, smaller localities, particularly rural areas, do not have the plans, policies, and capabilities of bigger cities like Norfolk and Virginia Beach.

Virginia Beach is known to be the leading locality, along with Norfolk, in climate adaptation planning. This credit primarily relies on a comprehensive city-wide study called "*Sea Level Wise*," released in March 2020, to address rising sea levels and recurrent flooding (Virginia Beach, 2020a). The study analyzed the impacts of SLR and flooding while assessing the impacts for four different city watersheds. It suggested a series of solutions to address such impacts in the citywide flood protection program. Virginia Beach's study is believed to be the most comprehensive in the state as it covers SLR and precipitation flooding with clear maps and designs. It is also public-facing because citizens can effortlessly learn how designs will change and impact their community (Virginia Beach, 2020b).

Dewberry, an engineering consulting firm in Virginia, Old Dominion University, and NOAA's Office for Coastal Management have been the main stakeholders in developing the Sea Level Wise plan. This plan led to a decision by the City Council to issue a bond referendum, called "The Ripple Effect" in November 2021, to issue general obligation bonds, up to $568 million, for the design and construction of Phase 1 in the citywide Flood Protection Program, including 21 projects (Virginia Beach, 2021). This referendum was passed, with 73% voting in favor of it. Resilience efforts in Virginia Beach started later than Norfolk; for example, Virginia Beach was not interested in being part of Hampton Roads Dutch Dialogues in 2015. It is believed that Virginia Beach became invested in resilience after being hit by Hurricane Matthew in October of 2016. This is compatible with the perceptions provided in 2.4.1, in that a significant event with large impacts can raise awareness and the need for action.

Hampton is another locality with a resilience plan and the first in Virginia to have issued resilience bonds in December 2020. The $12 million *Environmental Impact Bond* (EIB) is designed to support three nature-based projects in the city. Chesapeake Bay Foundation and Qualified Ventures, a finance firm, and The Kresge Foundation, a philanthropic foundation, have been the main partners of the city in issuing the EIB.

2.4.2.2. Regional Government

The Commonwealth of Virginia was divided into 21 political subdivisions called a "Planning District Commission (PDC)" by a General Assembly legislation in 1968 (Commonwealth of Virginia, 2022). HRPDC embraces the city of Norfolk as one of its 17 member jurisdictions, as shown in Figure 32. HRPDC represents its local jurisdictions on various issues, e.g., water and environment, economic development, emergency management, housing, and transportation. HRPDC is believed to be the lead PDC in Virginia

to address SLR and flooding mainly because it includes some of the most affected localities, such as Norfolk and Virginia Beach, who have been the pioneers of adaptation in the state. State funding is a small portion of funding at HRPDC, as it is believed to cover only 4-5 staff members, whereas currently, there are about 50 staff in the organization. The remainder of the funding comes from two additional sources: either member localities agree to allocate money in general or for a particular issue, or the organization applies and receives external funding sources, usually federal ones. In this section, we briefly go over the significant efforts of HRPDC in coastal adaptation.

2.4.2.2.1. Policies and Studies

A well-known policy measure by HRPDC is adopting a SLR scenario planning policy and approach in 2018 (HRPDC, 2018). This was formed as localities were using different scenarios in their planning efforts. To increase consistency in the lack of a statewide policy, HRPDC adopted the NOAA 2017 intermediate-high scenario, i.e., 1.5 feel for near, 3 feet for the midterm, and 4.5 feet for long term, asking localities to use that for their future planning.

There have been two Joint Land Use Studies (JLUS) focusing on SLR and persistent flooding led by HRPDC: the first study between the cities of Norfolk and Virginia Beach, and the Navy, released in 2019, and the second one between Chesapeake and Portsmouth, the Navy, and the Coast Guard, released in 2021. These are efforts to study, identify, and outline a prioritized list of projects to address SLR and flooding in the roads surrounding four military bases in the study areas. Norfolk and Virginia Beach's study recommends eight priority actions addressing flood mitigation and stormwater management for eight of the most critical roads leading to military facilities in the target sub-areas (HRPDC, 2019b). It also suggests specific regional coordination strategies regarding outreach, advocacy, policy, and development regulations critical to meeting the study's goals (Table 6). The second JLUS emphasizes the impacts of flooding based on different SLR scenarios, up to 3 feet, and identifies a list of prioritized actions to be pursued to address such impacts (HRPDC, 2021b).

Table 6. Summary of JLUS studies

JLUS	Goals	Funding	Involved Stakeholders	Outcomes
Norfolk and Virginia Beach	• Reliable access routes for DoD personnel • Adequate stormwater management systems • Reliable and resilient utility networks • Effective multi-scales collaboration • A regional prioritization	• $1.5 m Grant from DoD, formerly OEA[1], now called OLDCC[2] • Involved cities • HRPDC	• HRPDC • Involved cities • Secretary of Veterans and Defense Affairs • Naval Station Norfolk • Expeditionary Base (JEB) Little Creek-Fort Story • Naval Air Station (NAS) Oceana • Naval Support Activity (NSA) Hampton Roads • Army Corps of Engineers • U.S. Coast Guard (USCG) • HRMFFA[3]	• 22 Actions to tackle access to military facilities (including 8 priority actions) • 23 regional coordination strategies • 7 conversations for the next steps
Portsmouth and Chesapeake				• 36 Actions (4 highest priorities address comprehensive flood mitigation and stormwater management strategies for the routes leading to the military facilities)

[1] - Office of Economic Adjustment (OEA)

[2] - Office of Local Defense Community Cooperation (OLDCC)

[3] - Hampton Roads Military and Federal Facilities Alliance (HRMFFA)

JLUS	Goals	Funding	Involved Stakeholders	Outcomes
			• VDOT[4] • HRTPO[5]	• 36 policies and practices in 4 categories of coordination, advocacy, policy development and regulations, and technology and data

The next step after the studies is to raise funding for the design and implementation of suggested solutions for flood mitigation and stormwater management. This is an ongoing effort for the involved localities, HRPDC, military installations, and economic development and military-related nonprofit entities in the region to identify and tackle funding sources, which are mostly related to the Department of Defense (DOD). For example, they are trying to devise a framework to hire the Army Corps' Civil Works branch to design and implement the solutions. The challenge is that the Army Corps' Civil works cannot include military facilities in its studies unless the facility hires them. On the other hand, the budgeting schedule of the facilities is not aligned with the annual budgeting of surrounding localities. Therefore, for the Army Corps to have a holistic design, it needs to have federal funding being allocated to this effort. So, there is a regional effort to lobby Congress and DOD for such funding allocations.

HRPDC is involved in statewide policymaking mainly by being a regional representative on advisory committees for state policy and regulation changes. By volunteering to be part of such advisory committees, HRPDC learns about the ongoing issues and suggested changes; then, conveys the information in the regular monthly meetings of the PDC and asks for feedback from localities; upon receiving the feedback, synthesizes them as the position of the PDC back to the state-level policymaking effort. Technical Advisory Committee (TAC) for Coastal Resilience Master Plan is a recent example of such advisory committees. Another mechanism for HRPDC to impact policy is identifying a gap or a need and leveraging the local members' delegation in the General Assembly or their representatives in Congress to push for particular policy agendas. They formally release a policy suggestion through a "Position Statement" white paper. For example, HRPDC has been pursuing the formation of the "*Commonwealth Flooding Board* (CFB)" as a state entity to centrally plan and coordinate climate adaptation efforts related to flooding since 2020 (HRPDC, 2020c). The CFB is supposed to address the existing gap in collaboration and steering of climate adaptation efforts in the Commonwealth and oversee the allocation of state funding resources, CFPF in particular, to different localities and regions. Suggesting incorporating resilience into the state's prioritization of transportation projects has been another 2020 position statement (HRPDC, 2020b). It argues that building roads that are resilient to flooding requires a higher cost, but as resilience is not considered in the current scoring scheme, called the *SMART SCALE* system, a resilient project would be penalized by its high cost, and to address this caveat, Commonwealth Transportation Board (CTB) should apply a resilience factor in the scoring system.

In another position statement in 2020, HRPDC suggests the future precipitation pattern should be considered for the design of drainage systems as the climate trend shows an increase in precipitation, at least in a study in Virginia Beach. So, to avoid the future costs of flooding, it is better to have a higher investment in drainage systems, bearing the higher initial cost. The statement particularly asks the state of

[4] - Virginia Department of Transportation (VDOT)

[5] - Hampton Roads Transportation Planning Organization (HRTPO)

Virginia to devise predictive models of precipitation and update them every five years (HRPDC, 2020a). It also suggests that localities leverage their Congressional representation to push for funding for NOAA's weather service report, called Atlas 14, to be updated regularly. The policy positions of HRPDC usually stem from the needs and requests of a few member localities, then negotiated between all of the members to gauge the interest of all localities to make the required modifications needed to make it acceptable among them, and then use political power of local representatives on the state and federal legislation levels.

2.4.2.2.2. Programs and Projects

Hampton Roads Adaptation Forum is one of the oldest regional climate adaptation settings in Hampton Roads by the collaboration of HRPDC, Virginia Sea Grant, and Old Dominion University. Initiated in 2012 by funding from NOAA, the Forum serves as a conversation medium for local governments, academia, and nonprofit organizations to share findings, experiences, and learned lessons on SLR and flooding within Hampton Roads every quarter. Involved individuals in this area, and on the state level, have known and interacted with each other for a relatively long time even though they might have been moving in localities and organizations, and forums like this have an essential role in shaping such relationships.

The "*Coastal Resiliency Committee*" is the primary resilience-related committee involved with representatives from member localities that regularly meet to discuss the PDC level plans and endeavors regarding the issues of flooding and SLR. For example, in 2019, HRPDC developed a program called "*Get Flood Fluent*" as an educational outreach program to educate the public on the risks of flooding and flood insurance (HRPDC, 2019a). As another resilience-related effort, HRPDC has generated a dashboard of resilience projects, available online, showing ongoing projects in different member localities to provide an overall understanding of the projects, their progress, and costs to show the magnitude of climate challenges in the region. At the end of 2021, there were 592 projects with an estimated cost of $ 7.2 billion in the dashboard as a summary of projects are shown in Table 7, based on project types, Table 8, based on project status, and Table 9, based on locality. The majority of projects are drainage improvement projects (46%), while the most considerable portion of the cost (55%) is related to structural flood protection projects (HRPDC, 2021a). The average cost of a project indicated that structural flood protection projects are the most expensive, followed by floodproofing & buyout projects, beach replenishment, and road improvement projects.

Table 7. Dashboard of resilience projects in Hampton Roads by projects type

Project Type	Ave Cost of a Project (K$)	Number of Projects		Cost	
		Projects	Share	Cost (M$)	Share
Acquisition	365	44	7%	16	0.2%
Beach Replenishment	21,675	7	1%	152	2%
Drainage Improvements	5,734	271	46%	1,554	21%
Elevations/Floodproofing/Buyouts	46,493	8	1%	372	5%
Green Stormwater Management	1,764	72	12%	127	2%
Natural Shoreline Management	911	39	7%	36	0.5%
Road Improvements	21,011	42	7%	882	12%
Shoreline Armoring/Protection	2,291	14	2%	32	0.4%
Stream Restoration	753	36	6%	27	0.4%
Structural Flood Protection	142,519	28	5%	3,991	55%

Project Type	Ave Cost of a Project (K$)	Number of Projects		Cost	
		Projects	Share	Cost (M$)	Share
Wetland Restoration	1,926	31	5%	60	1%
Total	-	592	100%	7,248	100%

Looking at Table 8, we observe that about 90% of projects (based on their cost) are in the preconstruction phase, and 66% are in the proposed status, indicating that climate adaptation has not reached many constructions yet in Hampton Roads. The "Completed" projects show that they are mostly beach replenishment, green stormwater management, and drainage improvement projects, generally less expensive. Looking at the "Under Construction" projects, we see that they are mostly road and drainage improvements in Virginia Beach and Norfolk, with Norfolk's Ohio Creek Watershed Project being the most expensive one labeled as drainage improvement type.

Table 8. Dashboard of resilience projects in Hampton Roads by projects status

Project Status	Number of Projects		Cost	
	Projects	Share	Cost (M$)	Share
Proposed	170	29%	4,754	66%
Programmed	57	10%	372	5%
Under Design	133	22%	1,287	18%
Under Construction	47	8%	652	9%
Completed	185	31%	183	3%
Total	592	100%	7,248	100%

Table 9 shows that Virginia Beach and Norfolk have the highest value projects significantly different from the others, leading the way in defining resilience projects in Hampton roads, followed by Hampton. Hampton has a higher number of projects in general, while most of them are smaller and green infrastructures such as green stormwater management or wetland restoration.

Table 9. Dashboard of resilience projects in Hampton Roads by locality

No.	Locality	Cost of Projects (M$)	Number of projects
1	Virginia Beach	4,710	97
2	Norfolk	2,074	107
3	Hampton	200	145
4	Newport News	95	56
5	Chesapeake	51	97
6	Suffolk	47	21
7	Poquoson	20	3
8	James City County	17	29
9	Portsmouth	16	15
10	York County	16	15
11	Isle of Wight County	2	4
12	Southampton County	1	1

No.	Locality	Cost of Projects (M$)	Number of projects
13	Gloucester County	-	2
Total		7,248	592

2.4.2.3. State Government

We identify three significant efforts from state governors to have a holistic and intergovernmental approach to climate adaptation in Virginia. This section reviews each effort according to our interview data and the existing documents supporting these efforts. The first statewide effort to address climate change impact in Virginia dates back to Governor Kaine's administration in late 2007 when he issued an executive order to establish "*Governor's Commission on Climate Change*." The commission comprised about 40 citizens of Virginia, including experts, state lawmakers, and local government representatives, and it was chaired by Preston Bryant, the Secretary of Natural Resources. After meeting several times in 2008, the commission issued their final report called "Climate Action Plan" in December 2008 (Governor's Commission on Climate Change, 2008). Climate Action Plan offered 15 recommendations, primarily addressing greenhouse gas emissions and climate mitigation, except for the 14th recommendation that directly concerns climate adaptation and suggestions for dealing with the impacts of climate change. We summarize the recommendations based on the target and nature of recommendations; for example, a recommendation may be targeted towards local governments, suggesting that local government should include climate change impacts into their current planning efforts. This provides us with an opportunity to analyze Virginia's primary thoughts and concerns. As observable in Table 10, most of the recommendations speak about assessing the impacts of climate change, conserving nature during adaptation, including climate change into current planning, and intergovernmental integration of efforts in climate adaptation. Interestingly, the Secretary of Natural Resources is asked to develop a SLR adaptation strategy by January 2011 in an intergovernmental setting. However, this never happened as within the McDonnel administration, starting January 2010, the commission and its mission dissolved due to it not being favorable to this administration. We can observe this by looking at Figure 8, which shows the significant state-led policies regarding climate adaptation in Virginia; there is no significant event within the McDonnel administration.

Table 10. Summary of climate adaptation recommendations in Climate Action Plan

Target Stakeholder		Recommendation	Recommendation nature
General		State discretionary funding programs should require infrastructure projects receiving funding are resistant to climate change impacts	Including climate change into current planning
		Adaptation policies and programs should make use of nature-based strategies	Nature conservation
Local Governments		Include CC in comprehensive plans, zoning ordinances	Including climate change into current planning
		Develop adaptation plans for critical infrastructure	Plan for critical assets
		Establish policies to discourage new building in vulnerable coastal areas	Limit building in risky areas
General Assembly		Provide funding for the Virginia Geographic Information Network to acquire and process LiDAR data for the entire state	Data & modeling
		Require localities to have integrated shoreline management plans with VMRC	Intergovernmental integration
		Direct state institutions to assess climate change impacts on socioeconomically vulnerable populations	Impact assessment
Secretaries	Sec of Commerce	Adaptation plan to minimize impacts on the economy	Impact assessment

Target Stakeholder		Recommendation	Recommendation nature
	Sec of Transportation	Consider SLR & storm surge impacts in transportation planning for coastal Virginia	Including climate change into current planning
	Sec of Natural Resources	Lead an inter-agency and intergovernmental effort to develop a SLR Adaptation Strategy by January 1, 2011	Comprehensive planning
		Direct state agencies and universities to work with federal partners and others to come up with regional adaptive resource management	Intergovernmental integration
	Assistant to Governor for Preparedness	Lead a statewide assessment of the impact of climate change on emergency preparedness, response, and recovery plans and capacity in Virginia	Impact assessment
		Coordinate with DoD on climate change impacts on military installations	Intergovernmental integration
State Agencies	Overall	Develop adaptation plans for critical infrastructure	Plan for critical assets
		Establish policies to discourage new building in vulnerable coastal areas	Limit building in risky areas
	VMRC	Shoreline protection policy to avoid shoreline hardening	Nature conservation
	Department of Conservation and Recreation (DCR)	Save and maintain habitat diversity	Nature conservation
		Revise floodplain management plan to address SLR & storm surge	Including climate change into current planning
		Assess the need to expand Virginia's Resources Protection Area buffer designations	Nature conservation
		Assess climate change impacts on native species	Nature conservation
		Monitor available forecasting tools and amend its stormwater regulation to ensure the implementation of stormwater management in altered precipitation regime	Data & modeling
		Assess the consequences of climate change on the effectiveness of non-point source urban and agriculture best management practices	Impact assessment
	Department of Wildlife Resources	Save and maintain habitat diversity	Nature conservation
		Assess climate change impacts on native species	Nature conservation
	Virginia Department of Health (VDH)	Track disease generated/increased by climate impacts and add them to their databases	Impact assessment
		Identify vulnerable populations to SLR and increased heat (collaborate with local health departments)	Impact assessment
		Strengthen local public health initiatives for emergency responses in extreme weather events	Intergovernmental integration
		Ensure health districts have heat emergency response plans	Including climate change into current planning
	State Corporation Commission	Work with the insurance industry to analyze areas vulnerable to insurance loss	Impact assessment
	Department of Historic Resources	Assessment of social and cultural impacts of climate change in Virginia	Impact assessment

The second statewide effort was recognized in the McAuliffe administration, as he attempted to revive the Governor's Climate Change Commission, with the addition of resilience, called "*Governor's Climate Change and Resiliency Update Commission*," with an executive order in 2014 (Commonwealth of Virginia - Office of the Governor, 2014). The commission was charged to determine what recommendations from the Climate Action Plan were implemented, and then provide new recommendations and identify sources of funding to support the implementation of the recommendations. This time, Secretaries of Natural Resources and Public Safety and Homeland Security co-chaired the commission. The report and recommendations to the governor came out in late 2015 (Climate Change and Resiliency Update Commission, 2015). We summarize the main adaptation-related recommendations as:

1. The governor appoints a chief resilience officer as the initial point of contact for resilience-related issues
2. Virginia Institute of Marine Science (VIMS) develops a statewide protocol for SLR projections
3. Establish a climate change and resilience resource center to provide information and technical assistance for decision-makers and provide information for citizens and businesses
4. Create a bank to finance energy and resilience projects
5. Leverage federal dollars to make coastal communities more resilient

The first recommendation, which occurred before the report's release as the governor appointed the Secretary of Public Safety & Homeland Security as the first Virginia Chief Resilience Officer (CRO), addresses the need for the state to have central planning around climate adaptation. Recommendations (2) and (3) address the required data and models for SLR and flooding decision-making. Recommendations (4) and (5) address the funding needed to implement resilience projects as perceived to be a challenge. It is also noticeable that in this document, in contrast to Climate Action Plan, there is no mention of extreme heat and its health consequences, and climate risks are only limited to SLR and flooding.

The General Assembly, as shown in Figure 8, has two main legislations related to climate adaptation in the McAuliffe administration: first, is a joint subcommittee on recurrent flooding, which is still present but not very active today, and second is the creation of the Commonwealth Center for Recurrent Flooding Resiliency (CCRFR) as a collaboration between Old Dominion University, VIMS, and College of William & Mary to advise and support the Commonwealth by conducting interdisciplinary research on recurrent flooding and resilience (Virginia General Assembly, 2014, 2016). We observed the first bill on climate adaptation by General Assembly during this administration. Interestingly, both bills are directly about resilience and do not speak of climate mitigation as mitigation was, and still is, a political divide in the General Assembly. Both bills were introduced by Chris Stolle, a Republican delegate from Virginia Beach to the House of Delegates in the General Assembly. This speaks to another aspect of state-level legislation in the realm of climate adaptation: such bills are mainly pursued by the delegates and senators from the coastal localities as a response to the concerns and requests of local governments and the economic development institutions in their region and locality. For example, Lynwood Lewis - a Democratic senator from the Eastern Shore, and Keith Hodges – a Republican delegate from the Middle peninsula, are patrons on various SLR and flooding legislations.

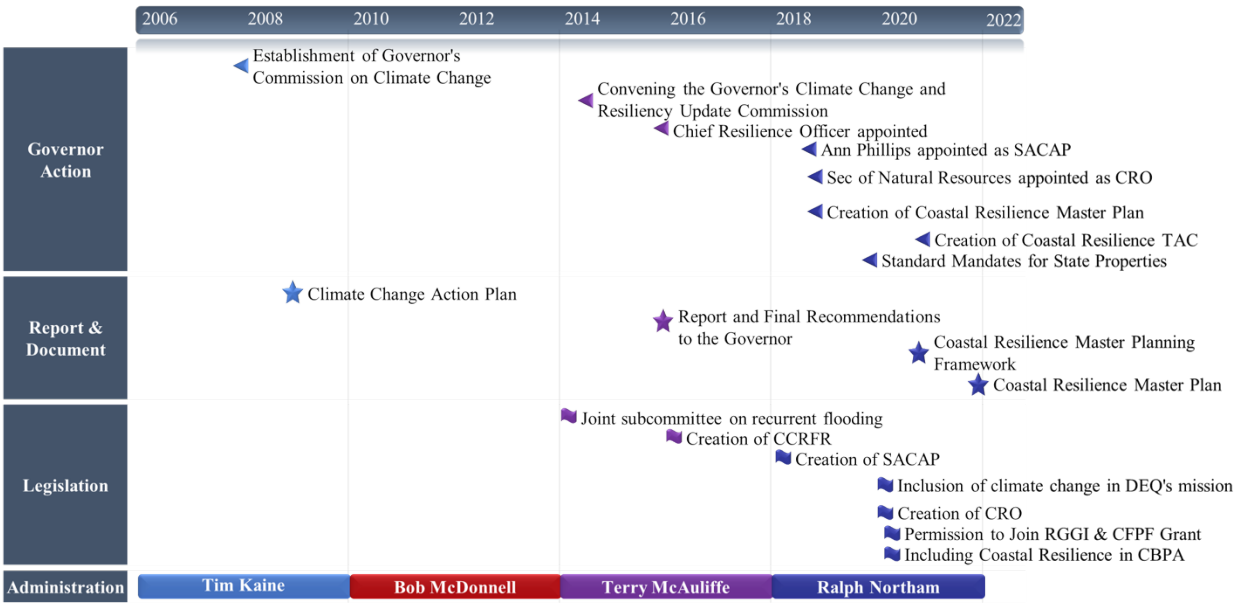

Figure 8. Main state-led policies to address climate adaptation in Virginia

The third and most significant statewide effort addressing flooding and SLR was during the Northam Administration, as observable in the most crowded part of Figure 8. This is aligned with the recurring theme we observed in our interviews, indicating that Virginia as a state had not done much about resilience prior to this administration but has been able to catch up, to some extent, particularly within the last two years of the administration. It is also interesting that Governor Northam was present in the two previous commissions and, as a person who was raised in Eastern Shore, the climate challenges of coastal Virginia have been influential in his political agenda. We observe several governor actions, usually through executive orders and several state-level legislations, leading to a statewide and intergovernmental approach in addressing the impacts of SLR and flooding.

There is a tendency to institutionalize the central point of contact on the state level. For example, the General Assembly created a position called "*Special Assistant to the Governor for Coastal Adaptation and Protection (SACAP)*" in 2018 to lead the statewide coastal adaptation strategy, assist with economic development activities associated with adaptations, and pursue federal, state, and local funding opportunities for adaptation initiatives (Virginia General Assembly, 2018). As another example, the General Assembly codifies the Chief Resilience Officer (CRO) position in 2020 and asks the CRO to identify high-risk areas, review plans for flood defense solutions, and help with the funding of solutions in consultation with SACAP (Virginia General Assembly, 2020a). Moreover, comprehensive statewide planning was of high importance for the governor, as evident in Executive Order 24, in November 2018, as the CRO and SACAP were put in charge of creating the Virginia Coastal Resilience Master Plan (Commonwealth of Virginia - Office of the Governor, 2018). The master plan was asked to be comprehensive and science-based, prioritize nature-based solutions, consider potential areas for coastal managed retreat, include detailed funding analysis, and recommend funding sources for the resilience solutions. There was also a focus on consulting with various stakeholders, including local and regional governments, federal partners, academic institutions, nonprofits, and the business community. This led to the release of "*Coastal Resilience Master Planning Framework*" in October 2020, followed by another executive order establishing the Coastal Resilience Technical Advisory Committee (TAC) to assist with

the creation of the master plan, perform risk assessment, and provide recommendations (Commonwealth of Virginia - Office of the Governor, 2020a). The master plan focuses on coastal localities in Virginia, dividing them into four regions, as shown in Figure 35: Fall Line North, Rural Coastal Virginia, Hampton Roads, and Fall Line South. The release of the master plan document, phase 1, in December 2021 was the culmination of the governor's efforts. The master plan document did the following (Commonwealth of Virginia - Office of the Governor, 2021):

- Provided status quo and projections of coastal flooding and land exposure for three dates in the future (2040, 2060, and 2080)
- Measured impacts of flooding on community resources, critical sectors, and natural infrastructure
- Estimated social vulnerability and combines it with flood hazard to identify areas with the highest need
- Conducted outreach efforts through localities and environmental organizations
- Established an inventory of existing resilience projects, by asking PDCs and localities, and provided a preliminary project evaluation (although not confident to use it as there are specific challenges regarding the accuracy and relevancy of data)
- Provided a list of available funding options (grants and loans)
- Created a web explorer to show the outcomes mainly designed to be used by local and regional governments

The master plan is believed to be a promising first step toward state leadership in resilience, which has been historically missing in the state. However, continuity of this effort is a severe challenge in the shadow of a new governor who might not be as invested as Governor Northam in climate resilience. Some segments of the recent efforts have been codified through the General Assembly, but there are still segments that the new governor can change by issuing an executive order.

Another critical legislation within recent years has been the formation of the *Community Flood Preparedness Fund* (CFPF) to help localities affected by recurrent flooding, SLR, and flooding from severe weather events. This is believed to be the most significant allocation of state funds to climate resilience. The primary financial source of CFPF is the revenues acquired from *Regional Greenhouse Gas Initiative* (RGGI), which is a cap-and-trade mechanism for curbing carbon emissions. Commonwealth of Virginia joined the initiative in January 2021, as the General Assembly had permitted the governor to do so in the 2020 season (Virginia General Assembly, 2020b). Virginia has been present in all four auctions in 2021 and has acquired $228 M within those auctions (RGGI, 2021). Regarding a 45% share of CFPF from RGGI proceedings, CFPF could have potentially allocated $102 M in 2021. Secretary of Natural Resources, DCR, and SACAP are the primary decision-makers on this allocation. There is also a worry about continuity of CFPF as the new governor, arguing that joining RGGI has a financial burden on residents of Virginia as it increases their electric bills, has indicated that he will try to withdraw from this regional initiative.

State agencies have played a role mainly by regulating and distributing funding and grants, primarily federally sourced, to localities. Policies and strategic plans of the agencies are highly influenced by the secretary under which they operate, and, as secretaries are political appointees by the governor, the state agencies are also affected by the political cycle of administration. However, as part of their budget comes from the federal government, they also have a certain level of independence and influence. Historically, the Secretary of Natural Resources has played a significant role in leading state-led efforts as that embraces

Department of Conservation and Recreation (DCR), Department of Environmental Quality (DEQ), Department of Wildlife Resources (DWF), and Virginia Marine Resources Commission (VMRC) as the departments whose functions are directly related to coastal adaptation. Secretary of Public Safety and Homeland Security has been another significant player mainly because it oversees the Virginia Department of Emergency Management (VDEM) as the central department in charge of emergency management that is also the primary FEMA contact in the state.

2.4.2.4. Federal Government

The federal government and agencies were out of the scope of our study. Our only interview with a federal entity involved in climate adaptation was the Army Corps of Engineers Norfolk District, the local branch of the Army Corps involved with the coastal storm risk study in Norfolk. However, we heard about some federal policies and programs during our interviews, and we are reporting them in this section.

It is believed that there is no comprehensive federal policy for SLR and flooding. However, there are some efforts in the current administration to address climate change impacts. We have identified a few of these efforts trying to address climate change impacts on a holistic federal level, as shown in Table 11. The first one is the formation of the *National Climate Task Force* in January of 2021, through an executive order by President Biden, to assist in the organization and deployment of a government-wide initiative to tackle climate change impacts (The White House, 2021a). A few months later, the Task Force initiated the *Coastal Resilience Interagency Working Group*, led by Council on Environmental Quality (CEQ) and NOAA, to increase coastal resilience in the nation (The White House, 2021b). The list of involved stakeholders for this effort, Table 11, provides a good overview of federal agencies involved in coastal adaptation. The Task Force and the Coastal Resilience IWG have great potential for setting policies and standards at the federal level within the following years.

Table 11. High-level federal policies regarding flooding and SLR

Policy/Program	Date	Goals & Description	Involved/Leading Stakeholders
Tackling the Climate Crisis at Home and Abroad - Executive Order 14008	January 2021	It puts the climate crisis at the center of US foreign policy and national security and takes a government-wide approach to the climate crisis. National Climate Task Force is created and charged to facilitate the planning and implementing a government-wide approach for combating the climate crisis.	Secretary of the Treasury Secretary of Defense Attorney General Secretary of the Interior Secretary of Agriculture Secretary of Commerce Secretary of Labor Secretary of Health and Human Services Secretary of Housing and Urban Development Secretary of Transportation Secretary of Energy Secretary of Homeland Security Administrator of General Services Chair of the Council on Environmental Quality Administrator of the Environmental Protection Agency Director of the Office of Management and Budget Director of the Office of Science and Technology Policy Assistant to the President for Domestic Policy Assistant to the President for National Security Affairs Assistant to the President for Homeland Security and Counterterrorism Assistant to the President for Economic Policy

Policy/Program	Date	Goals & Description	Involved/Leading Stakeholders
Coastal Resilience Interagency Working Group (IWG)	June 2021	It was formed by the National Climate Task Force and is co-led by the Council on Environmental Quality (CEQ) and National Oceanic and Atmospheric Administration (NOAA). It aims to elevate, coordinate, and accelerate the federal government's efforts to increase the resilience of the nation's coasts and coastal communities to the impacts of climate change. Three initial focus areas: 1. Aligning major Federal involvement in coastal resilience activities 2. Developing grant-making and data implementation strategies that will facilitate a coordinated working partnership with different layers of government 3. Facilitating the use of the Federal government's data sharing and mapping resources to improve coastal resilience investment decision-making	AmeriCorps Department of Agriculture (USDA) Department of Defense (DOD) U.S. Army Corps of Engineers (USACE) Department of Housing and Urban Development (HUD) Department of the Interior (DOI) Department of Transportation (DOT) Environmental Protection Agency (EPA) Federal Emergency Management Agency (FEMA) National Aeronautics and Space Administration (NASA) National Oceanic and Atmospheric Administration (NOAA)
Infrastructure Investment and Jobs Act	November 2021	This is an unprecedented $1.2 trillion bill addressing infrastructure needs in the US, with about $50 billion for cybersecurity and climate change. This resilience funding will protect infrastructure from cybersecurity attacks and address flooding, wildfires, coastal erosion, and droughts along with other extreme weather events.	President House of representatives Senate
Build Back Better Act	TBD	An unprecedented $550 billion bill invest in protection from coastal resilience to SLR and hurricanes.	

Table 11 also shows two unprecedented Acts that will significantly impact climate adaptation since they provide billions of dollars for financing resilience projects around the nation. The *Infrastructure Investment and Job Act* includes about $50 billion funding for flooding, wildfires, coastal erosion, droughts, extreme events, and cybersecurity (Congress of the United States, 2021a). For example, parts of the $ 1.4 billion solutions of the Army Corps for Norfolk are included in this Act, although the exact amount has not been clear to the local government at the time of our interviews. To be approved by the Senate, the *Build Back Better Act* is believed to be the most considerable effort to combat climate change in American history; although it is mainly focused on climate mitigation, it has some resources for coastal restoration, soil conservation, and forest management (Congress of the United States, 2021b). For example, there are new coastal storm studies to be authorized by the final passage of this bill.

There were several mentions of federal agencies throughout our interviews. Army Corps of Engineers (USACE) had the highest frequency as the participants referred to executed or planned coastal studies performed by the Army Corps. The role of the Army Corps in the regulation of infrastructure on or adjacent

to the bodies of water was another factor in considering them to be an active player of coastal adaptation in Virginia. FEMA is another influential body in this story. National Flood Insurance Program (NFIP) and the Community Rating System (CRS) have a high impact on local and individual decision-making efforts as they have been trying to take advantage of discount options. Several grant programs for hazard mitigation and recovery projects, e.g., HMGP[6], FMA[7], BRIC[8], PDM[9], go to localities, mainly through the Virginia Department of Emergency Management (VDEM). We do not discuss the details of such grant programs, as the Coastal Resilience Master Plan provides a database of available federal funding options with specifics on purpose, eligibility, and funding amount (Commonwealth of Virginia - Office of the Governor, 2021).

NOAA is another federal agency that we observed a lot in our data for two reasons: first, addressing NOAA speaking of climate data, modeling, and forecasts and challenges; secondly, the funding and grants that are usually distributed through Virginia Marine Resources Commission (VMRC), Virginia Sea Grant, and Department of Environmental Quality (DEQ).

Respondents also mentioned the Environmental Protection Agency (EPA), which sets the regulatory standards for various programs in the Department of Environmental Quality. Finally, the Department of Housing and Urban Development (HUD) was mentioned as an excellent funding potential for resilience projects that Virginia has to invest more in exploring. It was also noticeable that HUD grants are considered to bring social equity into consideration, in contrast with several other federal programs.

2.4.3. Main Non-Governmental Stakeholders

The previous section focused on the policies and programs on different governance levels to provide an understanding of the role and actions of governments in climate adaptation policymaking in Coastal Virginia. This section explores the role of main nongovernmental stakeholders in this practice. We have identified two groups of nongovernmental stakeholders who have been playing an essential role in this practice, i.e., *environmental nonprofits and academia*. We also identified the "private sector" as a stakeholder group usually called "missing player with high potentials." In the following subsections, we provide an overview of the role of each of these three groups and the most significant entities within each group.

2.4.3.1. Environmental Nonprofits

Environmental nonprofits mainly enter this story from the standpoint of environment conservation and protection, with their chief concern being issues like water quality, wetland preservation, land conservation, and renewable energies. In most cases, their focus is not necessarily climate adaptation, but they have been trying to address such issues as they have become more apparent. This section shows the leading environmental NGOs involved in climate adaptation in Virginia and then provides an overview of their role and functions in this practice. There is a network of collaboration between NGOs; they know each other and work together very well, with the slight exception of an ongoing conflict between some of the larger national/international organizations who are relatively new to Virginia and the existing small/medium ones

[6] - Hazard Mitigation Grant Program (HMGP)
[7] - Flood Mitigation Assistance (FMA)
[8] - Building Resilient Infrastructure and Communities (BRIC)
[9] - Pre-Disaster Mitigation (PDM)

who are native to Virginia. This conflict arises as the larger ones have higher capacity, mainly financial, but might not be familiar with how things work in Virginia.

Overall, we categorize environmental nonprofits based on the scope of their work, as shown in Figure 9. The local NGOs are usually small organizations, mostly volunteer-based, and are scattered around the state in a non-uniform pattern as some areas, like Northern Virginia, have a relatively high density. In contrast, some other areas, like the southwest, almost have no environmental NGO representation. The list of main stakeholders we provide in the local/regional category is limited to Norfolk and Hampton Roads as the geographic focus of our study. Nonprofits working on the state level and in cases beyond Virginia on the east coast are perceived to be the most influential NGOs in advancing climate adaptation policymaking on the state level in Virginia. They have a collaborative network, mediated through Virginia Conservation Network (VCN), to bring synergy into their work and influence policies, as shown in Figure 10. Finally, there are some larger national and international environmental organizations while some are newer to Virginia, e.g., EDF and Pew Charitable Trusts. It is also interesting that the success and involvement of such organizations are partly dependent on the local people they hire as involved people in this environment have known each other for a long time and to be known and trusted by others is a requirement for success.

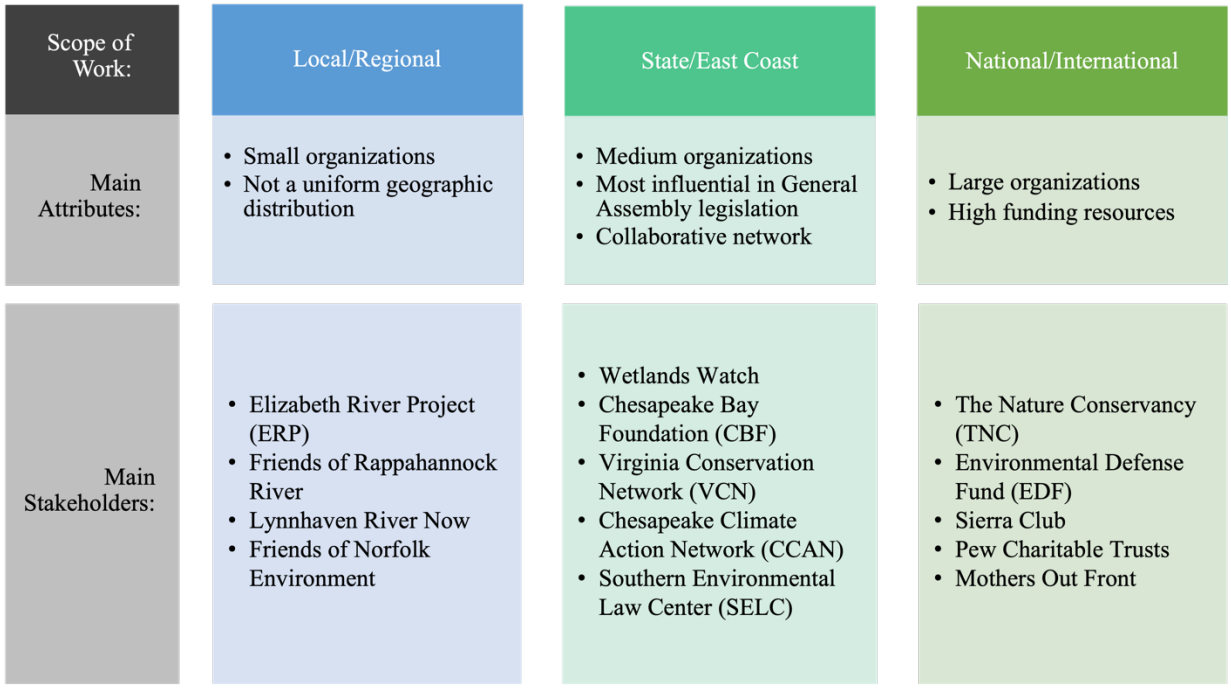

Figure 9. Main environmental nonprofits in climate adaptation

We summarize their role in climate adaptation in Figure 10 by dividing their function regarding different layers of governance: local/regional, state, and federal. Indeed, an interesting and probably practical aspect of their positioning is their tendency to work with diverse government levels and have some added value to pursue their work. Interacting with local governments, mainly local staff rather than elected officials, they carry information about the extent of climate adaptation in other localities, then advise and encourage them to define similar measures. This could lead to suggesting resources and grants enabling local staff to go further in this practice. A clear example of such engagement between environmental nonprofits and local governments is the advice of a couple of nonprofits on the CRS program of FEMA. They help a locality develop programs to use flood insurance discounts introduced under the CRS program. The advice of NGOs

to local government can also be realized through serving as an NGO representative on a local board or briefing city councils and county management.

Pilot studies and projects are other forms of functioning of NGOs. Testing the waters for a particular solution or type of work is usually appealing to the localities. So, environmental nonprofits, combining their efforts with other NGOs or academic resources, pursue projects that could lead to implementation and a larger scale. Chesterfield Height neighborhood of Norfolk or the managed retreat pilot project, both pursued by Wetlands Watch, are examples of such contributions of NGOs toward local government. Nonprofits also encourage nature-based solutions and even design implementation frameworks with benefits for all involved parties. The *Home Star Program*, done by the Elizabeth River Project, is an excellent example as it promotes living shorelines among citizens by paying half of the cost if a household decides to implement them on their property. The locality would fund the NGO's share, and the locality would be eventually compensated through EPA as living shorelines help water quality.

Environmental NGOs also have an essential function in community outreach and advocacy as they go to community events, learn about their problems, and address them by engaging with different government layers. The community outreach that organizations like CCAN did in the Coastal Resilience Master Plan is an example of such an effort. The idea was to have community meetings through which the citizens convey how climate impacts affect their lives and express their expectations from the state. Educating the public on climate change and SLR is another crucial aspect that several NGOs have done through information sessions, public meetings, targeted classes, online videos, and even mobile apps. Helping state agencies in locally enforced regulations is another engagement of environmental organizations with localities. Shoreline and tidal wetland management is an example as the regulations that are sourced from the state, VMRC in particular, and NGOs interact with local government to ensure they meet the requirements of the regulations.

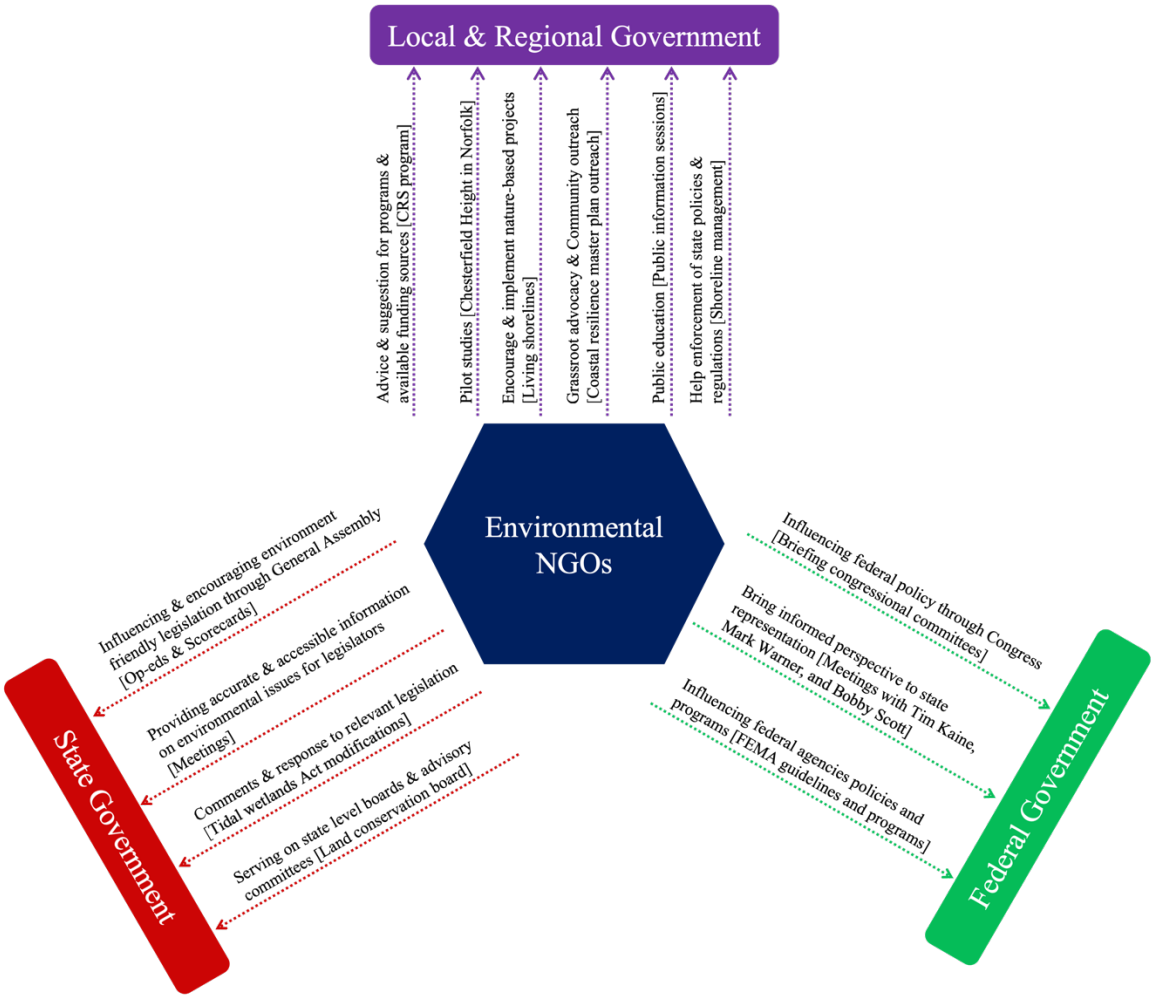

Figure 10. Role of environmental nonprofits in climate adaptation
Examples are included in brackets

Influencing state-level legislation is one of the primary mechanisms through which environmental nonprofits influence the climate adaptation policymaking process. Virginia being a Dillon Rule state, legislation and policies introduced and approved at the General Assembly have significant outcomes for local policies, so NGOs find the state legislation to be an appropriate way to pursue their agenda. Several tools are used for doing so, ranging from meetings and lobbying with delegates to writing op-eds on pieces of legislation, to even having a scorecard for legislators that is updated every year based on how they have voted on environmental issues, which is done by Virginia League of Conservation Voters (VLCV). To bring synergy and consistency in the efforts of environmental organizations, about 150 of them are gathered in a network called Virginia Conservation Network (VCN) that makes an environmental briefing book each year before the General Assembly sessions; it is called "our common agenda" (Virginia Conservation Network, 2022). Writing comments on legislation in the public comment period is another way of influencing the climate adaptation process for NGOs, and they usually do it as a collaboration between several organizations. A joint comment by Wetlands Watch, CBF, James River Association, SELC, and VCN on tidal wetlands guideline in April 2021, which indeed affects the guidelines, is an example of such type of action (Wetlands Watch, 2021b). NGOs also serve on several statewide boards and committees that

provide them with an understanding of the mood in the administration and allow them to influence the state-level decisions.

The relationship of NGOs toward federal level legislation is similar to their relationship toward the General Assembly but different in that their audience at the federal level is primarily Virginian representation in the House and Senate. Some individuals in the environmental nonprofits have broader access to federal lawmakers, particularly in the Democratic party. NGOs also try to influence the policies decided in a federal agency and do not need congressional approval by being involved in the programs of influential federal agencies in this area, such as the flood insurance program at FEMA.

2.4.3.2. Academia

Academic institutions are another stakeholder group that has shown a significant role in coastal adaptation policymaking within the last decade. Speaking to people outside of academia, we heard some names repeatedly: Virginia Institute of Marine Science (VIMS), Center for Coastal Resources Management (CCRM), Old Dominion University (ODU), Virginia Coastal Policy Center (VCPC) at William & Mary, University of Virginia (UVA), Commonwealth Center for Recurrent Flooding Resiliency (CCRFR), Hampton University, and Virginia Tech. We also heard about specific programs that have been initiated in academia, e.g., *Resilience Adaptation Feasibility Tool (*RAFT), Adapt Virginia, Virginia Sea Grant, and Hampton Roads Intergovernmental Pilot Project (IPP). Figure 11 summarizes the functions and objectives of academic institutions in this practice. Moreover, we provide an overview of the most mentioned academic-led programs to explain their role further.

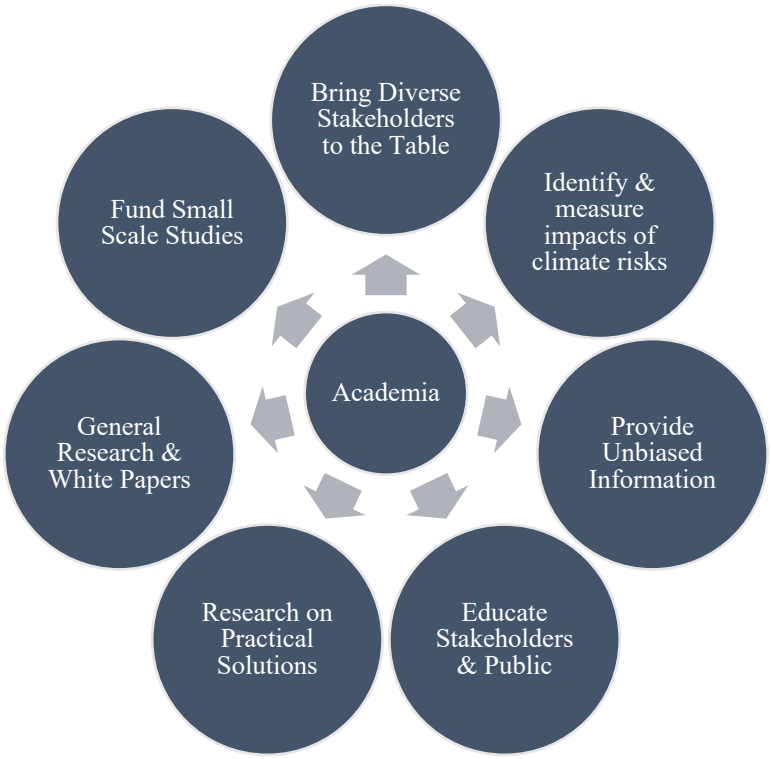

Figure 11. Role of academia in climate adaptation in Coastal Virginia

RAFT is a partnership between UVA, Institute for Engagement & Negotiation (IEN) in the school of architecture, VCPC at William & Mary, and ODU formed in 2015 to help Virginia's coastal localities improve resilience to flooding and coastal hazards while remaining economically and socially viable

(University of Virginia, 2022). RAFT undertakes a three-step process with a holistic approach to resilience, considering environmental, economic, and social aspects. First, it assesses the capacities of a community in emergency management, infrastructure, planning, policy, and community wellbeing through a scorecard setting. Then, there are community workshops to develop a resilience action checklist and locality implementation team. Finally, in a one-year implementation phase, the RAFT team assists the locality in addressing their highest impact challenge. It has received much recognition in the state as there have been two successful rounds, one in the Eastern Shore with the help of Accomack-Northampton PDC in 2018-19 with participation from seven localities, and another one in Northern Neck with the help of Northern Neck PDC in 2019-20 with participation from eight localities. The third round is now happening in the Middle Peninsula with the help of MPPDC with six participant localities that will conclude mid-2022. RAFT was initially funded by a National Fish and Wildlife Foundation (NFWF) through the design and pilot process. Then, several grants from Virginia Environmental Endowment, DEQ, NOAA, duPont Fund, and an anonymous donor have maintained its continuity. It is perceived as a long-term partnership between universities, while it is not very common for universities to collaborate well and commit to long-term projects.

Adapt Virginia (AdaptVA) is a web portal, launched in 2017, designed and implemented as a collaboration between CCRM, VCPC, and Wetlands Watch to provide SLR data, maps, studies, and tools to help citizens, businesses, and decision-makers at different governance levels (CCRM, 2022). The portal provides several GIS layers, including SLR scenarios, flooding, infrastructure, socioeconomic vulnerability, shoreline, and land for protection on different resolutions, designed to form a one-stop shop for policymakers. This portal was mentioned several times as one of the sources for acquiring information on resilience issues.

Virginia Sea Grant is a six-university partnership between VIMS, ODU, UVA, Virginia Tech, VCU, and George Mason University to support graduate students researching coastal and marine science. With a $2.7 million base funding, $1.8 million from NOAA, and $0.9 million from partner universities, each year they support about eight graduate students willing to do applied research for two years. The program encourages small pilot projects due to its requirement for the grant receiver to have a partner in the practice, a locality, for example, who supports their project. This is how we heard of projects funded through Virginia Sea Grant. Approximately 20% of the funded projects are in the realm of coastal resilience.

The Hampton Roads Intergovernmental Pilot Project (IPP) was led by Old Dominion University to create a framework for intergovernmental strategic planning on the impacts of SLR in Hampton Roads from 2014 to 2016 (Yusuf *et al.*, 2018). Including several stakeholders from different levels of government, IPP concluded that some formal structure is required to lead localities toward regional watershed-based planning for the impacts of SLR. This project is believed to be one of the first regional efforts to bring different stakeholders to a table and initiate the conversation.

2.4.3.3. Private Sector

The private sector is widely believed to be the missing player with considerable potential to influence resilience. The relatively short horizon of decision-making in the private sector, 3-5 years, and the multitude of pressing challenges the private sector has are the main reasons for the lack of engagement in this practice. On the potential side, there are three main arguments: one, the private sector will be capable of making required investments in a way that no other stakeholder can; two, they can influence the politics to pay attention and invest more in addressing climate impacts of SLR and flooding; three, particular industries,

such as banking and insurance, can have a significant influence if they include such climate risks in their decision-making frameworks.

We also observe several economic development nonprofits, usually in some form of private-public partnership, particularly in Hampton Roads, trying to address flooding and SLR by showing up at the decision and policymaking tables leveraging their influence on elected officials on both state and local levels. For example, it is believed the Hampton Roads Chamber of Commerce had an essential role in the political mobilization in the General Assembly that led to the creation of the Special Assistant to the Governor for Coastal Adaptation and Protection (SACAP) in 2018 as they felt the need for something to be done to combat the ongoing issues of flooding and SLR in their region. Such economic development nonprofits that technically represent several businesses in Hampton Roads also have a concerted effort to bring federal funding into the region as a key to addressing this challenge. Although their priorities are not necessarily related to climate resilience, due to their regional presence in Hampton Roads and closeness to HRPDC, they follow the situation on policies, decisions, and partnerships to some extent.

2.4.4. Most Influential Stakeholders

This section provides an overview of Virginia's most influential stakeholders in coastal adaptation policymaking. To do so, we first summarize the responses to one of our questions in the interviews: "Who are the most influential entities in coastal adaptation policymaking in Virginia?" as shown in Figure 12 and Figure 13. To draw these figures, we divide the stakeholders whose names are mentioned into three groups based on the frequency: The most substantial influence (more than five in frequency), the second high influence (between three & five in frequency), and medium influence (one or two in frequency). Looking at the names in these figures does not come as a surprise as most of the names are mentioned in previous sections of this chapter to be involved in policies, studies, programs, and projects. The highest influence stakeholders are the following:

- Governor
- General Assembly
- Local government
- Hampton Roads Planning District Commission (HRPDC)
- Wetlands Watch and Chesapeake Bay Foundation
- Special Assistant to the Governor for Coastal Adaptation and Protection (SACAP)
- Virginia Institute of Marine Science (VIMS)

After identifying influential stakeholders, we observe why a stakeholder is considered influential and powerful. We summarize the opinions on the role of stakeholders for each group of stakeholders, i.e., four governmental and three nongovernmental groups shaping seven stakeholder groups overall, in Figure 12 and Figure 13.

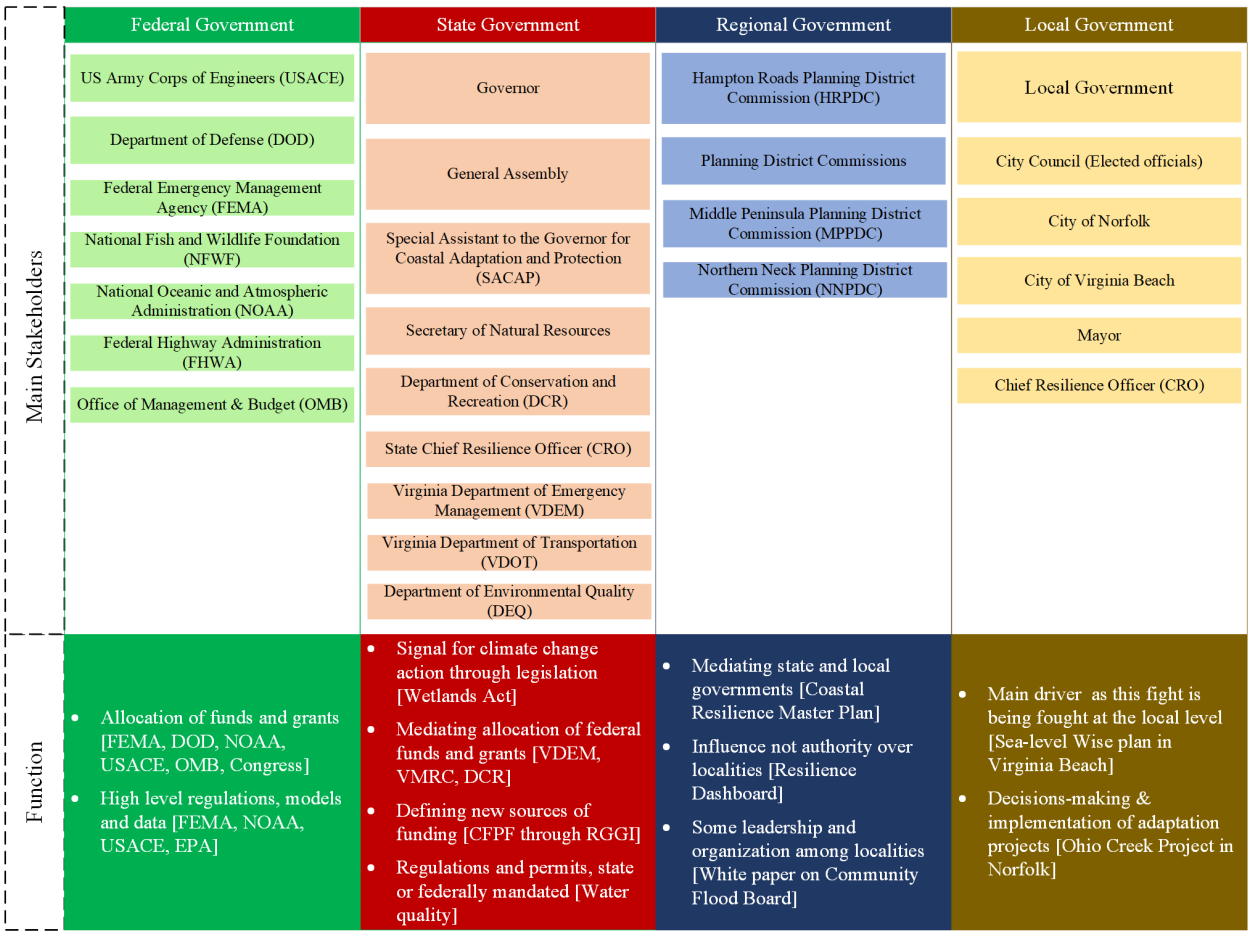

Figure 12. Most influential governmental stakeholders
Bigger rectangle indicates more significant influence

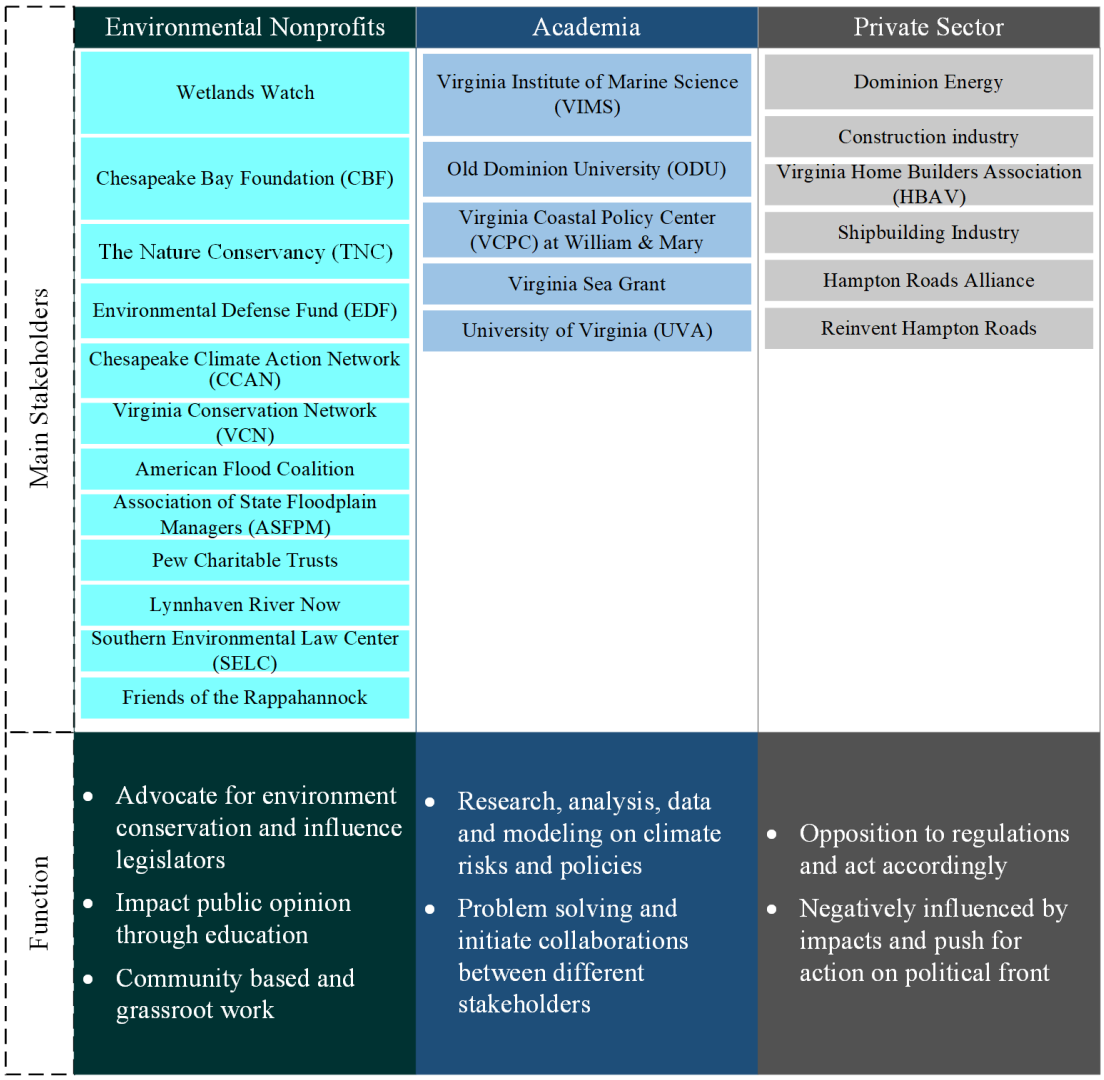

Figure 13. Most influential nongovernmental stakeholders
Bigger rectangle indicates more significant influencer

2.5. Conclusion and Future Research

The main objective of this chapter is to understand what has been happening in adaptation policymaking in Coastal Virginia, as a region with the highest relative SLR on the Atlantic coast of the U.S. More specifically, we have been eager to learn what policies have been introduced and who the major players are in this practice. Our primary data inquiry method has been semi-structured interviews with involved players from different levels of government, primarily local, regional, and state, environmental nonprofits, and academic institutions. We have also read several reports, documents, policies, and legislations along the way to acquire a more accurate understanding of this practice. We took two distinct approaches to analyze our interview data. First, we developed and used a keyword analysis method to understand the perception of climate risks, ongoing policies, main stakeholders, and significant geographies within Coastal Virginia. That provided us with general findings addressing our main research objective. So, from a methodologic perspective regarding the speed of keyword analysis, it shows to be promising for such type of inquiry. This method could be expanded to use sentiment analysis, another natural language processing application, to assess how each stakeholder group thinks about varied aspects of coastal adaptation.

We then shifted gears to our second method, thematic analysis, to obtain a transparent narrative of adaptation policies in Coastal Virginia. This approach confirmed the keyword analysis findings and added to their extent and depth. We summarize the findings in terms of perception of climate impacts, the practice of coastal adaptation policymaking, and the main stakeholders in this practice.

The main climate challenges in Coastal Virginia have been recurrent flooding and SLR. It was initiated by flooding stemming from SLR, and more recently, stormwater or pluvial flooding has become a challenge not only in coastal but also in Virginia. Extreme heat is another climate challenge, but it has not received considerable attention in policy response, as it is not as observable as flooding. The policy areas addressing the climate challenges embrace a wide range from emergency management to economic development.

Attention to climate impacts and the need for addressing them through policy response got momentum in the early 2010s. The practice of coastal adaptation policymaking has been a bottom-up and pixelated process, without any dominant decision-makers, initiated for the most part by localities that were most affected in Hampton Roads, e.g., Norfolk, and then expanding to other parts of the state. The progress and occurred successes have been widely dependent on the particular persons leading this effort within the involved entities, as moving a person from one entity significantly drops the effort and success level. It is also the case that most people in coastal adaptation in Virginia know each other, while they might move from one organization to another, making being known and trusted a requirement for success in planning and policymaking. “Virginia way” is a frequently used phrase highlighting the specifics of policymaking in Virginia that generally indicates some level of working in silos, without concerted communication and collaboration between involved stakeholders, and being conservative in making new decisions on the policymaking front.

There is a vast difference among localities in planning a response to such climate challenges, raising the necessity for state leadership to take some role to indicate a concerted climate adaptation policy framework. The cities of Norfolk and Virginia Beach were identified as the leading localities in climate adaptation due to the extent of planning and projects and the allocation of money to allow the projects to come out of the planning phase. However, several other localities, particularly the smaller and rural ones, have not had the institutional, technical, and financial capacity to plan their response to such climate stressors. There is a

great need for financial resources for adaptation, making it non-affordable for different governance levels. Most localities have been pursuing federal funding resources to address their challenge, but there is an ongoing belief that it cannot be enough, so the state and localities themselves have to allocate new funding for such efforts.

Some regional governments have played a role in synchronizing efforts of their member localities, mostly in standardizing their projections of SLR for the future and maintaining a conversation through which localities can share experiences and collaborate their efforts. Due to their formation, Planning District Commissions do not have authority over localities but can influence them by adding value to the ongoing local efforts. Like the local one, the regional effort is not uniform in Coastal Virginia as HRPDC is known to be the most advanced entity, and some others are behind in planning for adaptation. It is believed, mostly in academia, that regional planning and decision-making are necessary as political boundaries do not bind the threats of water. Such planning could be realized by a continuous dialogue between locally elected officials.

The State of Virginia has tried to address this problem in three administrations, while the most fruitful has been the last one during the Northam administration; this being due to an accumulation of experience, further clarity on the need for action, and particular emphasis from the governor. There have been several policy actions on the state level within the last couple of years trying to address the problem with an intergovernmental approach and allocate some funding to facilitate the process. The future of state-led efforts is unclear. On the one hand, the new governor is not interested in climate mitigation, e.g., opposition to the current carbon cap and trade mechanism but is also not very clear on how invested he is in climate adaptation. On the other hand, with the state having a masterplan and other ideas to institutionalize further the coastal adaptation efforts, e.g., a statewide board to lead the issue centrally, there is demand for furthering the issue, which, accompanied with more apparent impacts of the problem, makes it hard to ignore the issue entirely.

The lack of a comprehensive national-level policy on climate adaptation and the challenges with federal agencies' programs is an ongoing theme. At the same time, there are very recent efforts of the federal government, e.g., Council on Environmental Quality (CEQ), to centrally devise plans and policies for addressing such issues on a national level. Programs of federal agencies vastly affect the decision-making and shape of policies in localities. So, the recent federally initiated efforts and the infrastructure-focused legislations can have a considerable role in this story. Military presence in the state, particularly in Hampton Roads, gives a particular position to DOD for playing a role here. Historically there was hesitation on the DOD side to get more involved and invest outside of their facilities, but there are upcoming changes in the current federal administration paving the way for more involvement in this practice.

This research can go further in several different ways. A natural next step of our research is to analyze challenges and gaps in the practice of coastal adaptation policymaking in Coastal Virginia, which is being done in Chapter 3. It will play an essential role in informing different levels of governance within their future policymaking and planning efforts. It would also be interesting to run a comparative analysis between coastal adaptation practices in Virginia and other coastal states, identify and analyze differences to see if they are converging in certain aspects, and, if not, what is causing their differentiation. The gap analysis can also provide suggestions for research in addressing existing gaps. For example, as the managed retreat is identified as a challenge, building an analytical framework on a regional level in Hampton Roads is a viable and crucial inquiry as several aspects need to be modeled in an interdisciplinary setting.

As stated before, Norfolk and Hampton Roads were our study's focal points. It would be fruitful to focus on certain localities and regions known to be behind and learn about the dynamics of the practice and the substantial challenges they face. This research could also be extended to include federal-level stakeholders to better understand how the national programs are carried out and what stakeholders play significant roles in formulating and implementing federal policies. That could also expand our understanding to other major coastal areas in the United States, e.g., Louisiana, Texas, California, and Florida. Such a research agenda will be instrumental as climate adaptation policies in the US progress and mature in the coming years.

Chapter 3

Gap Analysis of Adaptation Policymaking

A successful climate adaptation policymaking requires a concerted effort among multiple governance levels due to its inherent multidimensionality and complexities. Discovering the challenges and governance gaps can provide insights for the policymakers paving the way for more effective policies in the future. This chapter intends to provide such analysis for Coastal Virginia, a strategic region in the United States receiving significant climate impacts, particularly SLR, and flooding. Utilizing semi-structured interviews with the main governmental and non-governmental stakeholders, we analyze, categorize, and relate the main adaptation challenges to understand the main governance gaps. Intergovernmental coordination and comprehensive planning and prioritization are the main overarching challenges, while the gaps at specific governance levels influence them. It is followed by recommendations for different levels of government informing the path forward from the stakeholders' perspective. A discussion of findings provides several implications for policymakers at the local, state, and federal levels. This research could be extended to other coastal and non-coastal areas to help formulate national and sub-national adaptation policies that maintain a holistic vision for adaptation policymaking while pondering the context-specificities of states, regions, and localities. It would be an essential task as adapting to climate change is still in its infancy stages, with the prospect of staying with us for the decades to come.

3.1. Introduction

The impacts of climate change on the U.S. coastal areas, e.g., rising sea levels, storms and hurricanes, threats to natural and human ecosystems, will intensify within the next several decades (Scavia *et al.*, 2002). Coastal Virginia has one of the highest relative SLR levels in the United States; therefore, there is a need for adaptation policies to address the imminent climate change impacts (Boon, 2012; NOAA, 2022b). It is projected that by 2080, about one million residents of Coastal Virginia will be exposed to major coastal flooding, and about 300K acres of land will become unhabitable due to daily flooding. Extreme climate events also pose a severe risk to the natural and built infrastructure in coastal areas, threatening an area that is responsible for 78% of Virginia's GDP (Commonwealth of Virginia - Office of the Governor, 2021).

Climate adaptation policies and measures vary across regions due to institutional, economic, societal, and cultural differences. As adaptation is known to be context-specific, understanding the specifics of adaptation in Coastal Virginia regarding the variances in governance levels, i.e., local, regional, state, and federal, and their role in the formation of adaptation practices, is crucial for informing the policymakers (Preston, Mustelin and Maloney, 2013; Wilson, 2022). At the same time, there is a need for coordinated and comprehensive planning across different forms and levels of government; however, the current adaptation policymaking seems to be highly fragmented. Our research strives to reveal this fragmentation and address challenges and governance gaps, providing insights for policymakers at different governance levels, ultimately leading to more effective adaptation policymaking (Shi, 2019; Hürlimann *et al.*, 2022). We are not aware of any research that takes this approach to climate adaptation in Coastal Virginia, so we

recognize this as a gap in the literature. Our research aims to address this gap with the following objectives and research questions:

1. To characterize the status of climate adaptation policymaking in Coastal Virginia
    a. Who are the major players in coastal adaptation policymaking, either inside or outside the formal governance levels?
    b. How are the climate risks perceived and addressed by the main stakeholders?
    c. What are the main policies that have been introduced at the local, regional, state, and federal levels?
2. To identify the main challenges and gaps in climate adaptation policymaking in Coastal Virginia
    a. What are the main overarching challenges and gaps specific to each governance level?
    b. How could these gaps influence policies moving forward?

The first objective is addressed in Chapter 2. By answering questions 2. a and 2. b, this chapter contributes to the current literature by identifying adaptation challenges in Coastal Virginia on different governance levels and the interdependence of these challenges. Building upon semi-structured interviews with the main involved stakeholders in the arena of climate adaptation policymaking in Coastal Virginia, the chapter also provides suggestions and guidelines for the future of climate adaptation in the region.

Our review of the related literature identifies four lines of research that attempt to understand climate adaptation challenges. The first strand of literature identifies the barriers and challenges of climate adaptation at the national level, using different methodologies, e.g., interviews, document analysis, and surveys (Biesbroek *et al.*, 2011; Clar, Prutsch and Steurer, 2013; Tangney, 2017; Molenveld, van Buuren and Ellen, 2020; Lee *et al.*, 2021). For instance, Biesbroek et al. (2011) categorize the barriers to development and implementation of climate adaptation strategies into seven clusters and, using a survey of 264 involved individuals in the Netherlands, find the ten highest-ranked barriers to adaptation, e.g., conflicting timescale, conflicting interests of actors, and lack of financial resources (Biesbroek *et al.*, 2011). As a recent example, Lee et al. (2021) identify ten critical barriers to the national adaptation program in England and relates the barriers to highlight broad potential solutions for the future of national adaptation in England (Lee *et al.*, 2021).

Another scholarly thread is centered around climate adaptation practice in the United States to understand the formation of adaptation policies in different states (Bierbaum *et al.*, 2013; Miao, 2019; Rai, 2020; Bromley-Trujillo and Holman, 2021). For example, Bierbaum et al. (2013) use policy document analysis to evaluate climate adaptation practice in the United States and identified the lack of funding, institutional constraints, and climate change anticipation as the most significant barriers; arguing that the way to adaptation advancement through learning is by doing (Bierbaum *et al.*, 2013). Using a quantitative approach, Miao studies the underlying reasons for a state to plan for climate adaptation through logistic regression and finds that experiencing more extreme weather events, economic activity in coastal regions, state income, and civic engagement partially explain the presence of a state adaptation plan (Miao, 2019).

Some articles take a regional approach to understand the barriers to climate adaptation. For example, Mark Lubell studies the governance gap, which is the breach between the problem of SLR and the implementation of adaptation solutions in the San Francisco Bay Area, to understand climate adaptation barriers using qualitative research (Lubell, 2017). He identifies six governance challenges followed by seven

recommended actions to improve adaptive capacity in the near term. Yusuf and John (2017) identify barriers to adaptation readiness in Hampton Roads, through a survey of stakeholders, by asking them about what part of the adaptation cycle they find to be the most challenging in this region (Yusuf and St. John, 2017). They find implementation and development of options the most challenging phases, while funding for adaptation is the most significant barrier to adaptation readiness.

Finally, literature assessing local adaptation and barriers is usually done by comparing particular cities (Baker *et al.*, 2012; Shi, Chu and Debats, 2015; Chen *et al.*, 2016; Woodruff, 2018; Valente and Veloso-Gomes, 2020). Leveraging a survey of climate adaptation planning in 2011, Shi et al. (2015) use logistic regression to predict whether a city has begun to engage in adaptation planning. They find commitment by local officials, municipal expenditure per capita, and perception of climate change to be significantly associated with the cities' engagement in adaptation planning. In another case, Valente and Veloso-Gomes (2020) identify adaptation barriers by reviewing the adaptation projects in several port cities, e.g., Venice, Hamburg, London, Rotterdam, New York, and Tokyo. They identify governance, socio-cultural, financial, political, and communicational barriers highlighting the need for adaptive planning to address them (Valente and Veloso-Gomes, 2020).

As illustrated in the literature review, studies that assess climate adaptation primarily select a governance level, either national, state, regional, or local, and evaluate the adaptation practices using a variety of qualitative and quantitative methodologies. However, it is imperative to include analyses on the relationship between these various governance levels regarding climate adaptation and policymaking to achieve a well-rounded, comprehensive synthesis on this subject matter. We address this gap using content analysis of interviews with the main stakeholders at the local, regional, and state levels in Coastal Virginia. We look at the Commonwealth of Virginia for state governance while supplementing our understanding with regional and local governance perspectives from Hampton Roads and the City of Norfolk.

Our analysis identifies the overarching adaptation challenges and the policy gaps on a multitude of governance levels. We identify the most salient gaps to inform a discussion on the policy implications of our findings. Implementing our approach to other coastal and non-coastal areas can inform local, regional, state, and federal policymakers on their influence, helping them establish adaptation policies. Such practice would be critical in formulating national and sub-national adaptation policies that can address climate impacts with a holistic vision, without the risk of losing specific insights influencing policies on a local, regional, and state basis.

This chapter continues as follows. Section 3.2 elaborates on our methodology, followed by our main findings presented in Section 3.3. We then discuss our findings and their policy implications in Section 3.4; followed by a conclusion and avenues for future research in Section 3.5.

3.2. Methodology

We conducted 42 semi-structured interviews with climate adaptation policymaking stakeholders in Coastal Virginia from August 2021 to January 2022. We initiated our sampling from the decision-makers involved in coastal adaptation in the City of Norfolk, as it has been the locality of interest in our study. Then, we extended our reach to the involved stakeholders in regional and state governments, environmental nonprofits, academia, and economic development nonprofits through the snowball sampling method. We stopped sampling when the following two things occurred: firstly, the answers we were hearing from the interviewees did not add any new information to what we had already collected, and secondly, the

suggestions we were receiving from an interviewee for whom to speak to next were all people and organizations we had already contacted, both of which indicated a saturation point (Guest, Bunce and Johnson, 2006). As Table 2 shows, we contacted 110 people within different stakeholder groups and were able to conduct a total of 42 interviews. We used email addresses, either available online or obtained from other interviewees, for contacting our potential participants and blocked 1.5 hours of their time for the interview. We audio-recorded the interviews, per our IRB-SBS[10] protocol, and transcribed the interviews through an online artificial intelligence platform (*Otter*, 2022). We then reviewed and edited the transcripts that gave us the raw data, in text format, for analysis.

We used thematic analysis through conventional content analysis introduced by Hsieh and Shannon (Hsieh and Shannon, 2005). Thematic analysis is a general qualitative method to extract themes (codes) from data, our data being the interview texts in our study. Coding, the process of extracting codes, was performed through a qualitative and mixed methods platform called "Dedoose" (*Dedoose*, 2022). Each participant responded to interview questions in three segments:

- Who are you? [Participant's role in their organization and organization's objectives and priorities]
- What do you do? [Organizations' programs & projects in climate adaptation, decision-making structure, and collaborations and partnerships]
- How do you evaluate the status quo? [Perspective on climate adaptation practice in Norfolk/ Hampton Roads/ Virginia, important players, barriers, and suggestions for future]

For the coding, we reviewed the responses and specified the parts informing our research questions. For example, most codes addressing the recommendations came from the third segment of interviews. To accomplish thematic analysis, we first reached a preliminary codebook through consensus building after the first two interviews were individually analyzed (Saldaña, 2013; Roberts, Dowell and Nie, 2019). Then, the interviews were individually coded. We modified the codebook two additional times during the coding process as new codes emerged. The final codebook was discussed and translated to the challenges and recommendations, stated in Section 3.3, as the foundation of our findings.

3.3. Findings

This section summarizes our findings in three general categories. First, we present the overarching challenges of coastal adaptation policymaking. Then, we identify and discuss the challenges at each level of governance, i.e., local, regional, state, and federal. Finally, we talk about the recommendations from interviews with the stakeholders.

3.3.1. Overarching Challenges in Coastal Adaptation Policymaking

We have identified eight distinct challenges with the climate adaptation practice in Coastal Virginia, i.e., intergovernmental coordination, comprehensive planning and prioritization, political awareness and incentives, funding sources, social equity, the resilience of natural resources, a controversy around retreat, and conflicts with the private sector, which are believed to be the most significant by the stakeholders. Each challenge is described with supporting quotes from the interviews.

[10] - Institutional Review Board for Social & Behavioral Sciences (IRB-SBS)

3.3.1.1. Intergovernmental Coordination

It is believed that there is no institution or entity in Virginia with a mission dedicated to planning for the climate risks and consistently overseeing various aspects of the situation. It is generally believed that mitigating the impacts of climate change, e.g., SLR, flooding, extreme heat, and drought, require both horizontal coordination (i.e., in one governance level such as a locality) and vertical collaboration between the different layers of governance, and both coordination levels have been missing in this practice. On the local level, the front line of combatting climate impacts, there is little coordination between local departments to ensure the programs and projects are well aligned; this is mainly because various executive units are used to working in silos without a clearly defined way for coordination between them. The same story holds on the state level. Different state agencies have been partially tackling climate risks affecting their scope of work and mission; however, there is no mechanism or entity to mediate them, ensuring that a high-level vision is withheld for the state in this practice. Due to the diverse and significant impacts of climate on health, transportation, natural resources, environmental quality, land conservation, housing, and emergency management, it is necessary to define a coordination protocol that would change this situation. The Coastal Resilience Master Plan and the setting designed to achieve it, the Technical Advisory Committee (TAC), is known to be the only statewide effort attempting to address intergovernmental coordination challenge known as a "good start." However, the state legislature should engrain such a setting in the Code of Virginia to become stable and long-term since climate impacts will remain and even aggravate in the years to come. Table 12 provides some clarifying quotes on this matter.

Table 12. Challenge of intergovernmental coordination

Finding	Supporting Quotes
Lack of institutions to strategically address climate impacts and coordinate adaptation	The depressing fact is that there is no entity within the state that is consistently and effectively focused on climate change issues.
	It [the practice of coastal adaptation policymaking] is disjointed. This [Coastal Resilience Master Plan] is the first time we have ever had some type of process to make a policy. So, that is great. In the last four years, we have made a bigger leap than ever before, and I think, sad for the rest of the coastal community, we have probably made more leaps than a lot of other states. My biggest concern is what is going to happen in the next four years, and how are we going to maintain that momentum forward?
	We have one active this year, which is the Commonwealth Flood Board, that we are going to push for. We have endorsed the idea of setting up a new state structure. They [the state] do not have climate change staff; they do not even really have flood mitigation staff. They have got a couple of people in DCR. Somebody in VDOT is working on this. You have VDEM, who has the FEMA money and those programs. So, it is this real hodgepodge. And we would like to see a different staffing structure and have a different entity that oversees the auction proceeds from RGGI.
Lack of required collaboration in different governance layers	But I just think the reality is that we are working in a space right now where we can have a dialogue. And again, there is much room for improvement. But, while we are probably talking more about Norfolk or the local level, we do need to be effective and driven by a statewide administration conversation. And I think there is some concern that we will need to make sure that the conversation and the leadership stays strong because I think that is a reality that we will need to continue to contend with.
	But when you go and talk about sustainability or resilience in Virginia Beach, you talk to the planning department; you talk to public works; you talk to a whole bunch of different departments. They might be independently doing really great work on it. But there is nobody that's pulling it all together and trying to organize. I think the same thing is happening on the state level, to be quite honest, that there is just not one, somebody that is accepting the fact that they are the head of it.
	Their programs [in the City of Norfolk] are not as integrated. I think everybody is struggling with this. The bigger the city, the more they struggle with it. You have got a resilience office; you have some designing construction efforts going on… We also worked with their floodplain manager, that is working with CRS and understanding, from a planning standpoint, where it floods. Where is the damage going to be? How do we help them? He is a great guy there, but I do not know that he is well integrated with the engineering side.
	But internal to the city, there is still a lot of silos, and we have been working to tear some of that down informally, but we still definitely have a way to go.

3.3.1.2. Comprehensive Planning & Prioritization

We identified a substantial challenge in the comprehensive planning in adaptation policymaking, comprising several aspects, i.e., lack of vision and a comprehensive approach, no agreement on solutions, not embracing all climate risks, and data deficiencies, as shown in Table 13. First, it is believed among several stakeholders that there is still no identification and vision for critical assets, natural and built, even after the Master Plan. Such inventory of assets should be achieved through technical risk assessment and community inputs, pacing the way for a long-term evaluation of options to protect them. Moreover, the local efforts are known to lack long-term thinking and planning, mainly due to their deep involvement with the challenges of day-to-day problems, leaving them with not much capacity and time to address long-term planning. In our observation, this emphasis on a long-term approach primarily comes from the environmental community and academia, encouraging the stakeholders involved with execution, i.e., local and regional governments, to extend their time horizon for making executive decisions.

In contrast to general agreement on challenges of flooding and SLR in different areas, there are several instances of disagreement on solutions that best address those challenges. For example, while some regional and local stakeholders in rural areas are trying to save the properties at risk for flooding, others believe that poses severe consequences for water quality, health, and aquaculture. It is also the case that some planned projects are perceived to be addressing only one aspect of climate risk without due consideration of others. Even at a considerable financial cost, if such unilateral projects are implemented, they will not solve the multifaceted climate problem. The argument against such projects stems from the scarcity of funding sources advocating for long-term thinking in planning, whereas the time horizon on the affected localities is practically shorter as they are trying to solve their most pressing problems.

Availability and sufficiency of data is another piece of the overarching gap in comprehensive planning in different ways. First, the deficiency of climate risk data and models impedes the effective identification of vulnerable areas in the planning process, which usually requires high-resolution data. For example, several areas of the state still do not have an appropriate hydrodynamic model to assess pluvial flooding, making any planning effort inadequate. Besides, accurate data on the projection of climate risks paves the way for greater attention in the affected localities, which are not proactively addressing such risks. For instance, showing how many buildings are going to regularly flood at a certain point in the future, as the output of the Master Plan, has been eye-opening to certain rural localities. Finally, a lack of modeling and data on social and natural characteristics of vulnerability limits the conversation across a wide range of stakeholders with different priorities, preventing them from finding common ground, which is necessary for effective solutions.

Table 13. Challenge of comprehensive planning & prioritization

Finding	Supporting Quotes
Lack of vision and prioritization	We need to improve our impacts and look at critical sectors, not just critical assets. So, we need to understand the criticality of individual assets. That is a significant undertaking. The only way we will get to that is by understanding what is an asset to a locality and then rolling that up to the state of those locally important assets. What is important to the region, and then what is important to the state to know what is most at risk, and we need to improve our hazard by getting more of the total flood picture.
	I think there should be some state guidance. I think that you have to decide. We cannot protect everything. We just cannot protect everything. We can protect some things for some amount of time. Shouldn't we protect the things that will have the greatest return on investment to the Commonwealth? That gets back to your equity question? How does equity play into which projects should move forward and which ones should not move forward? And I think that is an important question.

Finding	Supporting Quotes
	If you do not have a plan, it is really hard to get funding to build something, or you will build something that is not integrated within a plan. Thus, it is ad hoc, likely not the most efficient kind of investment, right? That is what I plan to do is tee up priorities, whether that is on flood risk mitigation from the narrowest sense to community resilience at the broadest sense. If there is not a plan, then it is just ad hoc. And we know what ad hoc investments are inefficient.
Lack of long-term and comprehensive approach in planning	As you get to those points, you can begin to talk to localities about life cycle costing, and about this investment looks really attractive now, but what is it going to look like in 20 years, when the access road gets flooded, and you have got to spend half a million dollars fixing a road for five houses? We are not there yet because the money in the present is real, and the money in the future is, you know, ephemeral made up.
	The City of Norfolk is the only city with a vision 2100 plan. They lay that out there, and people can go and look and see what is going to happen to their community. But I wonder how many people in Hampton Roads have even seen that plan.
No agreement on solutions	I mean, we want to wave a magic wand and have the right solutions implemented, but they have not been developed yet. And they are not necessarily easy to pull together.
	From the broader state level, it seems that the Middle Peninsula Planning District Commission and their representatives are actually proposing solutions that are very problematic for water quality. So, while we complain that many in Hampton Roads are not doing things that optimize and protect resources, I think they are probably on the far extreme. For example, they will say, let us fill wetlands so people can keep their yards from rising seas.
No embracing of all climate risks in planning	They have not really embraced climate change. I think climate change in terms of SLR, precipitation, and temperature are big drivers, and I think they are starting to recognize it. But if you look around the state agencies and say, who is working on these issues? Who is tracking the science? Who is trying to make the best use of funding to address these concerns? You would feel, wow, that is a list of names that's a little disorganized, not like a vision or an organized vision. I would say that is probably holding us back. It is kind of fun to be trying to break new grounds, but at the same time, it would probably be easier if we were just saying, let us help you do what the state is leading.
	Resilience is much more than flooding, and then much more in Virginia than flooding. So, what does the state really want to do here? It is going to have to decide.
Data deficiencies impede comprehensive planning	we do not have a model that could tell us where we have deficiencies in our stormwater system capacity. Some of the other regions around the country have models that can show where it is flooded. We can do that in terms of SLR and storm surge; the water is flowing over, it is like a bathtub model; it compares the water level to the land elevation, but stormwater capacity is different. You need to know exactly how big your pipe is, the slope of the pipe, and outfall elevation. We can only do the work that we have the data for. We just keep chipping away at that and talking to localities about whether you all want to do this together. Is everybody working on this? Don't you want to hear about what Virginia Beach or Portsmouth or somebody else is doing so that you can see what you get out of this kind of study?
	We have found that census tract data has been difficult for our community to use because our community has pockets of poverty and needs that do not fit neatly within a census tract but are scattered throughout the community. And it makes the census tract at that aggregate level very difficult to use for a lot of the needs that most communities might traditionally use census tracts for.

3.3.1.3. Political Awareness and Incentives

It is generally believed that the slow and long-term nature of climate impacts, such as SLR, prevents climate issues from receiving the attention they deserve from the public. The absence of high-impact natural hazards in Virginia is considered another factor that precludes attention from the public and politicians. At both the local and state level, politicians are generally known to be inattentive to climate impact policymaking; considering the short-term political cycle, they do not have much incentive to bring such issues to the top of their agenda. The lack of incentive also results from the unpopular message a local elected official would send if they raised climate risk in their narrative and asked for increased taxing to address them. As adaptation decision-making is expected to be primarily local, this challenge is highly emphasized for local elected officials rather than the lawmakers in the General Assembly. On the local level, most changes and efforts in local government are made through agency staff rather than elected officials. The staff generally

have a higher awareness of climate risks from the agency perspective since they have been serving longer than the elected officials and have more experience with the outcomes of climate risk, such as increasing stormwater problems, flooding of septic systems, transportation, and infrastructure issues. Most of the connections and collaborations of a locality with external stakeholders, e.g., environmental NGOs and academia, are established through their executive staff becoming more involved with the knowledge and practices of climate adaptation around the state and the nation (Table 14).

Table 14. Challenge of political awareness and incentives

Finding	Supporting Quotes
Lack of observed severity hinders a call for action	In emergency management, they say you want to take advantage of a good disaster. That is what a lot of places have done. They have hurricanes that have done a huge amount of damage. The North Carolina riverine flooding just wipes things out when the water floods. They say, oh, we need to figure out how to build back smart. That does not happen in Virginia. First of all, we have not been hit by much. But when we do, it tends to be the water came in and got your drywall wet, and then it went away. It did not wipe houses off the ground. It does not create the same call to action. If you want somebody to move, that is different. "My house is destroyed" is a different scenario; "it was scary, and a life-changing event" versus "it smelled awful for a few days because it was wet."
	Louisiana and Texas are doing very well because of their risk. Nothing focuses attention like floods or storms. Storms get people's focus, and that is what Texas and Louisiana have been doing for the last number of years just because they have had so many floods. You have the government focused on that and trying to be proactive. Vis-à-vis that in Virginia, I think it was an admirable effort to get Virginia to be proactive. I wonder where that is going now.
Lack of awareness and incentive in politicians and elected officials play an essential role	There are city staff, or locality staff, that want to make a difference but might be constrained by political powers. Political directives obviously dominate, and you cannot go against what the people in power and authority want. So, we have seen that to be the case. But basically, I think that there are communities where a local government staff person can just run with it if they have good ideas and want to propose alternative solutions. If there is a supportive political environment, then those people are typically let loose, and they can run wild with their ideas.
	We have made good progress up to a point. Two issues are really important here: this is not a tomorrow problem and the price tag. If you are going to do something as a political leader, as a politician, it is really expensive. The propensity to push it down the road is really powerful. Nobody likes to have their taxes raised, or whatever the mechanism is, nobody likes that. So, if it is not a problem that is going to bite me tomorrow, I tend to push this down the road, particularly when it is really expensive.
	We often ask them [the state legislators] to make courageous decisions; we ask them to make these key environmental policy choices. But sometimes, we do not make sure that they have the support of enough people within their community to make these steps and say, yes, this is not only the right decision, but this is the decision that my constituents want me to make for their benefit.

3.3.1.4. Funding Sources

Funding as a challenge came up in our interviews more than any other point, regardless of which stakeholder group the interviewee belonged to, shown in Table 15. There is no definite funding required to address coastal adaptation in Virginia since there has not been any comprehensive planning with a holistic perspective on the matter. Virginia Beach's adaptation strategy, Sea Level Wise, introduced projects whose costs add up to three billion dollars. Norfolk's study, done by the Army Corps of Engineers, introduced $1.4 billion worth of projects, which are believed not to consider the pluvial flooding (USACE, 2018). The Master Plan, published December 2021, intentionally does not provide a final number on the cost of resilience projects inventory since they are aware of the lack of a comprehensive inventory; however, it is estimated to be between 5-10 billion dollars. Wetlands Watch, an NGO, estimates the flooding projects of Coastal Virginia to be at $40 billion, without considering ongoing stormwater projects, private property, business expenses, and federal installations in this area (Wetlands Watch, 2021a).

Knowing adaptation will be costly, there is an ongoing debate on who should pay for it. Local and regional governments, which claim to lack the capacity to increase taxes, believe it should be paid by federal dollars

supplemented with state funding. It has been a massive expectation of localities from the state to supplement financial resources to help them in this matter. The state has attempted to introduce federal sources as possibilities, e.g., in the Master Plan, while not allocating extensive State money to adaptation. The most significant initiative has been the Community Flood Preparedness Fund (CFPF), sourced from the carbon auctions proceedings of RGGI[11], which Virginia joined in 2021. CFPF can potentially bring an annual $100 million, not comparable to the required funding mentioned earlier (Eghdami *et al.*, 2022a). On the federal level, the Army Corps and FEMA have been the primary sources of funding, while both are perceived insufficient, taking decades to afford the required investments in adaptation (Wetlands Watch, 2014, 2021a).

Table 15. Challenge of funding sources

Finding	Supporting Quotes
Critical need for funding and no agreement on who should pay	We need so much money, just globs of money. We need money at the local level; we need money everywhere.
	The problem is, how in the world are we going to pay for this? It is going to be God-awful expensive to do whatever needs to be done. A rough order of estimate, done, I want to say two to four years ago for just the City of Norfolk, was about a billion dollars. That is only one city. There are many cities, and they do not touch the water. So, where are we going to come up with that money? If you ask local political leaders, they will say, "it is the state." If you ask the state, they say, "it is the feds." If you ask the feds, they will say, "we do not know." It is just going to get worse.
	A lot of the adaptation efforts, either outline, in-place, or planned, we just do not have the money to implement any of them, both green infrastructure and gray infrastructure.
Insufficiency of funding at local & state levels	The General Assembly members are patting themselves on the back because we adopted RGGI, that Regional Greenhouse Gas Initiative. Those funds are estimated to be between $50 and $80 million a year for flooding. Now, one project in my neighborhood is $75 million. That is how much money they have in the CFPF for the entire state.
	I do not know how familiar you are with their finances and fiscal constraints, but Norfolk has a high tax rate. Then a high tax burden on the residents. They do not have that latitude to probably put the 10 or 15 cents on top of the real estate tax rate to cover for bond issuances like they should.

3.3.1.5. Social Equity & Underserved Communities

Underserved and socioeconomically vulnerable communities are at a significant disadvantage in climate adaptation. Most importantly, they have lower individual capacities to combat the impacts of climate change, which are in addition to their already present socio-economic challenges. Although there is a significant acknowledgment of this problem between stakeholder groups, particularly highlighted in NGOs and academia, the problem has not been practically addressed in adaptation policymaking for various reasons. For example, there is criticism on the Master Plan for insufficient engagement with such communities, while the leading team believes that this matter should be addressed more effectively in the future phases of the Master Plan. To get the engagement of the socioeconomically vulnerable requires building a relationship of trust, which can be recognized in a long-term continuous process rather than a one-shot event for a specific project (Table 16). We should also mention that there are recent efforts in governance levels to address diversity, equity, and inclusion in light of the national movement started in 2020; however, there is a long way to accomplish equitable policies in a diverse and inclusive manner.

[11] - Regional Greenhouse Gas Initiative (RGGI)

Table 16. Challenge of social equity & underserved communities

Finding	Supporting Quotes
Social equity is a significant challenge	There has been a huge reckoning in the environmental community in our failure to reach out to diverse communities, to impacted communities, and to understand the field as the broader social and racial justice movements have been occurring across industries... But the environmental justice movement has been a major component of that, not only because we realize the disproportion of impacts of climate change will be felt by these communities, but because we are realizing how important these communities are in leading and advancing this change and having it authentically be helpful. It is not only a political imperative, but it is a policy best practice and just a moral imperative.
Challenges in the involvement of underserved communities in decision-making	That is the big issue to outreach to lower-income communities. That is a big issue that we are fighting right now in Virginia. In 2020, Virginia joined the RGGI, which generates 10s of millions of dollars. In the legislation joining RGGI, they created a state flood fund called the Community Flood Preparedness Fund. They set aside 25% of the money in that legislation and said it must go to low-income geographic areas. So, we have been trying to get those low-income geographic areas engaged in the process at the local and state level, arguing for their needs within the context of this program. Because for the first time, these communities come to the table with a fistful of money, because you cannot get 25% of that x million dollars unless I, resident of low-income geographic area, am on board.
	You have to form relationships, be an ally, sit in the back, and listen for six months before you talk and before people trust you. That literally takes years of work. It takes years of work to have authentic grassroots relationships and volunteers, and I have only been here two years. We are not there yet.
	The nature of many of our boards and commissions is older residents, and it is not as diverse or inclusive as I would like it to be. But there is also a lot to be said about who has the time, the opportunity, and the willingness to talk about specific issues.

3.3.1.6. Resilience of Natural Resources and Environment

There is an ongoing debate on prioritizing natural resources and nature-based solutions in adaptation projects and programs (Table 17). The concern about the resilience of natural resources, e.g., wetlands, living shorelines, natural habitats, and fisheries, primarily stems from environmental nonprofits, academia, and state agencies whose mission involves protecting the natural environment. There has been some success in state legislation supporting nature-based solutions, e.g., making living shorelines the default option for shoreline management in 2020. However, there is still concern that conserving natural resources is not often prioritized in adaptation planning because protecting the already-built infrastructure, such as buildings, receives precedence in cost-benefit analysis. On the other hand, local governments and engineering designs such as the Army Corps' solutions usually argue for the necessity of sustainable designs if we want to protect our communities. This argument relates this challenge to the issue of "Retreat" to be discussed next.

Table 17. Challenge of resilience of natural resources & environment

Finding	Supporting Quotes
Resilience of natural resources is a crucial aspect of resilience	In the coastal adaptation world, I tend to see a lot more discussions about buildings and communities, and I am not saying that is bad, but there is not much conversation about resilience and adaptation of the resource itself. It tends to get lost in the conversation. So, I think we need to realize that the resilience of our natural resources is just as important as the resilience of our communities. In order to have a resilient community, you have to have resilient natural resources.
	There is no accounting for ecosystem services, or really, ecosystems generally are not given any kind of parity with gray infrastructure and the project prioritization list. So, even though wetlands play an essential role in helping to mitigate water inundation in communities, the plan [Master Plan] does not really reflect that. So, there is no priority to allow that ecosystem to migrate over time. In its current iteration, we have concerns that we are endangering some of these ecosystems that are necessary for long-term nature-based resilience.

Finding	Supporting Quotes
Natural resources do not receive enough attention in this practice	Typically, people who want to develop, especially if it requires a zoning change, come before the commission. A couple of new projects are coming up in Norfolk that has not been sorted out, but we have had some preliminary discussions. In one particular proposal that everyone is excited about, I see a lot of concrete and asphalt. I say, "show me something green." We have a problem with flooding. We have got to displace this water somehow. Tell me, "do you have cisterns? Do you have permeable pavers?"
	The hard part is how do we balance making sure they all stay protected while making sure we have clean water, healthy fish, and all of that. If you see some of the Corps of Engineers' plans that have come out, it is tidal gates across most of our significant tributaries and all of that. And that is all scary to me.

3.3.1.7. Retreat as a Controversial Issue

Retreat, sometimes known as a forbidden "R" word in localities, is subject to a deep controversy among the stakeholders, as shown in Table 18. Retreat from certain areas is believed to be inevitable by environmental nonprofits, academia, and state agencies, as protecting every area is deemed infeasible due to financial and environmental considerations. So, they assert the need to initiate a conversation around the managed retreat. For example, Governor Northam, as the state champion on coastal adaptation, writes about this need in his letter at the beginning of the Coastal Resilience Master Plan (Commonwealth of Virginia - Office of the Governor, 2021). On the locality side, there are several concerns over retreat. First, it threatens their fiscal stability, as retreat would decrease property taxes, which is the main revenue category in the local government. This problem is more pronounced for smaller and rural localities, as sometimes a strip of expensive housing along the water shapes most of the local government's revenue.

Moreover, acquisition and demolition of property, accompanied by the need for maintaining the land in the future, is considerably costly for a locality. It is also politically not appealing for a local government to announce they cannot save certain communities, and the only option is relocation. The only long-term plan for the retreat that we observed was the Norfolk Vision 2100, which associates parts of the city with "Yellow," as the areas with high climate risks and low critical assets, as potential retreat areas (City of Norfolk, 2016). Although Vision 2100 does not mention retreat and does not clearly define the "Yellow" borders, it is known to be the long-term thinking necessary for localities.

Table 18. Challenge of controversy on retreat

Finding	Supporting Quotes
Need to think and plan for retreat	As we talked about a retreat policy three to five years ago, it was futile, even though we knew it was what we wanted. But now, it has become apparent, because the impacts are so evident, that localities are going, "oh, my gosh, it is bad." Now, it will be even worse in 10 years, isn't it?
	They [localities] do not like that the state is going to develop a retreat manual. Some localities refuse even to acknowledge that a retreat manual is being adopted or developed. That is, to me, short-sighted; it is probably the nicest way I can put it, but it borders on reckless for the communities when you just stick your head in the sand on some of these critical questions... You need to think about the retreat. Those are tough things, and having the state tell localities takes some of the pressure off of them. So, I am very concerned about this strong push to reverse that order. Because I think it will lead to long-term consequences.
Strong opposition to retreat from localities	It [Coastal Resilience Master Plan Framework] talked about a relocation handbook. We talked to them [localities in Hampton Roads], and nobody wanted that. They said, "we are not ready for that. The state is going to write a relocation handbook?! We are not relocating people. That has not turned the corner and become a concept that many people who are in flood-prone areas are comfortable with."

3.3.1.8. Private Sector

Coastal adaptation is perceived to potentially conflict with economic development and private practice because they follow two different time horizons (Table 19). Adaptation planning involves long-term thinking, suggesting actions that are considered optimum in the long run, whereas in some segments of the private sector, real estate, for example, focuses on short-term profits. This fundamental difference can represent itself in different conflicts. For example, we heard stories of real estate associations lobbying against specific building codes and materials introduced to increase resilience because they increase building costs, negatively affecting their market. This conflict is mainly perceived as significant as the private sector is known to have the ability to influence political decisions on all governance levels.

Table 19. Challenge of private sector

Finding	Supporting Quotes
Economic development and resilience can be in conflict	Institutionally, I think there is always a conflict between the environmental community and development. When you have people saying, "I want you to widen my road to develop my community," and things like that, I can talk about the strange economic impacts of putting in this infrastructure and how it does not make sense or how it is terrible for climate, how it is bad for flooding, it is all seen as an obstructionist when you are trying to solve a housing crisis. It is very frustrating. There is familiarity with things like the environmental review process for site plan approval. It is seen as regulatorily burdensome, where in many ways we say, "you should be taking these things into consideration because the long-term lifecycle impacts of these choices are not going to be good."
Conflicts with the private sector	The harder challenges are with the real estate industry, especially in the private sector. In the real estate industry, the time horizon is to the point of sale. A real estate agent makes their money at the point of sale; they could not care less what happens in 20 years, generally speaking, because their money is when the contract closes, and "I get my 6% off the sale of this house." So, they necessarily have a shorter-term focus. I think we have difficulties with many people in the development community, and we are still trying to figure out how to get involved with them.
	The finance and banking community the same way, you know, at their national meetings, they talk about the need for resilience, but they still finance a house that's going to go underwater in 30 years, and not blink at it at all.
	Norfolk has three feet of freeboard that they passed locally. I think Chesapeake has 18 inches. Virginia Beach, I think we got to two feet. I do not think we ever got the third foot because the Tidewater Builders Association blocked that at the city council level. So, those builder associations have a huge state lobby. So, that is something that I do not believe the General Assembly would touch with a 10-foot pole to a minimum freeboard, which we need in flood-prone areas.

3.3.2. Challenges at Different Governance Levels

This section identifies the challenges specific to each governance level, i.e., local, regional, state, and federal.

3.3.2.1. Local Government

We identify three main challenges at the local government level: limited capacity, hesitance toward upper-level planning, and limited authority, as shown in Table 20. Limited capacity, most observable in small and rural areas, was the most highlighted challenge for local governments. This is addressed through limited staff, unfilled positions, lack of technical capability, and financial limitations, which put the smaller localities at a significant disadvantage compared to bigger cities like Virginia Beach and Norfolk. The state is expected to address this gap and provide a level playing field for all the localities. CFPF claims to consider this within its grant application process by conferring capacity building and planning awards.

There were also several remarks on the hesitance of local governments to regional and state planning, as they consider such planning efforts to hinder their autonomy. This is particularly challenging because effective intergovernmental coordination requires planning efforts beyond one governance level. So, as the

localities do not want to be told what to do, financial incentives are known to encourage localities for such planning efforts. For example, it is believed that localities would have better participation in the Master Plan process if it were tied to the CFPF grants.

Some stakeholders discussed that as Virginia is a Dillon Rule state, local governments are cautious in introducing new measures and policies for coastal adaptation, with the fear of that policy being challenged by the state. Under the Dillon Rule, local governments only have powers that are expressly granted by the State. This limitation makes local governments look to other localities as a checkpoint to see if similar policies have been introduced or not. Then, if it has not been introduced elsewhere, they would need further contemplation prior to introducing their policy, and this acts as a barrier to new policies being introduced at the level of the local government, ultimately impacting progress and change.

Table 20. Challenges at local government

Finding	Supporting Quotes
Limited capacity, particularly in smaller and rural areas	Remember that we have this extensive range; Virginia Beach can afford to do almost any project themselves; Gloucester or Poquoson is so much smaller. They do not usually have the staff even to manage that contract if they have the money. It is tough. It is a small shop in comparison.
	We know that smaller communities have those types of community projects that they need to do. But they do not have the expertise to build a good grant application. Just as an example, the last application, with the supporting paperwork we sent in for raising six houses, was 400 pages. A small community is not going to waste their time. The amount of documentation required for FEMA is a burden. And then having the expertise in order to build those applications is definitely a challenge.
	Rural areas are significantly disadvantaged in the game as it is being played right now. So, we are just now trying to figure out how to step into some of these rural areas and help develop capacity.
Hesitance toward upper-level planning	Because nobody wants to be told what to do; Virginia Beach does not want the City of Norfolk telling them what to do. The cities like their autonomy. They have different tax bases, they have different funding capabilities, and they are not willing to give up that autonomy.
	On the flip side, localities have been really dismissive of the master plan process because it is not formally tied to the fund [Community Flood Preparedness Fund]. They do not care if the Master Plan process goes away… Some PDCs even refused to submit their projects for prioritization, a very dismissive approach to that. And, not surprisingly, money is the thing that moves people.
	They will listen to him [an individual from the state government] if he comes in and says, hey, this is a huge problem, and these are the resources that the state is putting together to help you. Because unless he is bringing a checkbook, it is a local and state; it is one side and the other side. Because they will perceive it as the state coming down to ask one more thing they have to do, with no money behind it. So, for climate adaptation to go forward productively in our state, it has to be the whole package. It has to be funding for projects. It has to be resources to develop projects, and it has to be an overarching goal.
	We are wondering, at what point do we [City of Norfolk], as a major stakeholder in the state, get asked to participate? Maybe we are not on the TAC because they are helping to form a policy document that communities will use for funding, possibly. But there are also things like a push to develop a Commonwealth Flood Board. We wonder if it will be made up of all academics and no community stakeholders. We hope to have more of an influence on how some of these boards, commissions, and TACs are structured at some point.
Limited authority in local government	For Virginia, because the localities cannot act without the state legislature behind them, that is definitely a constraint. We are dependent on our state legislator to act and set up the policy framework under which we can then take action. I think that is key for us here. And I think that has been a source of frustration locally and regionally.
	The Dillon Rule is not a problem for the big cities because they use public safety and welfare and use police powers to overcome that. They are not afraid of challenges because they have money and scary attorneys. Rural communities are like, “oh, no, the Dillon Rule.” They freak out because they do not have a lot of the same support.
	So, it is the cities that have the authority. Then there is much talk about the Commonwealth being a Dillon Rule state where cities can only do and take action in areas where they have been granted to do by the state. In some ways, cities hide behind that not to take action. I think it does have an impact. So, I think the state also obviously, is a decision-maker.

3.3.2.2. Regional Government

We identified the absence of planning and decision-making on a regional level (Table 21) as a central gap. We have heard this narrative from several stakeholders, primarily nonprofits, academia, and even local government; arguing for the necessity of regional planning, as the water does not know political boundaries, and the benefits of planning regionally, e.g., more options, higher bargaining power for attaining federal financial resources, and sharing technical resources and expertise. The Little Creek Watershed is an example of the necessity of having a regional approach in planning, as storm surges in the watershed make Virginia Beach, Norfolk, and the Naval base flood. However, the Army Corps' study design in Norfolk only included surge barriers to protect Norfolk, but it could protect all three if there were a regional approach.

Table 21. Challenges at regional government

Finding	Supporting Quotes
Lack of regional planning	There has been a vacuum of regional leadership. That is the area I have focused on because I think, particularly flooding, does not know geopolitical boundaries. A floodplain does not just exist in one city or another. And so, to address flooding, we have to be looking at it on a regional basis, just as we do transportation.
	Each city has its own culture, politics, priorities, and vision. There is no common understanding across the whole region, except at the manager or mayor level through our regional Planning District Commission or even the Transportation Planning Organization. Through that effort, at least there is some knowledge sharing. But it is not necessarily a shared work plan that then comes back to the cities. You are responsible for your own stuff and your own city, and responding to your citizens and the culture and the politics of that.
	I like to say is no elected official gets elected to represent the region. That is a tricky dynamic. I was on a City Council years ago. In some ways, you are almost punished by the electorate for having that regional view.
	I think regional planning is really necessary across the board. The idea that your locality is going to develop a plan for the water that has no jurisdictional boundaries, and do so in a way that does not negatively impact another, or by internalizing all of the impacts from flooding to your city and not looking at potential regional collaboration, you are just going to get worse outcomes. Thinking across jurisdictional boundaries gives the localities more options for what they can do. It gives them the ability to leverage and share resources and get efficiencies of scale. If they are going to pull resources, it gives them more leverage when looking at federal resources. There are a lot of pragmatic reasons. And then there are just the scientific reasons for the fact that the rising waters do not care that you are the City of Norfolk; that sort of thing is irrelevant to water.

3.3.2.3. State Government

The main identified gaps at the state level are the absence of leadership and the challenge of policy continuity, as shown in Table 22. The stakeholders expect the state to be a leader in climate adaptation by providing vision, standards, and resources for local governments; however, as it had not happened until recently under the Governor Northam administration, the state is known to lack this leadership. It is also believed that the recent efforts have not been codified, and the next administration can quickly roll back the achievements by discontinuing the Master Plan process and RGGI participation, which is the primary source of state funding for climate adaptation. Lack of leadership and progressive adaptation policymaking is also observable in the legislative branch of the state, General Assembly, except for a few bills within recent years, e.g., permitting the governor to join RGGI and modifications in Chesapeake Bay Preservation and Tidal Wetlands Acts to include climate change.

Table 22. Challenges at state government

Finding	Supporting Quotes
Absence of leadership	We have had multiple sorts of false starts. The most recent, of course, would be the legislative committee that's overseeing the CCRFR. They are notable for their inability to do anything, and they have no sense of a mission.

Finding	Supporting Quotes
	The state has not been a very strong leader in resiliency. They know that. Maybe Virginia is catching up. I do not know. There has certainly been a lot going on in the last two years. But it has not shaken out yet in terms of structure and funding.
	Finding state representatives, state delegates, and senators that know what is going on is a barrier. It has been very hard to find champions for a lot of our legislation because it is a complicated field, there are many players, and you have to spend much time getting up to speed.
	If we are talking about climate adaptation, it is more about providing guidance and support to the localities than sending us your projects, and we will see if we fund it... If you are going to address climate adaptation, you have to address it as a whole. That means providing technical assistance; that means having engineers and hydrologists available to a community to see what type of project they could do to fix this or that. I think it is excellent to say, "Hey, give us a project, and we will see if we can fund it." But what about the people who cannot put a project together that will completely wipe a particular area away if they do not fix it? I think there is a balance there. Yes, funding is important. But if they cannot even put a project together, you are missing a whole swath of the Commonwealth of Virginia.
Challenge of policy continuity	We are taking great steps forward [creation of Coastal Resilience Master Plan]. But the big test is the support for the continued effort. It is not a report; it is not a project with a defined start and end. It is a process; it is a program; it has to continue and evolve. What we have done so far has been great. Much work, especially in the short duration. The true measure is what we will be able to continue to do, whether it will be successful or not.
	I would describe the Northam administration as being all-in on this topic. I think they did as much in four years as they could have. Well, this was not universally accepted. I think the General Assembly was not willing to write big checks for this, at least not quite yet. But I think he did as much as they could have done. So, it is just this good if as actively embraced by the Youngkin [new governor] administration as Northam. Let us see. I mean, he has made some pretty clear public comments so far on education, taxation, and several other topics. I have just heard nothing on this topic.
	The way Master Plan ultimately evolved, there is nothing in what is done that would commit anybody in state government to a sustained effort... It is not a plan; it is not a strategy; it is a list of projects and a funding source. While it was passed with bipartisan support, the first thing the incoming governor announces he wants to undo the RGGI. That is the funding source for the Master Plan and Community Flood Preparedness Fund. So that goes away, we are back at square one.
	The only way we will get it done is to have a governor come in who is onboard and committed from the very beginning of their term because you have only got three years to do anything in Virginia. Alternatively, we get a cadre of legislators that are interested and motivating. We used to have a group of bipartisan guys who were environmentally conscious and would do big things. That is how we got the Chesapeake Bay Preservation Act; we got the Tidal and Nontidal Wetlands Acts. But there is literally nobody in the General Assembly that when we think about environmental legislation and somebody to carry it, or some group to support it, there is nobody that jumps to mind now.

3.3.2.4. Federal Government

Although the stakeholders mainly addressed gaps and challenges in governance levels up to the state level, we identified two main gaps at the federal level: measurement and prioritization of problems and the need for military engagement and investment, as shown in Table 23. The first gap addresses how measurement policies guiding federal funding and grant programs, e.g., FEMA and Army Corps, prevent the initiation of equitable and efficient projects by having an old, narrowly defined definition for the benefits of a project. The second gap reflects on the significant presence of military installations in Virginia, particularly in Hampton Roads, arguing that DOD has to allocate specific financial sources to combat flooding in the areas surrounding military installations. For instance, it is argued that if the roads to an installation are flooded, it will hinder the readiness mission of the military, so they have to consider the surrounding areas. This argument has been the basis for a couple of Joint Land Use Studies (JLUS) performed in Hampton Roads (Eghdami *et al.*, 2022a). However, it is an incomplete discussion between regional and state authorities and the DOD to provide federal financial sources to design and implement resilience projects derived from the JLUS studies.

Table 23. Challenges at federal level

Finding	Supporting Quotes
Measurement and prioritization of federal programs impede efficiency and equity	Again, it is really complex, but the benefit-cost analysis, the primary federal measure that governs how alternatives are assessed and prioritized, will not quantify certain benefits. We know those benefits are quantifiable and monetizable; it just does not allow it. That is a huge missed opportunity and a significant need to fix. We need to get that right. I cannot say strongly enough how much we are missing in designing multiple benefit projects because the BCA [Benefit-Cost Analysis] processes were written 40 years ago, and we did not have the computing power that we have now; the knowledge to quantify those benefits, place them in a policy consideration and then value them. They are doing it in the international community, the World Bank, and the IDB; they are doing this elsewhere. You tell me, we cannot do it in the United States. Are we not smart enough to do this? Come on. There are ways to do this. The Brits are doing this. The Australians are doing this, and the Dutch are doing this.
	What has been widely missing in all of this, which is now ten years for me, is the federal government's proactive investment in adaptation. FEMA touted itself... They still policy-wise have not shifted to a proactive pre-storm investment on a major scale. That is what leaves core urban cities like Norfolk, Portsmouth, Hampton, and Newport News so vulnerable.
	There are always difficulties working with the feds, but one of the main challenges is how different agencies evaluate these projects. So, HUD [Department of Housing and Urban Development] lets you count the benefits of social and environmental justice and all that, but, as an example, Army Corps, all you will consider is direct physical damage. Did this house get wet? Did that car get wet? And so, the low-income public housing communities that we have, which are significant in Norfolk, lose on that equation.
There is a need for further military engagement & investment	I hope we could graduate where defense dollars could be given latitude for participation in that infrastructure investment. You have defense appropriations that are necessary for the operations of the base and in supporting the services. Then, there is only a small program for something that might be off-site... The installation fund should have the ability to work collaboratively and invest in that... It is better, at least conversation and understanding wise, now in 2021, than it was ten years ago when it was "we will take care of ourselves, we are going to put a wall around our base." But thankfully, because of a couple of Joint Land Use Studies, we have at least got the conversation and understanding going. I still do not think they have entirely evolved, though; how the money flows, and then the permanent permission to co-invest in projects like that.

3.3.3. Recommendations on the Path Forward

In this section, we summarize the main recommendations that were suggested by our interviewed stakeholders about the future of adaptation practice in Virginia. As shown in Figure 14, recommendations are directed towards different governance levels with a general recommendation for the practice. Although the gap identification included the federal government, it is interesting to notice that stakeholders who were mostly from local, regional, and state agencies did not provide governance recommendations at the federal level. Even the contacted federal entities selected since were locally present, e.g., Army Corps Norfolk District and military installation in the region.

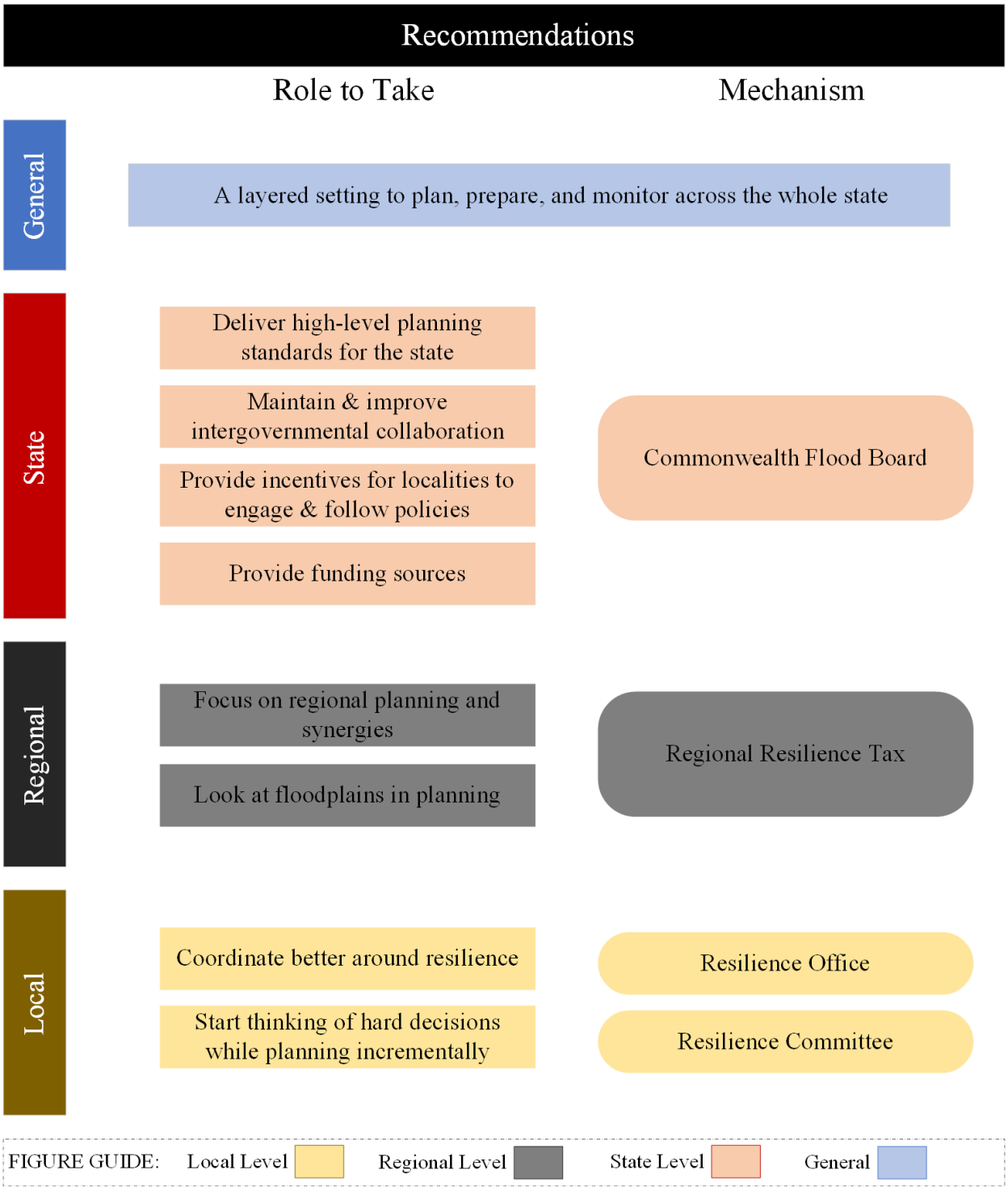

Figure 14. Recommendations on the path forward

In general, it is believed that a multi-layered system is needed to address climate impacts effectively by leveraging the capabilities of different levels of governance and extending coastal adaptation to embrace the full range of their jurisdictions (Table 24). This is deemed necessary for technical and political reasons, as non-coastal areas are also experiencing climate impacts, mainly through more intense precipitation. The

extension of adaptation strategies to inland areas will broaden political coalition and impact of climate legislation.

Table 24. Layered planning across all the state

Recommendation	Supporting Quotes
It should be layered planning across all the state	I think it should mirror how we do roads. There is a tiered system of the type of road and who invests in what, but it can be blended from all three levels of government to some degree. There is prioritization, and there are criteria for condition assessment and safety and all that. I think all three levels of government should be applying the same for flood protection programs.
	You need to find a clever way of doing both top-down and bottom-up. You cannot have it without the other one. You cannot have it be each municipality doing their own thing as there is too much duplication. There is no equitable distribution of resources there too. That is a big problem for some municipalities because they are poor and just way behind. I do not think that is in anyone's best interest. So, I do not think it should just be local efforts and let people do what they want, which is how it works now. Planning districts can help cross some divides... So, something up at a regional scale makes sense to me. If you are going to go through all this effort, you need to think about it statewide because while SLR is the motivating factor right now, rainfall patterns are changing too. So, it would not be wise, in my opinion, to make it only a coastal thing. If you are going to go to the effort, make it relevant to the entire Commonwealth, and get that done, and make it about climate adaptation rather than coastal adaptation.
	Adaptation is something that every layer of government has to be talking about. We must plan ahead because our marshes cannot migrate upland SLR in every spot… We have to plan ahead about where we are going to preserve our marshes because they play such a key role not just in choice stabilization and flood buffers like I talked about earlier, but carbon sinks too. A picture where we look at compound flooding, which is the term for all the flooding sources and heat. And, by the way, planning for what are we going to save realistically. That is a tall order. But I think that is what you have to do to have a complete picture.

On the local level, the main highly emphasized suggestion is that localities start thinking about the extent of the problem and how Retreat will play a role in their comprehensive plans, as shown in Table 25. This requires local governments to identify their critical assets by a collective approach and determine what areas in their jurisdiction would be alternatives for retreat. While this is not a decision that should be implemented today, it is also essential for localities to take incremental steps towards resilience. This could happen by adopting zoning ordinances that leverage several tools to incentivize more thoughtful development. It is also suggested to use the resilience office and resilience committee as executive options to bring harmony and consistency among the ongoing efforts on the local level. Such measures, indeed, will address the intergovernmental coordination challenge on the local level.

Table 25. Recommendations at local level

Recommendation	Supporting Quotes
Plan incrementally, start with more thoughtful development and thinking about retreat	I feel very pessimistic that localities will have the leadership to say, "okay, this is where we will draw the line, you have to move out, we will buy your property, demolish what is there and convert it to wetlands" or any degree of that. I do not see them doing that. Not to say that they should not get past that. But I think there are some incremental steps that are smart, like smarter development. For example, I think it is called PlaNorfolk 2030. They did some new planning and zoning ordinances to encourage development areas that were more inland that needed redevelopment versus incentivizing development or redevelopment in areas that are more prone to flooding. So, I do think if you get cities to start at that level, where they can bite it off in a way that feels comfortable, safe, and smarter; then eventually get into the retreat compensation.
	Everywhere, there is not enough money. I mean, there is no pretty way to paint that there is not enough money in this world to cover resilience projects to protect every single property. First of all, we are going to have to make some tough choices about what we are going to save in the long run; maybe not today, but in the long run.
	A local government can choose to do some things to create funding, and that is, they can adopt the ordinances to create a C-PACE program in their community, they can adopt tax incentives, for those who install resilience measures, they can adopt zoning, to funnel development to safer ground, that kind of thing.

Recommendation	Supporting Quotes
	Freeboard is basically like the low-hanging fruit for climate adaptation. It is super easy in the sense that it is just one sentence that needs to be changed in the ordinance. It goes before a political body. It can be contentious, but in our region, so many other communities have gone before and have done it that it just should not be that big of a deal. It used to be that much of our efforts were around things like getting a community to pass freeboard, but that was when there was no bigger fish to fry.
Higher coordination in the executive branch, through resilience office and resilience committee	Every locality needs some group of people like the office of resilience here in Norfolk that wakes up every day going around, "How are we going to solve this? How are we going to fund it?"
	We have advocated for regular meetings between departments to talk about these things in localities. It probably has to be led by somebody like at a deputy city manager level. They need to be aware of what the other ones are doing, what funding opportunities are out there, and how to phase all that.

The main recommendations at the regional level were to use floodplains as the basis for regional planning and introduce regional resilience taxes to bolster regional efforts, as shown in Table 26. It is argued that looking at the whole floodplain in planning and design will increase the efficiency and comprehensiveness of the outcomes. Some stakeholders argue that regional taxes are legally feasible and can become politically feasible because there is precedence in doing so for transportation projects.

Table 26. Recommendation at regional level

Recommendation	Supporting Quotes
Look at floodplains in planning	In Virginia and elsewhere, the governance we have over these kinds of efforts challenges efficiency. Ideally, we would look at the flood risks and resilience benefits across a floodplain. Because if you just deal with parts of a floodplain with a project, you could be missing an opportunity, or you could be moving your risks to someone else. This is a challenge how we move to a more natural systems-based approach to optimize our resilience efforts... If you look at the Master Plan, the state has already divided it into regions; the regions have some coherence vis-à-vis floodplain. I think that is a great starting point, and you are going to have to extend that inland to get to the inland floodplains, but I think that is the starting point.
Regional tax can provide considerable support for regional planning	The state of Virginia has in its code right now the authority for the creation of watershed improvement districts, and the majority of residents can vote them in. The problem with that is that you have to afford the self-imposed fee or tax. If you are a low-income resident and you are in the minority, most people in that area are wealthier than you. They might vote for a fee that you cannot afford to pay. That may not be the best tool for that area. But it is a tool. It is available.
	I am always going to beat the drum about money and infrastructure. We had significant transportation challenges in Hampton Roads that the General Assembly was not addressing. They allowed us to establish the Hampton Roads Transportation Accountability Commission, which manages the additional six cents or sales tax to address strategic transportation projects. Let us tax ourselves, let us manage ourselves, let us invest. And I think that is probably a model that Hampton Roads realistically has to reconsider in the future as well.

It is deemed critical to develop an institutional mechanism for leading the adaptation practice in Virginia at the state level, as shown in Table 27. The Commonwealth Flood Board is the missing entity to ensure the sustainability of adaptation practice; on the one hand, it introduces statewide policies and standards that safeguard an intergovernmental conversation. It also encourages and supports the local governments through incentives and funding sources. The recommendations at the state level correspond to several identified gaps in the previous sections showing how crucial it is for the stakeholders to see the state taking a leading role.

Table 27. Recommendations at state level

Recommendation	Supporting Quotes
Create Commonwealth Flood Board	There is a proposal on the table to create a State Flood Board, proposed before and has not been accepted by the General Assembly. There is a reluctance in Virginia to create standing entities; they tend to grow larger over time, they tend to hire more people and spend more money. Generally, the General Assembly members are not fond of that trend. So, they are reticent to create another standing State Board of some sort and give it any real authority. I think you can make a case where this should be an exception, and they should embrace this. This is not just a Coastal Virginia problem with the

Recommendation	Supporting Quotes
	change in storms, as I have more and more violent storms and rain events inland in Virginia that cause my rivers to flood. If you are anywhere near a river, and there are many in Virginia, you do have a dog in the fight. It is still a flooding event that adversely affects you. So, I think you can make a really strong case for creating a State Flood Board, given what I see in the decades to come and the weather trends that are coming. So, better to get ahead with this. I think that is a good mechanism for doing so.
Provide high-level planning standards around the state	The first Master Plan was just trying to tee up the coastal flood risks, like what is it? How bad is it? What are our alternatives, and who is doing something about it? Then, what does that mean for a statewide approach? It is just the start of a recurrent process. The Master Plan is just in phase one of this. Hopefully, it will continue, and it will start to think of the inland areas and then how they interact with the intertidal and coastal areas, and then what kind of governance you need to get the best kind of investment. That is going to occur, I hope, in the next iteration.
	I think it [climate adaptation plan] needs to have all levels and just understand the different roles we play at the state level. We can bring funding. We can set policy design criteria, but the local levels are going to have to identify what is important to them.
Maintain & improve intergovernmental collaboration	So, I really would love to see more interagency collaboration in the future. So, if I have counterparts, I would love a monthly meeting that just says what everybody is doing. I would also really like to see that the Master Plan continues to be managed. This is just one Master Plan because it was just the beginning. So, this ability for all of us to continue meeting and discussing is essential. Those would be the two biggest. Then there are all sorts of players in the game. So, if you want to be a part of it, there are so many people holding meetings and things of that sort. But the interagency discussion is the biggest for me.
Provide incentives for localities to engage & follow policies	We have a constitution that empowers localities to do zoning and land use policy. The federal, state or regional governments start messing with that; localities get mad. They guard that authority very carefully, and rightfully so. We should not have folks from Oregon telling the folks in Virginia how to organize themselves, 100% true. The problem is that then you have to set up a cajoling mechanism, a subsidy mechanism that localities opt into.
Provide funding sources	The state is going to need to think of other funding sources. The finance subcommittee recommended the creation of a resilience revolving loan fund. It can serve as a backup to the Community Flood Preparedness Fund right now. It can serve to supplement it later, when it is probably funded, or if you have a significant project that comes up. It is not purely resilience-oriented; it does multiple things... You can use Clean Water Act revolving loan funds to back it up with that. I think being able to pivot and having multiple sources is critical.

3.4. Discussion and Policy Implications

Firstly, we explore how the identified overall challenges and governance-specific gaps influence each other, eventually threatening climate adaptation implementation and success in Coastal Virginia, as shown in Figure 15. For example, considering "Limited Capacity" as an identified local gap certainly affects the "Comprehensive Planning" given that a capacity deficient locality would not be able to perform adequate adaptation planning. On the other hand, our stakeholders deem the state responsible for this lack of capacity, attributing it, at least partially, to missing leadership at the state level, indicating that "Absence of Leadership" has a significant influence on "Limited Capacity." Policymakers need to understand such correlations and influences as they think about improving this practice in the future.

"Comprehensive Planning" and "Intergovernmental Coordination" are critical in this story. Comprehensive planning is crucial because it directly influences several overarching challenges, i.e., social equity, the resilience of natural resources, and the controversy on retreat. These three are highly influenced by the lack of a widely accepted adaptation vision, which should be attained through planning conversations among local, regional, and state stakeholders. Comprehensive planning is also crucial because the identified gaps at different governance levels open their way to this conversation by influencing planning. For example, the measurement gap identified in federal agencies affects the planning as it neglects full consideration of the socio-economic aspects in the design of an adaptation project.

Intergovernmental coordination is crucial in two ways: first, it is an essential requirement to comprehensive planning due to the multi-level and multi-sectoral nature of climate adaptation; moreover, it is influenced by several other gaps, as shown in Figure 15. “Funding sources” is another significant gap, due to its influence on both comprehensive planning and implementation of adaptation projects. This multi-faceted effect is the reason why funding sources have the highest frequency in regards to challenges being mentioned by our stakeholders; thus aligning itself with the research previously mentioned by Yusuf et al., which is the main research conducted on adaptation barriers in Hampton Roads, concluding that funding is the most significant barrier to adaptation readiness (Yusuf and St. John, 2017). However, our analysis shows that although funding is mentioned the most in our talks with the stakeholders, comprehensive planning and intergovernmental coordination may play a more significant role in the planning and success of adaptation practice. This translates to different policy implications for the state government. Should the state government allocate new financial sources, or should it propose better spending of the currently allocated funding through the Community Flood Preparedness Fund (CFPF)? CFPF provided about $100 million in 2021 for adaptation in Virginia, which is not comparable to the state’s financial needs; however, this is a considerable amount of money if the policymakers allocate that for capacity building on the local and regional levels. So, we argue for the necessity of investment in building capacity, as the local capacity is essential for comprehensive planning and intergovernmental coordination. This could be realized through funding resilience officer positions and providing access to data sources and consulting in design and engineering on the local and regional levels. The latter also brings harmony and consistency in the adaptation practice of the state. Such measures will provide practical incentives for local governments to engage and contribute to the state-led practice. It is also aligned with the success story and long-lasting effect of engagement in the “100 Resilient Cities” program in the City of Norfolk.

Such capacity-building measures could be beneficial to localities that are ahead in addressing SLR and flooding and may help expand their adaptation efforts by encouraging them to bring other sources of climate impact, such as extreme heat and potential droughts into their planning efforts. Speaking in economics language, we expect investment in capacity building to have the highest return on investment. Capacity building can also increase the funding sources in various ways. For example, by bringing consistency and collaboration through local and regional resilience offices, there will be opportunities to develop promising regional, even state-level, applications to federal grants. This will exceptionally be beneficial if the federal government continues the recent approach of planning for climate adaptation, as we illustrated in Part A. Increasing capacities will also result in the creation and expansion of local adaptation plans with more programs and projects adding to the inventory of needed projects on the state level. This can support the need for financial sources as localities and the environmental community bargain with state-level policymakers. There is still not a precise evaluation of financial requirements for climate adaptation in Virginia mainly because the scope of risks and solutions are not clear yet; however, a clearer pecuniary understanding of the scope of the problem can pave the way for allocation of new sources.

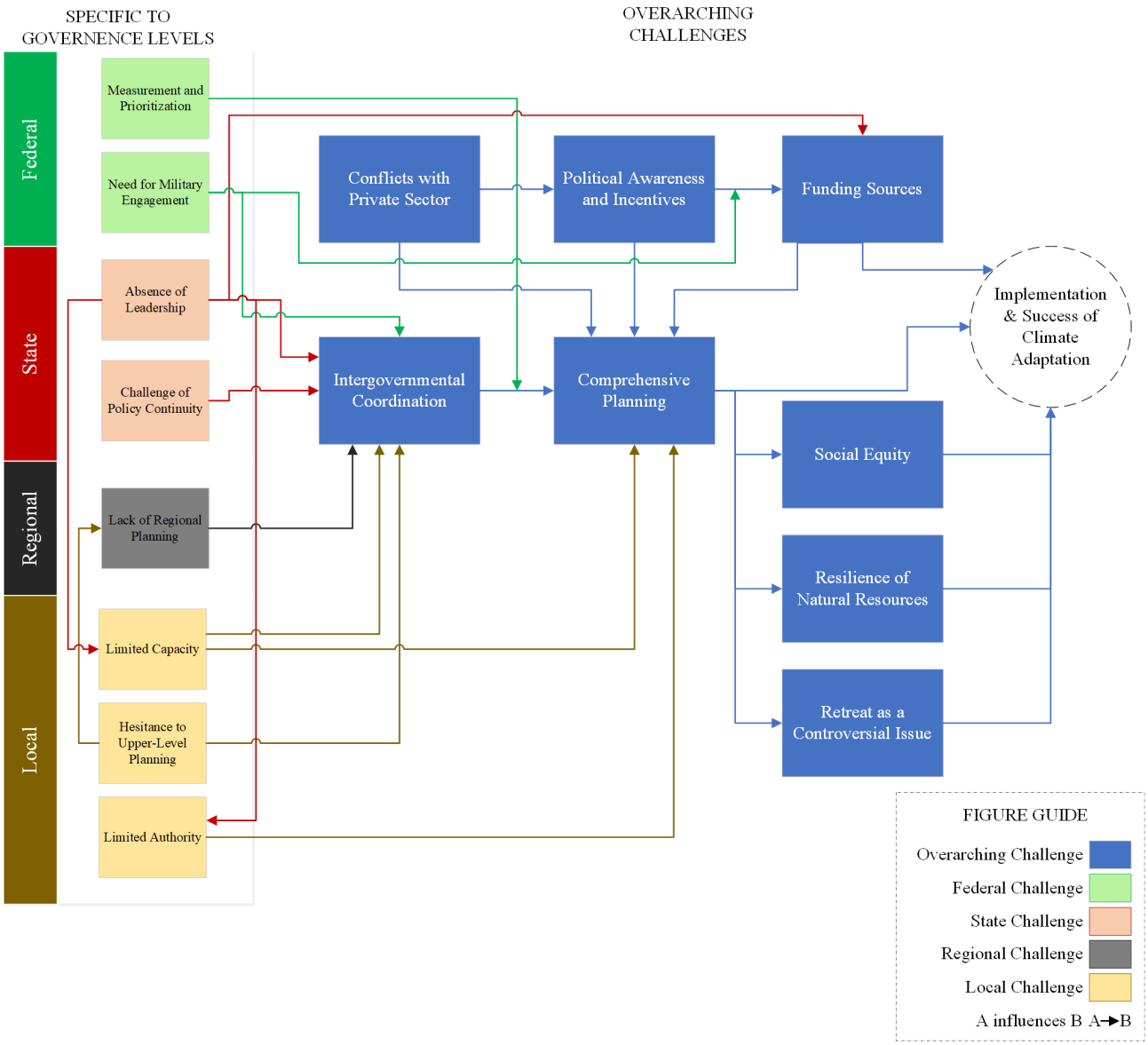

Figure 15. Network of climate adaptation challenges

Looking at the recommendations on the path forward, shown in Figure 15, we observe a great emphasis on comprehensive planning and intergovernmental coordination, followed by funding, confirming their importance for the success of climate adaptation practice. Interestingly, the stakeholders direct their expectations towards the state rather than the federal government for comprehensive planning coordination. The biggest expectation from the federal side is for the Department of Defense (DOD) to provide financial sources, as the military has a considerable presence in Virginia, particularly in Hampton Roads. A State Flood Board is the primary suggested mechanism for pursuing state leadership in this practice. With the emergence of a conservative governor, there seem to be two possibilities for the state moving forward. One is the reversal of the achievements done up to this point, by cutting the funding source, CFPF, not filling the position of special assistant to the governor for climate adaptation, and discontinuing the Coastal Resilience Master Plan, which is the biggest fear among the stakeholders as it reminds them of what happened during the McDonnel administration 12 years ago. The other possibility is that as a conservative governor, most likely not interested in climate mitigation, he may continue with climate adaptation to show

that his administration is addressing climate in some way. We need to see what possibility will be realized, and if it is the second option out of the two mentioned, the State Flood Board can become a reality. This would be a leap forward for statewide coordination in adaptation, hopefully paving the way for a statewide conversation on critical issues such as social equity, natural resources, and managed retreat. It would also be essential for the state-level policymakers to clearly define policy areas in which localities are given clear and adequate authority to pursue their adaptation efforts, as the Dillon Rule can potentially limit the local policies and decisions. For example, the City of Norfolk has introduced a zoning ordinance that includes resilience quotients to encourage building in less risky areas. It is very similar to Transfer of Development Rights (TDR); however, the city planning department has been avoiding using TDR as such transfers have to be done in a certain way according to the Code of Virginia, and they do not want to be affected by potential challenges of not following state rules (Eghdami *et al.*, 2022a).

After discussing the policy on the state level, we focus on the local governments as regional governments are not very strong based on their formation in Virginia. Thus, even the suggested regional planning and resilience tax targets the local governments, arguing that they should benefit from such options. Regional collaboration, not necessarily comprehensive planning, has been happening in Hampton Roads, where the need and financial capacity have been higher than in other regions. There is also a regional tax to support transportation projects in Hampton Roads. However, a resilience tax scheme needs regional adaptation planning that requires a challenging conversation for local leaders because adaptation projects have less mutual benefits than regional transportation projects that are being implemented as the result of a regional tax. Regional floodplain-based planning would be more feasible if encouraged by federal or state programs. For example, a state relocation program to move residents in certain flood-prone areas to safer areas can encourage regional planning by a cost-sharing scheme if a region participates in the program. Such programs can also be beneficial for less affluent localities in a region as they would proportionally pay fewer taxes while capturing the program benefits based on their climate risk situation. It would be interesting to develop economic models simulating such programs and scenarios to measure such extents as research and provide a framework for state and federal level policymaking and regional conversation among local leaders.

It is essential to note the challenges that local governments face when recommending actions for the future. Some of the localities have had a stagnant economy; some have experienced a decrease in population; some have a high poverty rate while challenged with several other issues. So, climate impacts come as a new external shock, threatening their viability. However, it would still be possible to keep an eye on the problem and try to line up local efforts to understand the scope of climate impact on the locality, and then identify their critical assets and learn about their options. Localities with limited capacity should be encouraged to introduce such actions into their agenda. Environmental nonprofits and academia can be extremely helpful for making this happen. For example, the RAFT[12] program by UVA, VCPC, and ODU has been able to step into rural areas and initiate a conversation about adaptation, as discussed in Part A (Eghdami *et al.*, 2022a). Such a model can be pursued in the future even if the state-level efforts are terminated with the new administration in the short run.

[12] - Resilience Adaptation Feasibility Tool

3.5. Conclusion and Future Research

We identified climate adaptation challenges in Coastal Virginia with two broad categories: first, the overarching challenges that impede adaptation in different governance levels or arise as the outcome of interactions between them; second, the gaps that are mainly present in one layer of governance. Among the eight main overarching challenges, comprehensive planning, intergovernmental coordination, and funding sources are identified as the most critical ones repeatedly addressed in other studies (Clar, Prutsch and Steurer, 2013). Insufficient political awareness and incentives is another identified challenge, directly impacting funding sources and comprehensive planning, well explored in the literature (Clar, Prutsch and Steurer, 2013). Social equity, the resilience of natural resources, and controversy about retreat are three main challenges that primarily arise from comprehensive planning and conversation among multi-level stakeholders. We identify conflicts with the private sector, particularly the real estate industry, as an overarching challenge while we did not find it in our literature review. So, it would be interesting to explore it in future research and learn more about the extent and dynamics of this gap using qualitative and quantitative methods.

Our second category of findings addresses specific governance levels. Going in top-down order, how federal agencies evaluate and prioritize adaptation projects has a significant impact on the adaptation in Coastal Virginia, as federal funding has been the primary financial source. It is argued in the literature that with a lack of federal initiatives in adaptation policymaking, some states initiate policymaking efforts to address climate impacts (Rai, 2020; Bromley-Trujillo and Holman, 2021). This finding, however, shows how existing federal policies inevitably impact adaptation on sub-national levels. The need for DOD investment in adaptation is the other federal gap arising from the substantial presence of the military in Coastal Virginia. It would be interesting, as future research, to investigate the impacts of federal policies in other states to achieve a clearer understanding of the needs and challenges on the national level. It is also interesting to explore the dynamics of bargaining over funding allocation to different states at the federal level as we observed the congressional representatives of Virginia playing a role in such allocations (Eghdami *et al.*, 2022a).

On the state level, the most highlighted challenge is that the state of Virginia has failed to be a leader in climate adaptation. As the trace of statewide efforts for addressing climate impacts dates back to 2008 with the formation of the Climate Action Plan, the continuity of state policy has been a significant challenge since then (Eghdami *et al.*, 2022a). This absence of leadership contrasts the studies that identify Virginia as a leading state in climate adaptation planning, based on the Climate Action Plan (Miao, 2019). Continuity of statewide adaptation efforts in the new administration will be tested by observing whether the new governor continues or ceases the statewide adaptation efforts of the previous administration. Studying how a state's role might be seen and interpreted differently in a Home Rule coastal state such as Florida would be interesting future research.

Regional planning for adaptation is another identified challenge in our analysis. This is aligned with the studies that show regional partnerships can catalyze innovation in climate adaptation (Bauer and Steurer, 2014). Regarding the potential efficiencies of taking a regional lens and floodplain-based governance, it would be interesting to study how such initiatives can be encouraged on a higher governance level as future research. Such a study should include a modeling framework to account for local incentives, based on strategic interactions, and characterize win-win scenarios for local governments to initiate regional partnerships.

Local governments are the main drivers of climate adaptation in Coastal Virginia, while Norfolk and Virginia Beach are significantly ahead of the other localities. While hesitance to involve with upper-level planning is a feature for these cities, the smaller and rural localities deal with substantial lack of capacity, primarily technical and financial, as well as with jurisdiction challenges. From a policy perspective, all the challenges identified in local governance point to the need for interventions from the state and federal government. It would be interesting to design and evaluate pilot interventions and identify essential requirements for the effective interventions.

In addition to the suggested avenues for future research, we find it interesting to explore further the controversy over Retreat from the perspective of local and regional planning. It is a complex problem as it entails a wide range of economic, political, societal, historical, and cultural considerations. Moreover, it would be critical to initiate an analytical framework to study and forecast such vast considerations to inform the ongoing controversy at different governance layers.

Chapter 4

Socioeconomic Vulnerability and Climate Adaptation

Coastal Virginia, a region with economic and strategic significance at the state and national level, has been experiencing the highest sea-level rise (SLR) on the Atlantic coast of the United States. This has been accompanied with a variety of climate hazards such as flooding and more frequent storms, igniting adaptation planning and decision-making on multiple governance levels. A spatial understanding of climate risk and its associations with socioeconomic vulnerabilities raises essential questions about the underlying roots of such associations and can help local governments prioritize social vulnerabilities in their adaptation efforts. Using coastal flooding as a substantial climate stressor in this region, this chapter strives to provide such an understanding paving the way for equitable and effective adaptation. The analysis reveals significant associations between climate risk and social vulnerability measures such as poverty, access to infrastructure, education, and housing in certain parts of Coastal Virginia. Climate risk is more common among presumably less vulnerable populations in other parts. It is then discussed how our vulnerability discoveries would influence policymaking on the local and state level. This research has several theoretical and empirical outcomes addressing the social equity and justice aspects of climate adaptation and can be extended to other areas at high climate risk to shed light on the associations between specific social vulnerabilities and climate risks.

4.1. Introduction

Coastal areas experience various climate challenges, most pressing of which are flooding and sea-level rise (Bukvic *et al.*, 2020). Coastal Virginia is considered at high climate risk due to land subsidence and accelerated SLR, as in some areas, the sea level is 14 inches higher than 1950 (Boon, 2012; Kopp, 2013; NOAA, 2022b). Coastal Virginia is home to 6 million people, 70% of the state's population, with 1,500 miles of roads and properties valued at a cumulative $17.4 billion that are at high risk of flooding and sea-level rise (Commonwealth of Virginia - Office of the Governor, 2021). It has been projected that by 2080, 341,000 buildings will be exposed to extreme coastal flooding causing about $5.1 billion annual damage (Commonwealth of Virginia - Office of the Governor, 2021). Virginia's Hampton Roads region has the highest rates of SLR on the Atlantic Coast of the U.S and is the second-largest U.S. population center at risk, after New Orleans (Eggleston and Pope, 2013). Hampton Roads is home to 15 military installations, including Naval Station Norfolk, the world's largest naval base, making it one of the largest concentrations of armed forces in the U.S (Kleinosky, Yarnal and Fisher, 2007; Sadler *et al.*, 2017). SLR and flooding in Coastal Virginia generate potential threats for military facilities, public and transportation infrastructure, ports and logistics, and tourism, in addition to private property damages (Van Houtven *et al.*, 2016; Sadler *et al.*, 2017; Yusuf *et al.*, 2021).

Communities of Coastal Virginia that are at increasing climate risk, e.g., SLR, flooding, higher intensity and frequency storms, and erosion, have three broad options: Protect through hard or soft structural options; Accommodate by changing land use, construction methods, and improving preparedness; Retreat by moving from high-risk areas to safer ones (Kleint *et al.*, 2001; Kirshen, Knee and Ruth, 2008). Communities at high climate risk have varied economic, institutional, social, and political capacities influencing their capability to adopt and implement any of these options (Smit and Wandel, 2006).

At the same time, there are several adaptation planning and policymaking efforts at the local, regional, and state levels trying to understand the nature and impacts of climate risks and identify the most vulnerable populations to climate hazards (Commonwealth of Virginia - Office of the Governor, 2021). Formulating appropriate adaptation policies to address the climate impacts necessitates an understanding of socioeconomic vulnerabilities and how they are associated with the climate risks. The primary objective of this chapter is to provide such understanding in the areas associated with high storm surge and flooding risk in Coastal Virginia (Kleinosky, Yarnal and Fisher, 2007). Socioeconomic vulnerabilities could have impact on climate risks in different ways. Vulnerable populations have been found to live in cheaper, less desirable housing sites, such as floodplains and unstable hillsides, that are more exposed to climate hazards (Maantay and Maroko, 2009; Martinich *et al.*, 2013; Kuhl *et al.*, 2014; Thomas *et al.*, 2019). Alternatively, buildings housing vulnerable populations may be poorly constructed, increasing their impact from climate stressors (Phillips, 1993; Hallegatte, 2013; Kuhl *et al.*, 2014). It has been shown that infrastructure investments, land use regulations, or new protected areas can disproportionately affect or displace disadvantaged groups (Chu, Anguelovski and Carmin, 2016). Socioeconomic vulnerability can also limit the access to resources required for combatting climate hazards. For example, three African American communities' social and political isolation on the Eastern Shore reduced their access to resources necessary for adapting to frequent flooding and their representation in government decision-making (Hesed and Paolisso, 2015). Exclusionary land use planning, zoning, and unequal enforcement of land use regulations are considered drivers of differential vulnerability, putting certain vulnerable communities at higher exposure to climate risks (Amorim-Maia *et al.*, 2022).

The contribution of this chapter is three-fold. First, it provides and maps a climate risk measure based on sea-level rise and flood risk for each Census block group in the study's region. Secondly, it develops a spatial socioeconomic vulnerability dataset containing twelve variables, including income, housing, poverty, race, education, employment, access to infrastructure, and age. Finally, it develops several regression models to connect climate risk to socioeconomic vulnerability to find the closest associations between vulnerabilities and climate risk.

Our literature review discovers a vast amount of scholarship on developing socioeconomic vulnerability indices using a combination of variables to identify socioeconomically vulnerable areas to be considered by climate adaptation policymakers (Cutter, S.L.; Carolina, S.; Boruff, B.J.; Carolina, S.; Shirley, W.L.; Carolina, 2003; Ahsan and Warner, 2014; Toké, Boone and Arrowsmith, 2014; Furlan *et al.*, 2021; Jeganathan, Andimuthu and Kandasamy, 2021; Sahana *et al.*, 2021; Wu, 2021). Stafford and Abramowitz (2017) identify communities with high social vulnerability to environmental hazards in Hampton Roads and Coastal Virginia (Stafford and Abramowitz, 2017). Using a variety of socioeconomic variables from census tract data, they develop and compare Principal Components Analysis (PCA) and clustering models to identify socially vulnerable tracts. The paper argues that PCA and clustering can complement the identification of vulnerable areas on both state and local levels. In another study on Coastal Virginia, Stafford and Renaud (2019) present measures to identify local business and government vulnerabilities to

sea-level rise (Stafford and Renaud, 2019). Using these two vulnerabilities accompanied by a physical vulnerability measure, they identify particular areas in Coastal Virginia that are vulnerable to sea-level rise. In another study, Liu et al. (2015) identify and map vulnerability to storm-surge flooding for 12 localities in Hampton Roads based on physical factors, built-up environments, and household conditions (Liu, Behr and Diaz, 2016).

Kashem et al. (2016) measure social vulnerability for three cities across the Gulf region of the US, Houston, New Orleans, and Tampa, building on measures of poverty, race, gender, and age (Kashem, Wilson and Van Zandt, 2016). Measuring social vulnerability over the last three decades, they find that vulnerability has become less concentrated through time. They suggest that using more granular data, census block groups, for example, can provide further detail of vulnerability in coastal areas of the U.S. In a study of heatwaves as a climate stressor, Macnee and Tokai (2016) develop and map a heat vulnerability index in Osaka City, Japan, using proxy variables, e.g., age, education, and unemployment (Macnee and Tokai, 2016). Implementing PCA, the paper maps the vulnerability index and exposure to heatwaves to identify the areas that need targeted action in climate adaptation policies.

There is a growing scholarship on environmental justice, climate justice, and differential vulnerability in adaptation, all arguing for a critical need to highlight the interrelationship between environmental and social issues and consider present and historical social vulnerabilities in studying the impacts of climate change and planning for future adaptation (Walker, 2012; Schlosberg and Collins, 2014; Anguelovski *et al.*, 2016; Shi *et al.*, 2016; Thomas *et al.*, 2019; Yang, Lee and Juhola, 2021; Amorim-Maia *et al.*, 2022). Differential vulnerability to climate hazards implies that certain communities and social groups experience a more significant impact from environmental risks primarily because of social, economic, historical, and political factors (Thomas *et al.*, 2019). Thomas et al. (2018) explore the literature to find the underlying causes for disproportionate exposure and impact from climate threats in certain communities (Thomas *et al.*, 2019). They propose four broad themes that help us understand social aspects of vulnerability: varied access to resources, governance processes, the influence of culture on identification and decision-making around risk, and knowledge and information.

Climate and environmental justice argue that adaptation must consider and tackle inequities, involve the vulnerable communities in planning and decision-making, consider cultural impacts, and build adaptive capacity for communities (Schlosberg and Collins, 2014). In a recent study, Chu and Cannon (2021) explore how equity, inclusion, and justice are included in the climate change adaptations of ten U.S. cities (Chu and Cannon, 2021). They find that although cities are beginning to address differential vulnerabilities, there needs to be a higher emphasis on social structures, e.g., socioeconomic status and race, and how they contribute to social vulnerabilities and climate injustice. They argue for the crucial need for specific metrics and indicators to measure and monitor climate equity and justice. Building on an extensive literature review of intersectionality and justice in climate adaptation, Amorim-Maia et al. (2022) propose a conceptual framework for intersectional climate justice (Amorim-Maia *et al.*, 2022). Defining intersectionality as "a core conceptual lens to understand how various forms of social inequalities and vulnerability interconnect and overlap with each other," they find it beneficial in climate justice to address overlapping systems of disadvantage and oppression that aggravate climate change impacts for disadvantaged communities. They introduce five main components as requirements of climate justice for adaptation: tackling economic reinforcers of racial and gender inequalities, remedying differential vulnerabilities, consideration of politics and ethics of care, implementing place-based approaches and building community resilience. In this research, we explore the existence of differential vulnerability in climate adaptation in Coastal Virginia and

argue that adaptation policies should consider the local patterns of social vulnerability to achieve equitable policies.

As illustrated in the literature review, studies addressing socioeconomic vulnerability in climate adaptation primarily implement a weighting scheme of different socioeconomic variables to develop a vulnerability map, which can be used to identify areas that need specific attention in adaptation policymaking. Environmental and climate justice research, meanwhile, address the ongoing vulnerabilities of disadvantaged communities and explore how climate impacts influence such communities. Our research contributes to this literature by examining the association between climate risk and socioeconomic vulnerability in Coastal Virginia. We explore whether certain aspects of socioeconomic vulnerability have significant power in explaining the distribution of climate risk. Learning about such associations has instrumental implications for adaptation planning of the local governments as it requires them to consider specific aspects of vulnerability in the design and implementation of adaptation programs. This approach can be extended to other coastal areas facing climate change impacts to identify specific climate risk and vulnerability associations. This can provide new insights for policymakers to learn about vulnerability and contemplate the ongoing drivers of climate risk as a requirement for effective programs in the future. More specifically, learning about the most associated socioeconomic vulnerabilities with climate risk can lead policymakers to strategically tackle the specific vulnerability measures as they plan for climate adaptation.

This chapter continues as follows. Section 4.2 explains the data and methods of the study, followed by the results in Section 4.3. We then discuss our findings, their policy implications, and the methodologic limitations in Section 4.4. Section 4.5 concludes the chapter by providing directions for future research. Regression diagnostics and robustness checks are provided in Appendices B and C.

4.2. Methodology

To relate socioeconomic vulnerability to climate risk, we first developed a climate risk measure for each unit of geographic analysis; we call this measure “Flood Risk” throughout the chapter. Then, we selected several demographic variables from the 2018 American Community Survey (ACS) on the most granular level, Block Group, to capture different types of socioeconomic vulnerability within the region (United States Census Bureau, 2020). Using Flood Risk as the dependent variable, we then identified correlations between demographic variables and Flood Risk by applying a series of stepwise regressions.

4.2.1. Data

To form our Flood Risk measure, we first used the National Flood Hazard Layer (NFHL) by FEMA to identify areas with a high risk of flooding, equal to a 1% annual flooding probability (Federal Emergency Management Agency (FEMA), 2022). Such models use the history of flooding and storm surge to determine flood elevations based on the natural and built environment of the coast (Federal Emergency Management Agency (FEMA), 2005). Since we are interested in understanding how flooding risk affects buildings and infrastructure, we used the National Land Cover Dataset, available from Natural Resources Conservation Service (NRCS), to identify the “developed lands” and use them as the basis of flood risk measure (Natural Resources Conservation Service (NRCS), no date). Developed land is defined as “Land occupied by buildings and related facilities used for residences, commercial sites, public highways, airports, and open space associated with towns and cities” (NRCS, 2012). Flood Risk is defined as the ratio of “developed areas with high flood risk” to “developed areas” in a block group as the geographic unit of analysis. Flood Risk is measured between 0 and 100, as mapped in Figure 16. We observe a distribution of risk that goes

from zero to close to 100 for some block groups, meaning that for some block groups, no houses or built infrastructure are at high flood risk, while in some others, almost all houses and built infrastructure are at high flood risk. The average risk measure for each area is reported in Table 28. Poquoson City has the highest risk values compared to the existing localities of the study, with an average risk measure of 76.7, whereas Williamsburg city has the lowest comparative risk, an average of 0.1.

Table 28. Overview of study areas

Area	Localities	Population	Population Density[13] (per sq. mi)	Block groups (#)	Data Points (#)	Flood Risk (Average[14])	Average Elevation[15] (m)
Northern Peninsula	King George, Lancaster, Northumberland, Richmond, and Westmoreland counties	75,433	64	57	53	14.4	20.8
Middle Peninsula	Essex, Gloucester, King and Queen, King William, Mathews, and Middlesex counties	91,242	55	66	63	15.4	17.5
Eastern Shore	Accomack and Northampton counties	44,699	23	41	38	21.0	7.3
Southern Peninsula (excluding Hampton & Newport News)	Charles City, James City, New Kent, and York counties Cities of Poquoson and Williamsburg	196,665	216	102	94	12.3	15.9
Virginia Beach	City	450,135	1,043	300	286	8.5	4.0
Norfolk	City	241,946	2,509	183	166	14.7	3.2
Portsmouth	City	94,188	2,015	78	71	15.7	3.3
Chesapeake	City	237,820	677	122	119	7.6	4.3
Hampton	City	135,583	670	97	89	26.0	3.3
Newport News	City	180,145	1,505	126	109	5.1	8.2
Total		1,747,856	-	1,172	1,088	-	-

[13] - Calculated for the whole area

[14] - Average over block group

[15] - Average over block group

We use land elevation data from The National Map (TNM) to calculate the average[16] elevation for each block group as a control measure in our regression model, further explained later. The data is collected from Digital Elevation Models (DEM) with a 1/3 arc-second (approximately 10 meters) resolution (United States Geological Survey (USGS), 2022). We used ArcGIS Pro for processing geographic information, i.e., flood risk, land coverage, elevation, Census geographic regions, and political boundaries (Esri, 2022).

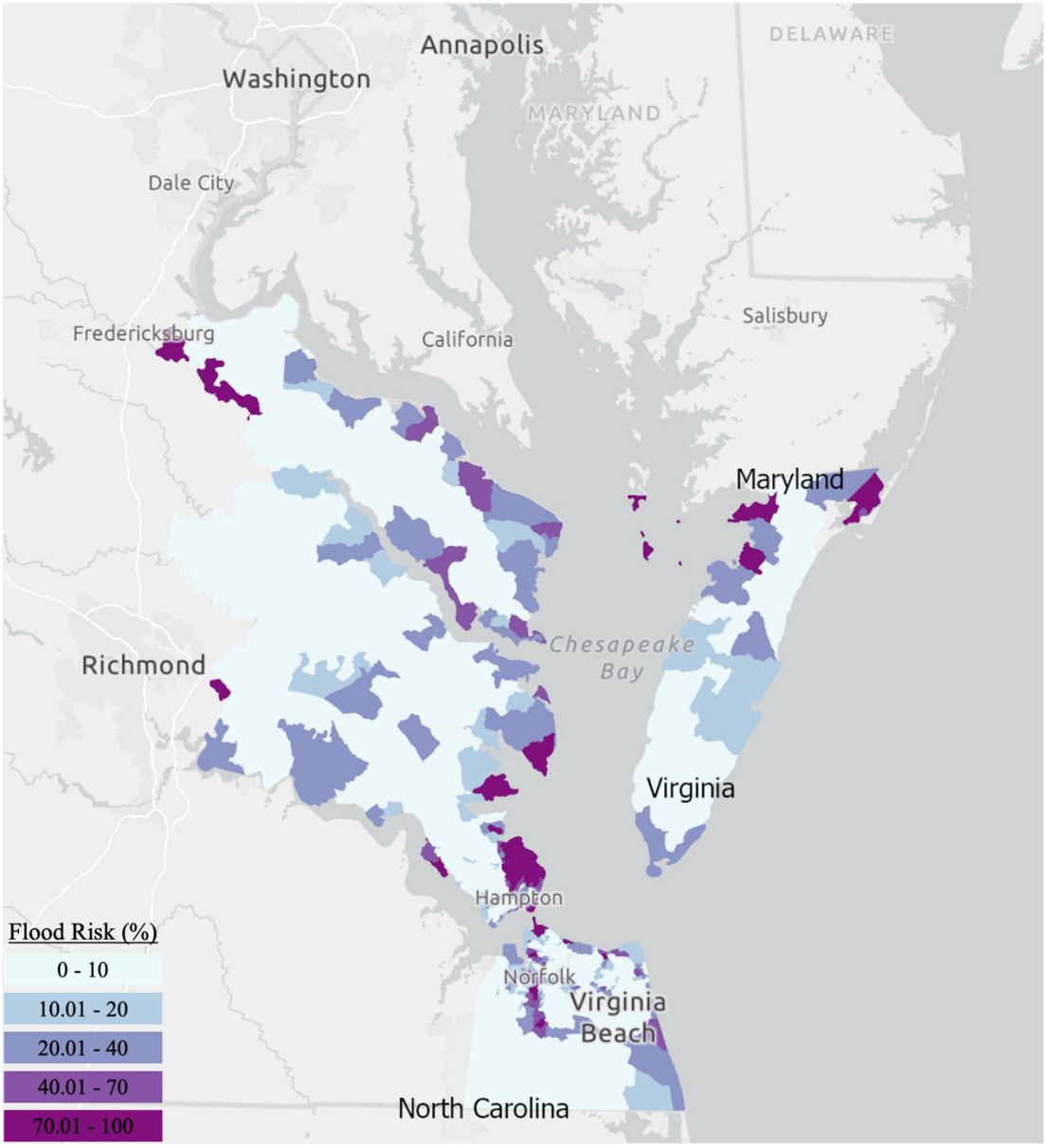

Figure 16. Flood risk for study area

[16] - Average over the entire data points in a geographic unit (block group); the elevation data points were approximately 10 meters apart.

Looking into ACS block group data, we formulated twelve variables to measure socioeconomic vulnerability, as shown in Table 29. We include measures for income, housing, poverty, race, education, employment, access to infrastructure, and age. Starting this research in 2020, we used the most recent available data, the 5-year estimates of 2018. The variables selected captured different dimensions of socioeconomic vulnerability at the block group level. In other words, each included measure speaks to a specific aspect of vulnerability that can eventually affect a household's decisions and behaviors in combatting the impacts of climate risks on their life (Shi *et al.*, 2016). Availability of data on the block group level has also been a limiting factor for selecting socioeconomic vulnerability variables as, for example, there were certain health related variables that were not available at the block group level.

Table 29. Socioeconomic vulnerability measures

Measure		Variable	Data (ACS, 2018)	Reference
Income	1	Household median income (inflation-adjusted)	• Median Household Income in The Past 12 Months (In 2018 Inflation-Adjusted Dollars)	B19013
Housing	2	Housing median value	• Median Value (Dollars)	B25077
	3	Renters' share of households[17]	• Housing Tenure	B25003
Poverty	4	Poverty rate of households[18]	• Poverty Status in the Past 12 Months by Household Type by the Age of Householder	B17017
	5	Share of social assistance receivers[19]	• Family Size by Cash Public Assistance Income or Households Receiving Food Stamps/Snap Benefits in The Past 12 Months	B19123
Race	6	Share of Black households[20]	• Race of Householder	B25006
Education	7	Share of below diploma[21]	• Educational Attainment for the Population 25 Years and Over	B15003
	8	Share of bachelor's degree & higher[22]		
Employment	9	Unemployment rate[23]	• Employment Status for The Population 16 Years and Over	B23025
	10	Ratio of military to civilian employment[24]		

[17] - Derived by diving the number of "renter occupied" by the sum of "renter occupied" and "owner occupied" housing units

[18] - Derived by diving the number of households with "income in the past 12 months below poverty level", divided by "total" households (we use the cumulative number of households below poverty level)

[19] - Derived by dividing number of households "with cash public assistance income" by "total" households

[20] - Derived by dividing number of "Black or African American alone" by number of "Total" households

[21] - Derived by summing attainment levels below "regular high school diploma" diploma for population 25 years and over, and dividing it by the "total population" 25 years and over

[22] - Derived by summing attainments of "bachelor's degree" and above in population 25 and over, and dividing it by the "total population" 25 years and over

[23] - Derived by dividing the number of "unemployed" by "in labor force" for the population 16 years and over

[24] - Derived by dividing "armed forces" by "civilian labor force" for the population 16 years and over

Measure		Variable	Data (ACS, 2018)	Reference
Access to Infrastructure	11	Share of no-internet access households[25]	• Internet Subscriptions in Household	B28011
Age	12	Share of over 65 population[26]	• Total Population (Sex by Age) • Relationship By Household Type (Including Living Alone) For the Population 65 Years and Over	B01001 B09020

Having block group as our unit of analysis, we divide our study region into sub-regions: Northern, Middle, and Southern peninsulas, Eastern Shore, and the main cities of Hampton Roads (Virginia Beach, Norfolk, Portsmouth, Chesapeake, Hampton, Newport News). Ideally, we would have preferred to run our regression model for each locality, either a city or county, but it was not possible because certain localities were small, not providing large enough set of observations; we used a minimum of 30 data points for a locality to consider it as a separate regression. There were block groups for which at least one variable was unavailable in ACS data; we deleted those data points to run our regression analysis consistently (84 block groups) as observable by the difference between the block groups and data points in Table 28. Eventually, we have ten study areas with 1088 data points, as shown in Table 28.

Table 30 summarizes the socioeconomic vulnerability variables for our study areas. The Northern and Middle Peninsulas and Eastern Shore have significantly lower population density as they are rural areas among our study regions. The Southern Peninsula, excluding the two relatively big cities of Hampton and Newport News, had a population density of 216 per square mile, which is significantly higher than rural areas and considerably lower than the cities; we call the area "Semi-urban" in this manuscript. The remaining areas are all cities with high population densities, and we call them "Urban areas" in the following sections.

The data shows variation across different areas for certain variables. Rural areas had a relatively lower share of renters, 25% on average, while urban areas had a higher portion of the population not owning a house, an average of 41% renter share. Virginia Beach, Chesapeake, and Southern peninsula generally have higher household income, higher median housing value, and a lower poverty rate, identifying them as wealthier among the study areas. The cities of Portsmouth, Norfolk, Hampton, and Newport News had the highest share of Black households, above 40%, whereas Middle and Southern peninsulas had the lowest share (Black and White populations are the primary racial groups as thy form 97% and 94% of households in the Middle and Southern peninsulas). Eastern Shore had the highest share without a high school diploma, 18.5%, indicating that area had the lowest educational attainment while the Southern peninsula had the highest proportion of its population holding a bachelor's degree or above, 44.3%.

Portsmouth had the highest unemployment rate, 8.8%, whereas rural areas showed the lowest unemployment rate., 4.1% on average. The City of Norfolk had the highest share of military to civilian labor, 22%, as the city is home to a large naval base; on the other hand, rural areas had the lowest rates of military labor as these individuals either lived on the military base, which tend to be in urban areas, or preferred to stay in urban areas. Rural areas also had the highest share of the population not having access to the internet, 24%, indicating that access to broadband infrastructure is a significant vulnerability for

[25] - Derived by dividing number of "with internet access" households by "total" households

[26] - Derived by dividing "total" number of people over 65 by "total" population

households in these areas. Portsmouth had the highest share of no-internet access within the urban areas, showing another dimension of vulnerability that significantly correlates with poverty in some studied areas. Rural areas also had a relatively higher share of their population aged over age 65, 22.4% on average compared to 13.9% in urban and semi-urban areas.

Table 30. Summary of Socioeconomic Vulnerability Variables for Study Areas

Area	Household median income ($)	Housing median value ($)	Renters' share of households (%)	Poverty rate of households (%)	Share of social assistance receivers (%)	Share of Black households (%)	Share of below diploma (%)	Share of bachelor's degree & higher (%)	Unemployment rate (%)	Ratio of military to civilian employment (%)	Share of no-internet access households (%)	Share of over 65 population (%)
Northern Peninsula*	60,594	255,233	22.8	10.5	20.0	22.3	10.0	27.3	4.9	1.6	20.5	23.3
Middle Peninsula*	61,596	218,776	20.6	9.5	8.7	15.7	12.0	21.8	3.5	0.9	23.9	21.0
Eastern Shore*	46,525	175,575	32.8	16.3	14.4	28.1	18.5	19.4	3.9	0.5	28.5	22.9
Southern peninsula* (excluding Hampton & Newport News)	85,039	312,393	26.0	6.7	5.0	12.9	6.0	44.3	4.9	4.7	10.2	19.2
Virginia Beach	74,186	274,300	35.9	7.1	8.1	18.8	6.8	35.2	4.4	9.8	8.9	13.2
Norfolk	49,146	199,400	56.9	18.1	19.3	40.2	12.2	28.2	6.6	22.0	14.1	10.7
Portsmouth	50,224	171,800	45.7	14.9	18.9	50.9	12.5	21.3	8.8	4.9	20.2	14.4
Chesapeake	75,790	265,600	28.7	8.2	8.0	29.1	7.8	32.5	4.8	6.0	8.9	12.5
Hampton	54,550	186,400	43.8	14.0	15.3	50.0	8.8	26.8	6.7	7.2	14.1	14.5
Newport News	51,884	193,100	50.9	14.3	17.0	41.7	9.9	25.5	6.2	9.3	15.9	12.4
Average	60,953	225,258	36.4	12.0	13.5	31.0	10.5	28.2	5.5	6.7	16.5	16.4
SD	13,173	48,425	12	4	6	14	4	7	2	6	7	5
Minimum	46,525	171,800	20.6	6.7	5.0	12.9	6.0	19.4	3.5	0.5	8.9	10.7
Maximum	85,039	312,393	56.9	18.1	20.0	50.9	18.5	44.3	8.8	22.0	28.5	23.3

**Average over the block groups in the Area*

4.2.2. Regression Model

We use linear regressions to find the association between socioeconomic vulnerability and climate risk based on the risk of flooding. The Flood Risk measure is considered the dependent variable, while the socioeconomic factors are introduced into the model as independent variables. This presumes that current development patterns may reflect the vulnerability of different communities, differentially exposing populations to climate risk, e.g., flooding and SLR may be more prominent in more vulnerable communities, as many low-income households have no option but to live in high-risk locations (Watts *et al.*, 2015). As explained in the introduction, socioeconomic vulnerability might have associations with lower quality housing, limited access to infrastructure and political resources, and exclusionary land use policies and regulations all affecting the exposure of vulnerable communities to climate risks.

We control for natural factors, using Elevation as the primary determinant of flood risk and fixed effects for each locality, either a county or a city, to capture the variation among localities. The general form of the regression model for each area is shown in Equation 1, where $I_j \in \{0,1\}$ is a dummy variable controlling for locality fixed effects.

$$\sqrt{Flood\ Risk_i} = \alpha\ .\ \text{Elevation}_i + \sum_{j \in \text{Localities}} \beta_j .\ I_j + \sum_{k \in \text{Set of selected Variables}} \gamma_k .\ \text{Socioeconomic Vulnerability}_k + \varepsilon_i$$

Eq 1. General Regression Model

We take the following five steps for running our regression models:

- Step 1: we standardize all the socioeconomic variables on a local basis to capture local variations and disregard different ranges of variety in variables. This was done by subtracting the local average and dividing by the local standard deviation for each value.
- Step 2: we use stepwise regressions for each of our ten study areas shown in Table 28 (Agostinelli, 2002). We run the stepwise regressions, forward and backward, for each area to select the features (socioeconomic variables) with significant correlation with risk, P-value lower than 0.1. To implement this, we use a Python package that executes stepwise linear regression (Aakkash, no date).
- Step 3: we check if the selected variables are correlated themselves, identified by a correlation higher than 50% in a correlation matrix of all variables. When two variables are correlated, we take two steps.
    - First, remove each of them one at a time and run the regression to see if the remaining variables remain significant in the same direction; we then save that regression in our set of viable regressions. Sometimes, two highly correlated variables were significant by influencing the dependent variable in different directions, but if only one is in the regression, it is not significant. Situations like this were caught and removed in this step.
    - Second, we remove one correlated variable from the variables set and rerun the stepwise regression to see if other variables have explanatory power in the absence of this specific variable which was removed.

- Step 4: We repeat the stepwise regression (Steps 2 and 3) with random order of variables (5 times) to ensure the selected variables are not dependent on the order through which they are introduced to the model. We observed no difference in the selected variables.
- Step 5: we end up with a set of saved regressions for each area, and we only report the one with the lowest AIC[27] value (Vrieze, 2012); the highest adjusted r-squared always accompanied the lowest AIC value. The saved regressions set only had one regression in several cases, which we reported in the results section.

We used the square root transformation of the Flood Risk measure because it did not meet the normality requirement for regression analysis. As shown in Appendix B, we use the regressions with untransformed Flood Risk as the dependent variable as a robustness check. To interpret the impact size of significant coefficients in the transformed regression, we back-transform the coefficient using 50 percent as the average level of risk and estimate the impact on climate risk, as shown in Equation 2, where γ_k is the coefficient. In other words, the estimated impacts in the next section generally speak to the impact of an independent variable on the risk for a block group at average risk (50%).

$$\Delta_{\text{Flood Risk}} = \gamma_k{}^2 + 2 \cdot \gamma_k \cdot \sqrt{50}$$

Eq 2. Back-transform method for estimating the impact of independent variables

4.3. Results

This section reports our regression results, as described in the previous section. They are divided into rural (three regressions) and urban and semi-urban areas (seven regressions). As a general observation, "Elevation" is always significant with a negative coefficient, meaning that increased elevation is associated with lower flood risk, as expected, given elevation is a substantial factor in determining the risk of coastal flooding (Bilskie *et al.*, 2014; Kulp and Strauss, 2019). The absolute value of the coefficient for Elevation is highest in the cities of Norfolk, Portsmouth, Chesapeake, and Hampton, associated with the estimated decrease of 34.7%, 33%, 20%, and 18.6% on the risk per one meter increase in elevation, as shown in Table 32. These numbers indicate that a one-meter increase in Elevation decreases the flood risk by at least 18% for a block group with an average risk measure in these localities. These cities also have the lowest average Elevation within the study areas, 3.2 meters for Norfolk, 3.3 meters for Portsmouth and Hampton, and 4.3 meters for Chesapeake. The elevation coefficient shows the importance of Elevation in determining flood risk in these cities. We do not observe large coefficients for Elevation in rural areas, although they are all negative and significant, which could be attributed to the comparatively lower variation of elevation in urban data points, measured based on the coefficient of variation.

We run regression diagnostics to ensure our models meet linear regression assumptions, i.e., linearity, normality, lack of multicollinearity, and homoscedasticity. The assumptions are generally satisfied with a couple of exceptions in homoscedasticity, as reported in Appendix C, that will not hinder the validity of our results.

[27] - Akaike Information Criterion (AIC)

4.3.1. Rural Areas

The regression results for the Northern and Middle peninsulas and Eastern Shore are presented in Table 31. Northumberland and Richmond counties are the significant local fixed effects in the Northern peninsula, showing they face a higher flood risk than Westmoreland, 24.5% and 20.9% accordingly. The share of adults with education lower than a high school diploma is significant, P-value of 0.08, with a positive sign. This generally means a higher share of residents without a high school diploma is associated with higher flood risk measure. More specifically, one higher standard deviation of the below high school diploma share is linked to an estimated 4.9% higher risk. This interesting observation indicates a significant connection between climate risk and lower educational attainment in the Northern peninsula. There is a moderate correlation between the share of below diploma and share of no-internet access households, 36%, stipulating parts of the lower education communities at climate risk do not have internet access. The share of Black households is another significant variable indicating a negative correlation between the Black population and flood risk. This can be interpreted as more White communities being at climate risk in the Northern peninsula, a phenomenon we also observe in the adjacent Middle peninsula with a more significant coefficient.

Gloucester County is the only significant fixed effect in the Middle Peninsula, indicating this county has a relatively lower climate risk compared to Middlesex County; however, there is relative homogeneity in exposure to climate risk among other localities of this area. Other than the share of Black households being significant and negative, there are two interesting observations here. First, the renters' share of households is negatively associated with the risk; a one standard deviation increase in renters' share translates to an estimated 8.1% decrease in climate risk. This can be interpreted as homeowners being at higher risk, a pattern that we also observe in Eastern Shore. The second observation is the positive correlation between the share of households with no internet access and risk; one standard deviation increase translates to an estimated 7.9% higher risk. We interpret this as an association between access to infrastructure and climate risk in the Middle Peninsula, which points at a significant socioeconomic vulnerability. It is also interesting to notice a high negative association between the no-internet access share and median income in this area, a correlation of -47%, underlining the vulnerability even more.

Looking at Eastern Shore's regression in Table 31, we observe a significantly higher risk for Accomack County, an overall estimated 28.3% higher risk. This interesting observation points out the difference between two neighboring counties in this area after controlling for Elevation as the primary determinant of the flood risk. We also observe a significant impact of the share of social assistance receivers on climate risk, an estimated impact of 9.1% for a one standard deviation increase with a P-value at 0.01.

Table 31. Regression results for rural areas

Northern Peninsula				R-squared = 0.67	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	4.54	0.65	6.96	0.00	-
Elevation	-0.11	0.02	-7.26	0.00	-1.5
Northumberland County	1.56	0.65	2.40	0.02	24.5
King George County	0.00	0.64	0.00	1.00	-
Lancaster County	0.51	0.65	0.78	0.44	-
Richmond County	1.35	0.72	1.88	0.07	20.9
Westmoreland County	0.78	0.62	1.27	0.21	-
Share of below diploma	0.34	0.19	1.76	0.08	4.9

Share of Black households	-0.32	0.19	-1.69	0.10	-4.4
Middle Peninsula			R-squared = 0.59		
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	5.94	0.64	9.36	0.00	-
Elevation	-0.15	0.02	-6.51	0.00	-2.1
Essex County	0.30	0.76	0.40	0.69	-
Gloucester County	-1.14	0.61	-1.88	0.07	-14.8
King and Queen County	0.13	1.00	0.13	0.90	-
King William County	0.50	0.80	0.63	0.53	-
Mathews County	-0.86	0.94	-0.91	0.37	-
Renters' share of households	-0.59	0.24	-2.44	0.02	-8.1
Share of Black households	-0.68	0.23	-2.94	0.01	-9.2
Share of no-internet access households	0.54	0.26	2.10	0.04	7.9
Eastern Shore			R-squared = 0.88		
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	7.03	0.52	13.50	0.00	-
Elevation	-0.67	0.05	-12.27	0.00	-9.0
Accomack	1.78	0.40	4.40	0.00	28.3
Share of social assistance receivers	0.62	0.21	2.95	0.01	9.1
Renters' share of households	-0.50	0.23	-2.19	0.04	-6.8

4.3.2. Urban and Semi-urban Areas

The regression results for the rest of our study areas, including Southern Peninsula as a semi-urban area, and the six cities of Virginia Beach, Norfolk, Portsmouth, Chesapeake, Hampton, and Newport News, are shown in Table 32. Looking at Southern Peninsula, Poquoson City is significant with a large impact, showing how this city faces a relatively high risk of flooding compared with Williamsburg City and other localities in the Southern Peninsula. Charles City and New Kent County also have significant positive coefficients indicating exposure to relatively higher climate risk than neighboring counties. It is also interesting that the poverty rate is positively associated with the risk, a P-value of 0.08, in the Southern Peninsula. This means that a block group with a one standard deviation increase in poverty rate bears an estimated 3.8% higher climate risk.

Looking at the City of Virginia Beach, we observe a highly significant and positive association between housing median value and the risk factor. The estimated impact indicates that a block group with a one standard deviation increase in median housing value is exposed to a 7.8% higher risk. We observe a similar pattern in Norfolk, P-value of 0.00, Portsmouth, P-value of 0.02, and Hampton, a weaker P-value of 0.05.

We observe two other significant variables in Virginia Beach's regression: share of social assistance receivers and renters' share of households, both indicating the association between socioeconomic vulnerability and climate risk. They both remain in the final regression because they do not have a high correlation with each other and the housing median value. Renters' share is highly significant with a positive coefficient, P-value of 0.00, indicating there are communities with a high share of renters at higher risk. We observe a similar pattern in Chesapeake with lower significance and estimate impact, P-value of 0.09 with 3.6% impact per one standard deviation of renters' share.

Table 32. Regression results for urban and semi-urban areas

Southern Peninsula				**R-squared = 0.78**	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	3.65	0.71	5.12	0.00	-
Elevation	-0.15	0.02	-7.47	0.00	-2.1
Poquoson City	5.20	0.82	6.38	0.00	Out of range
Charles City	1.88	0.79	2.39	0.02	30.2
James City	0.90	0.62	1.46	0.15	13.5
New Kent County	2.28	0.71	3.24	0.00	37.5
York County	-0.32	0.64	-0.50	0.62	-4.4
Poverty rate of households	0.26	0.15	1.78	0.08	3.8
Virginia Beach				R-squared = 0.38	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	5.85	0.33	17.61	0.00	-
Elevation	-0.95	0.08	11.85	0.00	-12.6
Housing median value	0.53	0.11	4.79	0.00	7.8
Share of social assistance receivers	0.24	0.11	2.12	0.04	3.4
Renters' share of households	0.32	0.11	2.93	0.00	4.6
Norfolk				R-squared = 0.82	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	12.70	0.48	26.37	0.00	-
Elevation	-3.16	0.15	-21.00	0.00	-34.7
Housing median value	0.38	0.11	33.30	0.00	5.5
Share of no-internet access households	0.18	0.09	71.80	0.06	2.6
Portsmouth				R-squared = 0.74	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	12.75	0.73	17.52	0.00	-
Elevation	-2.95	0.21	-13.78	0.00	-33.0
Housing median value	0.43	0.18	2.40	0.02	6.3
Chesapeake				R-squared = 0.64	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	8.54	0.51	16.91	0.00	-
Elevation	-1.59	0.11	-14.06	0.00	-20.0
Share of bachelor's degree & higher	0.32	0.15	2.15	0.03	4.6
Renters' share of households	0.25	0.14	1.72	0.09	3.6
Hampton				R-squared = 0.48	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	8.91	0.68	13.00	0.00	-
Elevation	-1.47	0.19	-7.63	0.00	-18.6
Housing median value	0.53	0.26	2.03	0.05	7.8
Share of no-internet access households	0.56	0.26	2.12	0.04	8.2
Newport News				R-squared = 0.32	
Variable	Coefficient	Std error	T-value	P-value	Estimated impact
Constant	4.26	0.43	9.96	0.00	-
Elevation	-0.34	0.05	-6.85	0.00	-4.7
Share of below diploma	-0.40	0.10	-3.93	0.00	-5.5
Ratio of military to civilian employment	0.26	0.13	2.02	0.05	3.7

In the City of Norfolk, other than the previously mentioned significance of housing value, the share of households without internet access is positively associated with the climate risk. It is interesting to notice that variable is highly linked to Black share of population, 51% correlation, and share of below diploma population, 50% correlation. These findings indicate that there are communities with lower education and access to infrastructure with higher minority share that are at relatively higher risk in Norfolk. The share of no-internet access households is also significant for Hampton City, P-value of 0.04, with a higher impact. This shows a similar story in Hampton as this variable is highly correlated with the share of below diploma.

Looking at Chesapeake City, the share of individuals with a bachelor's degree or higher carries a positive association with climate risk, significant at 3%. Considering the strong link between this share and housing value, 72% correlation, and income, 70% correlation, indicates there are wealthy communities with high educational attainments exposed to higher risk in Chesapeake. This, in fact, is not a sign of vulnerability as such communities have higher financial and educational potentials to address and mitigate the challenges of climate risk. However, another spectrum of the population is at high climate risk, shown by the significance of renters' share.

In Newport News, the share of individuals without a high school diploma is negatively associated with risk indicating there are communities with higher educational attainment that are at high risk. Expectedly, the below diploma share has a significant negative correlation with housing value and share of population with a bachelor's degree. Here, a new significant variable is the military to civilian employment ratio, a P-value of 0.05. This indicates that there are communities with a relatively higher population of military employees that are at climate risk. We summarize all the significant associations of the regression models in Table 33.

Table 33. Significant associations between socioeconomic vulnerabilities and climate risk

Vulnerability	Northern Peninsula	Middle Peninsula	Eastern Shore	Southern Peninsula	Virginia Beach	Norfolk	Portsmouth	Chesapeake	Hampton	Newport News
Poverty rate of households				+						
Share of social assistance receivers			+		+					
Share of no-internet access households		+				+			+	
Share of below diploma	+									-
Share of bachelor's degree & higher								+		
Share of Black households	-	-								
Renters' share of households		-	-		+			+		
Housing median value					+	+	+		+	

Vulnerability	Northern Peninsula	Middle Peninsula	Eastern Shore	Southern Peninsula	Virginia Beach	Norfolk	Portsmouth	Chesapeake	Hampton	Newport News
Ratio of military to civilian employment										+

4.4. Discussion and Policy Implications

The findings of the previous section indicate significant associations between socioeconomic vulnerability measures and climate risk in Coastal Virginia; the pattern is varied between different localities in our studied area, as shown in Figure 17. The identified associations speak to the presence of correlation between certain socioeconomic vulnerabilities and climate risks in a locality. Socioeconomic vulnerabilities can limit the capabilities of communities in different phases of the adaptation process, i.e., understanding climate risks, developing, assessing, selecting options, and eventually implementing solutions to combat the risks (Moser and Ekstrom, 2010). Therefore, each detected vulnerability poses specific challenges for a local government to address this capability limitation. Looking at the correlations between dimensions of vulnerabilities would help the government learn about the limited adaptive capacities of vulnerable at-risk communities. The association between climate risk and vulnerabilities also calls for the introduction of particular programs and initiatives in the planning and policymaking for climate adaptation.

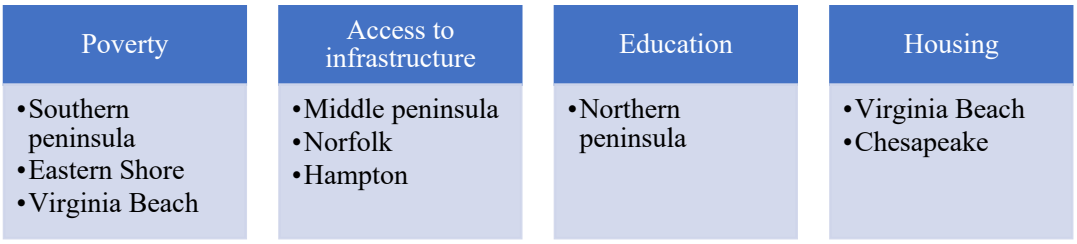

Figure 17. Summary of socioeconomic vulnerabilities

Share of social assistance receivers was significantly correlated with the risk in Eastern Shore and Virginia Beach, with a positive sign. In the Eastern Shore, this share holds a high positive correlation with the poverty rate of households, 62%, and a high negative correlation with the share of individuals holding a bachelor's degree or higher, 56%. These correlations indicate that there are communities at high climate risk with vulnerabilities related to poverty and low education attainment, both important in their capability to mitigate climate risks. In Virginia Beach, the share of social assistance receivers is highly linked to Black share, 51% correlation, and poverty rate, 50% correlation; we interpret this as high poverty communities living at a relatively higher risk. The poverty rate was significantly correlated with risk in the Southern peninsula as well. We also notice that the poverty rate is highly linked with the share of social assistance receivers in these areas, 47% correlation, moderately linked to income, -42% correlation, and the share of individuals without a high school diploma, 38% correlation. We interpret the significant coefficient for the poverty rate, accompanied by other correlations, to show the presence of socioeconomically vulnerable communities in this area, which have relatively higher exposure to climate risk.

Poverty-facing communities exposed to a higher risk of flooding in a locality often cannot afford to introduce protective measures for their assets in combatting flooding impacts. Local governments should consider specific programs and policies to mitigate their risk prior to the occurrence of flooding, during the incident, and after. This is aligned with ongoing discussions about the necessity in climate adaptation planning to improve access to infrastructure, public services, and awareness of climate impacts among

socially vulnerable communities (Shi *et al.*, 2016). Disadvantaged households and communities may also have several challenges, other than climate risks, that receive a higher priority (Amorim-Maia *et al.*, 2022). Poverty may translate to a lack of engagement in the adaptation policymaking process from such communities, resulting in their voices not being heard and their specific problems being disregarded or not understood, leading to their inability to access infrastructure and resources to mitigate climate impacts (Fiack *et al.*, 2021). Thus, it requires local governments to be proactive in engaging with vulnerable communities in adaptation planning.

The share of no-internet access households was significantly associated with climate risk, with a positive sign, in the Middle peninsula, Norfolk, and Hampton. It would be crucial for the governments of these localities to assess the extent of limited access to infrastructure in such vulnerable communities and to evaluate how equitably other infrastructure systems, e.g., transportation, water, and electric systems, are distributed between populations. Accessibility, quality, and reliability of such infrastructure systems would be necessary for each community to effectively respond to climate threats (Mearns and Norton, 2009). It is important for local governments to explore how infrastructure improvements can mitigate climate risks in vulnerable communities and prioritize such improvements in their adaptation efforts (Mearns and Norton, 2009; Pelling and Dill, 2010; Shi *et al.*, 2016). Lack of access to infrastructure for certain communities would also call for governments to develop their adaptation efforts with the participation of communities and non-governmental organizations to ensure vulnerable communities have representation in the decision-making process (Bulkeley *et al.*, 2013; Archer *et al.*, 2014). Lack of internet access specifically suggests that the local government needs additional or alternative means of communications in their adaptation programs as, without internet access, it might be difficult for communities to stay informed and engaged.

We observed a positive association between climate risk and the share of individuals without a high school diploma in the Northern peninsula. Regarding the moderate correlation of this share with the share having no-internet access, this could be interpreted as lower education communities, with relatively lower access to infrastructure, are at relatively higher climate risk in this area. Education deficit calls for programs for increasing communities' awareness about climate risk, mitigation alternatives, and available resources (Field, 2014; Lutz, Muttarak and Striessnig, 2014).

Renters' share significantly and positively correlated with climate risk in Virginia Beach and Chesapeake. In Chesapeake, the significance of renters' share and its high correlation with the share of social assistance receivers and Black share signals there are socioeconomically vulnerable communities who are exposed to relatively higher climate risk. Renters exposed to relatively higher risk need specific attention from the local government as flooding events would directly impact them while the owners generally make the decisions to prevent and mitigate such impacts (Dundon and Camp, 2021). They might not even be informed about the climate risks of their house because such information is solely conveyed to the owners (Dundon and Camp, 2021).

There was a significant and positive association between median housing value and the risk measure in Virginia Beach, Norfolk, Portsmouth, and Hampton. We interpret these findings as there are communities with high value of housing at climate risk in these cities. In all four cases, housing median value is highly linked to income and the share of individuals holding a bachelor's degree or higher, indicating that such communities are generally wealthier with higher educational attainments. This finding is aligned with the high desirability of being close to water shorelines leading to the high-value houses, primarily owned by wealthier households, on the shoreline in urban coastal Virginia.

The explanatory power of socioeconomic vulnerabilities underlines the disadvantages of such communities in exposure to climate risks. We only analyzed coastal flooding in this manuscript; however, other climate impacts, e.g., pluvial flooding, hurricanes, and extreme heat, may exacerbate the situation for vulnerable populations (Field, 2014). The general argument in social equity and environmental justice in climate adaptation is that as different populations are exposed to the climate risks as a new stressor, vulnerable communities have lower means to combat the risk (Kuhl *et al.*, 2014). The primary message of our analysis is that, at least for some cases, vulnerable populations are exposed to higher risk. This indicates that socially vulnerable communities having lower adaptation capacity are also facing higher climate risk in many instances. The other message is that some aspects of vulnerability are more closely aligned with climate risk in certain areas, which requires their local governments to consider those aspects in their adaptation policymaking efforts.

Understanding socioeconomic vulnerabilities is essential in planning and allocating resources for climate adaptation on different governance levels. It emphasizes the need to identify vulnerable communities and initiate specific programs to address the vulnerabilities on the local level. On a broader state or federal level, it can be a measure for allocating grants and loans to local governments. Integrating socioeconomic criteria in infrastructure design and decision-making is essential for equitable climate adaptation (Shi *et al.*, 2016). For example, the state government can maintain a socioeconomic vulnerability dashboard and use it as the baseline for allocating resources and projects to localities. Then an explicit adaptation grant could be awarded conditional on socioeconomic vulnerability criteria. More specifically, Virginia has recently initiated the Community Flood Preparedness Fund (CFPF), potentially distributing $100 million each year to localities to address their flooding issues. The vulnerability dashboard can be adopted as a requirement for any locality that will use CFPF funds.

We find that homeowners are at a higher climate risk in rural areas, e.g., the Middle Peninsula and Eastern Shore. The policy implication of this finding is that if retreat or relocation is going to be the solution to risk for some communities, it is probably harder to implement it in rural areas as it is harder to convince owners with higher attachment to relocate. In urban areas, high-value housing being at risk decreases local governments' incentive to relocate such communities as it increases their lost revenue from property taxes. Thus, overall local governments, either rural or urban, may be challenged in incentivizing relocation and would try to protect the housing and infrastructure as much as possible. This calls for a policy intervention from higher-level governments regarding retreat planning (Koslov, 2016; Siders, Hino and Mach, 2019).

The findings of this chapter are subject to certain methodologic limitations. First, the ACS 5-year estimates on block group level have a relatively high margin of error compared to less granular data. This can potentially influence the regression estimates. Using the 2020 Census data can potentially address this caveat; however, this data is still not available at this time. Secondly, there is criticism in the literature about using stepwise regression as it is argued that the outcomes are dependent on the order of introducing variables into the model resulting in unreliable outcomes (Wiegand, 2010). We addressed this challenge by repeating each regression with random order of variables, and we observed no difference in the selected variables, although the backward and forward methods sometimes provided different outcomes. This was not a problem for this research because, as explained in Section 4.2.2, we saved and compared our regressions after each round of ensuring the independent variables were not correlated. So, for each area, we had a few regressions that were eventually compared based on AIC to select the final model reported in this manuscript.

4.5. Conclusion and Future Research

This chapter developed a climate risk measure based on coastal flooding, derived several socioeconomic vulnerability variables, and tested if they could explain spatial patterns in risk exposure. We find vulnerability measures of poverty, access to infrastructure, education, and housing to explain climate risks in specific areas of the study. This poses two types of questions. First, why are certain factors significantly associated with the risk in one area? That is an essential exploration for local governments to understand the patterns of risk based on historical and ongoing patterns of neighborhood development, capital investment, and movement of people in a locality. The origins of such differential risk exposure might stem from the historical movement of vulnerable populations to undesired neighborhoods, or might be caused by inequitable investment decisions in infrastructure, or they might have been increased or exacerbated due to a lack of adequate political representation (Hoffman, Shandas and Pendleton, 2020; Nardone *et al.*, 2021; Schinasi *et al.*, 2022). Secondly, what should be done, now, to respond to an association between a vulnerability and climate risk? This question is crucial in adaptation planning and policymaking on different governmental levels. A local government learning about appropriate access to infrastructure in risky areas, for example, would need to examine how this access challenge affects citizens' abilities for an appropriate response to climate risk in understanding, planning, managing, and implementation. This could shed light on a lack of structural flood protection or insufficiency of drainage systems within the vulnerable areas of the locality. Local governments can leverage such insights for optimum, efficient, and equitable adaptation planning in the future. It would be crucial to understand the distribution of socioeconomic vulnerability and its relation to climate risk within localities at a higher governance level, for example, the state government. Understanding the different dimensions of vulnerability could affect the formulation of policies to allocate resources in places and programs that are most needed. It can also encourage the state government to track specific vulnerabilities through time and examine how they are prioritized in planning for adaptation. We believe such an effort is essential to ensure equitable climate adaptation because adaptation is in its primary stage of planning at this point, and many implementations remain to be realized in the years to come.

This research can be extended in several avenues. We used coastal flooding as the primary source of risk in developing our climate risk factor. It would be interesting to include other causes of risk, e.g., pluvial flooding or extreme heat, into the risk measurement and evaluate it based on the vulnerability measures. It would also be fruitful to expand the vulnerability variables to capture quality of life and physical and mental health factors using new data sources. This study can be extended to other coastal regions in the U.S. to identify and compare the vulnerabilities between Coastal Virginia and other regions. It would be particularly instrumental in formulating equitable adaptation policies at the national level. This chapter studied and associated climate risk with socioeconomic vulnerabilities. A next step is to assess whether local adaptation programs and projects address the vulnerabilities or aggravate the situation by inequitable distribution of available resources. Such assessment can become feasible as we learn more about the extent of adaptation and resilience projects in Coastal Virginia. This task is vital as discovering a potentially skewed resource allocation can pave the way for policy adjustment at the local level and policy intervention from higher levels of government. A different and exciting line of research is to analyze how a specific vulnerability can play a role in adapting communities to climate change impacts. For example, it would be essential to know how lack of educational attainment in specific communities affects their behavior and decision-making in adaptation. Discovering such linkages can certainly help local governments in their endeavors to design and implement adaptation and support programs.

Chapter 5

Policy Analysis for Managed Retreat

The findings of Chapters 2 and 3 indicate that local governments need to have a policy framework to effectively plan for climate adaptation. This chapter proposes a dynamic policy framework and then uses the framework to model managed retreat. Planning for a managed retreat is essential as public policies are needed to address at-risk households that might be damaged or destroyed by more frequent and severe storm surges and coastal flooding. To ensure the public's well-being and save billions of dollars in damages, the policies must mitigate the consequence and likelihood of risky extreme storm events. Design and implementation of policies face challenges in prioritizing community safety considering budget and community values as constraints. This chapter intends to answer the questions: 1) what are effective public policies to address climate risk at the household level in coastal areas, and 2) how does this scale fit within a community comprised of diverse individual households?

To answer these questions, an economic framework is developed, addressing housing policy analysis in coastal areas facing climate risk by modeling the decision of households to move from environmentally risky coastal areas to safer inland regions. This happens through a threshold model capable of explaining the moving decisions of households. Households with different wealth levels can decide to either stay or move to a safer location based on their perception of future risk and their financial and physical mobility. Different intervention scenarios by the government are developed and analyzed. This research has several theoretical and empirical outcomes demonstrating the behavior of households and the optimum policies to be taken, paving the way for a comprehensive policy analysis platform that would be adaptable to specific geographic, economic, and environmental conditions.

The proposed framework in this chapter can address adaptation challenges on different governance levels in an analytical and participatory manner, an approach that we will needed in Coastal Virginia and elsewhere as the impacts of climate change and their implications unfold within the decades to come.

5.1. General Policy Framework

Governments are developing adaptation policies at different levels by integrating climate aspects into their development frameworks (Field, 2014). Along with that, there is a rich body of research in climate adaptation trying to rank adaptation options based on theoretical or experimental studies around the globe (De Bruin *et al.*, 2009; Bachner, 2017; Bachner, Bednar-Friedl and Knittel, 2019; Vöhringer *et al.*, 2019; Molenveld, van Buuren and Ellen, 2020). There are also research studies suggesting adaptation frameworks. For example, Ranger et al. suggest a framework for adaptation decision-making, which entails three steps: structure the problem, appraise solutions, and implementation (Ranger et al., 2010). It provides some guidelines for policymakers approaching adaptation without providing an analytical tool or considering the decision-making process.

Research case studies can achieve significance if presented as a platform to inform existing social structures and enable implementation of political objectives but equally improve the existing institutions (Larsen et al., 2012). It is also suggested that using market-based instruments, e.g., preferential taxes, subsidies, and marketable permits, can engage local stakeholders, stimulate individual adaptation through price signals, and become more attractive as consequences of climate change intensify (Filatova, 2014). Finally, several papers argue for the importance of justice and vulnerability, concluding that adaptation planning participation should be broadened (Shi et al., 2016; Adger, Butler and Walker-Springett, 2017).

We propose a dynamic policy framework building upon the findings of previous chapters about adaptation policymaking in Coastal Virginia. More specifically, the lack of comprehensive planning is one of the main challenges for adaptation. The policy framework, shown in Figure *18*, strives to address this challenge by providing a structure to analyze the adaptation challenges and help local governments in decision-making and planning for adaptation. We mainly focus on local government as the previous chapters revealed that local governments are at the frontline of adaptation, and this fight is being fought primarily at the local level. There are a few critical components in the framework for addressing climate challenges through adaptation planning:

- Adaptation decisions must be modified and adjusted as new risks and issues arise, or new information and possibilities come to the scene. So, it should be an iterative process with continual evaluation
- Local governments are bound by regulations of higher-level governments and can take advantage of potential grants and supports from the state and federal government
- Objectives and ongoing challenges and issues are specific to each locality, providing significant inputs to the framework
- Engagement of various stakeholders in decision-making is necessary to ensure the policies are socially acceptable and equitable
- A “Policy Analysis Tool” is required to analyze policies in economic, social, and political dimensions. That provides input material for a fruitful conversation among decision-makers, stakeholders, and environmental advocates

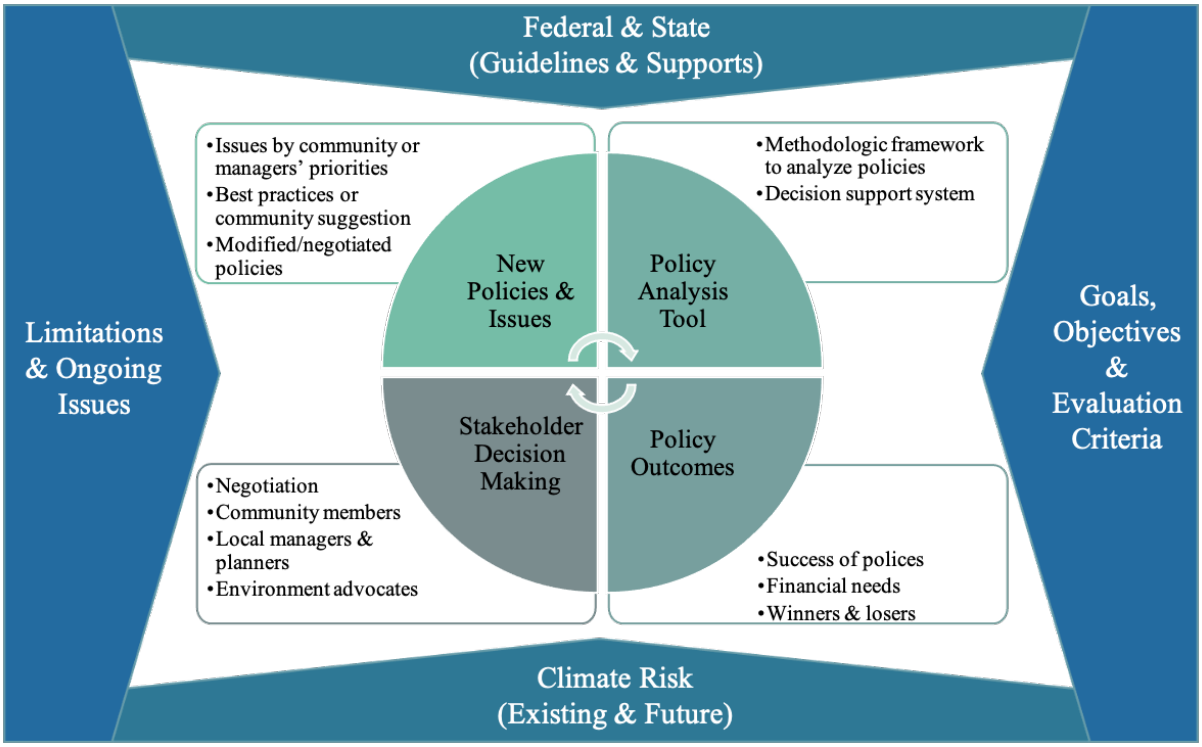

Figure 18. Policy framework for local adaptation

The "Policy Analysis Tool," shown in Figure *19*, is a crucial component of the policy framework for local adaptation policymaking. This tool provides a logical process for analyzing any policy issue. It is important to note that local governments, particularly in smaller and rural localities, may not have the technical capability to follow the steps of this tool for each policy issue. Therefore, it would be necessary for academia or some other capable agent to engage with local decision-makers to learn about their challenges and help them set up and implement this tool for essential adaptation decisions. These decisions include "managed retreat" or infrastructure investments with vast financial requirements and extensive socioeconomic consequences. Our previous analysis in Chapter 2 shows that academic institutions have historically been trying to engage with and help local governments, which could be an excellent opportunity to implement the proposed analysis tool.

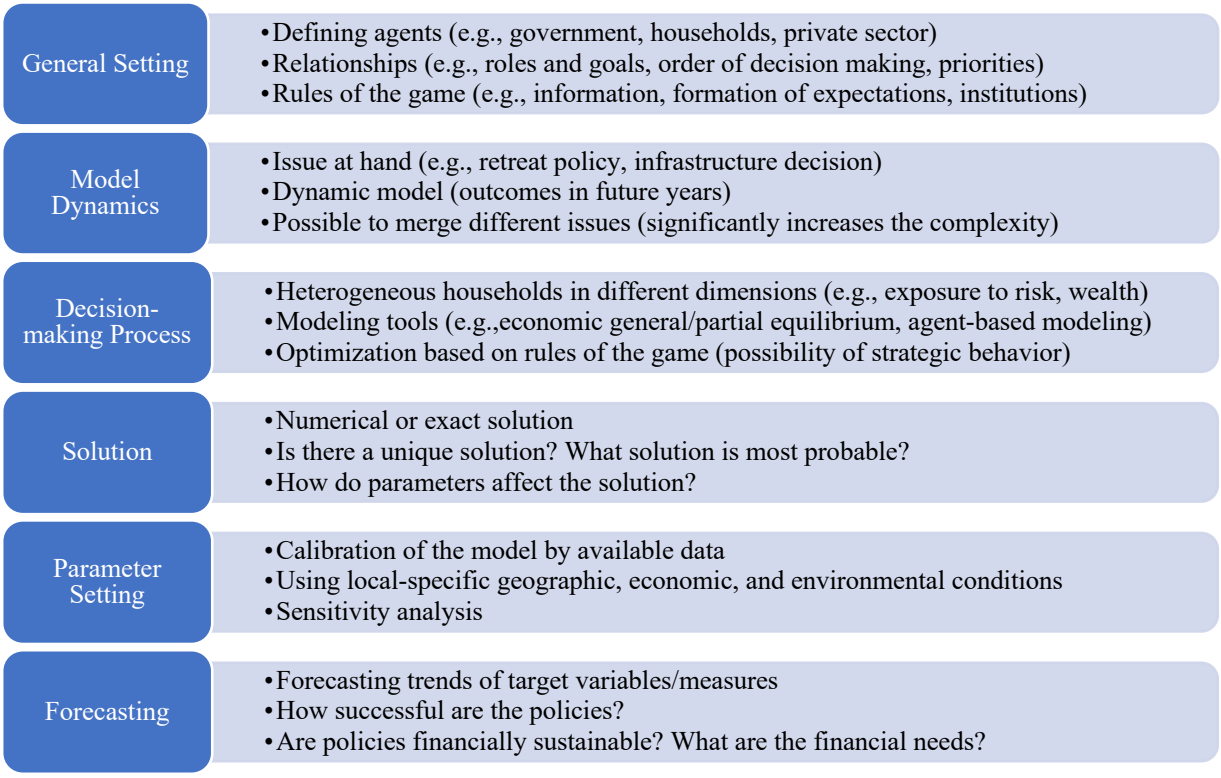

Figure 19. Policy analysis tool

5.2. Introduction to Managed Retreat

Climate change has increased the frequency and severity of weather-related natural disasters in the last decade and promises to continue this trend in the future (IMF, 2017). The United States has sustained 310 extreme weather and climate disasters since 1980, with costs exceeding $2.155 trillion (NOAA, 2022a). The annual average number of such disasters is 7.4 events from 1980 to 2021. However, this number rose to 17.2 events per year within the last five years, i.e., 2017 – 2021, indicating a 230% increase. Coastal areas are one of the most vulnerable locations for climate-related natural disasters. For example, flooding is estimated to be from 300% to 900% more frequent in U.S. coastal communities than just 50 years ago. At the same time, almost 40 percent of the U.S. population lives in high-population-density coastal areas, exposing them to the increased risks of sea-level rise, flooding, shoreline erosion, and other climate hazards (NOAA, 2021).

Within areas of high climate risk, there is heterogeneity among localities/neighborhoods regarding their risk of exposure to natural disasters. For households living in localities that are exposed to a high risk of disasters, it might be reasonable to move to safer locales. Assuming symmetric information, this will cause the property price in risky neighborhoods to decrease while the excess demand for housing in safer surroundings would increase property prices in those locations. This puts residents in areas of high climate risk at an economic disadvantage relative to those in safer locations. Low-income households and communities are at the greatest disadvantage in this situation. They are likely to have the least capacity for climate resilience in the form of insurance and damage-reduction modifications to their property and suffer the most significant losses as a percentage of household income as a result (SAMHSA, 2017). Furthermore, their relatively low assessed property value and high expected losses from disasters make them least likely

to be able to afford the move to more expensive and safer locations. The result is that when government-subsidized assistance is offered to residents in this situation, they tend to rebuild in the areas of high risk, thereby perpetuating the cycle of disaster-related immobility and poverty. Government safety-net programs, such as National Flood Insurance Program (NFIP), are of little to no benefit to households that are not informed or cannot afford the premiums. Furthermore, these programs encourage risk-seeking behavior among the insured by enabling them to rebuild repeatedly in areas of high risk from flooding. Indeed, the NFIP was $25 billion in debt in August 2017, partly because of this feature (WSJ, 2017).

Managed retreat is an adaptation solution suitable for high-risk areas with a high risk of flooding, storm surge, and SLR, defined as "the purposeful, coordinated movement of people and assets out of harm's way" (Siders, 2019b). Most examples of managed retreat have happened as a response to the damages and disruptions of disasters; however, managed retreat has to become a proactive adaptation solution for particular areas (Lawrence et al., 2020). There is a growing body of literature introducing managed retreat's determinants and challenges based on case studies and experiences of previous retreat programs (Hino, Field and Mach, 2017; Siders, 2019a; Doberstein, Tadgell and Rutledge, 2020; Dundon and Abkowitz, 2021; Pinter, 2021; Tubridy, Scott and Lennon, 2021). For example, Miao and Davlasheridze (2022) study the institutional factors affecting government buyouts in an empirical analysis of buyout projects funded by the federal Hazard Mitigation Grant Program from 1990 to 2016 (Miao and Davlasheridze, 2022). They find that counties with higher property tax and less reliance on the tax have more buyout projects suggesting that fiscal limitations have a significant role in undertaking buyout decisions. Interestingly, they find that flood insurance and levee protection negatively affect the buyouts of flood-prone properties. Siders (2019) discusses several practical, institutional, and psychological barriers creating the need for leadership, vision, and coordination of diverse actors (Siders, 2019a). Siders also argues for an urgency to plan and have conversations about managed retreat and to formulate policies that can help coastal areas, which can be implemented within the next few decades.

There has also been recent attention to social equity and climate justice in managed retreat, calling for better evaluation measures and broader transparency and community involvement in the process of policy design and implementation (Aidoo, 2021; Siders and Ajibade, 2021). For example, Kraan et al. study social equity in buyout programs of the U.S. by identifying the primary stakeholders and presenting guidelines to reduce the existing social inequities (Kraan et al., 2021). The four primary stakeholders in this story are communities in which the buyouts occur, potential participants, households remaining in buyout communities, and destination communities. In a recent study, Tubridy et al. (2022) suggest a coproduction approach to address the justice issues of managed retreat in coastal areas (Tubridy, Lennon and Scott, 2022). Coproduction, as they suggest, involves gathering local risk data, connecting the local knowledge to the formal decision-making process, and a community-led retreat process.

Given its importance for human welfare and the economy, there is a dearth of research on the theory and practice of climate adaptation, its political economy and understanding the role and behaviors of stakeholders (Fankhauser, 2017). Housing policy regarding natural disasters is a wicked and messy problem. For example, the extant literature on home buyout programs is too sparse to determine their viability or desirability as a disaster recovery tool (Binder and Greer, 2016). Although the U.S. government has used buyout programs intermittently since the late 1970s and promoted their use as disaster policy tools, evidence indicates that policy learning in this area is limited or absent (Greer and Brokopp Binder, 2017). Moreover, there is a lack of planning frameworks and tools to support local, state, and federal decision-making about the managed retreat as an adaptation solution; frameworks that anticipate the policy outcomes

and help the policymakers design effective and efficient retreat programs (Lawrence et al., 2020; Dundon and Abkowitz, 2021). This chapter addresses this gap by using the policy analysis tool introduced earlier to model managed retreat policies for a risky area and answer the following questions:

- How to model and compare different retreat policies?
- What retreat policy is the most successful for a locality?

As micro-level decision-making of households is required to find each policy's outcomes, a general equilibrium economic framework is developed to address these questions, focusing on housing policy analysis in coastal areas facing climate risk (Shoven and Whalley, 1992). The research will model a household's decision to move from an at-risk coastal area to a safer inland region. Households with different wealth levels can decide to stay or move to a safer location based on their perception of future risk and economic and physical mobility. The following intervention scenarios are developed and analyzed by measuring the success, cost, and discriminatory impacts using simulated data. The scenarios are chosen based on their use in the economics literature and their intuitive potential for helping the process from a policymaker's perspective (Filatova, 2014):

1. Climate Aware Home Insurance (CAHI)
2. Subsidizing Home Insurance Premiums in High-risk Areas (SHIP)
3. Subsidizing Relocation to a Safe Area (SRSA)
4. Taxing Risky/Subsidizing Safe Construction (TRSS)
5. Offering Home Buyouts in Risky Areas (OHBR)
6. Mortgage Adjustment for Risky Areas (MARA)

5.3. Model Development

This section will model the six introduced policy intervention scenarios for the government. For each scenario, we develop and solve a model to represent the policy, then use scenarios to examine the policy's effect on households' decision-making for climate risk mitigation. Our general framework includes three main modules: households, government, and other influential entities, including insurance and banking sectors, Figure *20*. Households are utility maximizers with heterogeneity in their wealth and exposure to the risk of natural disasters. The government is assumed to be benevolent in introducing a housing policy to help citizens mitigate the risks of natural disasters. It is also assumed that the government has ex-ante information about the risks of natural disasters and the wealth of the population, so by designing a policy, it would be able to estimate the outcomes of a policy before the implementation. This provides the government with an opportunity to analyze and compare different policies. The third module of the framework considers banking and insurance sectors as competitive economic agents that respond to policies and regulations to maximize their profit. We use a dynamic model with three periods here, while each period is considered to be 20 years in estimation and evaluation of the models:

- Period Zero: Households realize the risk posed by natural disasters
- Period One: Government introduces a policy while households and other stakeholders make decisions accordingly
- Period Two: Natural disaster happens and affects different localities based on their risk factor

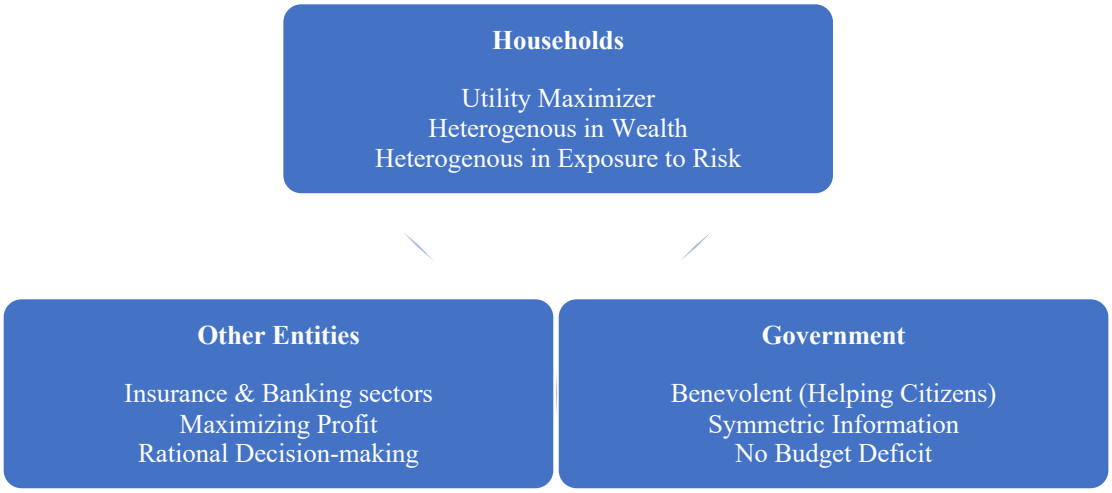

Figure 20. Conceptual framework of the analysis

We want to see which homeowners will benefit from the proposed policies and to what extent. To make the scenarios comparable, we assume the same wealth distribution and credit risk for homeowners (households), the same risk level for a disaster event, the same geographic distribution of population in different areas, and demand function for housing in different geographies across all scenarios. Housing demand is assumed a log-linear function that is negatively affected by the price of the house in the market, price elasticity of demand (b) having a negative value (Hanushek and Quigley, 1980). We also calculate the total cost of each policy and compare them to understand the budget a government needs to allocate for the implementation of different policies. Moreover, we analyze the equity of government interventions in the discussion section. Equation (3) shows the general model while the details are explained in Table 34.

$$\underset{C_0^i, C_1^i, I^i, M^i}{\text{Max}} Z^i = U(C_0^i) + \beta . U(C_1^i) + \beta^2 . \left[M^i . \left[I^i . U_H^S + (1-I^i) . (1-\rho^S) . U_H^S \right] + (1-M^i) . \left[I^i . U_H^R + (1-I^i) . (1-\rho^R) . U_H^R \right] \right]$$

Subject to:

$$C_0^i + C_1^i + M^i . \left[\Delta P + I^i . Pr^S + MC \right] + M^i . \left[IP_1 . I^i . (-s^I . Pr^S) + IP_2 . (-s^M . \Delta P) + IP_3 . [(1-s^C) . P_S - P_R] + IP_4 . (-s^R . MC) \right] + (1-M^i) . \left[I . Pr^R \right] + (1-M^i) . \left[IP_1 . I^i . (-s^I . Pr^R) + IP_3 . P_R . \tau^C \right] \leq W^i \quad (3)$$

$$C_0^i, C_1^i \geq 0, I^i \in \{0,1\}, M^i \in \{0,1\}$$

$$IP_1, IP_2, IP_3, IP_4 \in \{0,1\}$$

Table 34. Settings of the managed retreat model

Sign	Definition	Type
U	Utility of consumption	Setting of the model
U_H	Utility of having a house	Setting of the model
C_0^i	Consumption at time 0	Households' decision variable
C_1^i	Consumption at time 1	Households' decision variable
I^i	Decision to take insurance	Households' decision variable
M^i	Decision to move	Households' decision variable
IP_1	Intervention policy 1 (Insurance subsidy)	Government's decision variable
IP_2	Intervention policy 2 (Moving subsidy)	Government' decision variable

Sign	Definition	Type
IP_3	Intervention policy 3 (Construction tax & subsidy)	Government' decision variable
IP_4	Intervention policy 4 (Relief subsidy)	Government' decision variable
MC	Moving costs	Parameter
β	Discount factor of time	Parameter
ρ^R, ρ^S	Risk factor of risky & safe area	Parameter
s^I	Insurance subsidy	Parameter
s^M	Moving subsidy	Parameter
s^R	Relief subsidy	Parameter
s^C	Construction subsidy	Parameter
τ^C	Construction tax	Parameter
ΔP	Difference of housing price in safe & risky area	Variable
Pr^R, Pr^S	Insurance premium in risky & safe area	Variable

5.3.1. Climate Aware Home Insurance (CAHI)

Within this policy, a particular property insurance is introduced that considers climate risks in the prices (premium) that insurance providers offer. Two versions of this policy are analyzed here: First, households do not move from a risky area to a safer one, and second, households choose to move to a safer area.

No Moving. This model is formed of two main stakeholders: households and insurance companies. We will introduce the utility function and budget constraint for both. The households' problem is shown in equation (*4*).

$$\max_{C_0,C_1,I^i} Z^i = U(C_0{}^i) + \beta.U(C_1{}^i) + \beta^2.U_H{}^i.[1-(1-I^i) \,.\, \rho^i]$$

Subject to: (4)

$$C_0{}^i + C_1{}^i + I^i \,.\, Pr^i \leq W^i$$

$$I^i \in \{0,1\}\,,\; C_0{}^i, C_1{}^i \geq 0$$

Where $C_0{}^i$ and $C_1{}^i$ are consumption of household (i) in the first and second periods. β is the discount factor and ρ^i is the riskiness of the house. I^i represents the decision of the household (i) to either take or not take the insurance by paying a premium (Pr^i) at time zero and covering the damages to the house at time two by the insurance company. U is the utility function of consumption, which is assumed to be logarithmic as repeatedly used in the literature (Mas-Colell, Whinston and Green, 1995). Decision-making for each household determines if they buy the insurance and how much they spend on consumption. We use method of Lagrange multipliers to solve the decision-making problem (Shoven and Whalley, 1992). Deriving and solving the first-order conditions for each household, we will have equation (*5*).

$$Z_1{}^i = (1+\beta).\log(W^i) - (1+\beta).\log(1+\beta) + \beta.\log(\beta) + \beta^2.(1-\rho^i).U_H{}^i$$
$$Z_2{}^i = (1+\beta).\log(W^i - Pr^i) - (1+\beta).\log(1+\beta) + \beta.\log(\beta) + \beta^2.U_H{}^i \quad (5)$$

Where $Z_1{}^i$ is the maximum utility household (i) can receive without insurance, while $Z_2{}^i$ is its maximum utility with insurance. Each household will choose the option that provides them with the highest utility.

Assuming the insurance industry is competitive, we would know that the profit for the insurance company is zero. So, the insurance company receives Pr^i from household (i) and will pay P (House Price) at the time of the disaster, which will happen by probability ρ^i. We assume that the house price and the risk would be the same for all the houses in an area. The zero-profit condition would result in equation (6).

$$Pr^i = P * \rho^i \tag{6}$$

$$W^* = \frac{P \cdot \rho^R}{1-\exp\left(-\frac{\beta^2 \cdot \rho^R \cdot U_H}{1+\beta}\right)} \tag{7}$$

Using equations (4), (5), and (6), the wealth threshold (W^*) for buying the insurance is shown in equation (7). So, households with a wealth level higher than W^* would buy the home insurance, while the lower ones will not and remain uninsured. Analyzing equation (7), we derive $\frac{\partial W^*}{\partial \rho^R} \geq 0$, meaning that if a locality is riskier, the wealth threshold would be higher. This means that a smaller portion of households in a riskier locality would buy insurance, which is opposite to what should indeed happen. This has an implication for the policymaker to pay more attention to riskier areas in that introduction of specifically designed insurance would probably not help the community a lot. Another executive form, which has similar results, would be to establish a new insurance program to handle risks associated with climate change. This program would have the same implications in terms of modeling, which will be discussed later.

Possibility of moving. In this case, we analyze households' decisions in two dimensions: buying insurance and moving. For households living in a safe area, the decision would be similar to the standard CAHI case as they just need to decide on buying insurance. However, households in the risky area have four options:

- Move & Buy Insurance
- Move & Not Buy Insurance
- Not Move & Buy Insurance
- Not Move & Not Buy Insurance

Then, the utility of a household (i) living in a risky area would be either of the formulas in equation (8). The household then would pick the best option for them. We will discuss the outputs in the next section.

$$\begin{aligned}
Z_1^i &= (1+\beta).\log(W^i - \Delta P - Pr^S) - (1+\beta).\log(1+\beta) + \beta.\log(\beta) + \beta^2.U_H^S \\
Z_2^i &= (1+\beta).\log(W^i - \Delta P) - (1+\beta).\log(1+\beta) + \beta.\log(\beta) + (1-\rho^S).U_H^S \\
Z_3^i &= (1+\beta).\log(W^i - Pr^R) - (1+\beta).\log(1+\beta) + \beta.\log(\beta) + \beta^2.U_H^R \\
Z_4^i &= (1+\beta).\log(W^i) - (1+\beta).\log(1+\beta) + \beta.\log(\beta) + \beta^2.(1-\rho^R).U_H^R
\end{aligned} \tag{8}$$

5.3.2. Subsidizing Home Insurance Premiums in High-risk Areas (SHIP)

The government would partially cover the home insurance plan specifically designed to consider climate change risks in this scenario.

No Moving. The outcome here would be similar to the one of the previous section, with a slight modification of the introduction of the subsidy rate into the model, depicted in equation (9).

$$W^{*}=\frac{(1-s^{I})P\,.\,\rho^{R}}{1-\exp\left(-\frac{\beta^{2}.\,\rho^{R}.U_{H}}{1+\beta}\right)} \tag{9}$$

Possibility of moving. Here, the utility of a household (i) living in the risky area would be either of the formulas in equation (10). The household would pick the best option for them. We will discuss the outputs in the next section.

$$\begin{aligned}
Z_1^{\,i} &= (1+\beta).\log\left(W^{i}-\Delta P-(1-s^{I}).Pr^{S}\right)-(1+\beta).\log(1+\beta)+\beta.\log(\beta)+\beta^{2}.U_H^{\,S}\\
Z_2^{\,i} &= (1+\beta).\log(W^{i}-\Delta P)-(1+\beta).\log(1+\beta)+\beta.\log(\beta)+(1-\rho^{S}).U_H^{\,S}\\
Z_3^{\,i} &= (1+\beta).\log\left(W^{i}-(1-s^{I}).Pr^{R}\right)-(1+\beta).\log(1+\beta)+\beta.\log(\beta)+\beta^{2}.U_H^{\,R}\\
Z_4^{\,i} &= (1+\beta).\log(W^{i})-(1+\beta).\log(1+\beta)+\beta.\log(\beta)+\beta^{2}.(1-\rho^{R}).U_H^{\,R}
\end{aligned} \tag{10}$$

5.3.3. Subsidizing Relocation to a Safe Area (SRSA)

Here, we model a policy that encourages house owners to move from risky to safe areas by subsidizing the price difference. Here, we assume there are two areas, safe (S) and risky (R). Households living in the risky area could sell their house and move to the safe area. However, due to higher demand for the safer area, they need to pay higher, shown by $\Delta P = P_S - P_R$. If a household (i) does not move, their problem would be as shown in equation (11).

$$\max_{C_0,C_1,I^{i}} Z_1^{\,i}=U(C_0^{\,i})+\beta.U(C_1^{\,i})+\beta^{2}.(1-\rho^{R}).U_H^{\,R}$$

Subject to:

$$\begin{aligned}
&C_0^{\,i}+C_1^{\,i}\le W^{i}\\
&C_0^{\,i},C_1^{\,i}\ge 0
\end{aligned} \tag{11}$$

Where $C_0^{\,i}$ and $C_1^{\,i}$ would be their consumption in the first and second period, while W^{i} represents the wealth of the household (i). U is the utility acquired by consumption and $U_H^{\,S}$ ($U_H^{\,R}$) shows the utility of having a house in the safe (risky) area. If the household decides to move, their problem is formulated in equation (12).

$$\max_{C_0,C_1,I^{i}} Z_2^{\,i}=U(C_0^{\,i})+\beta.U(C_1^{\,i})+\beta^{2}.(1-\rho^{S}).U_H^{\,S}$$

Subject to:

$$\begin{aligned}
&C_0^{\,i}+C_1^{\,i}+(1-s^{M}).\Delta P\le W^{i}\\
&C_0^{\,i},\,C_1^{\,i}\ge 0
\end{aligned} \tag{12}$$

The household would not need to pay all the price difference, as government subsidizes the price difference with parameter s^{M}. The wealth threshold would be defined as a wealth level that divides households living in the risky area into two groups: those with lower wealth than threshold equation (13) who stay, and those with higher wealth than threshold who leave.

$$W^{*}=\frac{(1-s^{M}).\Delta P}{1-\exp\left(-\frac{\beta^{2}\left[(1-\rho^{S}).U_H^{\,S}-(1-\rho^{R}).U_H^{\,R}\right]}{1+\beta}\right)} \tag{13}$$

Equation (13) shows that the subsidy directly affects the households' decision-making by decreasing the wealth threshold. Indeed, the higher the subsidy, the higher the share of the population that would move to the safe area. It is also observable that a higher price difference between the safe and risky area would translate to a lower moving of households. This price difference would be determined based on housing demand functions in the safe and risky areas.

5.3.4. Taxing Risky/Subsidizing Safe Construction (TRSS)

This policy takes advantage of tax and subsidies on construction. For the purpose of illustration, we assume a 20-year average life for a house. Thus, the policy could be formulated within the framework of the model introduced before. If a household decides to move, its optimization problem would be as equation (14). Equation (15), however, represents the case when the household decides to stay. So, comparing the two possibilities, a household will decide to move or stay. To achieve their goals, the policymaker would observe this behavior and adjust their policy instruments, subsidy (s^C), and tax (τ^C). By deriving the first-order conditions, the wealth threshold for the decision on leaving would be as shown in equation (16).

$$\max_{C_0,C_1} Z_1^{\,i} = U(C_0^{\,i}) + \beta.U(C_1^{\,i}) + \beta^2.(1-\rho^R).U_H^{\,R}$$

Subject to:

$$C_0^{\,i} + C_1^{\,i} + \tau^C.P_R \leq W^i \tag{14}$$

$$\max_{C_0,C_1} Z_1^{\,i} = U(C_0^{\,i}) + \beta.U(C_1^{\,i}) + \beta^2.(1-\rho^S).U_H^{\,S}$$

Subject to:

$$C_0^{\,i} + C_1^{\,i} + (1-s^C).\ P_S - P_R \leq W^i \tag{15}$$

$$W^* = \tau^C.P_R + \frac{(1-s^C).P_S - (1+\tau^C).P_R}{1-\exp\left(-\frac{\beta^2\left[(1-\rho^S).U_H^{\,S} - (1-\rho^R).U_H^{\,R}\right]}{1+\beta}\right)} \tag{16}$$

5.3.5. Offering Home Buyouts in Risky Areas (OHBR)

Entering the housing market as a buyer would be another intervention policy. Here, by being a house buyer in the risky area, the government keeps the price of houses almost stable in that area. However, as households who possibly sell their houses in the risky area would like to move to a safe one, prices would ascend in the safe one. This means that affordability would still be an issue for some households. The wealth threshold for households would be formulated as equation (17). This shows that the threshold would decrease by this intervention, meaning that more households would decide to move.

$$W^* = \frac{\Delta P}{1-exp\left(-\frac{\beta^2.\left[(1-\rho^S).U_H^{\,S} - (1-\rho^R).U_H^{\,R}\right]}{1+\beta}\right)} = \frac{P^S{}_{new} - P^R{}_{old}}{1-exp\left(-\frac{\beta^2.\left[(1-\rho^S).U_H^{\,S} - (1-\rho^R).U_H^{\,R}\right]}{1+\beta}\right)} \tag{17}$$

5.3.6. Mortgage Adjustment for Risky Areas (MARA)

This intervention refers to a mandate for financial institutions to provide mortgages that permit moving to a new house without extra costs. Indeed, most houses are financed by mortgages, and moving decisions are seriously affected by mortgage costs. Implementing this policy into our basic model with the introduction of mortgage cost, M, would result in equation (18) as the moving threshold. As the policy adjustment takes

effect, the cost of M would decrease to zero, increasing the percentage of households willing to move. Admittedly, this is a major market intervention by the government, which is an unlikely scenario in the real world, even under a policy of managed retreat from increasing climate risk.

$$W^{*}=\frac{\Delta P+M}{1-\exp\left(-\frac{\beta^{2}.\left[(1-\rho^{S}).U_{H}{}^{S}-(1-\rho^{R}).U_{H}{}^{R}\right]}{1+\beta}\right)} \tag{18}$$

5.4. Results

This section discusses the outcomes of the policies introduced in the previous section. We use simulated data to evaluate the outcomes. We simulate data for a risky area, a risk factor of 80%, 1,000 houses, and a safe area, a risk factor of 10%, 10,000 houses. We assume each household living in the risky area owns a house and holds a wealth stack, which is simulated by Chi-square distribution as shown in Figure 21 (The Federal Reserve, 2020; U.S. Census Bureau, 2022). The housing market is assumed to be competitive following the rule of supply and demand, meaning that as households move to the safe area, the price of houses in both areas will change based on the demand function for housing. We assume parameter β to be 0.82 as the compound utility discount factor for 20 years, while the annual discount rate is assumed 0.99 in accordance with estimates of close to one in the economics literature (Andreoni et al., 2010). We implemented the introduced models in Python to attain numerical results based on the simulated data.

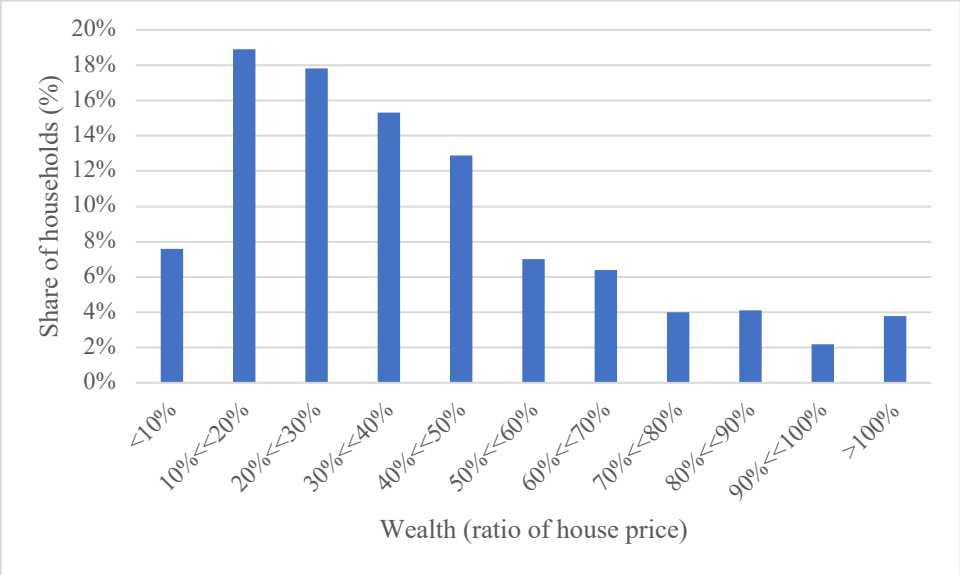

Figure 21. Distribution of wealth for residents of the risky area

5.4.1. Climate Aware Home Insurance (CAHI)

No Moving. By considering a logarithmic function for $U_H{}^{i}$ in equation (4), the wealth threshold for taking the insurance would be as shown in equation (19). As observable in Figure 22, by the increase of risk in an area, the wealth threshold for taking the insurance would increase, and insurance intake drops. This is a massive problem since by increasing the risk, we expect more households to buy insurance. However, the model shows that the opposite is likely. For example, in an area with 80 percent of households at risk, only about 10 percent of the households would take the insurance.

$$W^{*}=\frac{P\cdot\rho^{R}}{1-P^{\frac{-\beta^{2}\cdot\rho^{R}}{1+\beta}}} \tag{19}$$

Possibility of Moving. The outcome of this scenario is depicted in Figure 23. We observe the same pattern here. Moreover, there is an increasing pattern of moving as the risk increases.

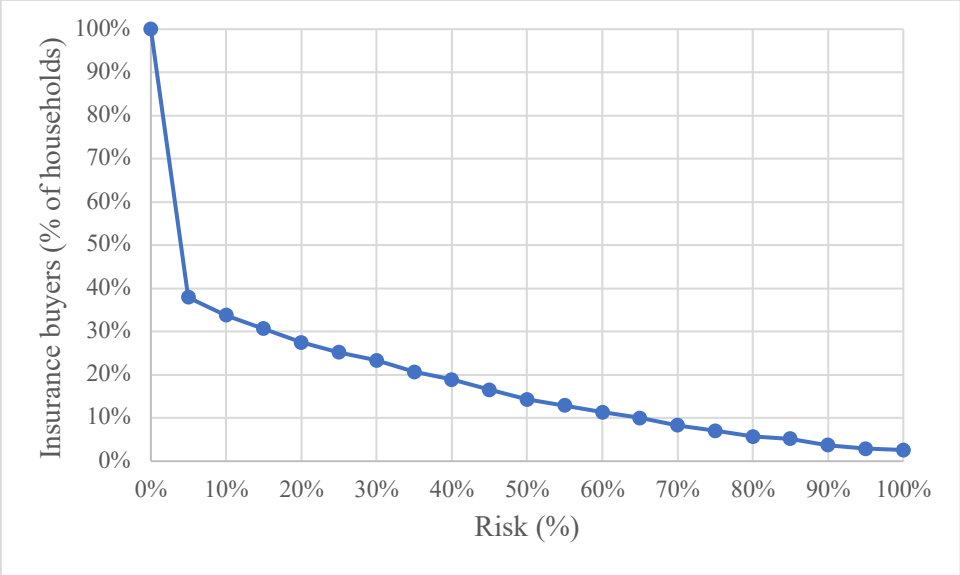

Figure 22. Insurance uptake for areas with different risk level

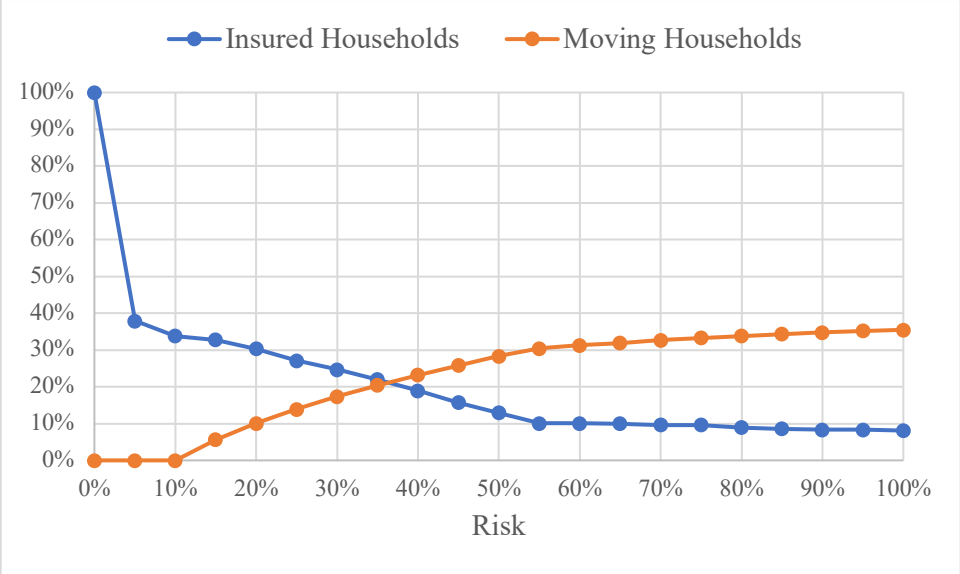

Figure 23. The pattern of moving and buying insurance versus exposed risk

5.4.2. Subsidizing Home Insurance Premiums in High-risk Areas (SHIP)

No Moving. By subsidizing the insurance, the rate of insured households would increase as the wealth threshold decreases. This brings about a higher cost for the government, as shown in Figure 24. At a subsidy of 100 percent, everybody will buy the insurance plan, and it will cost the government about 80 percent of house prices in the risky area.

Possibility of moving. We observe in Figure 25 that, by increasing the subsidy to insurance premiums, more households would tend to stay in the risky area and not move to the safer one.

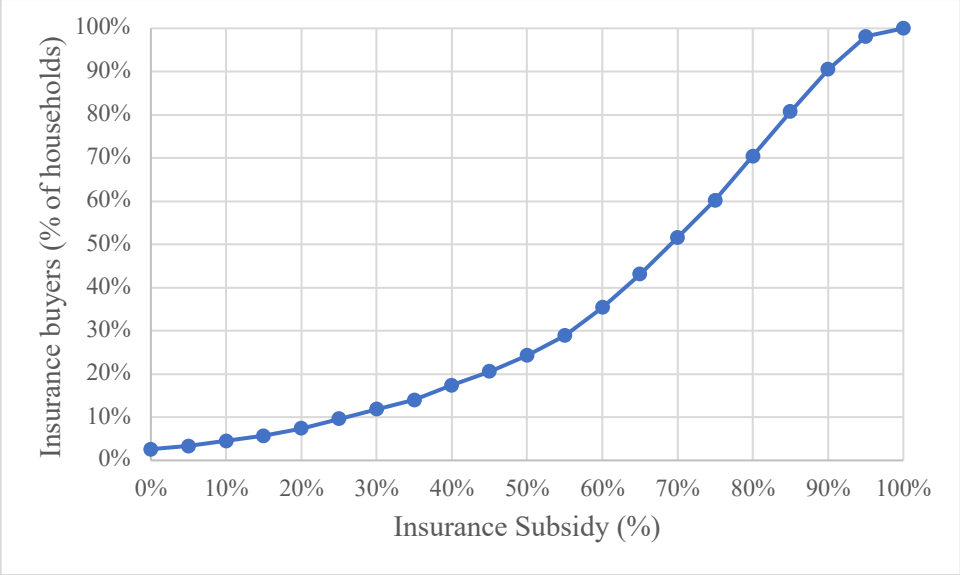

Figure 24. Subsidizing home insurance vs. insurance uptake

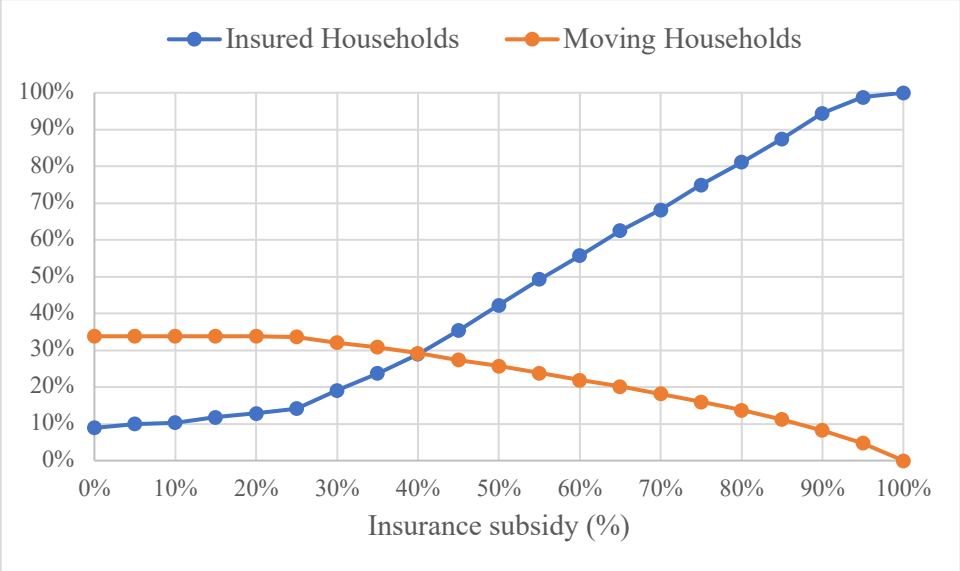

Figure 25. Subsidizing home Insurance vs. insurance uptake and moving

5.4.3. Subsidizing Relocation to a Safe Area (SRSA)

The decision to move would increase the demand for housing in safe areas resulting in higher prices. This framework assumes a logarithmic shape for the demand function, represented in equation (20) relating the house price and demand in the locality (j). In this form, b^j would be the price elasticity of demand for housing in the locality (j). We use this parameter to determine how much price changes due to increased demand. Assuming b^j is the same for both risky and safe areas, the same price at the beginning for both areas, and also a uniform distribution for wealth in both areas, equation (21) tells us that if the safe area is bigger (higher population), the price increase would be lower and, consequently, wealth threshold for moving decision in the risky area would be lower. From a policy point of view, this means that as a government tries to establish such a policy, it would be better to extend the geographic boundaries of the safe areas defined within the policy. It would eventually encourage more moving decisions as a desired outcome for the policymaker.

$$\log(D^j) = a^j + b^j . \log(P^j) \tag{20}$$

$$\Delta P = \Delta P_S - \Delta P_R = \frac{P_0^S}{b} \cdot \frac{\Delta D^S}{D_0^S} + \frac{P_0^R}{b} \cdot \frac{\Delta D^R}{D_0^R} = \frac{P_0^R}{b} \cdot \frac{\Delta D^R}{D_0^R} \cdot \frac{pop_0^S + pop_0^R}{pop_0^S} \tag{21}$$

$$W^* = \frac{(1-s).\frac{P_0^R}{b} \cdot \frac{\Delta D^R}{D_0^R} \cdot \frac{pop_0^S + pop_0^R}{pop_0^S}}{1-\exp\left(-\frac{\beta^2\left[(1-\rho^S).U_H^S - (1-\rho^R).U_H^R\right]}{1+\beta}\right)} \tag{22}$$

Then, equation (13) would be solved as shown in equation (22). We can have the following observations from this outcome:

- $\frac{\partial W^*}{\partial b} \leq 0$, meaning that a higher price elasticity would result in more households moving as their moving would not change price very much
- $\frac{\partial W^*}{\partial \rho^R} \leq 0$, meaning that localities with higher risk would move more to safer places
- $\frac{\partial W^*}{\partial \beta} \leq 0$, meaning that higher appreciation of future risk would result in a higher percentage of households moving
- The smaller population of a risky area (in comparison with the safe area) would make a higher portion of households move
- This policy is not able to encourage households at the lowest part of the wealth distribution to move unless the subsidy covers all the price gap

Figure 26 shows the percentage of households moving and the consequent cost of the policy for different subsidy levels.

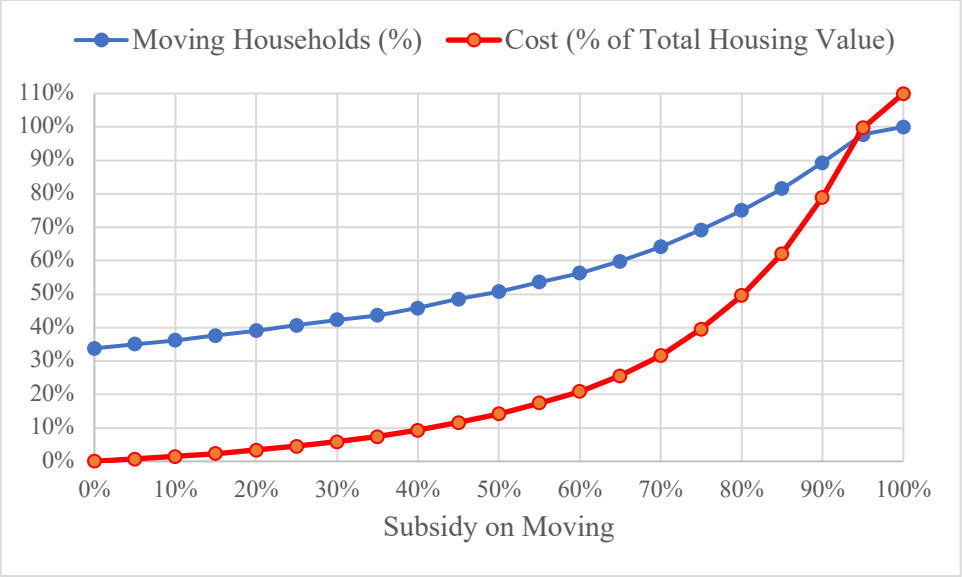

Figure 26. Rate of moving and associated cost vs. subsidy on moving

5.4.4. Taxing Risky/Subsidizing Safe Construction (TRSS)

This policy would be financially self-sufficient in that the budget for a construction subsidy in the safe area would be collected by taxing the construction in the risky area. However, this cannot pass a certain level of subsidy since a higher subsidy means a higher rate of moving to the safe area and a lower tax base in the risky area (as shown in Figure 27).

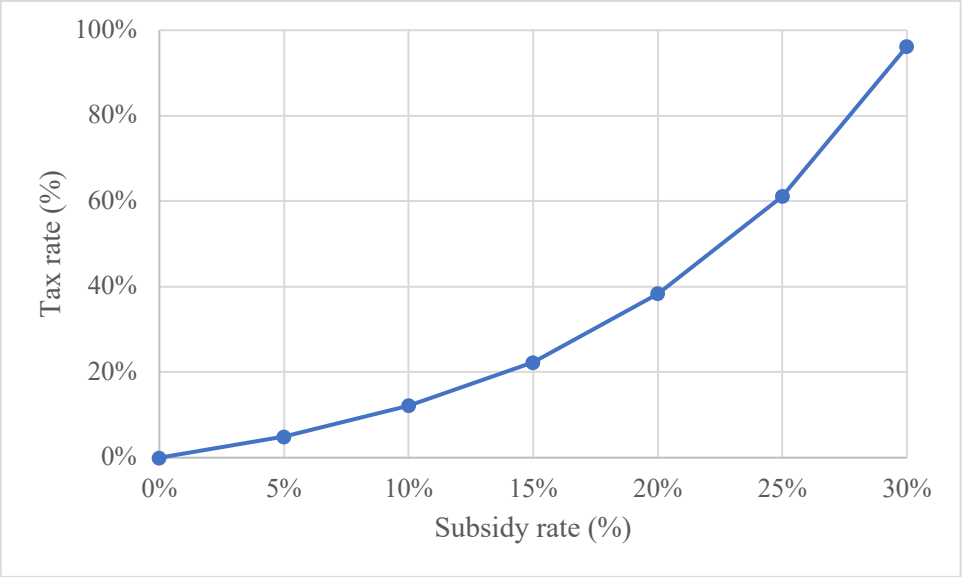

Figure 27. Required taxing to afford to subsidize moving to a safe area

5.4.5. Offering Home Buyouts in Risky Areas (OHBR)

91% of households in the risky area are likely to move. However, 9% of households in the lowest wealth range in the risky area will not move because although their property is bought, they cannot afford to buy a house in the safe area.

5.4.6. Mortgage Adjustment for Risky Areas (MARA)

38% of households living in the risky area will move by introducing this policy. This happens because the transaction cost of moving, as represented by the cost of a new mortgage in the safe area, has been reduced to an affordable level.

5.5. Discussion and Policy Implications

For households living in a risky area, the moving rate or percentage of the households who decide to move is the main index to measure the success of an introduced policy. Thus, we expect a successful policy to have a high moving rate. For policies that include taxing and subsidizing, we consider three versions based on their expected moving rates: conservative (20%), moderate (50%), and aggressive (90%), as shown in Table 35. Insurance uptake rate or the percentage of households that purchase insurance is another measure of success for scenarios that introduce insurance as a policy measure. Cost is another performance index for a policy, as defined by the ratio of the required cost of the policy to the value of housing in the risky area. For measuring equity, we introduce a discrimination index, defined as the standard deviation of the budget going to households with different wealth levels normalized by the average amount of money going to households that receive help from the government as the policy is implemented. For this index, a higher value means higher discrimination, and an equitable policy needs to have a discrimination index close to zero.

Table 35. Comparison of introduced policies

Policy Name	Moving Rate (% of households)			Insurance Intake Rate			Cost (Ratio of Houses Value)			Discrimination		
	C*	M**	A***	C	M	A	C	M	A	C	M	A
CAHI	34%			9%			0%			0		
SHIP	34%	26%	8%	13%	42%	94%	0%	8%	58%	2.6	7.5	6.9
SRSA	39%	51%	89%	10%	13%	23%	3%	14%	79%	1.2	1.0	0.3
TRSS	41%	49%	57%	0%			0%			1.2	1.0	0.9
OHBR	91%			0%			91%			0.3		
MARA	38%			0%			2%			1.29		

* Conservative version of the policy
** Moderate version of the policy
*** Aggressive version of the policy

The most successful policy in terms of encouraging households to move to the safe area, OHBR is the most successful, with a 91% moving rate. Under this policy, offering home buyout in risky areas, the government can achieve the highest rate of moving households, but 9% of households still do not move. This share of the population cannot afford a house in the safe area even with the buyout, which means the government needs to design specific policies for households at the bottom of the wealth pyramid. This finding corroborates the fact that households of low income and historically disadvantaged socioeconomic status routinely suffer the greatest losses from disasters as they are less prepared, are more likely to live in habitations that are vulnerable to disasters, and face many barriers to receiving aid and rebuilding their homes (SAMHSA, 2017). Knowing this, the government must add and implement new policy measures targeted at the most socioeconomically vulnerable households in the at-risk community. For example, the

government can build new housing units in safer areas and encourage the households below a certain socioeconomic threshold to trade their current housing with the new ones without further payment or financial burdens.

Overall, under all the policies, households with higher wealth decide to move earlier by taking advantage of an introduced policy, while households with lower wealth than a certain threshold will not take the policy and therefore remain in the risky area. We also observe that as subsidy policies move from conservative to aggressive, more households undertake the policy measure as the threshold comes down. Among subsidy plans, subsidizing relocation to a safe area (SRSA) is the most successful as it reaches to 89% moving rate in its aggressive version.

Cost is another index of our evaluation, and we can observe that higher rates of moving entail a higher cost for the government. As a government plans to implement a policy, the cost will be essential to consider. We try to address this by introducing TRSS, a policy scenario that is financially sustainable by taxing risky and subsidizing safe construction. However, its moving rate cannot exceed 57%, as allocating a higher subsidy than 30% will not be affordable based on tax collection capacity in the risky area. This generally means that a successful policy will require budget allocation from the government, which should be afforded by introducing appropriate taxing measures to address climate risks. TRSS is conceptually the closest one to Transfer of Development Rights (TDR) that are used by certain localities to limit the development in high-risk areas (Filatova, 2014). However, our analysis shows that this measure has limited success in deriving relocation and could be mostly used as a transition from the status quo to an eventual managed retreat.

Insurance uptake is another index that brings about interesting insights in this framework. First, we observe that insurance uptake drops as an area's risk measure is higher. This happens because a higher risk rating implies higher insurance premiums. For example, with 80% risk factor in our risky area, only 6% of the population will buy the insurance plan, while in our safe area, with 10% risk factor, 34% take the insurance policy, as illustrated in Figure 22. Moreover, intruding more aggressive insurance subsidies will discourage households from moving, as we see under SHIP policy. Indeed, by introducing an aggressive insurance subsidy, only 8% of residents in the risky area will move, while in the conservative version of this policy, 34% decide to move. In other words, helping households on the insurance plan can act contrary to the goal of households moving out of risky areas. This is an important takeaway for the policymaker to know that although insurance subsidies have a lower cost than the home buyout, they need to be aware of possible negative consequences of such policies, in that they induce households to stay in the risky area rather than moving. This finding is in harmony with the empirical work on the history of managed retreat, claiming that the flood insurance uptake rate can hinder the introduction of buyout projects (Miao and Davlasheridze, 2022).

Considering equity, as an introduced policy can encourage more households to move to safety, the discrimination index decreases, making it more equitable. For instance, we observe in SRSA that the aggressive version has a higher rate of moving and a lower discrimination index than the conservative version of the same policy.

Our following discussion is how the distribution of wealth affects policy success for two communities with comparable climate risk? The threshold for deciding to move, W^*, is the primary determinant of moving rate as a significant measure for the success of a policy. Therefore, a relatively wealthier community living at risk will subsequently have a higher moving rate, whereas a socioeconomically vulnerable community

at risk will have further difficulty in doing so. The policy implication for this finding is that a local government must identify the socially vulnerable populations in planning for adaptation and adjust their policy to ensure its success around different communities. This also means localities with higher socioeconomic vulnerability, e.g., high poverty rate, would generally have a more arduous path in planning for the managed retreat, speaking to a need from intervention from higher-level governments.

Our final discussion considers the perception of risk by households. As observed in the results of different policy measures, risk factor negatively influences the wealth threshold for relocation, $\frac{\partial W^*}{\partial \rho^R} \leq 0$, meaning a higher risk factor would decrease the threshold resulting in higher relocation. Now, we pose this question: what happens if the households have a lower estimation of their exposed risk than its actual value? The previously mentioned influence indicates that if households have a lower estimation, they will be less encouraged to move, lowering the success of an introduced policy. Based on previous chapters, we know that people generally tend to minimize the climate risk, which indicates a successful managed retreat policy requires the government to educate the households of at-risk areas about the actual extent and consequences of climate risks in their community. This would be an essential success requirement regardless of the chosen policy.

5.6. Model Expansion

The previously introduced policies did not consider how the government would pay for a policy. This section expands the model by considering the revenue side for the government to pay for an introduced policy. Although this could be done for any of the policies, we merely focus on the third one, subsidizing relocation to a safe area, to explore dynamics and implications of the model by introducing the government's revenue into the model. We assume the government imposes a wealth tax with a flat rate, shown as τ. So, the government's budget constraint would be as shown in (23).

$$\underset{C_0^i, C_1^i, I^i, M^i}{\text{Max}} \; Z^i = U(C_0^i) + \beta . U(C_1^i) + \beta^2 . [M^i . (1-\rho^S) . U_H^S + (1-M^i) . (1-\rho^R) . U_H^R]$$

Subject to:

$$\text{Households' budget: } C_0^i + C_1^i + M^i . [(1-s^M) . \Delta P] \leq (1-\tau) . W^i \qquad (23)$$

$$\text{Government's budget: } \tau . \sum_{\text{all HH}} W^i = s^M . \sum_{\text{moving HH}} \Delta P$$

$$C_0^i, C_1^i \geq 0, \; M^i \in \{0,1\}$$

Solving this problem, we derive a moving threshold under the policy and divide it by the threshold for the no-policy situation to obtain a threshold ratio, shown as η in (*24*). From a policy perspective, it would be interesting to observe how an increase in the relocation subsidy impacts the threshold ratio. To do so, we take the derivative of the ratio regarding the subsidy level and derive λ. The sign of lambda, equation (*24*), determines if the subsidy indeed encourages the relocation. Our analysis shows that for small values of subsidy rate, lambda is negative, indicating that the policy encourages relocation by decreasing the moving threshold. There is a possibility that higher subsidy rates could discourage relocation by raising the threshold, depending on the parameters of a locality. This interesting observation tells us that, with lower subsidies, a redistribution of wealth through tax encourages the households in the middle of the wealth spectrum. Nonetheless, in specific localities, going beyond a subsidy/taxing scheme would be discouraging those households that are at the threshold because the discouraging effect of the tax outweighs the encouraging influence of the subsidy. Moreover, this shows that, at least for specific localities and

circumstances, affording the policy cost through such a taxing scheme would not be feasible. That could be a call for intervention from higher levels of beyond local government. Such intervention could come from the State or Federal government.

It would be interesting to observe how the policy outcome varies based on the risk factor of a risky area. Our analysis shows $\frac{\partial \eta}{\partial \rho^R} < 0$ indicating a lower moving threshold for a higher risk factor, which translates to a higher moving rate for localities at higher risk under this scenario.

$$\eta = \frac{W^*(\text{policy})}{W^*(\text{no-policy})} = \frac{(1-s^M).[1-\zeta]}{1-s^M.\frac{\sum_{\text{moving HH}} \Delta P}{\sum_{\text{all HH}} W^i} - \zeta}$$

$$\lambda = \frac{\partial \eta}{\partial s^M} = \frac{(1-\zeta).\left(\frac{\sum_{\text{moving HH}} \Delta P}{\sum_{\text{all HH}} W^i} - 1 + \zeta\right)}{\left[1-s^M.\frac{\sum_{\text{moving HH}} \Delta P}{\sum_{\text{all HH}} W^i} - \zeta\right]^2} \quad (24)$$

$$\zeta = \exp\left(-\frac{\beta^2\left[(1-\rho^S).U_H{}^S - (1-\rho^R).U_H{}^R\right]}{1+\beta}\right)$$

As another expansion to the model, we introduce support from higher-level governments into the model by adding a multiplier, G. This multiplier captures a partial payment of the policy cost by the state or federal government, as shown in (25), replicating the adaptation programs with a cost-sharing model between local and federal/state government (Figure 28). The higher government's support encourages relocation by decreasing the moving threshold compared to the previous setting (25). This could be a basis for the state or federal government in planning their adaptation efforts in supporting local adaptation as it provides them with an impact analysis for the intervention.

Higher level government	Local government
•State or federal •Partially contributes; share = G-1/G	•Paying for the rest; share = 1/G •Imposes tax for its part

Figure 28. Cost-sharing between the local and higher-level government

Government's budget: $G.\ \tau.\sum_{\text{all HH}} W^i = s^M.\ \sum_{\text{moving HH}} \Delta P$

$$\eta^* = \frac{W^*(\text{policy})}{W^*(\text{no-policy})} = \frac{(1-s^M).[1-\zeta]}{1-\frac{s^M}{G}.\frac{\sum_{\text{moving HH}} \Delta P}{\sum_{\text{all HH}} W^i} - \zeta}$$

$G \geq 1 \Longrightarrow \eta^* < \eta \Longrightarrow$ Threshold $\downarrow$ (25)

$$\lambda^* = \frac{\partial \eta^*}{\partial s^M} = \frac{(1-\zeta).\left(\left[1+s^M\left(\frac{1}{G}-1\right)\right].\frac{\sum_{\text{moving HH}} \Delta P}{\sum_{\text{all HH}} W^i} - 1 + \zeta\right)}{\left[1-\frac{s^M}{G}.\frac{\sum_{\text{moving HH}} \Delta P}{\sum_{\text{all HH}} W^i} - \zeta\right]^2}$$

5.7. Conclusion and Future Research

This chapter proposes an analytical framework for designing housing policy in climate-vulnerable coastal areas. We introduce six policy scenarios and compare them in terms of their success, cost, and social equity. We borrow from economics literature to form and evaluate our model using a general equilibrium approach to model housing and decision making of households as well as a partial equilibrium approach to analyze the behavior of a benevolent government that tries to mitigate the risks and bring about a social optimum for the community. Within our analyses, we address trade-offs of the government for designing an effective policy measure. Specifically, we address moving rate, insurance uptake, cost, and discrimination as indices for evaluation of each policy and provide quantitative measures in each regard. A critical finding of the chapter is that generally designed policies cannot help households at the bottom of the wealth pyramid. General policies are not effective for such vulnerable populations, and specific policies need to be designed to meet the needs of this group. This could be a fruitful avenue of research in the future.

The home buyout policy was the most successful among our scenarios. This policy bears a high cost for the government, which needs to be acquired by appropriate taxing measures that address climate risks. Modeling the revenue side for the policymaker and observing how taxing policies might change the policy outcomes would be an exciting direction for future research. We provided a model expansion for the relocation subsidy policy to consider likely revenue streams for retreat, showing that managed retreat can be a practical local adaptation policy, especially if supported by the state or federal government. It would be a promising avenue of research to reevaluate policy success by considering revenue side and observe if they would be different from what we found in this chapter. It would also be interesting to introduce and compare the outcomes of different taxing schemes, e.g., income, consumption, and wealth, on policy success.

It would be interesting to observe the outcomes of this framework for certain coastal localities regarding their risk exposure and the preferences of stakeholders in those localities. In this chapter, we used simulated data for risk exposure and wealth distribution of an area at high climate risk. The main reason for doing so, instead of applying the framework to real data, was the absence of risk factor as introduced in our model. Thus, it would be promising to derive reliable estimates for the risk factor and leverage them to achieve model outcomes for real situations and localities. Such an action would practically assist local governments in introducing adaptation policies as it provides an analytical framework to address the trade-offs and informs the decision-makers about the possible outcomes of different policies. Thus, there is a crucial need for such a policy analysis framework to anticipate possible outcomes and the potential shortcomings through a quantitative analysis framework.

The proposed model can be expanded in several directions to capture specific challenges and questions in climate adaptation. For instance, it would be interesting to relax the rationality of households by introducing some imitation in decision-making among households. Leveraging an agent-based modeling approach, it would be possible to model such behaviors and then use customized surveys to calibrate the model and propose actionable solutions to local governments. It would also be exciting and fruitful to extend the decision-making horizon of the government by introducing a sequence of decisions for the managed retreat that brings about path-dependency into the issue. Then, dynamic programming could be used to model this phenomenon to reproduce the real-world case in that the government's decision is not a single shot but rather a series of policies and decisions that eventually lead to responses from other entities and determine the future of adaptation efforts. Such effort would be able to determine how specific policies could limit the future options for the government, adding to the insights for adaptation policymaking.

Chapter 6
Conclusion

This chapter summarizes the findings and contributions of this dissertation, provides avenues for future research and demonstrates the author's career path after graduation.

6.1. Overview of Findings and Contributions

In this dissertation, we used various qualitative and quantitative research methods to explore climate adaptation policymaking. The contributions of this research to the climate adaptation literature are as follows:

- A multi-governance approach to characterizing adaptation policies to shed light on complexities and interdependencies between different governance levels, i.e., local, regional, state, and federal
- Identifying the main challenges and governance gaps in adaptation policymaking in Coastal Virginia
- Mapping socioeconomic vulnerabilities and climate risk in Coastal Virginia and identifying correlations to inform adaptation policymaking
- Proposing an analytical policy framework to facilitate local adaptation policymaking
- Modeling managed retreat as an inevitable policy for specific areas at high climate risk
- Publishing four journal papers, three first author, and two conference papers, one first author related to this research topic

Each chapter 2-5 has either been published or is in the publication process as a journal or conference paper. Chapter 2 showed the extent of adaptation policymaking in Coastal Virginia and how it has been mainly a fragmented and bottom-up practice. It also portrayed the dynamics of adaptation policymaking on multiple governance levels providing insights on how they influence one another. Chapter 3, building upon the discovered dynamics in the previous chapter, provided an analysis of the most salient challenges in adaptation policymaking for Coastal Virginia. It was shown that comprehensive planning and intergovernmental coordination are the most significant challenges based on the interactions between overarching challenges and the gaps specific to each governance level. We also discussed the suggestions for different government layers in the future and how interventions from higher-level governments, state and federal, can build capacity, provide vision, and bring harmony to adaptation efforts at different localities with varied economic, technical, and institutional capacities.

Chapter 4 took a quantitative approach to assess socioeconomic vulnerabilities in Coastal Virginia as a clear perception of the vulnerabilities and their associations with climate risk would be essential for effective and equitable adaptation policymaking. It was shown that certain measures of poverty, access to infrastructure, education, and housing are associated with the developed measure of flood risk as one of the leading climate

stressors in Coastal Virginia. It was also revealed that patterns of vulnerability are varied in this area, e.g., rural vs. urban areas, indicating the essential task for each locality to learn about the underlying causes of the vulnerabilities and specific attention to them in their future adaptation efforts. It was also discussed that interventions from higher-level governments, e.g., state and federal, would be required for the success of particular policies such as managed retreat.

Chapter 5 proposed a policy framework for local adaptation policymaking building upon certain pillars: flexibility, context specificity, active engagement of communities and stakeholders, and higher government involvement. The framework can analyze and introduce effective and accepting policy measures as its analysis tool can inform various stakeholders about potential policy outcomes providing an opportunity for collective and informed adaptation decisions. Then, several policy options for the managed retreat were developed, analyzed, and compared based on their success in encouraging people living at high risk to leave and how costly and equitable each policy was. The model was then expanded to observe the impacts of taxing and help from a higher government level. The home buyout was shown to have the highest success for encouraging people to move, while it was revealed that certain parts of the vulnerable population would not move under any scenario. This speaks to the necessary task of local governments to introduce policies that specifically address the most vulnerable communities. It was also shown how financial support from the state or federal government could increase the success of an introduced policy. Such insight can be quantified in our framework, assisting the state and federal governments in devising optimum adaptation policies.

From a systems analysis perspective, this dissertation is an attempt to understand adaptation policymaking in Coastal Virginia, and systematically analyze its status in order to provide directions for improving this practice in the future. To do so, we leveraged several methodologies and knowledge areas in qualitative and quantitative analysis. Tackling a pressing issue such as climate adaptation with a broad approach has been the overarching methodologic contribution within systems thinking and analysis. In other words, each aspect of a broad issue like adaptation requires particular methodologies that are capable of addressing that aspect. We used stakeholder interviews to form our understanding of the adaptation practice and its intricacies. Moreover, the interviews provided insights and direction for the next quantitative chapters. The importance of social equity in adaptation prompted a more thorough examination of the association between climate stressors and socioeconomic vulnerability, which was partially addressed in chapter 4. A lack of planning and prioritization became evident that called for an analytical framework for adaptation planning; this was addressed in chapter 5. There could be potentially several other chapters building upon the derived insights in our interviews. We address some of them as directions for future research.

This dissertation provides us with a big picture of climate adaptation policymaking in Coastal Virginia: a fragmented system without clear objectives, evaluation criteria, and defined roles. We observed a variety of challenges and tensions in the political, social, and technical domains that have impeded a strategic response to climate impacts. There is an ongoing conflict between short-term remedies and long-term solutions; and the status quo, although improved compared to the past, does not show a clear path for systematically resolving such conflicts. Effective and efficient adaptation policymaking requires a multi-sectoral and multi-level governance approach that is unprecedented in this region, and also in lots of other regions of the world. Therefore, any effort to meticulously observe the various dynamics of this issue and frame them with a consistent approach, will benefit adaptation policymaking, and we are in dire need of that in the future.

6.2. Suggestions for Future Research

Although Coastal Virginia has been the focus in Chapters 2, 3, and 4, the implemented methodologies could be expanded to other coastal and non-coastal areas. So, it would be an inspiring avenue of research to perform similar analyses for other coastal areas in the United States, e.g., the Gulf region and California. The outcomes will probably be different for other areas because the institutional, economic, political, social, and cultural circumstances would differ for those areas. However, comparing such different outcomes and assessing how the observed patterns are similar or specific to one area presents important insights for a national adaptation policy framework as a national and comprehensive policy framework for climate adaptation yet needs to be created in the U.S. As another line of research, it would be interesting to consider climate hazards other than flooding in the vulnerability analysis of Chapter 4 and observe how other risks are associated with vulnerabilities.

The policy framework and the retreat modeling of Chapter 5 serve as theoretical models applicable in various localities and contexts. Having such a framework would be essential for appropriate adaptation decision-making on the local level. Thus, forming local partnerships and leveraging them to implement the framework would be fruitful both for research and practice of adaptation. Such effort entails engagement with the governmental and non-governmental organizations, learning about their adaptation issues, adjusting the framework, and formulating a conversation around the ongoing adaptation issues. This would be a much-needed action as adaptation is primarily in its infancy and would need an analytical framework for effective planning and evaluation in the years to come. From a modeling perspective, several research questions could be pursued, building on this framework. For example, it would be interesting to model regional collaborations and study the circumstances that encourage local governments in a region to form regional alliances and adaptation initiatives; it was suggested in Chapter 4 that regional planning can increase the success and efficiency of adaptation efforts. Such a model can also inform the national adaptation policies on effectively encouraging regional adaptation planning.

Another future research opportunity is to model the political economy side of local adaptation policymaking. Political economy has different meanings (Weingast and Wittman, 2008), but here, it would entail using economics methodology to analyze institutions and political behavior. More specifically, the formation of a policy in the local political context would be of interest to see how engagement of stakeholders could affect the policy choice. Previously, collective adaptation decision-making that engages all communities was suggested as a necessity to address socioeconomic vulnerabilities. This modeling approach would study the general equilibrium outcomes of a collective decision-making process and ascertain the effect of engagement on policy choice. Collective decision-making is a more complicated process in deciding the policy as more entities, with diversified preferences, are directly involved, which raises the possibility of strategic behavior in their decision-making. It would analyze if/how this process could lead to an agreement among the community and how different the outcome would be from classic policymaking. This modeling effort will also pave the way for further analysis of different institutional settings and governance structures in urban and rural areas.

Social equity and climate justice are inseparable parts and at the core of adaptation; however, the current adaptation practice in Coastal Virginia and elsewhere has a long way to achieve equitable adaptation. We tried to shed light on the association between vulnerability and climate risk arguing for essential attention to vulnerabilities in prioritizing adaptation programs and projects. A necessary and fruitful avenue for research is to develop measures for assessing the status quo of adaptation in addressing equity. Such

measures have to be straightforward enough to be implemented on multiple levels of governance and lead the assessments on how adaptation efforts are helping or hurting the vulnerable populations.

6.3. Publications

This research has resulted in the following publications:

1. *Eghdami, S.,* Michel, V., Shafiee-Jood, M., Louis, G. (2022) 'Climate Adaptation Policy Analysis in Coastal Virginia, Overview of Existing Policies and Main Stakeholders', Climate Policy [submitted] (Eghdami *et al.*, 2022a)
2. *Eghdami, S.,* Michel, V., Shafiee-Jood, M., Louis, G. (2022) 'Gap Analysis of Climate Adaptation Policy Analysis in Coastal Virginia', Climatic Change [submitted] (Eghdami *et al.*, 2022b)
3. *Eghdami, S.,* Scheld, A. M., Louis, G. (2022) 'Socioeconomic Vulnerability and Climate Adaptation in Coastal Virginia', Climate Risk Management [submitted] (Eghdami, Scheld and Louis, 2022)
4. Michel, V., *Eghdami, S.,* Shafiee-Jood, M., Louis, G. (2022) 'Assessing Role of Social Equity in Coastal Community Planning for Climate Adaptation', working paper (Michel *et al.*, 2022)
5. *Eghdami, S.,* Troy A., Michel, V., Louis, G. (2020) 'Policy Analysis for Community Retreat in Coastal Regions', in Proceedings of the International Annual Conference of the American Society for Engineering Management, pp. 1–13 (Eghdami *et al.*, 2020)
6. Michel, V., *Eghdami, S.,* Hadley, K., Louis, G. (2020) 'A Framework for Characterizing Multilevel Water Governance: A Case Study of Baltimore, Maryland', in Proceedings of the International Annual Conference of the American Society for Engineering Management, pp. 1–10 (Michel *et al.*, 2020)

6.4. Career Forward

I will be a Boston Consulting Group (BCG) consultant in Washington, DC starting August 1, 2022. My educational and research experience in the Ph.D. program in systems engineering will enable me to tackle real-world problems, provide modeling frameworks, implement efficient and practical analyses, and provide clients with a flexible and reliable solution structure. I will try to experience different industries and practice areas to acquire an overarching understanding of the consulting job before concentrating on public policy and international development as my favorite areas in management consulting.

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Appendices

A. Maps of Policies and Programs (Chapter 2)

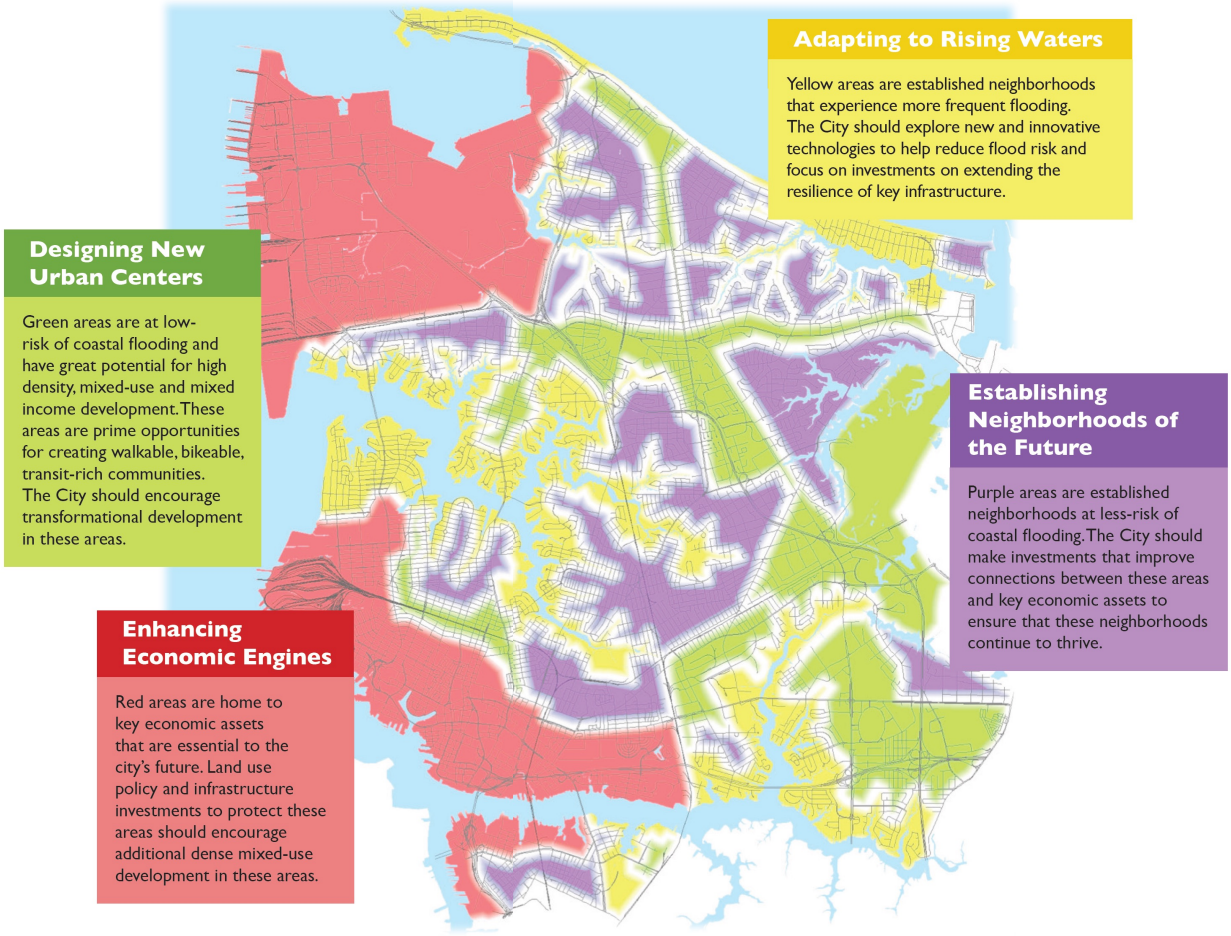


Figure 29. Norfolk Vision 2100 Map
Source: (City of Norfolk, 2016)

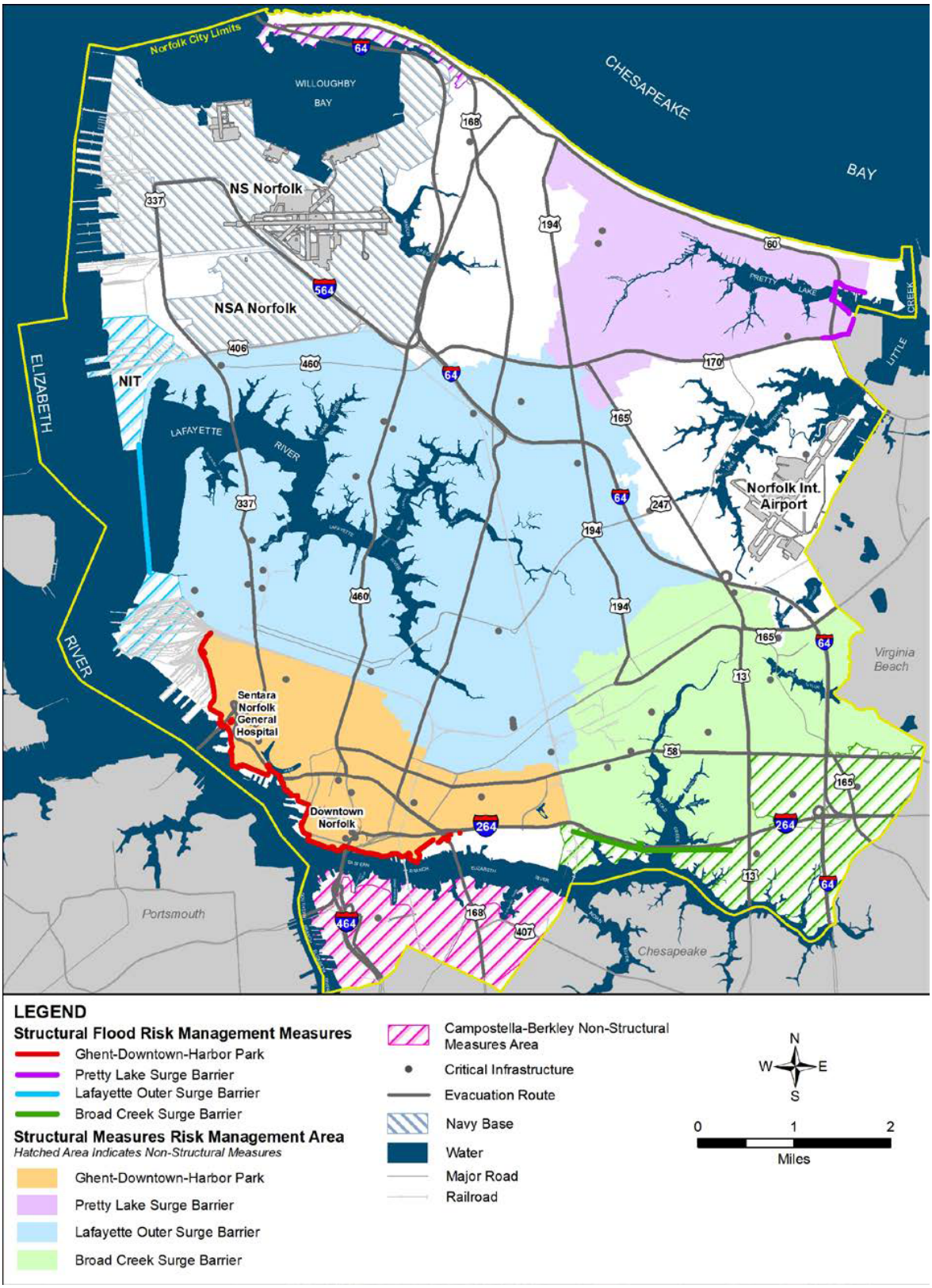


Figure 30. Army Corps of Engineers' Designs for City of Norfolk
Source: (USACE, 2018)

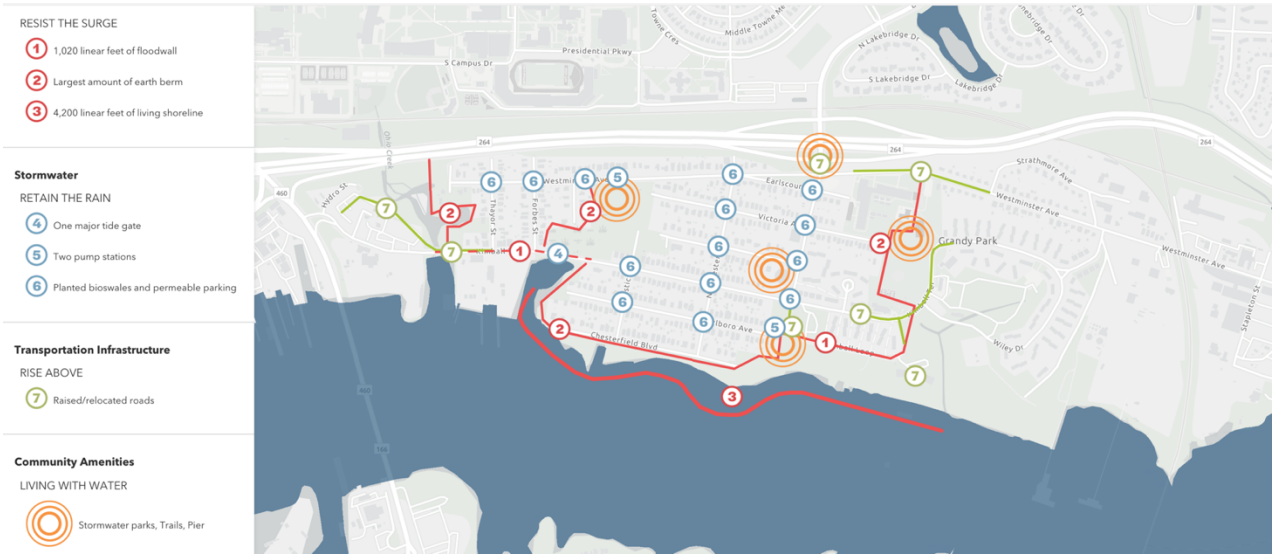


Figure 31. Map of Ohio Creek Watershed Project
Source: (City of Norfolk, 2019)

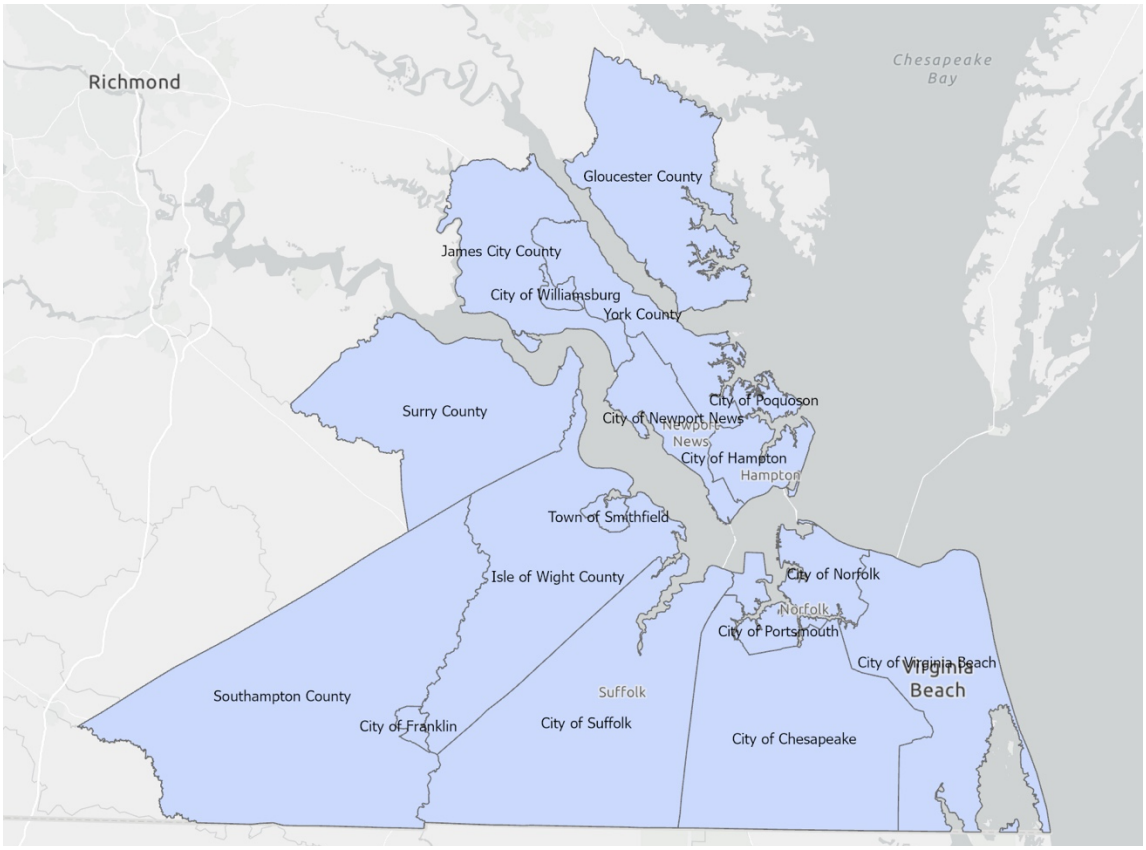


Figure 32. Member Jurisdictions of HRPDC
Source: (HRPDC, 2022)

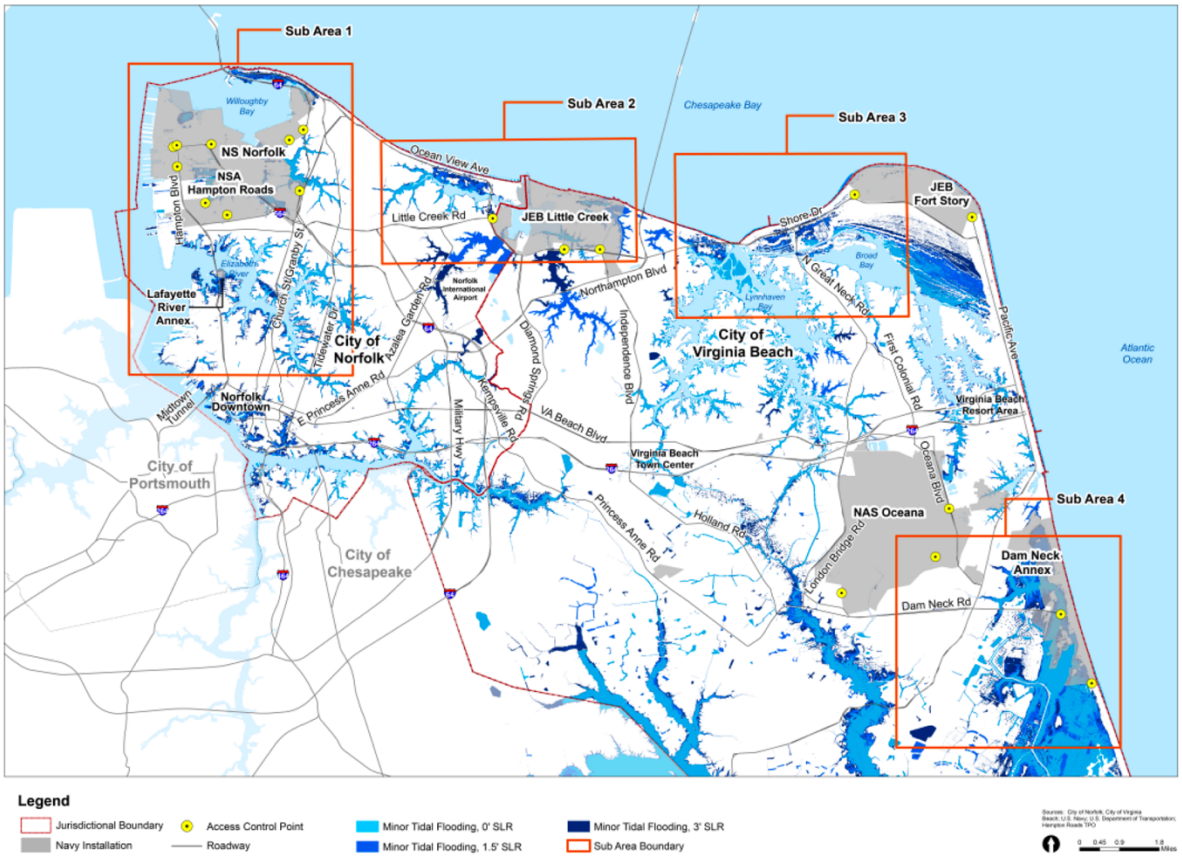


Figure 33. SLR Scenarios and Target Sub-areas in Norfolk - Virginia Beach JLUS
Source: (HRPDC, 2019b)

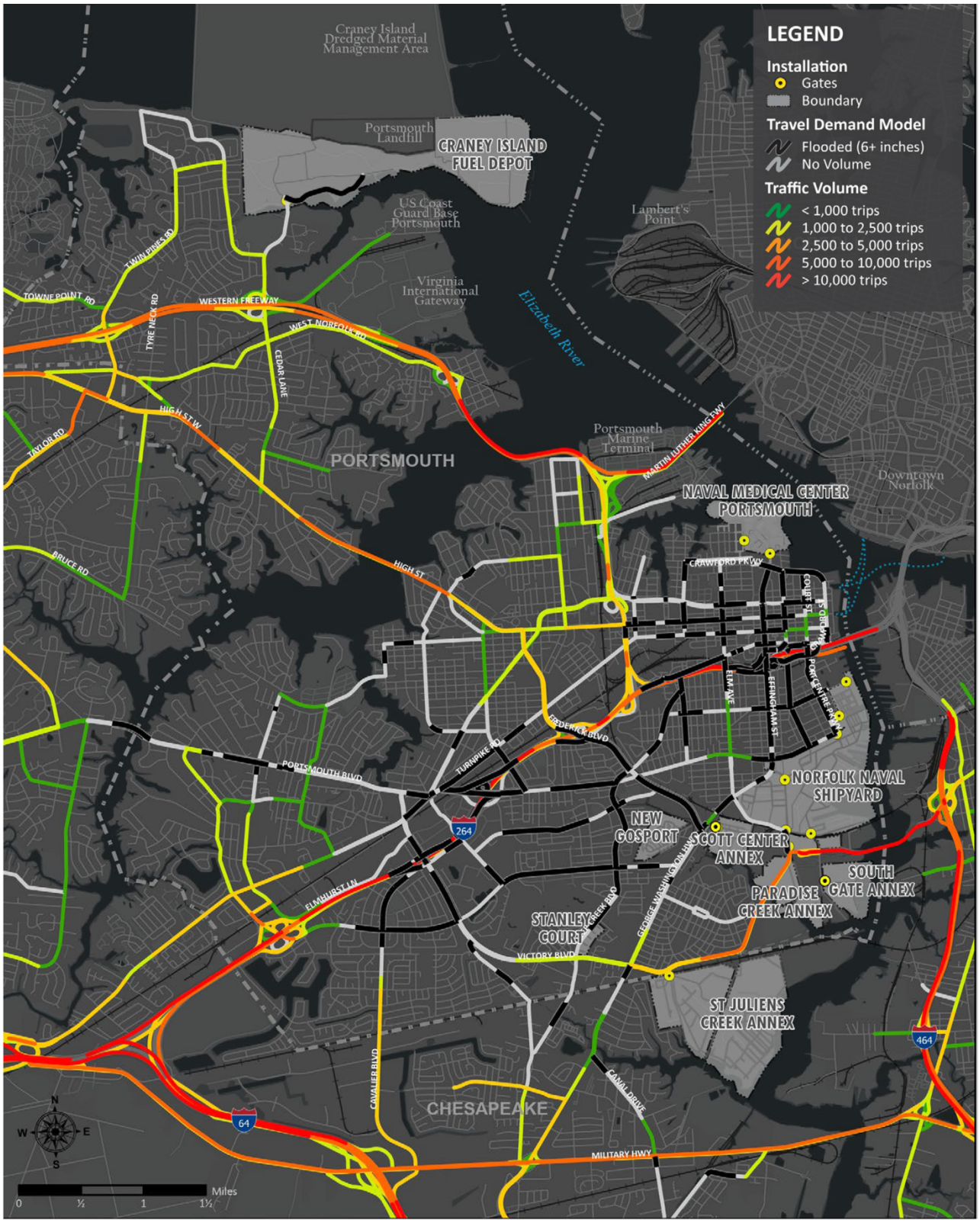


Figure 34. Impact of Flooding on the Traffic in Portsmouth - Chesapeake JLUS
Source: (HRPDC, 2021b)

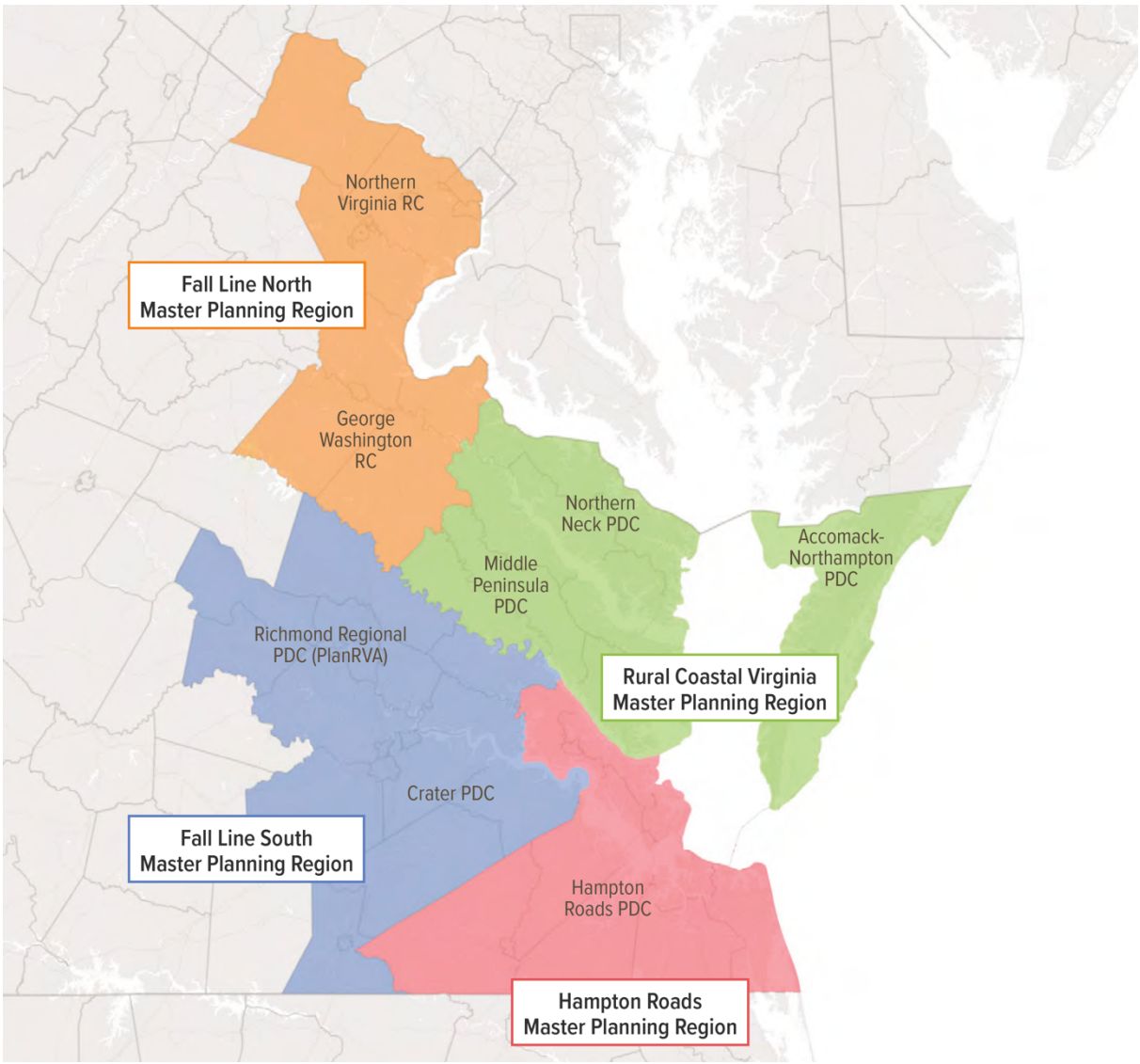


Figure 35. Costal Resilience Master Plan Regions (Eight PDCs)
Source: (Commonwealth of Virginia - Office of the Governor, 2021)

B. Robustness Check for Regressions (Chapter 4)

This section reports the results of the regression models in which the climate risk factor is the independent variable. We initially used a transformation of the risk factor to address the normality assumption. As shown in Table 36 and Table 37, the socioeconomic variables generally remain significant, confirming the robustness of our regression models.

Table 36. Robustness regressions for rural areas

Northern Peninsula			**R-squared = 0.59**	
Variable	Coefficient	Std error	T-value	P-value
Constant	23.61	5.07	4.66	0.00
Elevation	-0.68	0.12	-5.90	0.00
Northumberland County	10.70	5.05	2.12	0.04
King George County	0.00	4.97	0.00	1.00
Lancaster County	5.14	5.05	1.02	0.31
Richmond County	7.49	5.56	1.35	0.18
Westmoreland County	2.68	4.80	0.56	0.58
Share of below diploma	3.23	1.49	2.17	0.03
Share of Black households	-2.99	1.46	-2.05	0.05
Middle Peninsula			R-squared = 0.50	
Variable	Coefficient	Std error	T-value	P-value
Constant	31.19	6.03	5.17	0.00
Elevation	-0.98	0.23	-4.34	0.00
Essex County	0.38	7.14	0.05	0.96
Gloucester County	-1.24	5.74	-0.22	0.83
King and Queen County	-0.17	9.45	-0.02	0.99
King William County	4.62	7.54	0.61	0.54
Mathews County	-6.38	8.93	-0.72	0.48
Renters' share of households	-6.76	2.28	-2.97	0.00
Share of social assistance receivers	4.82	2.23	2.17	0.04
Share of Black households	-4.94	2.13	-2.32	0.02
Eastern Shore			R-squared = 0.83	
Variable	Coefficient	Std error	T-value	P-value
Constant	50.11	6.07	8.26	0.00
Elevation	-5.91	0.63	-9.34	0.00
Accomack County	20.13	4.71	4.28	0.00
Renters' share of households	-5.56	2.67	-2.08	0.05
Share of social assistance receivers	6.12	2.44	2.51	0.02

Table 37. Robustness regressions for urban and semi-urban areas

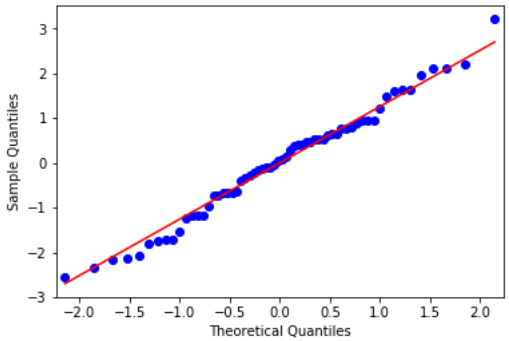
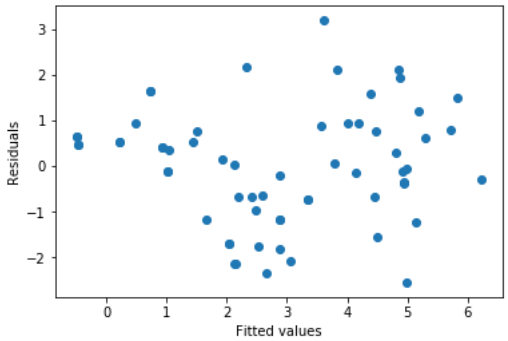
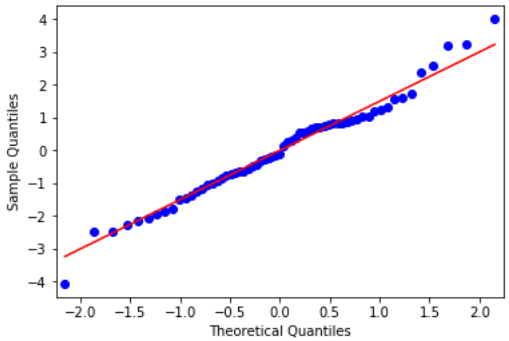
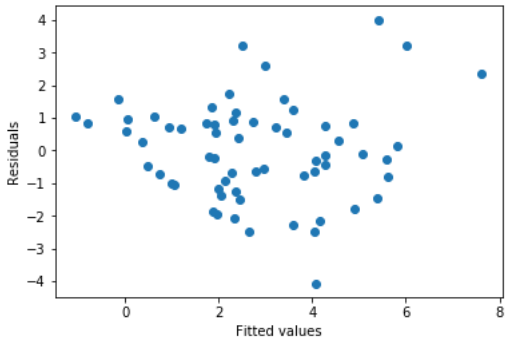
Southern Peninsula (Ex Hampton & Newport News)				**R-squared = 0.77**
Variable	Coefficient	Std error	T-value	P-value
Constant	18.93	6.67	2.84	0.01
Elevation	-0.83	0.19	-4.47	0.00
Poquoson City	59.11	7.63	7.75	0.00

Charles City	8.56	7.37	1.16	0.25
James City	2.55	5.76	0.44	0.66
New Kent County	8.94	6.60	1.35	0.18
York County	-2.77	5.97	-0.47	0.64
Poverty rate of households	2.38	1.38	1.72	0.09
Virginia Beach City			R-squared = 0.38	
Variable	Coefficient	Std error	T-value	P-value
Constant	34.09	2.56	13.33	0.00
Elevation	-6.46	0.62	10.41	0.00
Housing median value	3.16	0.86	3.69	0.00
Share of social assistance receivers	2.00	0.87	2.30	0.02
Renters' share of households	1.70	0.84	2.03	0.04
Norfolk City			R-squared = 0.75	
Variable	Coefficient	Std error	T-value	P-value
Constant	94.03	4.68	20.05	0.00
Elevation	-25.25	1.46	-17.24	0.00
Housing median value	3.24	1.10	42.90	0.00
Share of no-internet access households	1.60	0.94	1.70	0.09
Portsmouth City			R-squared = 0.63	
Variable	Coefficient	Std error	T-value	P-value
Constant	91.71	7.37	12.45	0.00
Elevation	-22.89	2.17	-10.55	0.00
Housing median value	3.90	1.97	1.99	0.05
Share of Black households	3.10	1.85	1.68	0.10
Chesapeake City			R-squared = 0.52	
Variable	Coefficient	Std error	T-value	P-value
Constant	51.00	4.05	12.60	0.00
Elevation	-10.02	0.91	-11.03	0.00
Share of bachelor's degree & higher	2.55	1.20	2.14	0.04
Renters' share of households	2.44	1.15	2.12	0.04
Hampton City			R-squared = 0.46	
Variable	Coefficient	Std error	T-value	P-value
Constant	69.15	6.58	10.50	0.00
Elevation	-13.17	1.84	-7.13	0.00
Share of social assistance receivers	-5.91	2.45	-2.41	0.02
Share of no-internet access households	6.07	2.45	2.47	0.02
Newport News City			R-squared = 0.35	
Variable	Coefficient	Std error	T-value	P-value
Constant	18.57	2.42	7.68	0.00
Elevation	-1.68	0.28	-6.02	0.00
Share of below diploma	-2.26	0.61	-3.69	0.00
Share of Black households	1.47	0.89	1.66	0.10

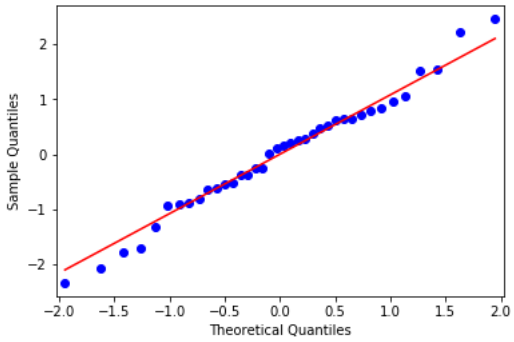
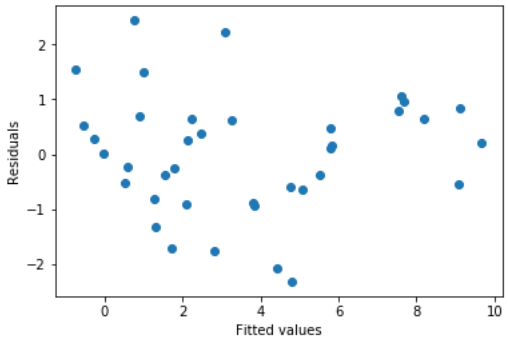
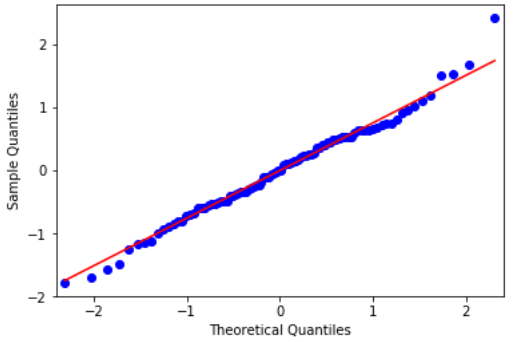
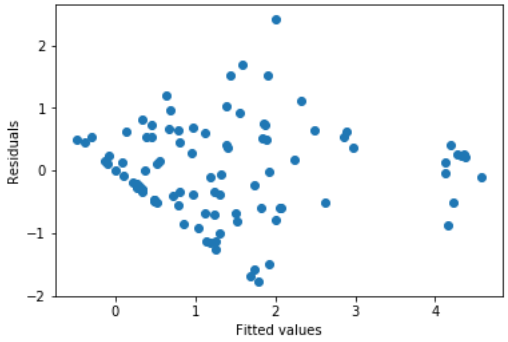
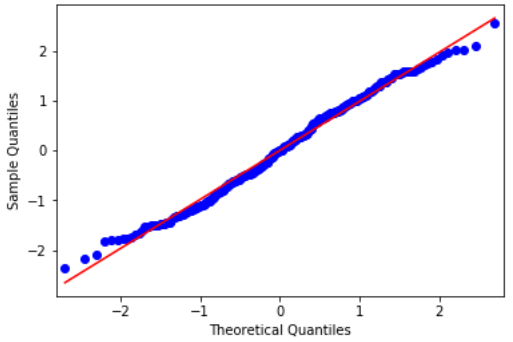
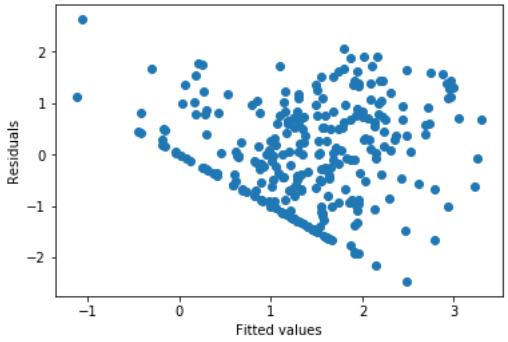
C. Regression Diagnostics (Chapter 4)

This section reports the tests for checking regression assumptions for our regression models. The results generally approve the assumptions with a couple of exceptions, which are part of the data limitations in this study.

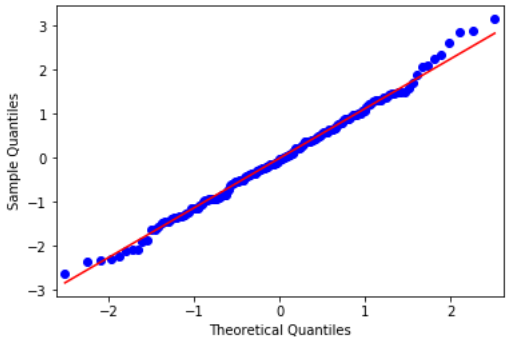
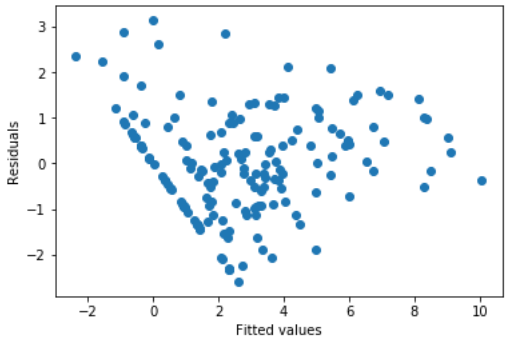
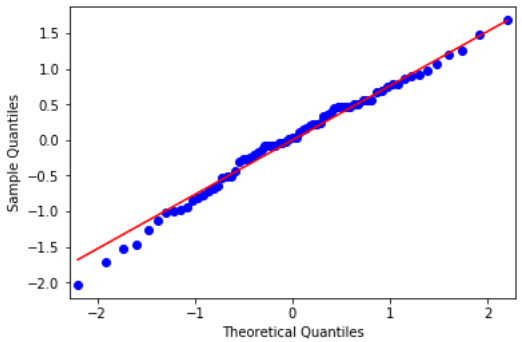
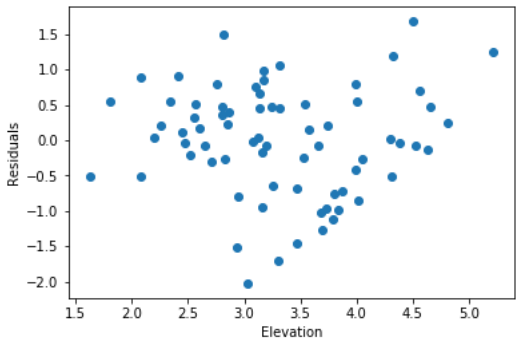
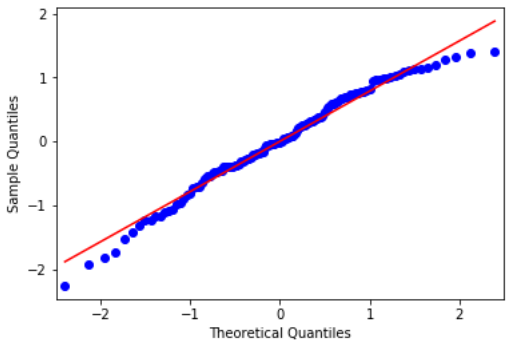
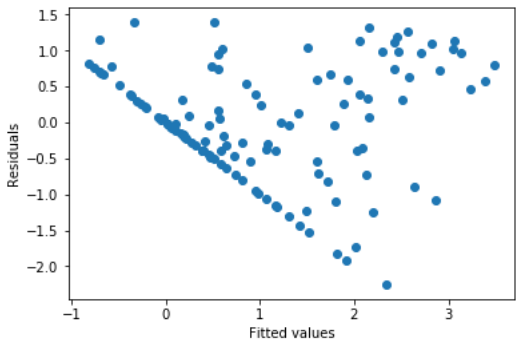
Table 38. Regression diagnostics

Regression	Jarque-Bera (P-value)	Breusch-Pagan (P-value)	Durbin-Watson	QQ Plot	Residuals vs. Fitted values
Northern Peninsula	0.83	0.37	1.84		
Middle Peninsula	0.83	0.15	1.55		

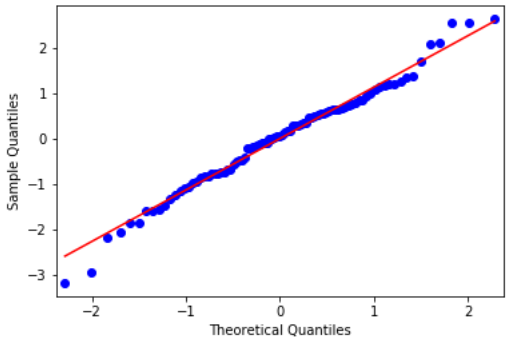
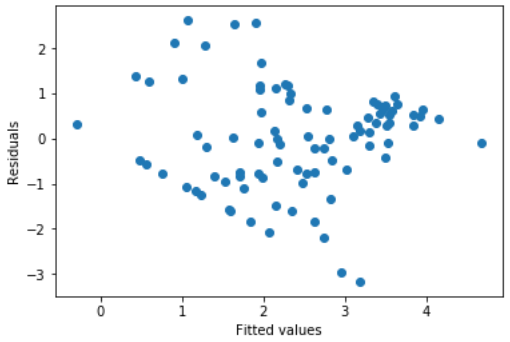
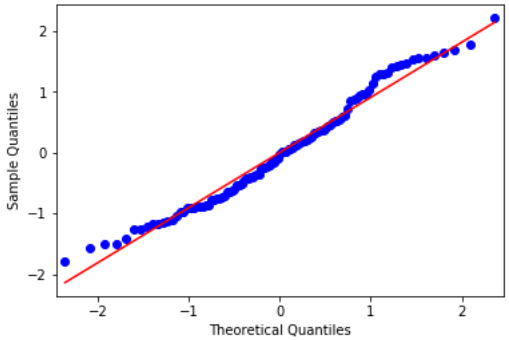
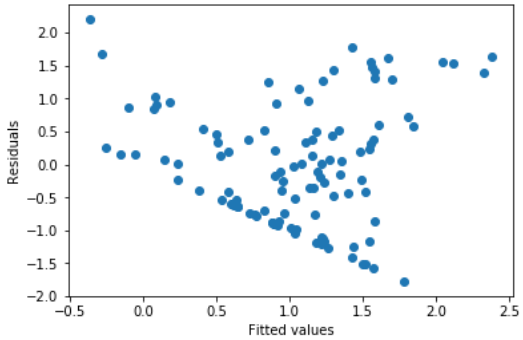
APPENDIX C. REGRESSION DIAGNOSTICS (CHAPTER 4)

Regression	Jarque-Bera (P-value)	Breusch-Pagan (P-value)	Durbin-Watson	QQ Plot	Residuals vs. Fitted values
Eastern Shore	0.99	0.17	1.98		
Southern Peninsula	0.64	0.16	1.50		
Virginia Beach	0.05	0.02	1.52		

APPENDIX C. REGRESSION DIAGNOSTICS (CHAPTER 4)

Regression	Jarque-Bera (P-value)	Breusch-Pagan (P-value)	Durbin-Watson	QQ Plot	Residuals vs. Fitted values
Norfolk	0.65	0.07	1.56		
Portsmouth	0.78	0.02	1.76		
Chesapeake	0.87	0.01	1.56		

APPENDIX C. REGRESSION DIAGNOSTICS (CHAPTER 4)

Regression	Jarque-Bera (P-value)	Breusch-Pagan (P-value)	Durbin-Watson	QQ Plot	Residuals vs. Fitted values
Hampton	0.15	0.27	1.40		
Newport News	0.13	0.003	1.48		

D. Correlation Matrices for Socioeconomic Variables (Chapter 4)

This section includes the correlation matrices for socioeconomic variables in different areas of the study.

Table 39. Correlation matrix for Northern Peninsula

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	12%	-34%	-53%	-36%	-20%	-24%	42%	-25%	-7%	-35%	14%
Housing median value	12%	100%	1%	0%	0%	-19%	-18%	30%	-4%	10%	0%	28%
Renters' share	-34%	1%	100%	48%	31%	36%	-11%	-13%	32%	17%	10%	-6%
Poverty rate	-53%	0%	48%	100%	43%	2%	8%	-23%	29%	11%	19%	-11%
Share of social assistance receivers	-36%	0%	31%	43%	100%	-8%	21%	-4%	41%	-5%	17%	-17%
Share of Black households	-20%	-19%	36%	2%	-8%	100%	26%	-10%	0%	20%	29%	-11%
Share of below diploma	-24%	-18%	-11%	8%	21%	26%	100%	-16%	2%	-12%	36%	7%
Share of bachelor's and higher	42%	30%	-13%	-23%	-4%	-10%	-16%	100%	3%	3%	-4%	43%
Unemployment rate	-25%	-4%	32%	29%	41%	0%	2%	3%	100%	-6%	0%	-5%
Military to civilian ratio	-7%	10%	17%	11%	-5%	20%	-12%	3%	-6%	100%	-14%	-12%
Share of no-internet access	-35%	0%	10%	19%	17%	29%	36%	-4%	0%	-14%	100%	21%
Share of over 65	14%	28%	-6%	-11%	-17%	-11%	7%	43%	-5%	-12%	21%	100%

Table 40. Correlation matrix for Middle Peninsula

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	10%	-36%	-50%	-39%	-8%	-11%	16%	-18%	-25%	-47%	-23%
Housing median value	10%	100%	4%	-28%	-25%	-17%	-23%	15%	-9%	-24%	-6%	40%
Renters' share	-36%	4%	100%	18%	15%	-3%	2%	19%	-11%	14%	19%	19%
Poverty rate	-50%	-28%	18%	100%	45%	4%	9%	0%	16%	24%	27%	-2%
Share of social assistance receivers	-39%	-25%	15%	45%	100%	-21%	29%	-19%	12%	17%	6%	-18%
Share of Black households	-8%	-17%	-3%	4%	-21%	100%	17%	-6%	-13%	-9%	26%	6%
Share of below diploma	-11%	-23%	2%	9%	29%	17%	100%	-39%	-3%	-26%	22%	5%
Share of bachelor's and higher	16%	15%	19%	0%	-19%	-6%	-39%	100%	2%	11%	2%	22%
Unemployment rate	-18%	-9%	-11%	16%	12%	-13%	-3%	2%	100%	10%	-2%	-7%
Military to civilian ratio	-25%	-24%	14%	24%	17%	-9%	-26%	11%	10%	100%	-20%	-20%
Share of no-internet access	-47%	-6%	19%	27%	6%	26%	22%	2%	-2%	-20%	100%	44%
Share of over 65	-23%	40%	19%	-2%	-18%	6%	5%	22%	-7%	-20%	44%	100%

Table 41. Correlation matrix for Eastern Shore

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	48%	-25%	-56%	-35%	-4%	-61%	49%	-8%	-11%	-47%	10%
Housing median value	48%	100%	-17%	-46%	-48%	-45%	-56%	76%	-18%	3%	-71%	34%
Renters' share	-25%	-17%	100%	52%	38%	50%	33%	-29%	16%	-21%	26%	-51%
Poverty rate	-56%	-46%	52%	100%	62%	45%	47%	-48%	23%	0%	60%	-19%
Share of social assistance receivers	-35%	-48%	38%	62%	100%	43%	38%	-56%	40%	-3%	49%	-33%
Share of Black households	-4%	-45%	50%	45%	43%	100%	43%	-47%	21%	-21%	55%	-20%
Share of below diploma	-61%	-56%	33%	47%	38%	43%	100%	-66%	20%	4%	72%	-13%
Share of bachelor's and higher	49%	76%	-29%	-48%	-56%	-47%	-66%	100%	-6%	24%	-72%	20%
Unemployment rate	-8%	-18%	16%	23%	40%	21%	20%	-6%	100%	22%	33%	-11%
Military to civilian ratio	-11%	3%	-21%	0%	-3%	-21%	4%	24%	22%	100%	4%	14%
Share of no-internet access	-47%	-71%	26%	60%	49%	55%	72%	-72%	33%	4%	100%	-7%
Share of over 65	10%	34%	-51%	-19%	-33%	-20%	-13%	20%	-11%	14%	-7%	100%

Table 42. Correlation matrix for Southern Peninsula (excluding Hampton & Newport News)

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	68%	-55%	-42%	-43%	-48%	-46%	81%	-13%	-8%	-45%	6%
Housing median value	68%	100%	-41%	-17%	-37%	-49%	-45%	64%	-3%	9%	-28%	33%
Renters' share	-55%	-41%	100%	25%	43%	25%	29%	-34%	7%	13%	20%	-19%
Poverty rate	-42%	-17%	25%	100%	47%	30%	38%	-41%	22%	-7%	38%	4%
Share of social assistance receivers	-43%	-37%	43%	47%	100%	34%	37%	-42%	13%	-10%	34%	2%
Share of Black households	-48%	-49%	25%	30%	34%	100%	51%	-52%	-2%	3%	38%	-18%
Share of below diploma	-46%	-45%	29%	38%	37%	51%	100%	-55%	-2%	3%	45%	-8%
Share of bachelor's and higher	81%	64%	-34%	-41%	-42%	-52%	-55%	100%	-11%	3%	-52%	8%
Unemployment rate	-13%	-3%	7%	22%	13%	-2%	-2%	-11%	100%	-30%	3%	13%
Military to civilian ratio	-8%	9%	13%	-7%	-10%	3%	3%	3%	-30%	100%	15%	-5%
Share of no-internet access	-45%	-28%	20%	38%	34%	38%	45%	-52%	3%	15%	100%	12%
Share of over 65	6%	33%	-19%	4%	2%	-18%	-8%	8%	13%	-5%	12%	100%

Table 43. Correlation matrix for Virginia Beach

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	72%	-63%	-45%	-47%	-48%	-39%	67%	-19%	-15%	-42%	28%
Housing median value	72%	100%	-34%	-30%	-43%	-52%	-41%	81%	-20%	-18%	-24%	49%
Renters' share	-63%	-34%	100%	40%	40%	47%	19%	-30%	12%	26%	25%	-33%
Poverty rate	-45%	-30%	40%	100%	50%	37%	37%	-31%	16%	2%	25%	-25%
Share of social assistance receivers	-47%	-43%	40%	50%	100%	51%	44%	-47%	19%	-1%	23%	-33%
Share of Black households	-48%	-52%	47%	37%	51%	100%	26%	-49%	23%	9%	16%	-44%
Share of below diploma	-39%	-41%	19%	37%	44%	26%	100%	-50%	9%	-7%	35%	-20%
Share of bachelor's and higher	67%	81%	-30%	-31%	-47%	-49%	-50%	100%	-26%	-10%	-32%	45%
Unemployment rate	-19%	-20%	12%	16%	19%	23%	9%	-26%	100%	3%	-3%	-16%
Military to civilian ratio	-15%	-18%	26%	2%	-1%	9%	-7%	-10%	3%	100%	-3%	-17%
Share of no-internet access	-42%	-24%	25%	25%	23%	16%	35%	-32%	-3%	-3%	100%	10%
Share of over 65	28%	49%	-33%	-25%	-33%	-44%	-20%	45%	-16%	-17%	10%	100%

Table 44. Correlation matrix for Norfolk

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	59%	-61%	-66%	-62%	-60%	-50%	66%	-33%	16%	-48%	20%
Housing median value	59%	100%	-11%	-27%	-46%	-55%	-48%	78%	-26%	17%	-38%	25%
Renters' share	-61%	-11%	100%	55%	47%	32%	26%	-21%	25%	12%	22%	-29%
Poverty rate	-66%	-27%	55%	100%	64%	49%	46%	-36%	36%	-26%	41%	-17%
Share of social assistance receivers	-62%	-46%	47%	64%	100%	66%	57%	-55%	45%	-25%	44%	-24%
Share of Black households	-60%	-55%	32%	49%	66%	100%	57%	-60%	40%	-31%	51%	-20%
Share of below diploma	-50%	-48%	26%	46%	57%	57%	100%	-56%	22%	-27%	50%	-6%
Share of bachelor's and higher	66%	78%	-21%	-36%	-55%	-60%	-56%	100%	-39%	19%	-44%	26%
Unemployment rate	-33%	-26%	25%	36%	45%	40%	22%	-39%	100%	-17%	17%	-28%
Military to civilian ratio	16%	17%	12%	-26%	-25%	-31%	-27%	19%	-17%	100%	-25%	-4%
Share of no-internet access	-48%	-38%	22%	41%	44%	51%	50%	-44%	17%	-25%	100%	20%
Share of over 65	20%	25%	-29%	-17%	-24%	-20%	-6%	26%	-28%	-4%	20%	100%

APPENDIX D. CORRELATION MATRICES FOR SOCIOECONOMIC VARIABLES

Table 45. Correlation matrix for Portsmouth

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	65%	-73%	-70%	-62%	-50%	-67%	64%	-36%	7%	-70%	24%
Housing median value	65%	100%	-40%	-38%	-45%	-41%	-62%	65%	-29%	11%	-49%	44%
Renters' share	-73%	-40%	100%	61%	59%	30%	39%	-43%	16%	16%	43%	-42%
Poverty rate	-70%	-38%	61%	100%	62%	39%	62%	-51%	37%	-12%	58%	-23%
Share of social assistance receivers	-62%	-45%	59%	62%	100%	45%	61%	-49%	44%	-17%	63%	-28%
Share of Black households	-50%	-41%	30%	39%	45%	100%	52%	-38%	31%	-12%	59%	0%
Share of below diploma	-67%	-62%	39%	62%	61%	52%	100%	-66%	45%	-23%	59%	-13%
Share of bachelor's and higher	64%	65%	-43%	-51%	-49%	-38%	-66%	100%	-30%	29%	-54%	33%
Unemployment rate	-36%	-29%	16%	37%	44%	31%	45%	-30%	100%	-11%	31%	-6%
Military to civilian ratio	7%	11%	16%	-12%	-17%	-12%	-23%	29%	-11%	100%	-21%	-13%
Share of no-internet access	-70%	-49%	43%	58%	63%	59%	59%	-54%	31%	-21%	100%	-2%
Share of over 65	24%	44%	-42%	-23%	-28%	0%	-13%	33%	-6%	-13%	-2%	100%

Table 46. Correlation matrix for Chesapeake

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	83%	-73%	-65%	-62%	-64%	-59%	70%	-44%	9%	-64%	-1%
Housing median value	83%	100%	-62%	-51%	-51%	-53%	-58%	72%	-29%	11%	-60%	6%
Renters' share	-73%	-62%	100%	58%	58%	56%	46%	-46%	38%	-4%	52%	-22%
Poverty rate	-65%	-51%	58%	100%	81%	49%	52%	-45%	60%	-15%	41%	-14%
Share of social assistance receivers	-62%	-51%	58%	81%	100%	56%	60%	-49%	57%	-6%	39%	-28%
Share of Black households	-64%	-53%	56%	49%	56%	100%	38%	-46%	44%	0%	42%	-8%
Share of below diploma	-59%	-58%	46%	52%	60%	38%	100%	-69%	29%	-12%	62%	-13%
Share of bachelor's and higher	70%	72%	-46%	-45%	-49%	-46%	-69%	100%	-26%	8%	-61%	10%
Unemployment rate	-44%	-29%	38%	60%	57%	44%	29%	-26%	100%	5%	23%	-2%
Military to civilian ratio	9%	11%	-4%	-15%	-6%	0%	-12%	8%	5%	100%	-16%	-21%
Share of no-internet access	-64%	-60%	52%	41%	39%	42%	62%	-61%	23%	-16%	100%	14%
Share of over 65	-1%	6%	-22%	-14%	-28%	-8%	-13%	10%	-2%	-21%	14%	100%

Table 47. Correlation Matrix for Hampton

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	54%	-70%	-66%	-50%	-48%	-41%	65%	-42%	-1%	-56%	24%
Housing median value	54%	100%	-21%	-28%	-43%	-26%	-44%	59%	-30%	19%	-42%	-3%
Renters' share	-70%	-21%	100%	57%	44%	47%	28%	-43%	15%	18%	28%	-47%
Poverty rate	-66%	-28%	57%	100%	43%	48%	19%	-33%	38%	-5%	35%	-33%
Share of social assistance receivers	-50%	-43%	44%	43%	100%	46%	31%	-48%	19%	-13%	36%	-25%
Share of Black households	-48%	-26%	47%	48%	46%	100%	28%	-39%	45%	-9%	34%	-20%
Share of below diploma	-41%	-44%	28%	19%	31%	28%	100%	-49%	15%	-1%	47%	3%
Share of bachelor's and higher	65%	59%	-43%	-33%	-48%	-39%	-49%	100%	-26%	17%	-44%	21%
Unemployment rate	-42%	-30%	15%	38%	19%	45%	15%	-26%	100%	-22%	11%	-17%
Military to civilian ratio	-1%	19%	18%	-5%	-13%	-9%	-1%	17%	-22%	100%	-7%	-13%
Share of no-internet access	-56%	-42%	28%	35%	36%	34%	47%	-44%	11%	-7%	100%	26%
Share of over 65	24%	-3%	-47%	-33%	-25%	-20%	3%	21%	-17%	-13%	26%	100%

Table 48. Correlation matrix for Newport News

Socioeconomic variables	Median income	Housing median value	Renters' share	Poverty rate	Share of social assistance receivers	Share of Black households	Share of below diploma	Share of bachelor's and higher	Unemployment rate	Military to civilian ratio	Share of no-internet access	Share of over 65
Median income	100%	67%	-78%	-74%	-75%	-72%	-50%	77%	-23%	32%	-67%	21%
Housing median value	67%	100%	-37%	-47%	-57%	-59%	-57%	74%	-14%	28%	-54%	10%
Renters' share	-78%	-37%	100%	55%	56%	50%	29%	-51%	12%	-9%	44%	-34%
Poverty rate	-74%	-47%	55%	100%	75%	57%	49%	-56%	32%	-21%	58%	-23%
Share of social assistance receivers	-75%	-57%	56%	75%	100%	69%	56%	-62%	27%	-36%	64%	-27%
Share of Black households	-72%	-59%	50%	57%	69%	100%	45%	-68%	20%	-29%	63%	-18%
Share of below diploma	-50%	-57%	29%	49%	56%	45%	100%	-64%	33%	-22%	50%	-2%
Share of bachelor's and higher	77%	74%	-51%	-56%	-62%	-68%	-64%	100%	-24%	27%	-57%	17%
Unemployment rate	-23%	-14%	12%	32%	27%	20%	33%	-24%	100%	-29%	14%	-16%
Military to civilian ratio	32%	28%	-9%	-21%	-36%	-29%	-22%	27%	-29%	100%	-35%	-17%
Share of no-internet access	-67%	-54%	44%	58%	64%	63%	50%	-57%	14%	-35%	100%	7%
Share of over 65	21%	10%	-34%	-23%	-27%	-18%	-2%	17%	-16%	-17%	7%	100%