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Sea-Level Rise and Storm Surge Flooding Risk in Phippsburg, ME

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Executive Summary
Over the past 7 weeks, our group has worked with Laura Sewall of the Phippsburg Comprehensive Planning Committee to create a methodology for assessing properties' risk to the impending effects of sea-level rise and storm surge, as well as provide recommendations and examples to the Committee on dealing with the socioeconomic effects of these issues. Because Phippsburg is a very large town compiled by 9 distinct villages, we decided to look at a specific area that is densely developed and particularly vulnerable to the effects of sea-level rise and provide risk assessments for the properties that inhabit it. We chose Popham Beach to be that area because it was both particularly accessible to us for data collections and it potentially contained the greatest number and most vulnerable properties of any other village.

We surveyed about 84 different houses along the coast of Popham and we found there was a very concerning number of houses and buildings which were not only at-risk for future extreme SLR scenarios, but at-risk for current highest annual tide and storm surge occurrences. Some of these very vulnerable homes were even newly built, and as the number of people moving to Phippsburg continues to increase, the number of homes vulnerable to SLR and storm surge flooding is also predicted to increase. We created maps using data from the Maine GeoLibrary to visualize which homes are located in parcels projected to be affected by Sea-level rise and using an elevation methodology based around "first-floor elevation", we were able to find which homes would be vulnerable to sea-level rise and storm surge, and there were an alarming number of them in this particular example. Under a 10.9ft SLR scenario by 2100, 49% of properties will be flooded, with many being projected as dangerously close to flooding. Despite the 10.9ft SLR scenario once being labeled an "extreme" scenario, SLR scenarios have continued to shift towards the more extreme end as annually recorded SLR measurements continue to accelerate faster than expected. Also, 92% of properties are at-risk from flooding via a category 4 hurricane. These properties typically included homes that had **both** a high first-floor elevation as well as a high topographical elevation, and even despite these homes being somewhat resistant to the flooding effects of category 4 hurricanes, the wind speed itself could harm homes that are built on mountains and don't have a particularly stable foundation.

Although their effects have continued to accelerate, sea-level rise and storm surge are no new occurrences. Many other low-lying coastal communities have had to deal with their effects. There is a series of interconnecting effects that must be planned for in order for residents to avoid displacement. As people are forced out of coastal communities they will be forced to move inland and build new homes, which also typically coincides with an increase in property prices. Since Phippsburg has many multi-generational homes that get by from fixed incomes, these long-term residents will have a difficult time relocating and can very well be priced out from the town they've lived in forever. Based on our sea-level rise and storm surge risk assessments we have crafted some recommendations to the Comprehensive Planning Committee to ensure that this does not occur. These include the tactical use of voluntary managed retreat to avoid a steep tax burden on the residents of Phippsburg when homes inevitably begin to move, the alteration of zoning laws to find a middle ground between preserving the rural nature of Phippsburg and allowing for denser development to prevent further increases in housing costs for residents, and the future implementation of affordable housing options in Phippsburg for people as sea-level rise indirectly makes the cost of housing too high to handle. Nonetheless, the perspective of Phippsburg residents is of utmost importance and they should remain to have a choice in where

they live, but current and potential residents deserve to know how this very real threat will affect their homes and investments in the future, and there should be a great deal of collaboration and planning before it is too late.

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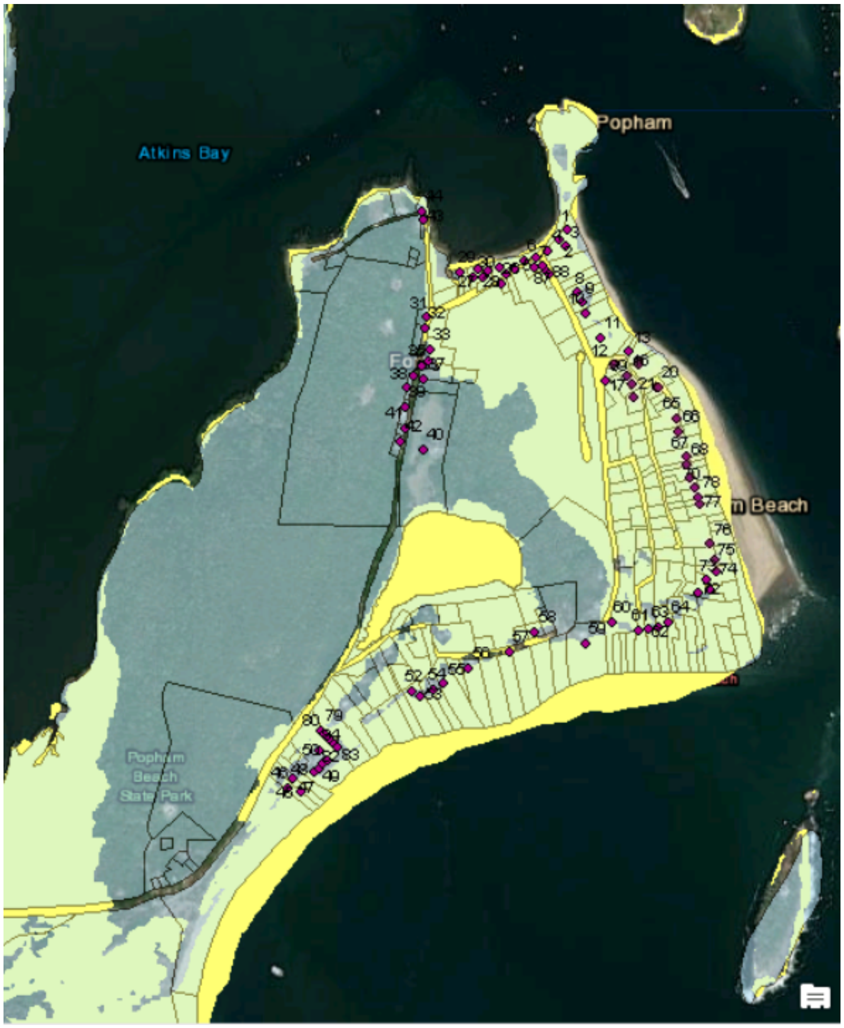

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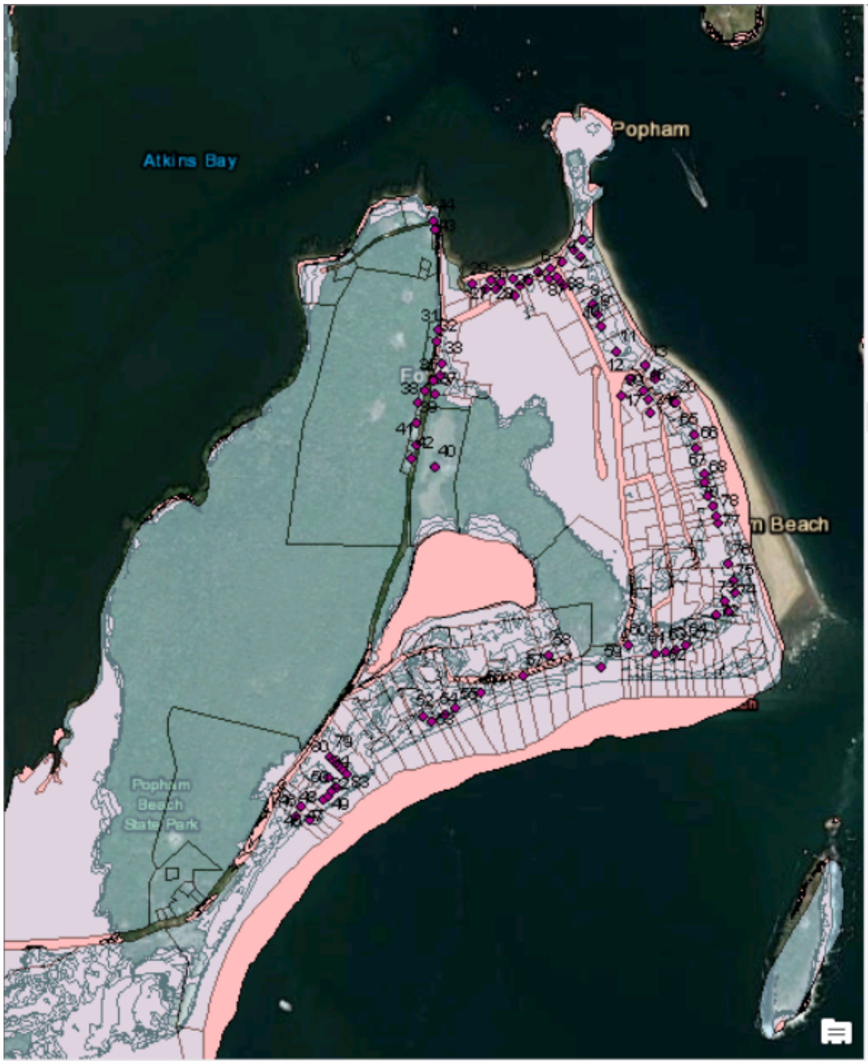

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Section 2: Introduction

Background

As climate change continues to warm the Earth at an unprecedented rate, sea-level rise becomes more and more of a growing concern for coastal communities around the world. Sea-level rise occurs for two main reasons: the first is thermal expansion and the second is melting glaciers. Warm water takes up more space than cold water, so as the Earth's average temperature increases, the oceans heat up and expand. Glacier melt, on the other hand, is rather straightforward. While loose ice may melt and be offset by rules of water displacement, glaciers are essentially land masses made of ice. When that ice melts, sea-level rises drastically (NRCM, 2021). Sea-level rise has already had a huge impact on certain coastal communities, displacing thousands of families whose homes and businesses have been destroyed by flooding, and its effects are not slated to slow down anytime soon as the World still struggles to deal with the mitigation of climate change. Another issue we look to consider is the effects of a growing number and intensity of storms. A storm surge is a rise in sea level that occurs during storms with the potential to severely flood low-lying coastal communities. A higher sea level (and thus deeper water) has the potential to flood low-lying coastal buildings and makes it easier for wind and waves to push water toward the shore. For example, a 1-m higher sea level will make a given storm surge and its waves run up not just 1 m higher but closer to 1.5 m, and in some places even 2 m higher (Rahmstorf, 2017). As these people are forced to retreat, they must move inland, often having severe indirect effects such as urban sprawl, which in turn, increase real-estate prices and increase carbon emissions further (Johnston et al., 2014). Without plans in place, vulnerable communities will be priced out of their areas resulting in less sustainable towns and cities all over. These effects of sea-level rise can potentially be negated through the amendment of zoning laws and housing policies to place emphasis on the incentivization of denser development as well as affordable housing.

Sea-level rise and climate change will have significant impacts on coastal towns and cities, which make up a large fraction of the state of Maine. Additionally, these areas have seen dramatic increases in development and influx over recent decades (Johnston et al., 2014). Since 1950, the sea-level off the coast of Maine has risen 8 inches due to changes in ocean circulation and ice melt (SeaLevelRise.org). Solutions, however, can be complicated because the state must find solutions that protect communities from sea-level rise and storm surge while protecting and preserving important coastal habitats. In the last decade alone, sea-level rise has increased to as much as an inch every 6 years and scientists estimate a 6-inch increase in the next 16 years. Despite this rather severe threat of sea level rise in the coming decades, people are moving to coastal Maine communities at a consistent pace (US Census, 2021). As sea-level rises people will be forced to move inland and will sprawl out without zoning laws that allow dense, affordable development (Johnston et al., 2014). This additional housing pressure on limited land will drive up the cost of housing and accelerating already occurring processes of gentrification.

Phippsburg, ME is a relatively small coastal town in the Casco Bay region of the state with a population of around 2,000 and with an abundance of coastal property and infrastructure, it is very vulnerable to sea-level rise, flooding and storm surges (Simon, 19). The town's vulnerability to these threats requires immediate attention and careful planning as eventually community members will be displaced whether they live in a multi-generational home or just moved there. Current Phippsburg zoning laws require every house to be built on at least one acre of land, incentivizing sprawl and thus both increasing property prices and perpetuating the cycle of carbon emissions that has caused sea-level rise in the first place (The Town of Phippsburg, 2012). With many multi-generational coastal residents of Phippsburg living on fixed incomes, if sea-level rise destroys their homes and displaces them, there needs to be affordable housing options for these citizens whose livelihood depends on life in Phippsburg. We hope to address these issues with the Comprehensive Planning Committee for potential inclusion in the 2021-2031 Phippsburg Comprehensive Plan, which will provide a series of steps which will help the town deal with the growing threat of sea-level rise and storm surge.

Issues at Hand

Estimating the risks of sea-level rise and storm surge can be a difficult task as most of the data is based on long term projections which are difficult to predict. What we do know is that what were once considered more extreme projections for sea-level rise have become moderate scenarios as physically measured sea-level rise continues to accelerate each year. The Phippsburg Comprehensive Planning Committee, and the Phippsburg community as a whole, could make great use of updated sea-level rise projections and data so that the town is better equipped to deal with its effects. The town also currently lacks building footprint and elevation data, which are both important factors for determining which houses and types of locations are particularly vulnerable based on different SLR scenarios and hurricane intensities. A methodology for precisely measuring SLR and SS risk could provide the town with a useful tool for future planning. The final main issue we are observing is the projected sprawl and rising property prices that result as effects of sea-level rise and storm surge. Since sea-level rise and storm surge will inevitably displace residents of Phippsburg, it would be useful for the planning committee to consider options to lower the financial burden on residents forced to relocate inland through affordable housing policy and denser development initiatives.

Aims and Objectives

Aim: The aim of this project is to develop an effective methodology for assessing SLR and storm surge risk and use it to provide land-use recommendations to the Phippsburg Comprehensive Plan Committee to help the town plan for denser and more affordable housing, while adapting to future sea-level rise and storm surge challenges.

<u>Objective 1:</u> Identify buildings most at-risk of flooding from future sea-level rise and storm surge scenarios through the collection of first-floor elevation and SLR projection data and create SLR risk maps to help assess the SLR and storm surge risk properties on Popham Beach are vulnerable to.

<u>Objective 2:</u> Identify and evaluate effective zoning laws and affordable housing policies to increase density and lower housing prices in Phippsburg based on policies implemented in other communities vulnerable to sea-level rise.

Section 3: Methodology

This methodology is intended to help us make inferences about buildings' risk to sea-level rise and storm surge scenarios via finding their elevations. The methodology centers around finding the First-floor elevation of coastal buildings and based on a specific sea-level rise scenario, we can infer how at-risk a particular building is.

1. **Building Sampling**

Using google earth we found a sample of coastal buildings and their precise locations. On ArcMap, we marked these precise locations so we could determine their topographical location, which will be expanded upon in a later step.

2. **Number of Steps**

First-Floor Elevation Data, or FFE, is the height (in feet) from the ground to the first floor. To determine this FFE we had to count the number of steps from the ground to the first floor. If there were multiple staircases, it was unimportant which one we looked at because the FFE would later be combined with topographical elevation, so as long as we marked the correct staircase, the elevations would be the same.

3. **Topographical Elevation**

We attempted to find completed digital elevation data in order to get the most precise elevation data but were unable to find a version compatible with our mapping software. We instead used a 2ft. contour map found on the Maine GeoLibrary database and included an error estimate with our final calculations. Once we added the contour layer to ArcMaps, we were able to join the contour data with the building footprint locations to find each property's topographical elevation.

4. **First-floor Elevation**

The First-floor elevation was found simply by adding the number of steps converted into feet with the topographical elevation. We achieved this with a simple excel command.

5. **Sea-Level Rise Scenarios**

In this step, we found sea-level rise scenario maps from the Maine GeoLibrary database and combined them with the components above to determine which buildings were at-risk from a particular sea-level rise. In this project, we looked at year 2100 projections, which included a HAT scenario, a HAT + 3.6ft scenario, a HAT +6.1ft scenario, as well as a HAT +10.9ft scenario.

6. **Storm Surge Scenarios**

As done in the step above, we found storm surge flooding map layers from the Maine GeoLibrary database and combined them with the components above to determine which buildings were at-risk from a particular category of hurricane. In this project, we looked at flooding from categories 1-4.

7. **Risk Assessment**

Once all of these steps were completed, we were able to make inferences about how at-risk particular buildings in our sample are from sea-level rise and storm surge. We made a pretty general ranking for each building between the values 1 & 9, with 1 being no risk and 9 being very at-risk. We made separate risk rankings for each separate scenario.

Section 4: Results and Discussion

Highest Annual Tide = 5.8ft (Maine DEP, 2018)

Category 1 Storm Wind Speed: 74-95 mph (NHC, 2021)

Category 2 Storm Wind Speed: 96-110 mph
Category 3 Storm Wind Speed: 111-129 mph
Category 4 Storm Wind Speed: 130-156 mph

Scenarios	Proportion at-Risk
HAT	0/84 or (0%)
HAT +3.9ft SLR	6/84 or (31%)
HAT +6.1ft SLR	21/84 or (37%)
HAT +10.9ft SLR	41/84 or (49%)
Category 1 Storm Surge	20/84 or (24%)
Category 2 Storm Surge	43/84 or (51%)
Category 3 Storm Surge	67/84 or (80%)
Category 4 Storm Surge	77/84 or (92%)

These properties are extremely vulnerable to any further sea-level rise and are included in each other sea-level rise scenario. These properties typically have very low elevations as well as a location very close to the ocean. Based on our HAT estimate of 5.8ft provided by the Maine DEP, 0 of 83 properties are at risk of flooding due to the highest tide in a given year. This number of properties at-risk increases from 0 to 6 when viewing the HAT +3.9 SLR scenario. Again, most of these properties are also very low-lying. If emissions were to be reduced greatly, we would still likely see a 3.9ft SLR on top of the HAT estimate. This increase in sea level would more than double the number of houses at risk, now including those that are located slightly higher than HAT and slightly farther from the ocean. The next scenario, based on intermediate-level emissions, predicts a 6.1ft increase in sea level on top of the HAT estimate. Consequently, this will threaten 37% of properties. This scenario includes those that are not as close to the ocean, as well as those that may live at slightly higher elevations. The highest emissions scenario, referred to as "business as usual," forecasts a SLR of 10.9ft on top of the base HAT estimate. This indicates a water level that reaches much farther inland and may affect houses that may have never considered their property at risk of SLR. This scenario would put 49% of properties at-risk.

Projections based on storm surge reflect the greater threat these properties face. In a Category 1 storm, 24% of houses are considered at risk. This poses similar risk to that of the HAT +3.9ft SLR scenario. This area at risk doubles during a Category 2 storm surge projection, encompassing 51% of the buildings, which is half of the area studied. We observe substantially more houses threatened with our Category 3 storm projections. In this scenario, the flooding reaches much farther inland than previously discussed scenarios. This can cause extensive and severe damage in properties close to the shore, while likely resulting in widespread damage farther inland than we ever thought possible. The projected risk-area becomes catastrophic in a Category 4 flooding scenario. This would not only devastate the area studied but would severely impact many of Maine's coastal areas. 91% of houses in the area studied would be threatened in this scenario. Even low to moderate scenario projections can have widespread impacts throughout the study area and other parts of Maine.

Therefore, it is evident that without updating the past data used in risk evaluation of SLR and storm surge, the true risk posed in the future will be largely mis conceptualized. Proper quantification will allow establishment of a clear plan with specific measures that properly accounts for the level of the threat, while providing a plethora of alternatives/solutions in the event that properties succumb to the projected scenarios. Even in more moderate emissions scenarios, that at this point are more than likely in the next century, we still see that a large amount of the properties studied will be threatened in some way. This also does not mean we should dismiss more severe scenarios, because many of the projections that were once considered improbable are now the reality we currently facing. If we continue to avoid addressing this threat, we may lose coastal communities that have been tied to the area for generations. And, if the threat is not accepted and properly prepared for, we may lose the rural feel that defines Phippsburg and draws so many to the area. Not to mention, this will also impact other coastal communities across the nation.

Section 5: Recommendations for Next Steps

After detailed analysis of our SLR and storm surge risk-assessment maps, we came up with three recommendations regarding policy use that we believe could be beneficial for the town of Phippsburg's' future. First, we suggest that Phippsburg implement more emergency response routes to provide more accessible escape options in the event of flooding. We suggest this because as it stands, Popham Road is the only accessible route to many housing properties near Popham beach. Thus, in the case of a severe flood, having only one way out would be detrimental to a safe escape. Second, we recommend that the town of Phippsburg devise a plan for managed retreat to maximize efficiency and dim the stress of relocation on taxpayers. Accompanying this, is the suggestion that the committee consider the implementation of dense affordable housing to prevent multi-generational families operating on a fixed income from being priced out of Phippsburg. We say this because the socioeconomic impacts of increasing SLR and storm surge will pose significant difficulties for low-income families. Third, we suggest that Phippsburg further protect the coast through the creation of sand dunes able to absorb the impacts of sea-level rise and flooding. Also, to potentially introduce a land acquisition program which entails the purchase of coastal land that is damaged or prone to damage and use it for conservation study purposes. Popham beach is already a useful example of such green infrastructure that is able to assist in mitigating the effects of sea-level rise and flooding. We hope the committee considers our recommendations for the comprehensive plan.

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