Flood Impact Analysis: Future Sea Level Rise Scenarios in Salem, MA

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Introduction & Methods

Sea level rise is one example of the profound changes occurring on our planet due to warming global temperatures as a result of human induced climate change. Three potential flood height scenarios have been modeled by the National Oceanic and Atmospheric Administration (NOAA) of 2.7 meters, 3.7 meters, and 4.6 meters depending on the level of future carbon emissions. These scenarios, based on projections of low, moderate, and high carbon emissions scenarios, are calculated by adding predicted sea level rise by the year 2100 to height of the highest tide above median sea level to height of storm surge. The three flood height levels were used to assess areas of the city of Salem that are at risk of flood due to future sea level rise by creating a digital elevation model of the city on ArcMap 10.3.1. Any areas in the city that had an elevation lower than the three predicted flood heights was determined to be a flood risk area. Once flooded areas in Salem were determined, layers of infrastructure data including roads, commuter rail, bus routes, housing, underground storage tanks, and hazardous materials sites were identified that are at risk of flood (see figures 3, 6 and 9; see tables 2, 4 and 6). Lastly, map data layers of demographics information from the U.S. Census Bureau provided an assessment of percent of residents in Salem who would be impacted by sea level rise, as well as particular vulnerable members of society, specifically elderly 65 and older, black and African American populations, and Hispanic and Latino populations affected (see tables 1, 3 and 5) . Results show that under 2.7m of flood height, 4.7% of the city will be impacted (see fig. 1); under 3.7m, 14.3% of the city will be impacted (see fig. 4); and under 4.6 meters 19.2% of the city will be impacted (see fig. 7).

Flood Scenarios Under 2.7 m Sea Level Rise

Figure 1: Salem Flood Area 2.7m

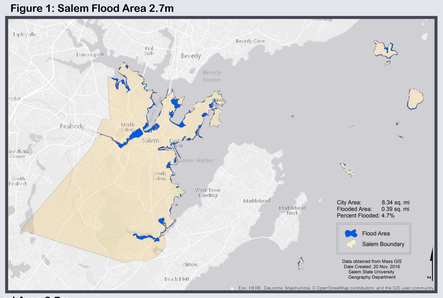

Figure 2: Population Impact in Flood Area 2.7m

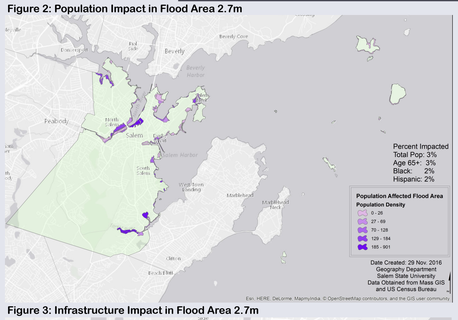

Table 1: Population Impact 2.7m

Population & Demographics	% Impacted by Flood
Total Population	3
65 years and older	3
Black/African American	2
Hispanic/Latino	2

Figure 3: Infrastructure Impact in Flood Area 2.7m

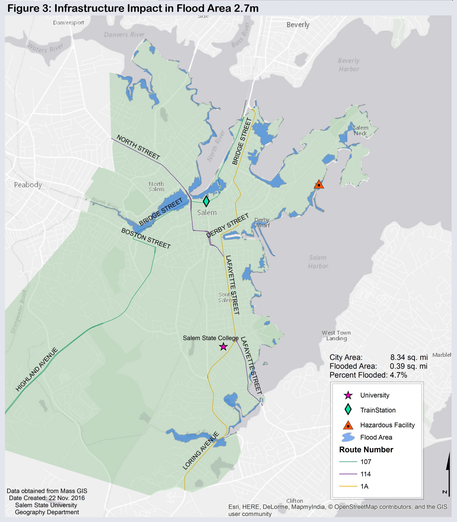

Table 2: Infrastructure Impact 2.7m

Type of Infrastructure	Amount Impacted	Total in Salem
Roads	4.1 mi	136.7 mi
Commuter Rail Track	0.3 mi	3.9 mi
MBTA Bus Routes	3.5 mi	88 mi
Mass DEP Major Facilities*	1	8
Structures	1,715,820 sq. ft.	22,097,858 sq. ft.

Flood Scenarios Under 3.7 m Sea Level Rise

Figure 4: Salem Flood Area 3.7m

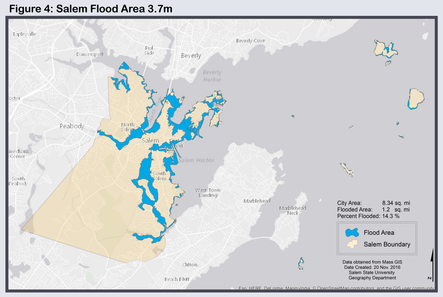

Figure 5: Population Impact in Flood Area 3.7m

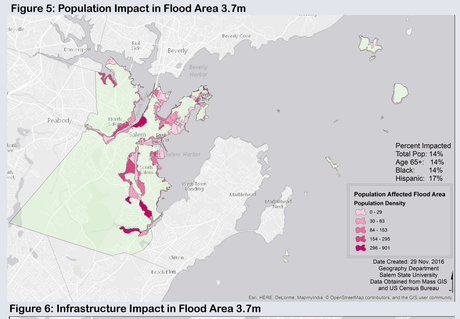

Table 3: Population Impact 3.7m

Population & Demographics	% Impacted by Flood
Total Population	14
65 years and older	14
Black/African American	14
Hispanic/Latino	17

Figure 6: Infrastructure Impact in Flood Area 3.7m

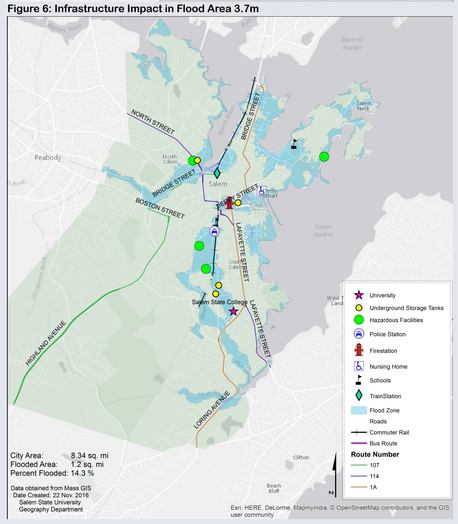

Table 4: Infrastructure Impact 3.7m

Type of Infrastructure	Amount Impacted	Total in Salem
Roads	19 mi	136.7 mi
Commuter Rail Track	1.8 mi	3.9 mi
MBTA Bus Routes	13.5 mi	88 mi
MBTA Bus Stops	16	137
Schools	2	15
Hospital	-	1
Nursing Homes	1	4
Fire Stations	1	4
Police Stations	1	1
Train Station	1	1
Underground Storage Tanks*	4	16
Mass DEP Major Facilities*	5	8
Structures	4,884,520 sq. ft.	22,097,858 sq. ft.

* Indicates hazardous materials involved with this category of structure, such as methane, propane, or petroleum.

Flood Scenarios Under 4.6 m Sea Level Rise

Figure 7: Salem Flood Area 4.6 m

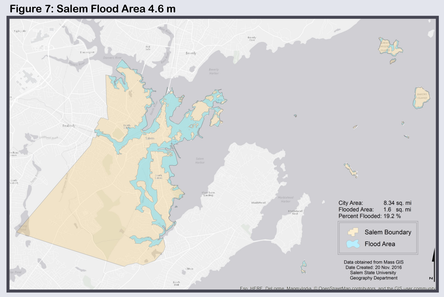

Figure 8: Population Impact in Flood Area 4.6 m

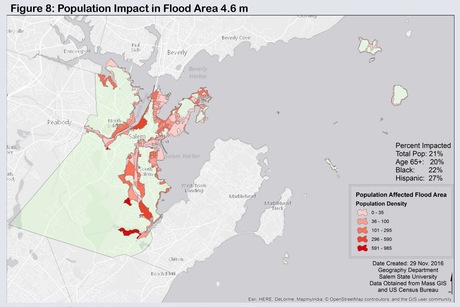

Table 5: Population Impact 4.6m

Population & Demographics	% Impacted by Flood
Total Population	21
65 years and older	20
Black/African American	22
Hispanic/Latino	27

Figure 9: Infrastructure Impact in Flood Area 4.6 m

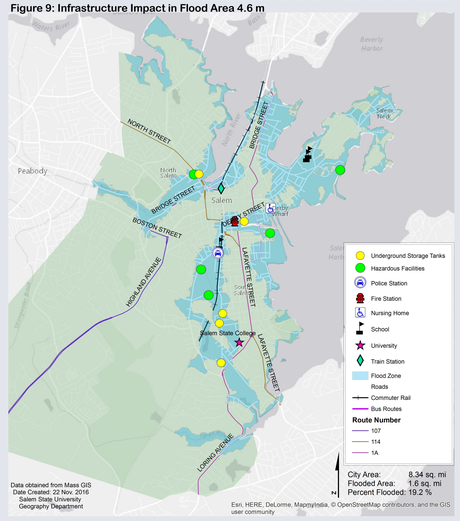

Table 6: Infrastructure Impact 4.6m

Type of Infrastructure	Amount Impacted	Total in Salem
Roads	28.6 mi	136.7 mi
Commuter Rail Track	2 mi	3.9 mi
MBTA Bus Routes	20.2 mi	88 mi
MBTA Bus Stops	16	137
Schools	3	15
Hospital	-	1
Nursing Homes	1	4
Fire Stations	1	4
Police Stations	1	1
Train Station	1	1
Underground Storage Tanks*	5	16
Mass DEP Major Facilities*	5	8
Structures	6,414,229 sq. ft.	22,097,858 sq. ft.

* Indicates hazardous materials involved with this category of structure, such as methane, propane, or petroleum.

Discussion

An assessment of tax parcels in the City of Salem shows that under the three sea level rise scenarios of 2.7 meters, 3.7 meters, and 4.6 meters, $335,551,835.00; $801,357,232.00; and $1,058,483,146.00 of total property value is at risk of flooding, respectively. The proposed and approved budget for the City of Salem for FY2017 is $150,952,820.00. This is not nearly enough money to address the economic costs that may be incurred at the most modest sea level rise scenario modeled for the future. In addition, the city faces the cost of needing to re-route or raise between 7% to 53% of the commuter rail tracks that run through Salem(see tables 2, 4 and 6). The shape of the flood area, especially at the moderate and high scenarios indicates the possibility for areas in North and Southeast Salem to become isolated from the rest of the resources of the city (see figures 4 and 7). The one major structure that was assessed and found not to be impacted directly by flooding was the hospital in Salem. Access to the hospital however will be restricted, as the coastal areas of town, as well as north and southeast Salem will have roads and bus routes that are cut off from access to the center of the city. Percentages of vulnerable members of population mirror the percentage of total population that will be impacted in each scenario of flooding (see tables 1, 3, and 5).

Sources

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- Global sea level rise model: Paris A et al (2012): Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OARCPO-1. 37 pp.
- Methods to localize sea level rise projections: Tebaldi C, Strauss BH & Zervas CE (2012). Modeling sea level rise impacts on storm surges along US coasts. Environmental Research Letters, 7(1). 014032.