Historic Redlining and Sea Level Rise Impacts
in Norfolk, Virginia

by Brooke Elliott and Tsehai Ricketts

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Our Problem Statement

The Problem

- Flooding impacts many coastal cities in the United States, especially as sea levels continue to rise due to anthropogenic climate change.
- This flooding may disproportionately impact certain populations based on social and historical processes..
- Understanding how flooding affects vulnerable people in our major cities helps us work toward a more equitable future.
- **Our research aims to discover if the historic redlining perpetrated by the Home Owners Loan Corporation impacts the likelihood of future flooding experienced in Norfolk, Virginia.**

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Background Information

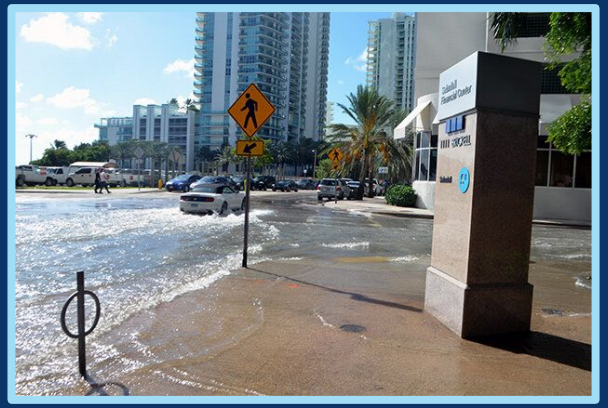
Glossary: Types of Coastal Flooding

Inland Flooding:

intermittent flooding of areas not directly touching the coast.

Tidal Inundation:

continuous flooding of shoreline areas.



(note: both of the above examples occurred in Florida, a coastal US state.)

Glossary: Redlining

- The term for the practice of drawing boundaries around neighborhoods based on residents' race and class, depriving them of resources and opportunities in the short and long term.
    - Lower grades were assigned to neighborhoods with higher proportions of minority residents.
- Perpetrated by the Home Owners Loan Corporation (HOLC), a government-sponsored corporation that categorized the “riskiness” of lending to households in different neighborhoods.

Basis for Study

- A 2023 study by Steinberg-McElroy et. al found that neighborhoods in NYC that historically received lower HOLC grades were more likely to experience flooding than neighborhoods that historically received higher HOLC grades.
    - The study merged historical HOLC boundaries with modern census tracts to give the census tracts an equivalent HOLC grade.
    - These boundaries were then overlaid with flooding extents to calculate the amount of flooding in each tract.
- The city of Norfolk, VA was selected for this study for its capacity to experience coastal flooding and its extensive history of redlining.
    - Using a similar methodology to the one outlined above, we can investigate whether areas of Norfolk, VA with lower HOLC grades (and thus more vulnerable populations) were also more at risk of flooding.

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Sources of Data

Our Data

HOLC Polygons

The University of Richmond's Mapping Inequality project allows users to download HOLC boundaries in a GeoJSON format.

Census Block Groups

Up-to-date census block groups are free to download on the US Census Bureau's website in shapefile form.

Sea Rise Levels

The National Oceanic and Atmospheric Administration provides shapefiles containing flooding extents in different scenarios (i.e. different locations and levels of sea rise in feet.)

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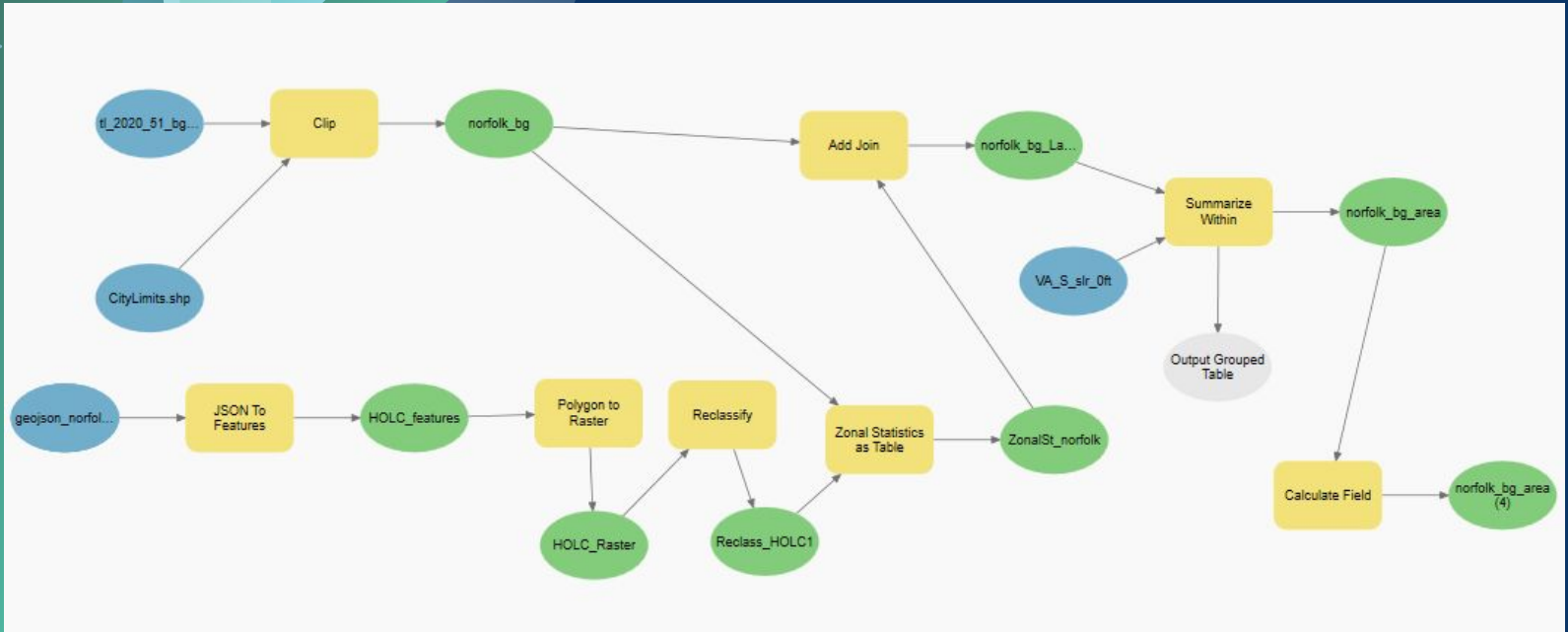
Methodology

Methodology

- Create the model in ArcGIS..
  - Create a layer of graded census blocks based on each block's historic HOLC grade.
  - Calculate the flooding extent per block group according to various scenarios (e.g. 1 foot of sea level rise, 2 feet of sea level rise, etc).
- Export the model builder to a Python script.
- Create user-friendly ArcGIS tools based on these Python scripts.
- Produce proportional symbol maps and box plots to analyze flooding by HOLC grade in Norfolk, Virginia.

Model


tl_2020_51_bg...
Clip
norfolk_bg
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Summarize Within
norfolk_bg_area
CityLimits.shp
VA_S_slr_0ft
Output Grouped Table
geojson_norfol...
JSON To Features
HOLC_features
Polygon to Raster
Reclassify
Zonal Statistics as Table
ZonalSt_norfolk
Calculate Field
norfolk_bg_area (4)
HOLC_Raster
Reclass_HOLC1

Model

1) Clip a census block group layer for Virginia to Norfolk city limits.
2) Assign an HOLC grade to each census block group.
3) Convert HOLC data to a shapefile layer.
4) Convert the shapefile to a raster using the Polygon to Raster tool.
5) Reclassify the resulting raster to assign a number corresponding to each HOLC grade.
    a) (A becomes 1, B becomes 2, etc.)
6) Run the Zonal Statistics as Table tool to calculate which HOLC grade constitutes a majority of each census block group.
    a) If two different HOLC grades cover a block group, the block group's grade is determined by the HOLC grade with the most coverage there.
7) This table is joined back to the census block group layer.
8) Use the the Summarize Within tool to find the amount of area in each census block group impacted by flooding at 0 feet of sea level rise using NOAA data.
    a) Calculate a new field to determine the percentage of each block group impacted.
9) Convert the resulting model into a Python script.

Our ArcGIS Tools

Norfolk Sea Rise Level

- Allows users to input a sea rise level between 0 and 10.
- Creates a layer showing sea level rise scenarios in Norfolk, Virginia based on the number entered by the user.

General Sea Rise Level

- Allows users to select from a drop-down menu containing three sea level rise scenarios.
- Asks the user to input a HOLC GeoJSON file and a city boundary shapefile from anywhere in Virginia.
- Creates a layer showing one sea level rise scenario in the city selected.

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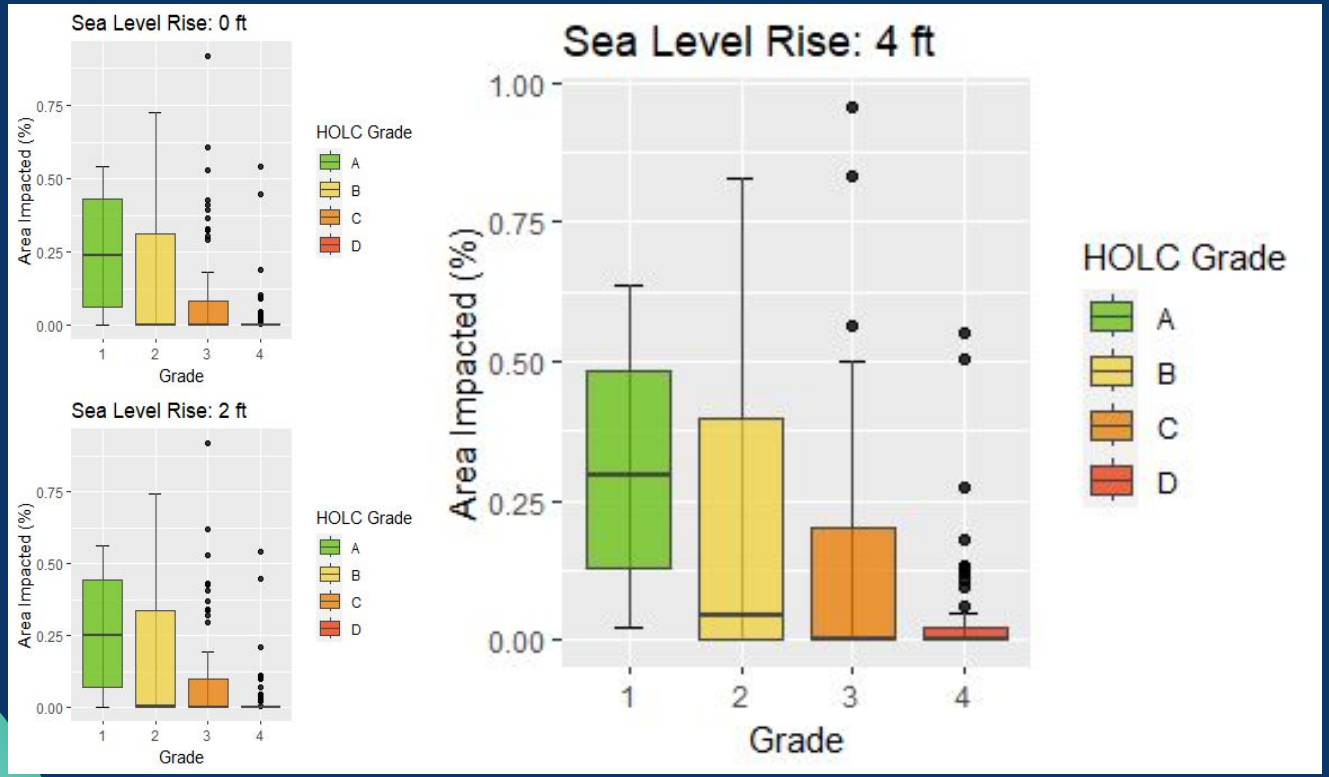
Results

Results

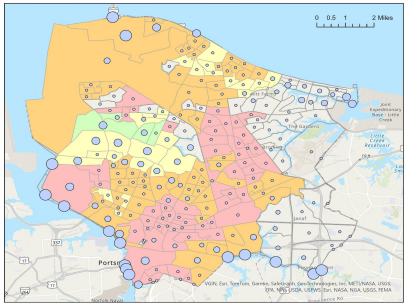
- Our results diverged heavily from the results of the 2023 study of stormwater flooding in New York!
    - The census blocks most likely to be impacted by flooding were given grades of A by the HOLC, while the census blocks least likely to be impacted by flooding were given grades of D by the HOLC.
- Lower-graded districts of cities in coastal New York experienced more frequent and widespread flooding, while lower-graded districts of Norfolk, Virginia actually experienced less flooding than higher-graded districts.

Figures: Box Plots

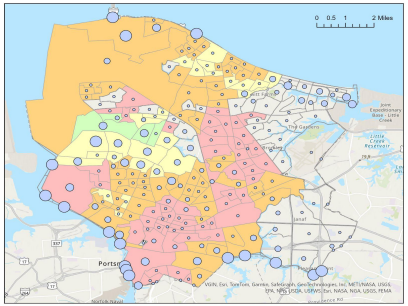


Figures: Maps

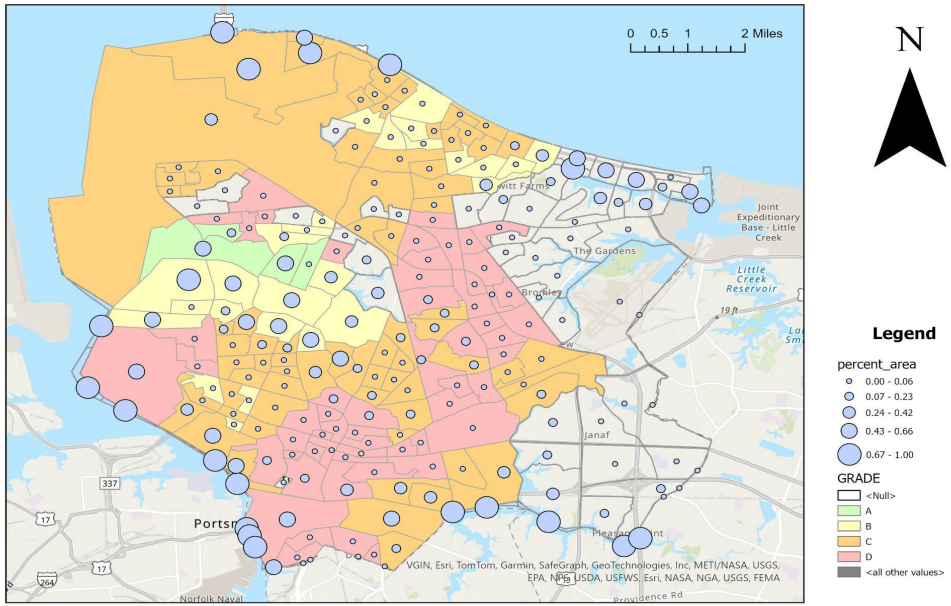
Percent Area Impacted by Norfolk Block Group: Zero Feet of Sea Level Rise



Percent Area Impacted by Norfolk Block Group: Two Feet of Sea Level Rise



Percent Area Impacted by Norfolk Block Group: Four Feet of Sea Level Rise



Why We Got These Results

- Another study of flooding in Miami found that, in some coastal cities, the wealthy monopolize beachfront property; therefore, in some locations, historically wealthier parts of these cities actually experience more flooding.
    - Wealthy white citizens in cities like NYC and Houston experience less flooding, while wealthy white citizens in cities like Miami and Norfolk experience more flooding.
- Norfolk has also constructed floodwalls near their downtown area, which historically received lower HOLC grades (C and D). This may have prevented flooding over time or changed the locations with the most extreme levels of flooding.

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Analysis and Evaluation

Analyzing Our Results

- In the future, it will be important for researchers to evaluate urban coastal flooding on a case-by-case basis.
- Minority and working-class populations are **more vulnerable** to flooding in cities like Houston and NYC, but they are **less vulnerable** to flooding in cities like Norfolk and Miami.
    - From this study and studies before it, we can divide major American coastal cities into two models:
        - Norfolk-Miami (affluent citizens most affected by flooding)
        - NYC-Houston (minority citizens most affected by flooding)
- This research and further research in this field will help city governments in determining which populations in a given city are most vulnerable to climate change.

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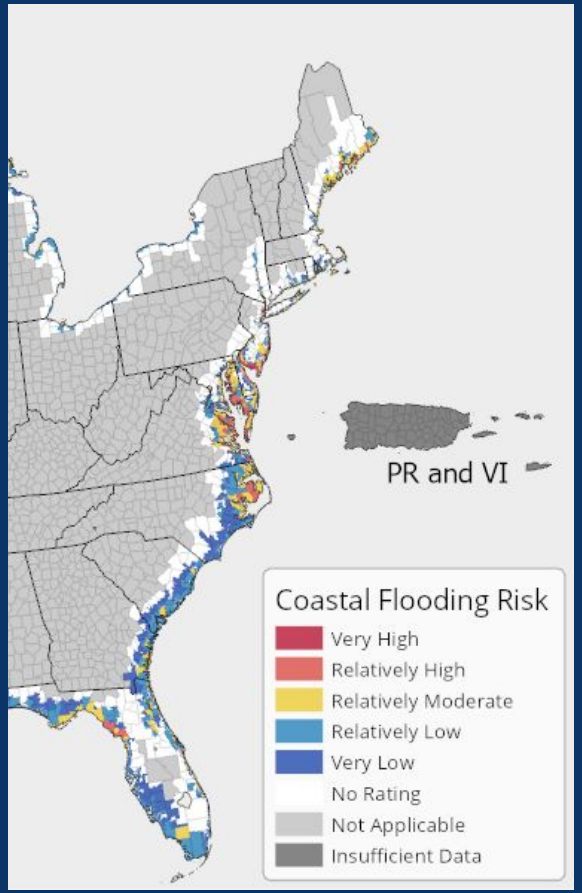
Future Extensions

Further Studies

- New tools would be invaluable in determining how climate change will impact our coastal cities.
    - Our second tool created for this project allows the user to simulate three different sea level rise scenarios for any city in Virginia.
    - A version of this tool (or multiple versions) that worked for other US states and territories would be critical for further research.
- Another study could be conducted to simulate sea level rise scenarios in other major coastal cities with a history of redlining, sorting them into the Norfolk-Miami or NYC-Houston models.



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