Project Website: https://geog3540.github.io/ssetu/FinalProject.html

1. Introduction

Natural disasters like flooding are one of the most destructive events, affecting communities globally, causing significant displacement, economic losses and threats to safety. According to (CDP, 2024), there have been 44 floods occurred in the US in between 1980 to October 2024, killing at least 738 people and causing more than a billion dollars in damage each. On average, these flood events cost $4.5 billion every year. The prevalence of floods in Mid-Western States like Iowa is especially concerning. According to (Alabbad & Demir, 2022), approximately $3.8 billion losses including 15 casualties have happened due to flooding in the US in between 1980 to 2021. The 2019 flood in Iowa caused damages worth of nearly $1.6 billion. The effects of changing climate coupled with population growth and human interventions due to urbanization are increasing the frequency of flood events and exacerbating the impacts.

The increasing frequency and intensity of flood events have underscored the need for comprehensive flood hazard management, especially flood prone areas like Johnson County, Iowa. Located along the Iowa River and its tributaries, Johnson County has experienced historical flood events, with the 2008 Iowa flooding (Citizen, 2018), acting as a reminder of the region's vulnerability to flooding. The increasing risk and vulnerability of flooding poses significant threat to the resilience of the community, especially for the flood prone areas like Johnson County, Iowa. Proper interventions to effectively maintain and reduce the risk of flooding therefore become critical.

This project aims to assess the exposure and risk of flooding in Johnson County, Iowa. With flood risk being a function of flood hazard and vulnerability (Ali, Bajracharya, & Koirala, 2016), it is critical to analyze exposure and vulnerability to flood hazard. This study examines the spatial distribution of flood-prone areas, identified the vulnerable population based on density and income level and analyzed the vulnerability of residential, commercial, industrial and other infrastructure by simulating the average flood depth at a 500-years return period flood event – a historic flood event occurs in 500 years. This flooding definition indicates the probability of having such an event in a year is 0.2% (Beddoes, 2021).

1.1. Research Questions

With the overarching goal of assessing the spatial pattern of flood risk and vulnerability in Johnson County, Iowa, this project is guided by the following research questions:

1. Which areas of Johnson County, Iowa are most exposed to flood hazard during a 500-years return period flood event?
2. How does the level of vulnerability vary across different areas, considering population density and household income?
3. Which infrastructures are most at risk of flood hazard and need a comprehensive flood management plan at the onset of a 500-years return period flood event.

1.2. Goal

The goal of the project is to provide an insight into the flood risk and vulnerability of Johnson County, Iowa. Leveraging publicly available data, GIS and ObervableHQ, the project seeks to identify high-risk areas and high-risk infrastructure by determining the average flood depth. This project aims to support the decision-making process regarding flood plain management and strengthen the preparedness and resilience of the community.

1.3. Objectives

2. Identify high-risk areas/hotspot areas for a 500-year-return period flood event by simulating the average flood depth at block group level.
3. Map the level of vulnerability by population density and median household income at block group level
4. Identify the infrastructures including residential, commercial, industrial and other use buildings at risk of flood with 500 years return period

1.4. Target Audience

Since this project targets to inform floodplain management and resilience planning, the primary audience of these analysis will be the local decision-makers including city and county planners and local government officials. Different agencies for emergency management like The Johnson County Emergency Management Agency and City Fire Departments are the other target audience of this project. To raise awareness about flood risks and to promote community resilience to flood hazard, different community organizations like United Way Johnson County and Washington County, and the residents are the key stakeholders and target audience of these analysis. Finally, to contribute to flood research, this project also targets academicians and researchers.

2. Data Collection

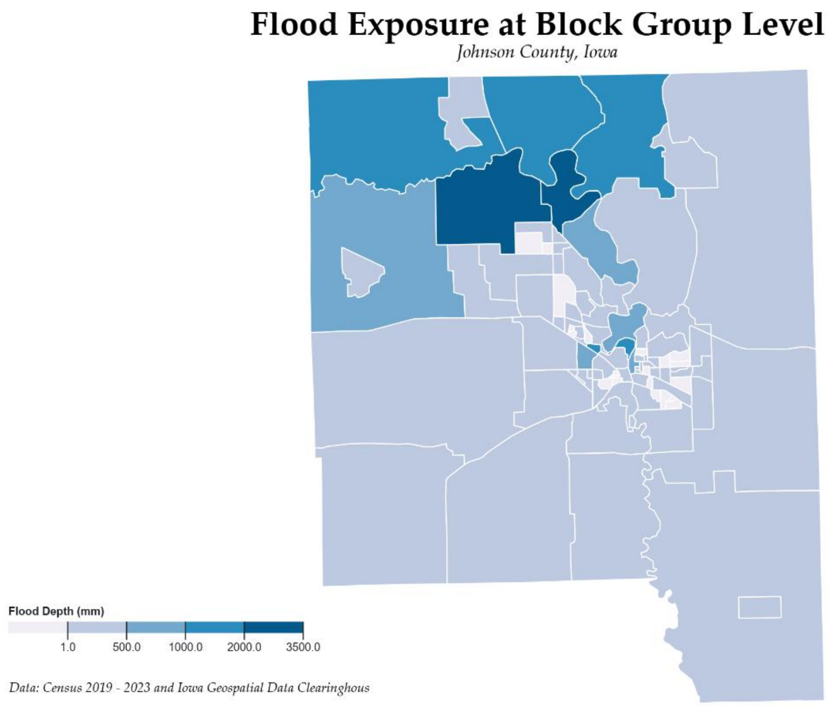
For this project, spatial data were collected from multiple online sources. To map exposed infrastructures during flood events, building footprint data was collected from (FEMA, USA Structures, 2022). To conduct the exposure analysis, Flood Gradient Boundaries of Flood Events in Iowa datasets were collected from State of Iowa Geospatial Database (Kohrt, 2020). The floodplain boundaries delineate areas at highest risk and the likelihood of flood occurrence. The administrative boundaries (State/County/Block Groups) are collected from www.nhgis.org. To simulate the average flood depths, depth grids were collected from the Iowa Department of Management. The depth grids were developed using Hydrologic Engineering Centers River Analysis System (HEC-RAS) as part of the Iowa Statewide Floodplain Mapping Project (Management, 2025). For flood depth analysis, the 8-digit hydrologic unit code (HUC8) data were used in this project.

3. Methods and Analysis

To achieve the goal of this project, different geospatial tools, visualization techniques and classification methods were used. The following segment describes the methods used for each analysis.

3.1. Flood Hazard Zones Identification

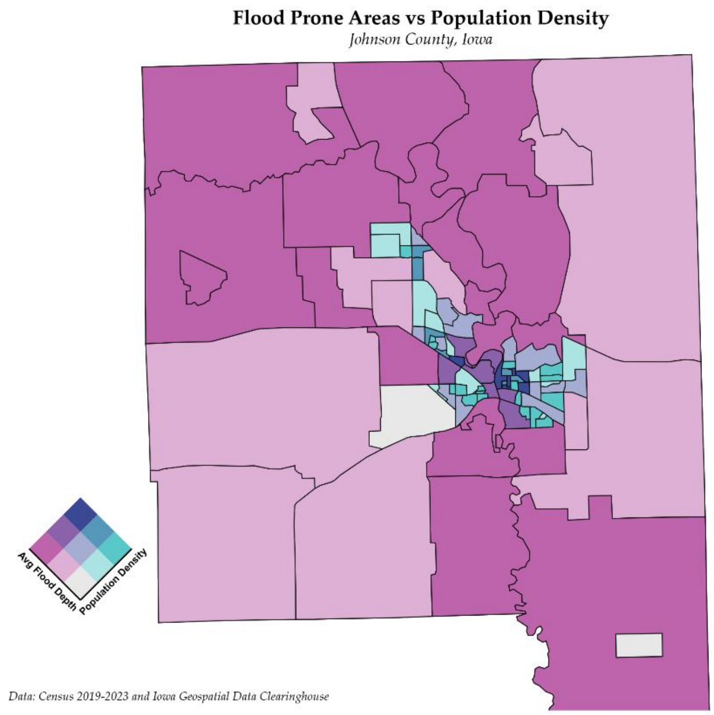
To identify high-risk block groups for flooding, the block groups shapefile from NHGIS and flood depth raster grids (HUC-8) were used. The data were first processed in QGIS using zonal statistics tool – a spatial analysis tool used to determine different statistical values such as count, sum and mean of specific zones or polygons by a vector or raster dataset. The average flood depths were stored in a csv file which contains other information like total population per block groups, obtained from NHGIS. After determining the average flood depth in QGIS, the shapefile was transformed into a Geojson file which is compatible with Observable notebook for mapping purposes. To illustrate the spatial pattern of flood depth, choropleth mapping technique was used as it is ideal for visualizing spatial variation in data using color gradients. For classification, manual interval method was used to adjust the break points for flood depth manually. This method was used because other methods like natural breaks or quantiles may not reflect the local reality of flooding. Unlike other methods, manual classification allows for customize breakpoints which can help account for meaningful distinction in flood risks.



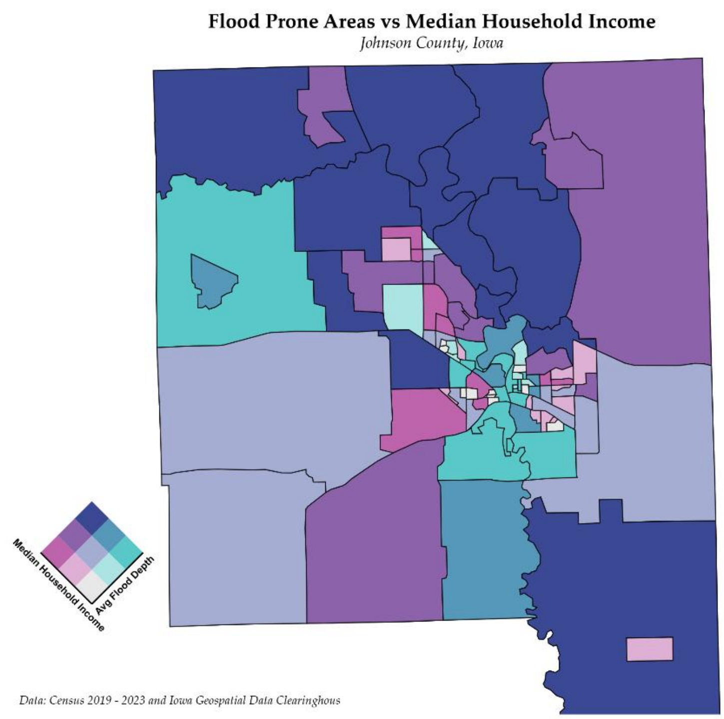
The choropleth map represents varying flood depths across different block groups in Johnson County. To represent the intensity of flooding, I used the shades of blue with light blue reflecting lower water level and deep blue reflecting higher water level. The legend shows flood depth ranging from 0 mm to 3500 mm, reflecting the severity of flooding. The map shows darker blue mostly in the northern and western parts of the county, with a few block groups in the central areas. This indicates higher risk areas with deeper flood depth and may be more vulnerable because of the proximity to river and damn. On the other hand, the entire southern and eastern parts of the county have lower risk of flooding. This could be due to higher elevation or better drainage systems in place.

3.2. Flood Vulnerability by Population Density and Median Household Income

To measure the level of vulnerability of flooding at block groups level, the same data were used as the high-risk area identification. To visualize flood vulnerability by population density, bivariate mapping techniques was used on Observable notebook. It is a powerful technique used to analyze the relationship between two variables or two aspects of an analysis in a single map. I used bivariate for this analysis, as it allowed me to assess the correlation between demographic and socio-economic factors with people’s tendency to settle in and whether there are any underlying factors such as affordability and development patterns etc. for classification, I used quantile classification method – as it divides data into equal sized groups which ensures all groups are fairly represented. Since I visualized both flood depths and population density/median household income in the same map, quantile method was best suited as it prevents any single category from overpowering the visualization and it reveals the relationships without skewing the map with large variations in the data. It ensures that the spatial patterns across different regions are reflected meaningfully with balanced data points from both variables.



The map shows that some of the central, south-eastern and north-western block groups possess higher vulnerability to flooding as these areas are characterized by moderate to high level of flood depth. However, the population density are highest at central block groups are likely include Iowa City, Coralville and North Liberty, suggesting that urban development has occurred in the higher flood risk areas. While the northern and south-eastern parts have higher flood depth, the population density if comparatively low in these regions. The east and south-west parts of the county have moderate to low population density and lower flood depth. These areas are likely characterized by rural development with higher elevation.

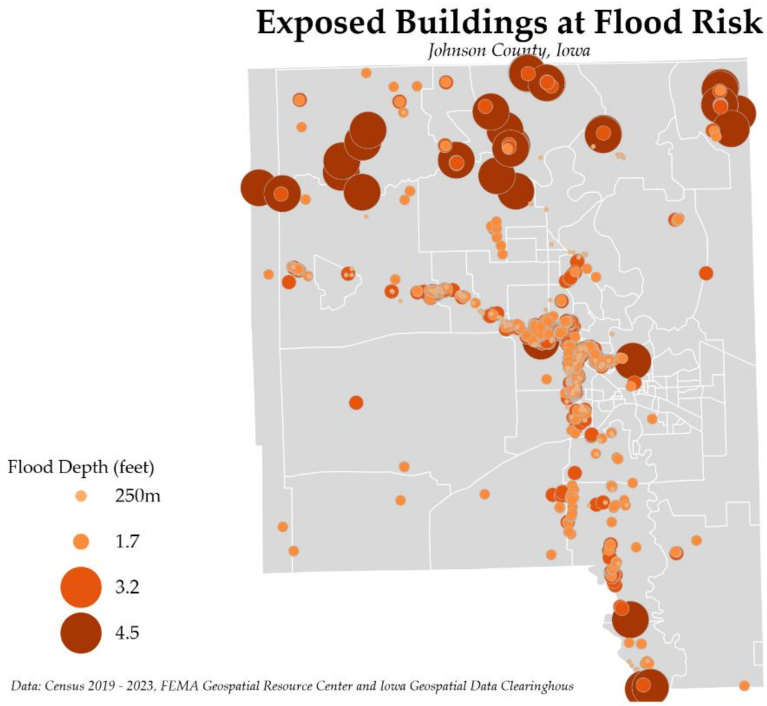


The bivariate map of average flood depth and median household income reveals the socio-economic vulnerability to flooding based on the choice of settlement. The blue color scheme represents low to higher household income while the purple color scheme represents low to high flood depth. The map reflects varying data for both median household income and flood risk across the region. The norther region and south-eastern part of the county with deep blue indicates higher median household income and higher flood vulnerability. This relationship signifies the choice of housing in the flood prone area does not rely on income level. In other words, higher income people are more likely to reside in the floodplain areas, indicating these areas have high property value due to the close proximity to water bodies and nature. Meanwhile, the central part represents a wide variety both in household income, indicating these block groups are more urbanized where people with diverse background and income level reside.

3.3. Flood Risk Assessment for Different Structures

To assess the flood risk at structural level, I used Graduated Symbol Mapping technique. The building footprint shapefiles, floodplain boundary for 500-years return period flood and flood depth raster grids (HUC-8) were used. The footprint data was first processed in ArcGIS Pro for selecting the buildings exposed to flooding. The exposed building polygons were then used for zonal statistics to calculate the mean flood depth for each building overlaying the depth grids. Finally, the polygon features were transformed into points and later into geojson file in mapshaper.org. For basemap, the Johnson County block group json file used for other analysis was used here as well.

For classification, I used quantile method as it helps highlight variations across the region without creating uneven clusters of data points. As flood depth can be skewed, a few locations have higher flood levels while most of the block groups see minor effect, I felt that quantile method is best suited because it can balance the variation by dividing the range of flood depths into equal parts. This makes it easier to identify which buildings are at severe risk of damage by flooding.



The number of buildings ranging from residential, commercial, industrial to agricultural and other purposes on the floodplain boundary are quite significant. While most of these buildings have low to moderate flood vulnerability as the average flood depth is on lower side, the most vulnerable structures seem to be clustered in norther part of county near the river and lake areas. Infrastructures on the norther part of the county may experience widespread flooding due to less drainage infrastructure and significant property damage.

4. Learning Outcomes and Lessons Learned

This project has provided me with valuable experience of flood hazard assessment, risk and vulnerability mapping. By integrating geospatial tools like ArcGIS Pro, QGIS and ObservableHQ, I have gained a good understanding of how flood risk can be evaluated through statistical techniques, classification and visual representation. The process of combining different datasets including block groups, flood depth grids, building footprints, and socio-economic indicators in csv datasets has emphasized the importance of multi layered data analysis in hazard assessment. In addition, interpreting the spatial distribution of socio-economic factors and infrastructure vulnerability has underscored the actual effects of flood events and the significance of resilient planning approaches.

Through this project, I have learned how critical it is to prepare the data before visualization and the importance of selecting the right classification method. The process of flood depth simulation confirmed the necessity of proper hydrological modeling to provide accurate flood predictions.

5. **Limitations of Visualizations and Data**

Despite having a significant learning outcome in flood risk assessment, a few limitations exist in both the visualizations and data. One of the major limitations is the extent of the flood depth raster grids. Since these raster datasets cover a larger area, these may not capture local variations in flood extent. The data sources also have some constraints including missing values in median household income and uncategorized building uses in the footprint data which could impact the accuracy. The manual classification method used for choropleth maps may be effective in providing customized insights into risk levels, it may introduce subjective bias in determining the categories for flood risk.

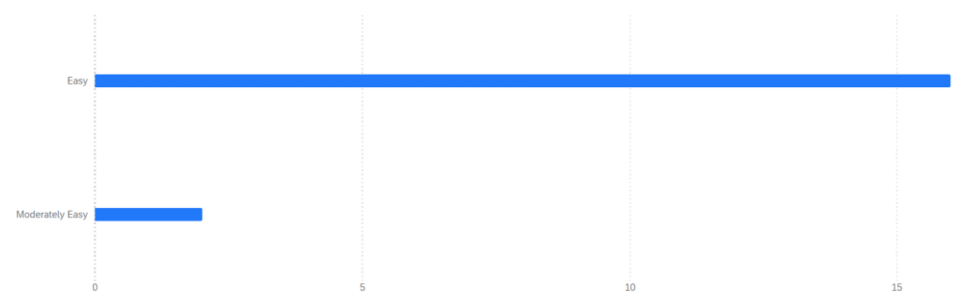
6. **Future Directions**

Future efforts on this project can be expanded by including dynamic flood simulations to provide higher accuracy of flood forecasting. Also, different socio-economic variables like access to emergency facilities, housing prices, and shortest path analysis could be integrated. This analysis could add to the risk and vulnerability of flooding due to climate change. I also think spatial scope could be broadened and this would be adding more interest if this project was conducted for larger geographic areas like the entire state or the country.

7. **Usability Survey**

I conducted a usability survey with the high-risk area identification map. The survey included six questions and 18 responses were recorded. The survey results were analyzed in the following sections:

Q1. How easy it is to understand variation in flood depth from this map?

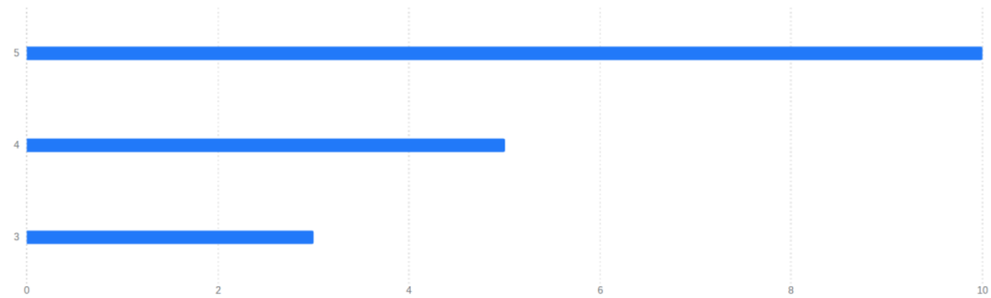


Among 18 respondents, 88.9% found the map easy to understand the variation in flood depth while 11.1% found it moderately easy to see the variation.

Q2. Do you find the color gradient effective?

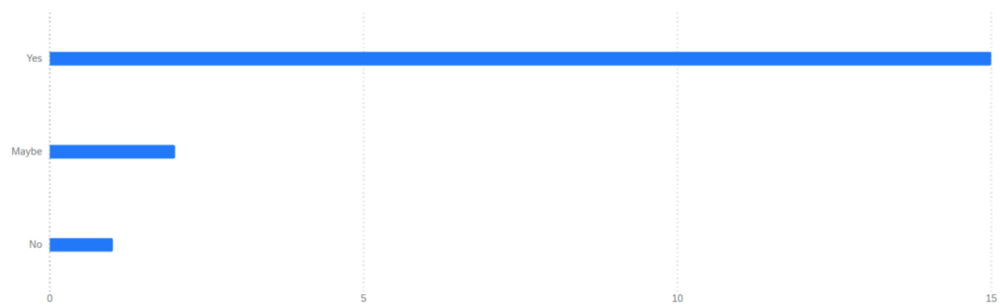
94.4% respondents thought the color gradient is effective while 5.6% respondents were unsure about it. I used sequential color palate to show the gradual variation in the data points.

Q3. How would you rate the overall readability of the map?



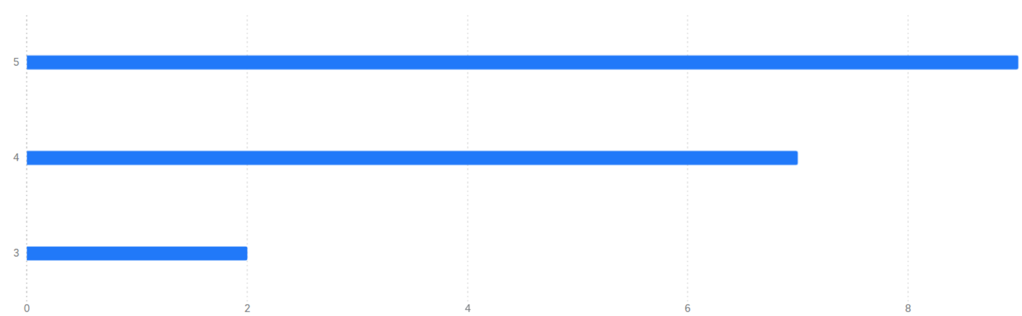
55.6% students found the overall map readable while 27.8% was unsure about this and 16.6% didn't think the map readable.

Q4. Do you find the legend understandable?



Approximately 83.3% respondents found the map legend understandable. However, 11.1% students were unsure about the readability of the legend while 5.6% student could not understand the legend.

Q5. How would you rate the design of this map?



Half of the respondents (50%) rated the map design a 5, while approximately 39% gave it a rating of 4. The remaining 11% rated it as 3.

Q6. What improvement would you suggest to enhance the design, readability, and color gradient of this map?

My survey included this open-ended question, and the collection of feedback was quite interesting. Some of the students thought the map looks great and there is nothing to be modified, while others had a varieties of constructive thought like adding some context into the block groups, adding features representing rivers and damns location, elevation patterns, modifying the outline color, incorporating more information about the flood depth, adding the definition of severity, using different spatial extent and using different unit for flood depth. While I would like to address all the feedback, due to time limitations, I could make changes to the flood depth unit (converted millimeters into feet) for easy understanding.

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