1 Project 1

1.1 Goal

The goal of this project is to develop a spatial framework for assessing flood risk and estimating potential flood damage in Washington, D.C. using FEMA's National Flood Hazard Layer (NFHL) data. By integrating base flood elevation data, flood hazard zones, and digital elevation models, the project aims to identify vulnerable areas, quantify the intensity of potential flooding, and evaluate the exposure of buildings and infrastructure. This analysis will support more informed decision-making for disaster preparedness, urban planning, and environmental resilience.

1.2 Quantifying Flood Damage and Intensity Using NFHL Data

To quantify the extent of flood damage or intensity using FEMA's National Flood Hazard Layer (NFHL), we integrate flood hazard data with elevation models and exposure layers such as buildings or population.

1.2.1 Step 1: Define Flood-Prone Areas

We use Layer 28 from NFHL, which provides flood hazard polygons. High-risk zones include flood zone designations such as `AE`, `A`, and `V`. The `SFHA_TF` attribute (Special Flood Hazard Area) can be used to filter for high-risk areas:

```
flood_zones <- nfhl_get(dc_aoi, 28)
sfha <- flood_zones %>% filter(SFHA_TF == "T")
```

1.2.2 Step 2: Overlay Exposure Data

Overlay the flood hazard zones with assets like building footprints, population grids, or critical infrastructure:

```
buildings <- st_read("dc_buildings.geojson")
flooded_buildings <- st_intersection(buildings, sfha)
nrow(flooded_buildings)  # Number of exposed buildings
```

1.2.3 Step 3: Estimate Flood Depth

Using Base Flood Elevation (BFE) data from Layer 16 and Digital Elevation Models (DEMs), we can estimate the flood depth as the difference between BFE and ground elevation:

```
dem <- rast("dc_dem.tif")
bfe$ground_elev <- terra::extract(dem, vect(bfe))[,2]
bfe$flood_depth <- bfe$ELEV - bfe$ground_elev
```

Flood intensity can be categorized as:

- Low: 0–0.5 meters
- Medium: 0.5–1.5 meters
- High: greater than 1.5 meters

1.2.4 Step 4: Estimate Economic Damage

If building values are available, depth-damage curves can be used to estimate economic losses. These curves relate flood depth to the percentage of damage:

```
flooded_buildings$flood_depth <- 1.2  # meters

flooded_buildings$damage_ratio <- ifelse(
  flooded_buildings$flood_depth > 1.5, 0.9,
  ifelse(flooded_buildings$flood_depth > 0.5, 0.5, 0.2)
)

flooded_buildings$damage_estimate <-
  flooded_buildings$damage_ratio * flooded_buildings$property_value
```

1.2.5 Required Data and Tools

Data Type	Source	Purpose
Flood Hazard Zones (Layer 28)	NFHL	Define flood-affected area
Base Flood Elevation (Layer 16)	NFHL	Estimate flood water height
Digital Elevation Model (DEM)	USGS, AWS	Compare BFE with ground elevation
Buildings / Land Use	OSM, Local GIS	Quantify assets at risk
Damage Curves	FEMA, USACE	Convert depth to economic damage

Table 1: Key data inputs for flood damage quantification

1.2.6 Useful R Packages

- `sf`, `dplyr`, `tmap` – spatial operations and visualization
- `terra` – raster and DEM analysis
- `NFHL` – access FEMA flood layers
- `exactextractr` – efficient raster extraction over polygons

This framework supports practical, GIS-based flood risk assessments using publicly available FEMA and elevation data.

2 Project 2

2.1 Project Goal

The primary objective of this project is to develop spatial regression models that explain elevated asthma prevalence in the Washington, D.C.–Maryland–Virginia (DMV) area based on a combination of environmental exposures and social vulnerability indicators. Using model-based asthma estimates from the CDC PLACES dataset, we integrate environmental factors from EPA's EJScreen (e.g., $PM_{2.5}$, ozone, traffic proximity), social vulnerability indicators from the CDC/ATSDR Social Vulnerability Index (SVI), and flood risk exposure from FEMA's National Flood Hazard Layer (NFHL).

The goal is to quantify the spatial relationship between these variables and asthma outcomes, and to identify geographic patterns of disproportionate burden in communities affected by both environmental and socioeconomic disadvantage.

3 Project 3: Flood Risk Mismatch in the Mid-Atlantic

Objective

This project aims to analyze the spatial alignment between FEMA-designated flood hazard zones (Layer 28) and historically observed flood events reported by NOAA from 1950 to 2023. Focusing on the DMV region (District of Columbia, Maryland, Virginia), and expanding to the broader Mid-Atlantic region if needed, the project will identify areas where flood events have occurred *outside* mapped flood zones, highlighting possible gaps in floodplain mapping and risk communication.

Geographic Scope

- **Primary focus:** District of Columbia, Maryland, Virginia (DMV)
- **Extended region (if needed):** Mid-Atlantic (Delaware, Pennsylvania, New Jersey, West Virginia)

Data Sources

Dataset	Source	Purpose
FEMA NFHL Layer 28	`NFHL` R package	Spatial polygons representing FEMA flood hazard zones
NOAA Storm Events Database	NCEI	Historic flood events (location, date, damage) from 1950–2023
TIGER/Line shapefiles	US Census / `tigris`	County, ZIP Code, and census tract boundaries
ACS / Census (optional)	`tidycensus`	Population and socioeconomic data for risk normalization

Table 2: Data sources for flood zone and historic flood event analysis

Methodology

1. **FEMA Flood Zone Extraction:**
   - Extract Layer 28 polygons for the DMV region using the `NFHL` R package.
   - Filter for Special Flood Hazard Areas (SFHA) using `SFHA_TF == "T"`.
2. **NOAA Flood Event Collection:**
   - Download and filter NOAA flood events (1950–2023) by event type: `Flood`, `Flash Flood`, and `Coastal Flood`.
   - Extract geolocation, event date, event type, and damage estimates.
3. **Spatial Join and Aggregation:**
   - Assign events to census tracts or ZIP Code Tabulation Areas (ZCTAs).
   - Count flood event frequency per spatial unit.
   - Overlay flood event hotspots on FEMA SFHA zones.
   - Identify:

  - Matching areas (events inside SFHA)
  - Mismatch areas (events outside SFHA)

4. **Time Series Analysis:**
   - Aggregate events by decade.
   - Plot trends in event frequency and severity using damage amounts.

Expected Outputs

- An **interactive map** overlaying FEMA flood zones and flood events.
- A **time series plot** of flood event frequency by decade (1950–2023).
- A **summary table** of counties or tracts with the highest flood recurrence.
- A **mismatch analysis** showing flood events that occurred outside mapped FEMA flood zones.