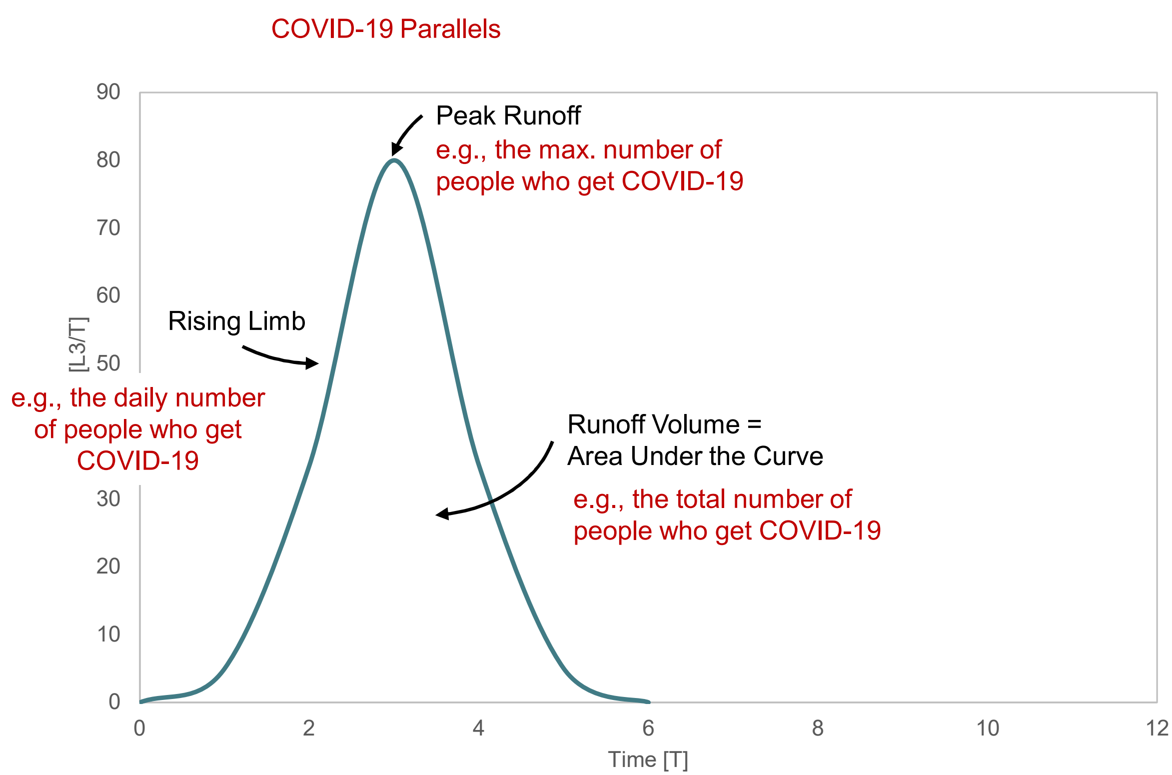
Flood Hydrology 101:
An (Academic) Engineering Crash Course

Part I:
101: Flood Hydrographs and Hazard Mitigation
201: Making Flood Hazard Maps
301: Estimating Flood Damage & Risk

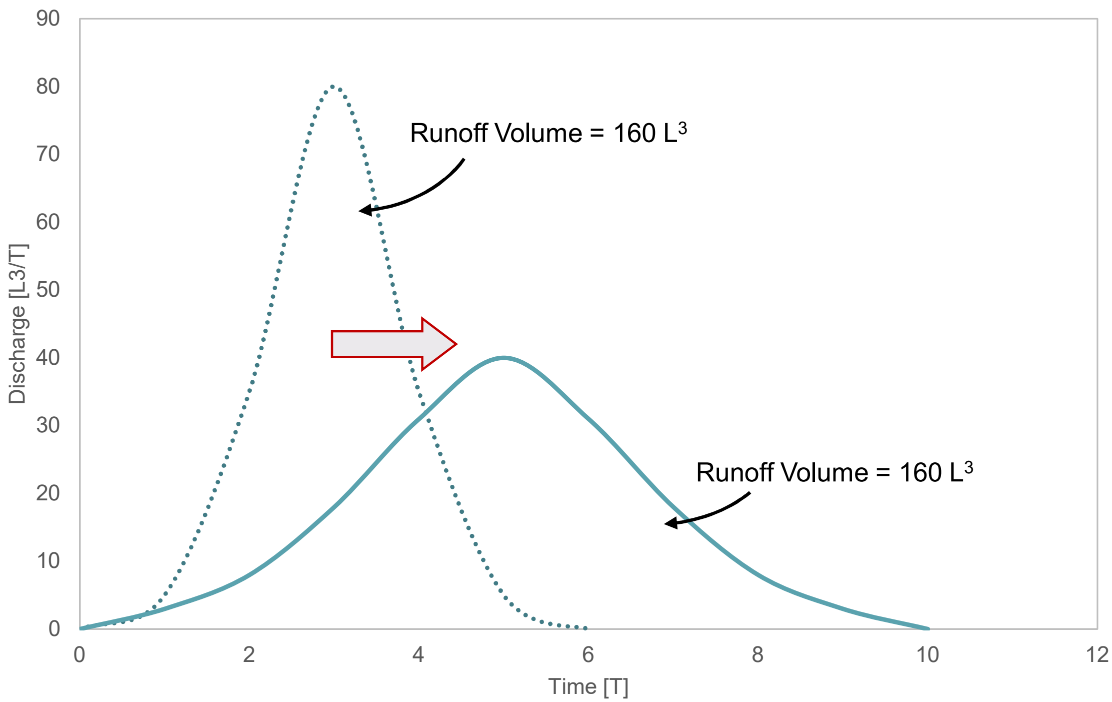
Part II:
- Where is it flooding in our community and by how much?
- How many homes, streets & businesses?

Goals:
- To familiarize everyone with the available data and where it comes from (incl. uncertainty)
- Provide everyone with resources to estimate their flood risk at home

101: Flood Hydrographs and Hazard Mitigation



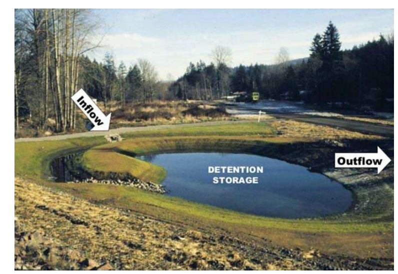
101: Flood Hydrographs and Hazard Mitigation



Volume remains the same, but the peak occurs later and is lower.

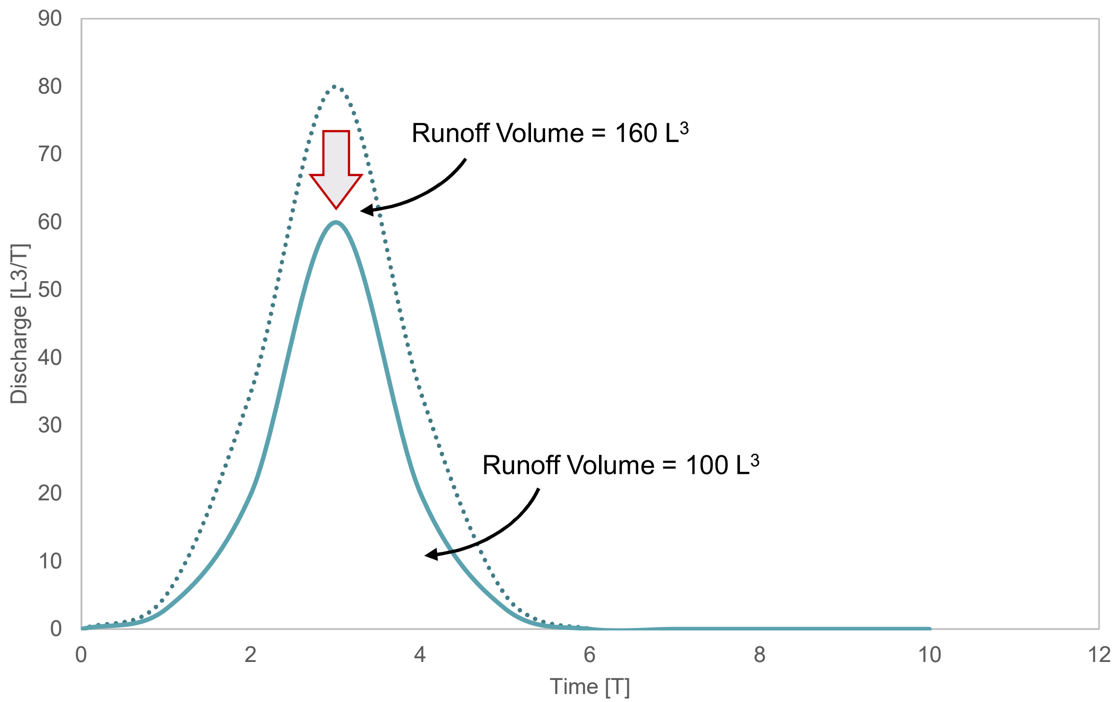
Slow the wave

- Increase Detention
- Decrease Connectivity



e.g., COVID parallel: slowing the spread via social distancing and masks

101: Flood Hydrographs and Hazard Mitigation



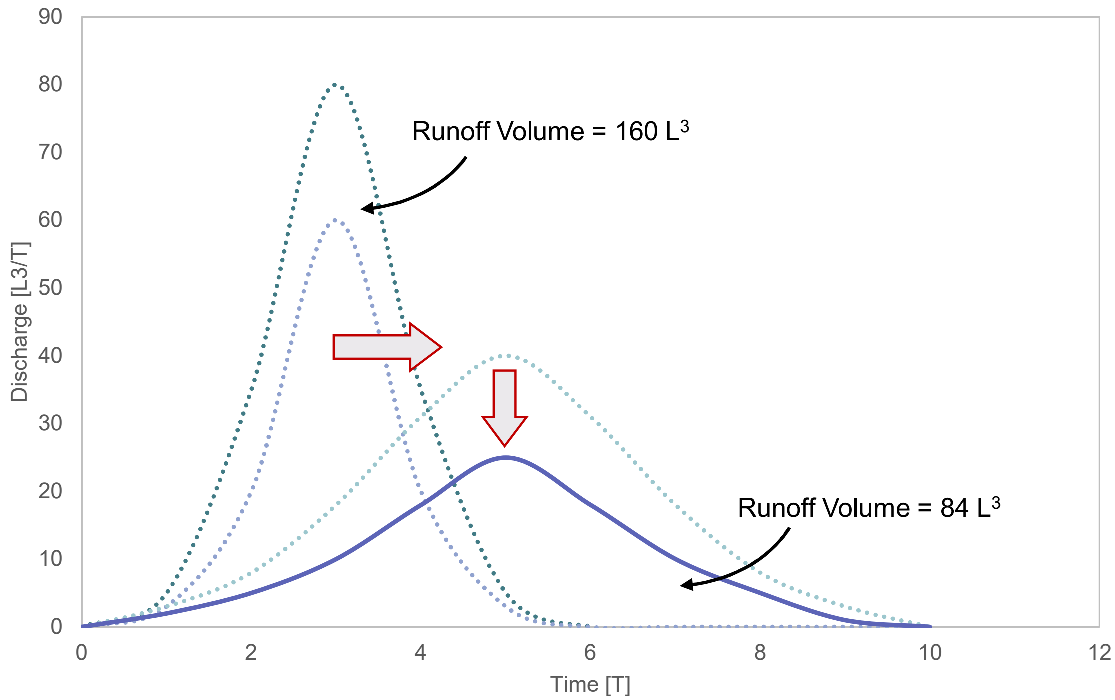
Timing [sometimes] remains the same, but the peak is lower.

Reduce the Volume

- Increase Retention
- Increase Infiltration

e.g., COVID parallel: vaccines

101: Flood Hydrographs and Hazard Mitigation

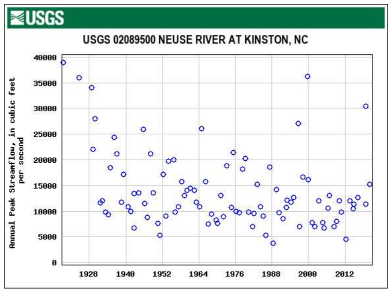


Reduce the Volume
and Slow the Wave

These all mitigate the *hazard* associated with flooding. I will come back to this later in the presentation.

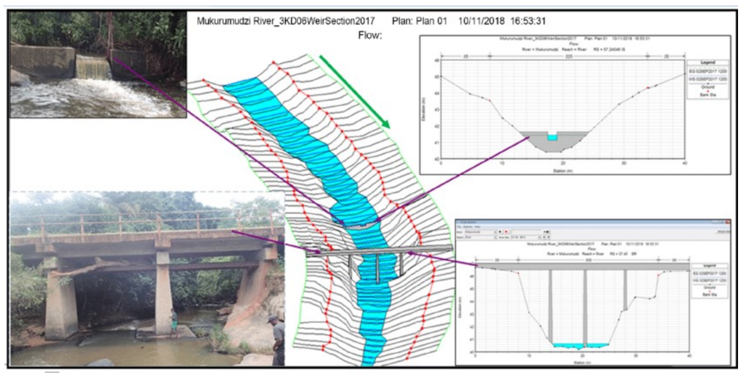
201: How do engineers translate discharge hydrographs into flood hazard maps?

Method #1



Statistical Analysis (River Gages)

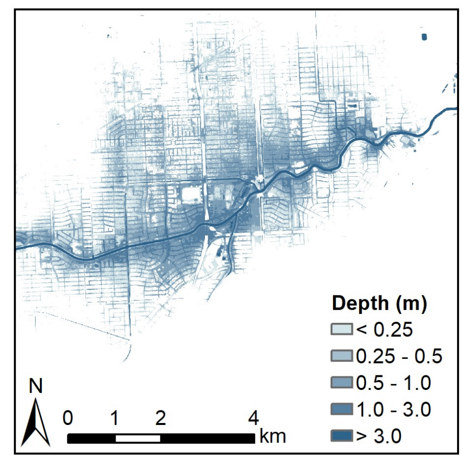
Discharge or Stage



Hydraulic Model

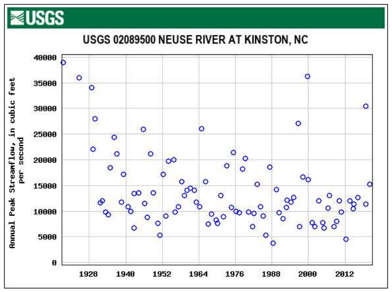
Water Depths

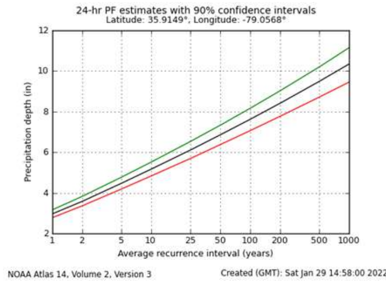
1% Flood Hazard Delineation

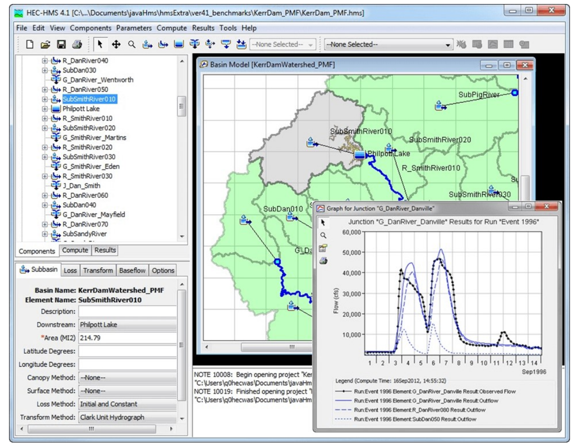


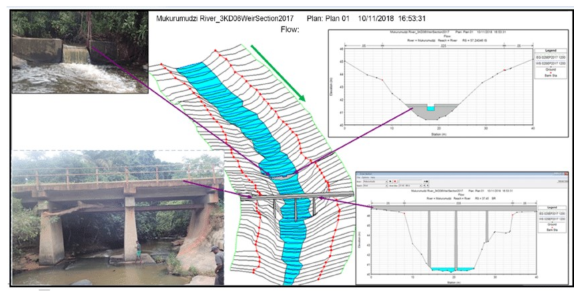
201: How do engineers translate discharge hydrographs into flood hazard maps?

Method #2









Statistical Analysis (River Gages)

Statistical Analysis (Rain Gages)

Precipitation

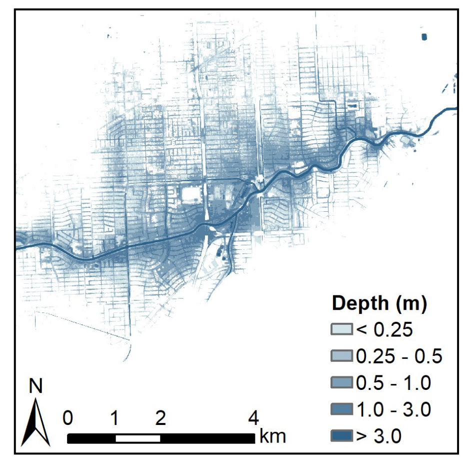
Hydrologic Model

Discharge

Hydraulic Model

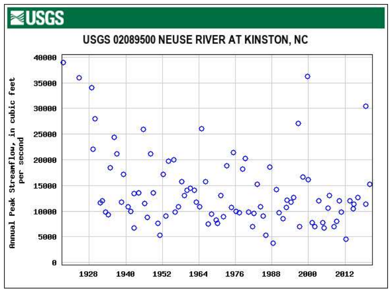
Water Depths

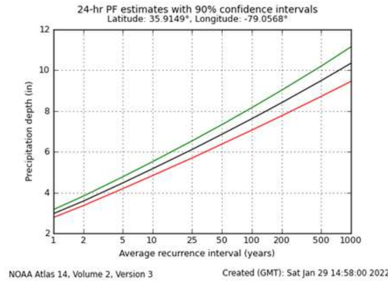
1% Flood Hazard Delineation

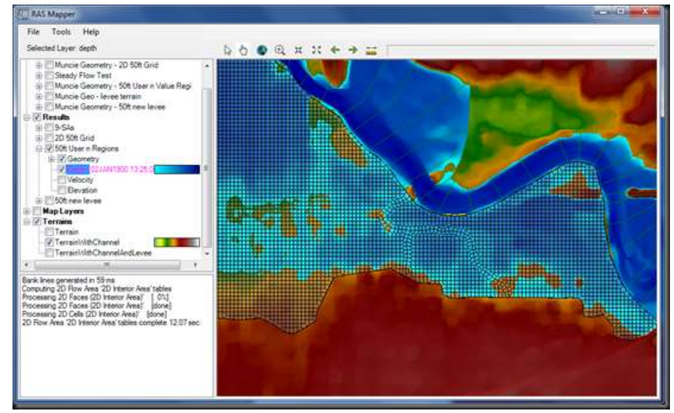


201: How do engineers translate discharge hydrographs into flood hazard maps?

Method #3







Statistical Analysis (River Gages)

Statistical Analysis (Rain Gages)

Precipitation

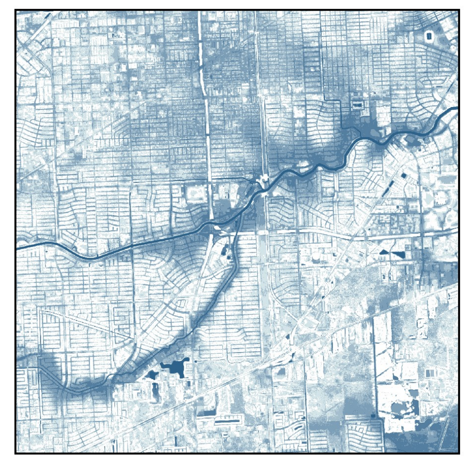
Hydrologic Model

Hydraulic Model

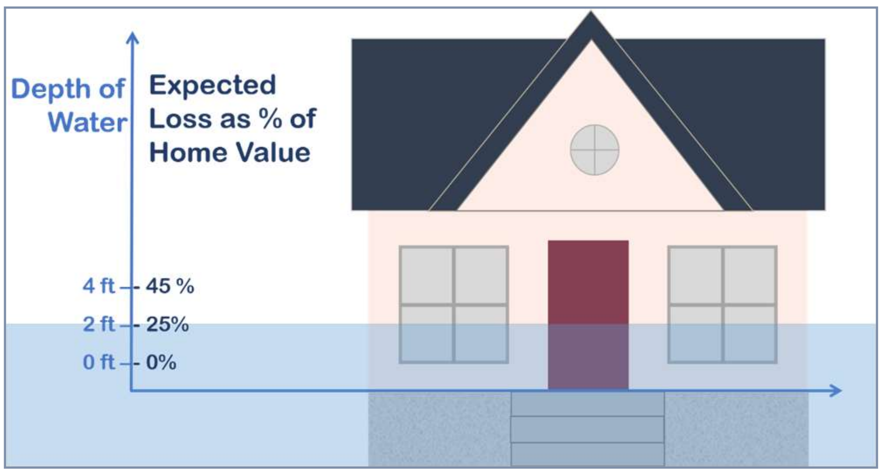
Hydrodynamic Model

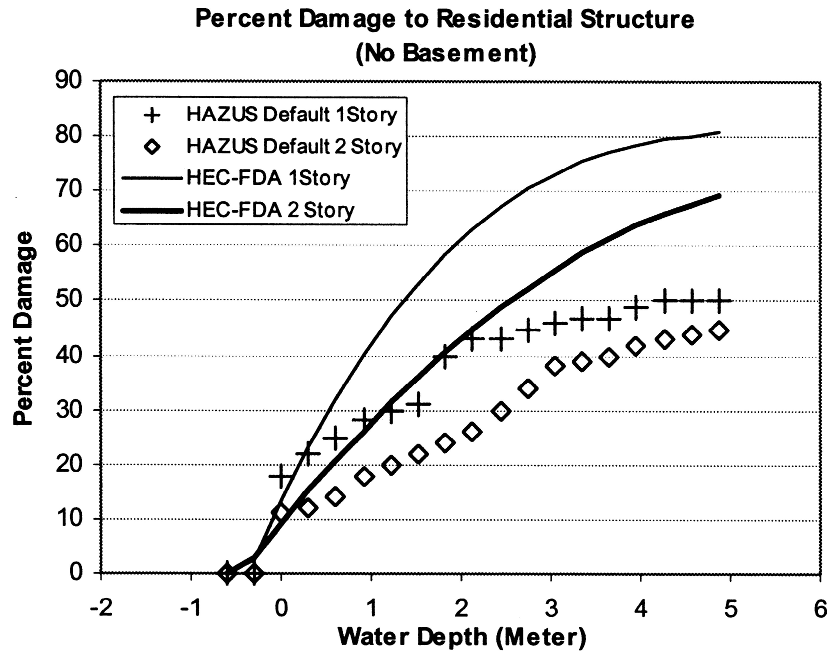
Water Depths

1% Flood Hazard Delineation



301: How do engineers estimate structural (monetary) damage?





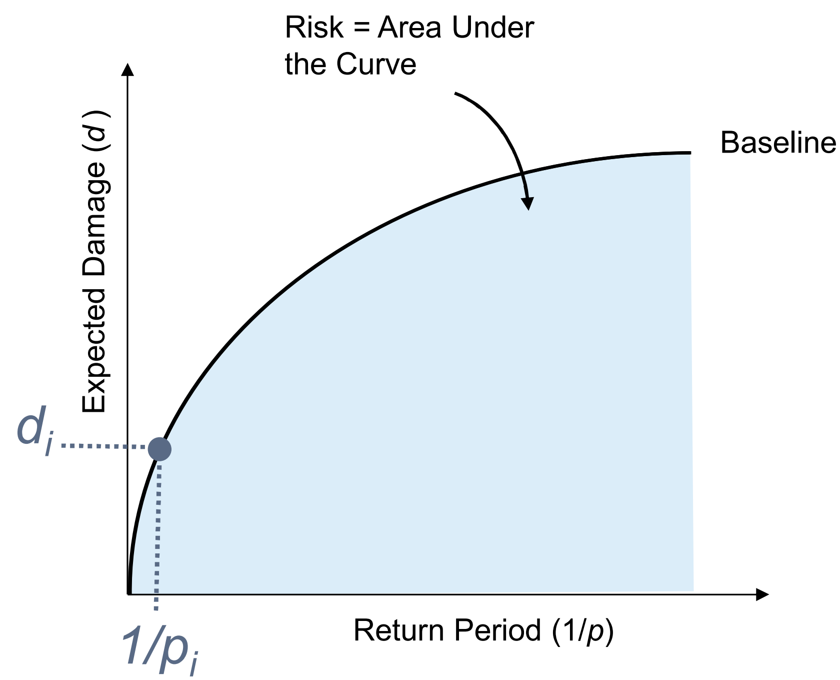
*depth-damage curves are also called:
- (structural) vulnerability curves
- fragility curves

301: How do engineers estimate structural (monetary) risk?

Risk = annual expected damage :

$$E(d) = \sum p_i \cdot d_i$$

Expected Damages ($/yr) = Sum of (Annual Probability of Occurrence (1/yr) X Damage from the Flood ($)) across all modeled events

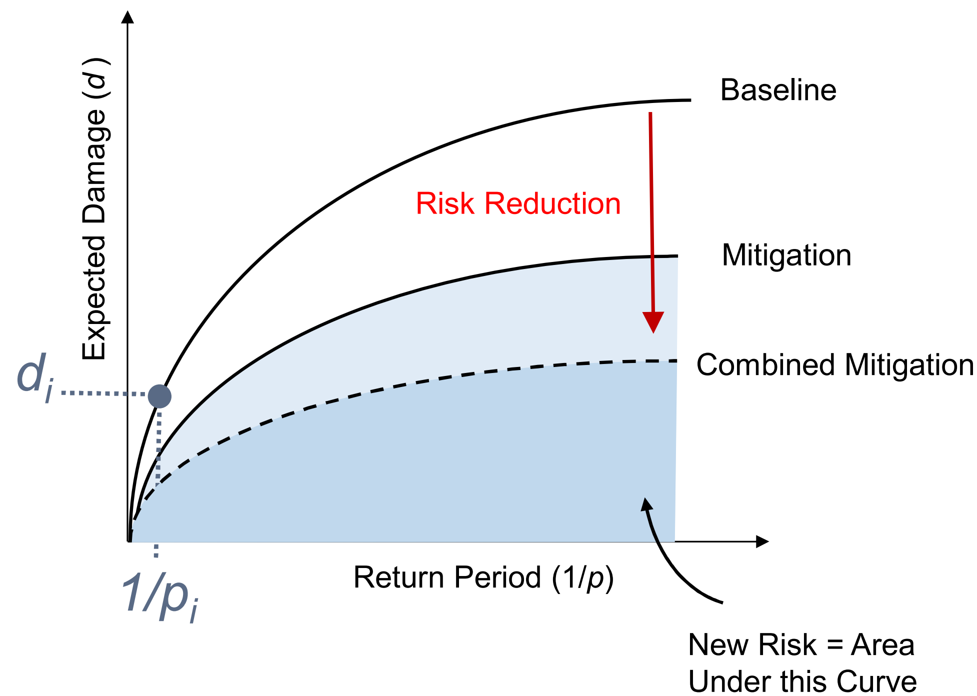


301: How do engineers estimate risk reduction? A bit more sophisticated than just CBR.

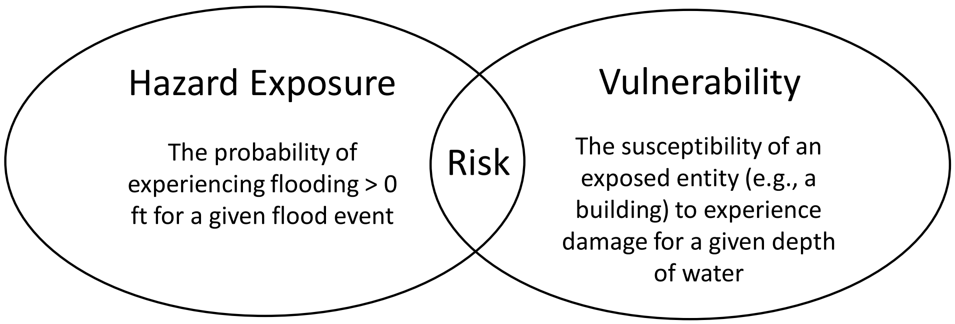
Risk = annual expected damage :

$$\mathrm{E(d)} = \sum p_i \cdot d_i$$

Expected Damages ($/yr) = Sum of (Annual Probability of Occurrence (1/yr) X Damage from the Flood ($)) across all modeled events



Risk = Hazard Exposure x Vulnerability



To mitigate flood risk, you can alter the flood depth (e.g., change the hazard) or you can ‘live with the water’ (e.g., change exposure or vulnerability)

Mitigate Hazard:
- Levees
- Retention/Detention

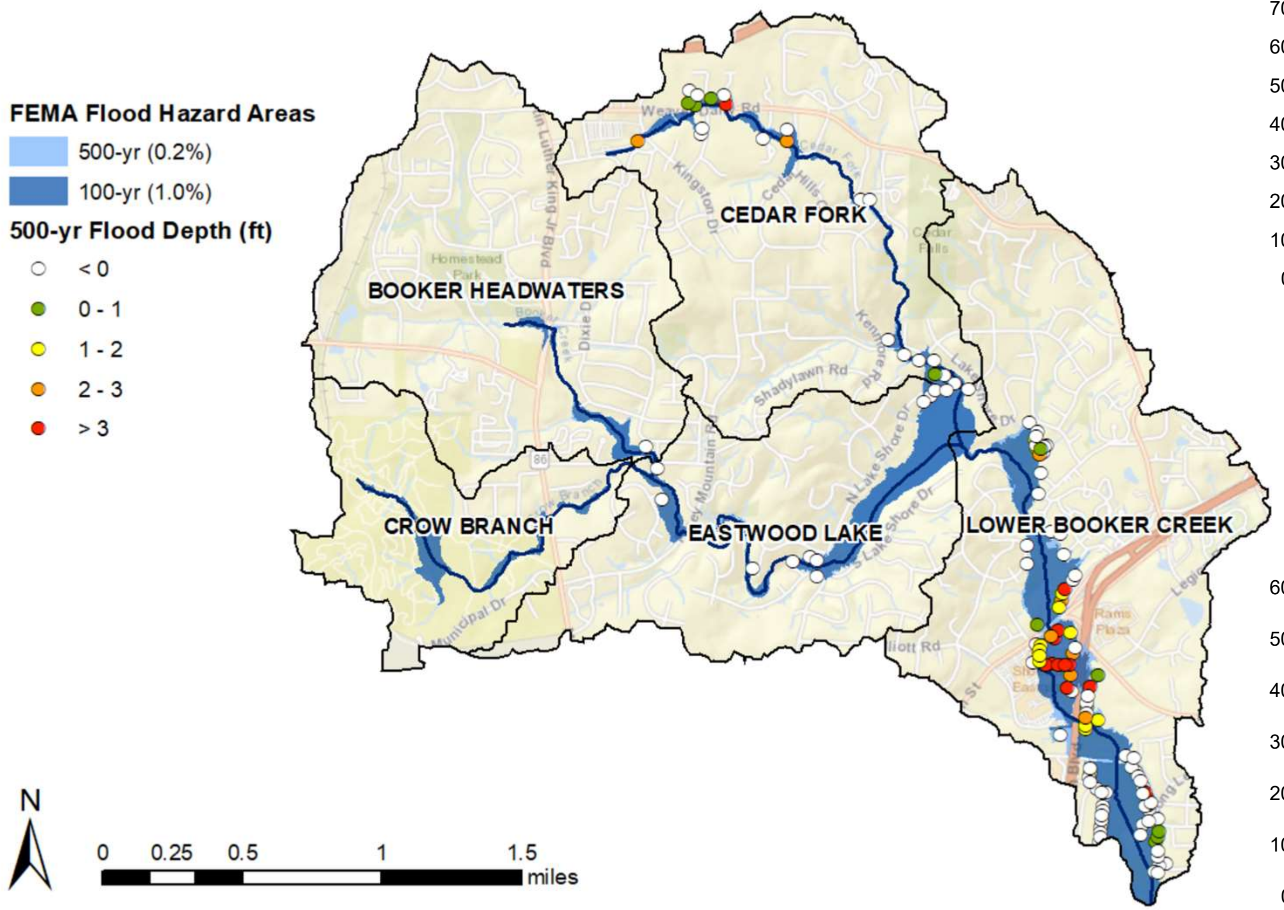
Mitigate Exposure:
- Elevate
- Buyout

Mitigate Vulnerability:
- Floodproofing
- Flood warning

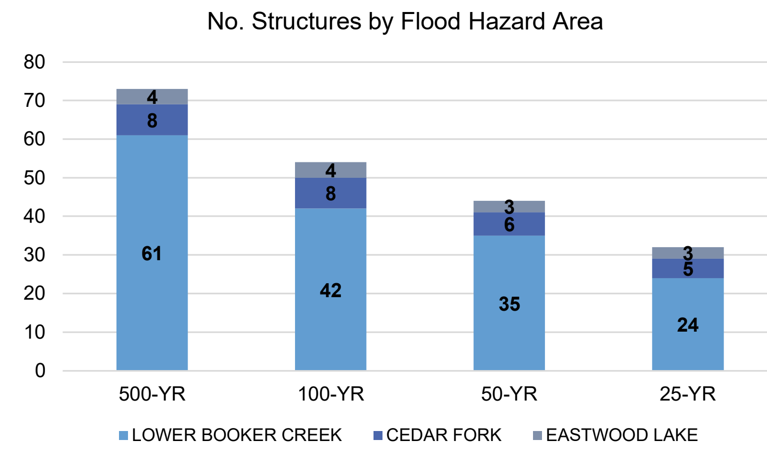
**However, reducing risk may be about more than just mitigating structural losses.

Eastgate Shopping Center, Google Street View

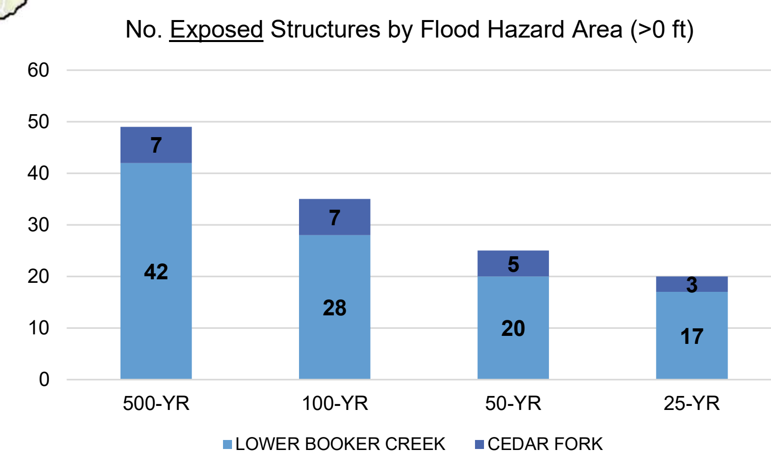
What is the current hazard exposure in Booker Creek Watershed?

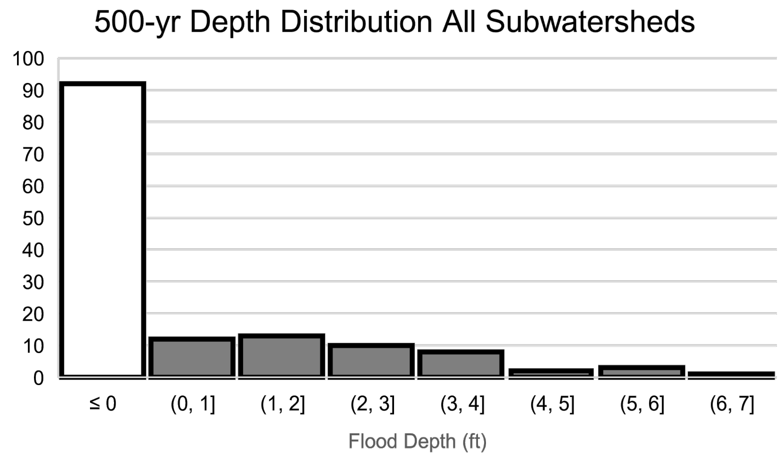


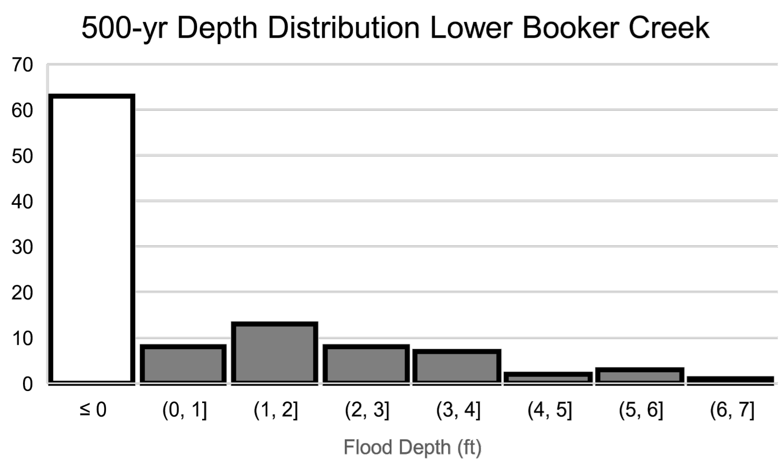
*These estimates are based on the statewide floodplain maps from NC DEM.
Town staff may have access to more detailed/recent data that is slightly different.

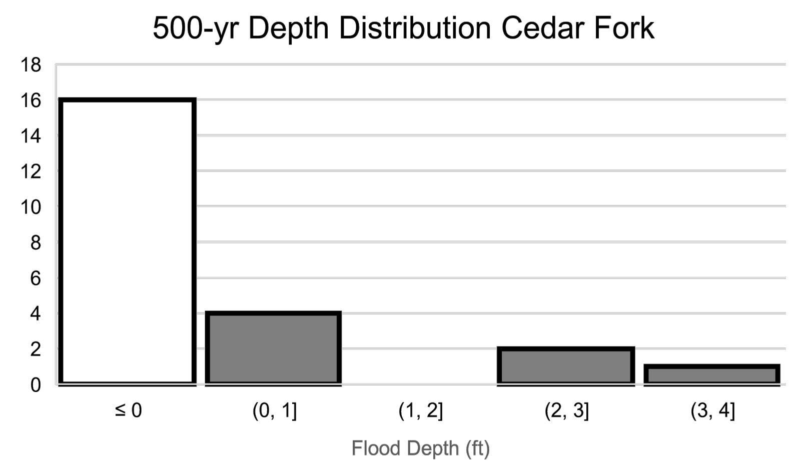


*includes the white dots

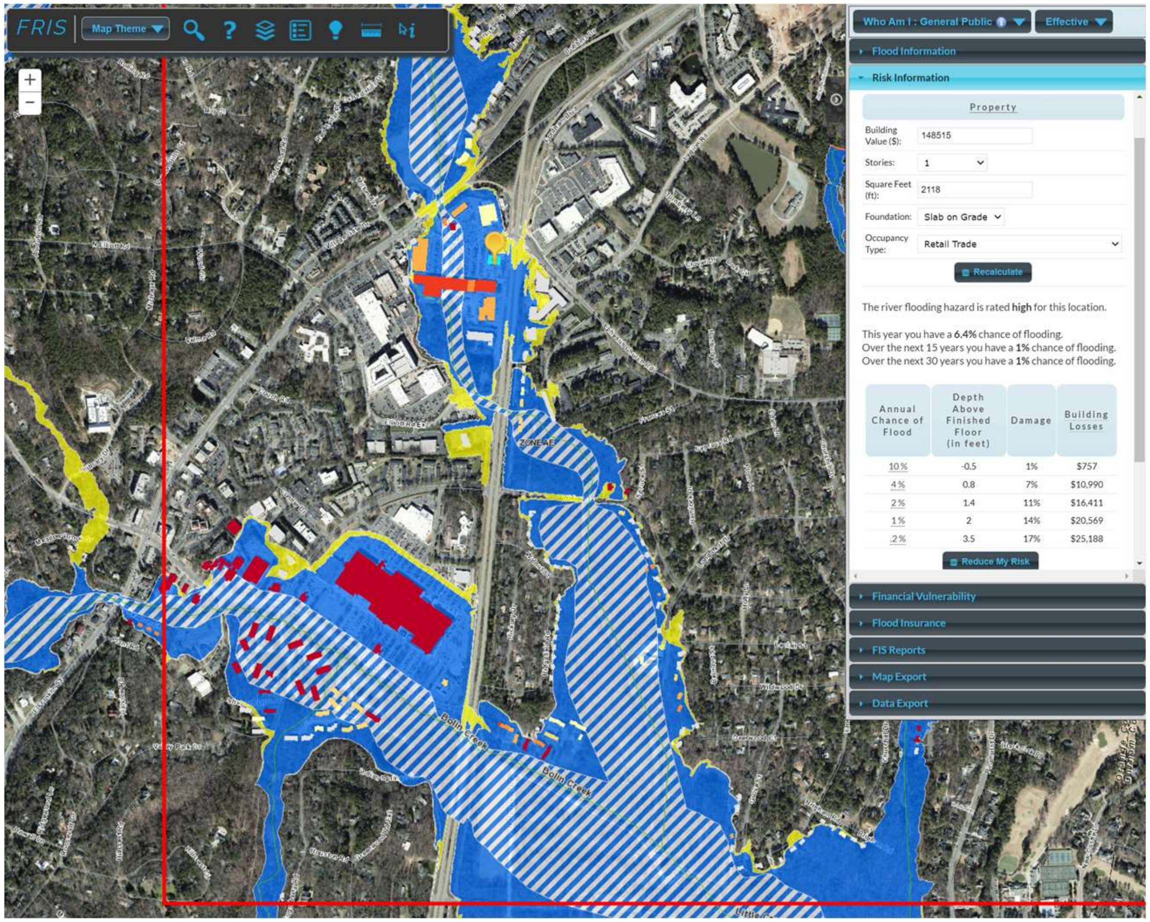



500-yr Depth Distribution All Subwatersheds
100
90
80
70
60
50
40
30
20
10
0
≤ 0
(0, 1]
(1, 2]
(2, 3]
(3, 4]
(4, 5]
(5, 6]
(6, 7]
Flood Depth (ft)


500-yr Depth Distribution Lower Booker Creek
70
60
50
40
30
20
10
0
≤ 0
(0, 1]
(1, 2]
(2, 3]
(3, 4]
(4, 5]
(5, 6]
(6, 7]
Flood Depth (ft)

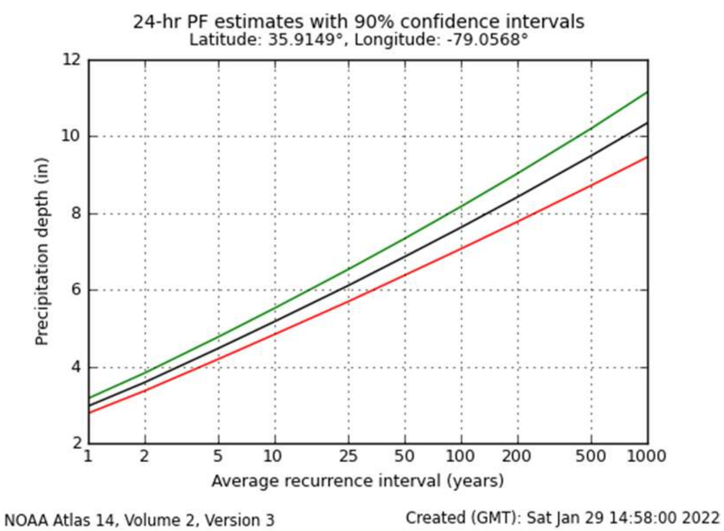

500-yr Depth Distribution Cedar Fork
18
16
14
12
10
8
6
4
2
0
≤ 0
(0, 1]
(1, 2]
(2, 3]
(3, 4]
Flood Depth (ft)

What else can we do with this hazard exposure information? Estimate risk!



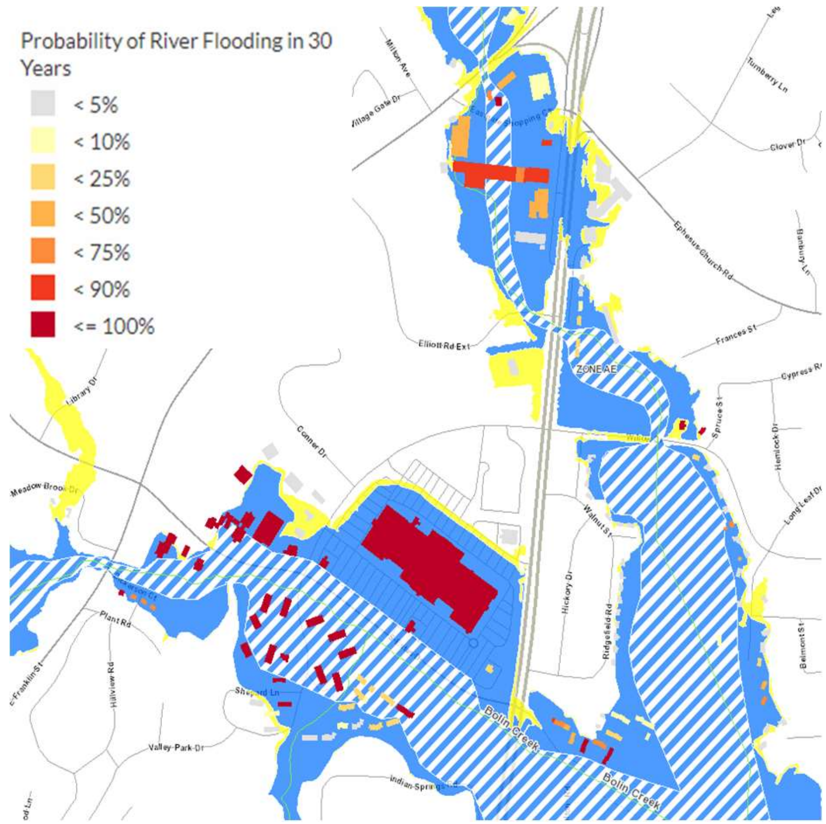
NC FRIS Database:
https://fris.nc.gov/fris/Home.aspx?ST=NC

What size storms are we talking about?



For Chapel Hill, 24-hr storm:

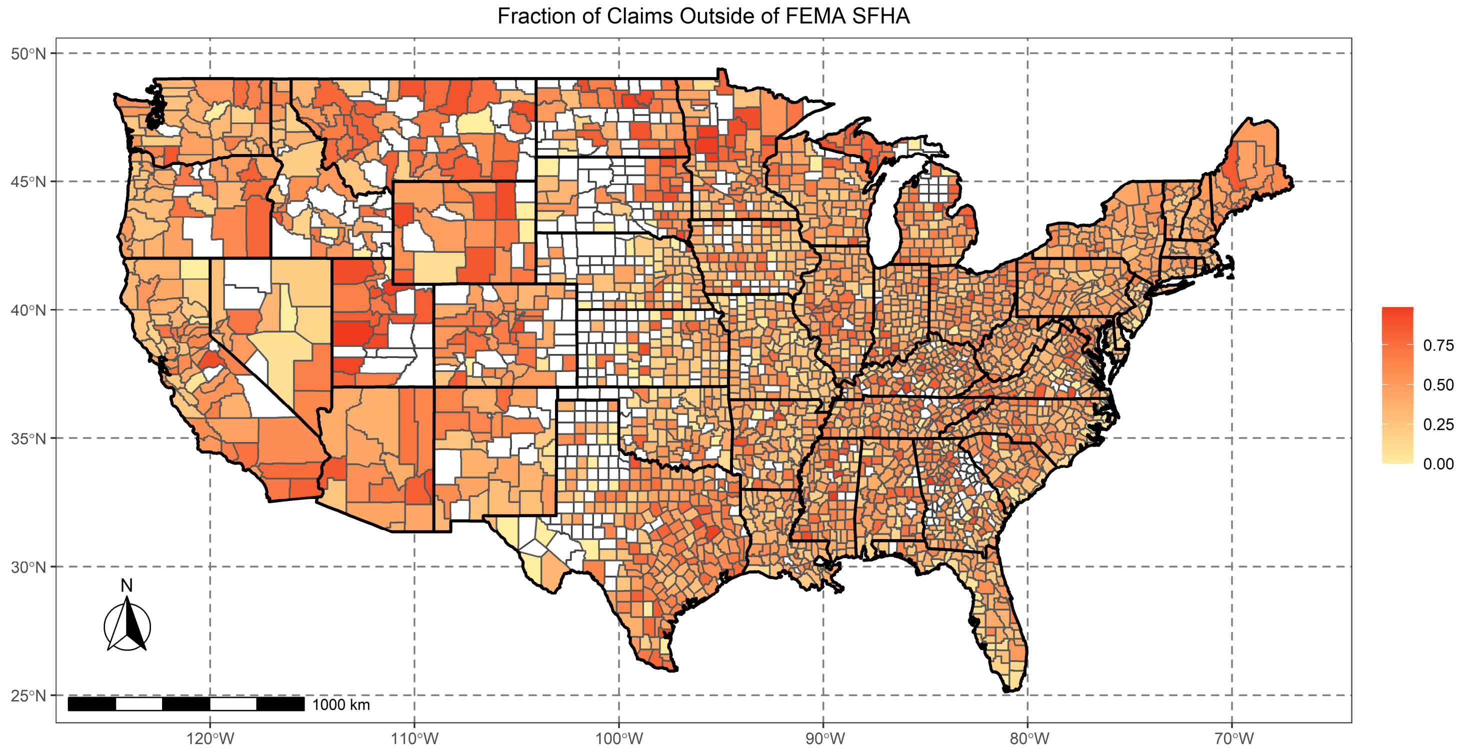
- 25-yr (4% AEP) 6.11 in
- 50-yr (2% AEP) 6.86 in
- 100-yr (1% AEP) 7.62 in
- 500-yr (0.2% AEP) 9.49 in



NOAA Atlas 14 Precipitation Estimates:
https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nc

NC FRIS Database:
https://fris.nc.gov/fris/Home.aspx?ST=NC

What might we be missing? Why?



Nationwide, 33% of insurance claims and 28% of insured flood loss has occurred outside of the mapped FEMA SFHA (i.e., 100-yr floodplain). In Orange County, NC 29% of insurance claims and 11% of historical <u>insured</u> flood loss have occurred outside the SFHA.

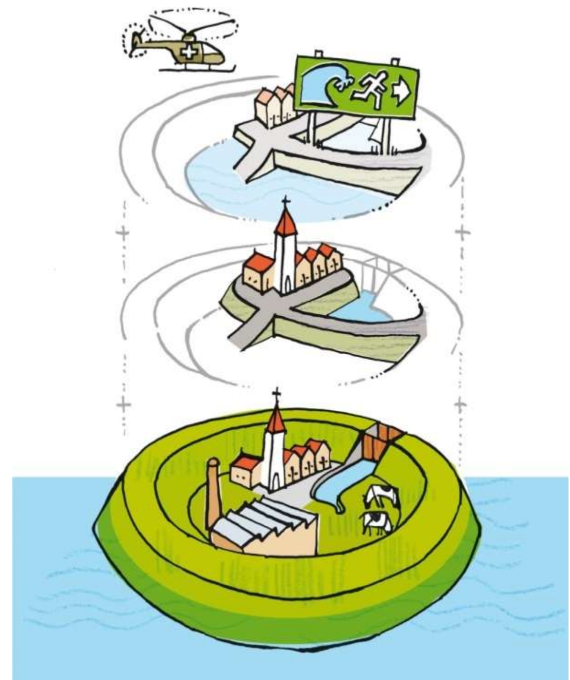
The End Bits

There is no such thing as <u>no flooding</u>

The community has (some) agency to define our risk tolerance and what standard we want to mitigate to:

- *some of this is driven by FEMA*
- Prioritize structures, households, businesses, infrastructure
- Design for future Climate
  - Larger Magnitude Rainfall Events
  - (Likely) More Intense Rainfall Events
- Fluvial (River) <u>and</u> Pluvial (Urban) floods
- Lots of evidence that “green”/”nature-based” infrastructure are more resilient over the long term, but the volumes that need to be mitigated are large. It will take a multi-layer approach.

Multi-Layer Safety Approach



(Rijkswaterstaat 2015)

What is acceptable risk? What are the trade-offs?