LECTURE #20: Flooding Disasters: Science

Date: 2 April 2025

I. Flooding Hazards:

- what is a flood?
  - damaging floods result when the volume of river/stream flow exceeds natural barriers and/or the levels of flood preparedness
    - because flow is greater or longer than expected
    - because of an incomplete understanding of local hazards

  - natural causes:
    - heavy rain
    - dam failure
    - rapid snowmelt / ice jams
    - deforestation
    - steep slopes
    - storm surges during tropical storms / hurricanes

- flooding can have different effects on different parts of a stream/river:
  - *upstream:* rapid rise and fall of water level
  - *downstream:* slower rise and fall, but larger area affected

- important hazard to understand:
  - most chronic and costly natural hazard in the United States
  - causing an average of ~ 90 fatalities per year in the US and ~ $180 to $500 billion damage *(1-2% of the US GDP)!*

  - most at risk towns in the United States:
    - ~ 3,800 towns and cities of more than 2,500 inhabitants located in flood plains

Costliest U.S. Flood Disasters: 1978 – 2023

2005	Hurricane Katrina	$16.2
1993	Mississippi floods	$12.0
2017	Hurricane Harvey	$9.0
2012	Hurricane Sandy	$8.9
2008	Hurricane Ike	$2.7
2016	Louisiana storms/floods	$2.5
2004	Hurricane Ivan	$1.7
2021	Hurricane Ida	$1.6
2004	Hurricane Jean	$1.5
2011	Hurricane Irene	$1.3
2017	Hurricane Irma	$1.2

**** in billions of US dollars from the National Flood Insurance Program***

Deadliest U.S. Flood Disasters

deaths	name	state	year
2,209	Johnstown Flood	PA	1889
1,833	New Orleans *(Katrina)*	LA	2005
431	St. Francis Dam failure	CA	1928
385	Ohio River	multiple	1937
360	Dayton Flood	OH	1913
246	Mississippi Flood	multiple	1927
238	Black Hills Flood	SD	1972
115	Los Angeles Flood	CA	1938
90	Columbus	OH	1913
80	Laurel Run Dam failure	PA	1977
78	Austin Dam failure	TX	1911

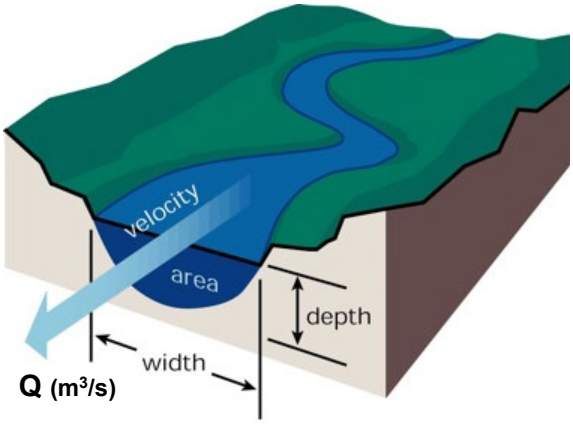
- flood severity factors:

Natural	Anthropogenic
1. rainfall	1. urbanization
2. infiltration rate (soil types)	2. slope modification
3. climate	3. timber industry
4. season	4. flood control measures
5. vegetation	5. agriculture

II. Streams/Rivers

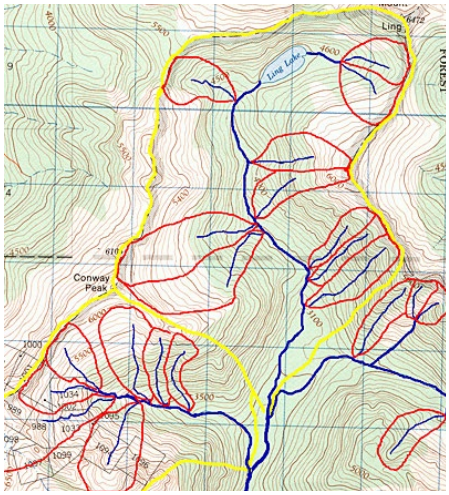
- use of river valleys puts people/infrastructure in areas prone to flooding:
  - housing
  - transportation routes
    - highways, railroads, waterways
  - agriculture
    - fertile soils
  - water supply
    - drinking, irrigation, manufacturing

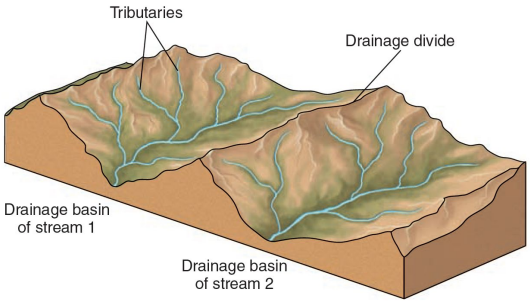
- basic stream flow information:
  - width: bank-to-bank distance (m or ft)
  - depth: distance from water surface to stream bed (m or ft)
    - usually averaged from several measurements
  - length: distance from stream head to entrance into a larger water body (m or ft)
    - longest - 6,693 km (Nile River)



  - discharge (Q): volume / time
    - units: m^3/s or ft^3/s
    - can vary from < 1 to 200,000 m^3/s (Amazon River)

- drainage basin: basic unit of surface water hydrology
  - all land area sloping toward a particular discharge point
  - outlined by topographic divides
    - divide: highest point between stream drainage basins





- stream flow
  - relationship between precipitation rate and infiltration rate
    - determines how much water remains on the surface

  - **infiltration capacity:** capacity of a soil to absorb water
    - varies with soil type, soil condition, time of precipitation event
    - also, a function of the amount of impervious surfaces in an urban environment

  - if precipitation rate is greater than the infiltration capacity of the ground
    - increased run off
    - increased flooding potential

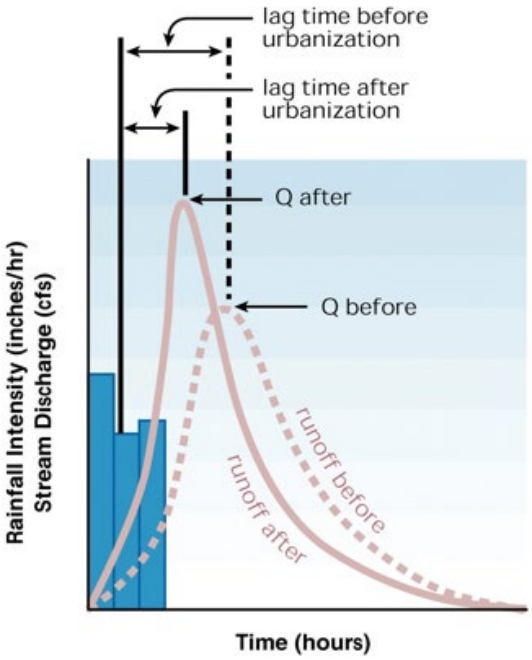
    - high infiltration rates:
      - coarse soil
      - well-vegetated land
      - low soil moisture
      - porous topsoil

    - poor infiltration rates:
      - impermeable crusts in the soil
      - salt layers
      - cold weather *(frozen soil has poor infiltration)*
      - compaction
      - paved *(impervious)* surfaces

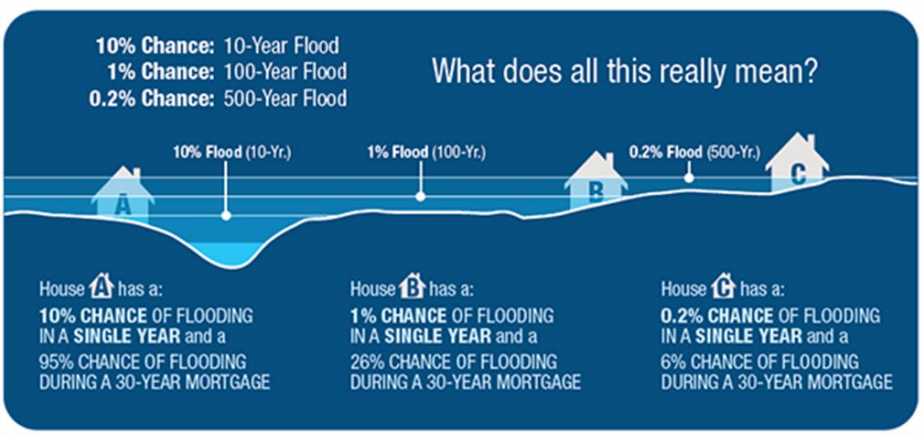
- flood related natural hazards:
  - erosion
  - landslides

- increased hazard risk due to human practices/policies/behaviors:
  - urbanization and modification of river valleys
    - may decrease the effects of one/more of the natural hazards
    - or may decrease one and increase another

- **Hydrograph**
  - discharge rate (Q) in m^3/s (plus rainfall amount) versus time
  - measured by a stream gauge
    - *we'll talk more about these in the next class*
  - varies with infiltration capacity and rainfall amount
  - *notes:*



- flooding frequency
  - larger floods are more rare
  - e.g., "100-year flood"
    - statistical probability of a large flood on a given river
    - 1% chance in any year
    - can happen 2 years in a row or more than once in any year



III. Case Study: Historical Flooding in the Pittsburgh Region

- 1936 Pittsburgh Flood
  - primary causes
    - prolonged precipitation (snow & rain)
    - high intensity, shorter duration rains
    - certain areas had large flash floods
    - steep slopes, thin soil cover, low vegetation

- timeline
  - March 17-20
    - widespread flooding in many northeastern states
    - Pennsylvania: heavy snows throughout the winter with very little melting
  - March 17th - 24 hours of heavy rains
  - March 18th - large ice jams on Monongahela and Allegheny as the rivers thawed
- aftermath
  - Ohio River crested at 46 feet *(flood stage = 25 feet)*
    - initial estimates stated ~ 33 feet
    - therefore, many people returned to homes or never left and then were trapped
  - power and water cut off
  - water contamination by sewage
  - damage:
    - 108 dead in PA (153 dead total)
    - 500 injured
    - 135,000 homeless
    - $250,000,000 in property damage *($4.6 billion today!)*

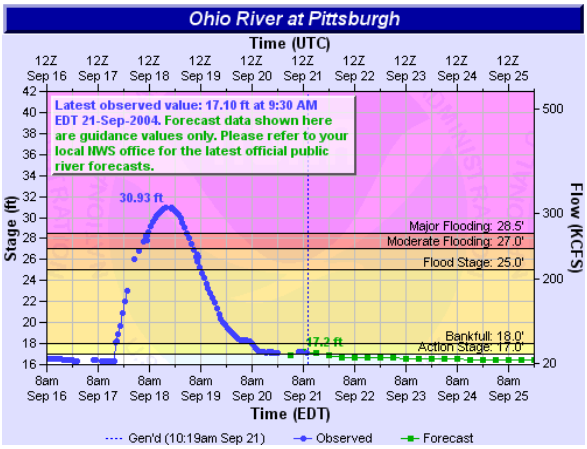
The Point

Stanwix St.

- consequences of the flooding in 1936
  - *Flood Control Act of 1936*
    - full federal funding for large civil works projects
    - dams, levees, etc.
    - recognized flood control was the federal government's responsibility
  - *Flood Control Act of 1938*
    - Army Corps of Engineers (ACE) had the right to acquire land for flood control using eminent domain
    - later amendments stipulated that the ACE limit construction
    - also incorporate recreational functionality

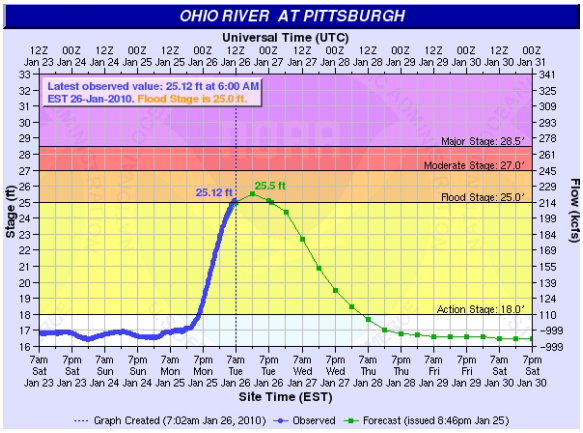
- 2004 Pittsburgh Flood
  - due to the remnants of Hurricane Ivan
    - 5-9” inches of rain fell on southwestern PA
    - 16 dams control about 40% of the drainage area
    - two 7-million-gallon storm drainage ponds captured much of the rainfall
    - however, there was still extensive flooding and damage

from the Smithfield St. Bridge (2004)



2004 hydrograph

approximately the same view (now)



2010 hydrograph