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[May 8, 2025]

Design for Flood Resilience

Part 1: Floodplain Management and Flood Resistant Design

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Middle Delaware Enrichment Webinar #2 – Sponsored by Delaware River Basin Commission & Presented by PEMA

WELCOME

THOMAS HUGHES

Director, EM Mitigation, Insurance, and Resilient Communities Office,

PA Emergency Management Agency (PEMA)

(Former PA State Hazard Mitigation Officer)

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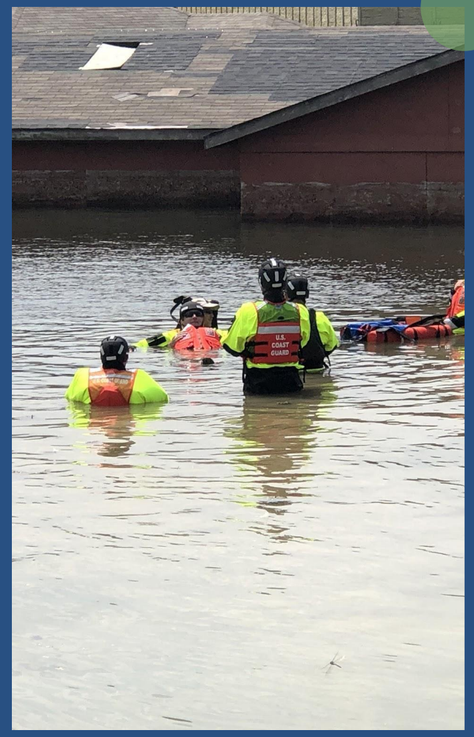

Learning Objectives

1. Identify the **risks** associated with different types of flooding
2. Explain the advantages of **watershed management based on future conditions**
3. Describe f**lood resistant design measures** for buildings and infrastructure

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Learning Objective 1:

Identify the **risks** associated with different types of flooding

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Flood Risks in the U.S.

Riverine
(“Inland”)

- Stream overbank flooding
- Dam or levee failure

Coastal

- Wave action
- Storm surge & erosion

Shallow

- Surface runoff
- Urban drainage overflow

Alluvial
(“Uncertain flow”)

- Flash floods/distant storms
- Movable streambeds

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Flood-related Risks

Inundation
of inland or tidal waters

Rapid Accumulation
of runoff

Mudflow
on normally dry land

Collapse/Subsidence
of land resulting from erosion, waves, or water currents exceeding normal cycles that result in flood

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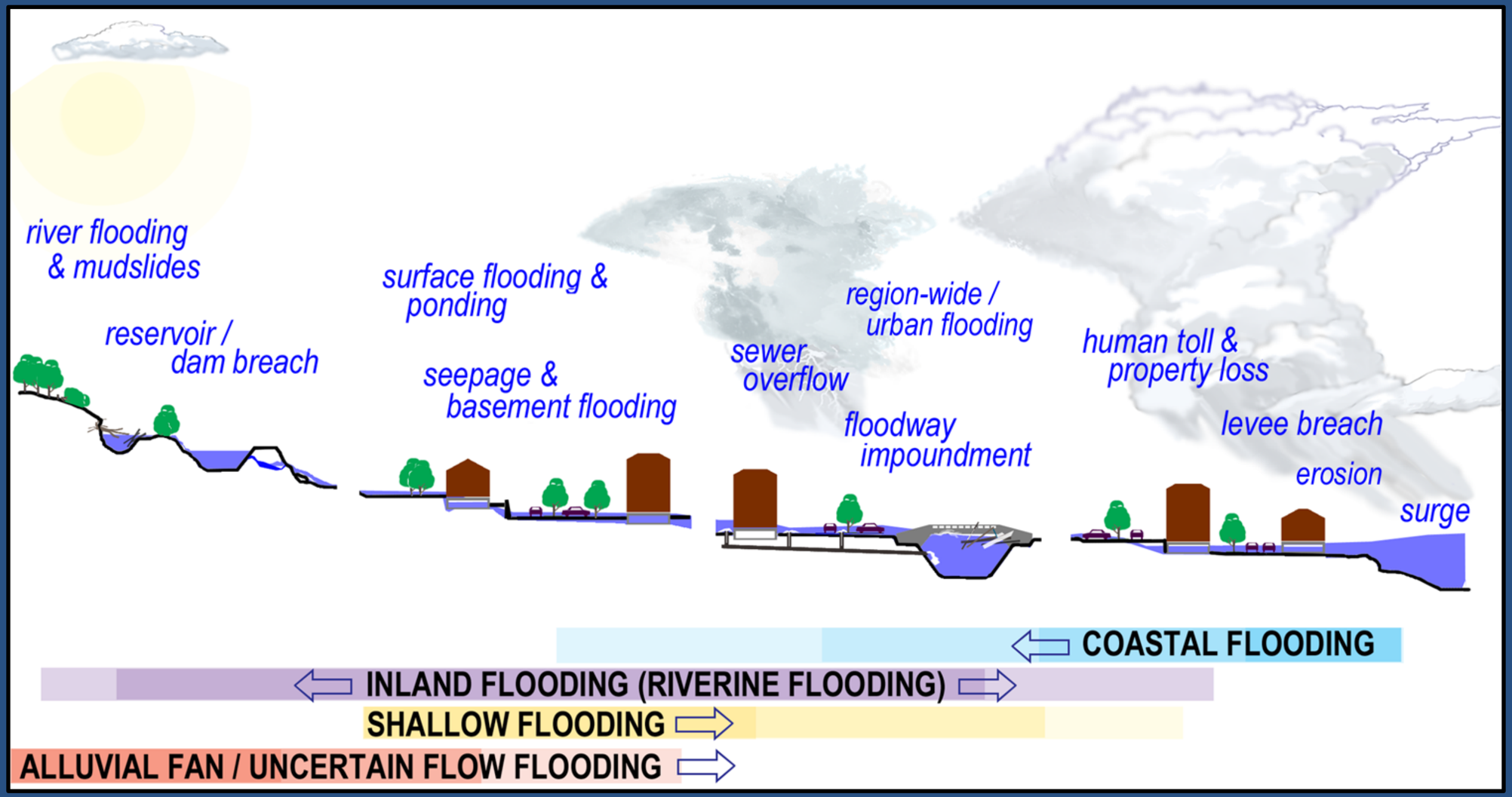
Combined Flood Risks



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Large issues...

Flash floods - the #1 weather-related killer in the United States

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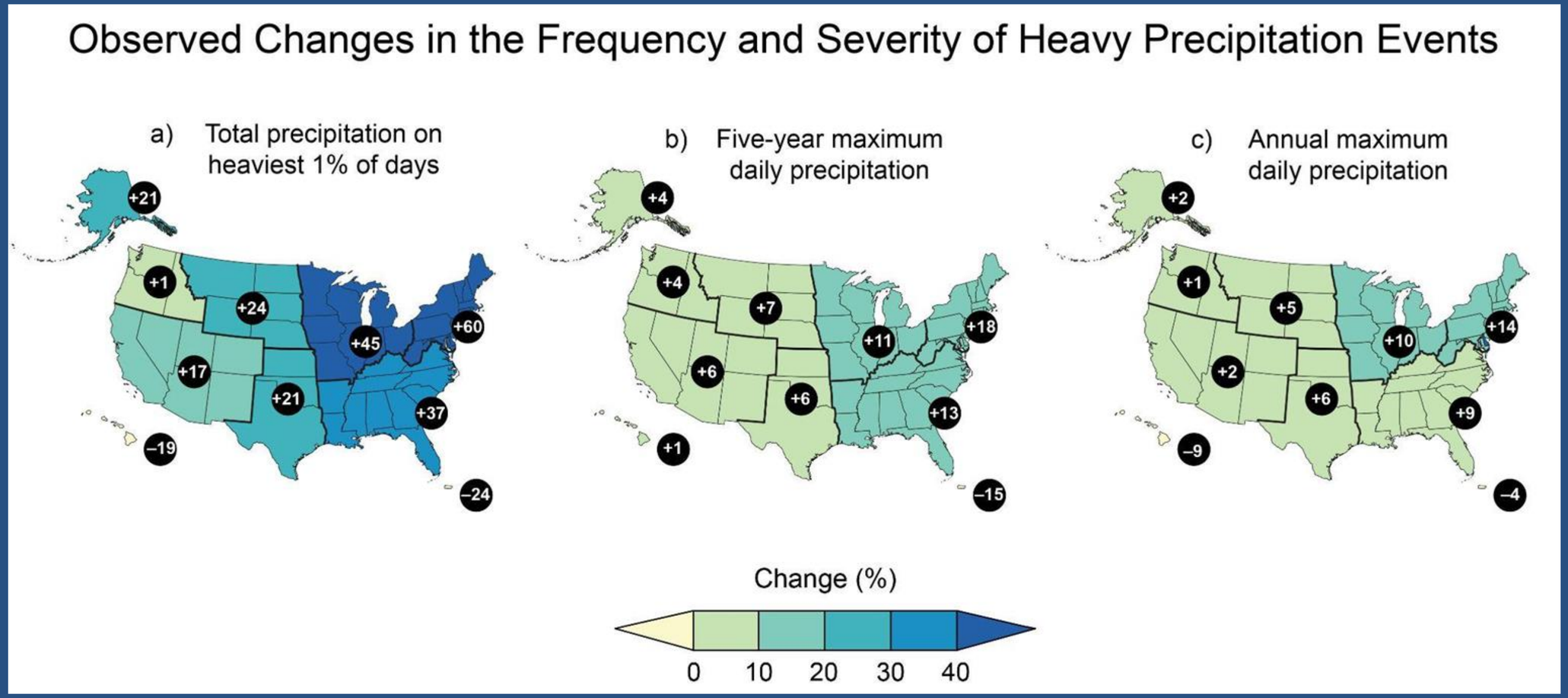
Turn Around Don’t Drown

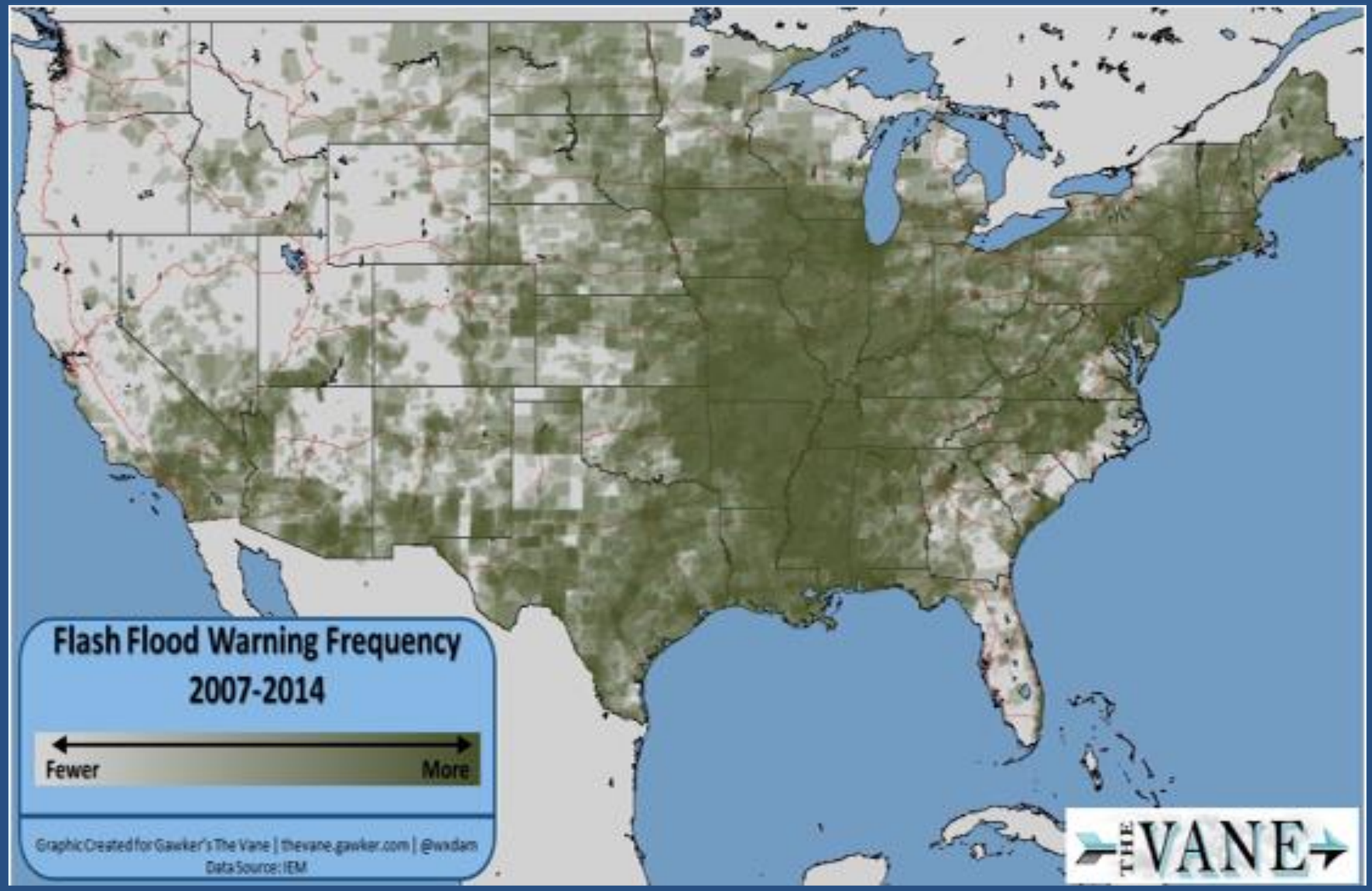
...Small Steps

Precipitation Trends



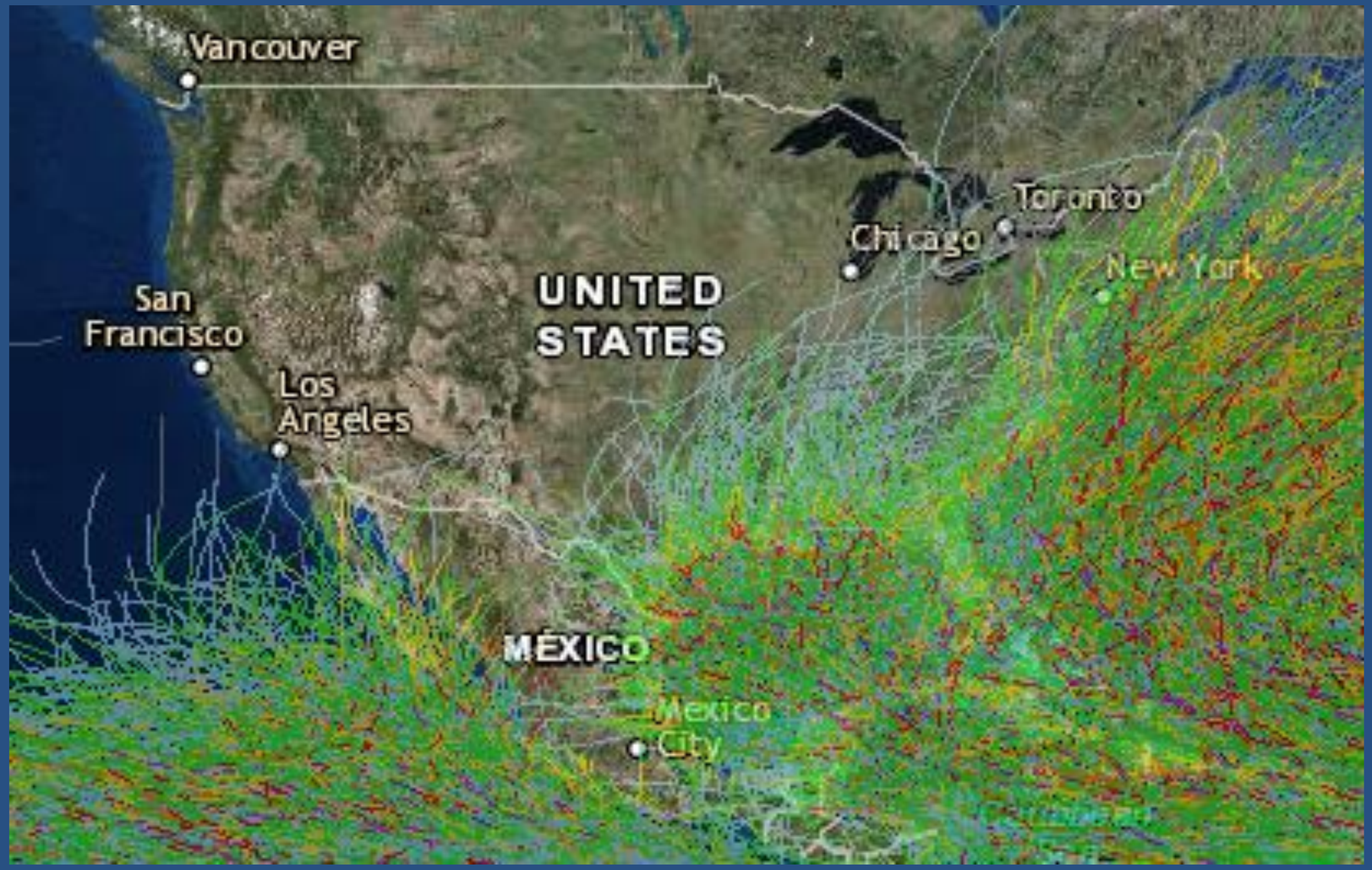
Fifth National Climate Assessment.
https://nca2023.globalchange.gov/chapter/2#fig-2-7

Flash Flood Warning Frequency



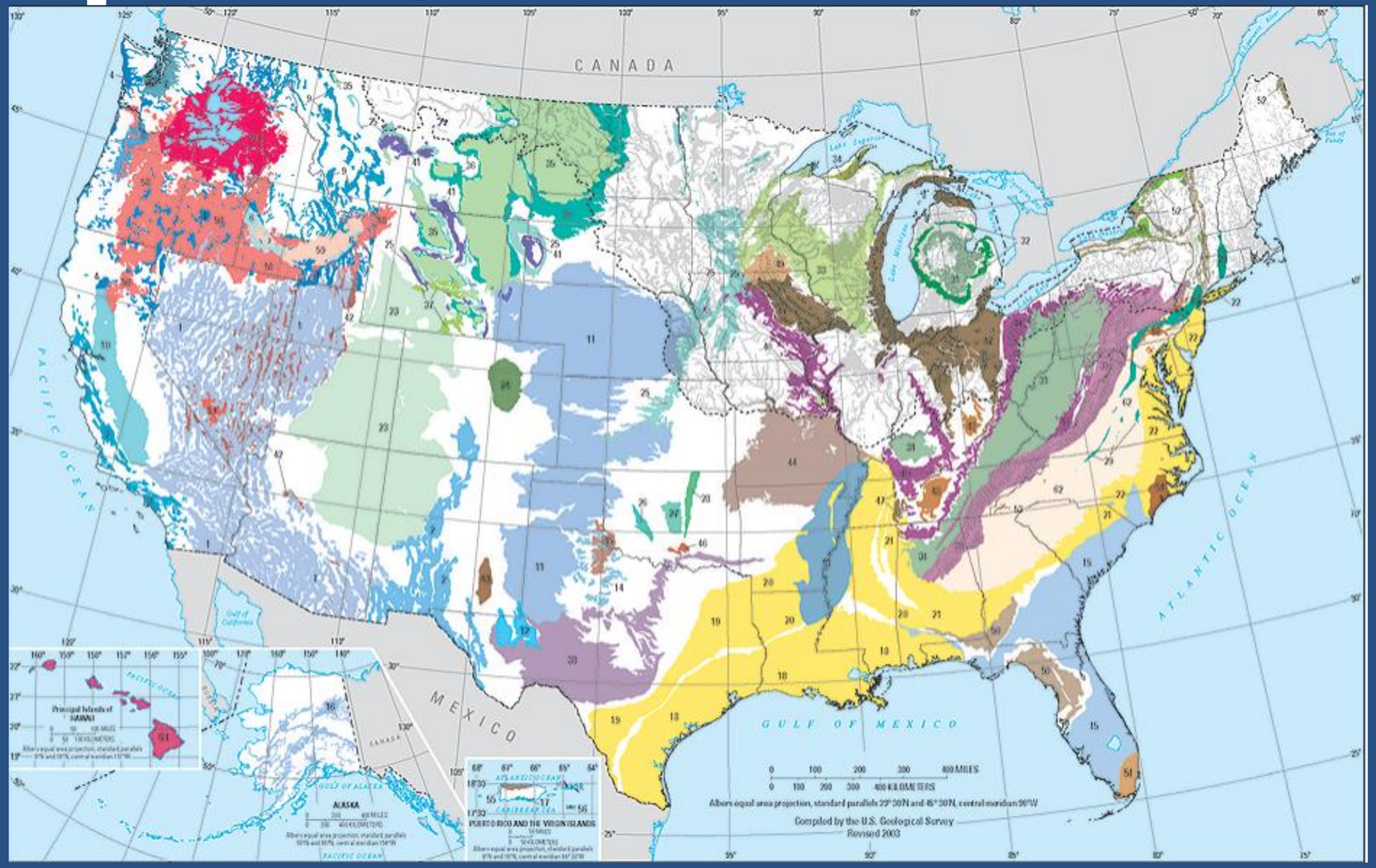
Map (2014) by Dennis Mersereau - http://thevane.gawker.com/maps-which-parts-of-the-u-s-see-flash-floods-most-often-

Coastal Storm Trends



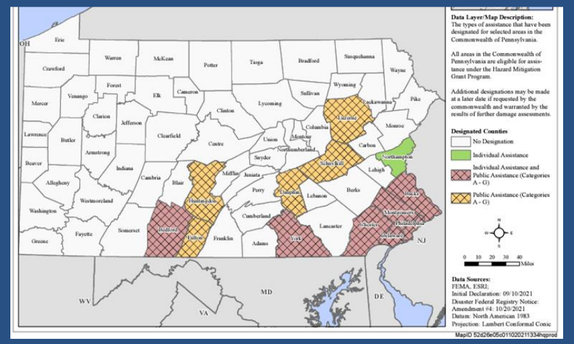
Historical Hurricane Tracks -
https://coast.noaa.gov/hurricanes

Aquifers: Our water bank account



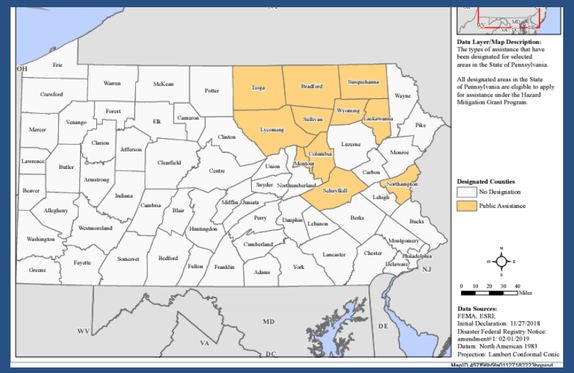
Map of the Principal Aquifers of the United States
https://www.usgs.gov/media/images/aquifers-map-principal-aquifers-united-states

Pennsylvania Disaster Declarations: 2011 - 2021



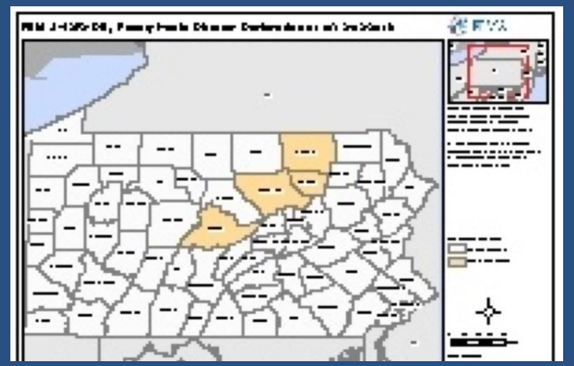
#4618
Sep. 10, 2021
Hurricane Ida
$243.8M obligated

#4149
Jun. 26-Jul.12, 2013
Severe storms,
Tornadoes & flooding
$25M obligated

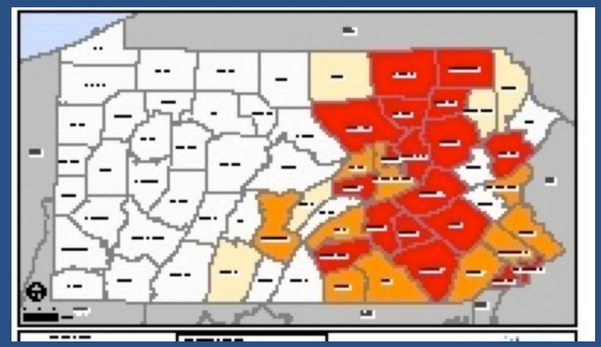


#4408
Nov. 27, 2018
Severe storms & flooding
$88.65M obligated

#4099
Oct. 26-Nov. 8, 2012
Hurricane Sandy
$12.8M obligated



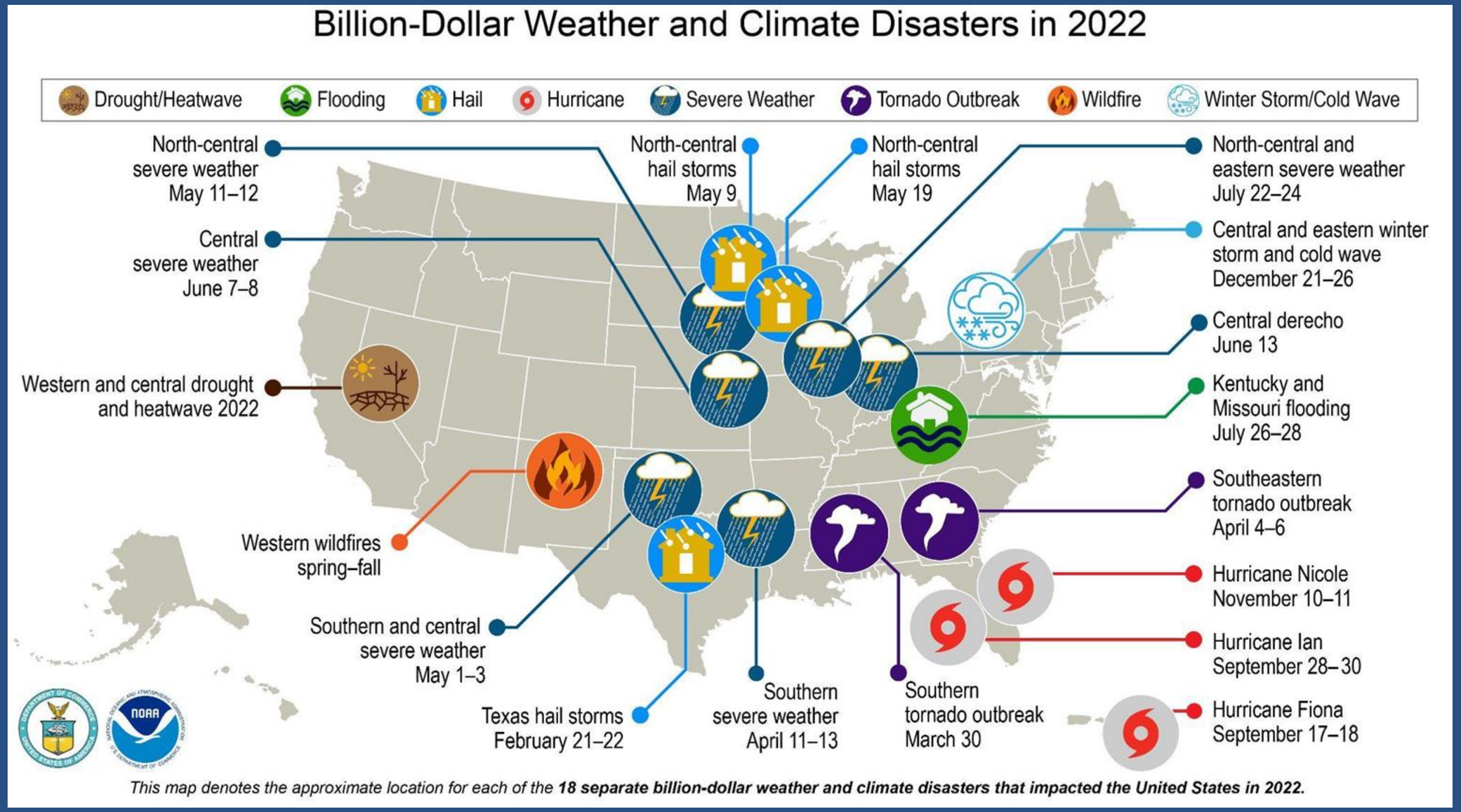
#4292
Oct. 20-21, 2016
Roads & bridges
$4.2M obligated



#4030
Sep. 03 Oct. 15, 2011
Tropical Storm Lee
4,542 residences
(only 25% insured)
$250M obligated

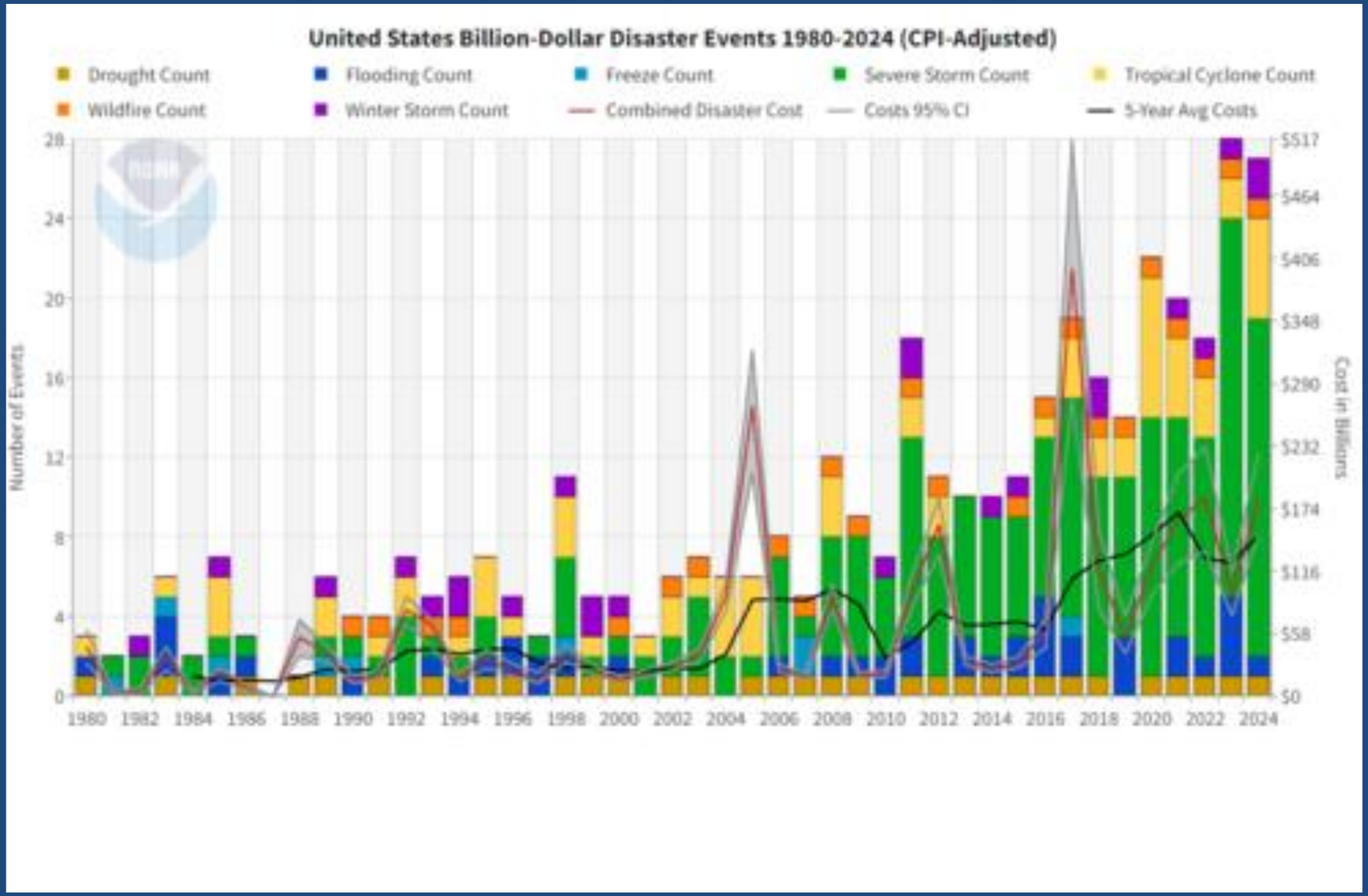
Disaster Declarations for Pennsylvania | FEMA.gov
www.fema.gov/disasters/grid/state-tribal-government

Increasing Severity and Cost - U.S.



Fifth National Climate Assessment.
https://nca2023.globalchange.gov/chapter/2#fig-2-6

Increasing Severity and Cost - U.S.



https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:0209268

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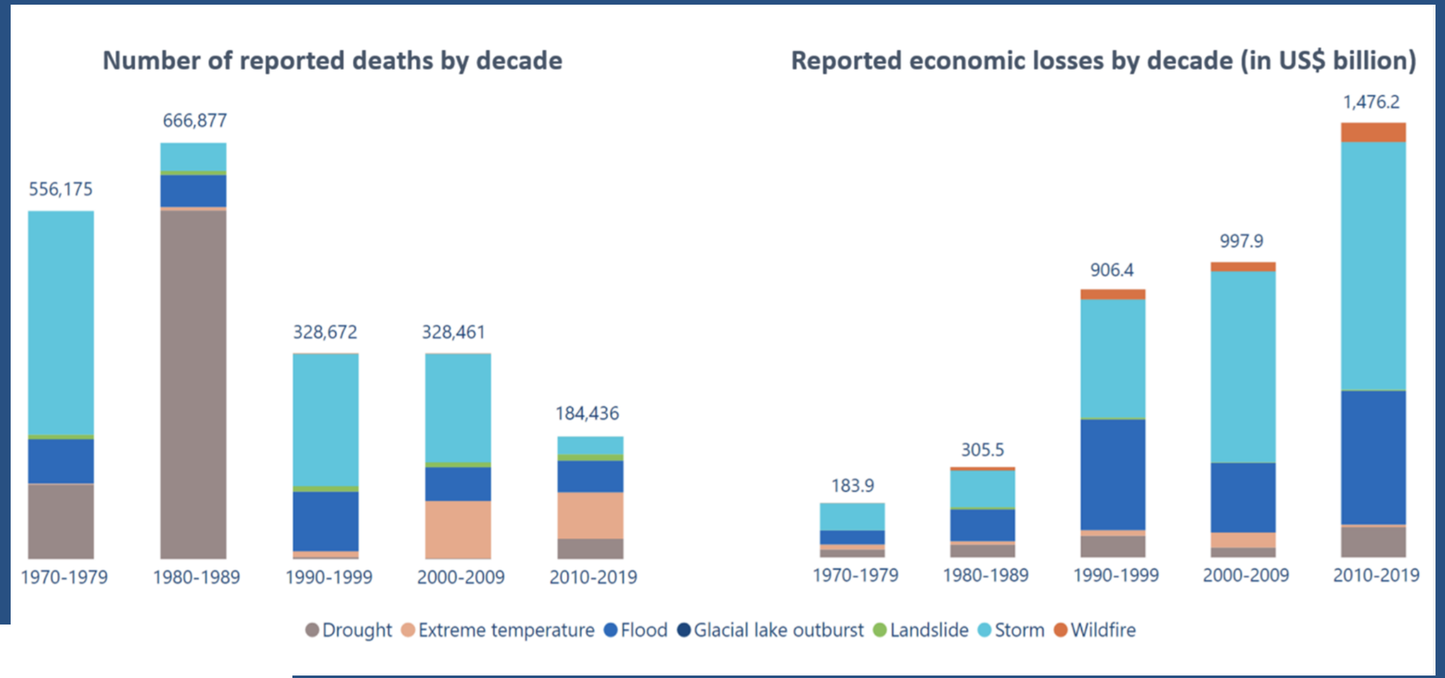
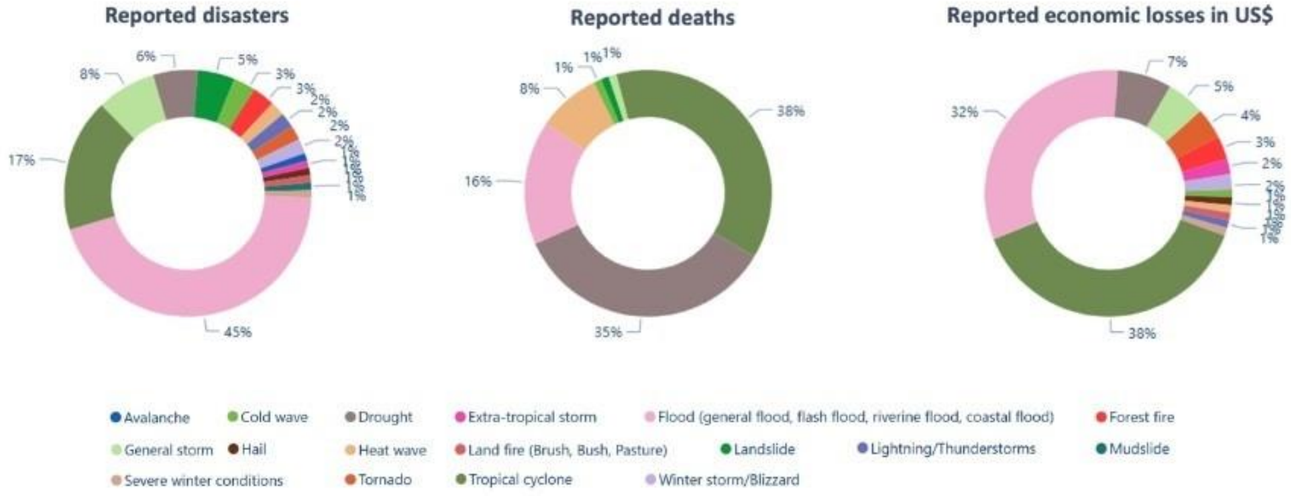
Increasing Severity and Cost - Global



Hazards overview

Globally, flood-related disasters were the most prevalent. In terms of the impact, tropical cyclones were the leading cause of reported human and economic losses between 1970 and 2021.



World Economic Forum
https://www.weforum.org/agenda/2023/06/extreme-weather-economic-costs-death-numbers/

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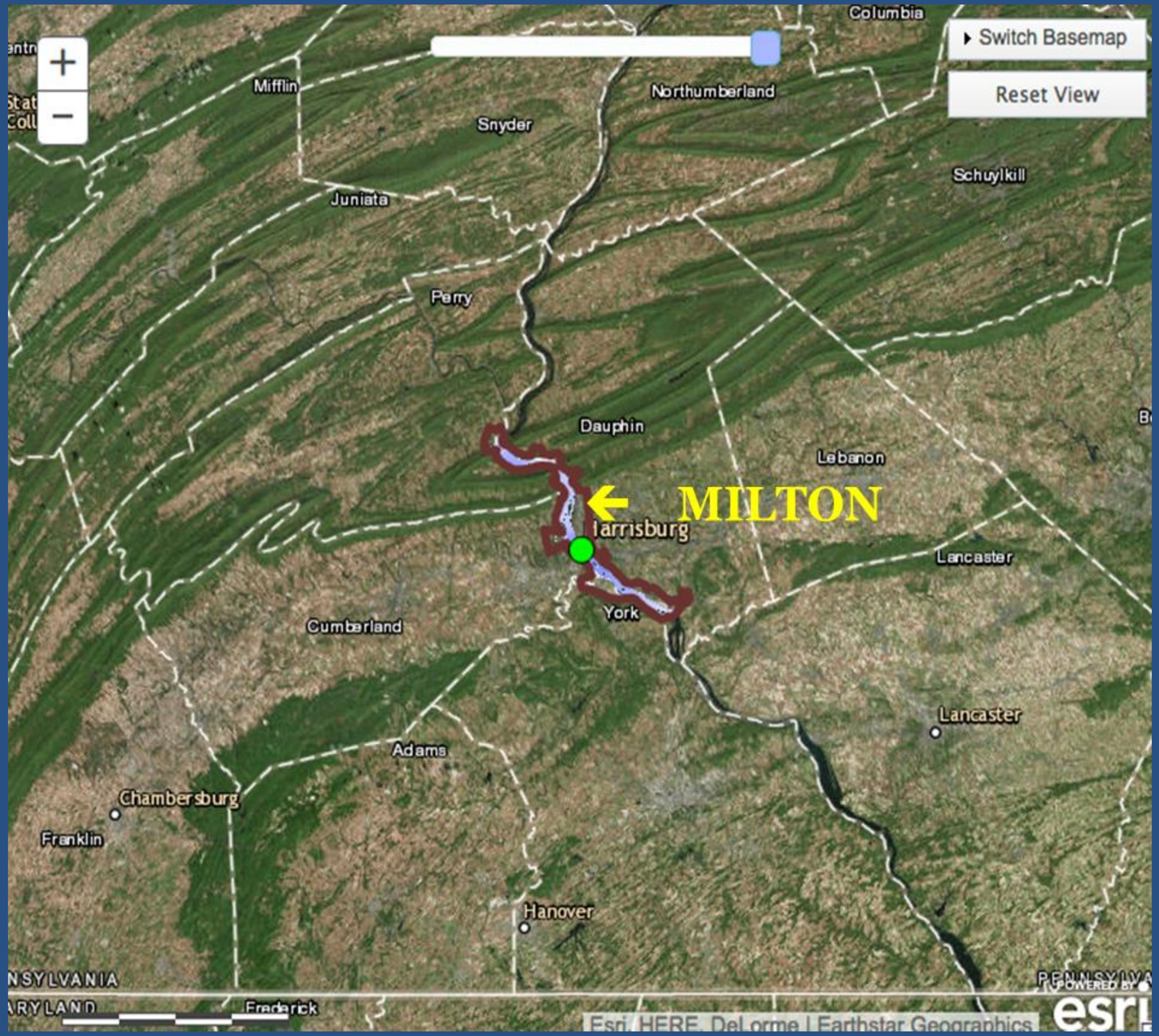
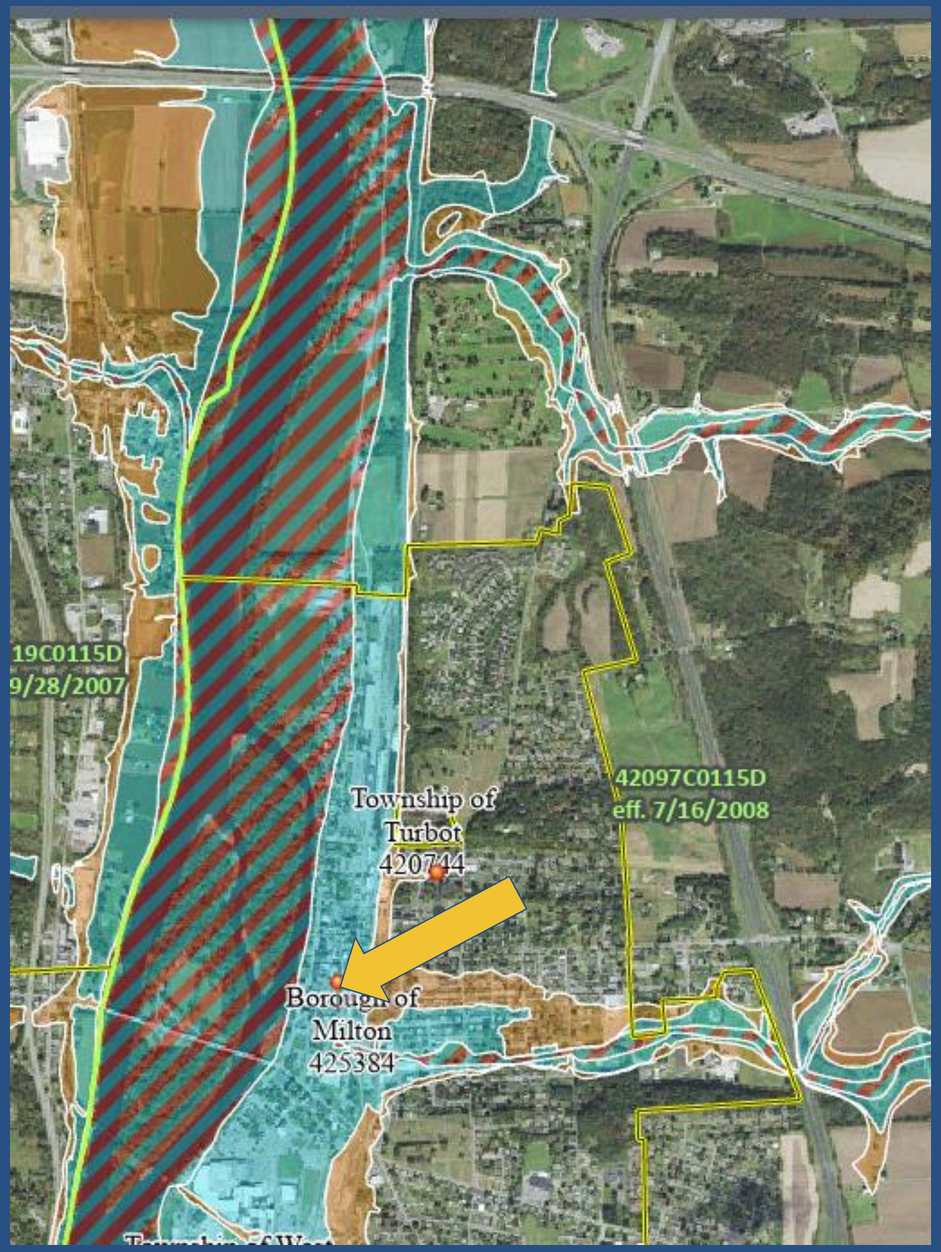
Case Study:

Milton, PA (Northumberland County)

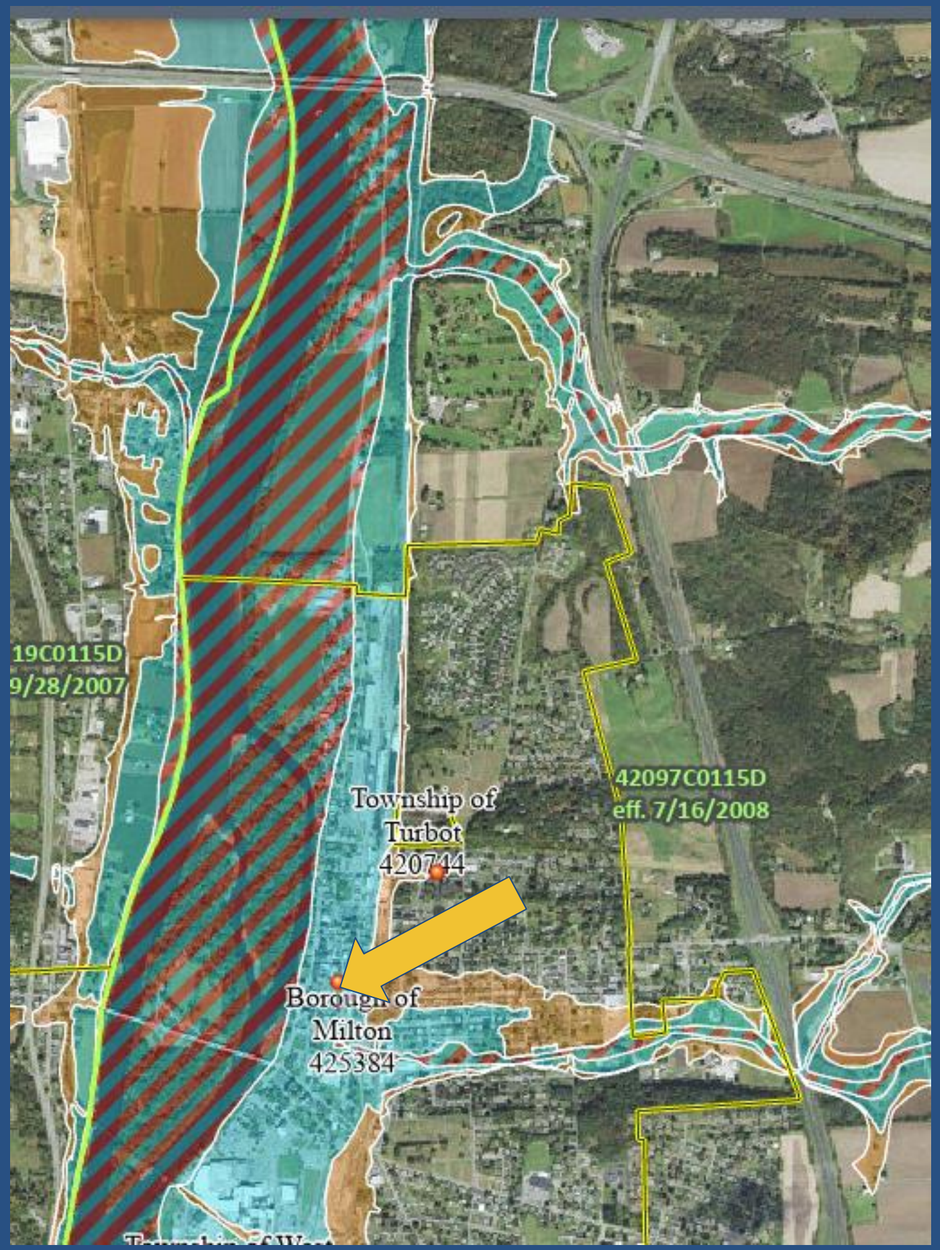





The crest of the 1972 flood in Milton.

1889	Spring flood
1894	Spring flood +29 ft. crest
1936	Heavy spring rain, snow melt
1972	Jun. Hurr. Agnes +35 ft. crest
1975	Sept. flood (>25% loss)
1996	Jan. flood w/ snow/ice/thaw

URS, Looking to the Future: Alternatives for Reducing Flood-Related Damage in Historic Communities Milton, Pennsylvania (2002)



A kayaker explores Milton during the 1894 flood.

*MAP: msc.**fema**.gov/portal/search*
PHOTOS: [1] Milton Historical Society [2] Donald Watson


PITTSBURGH'S
ACTION NEWS 4

- Acquisition & Demolition
- Relocation
- Levees & floodwalls
- Stream channel alteration

- Watershed management
- Green infrastructure

- Building Elevation
- Wet floodproofing
- Dry floodproofing
- Mitigation Reconstruction

- Raised streets/dry access

URS Corp., Looking to the Future: Alternatives for Reducing Flood-Related Damage in Historic Communities Milton, Pennsylvania (2002)

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Learning Objective 2:

Explain the advantages of **watershed management based on future conditions**

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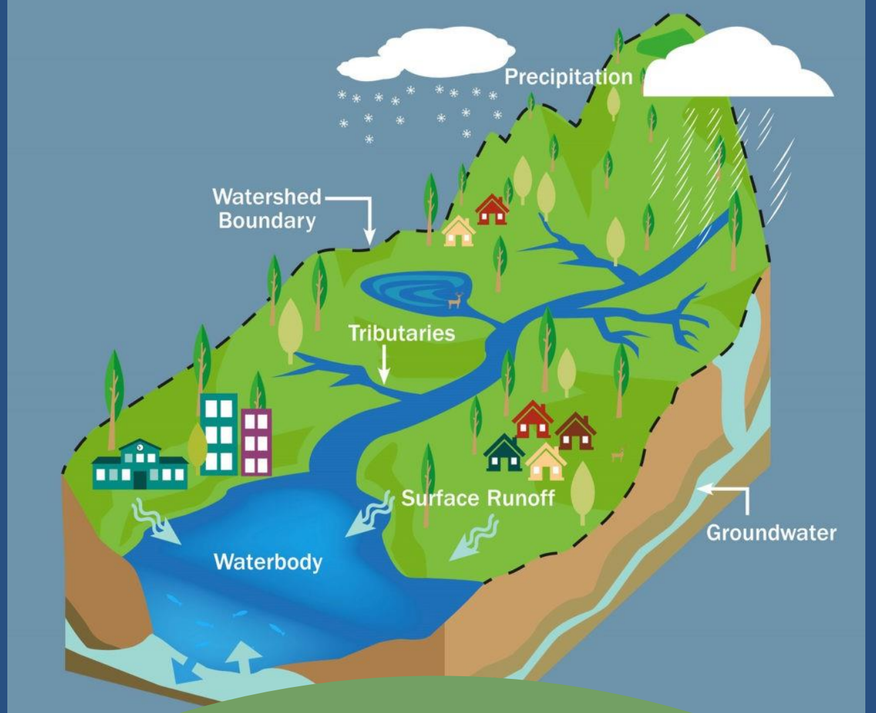
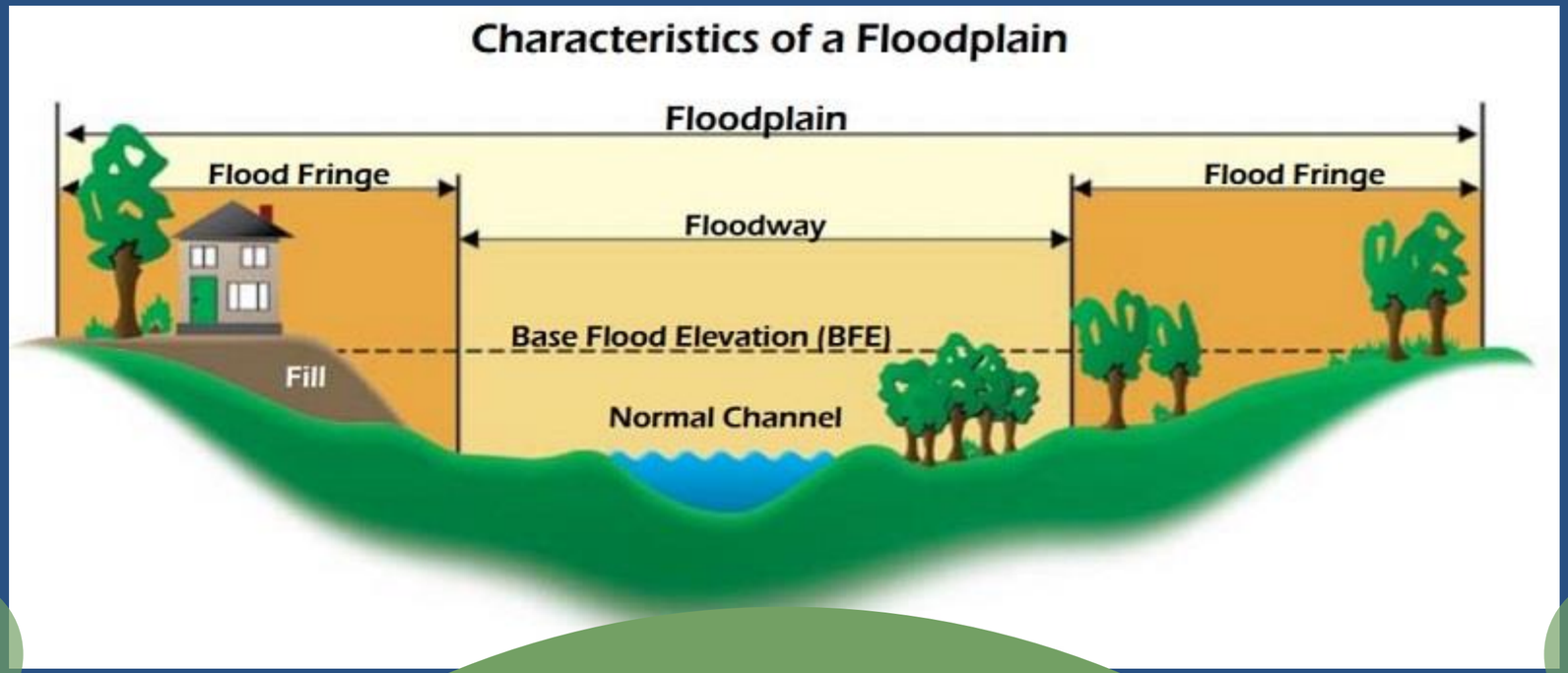


WATERSHED

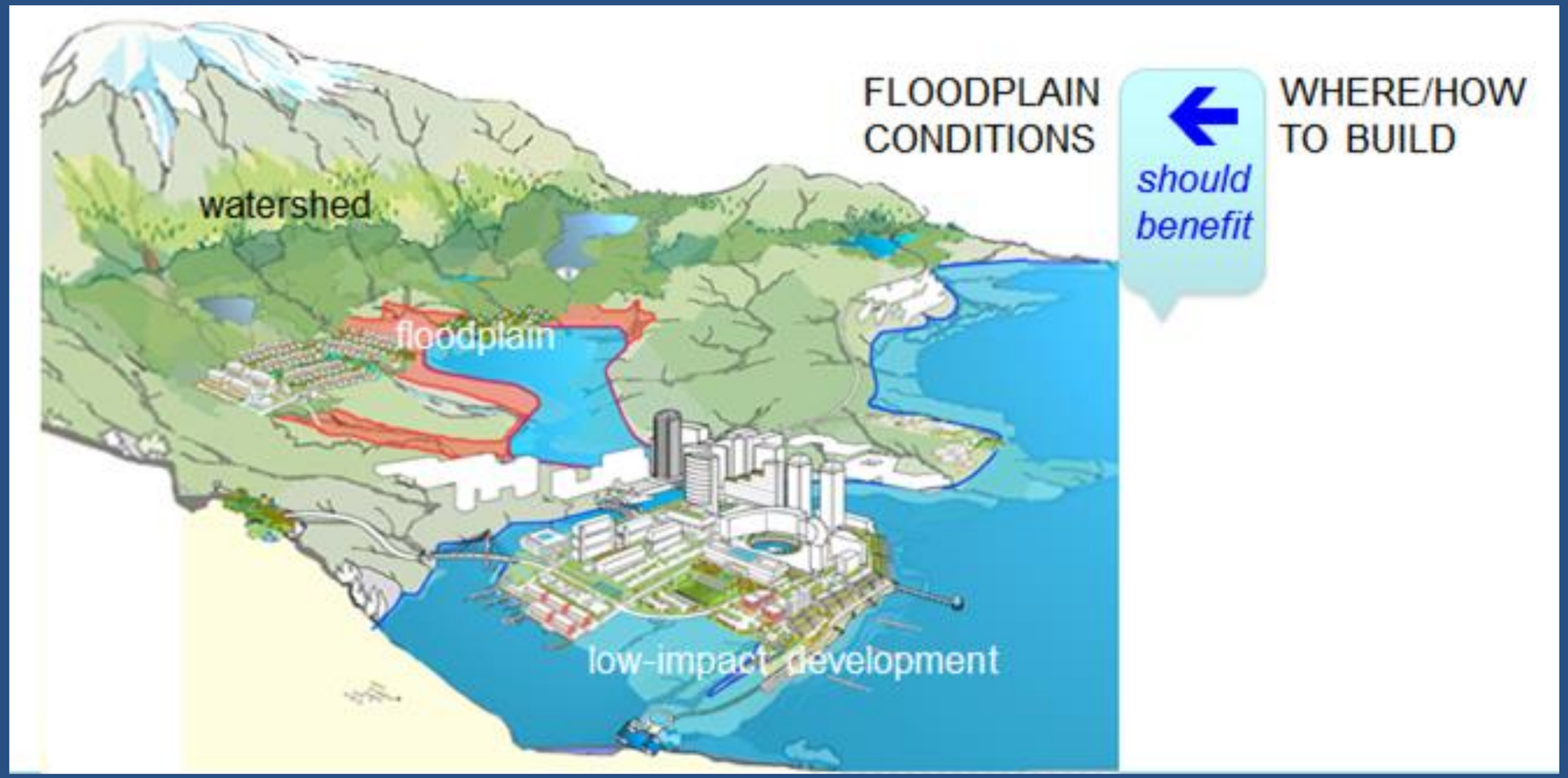
A specific area of land that drains water, sediment, and dissolved materials into a river system or other body of water



FLOODPLAIN

Any land area susceptible to being inundated by floodwaters from any source.

Building in the Floodplain



Think like a watershed!

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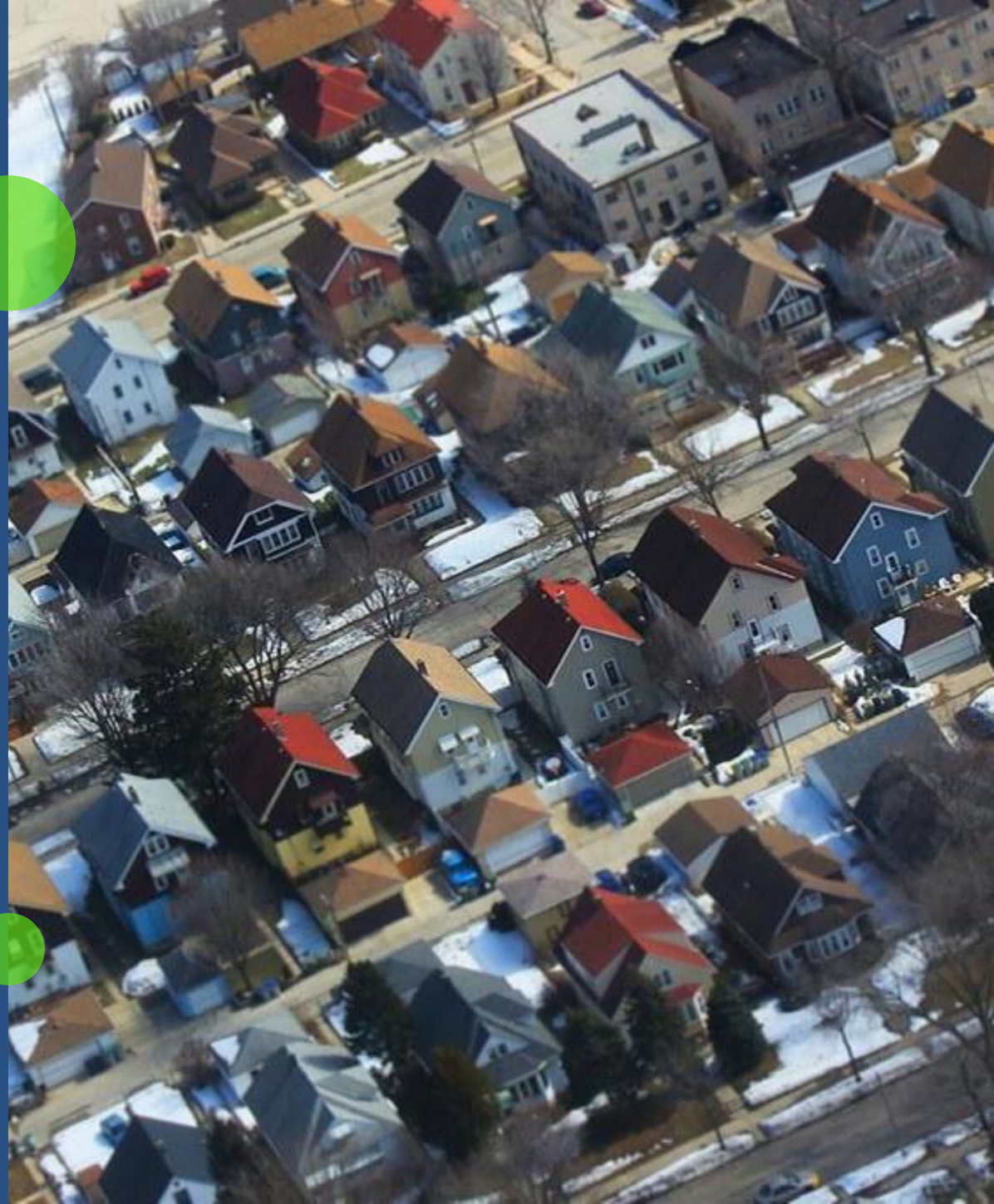
ASFPM's *No Adverse Impact*

- **No Adverse Impact** *establishes standards and practices so that actions of one property owner are not allowed to adversely affect the rights of other property owners*
  - Increased flood peaks
  - Increased flood stages
  - Higher flood velocities
  - Increased erosion and sedimentation, or
  - Other impacts the community considers important



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Design for Flood Resilience

Community Rating System (CRS)

Voluntary incentive program that recognizes and encourages community floodplain management practices that exceed the minimum requirements of the NFIP

- Flood insurance rates are discounted to reflect the reduced flood risk resulting from the community's efforts that address three goals:
  - Reduce and avoid flood damage to insurable property
  - Strengthen and support the insurance aspects of the NFIP
  - Foster comprehensive floodplain management

OMB No. 1660-0022
Expires: March 31, 2020

National Flood Insurance Program
Community Rating System

Coordinator's Manual

FIA-15/2017

FEMA

Naturally Resilient Communities

https://nrcsolutions.org/mapping-planning-regulation-enhanced-floodplain-mapping /

Building as a watershed

Brock Environmental Center
PHOTO: © Prakash Patel courtesy SmithGroupJJR Architects

Design for Flood Resilience

Learning Objective 3:

Describe f**lood resistant design measures** for buildings and infrastructure

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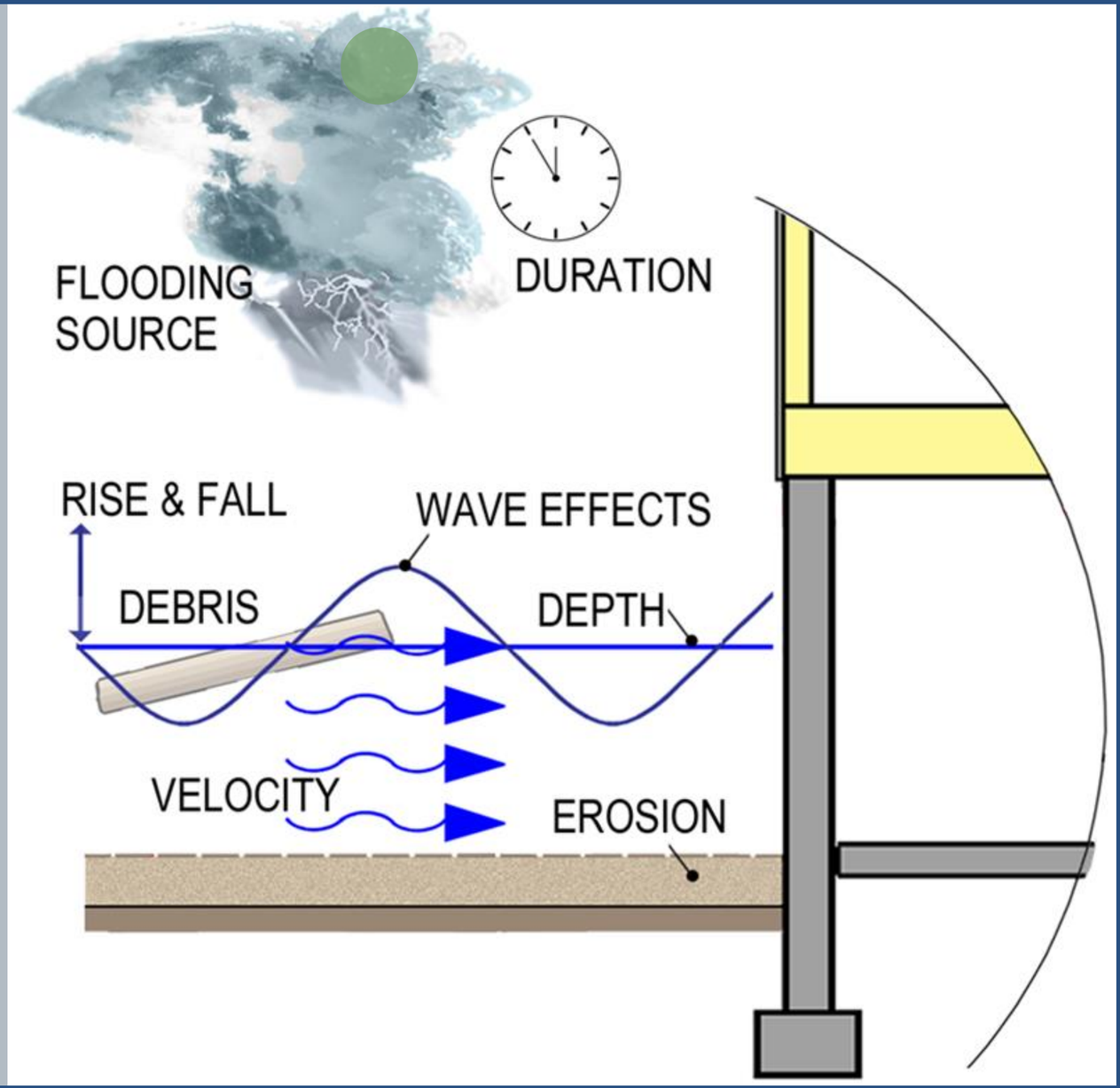
Flood Design Variables

- Source of flooding
- Flood depth
- Flood velocity
- Flood duration
- Rate of rise and fall
- Wave effects
- Flood-borne debris
- Scour & erosion



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Flood Resistant Design

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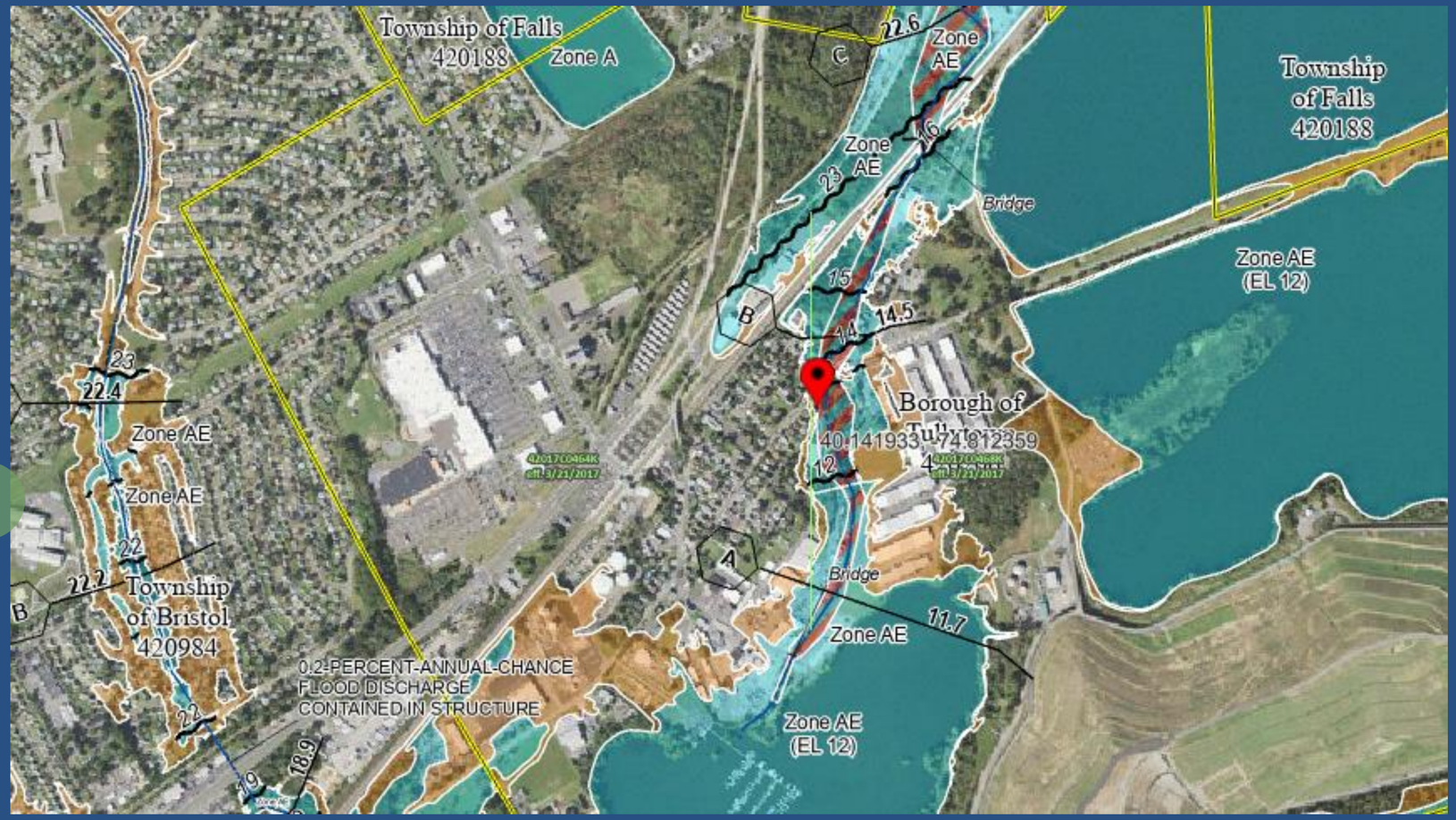
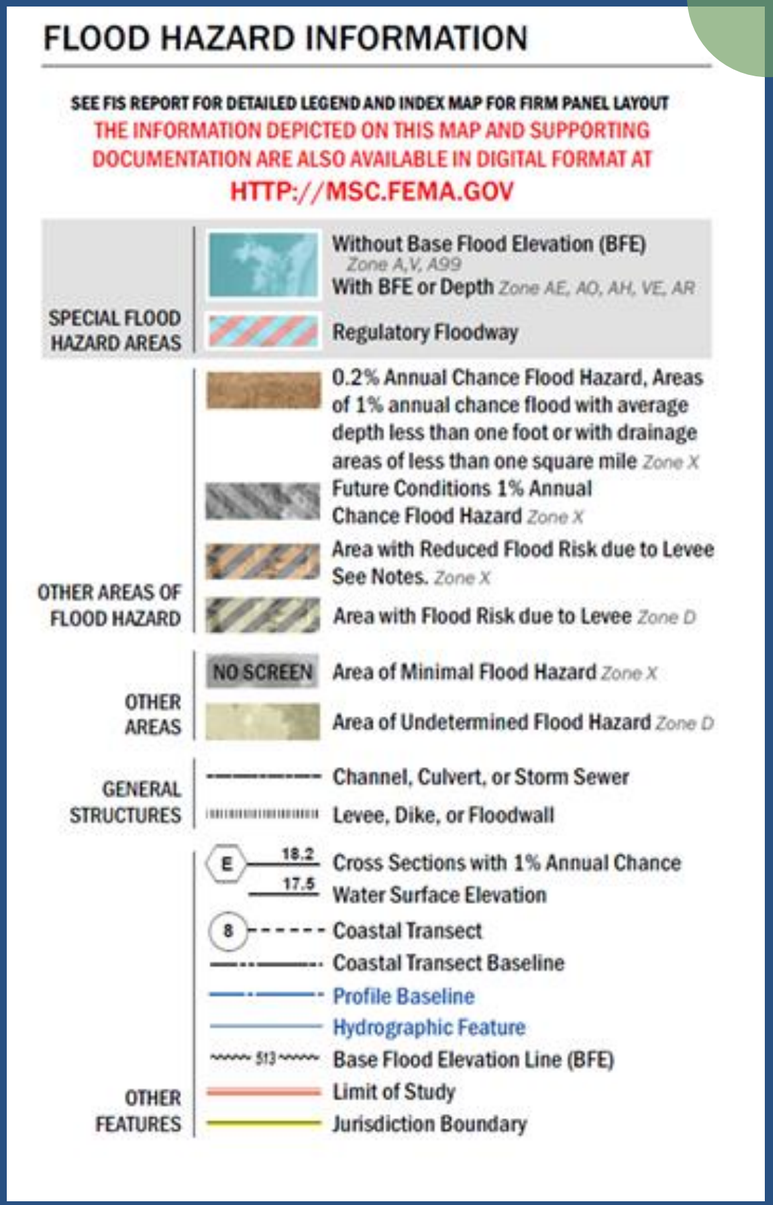


Digital Flood Insurance Rate Maps (FIRMs)



FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

THE INFORMATION DEPICTED ON THIS MAP AND SUPPORTING DOCUMENTATION ARE ALSO AVAILABLE IN DIGITAL FORMAT AT

HTTP://MSC.FEMA.GOV

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A,V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN — Area of Minimal Flood Hazard *Zone X*
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- E 18.2 / 17.5 — Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 — Coastal Transect
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature
- 513 — Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary

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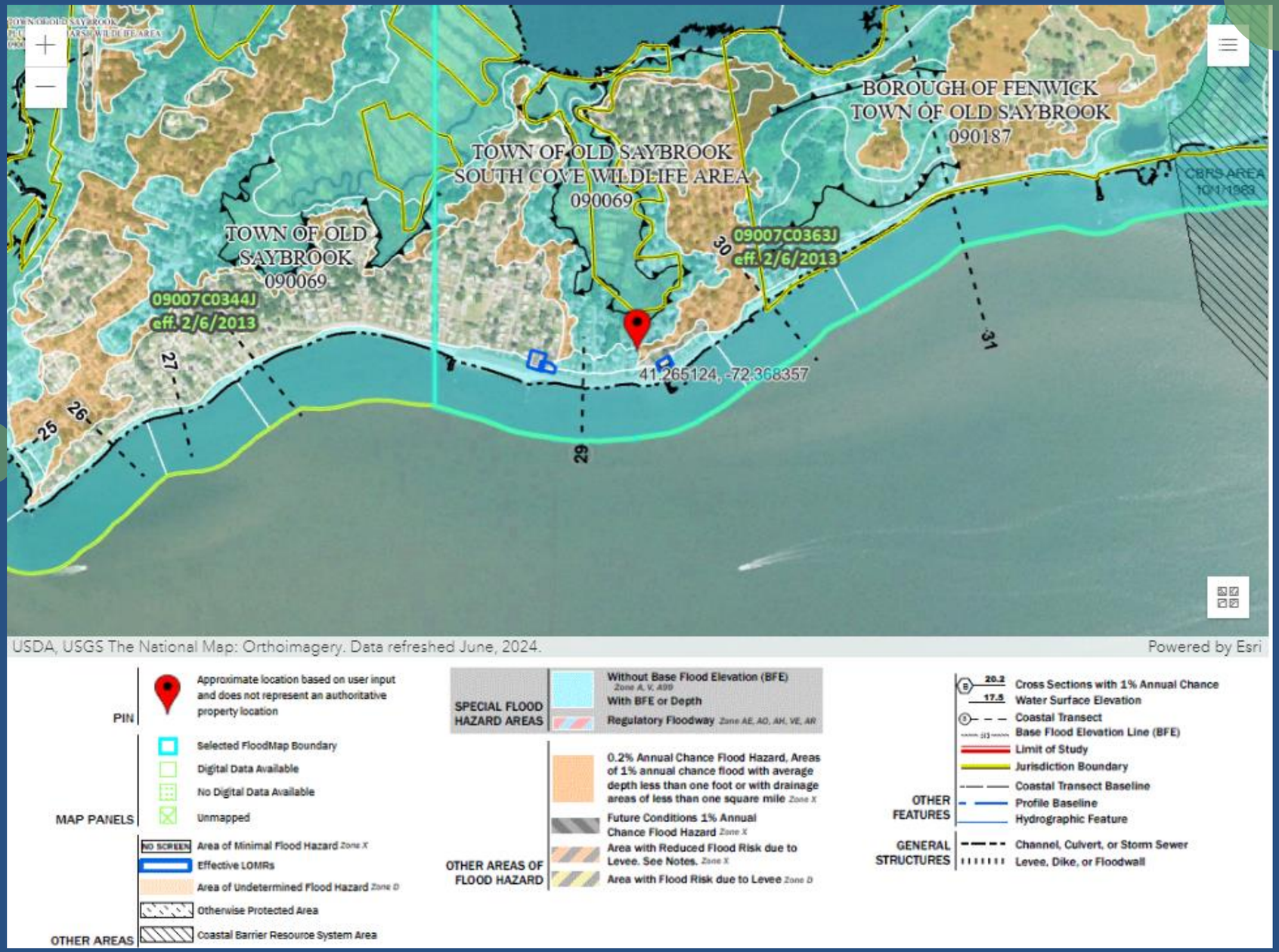

Digital Flood Insurance Rate Maps (FIRMs)

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- [FEMA Flood Maps]
- Enter address, place, or coordinates
- Click map and menu for “Dynamic Map” or “Map Image” will appear
- One page FIRMette will be generated from the options

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Flood Insurance Rate Map (FIRM) Download

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State Specific FIRMs

- If the FEMA FIRM website is not working properly, consider using your state specific FIRM website
- For example, Pennsylvania has a great FIRM resource center
- https://pafloodrisk.psu.edu/home/

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National Flood Insurance Program

Introduction

- The NFIP was created as a result of the passage of the **National Flood Insurance Act of 1968**.
- Congress enacted the NFIP in response to:
  - Lack of availability of private insurance
  - Increases in federal disaster assistance due to floods.
- The NFIP is a federal program, managed by FEMA, and has **three** components:
  - To provide flood insurance
  - To improve floodplain management
  - To develop maps of flood hazard zones.

https://ksa-insurance.com/blog/nfip-changes/

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Design for Flood Resilience

National Flood Insurance Program

Statistics:

- Structures built to meet of exceed NFIP minimum floodplain management standards incur at minimum **65% less flood damage** on average
- NFIP saves **$2.4B in avoided losses** each year
- NFIP has saved $**100B in avoided losses** over the past 40 years

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Roles and Responsibilities

FEMA

- National Flood Insurance Program (NFIP)/Floodplain Management Oversight
- Risk Identification (Mapping)
- Establish development/building standards
- Provide affordable flood insurance coverage
- Approval of local floodplain ordinances when developed and revised

State Agencies

- State NFIP)/Floodplain Management Oversight
- Establish development/building standards
- Provide technical assistance to local municipalities/agencies
- Evaluate and document floodplain management activities
- Training for Public Officials, and those working in the floodplain

Counties

- May provide floodplain management assistance **but** legal responsibility of the NFIP activities still rests with the participating municipality
- Services could include:
    - Floodplain permitting
    - Assistance for Substantial Damage/Substantial Improvement Assessments/Recordation
    - Public official training

Local

- Revision, Adoption, and Enforcement of the FEMA approved floodplain ordinance
- Issuance or Denial of Development/Building Permits
- Inspection of Development and Maintenance of Records specific to the Special Flood Hazard Area and flood-prone areas within the municipality.
- Oversight of development planning and implementation activities

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Design for Flood Resilience

National Flood Insurance Program

Substantial Damage:

“damage of any origin is sustained by a structure whereby the cost of restoring the structure to it’s before damaged condition would equal or exceed ***50 percent of the market value*** *of the structure before the damage occurred”*

- Applies to structures in a Special Flood Hazard Area (SFHA)
- Land value is excluded from this determination
- If substantially damaged, owners may:
  - Elevate structure
  - Relocate or demolish structure
  - Flood proof a non-residential structure

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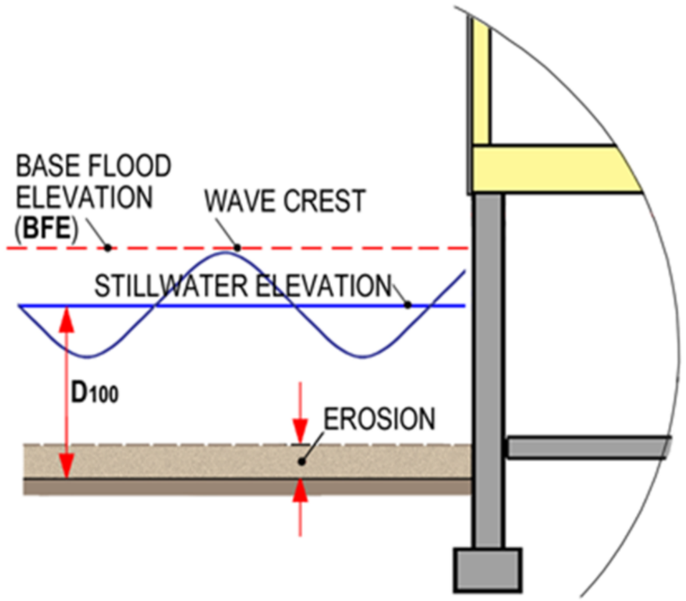

- Primarily intended for use in Federal Insurance Rates Maps (FIRMs)
- Based on *historical* flood data
- Not a sufficiently accurate indicator of *future* flood risk

Additional analysis of local and future probable conditions is required

@ Donald Watson

DISASTER RISK REDUCTION
Ambassador Curriculum

Design for Flood Resilience

Base Flood Elevation (BFE)

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Design for Flood Resilience

Base Flood Elevation (BFE) Continued

- Be sure to check building codes, Notices of Funding Opportunities (NOFO), and local ordinances in addition to FIRM for BFE levels
- Building codes can go above and beyond BFE levels in the FIRM and must be followed
- NOFOs can often have valuable information that can influence decision making on design for flood mitigation

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Design for Flood Resilience

NFIP Technical Bulletins

- Provide guidance for complying with the NFIP's building performance requirements contained in the US Code of Federal Regulations
- Great for homeowners, insurance agents, building professionals, and designers
- Example: Technical Bulletin 1, Openings in Foundation Walls and Walls of Enclosures (2020)
- *NFIP Technical Bulletins*

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Design for Flood Resilience

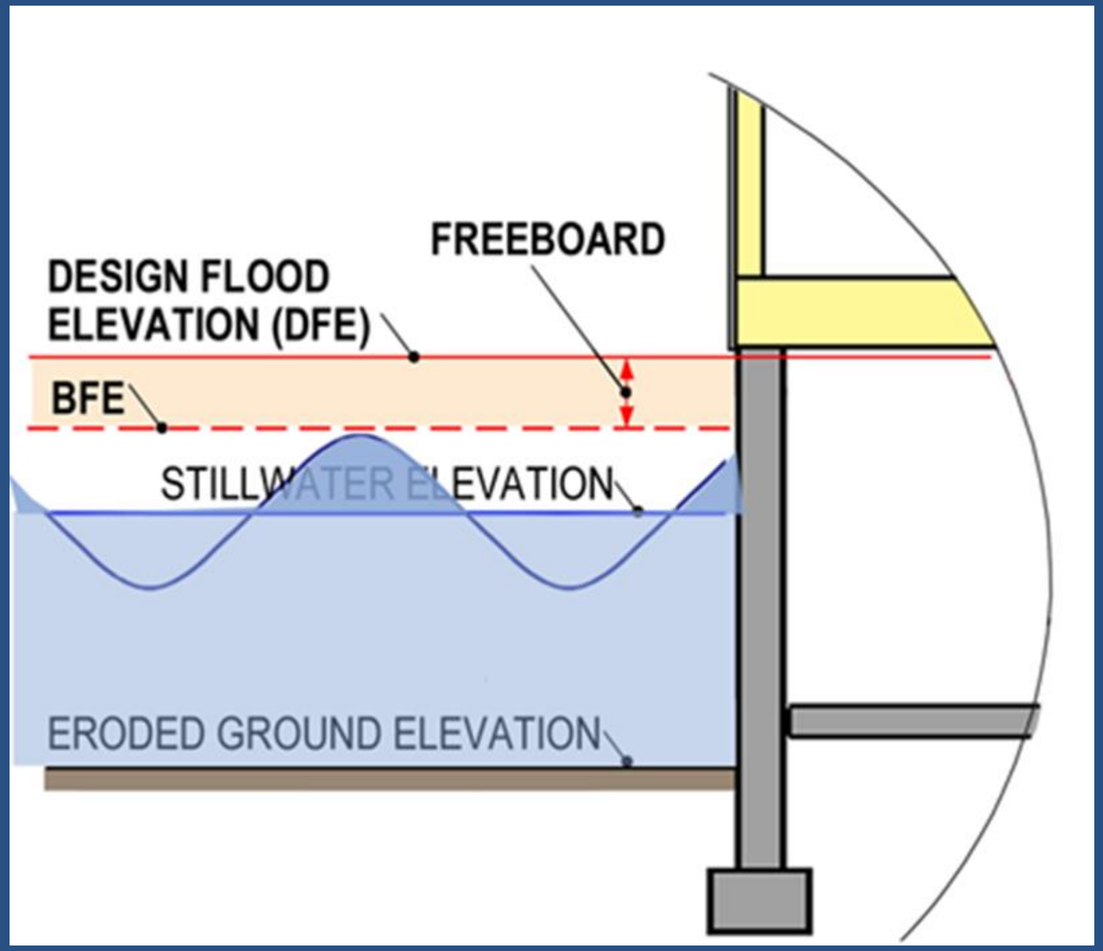
Probability Table

PROBABILITY OF NATURAL HAZARD EVENT FOR VARIOUS PERIODS OF TIME

Length of Period (Years)	Frequency – Recurrence Interval					
	10-Year	25-Year	50-Year	100-Year	500-Year	700-Year
1	10%	4%	2%	1%	0.2%	0.1%
10	65%	34%	18%	10%	2%	1%
20	88%	56%	33%	18%	4%	3%
25	93%	64%	40%	22%	5%	4%
30	96%	71%	45%	26%	6%	4%
50	99+%	87%	64%	39%	10%	7%
70	99.94+%	94%	76%	51%	13%	10%
100	99.99+%	98%	87%	63%	18%	13%

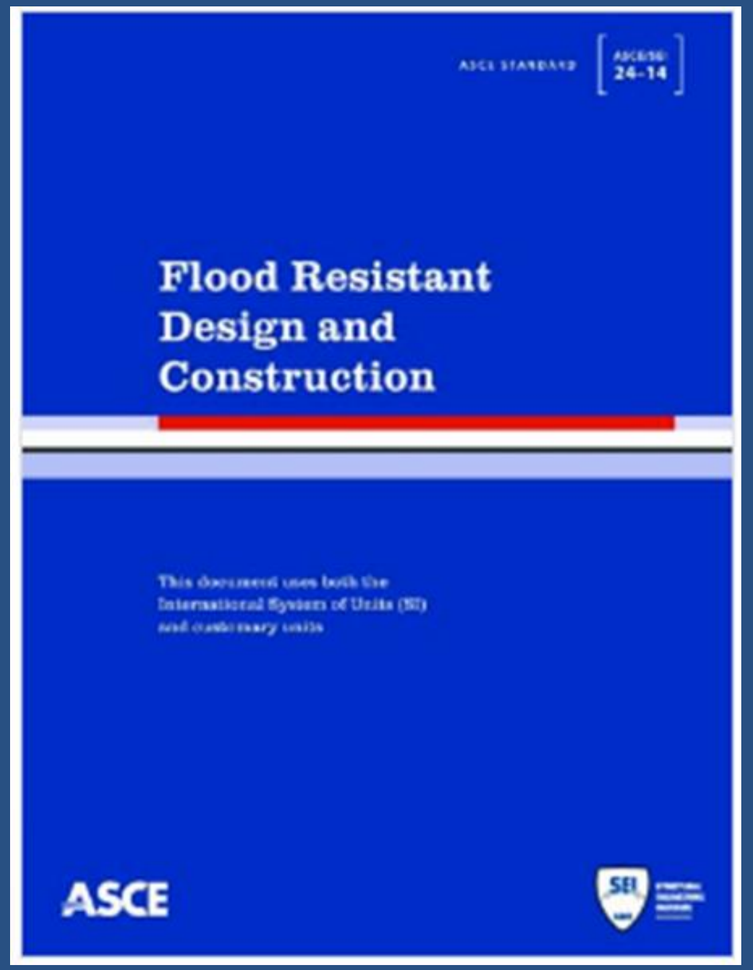
FEMA P-55 Coastal Construction Manual 4th edition (2011)

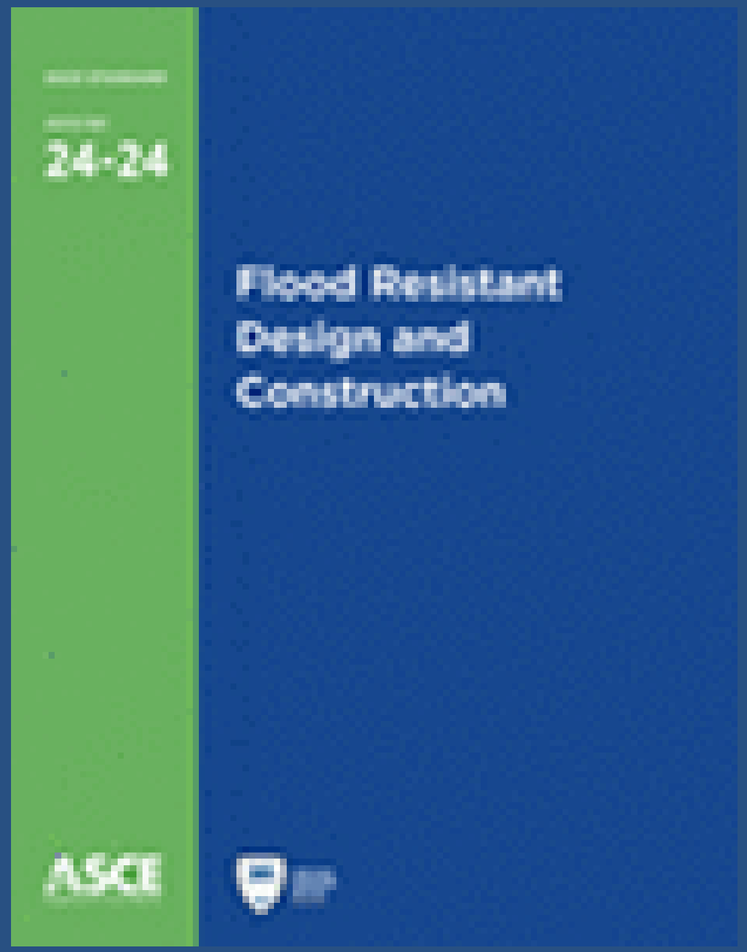
Design Flood Elevation (DFE)



- The regulatory flood elevation established by State authorities & adopted by local jurisdictions
- May equal or exceed NFIP requirements for BFE, cannot be less
- May be higher than the BFE by adding height, called "**freeboard**," to represent **Safety Factor** above the BFE

Flood Resistant Design

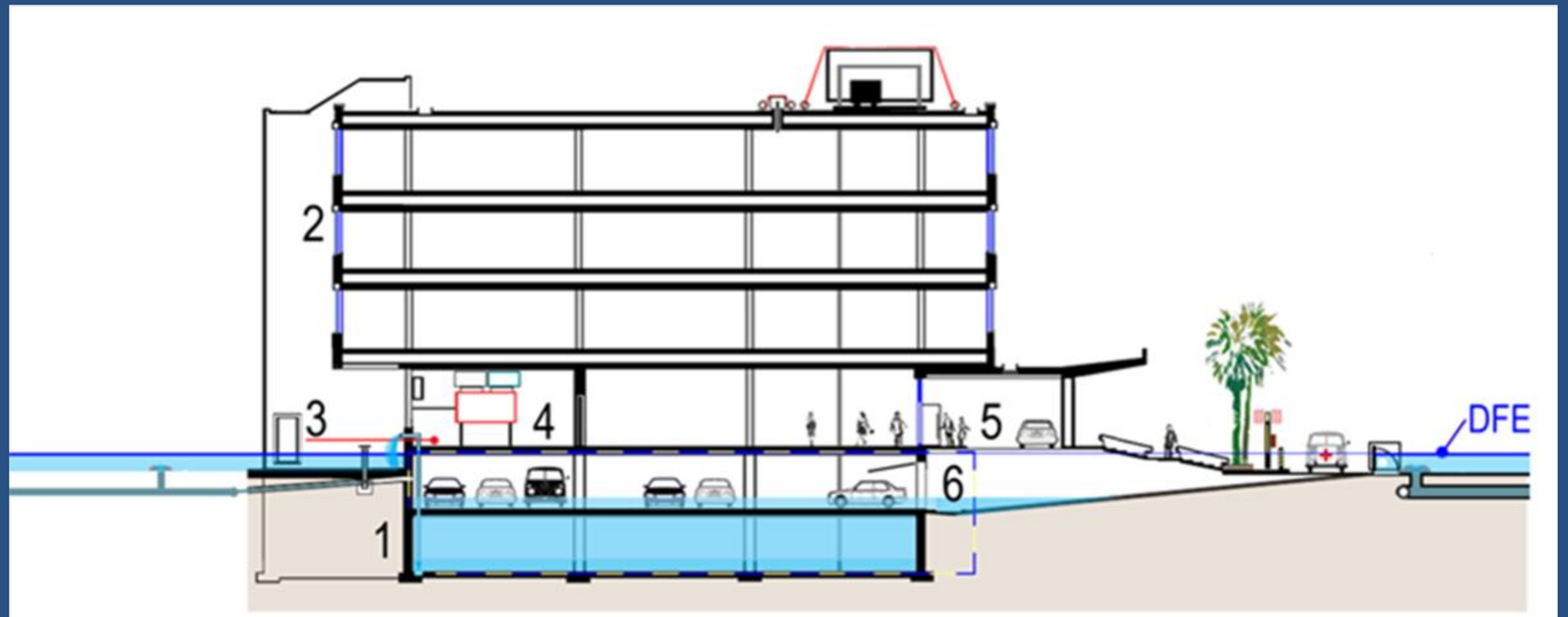




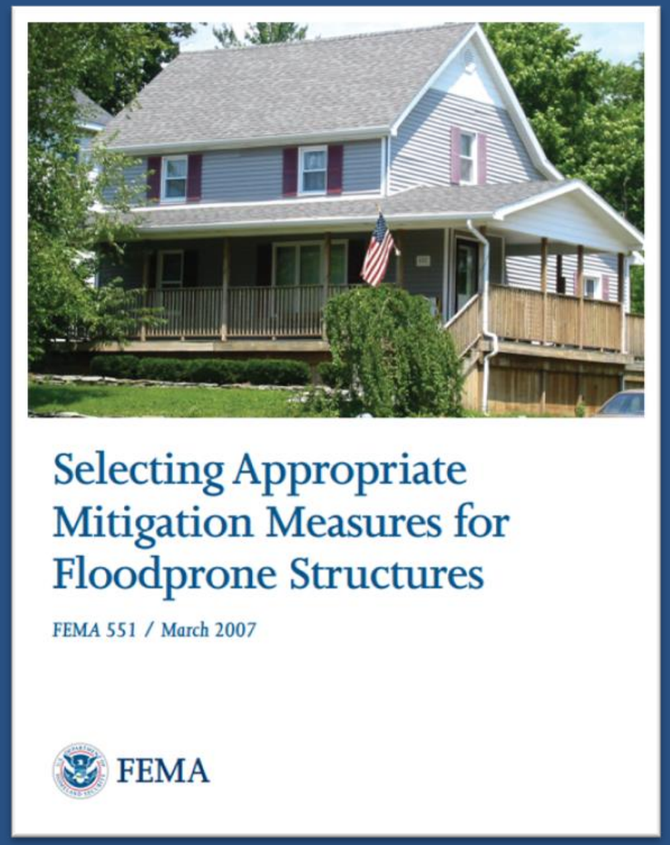
- Old ASCE 24: Flood Resistant Design and Construction
- Published by the America Society of Civil Engineers (ASCE)
- The NFIP and International Building Codes reference ASCE 24 as the standard
- Costs $135.00 on website

https://ascelibrary.org/doi/10.1061/9780784485781#:~:text=Flood%20Resistant%20Design%20and%20Construction%2C%20ASCE%2FSEI%2024%2D24,regulations%20in%20flood%20hazard%20areas.

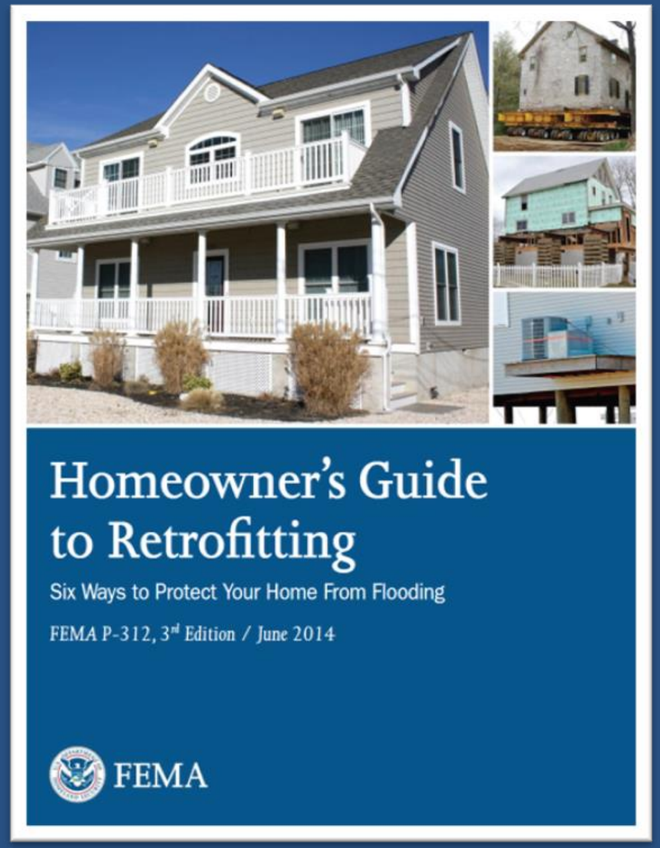
Flood Resistant Design



1 - Foundation is intact
2 - Envelope is impact resistant
3 - Lowest Fl. is above DFE
4 - Utilities are intact & operational
5 - Building is safe and accessible
6 - Breakaway elements (as needed)



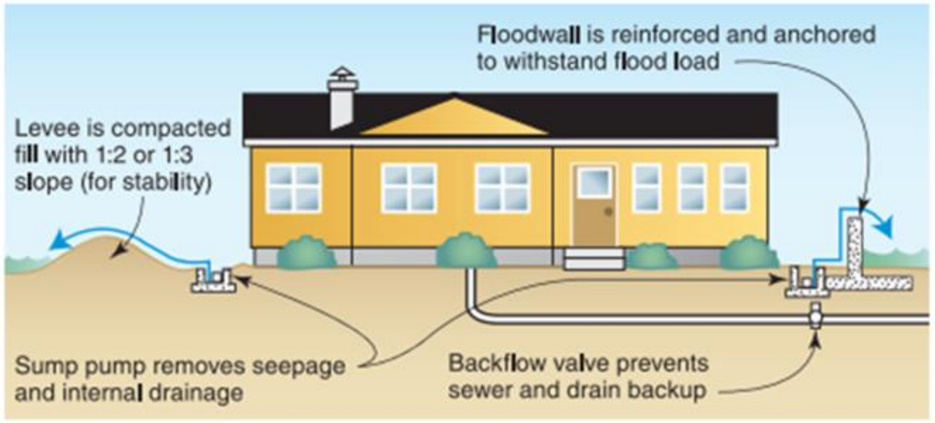
FEMA 551



FEMA P-312

Flood Mitigation
Existing Residential

FEMA 551 Selecting Appropriate Mitigation Measures for Floodprone Structures (2007), FEMA P-312 Homeowner's Guide to Retrofitting (2014)

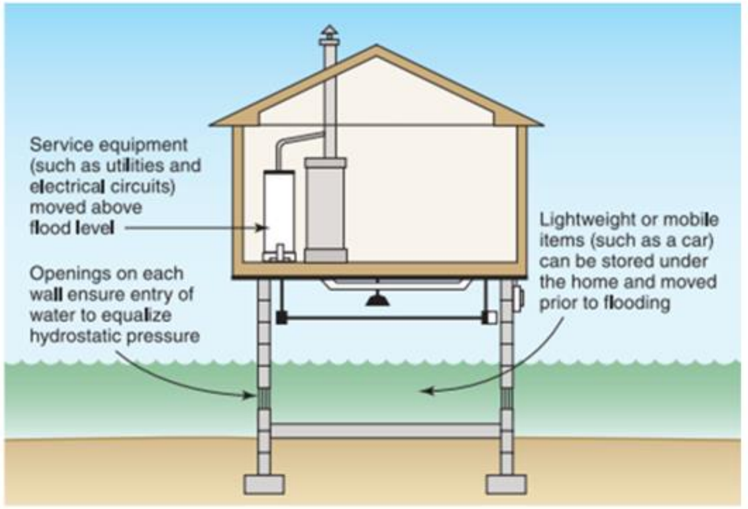


Barrier System

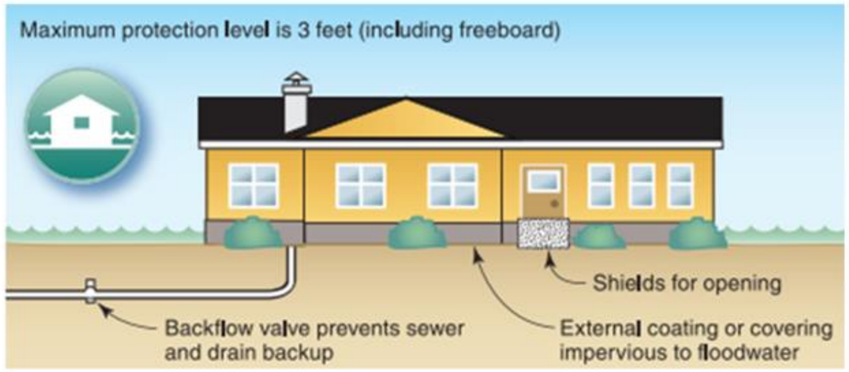
Building a floodwall or levee around the home to restrain floodwaters.

Home Elevation

Raising a home so that the lowest floor or lowest horizontal member is at or above the regulated flood level.



Figures from: FEMA P-312 Homeowner's Guide to Retrofitting (2014)

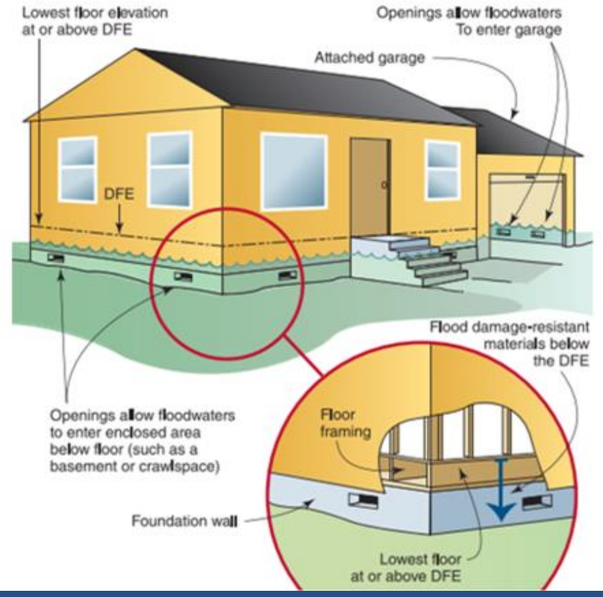


Dry Floodproofing

Sealing the home to prevent floodwaters from entering.

Wet Floodproofing

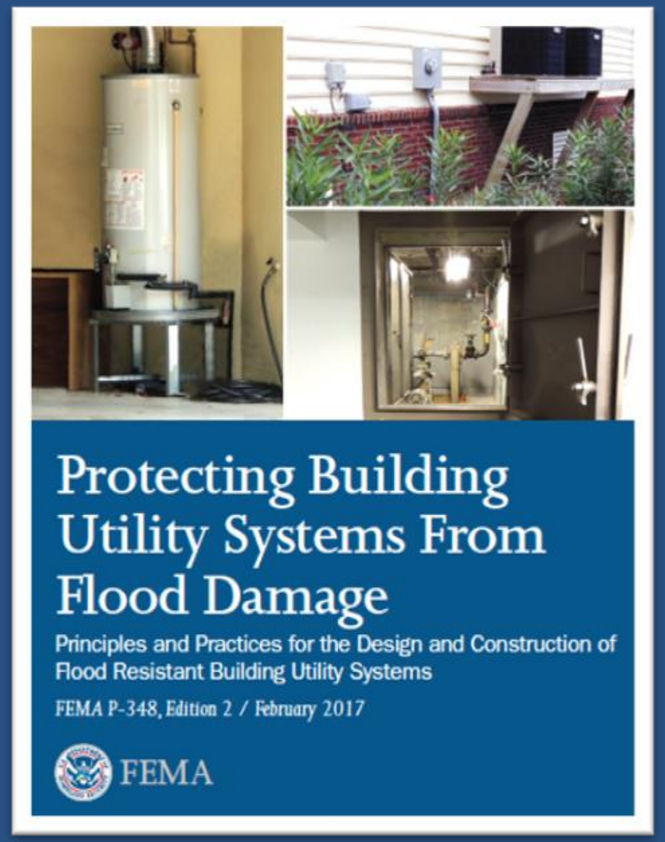
Making portions of the home resistant to flood damage and allowing water to enter during flooding.



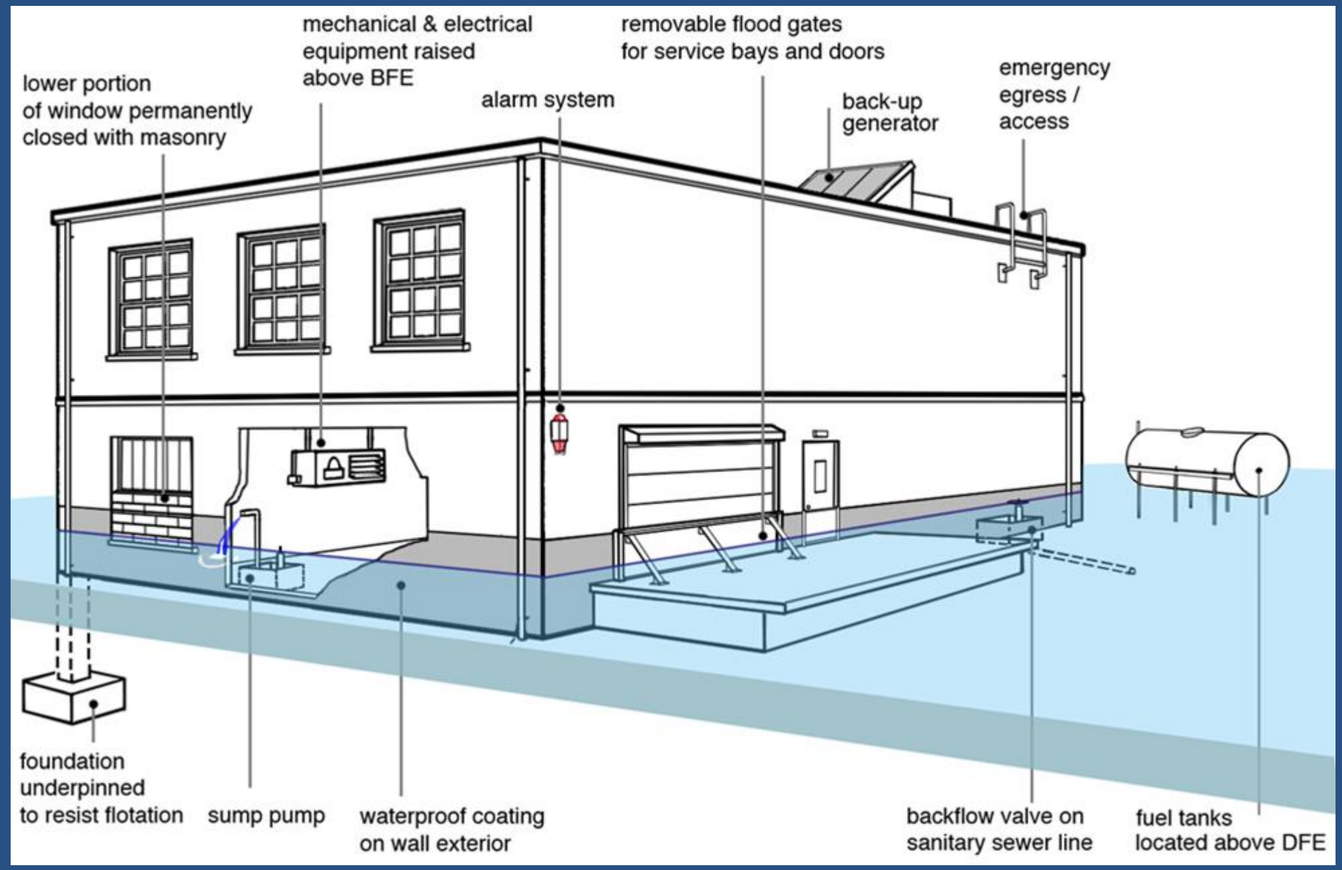
Figures from: FEMA P-312 Homeowner's Guide to Retrofitting (2014)

Flood Mitigation

Existing Commercial



FEMA P-348



FEMA P-348 Protecting Building Utility Systems from Flood Damage (2017)

Case Study: Critical Facilities

Minot Water Treatment Plant

Minot Water Treatment Plant, Minot, ND
Photography per Houston Engineering, Inc

- Installation of a 14-foot floodwall
- Avoids physical damage to potable water treatment facilities and large electrical equipment
- Completed in 2017

FEMA – Hazard Mitigation Assistance Portfolio: Minot Water Treatment Plant Floodwall

Case Study: Historic Structure

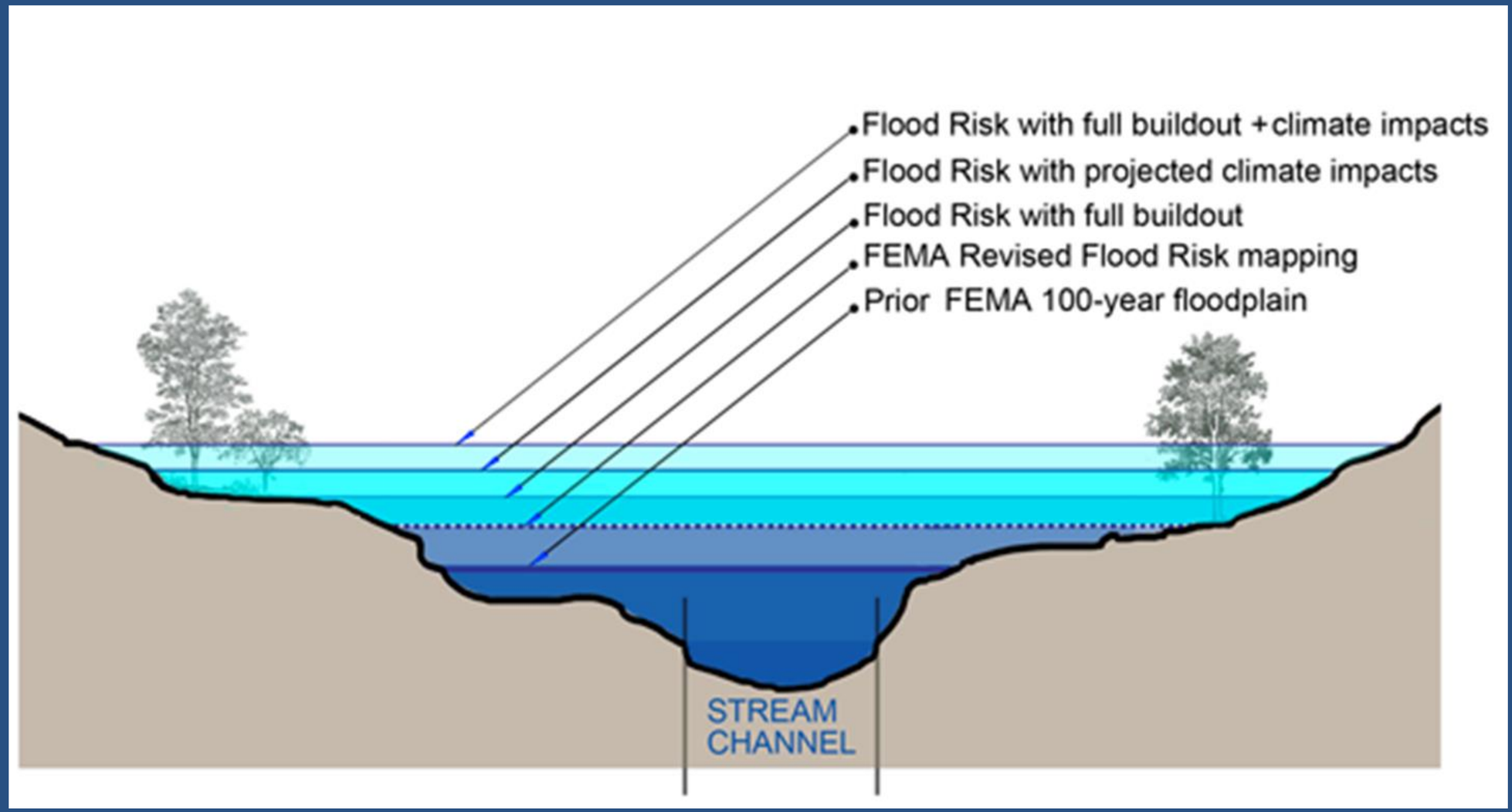
Lanphear's Stable, RI

Photography of Marinas
Watch Hill Harbor

- Lanphear's Stable is a historical livery constructed in 1885
- Pre-mitigation the flood risk level for this property was approximately 8-9 ft above the existing grade
- The building was elevated, the lowest level wet floodproofed, and utilities elevated.
- Through combination of flood mitigation measures the historic character and features were preserved while making the building more resilient.

Guidelines on Flood Adaptation for Rehabilitating Historic Buildings – Case Study 4

Design for Future Conditions



Christopher P. Jones (2009) Flood Resistance of the Building Envelope National Institute of Building Sciences
http://www.wbdg.org/resources/env_flood.php/

Nature-Based Solutions

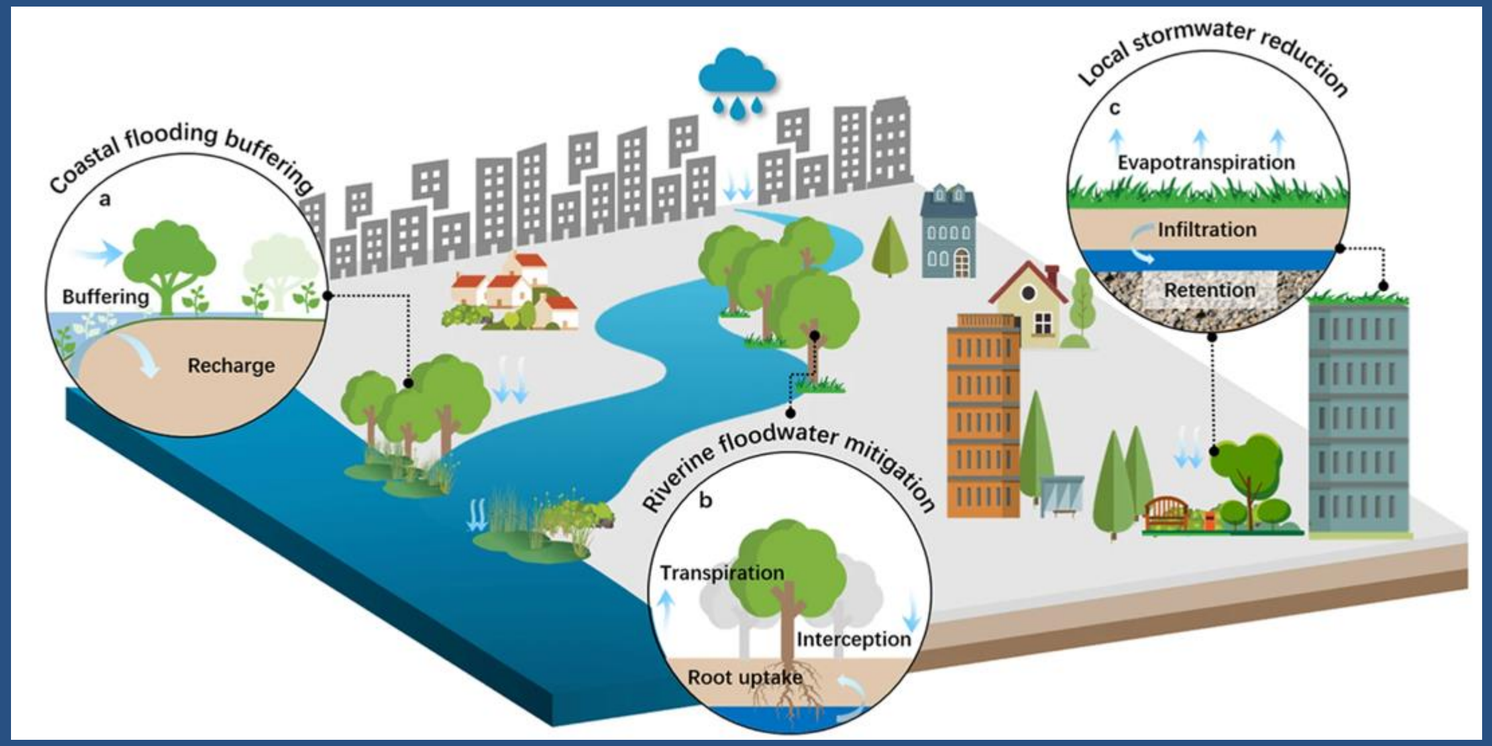
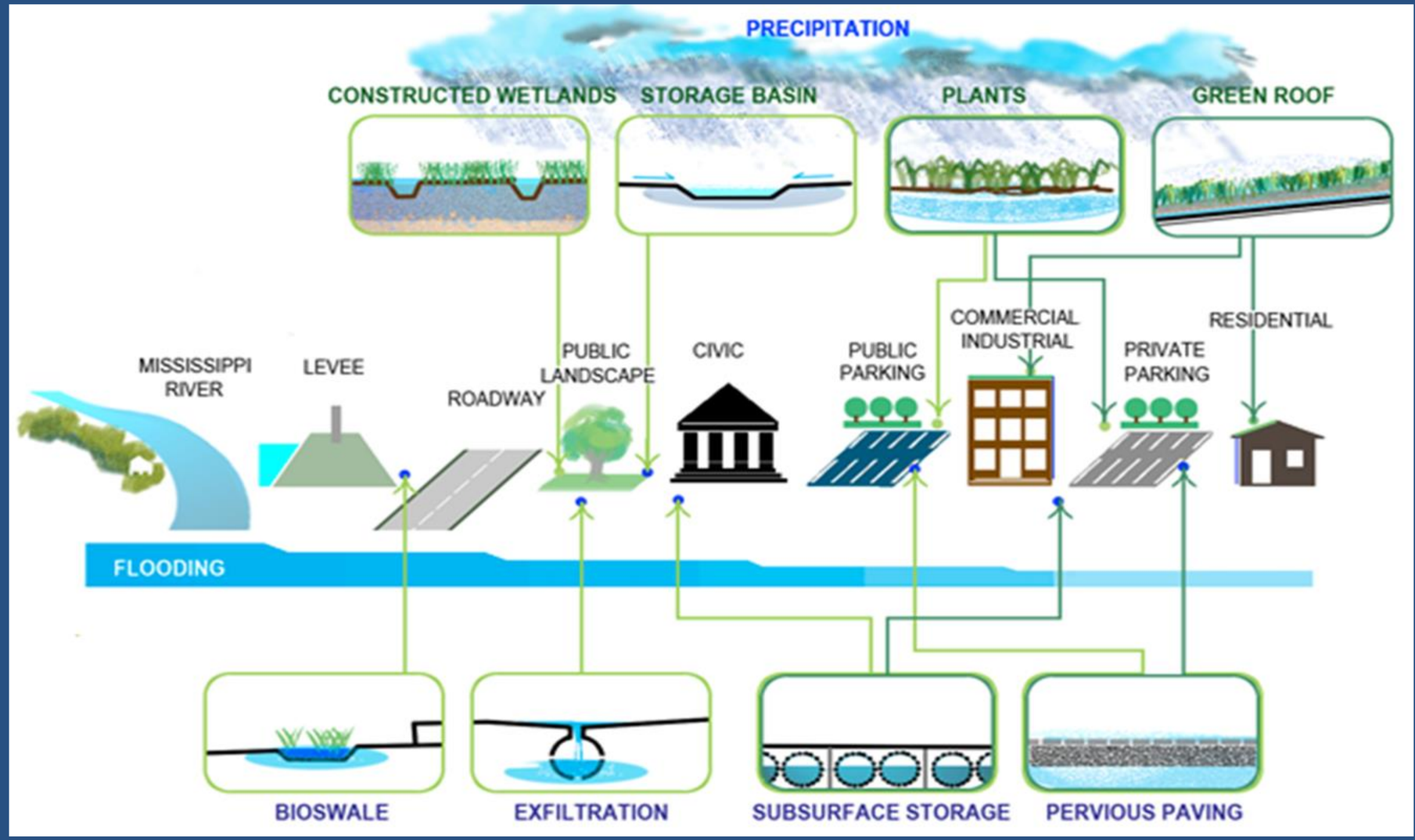


Figure from: Zhou, K., Kong, F., Yin, H. et al. Urban flood risk management needs nature-based solutions: a coupled social-ecological system perspective. npj Urban Sustain 4, 25 (2024).

Sustainable planning, design, environmental management, and engineering practices that weave natural features or processes into the built environment to build more resilient communities

FEMA – Building Community Resilience With Nature-Based Solutions (2021)

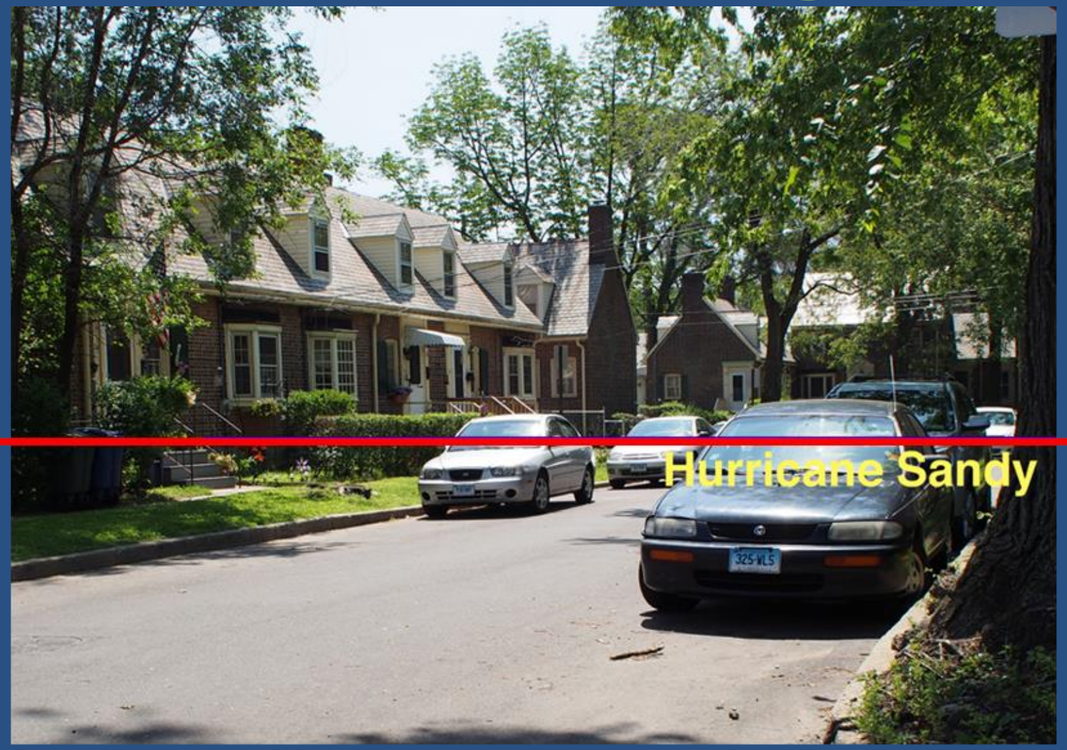
Living with Water: New Orleans



Waggonner & Ball, Greater New Orleans Urban Water Plan: Greater New Orleans Regional Economic Development. *http://livingwithwater.com*

Case Study

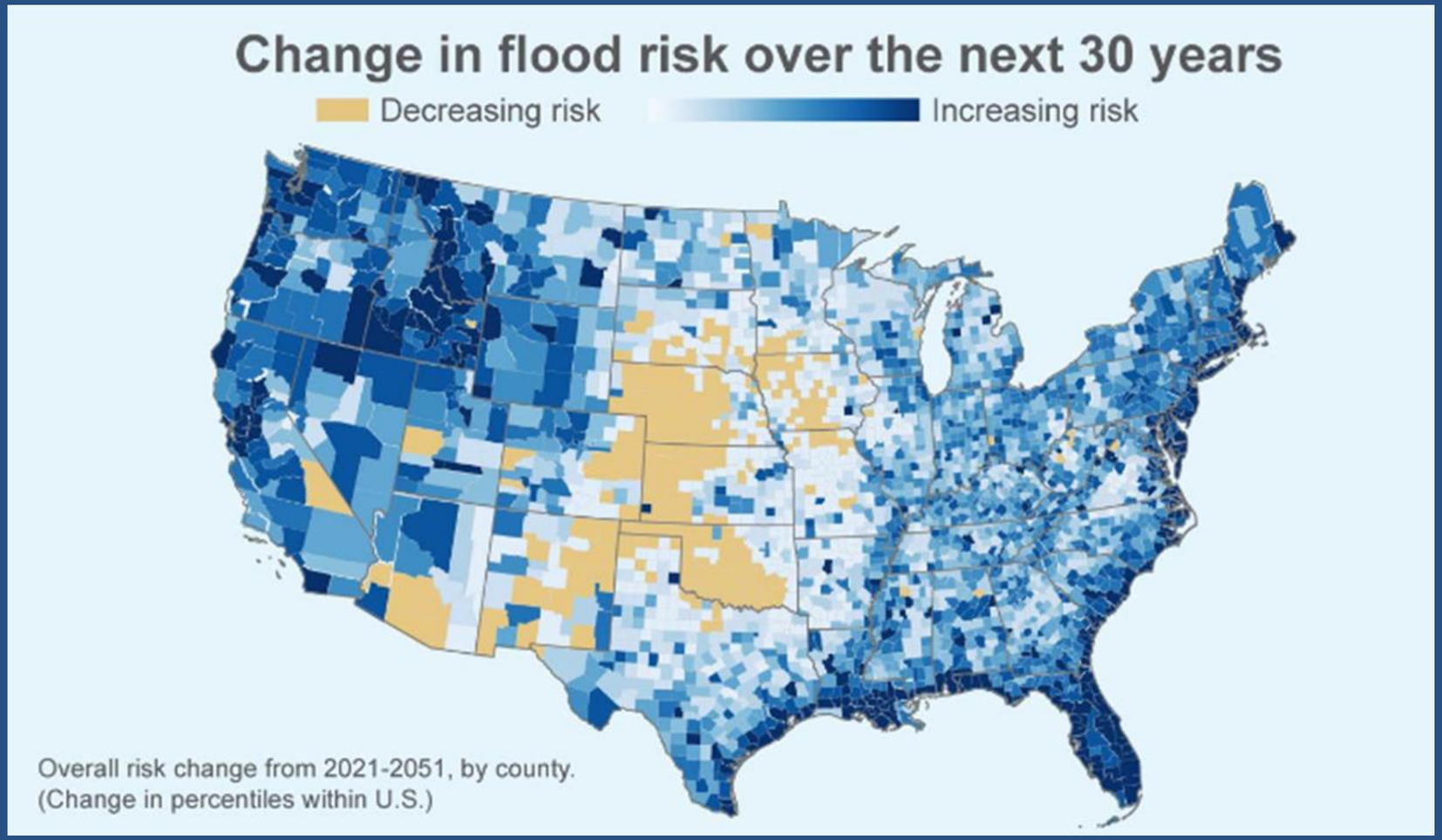
Resilient Bridgeport



Seaside Village, Bridgeport CT

US HUD Rebuild By Design Resilient Bridgeport Waggonner & Ball Architects
http://resilientbridgeport.com

Future Flood Risk



First Street Foundation, The 3rd National Risk Assessment (2021)

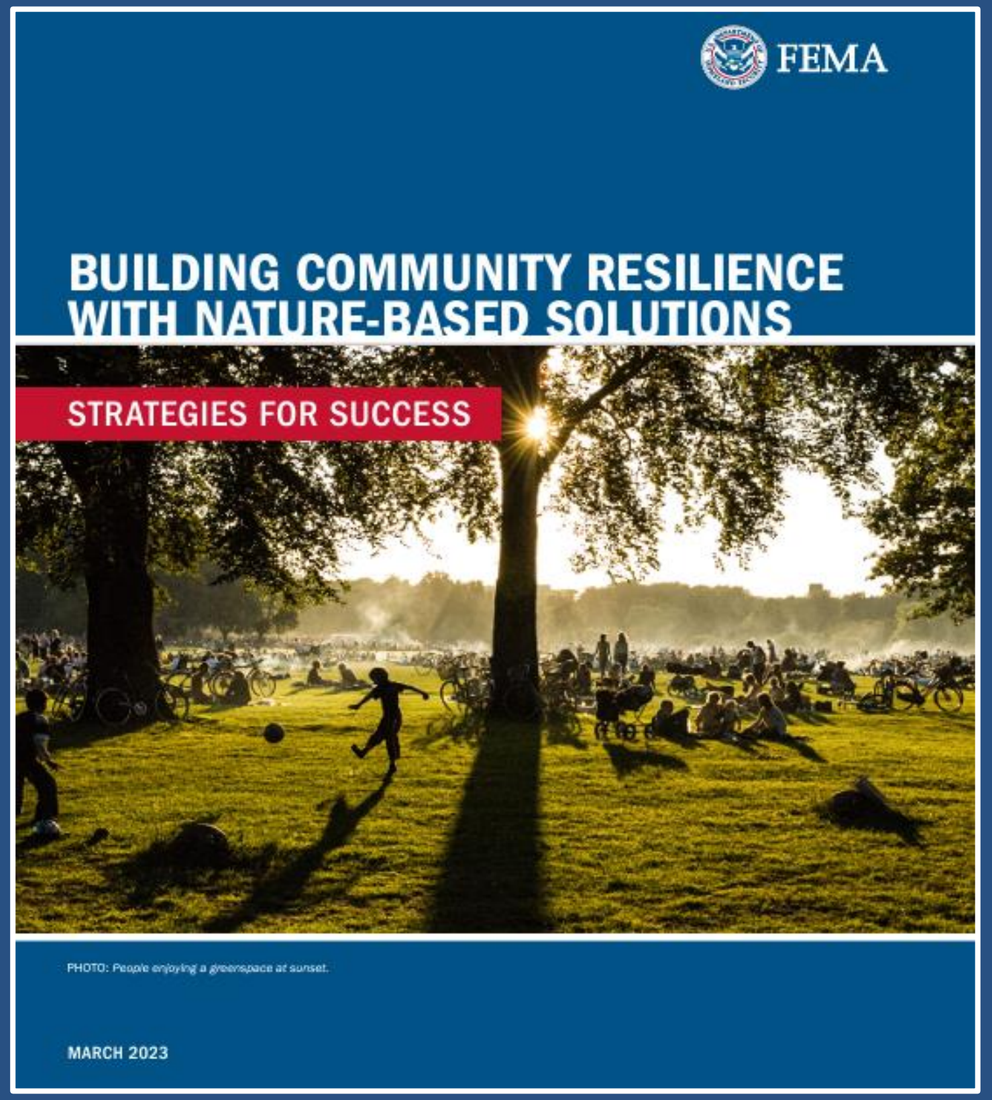
NHMA

RESOURCES

ASFPM - No Adverse Impact Guides

ASFPM (2009) No Adverse Impact How-To Guides Association of State Flood Plain Managers
/www.floods.org/NoAdverseImpact/NAI_White_Paper.pdf

NHMA



Building Community Resilience With Nature-Based Solutions: Strategies for Success

Building Community Resilience with Nature-Based Solutions: Strategies for Success

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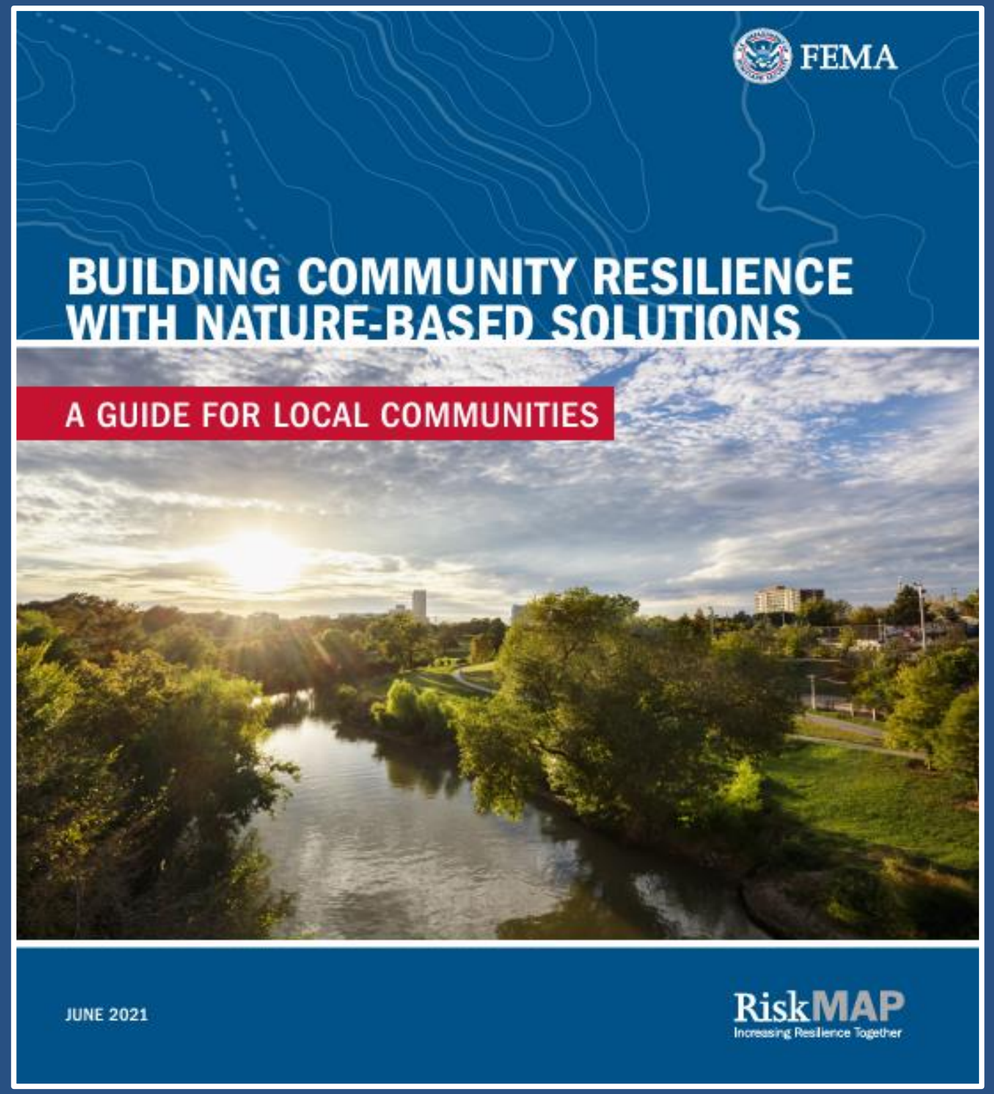
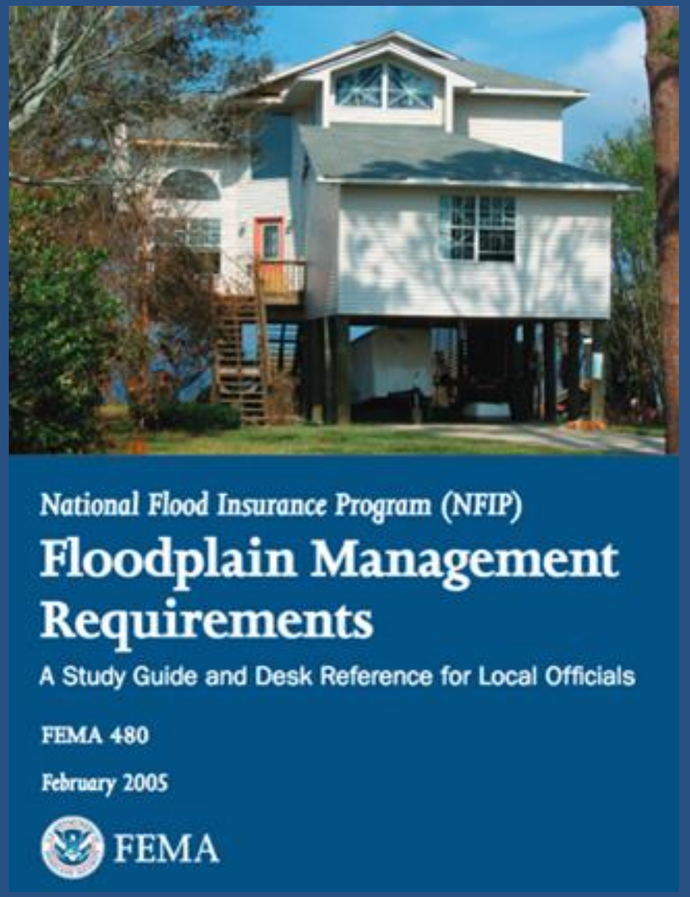


Building Community Resilience With Nature-Based Solutions: A Guide for Local Communities

Building Community Resilience with Nature-Based Solutions: A Guide for Local Communities

FEMA 480 Floodplain Management



FEMA 480 Unit O, p. O-3

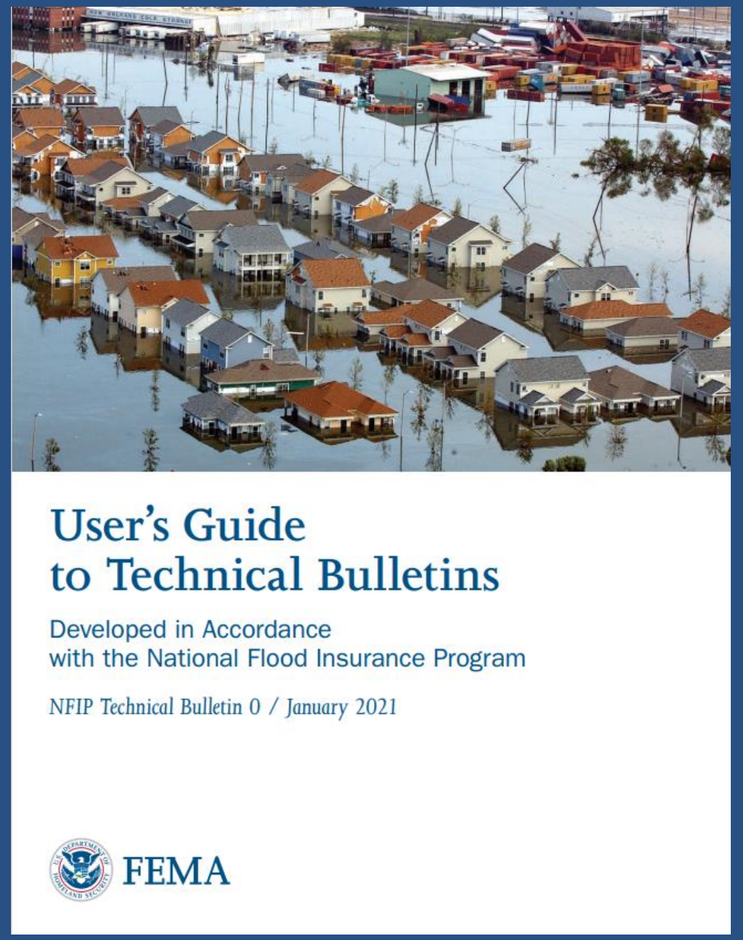
A. Introduction

The responsibility for reducing flood losses is shared by all units of government—local, state and federal—and the private sector.

Fulfilling this responsibility depends on having the knowledge and skills to plan and implement needed floodplain management measures. The fundamental floodplain management program that most others are built on is the National Flood Insurance Program (NFIP).

https://www.fema.gov/sites/default/files/documents/fema-480_floodplain-management-study-guide_local-officials.pdf

FEMA Technical Bulletins



Representative titles

1. User's Guide to Technical Bulletins
2. Openings in Walls of Enclosures
3. Flood Damage-Resistant Materials
4. Non-Residential Floodproofing
5. Elevator Installation
6. Free-of-Obstruction Requirements

https://www.fema.gov/emergency-managers/risk-management/building-science/national-flood-insurance-technical-bulletins

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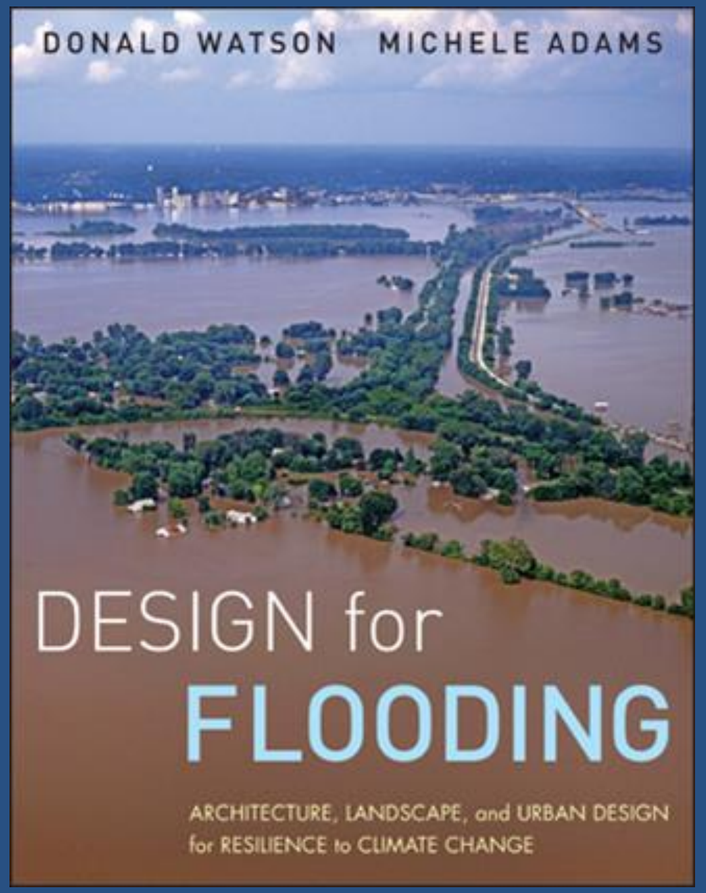
Design For Flooding



Donald Watson, FAIA

EarthRise *design*

Earthrise001@SBCglobal.net

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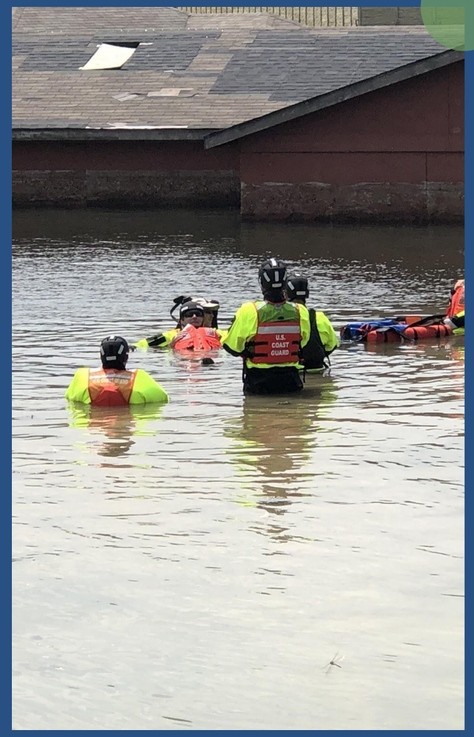

Learning Objectives Review

1. Identify the **risks** associated with different types of flooding
2. Explain the advantages of **watershed management based on future conditions**
3. Describe f**lood resistant design measures** for buildings and infrastructure

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Q&A

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THANK YOU