

# Outline

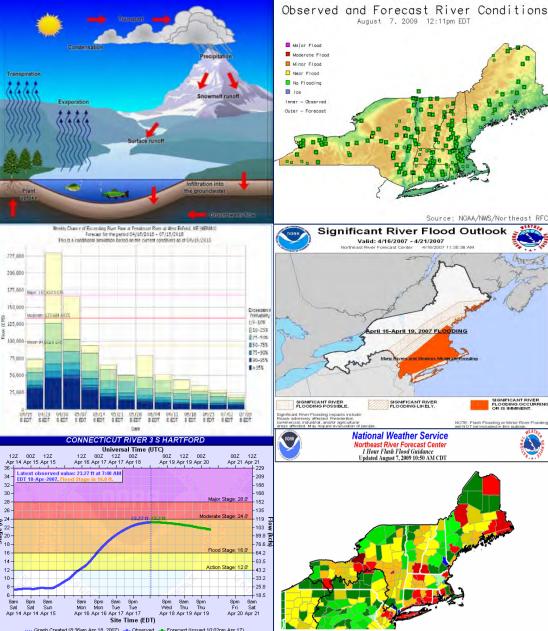
- An overview of our changing climate
  - Rainfall/Temperature trends
  - Changes in flood & drought behavior
  - Increasing Coastal Flood Risk
- The challenges before us
- A look at a few best practices to stem the tide of flooding

# River Forecast Center Responsibilities

Calibrate and implement a variety of hydrologic and hydraulic models to provide:

- River flow and stage forecasts at 180 locations
- Guidance on the rainfall needed to produce Flash Flooding
- Ensemble streamflow predictions
- Ice Jam and Dam Break support
- Water Supply forecasts
- Partner with NOAA Line Offices to address issues relating to Hazard Resiliency, Water Resource Services, Ecosystem Health and Management, and Climate Change





**DV2** David

David Vallee, 2/19/2019

# We have been a little busy these past 12 years! Job Security in the face of changing flood behavior!!



Record Flash Flooding from 5-7 inches of rain. Westport, Connecticut, September 25<sup>th</sup>, 2018.



St-Jean-sur-Richelieu, Quebec, Canada, 5/6/11 Photo: AP//Canadian Press, R. Remoirz



Providence Street - Warwick, RI at 1030 am Wednesday 3/31/10

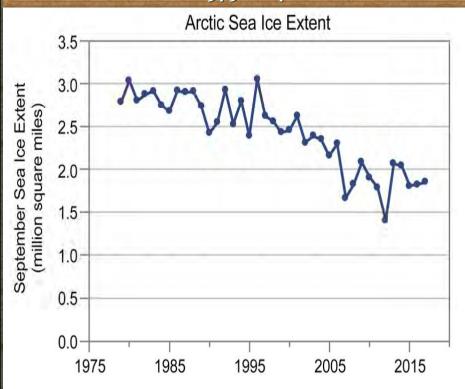


Home washed off its foundation along the Schoharie Creek, Prattsville, NY – Tropical Storm

### The latest Science:

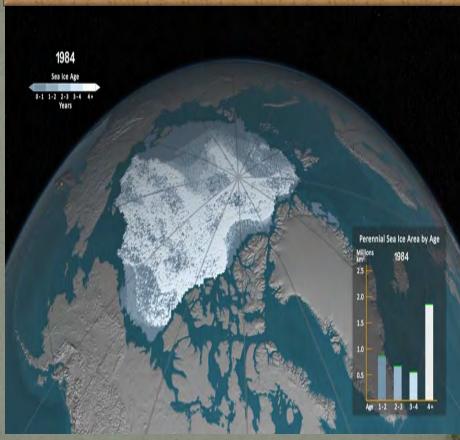
# A warming planet and shrinking Arctic Sea ice

September Minimum Sea Ice Cover 1979-2017



This graph shows the average area covered by sea ice during September each year. Minimum sea ice extent has decreased 12% per decade since 1979. Reference: Fourth National Climate Assessment <a href="https://nca2018.globalchange.gov/chapter/1/#fig-1-2">https://nca2018.globalchange.gov/chapter/1/#fig-1-2</a>

2016 Arctic Sea Ice Summer Minimum

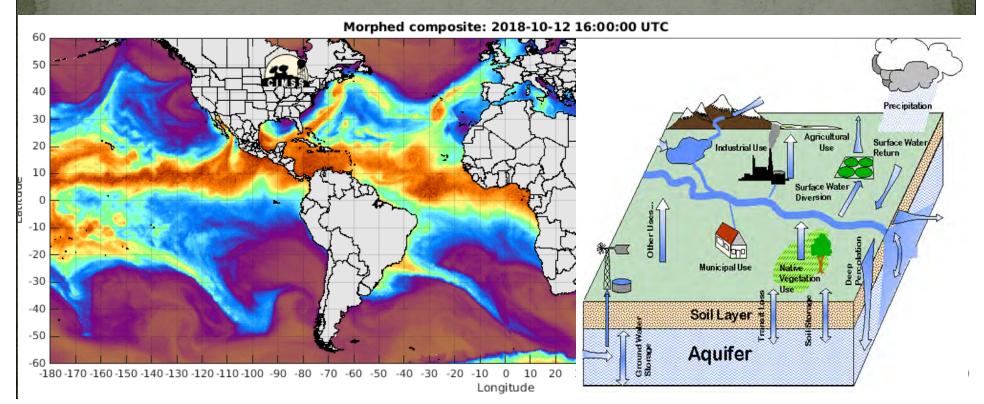


Loop of September Summer Minimum Ice Extent from 1984 through 2016. Note the steady decrease in coverage. Reference: Fourth National Climate Assessment.

https://nca2018.globalchange.gov/chapter/2/#keymessage-7

# Is there a common theme to recent floods?

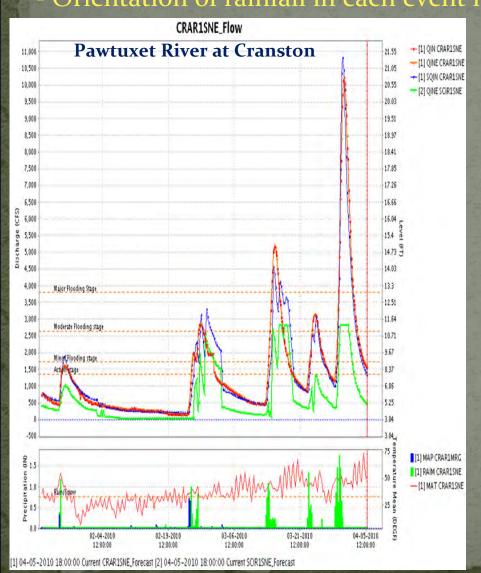
- Several:
  - Slow moving weather systems a blocked up atmosphere
    - Related to loss of artic ice cover
    - Multiple events in close succession or one big slow moving storm
  - Results in saturated antecedent conditions before "main event"

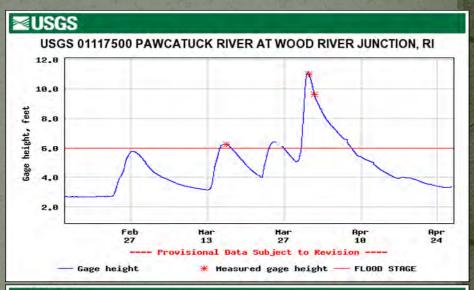


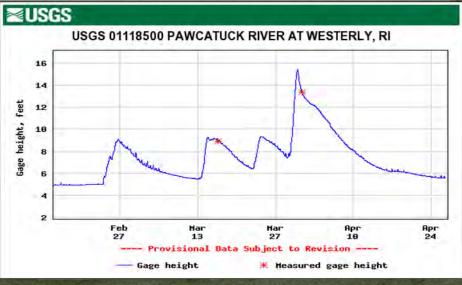
# So what brought us to the tipping point in 2010?

- A wet fall & early winter

- Sequence of 4 big rain events in 5 weeks: "Persistent Jetstream Pattern"
- Orientation of rainfall in each event hit the Pawtuxet and Pawcatuck Basins

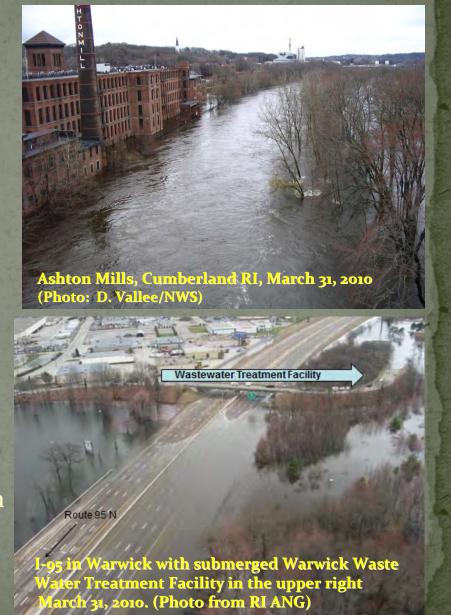






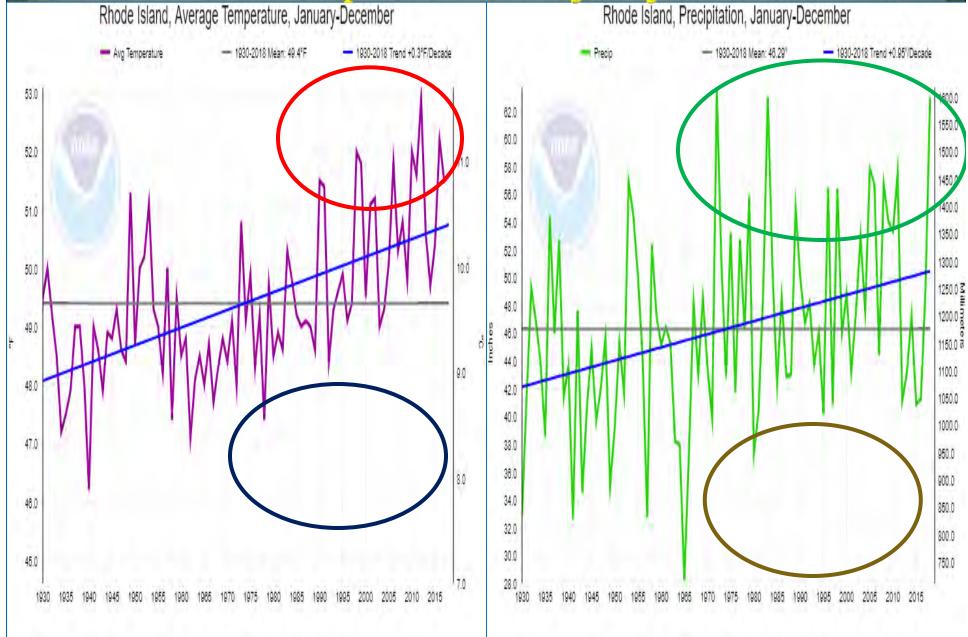
# The Changing Climate

- Common themes across New England:
  - Increasing annual precipitation
  - Increasing frequency of heavy rains
  - Warming annual temperatures
  - Wildly varying seasonal snowfall
- Shift in precipitation frequency (50, 100 yr 24 hr rain)
- For smaller (<800 sq mi) basins trend toward increased flood magnitude and/or frequency
  - Most pronounced where significant land use change and/or urbanization has occurred



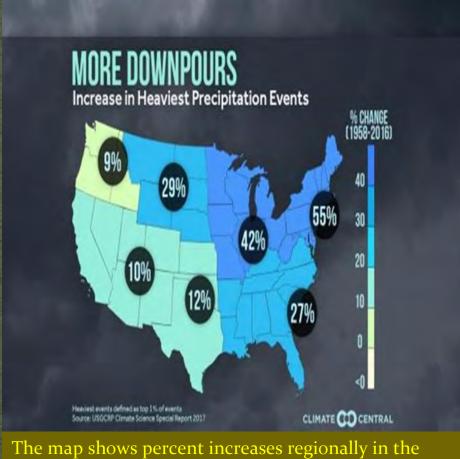
### A Look at Temperature and Precipitation Trends

http://www.ncdc.noaa.gov/cag 2018: 3rd wettest year!



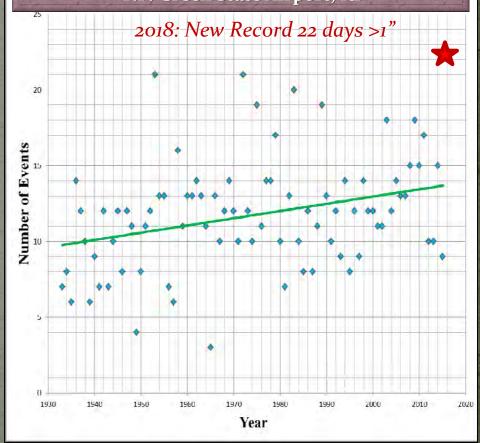
# Change in frequency of Heavy Precipitation • Intense precipitation events (the heaviest 1%)

- RI used to average 8 days a year of >1" of rain or more
- Today we are averaging nearly 15 days!



amount of precipitation falling in very heavy events (defined as the top 1% of all daily events) from 1958 to 2016.

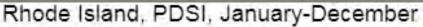


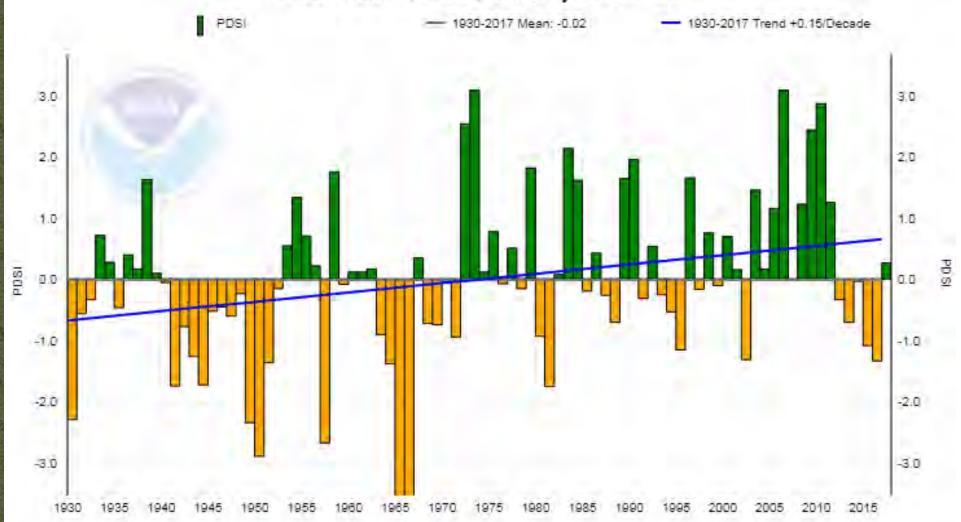


Source: N. Strauss, NERFC

# Changes in the Palmer Drought Index

http://www.ncdc.noaa.gov/cag





Since the late 60s, similar signature of much shorter, less intense dry periods and longer higher amplitude wet periods

# Trends in Flood Frequency:

From the Practitioner's perspective

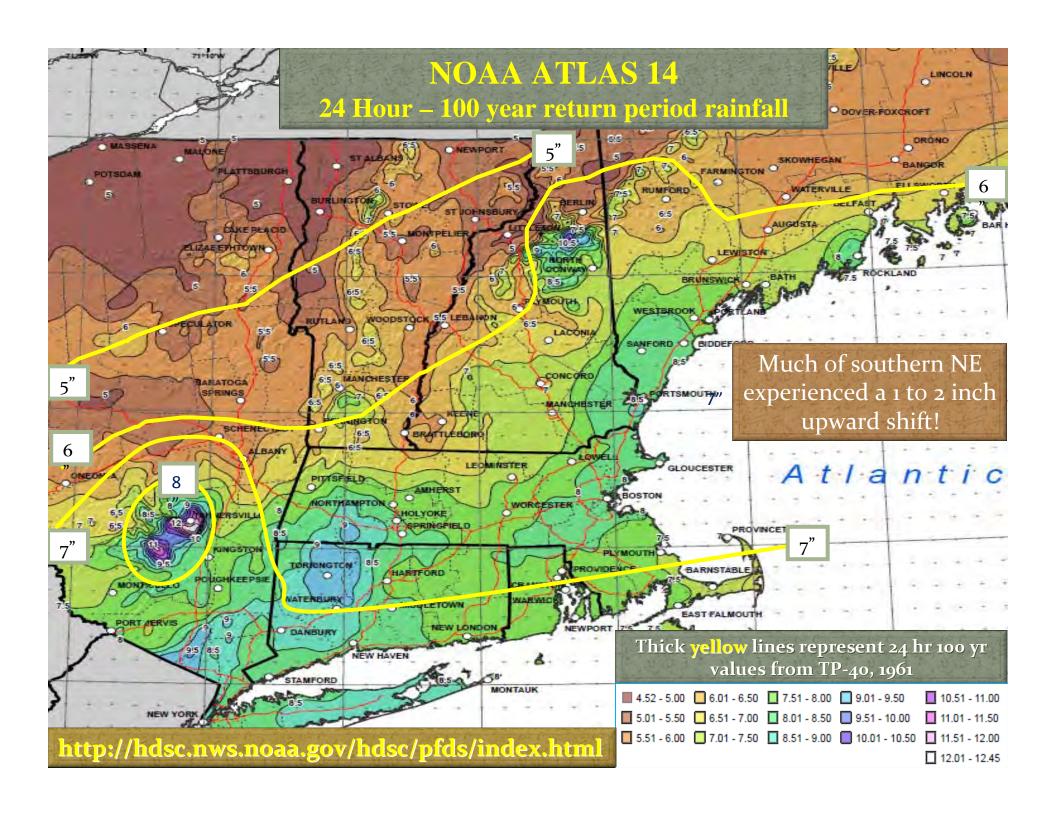
- Small watersheds feeling the effects
  - Changes in frequency/magnitude
  - Part land use/urbanization
    - Compounded by encroachment in the floodplain
  - Part changing climate
- Larger basins with flood control haven't seen as noticeable a shift
  - Most USACE reservoirs are built for 6-8 inch runoff events
  - Greater capacity to handle more rain
- Urban "flash floods" increasing
  - Storm water systems cannot handle the volume of intense rainfall



Scituate Reservoir at it's peak discharge March 31, 2010



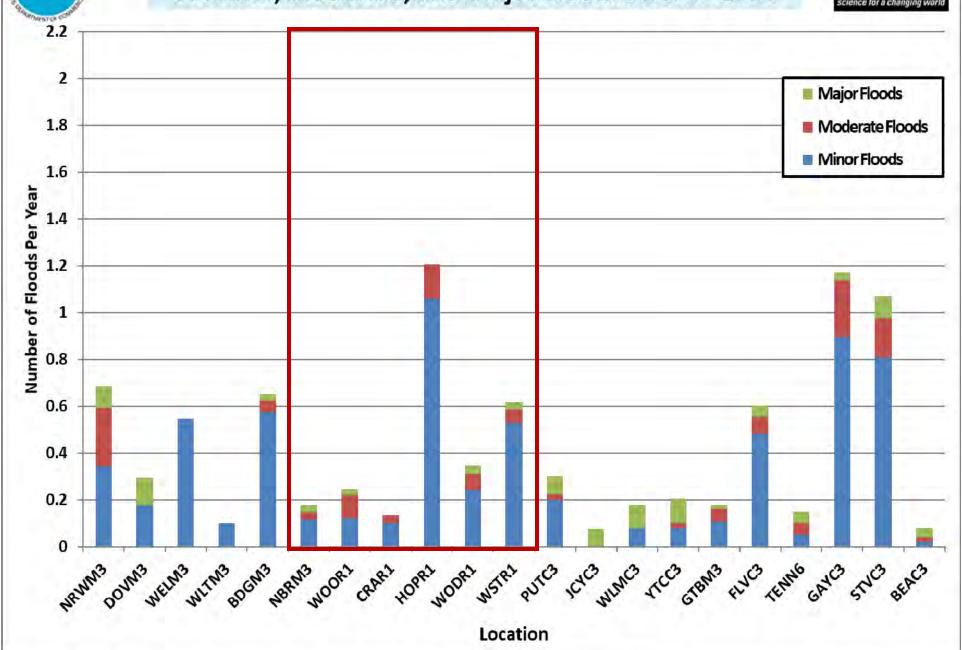
Kenyon Industries, Pawcatuck River, March 31, 2010. Photo: C. Fox





# Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods Prior to 1970

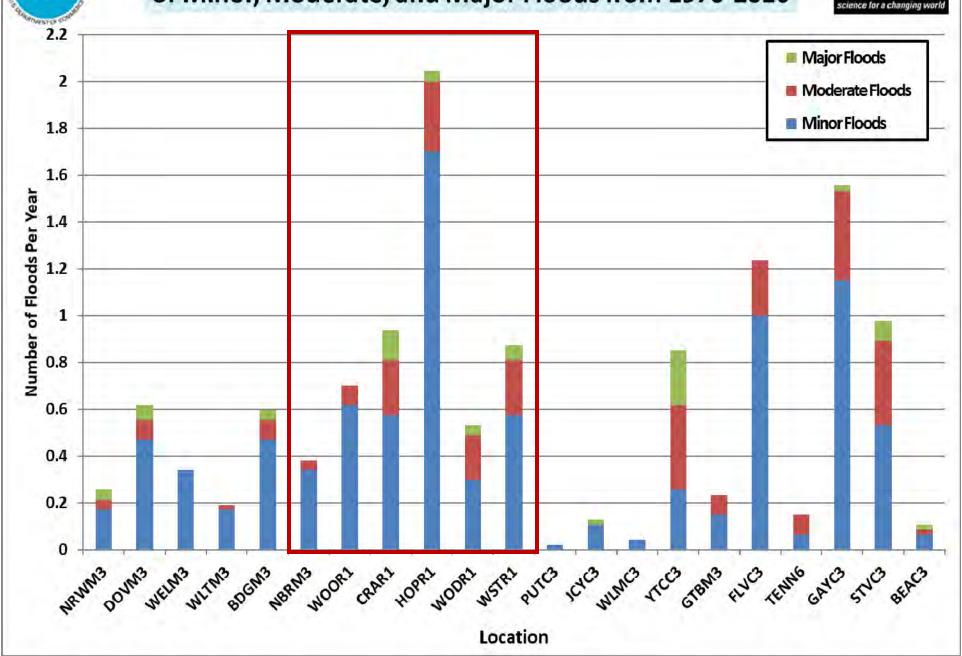


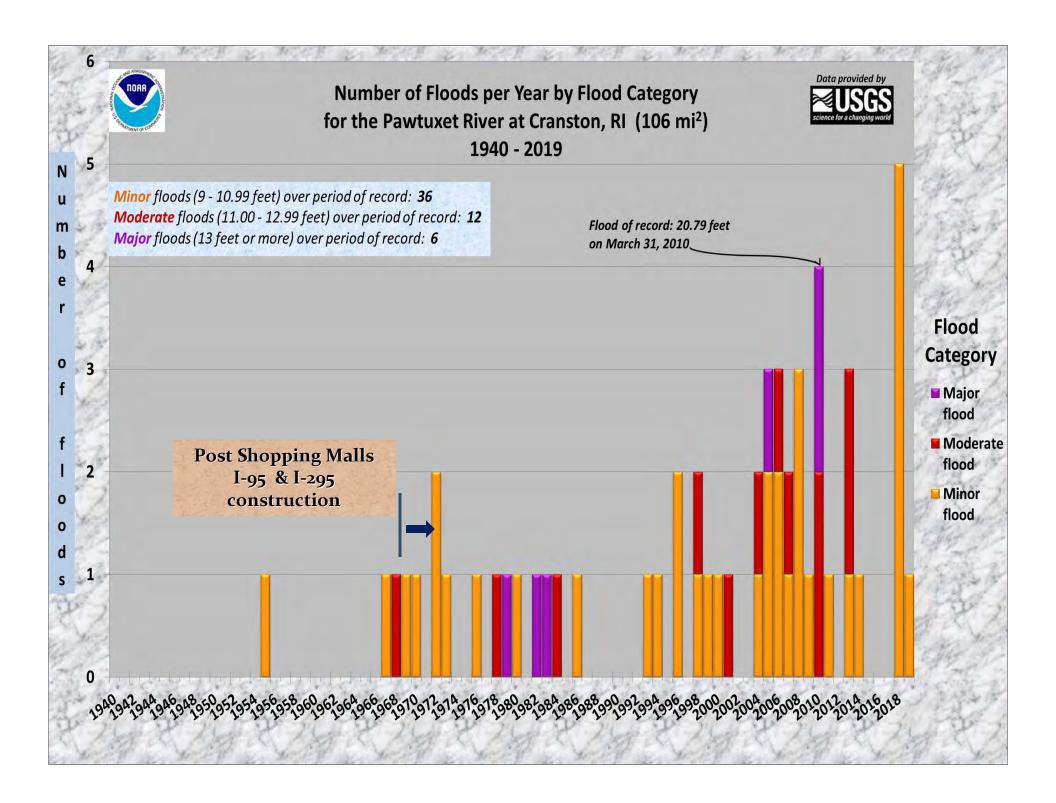




# Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods from 1970-2016



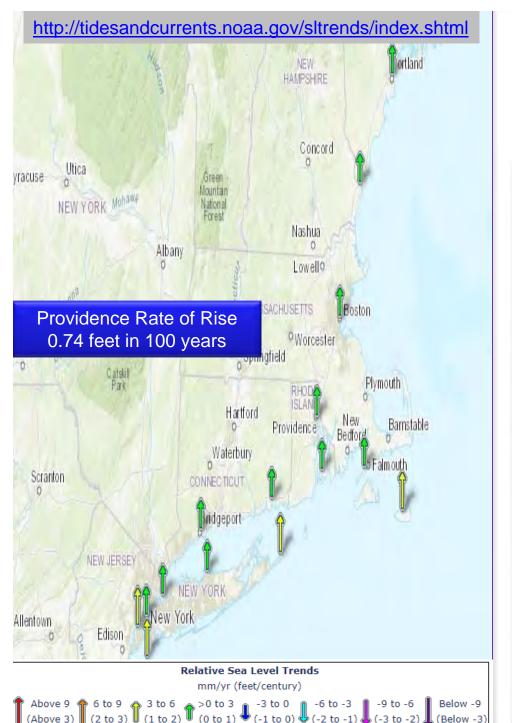






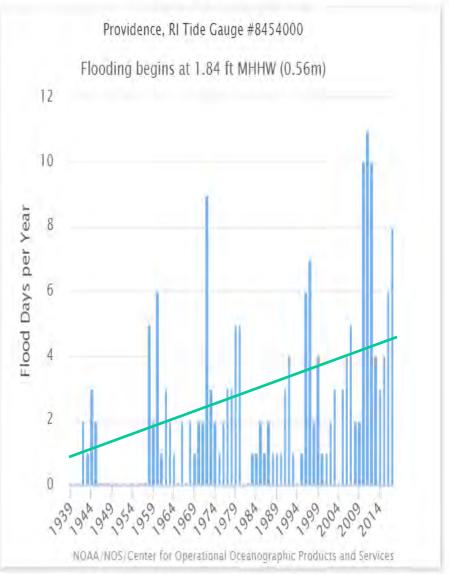
# Lets move to the coast: Sea Level Rise Increasing high tide flood events





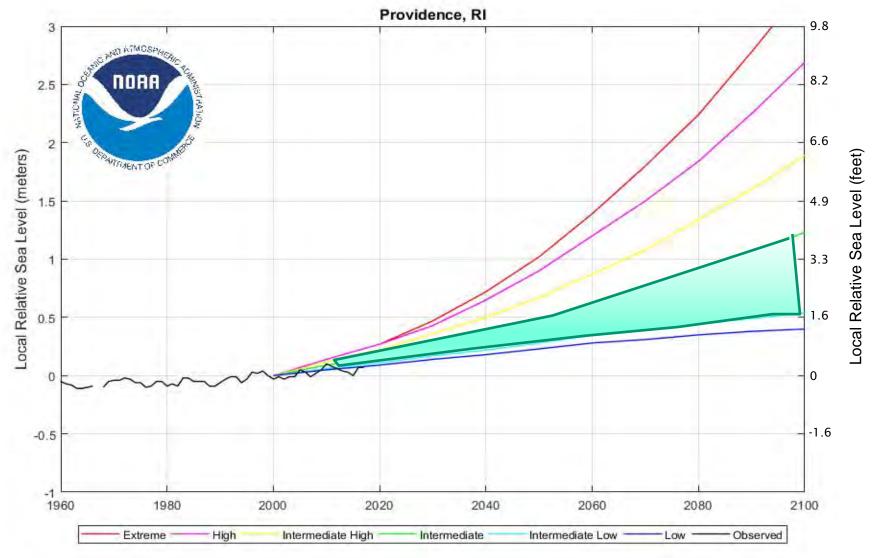
# **High Tide Flooding**

Historical Yearly Inundation Events



### Annual Mean Relative Sea Level since 1960

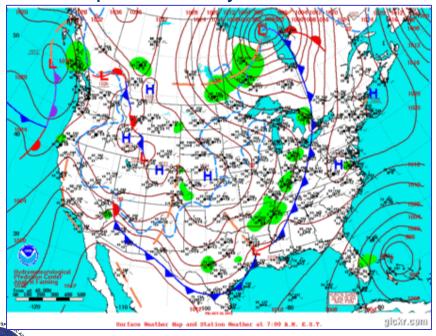
### with various regional emissions scenarios

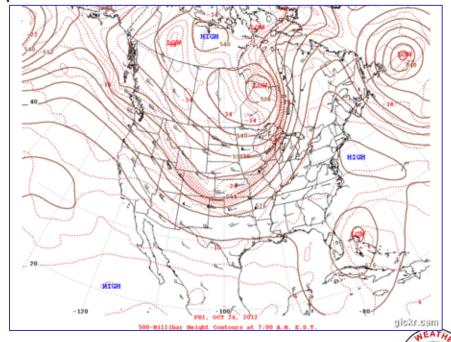


https://tidesandcurrents.noaa.gov/sltrends/sltrends\_station.shtml?plot=scenario&id=8454000

# **Sandy: A Perfect Storm of Sorts**

- ☐ Formed in the western Caribbean
  - o Not at all unusual for late October
- □ Encountered a very deep trough of Low Pressure in the eastern United States and very strong High Pressure moving southward from the Canadian Maritimes
  - o A winter-type dual jet stream set up (classic for a New England Hurricane)
  - o Captured Sandy & blocked her attempt to race out to sea

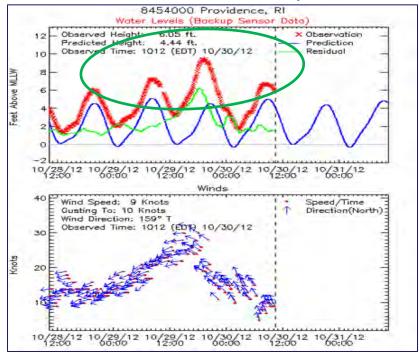




### **Long Duration Southeast Fetch**

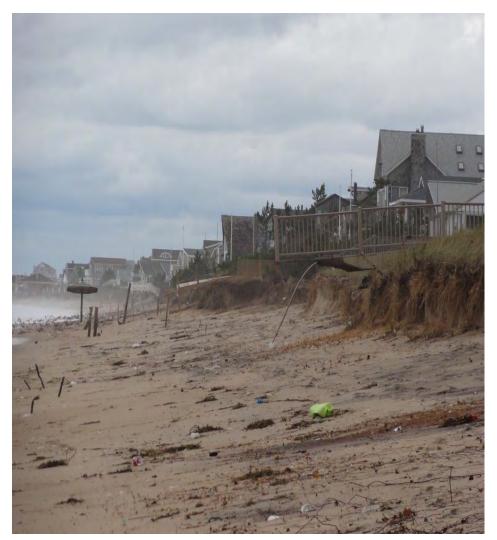
### Damaging Waves, Multiple Tide Cycles & a 4-5 ft Storm Surge

- ☐ Southeast swells built on 2 days of southeast winds were driven right into the south coast of RI
  - o Impacted Multiple Tide Cycles worst of which was Monday night
  - o 15-30 foot seas resulted in relentless pounding surf which first weakened then obliterated the 6-10 foot dunes along parts of the coast
  - o Storm surge of 4-5 feet atop a "middle-of-the-road" astronomical tide produce a total water level (storm tide) of 9.6 feet; One foot shy of Hurricane Bob in '91
  - o What she lacked in intensity she made up for in duration!





# Varying flavors of erosion and dune overtopping



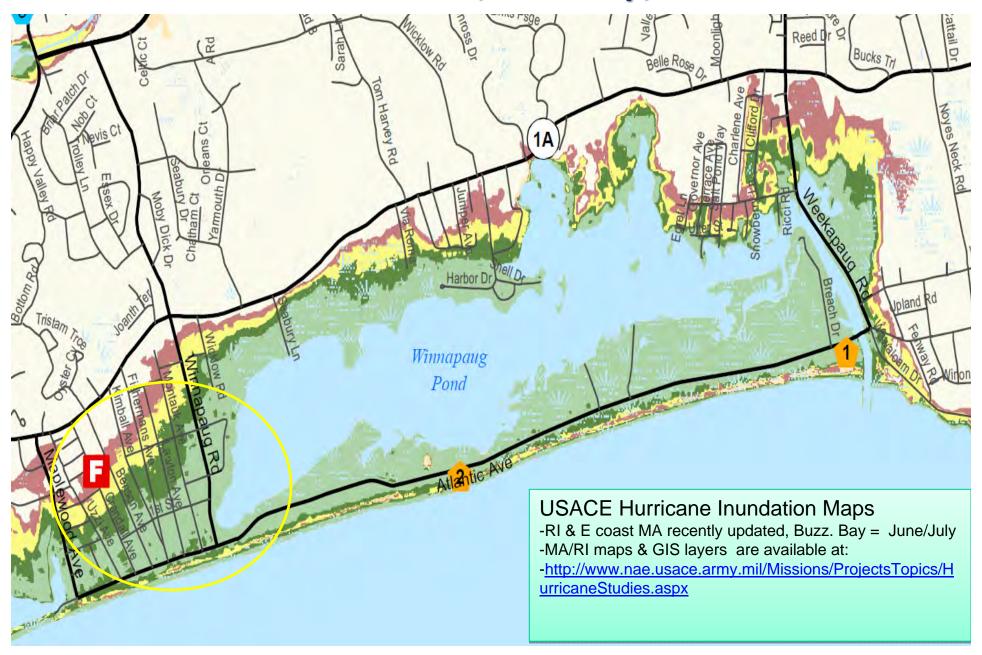


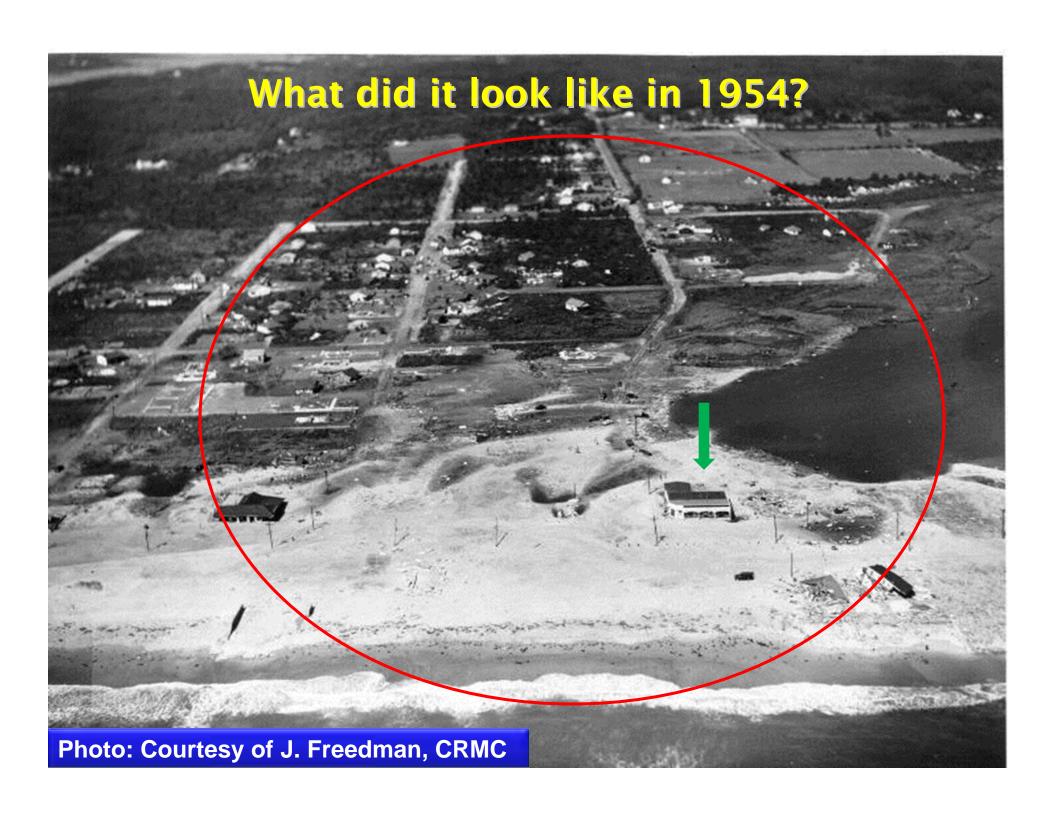
Damage along Atlantic Avenue, Westerly, RI following Hurricane Sandy



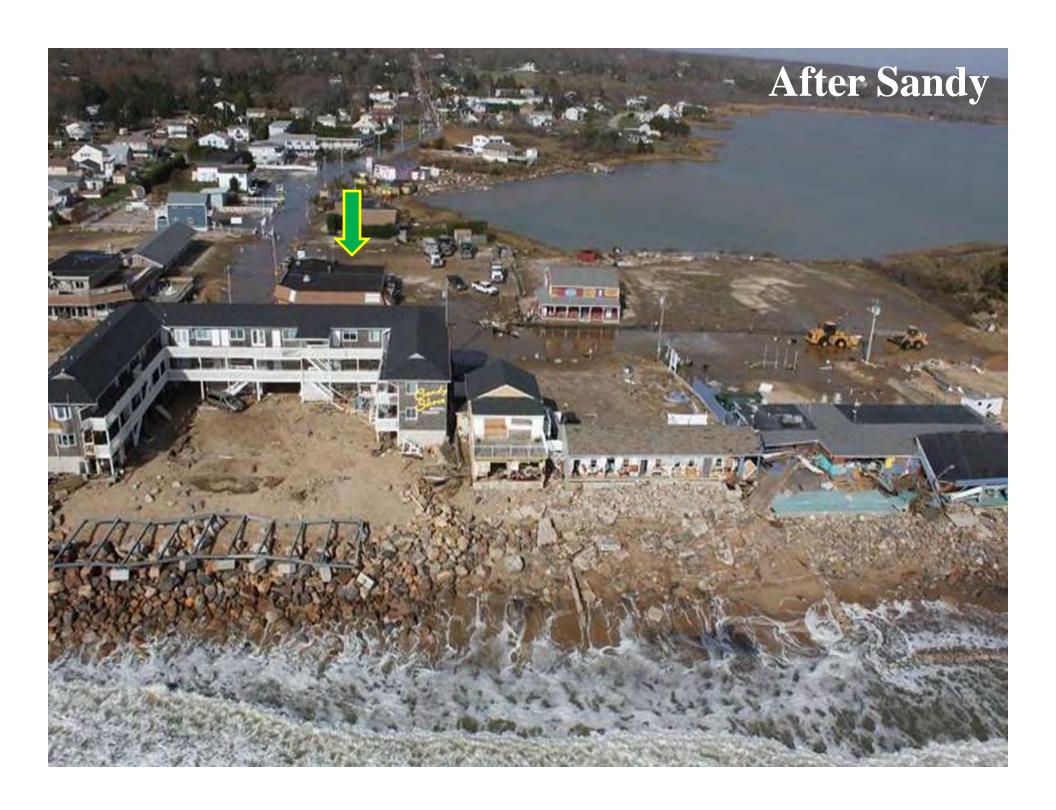


# What should we be expecting on Atlantic Ave, Westerly, RI?

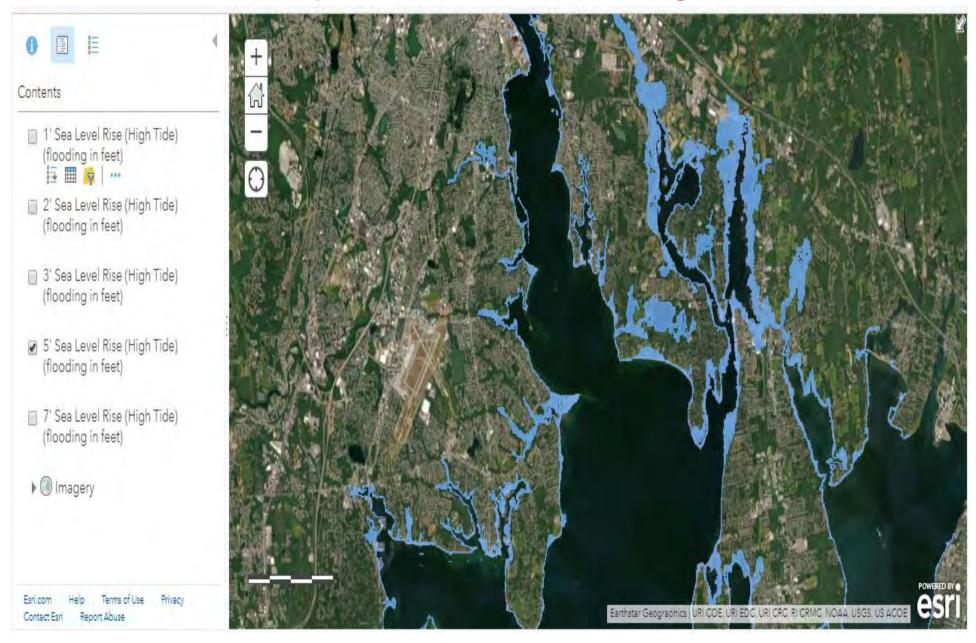






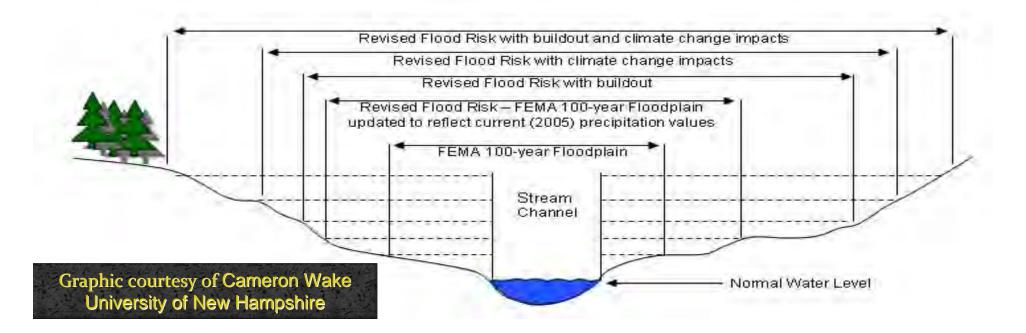


### https://uri.maps.arcgis.com/home/webmap/viewer.html?useExisting=1 http://www.beachsamp.org/stormtools/stormtools-map-gallery/ http://sealevel.climatecentral.org/



# Far reaching implications: Protect, Adapt or Retreat???

- Floodplain, land use, infrastructure, dam spillway requirements, drainage requirements, storm water management, non-point source runoff, bridge clearances, "hardening" of critical facilities in the floodplain, property values etc...
- Flood Insurance work to increase participation
- How much risk are we willing to insure and accept?



# Practices that are working to mitigate losses due to heavy rains and flooding









# The Neponset Basin:

# Natural Valley Storage & **Wetlands Restoration**

Land Trusts can help to:

- Preserve the land
- Retain and restore grounds to their natural state
- Increase rainfall/runoff storage capacity of a given parcel of land
- Improve water quality through restoration of lands and vegetation to a more natural state
- Reduce storm water runoff

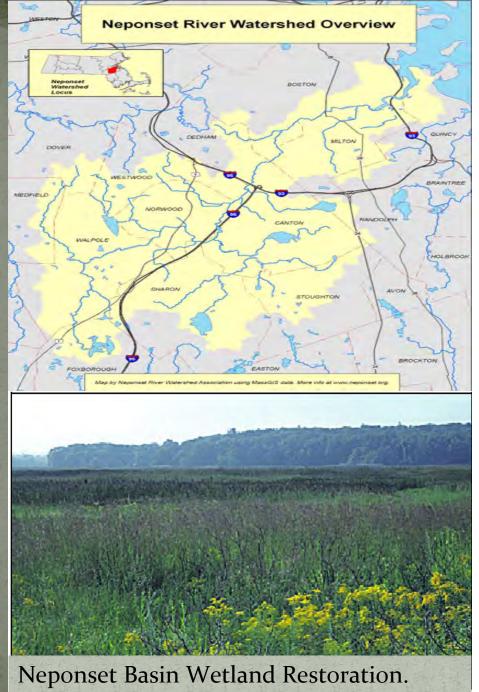
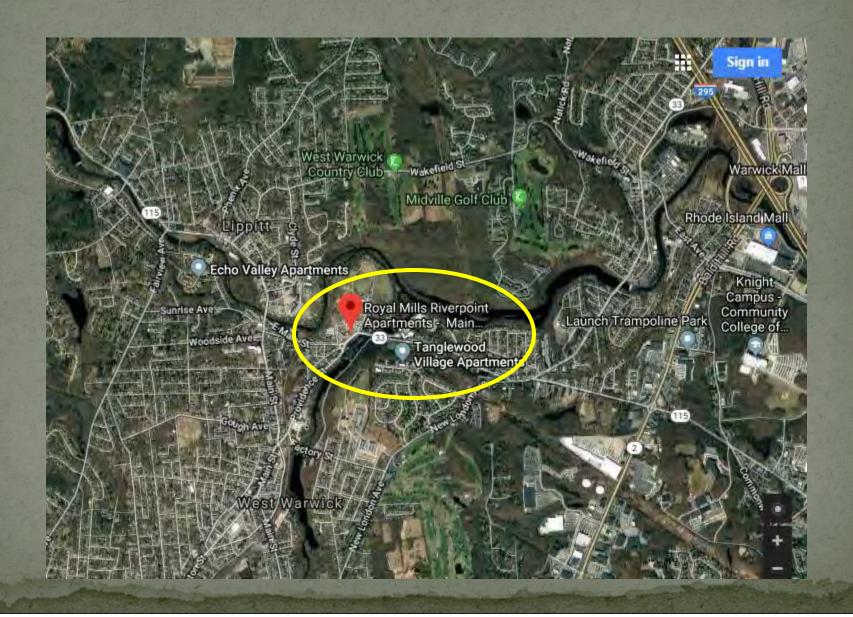


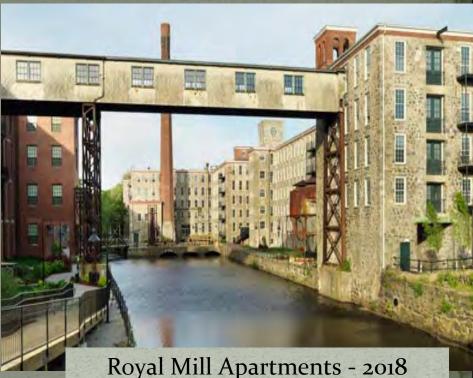
Photo: MA Exec. Office Env. Affairs

# Smart Building Approaches



# Smart Building Approaches





Royal Mill Apartments - 2018

Concept: Refurbish old textile mill into apartments Challenge: Flood-prone area on the Pawtuxet River Plan: Critical infrastructure located on floors 2 and above

Lowest levels used for parking so can be cleared

### Chelsea Screen house

Assessing Vulnerability and Taking Mitigating Actions Elevating Critical Infrastructure



Chelsea Creek Screen House Southwest Facility View



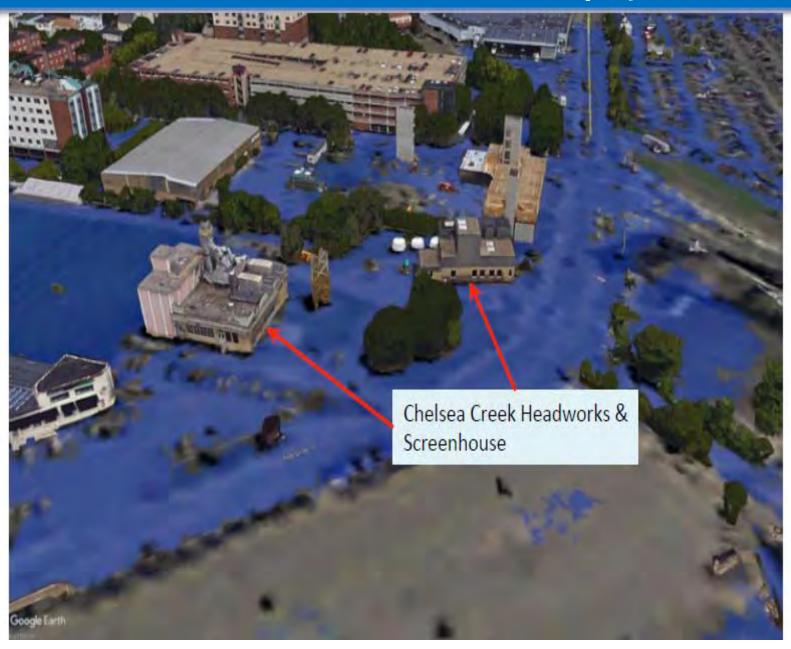
Chelsea Creek Screen House Backup Generator

Slide courtesy of Lise Marx, Senior Program Manager, Master Planning Massachusetts Water Resources Agency (MWRA)



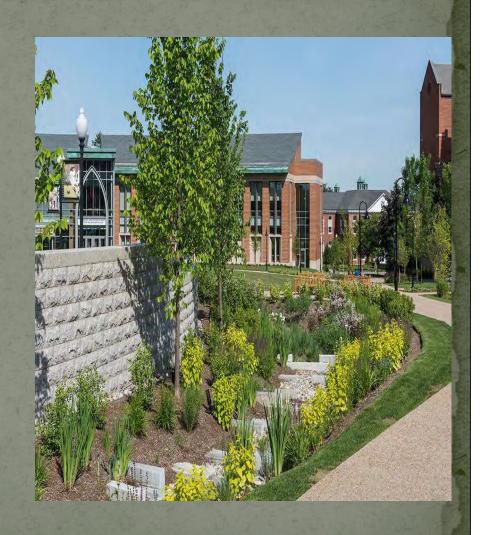
# They Did Their Homework!

Model simulation of inundation for the January 4-5, 2018 Nor'easter



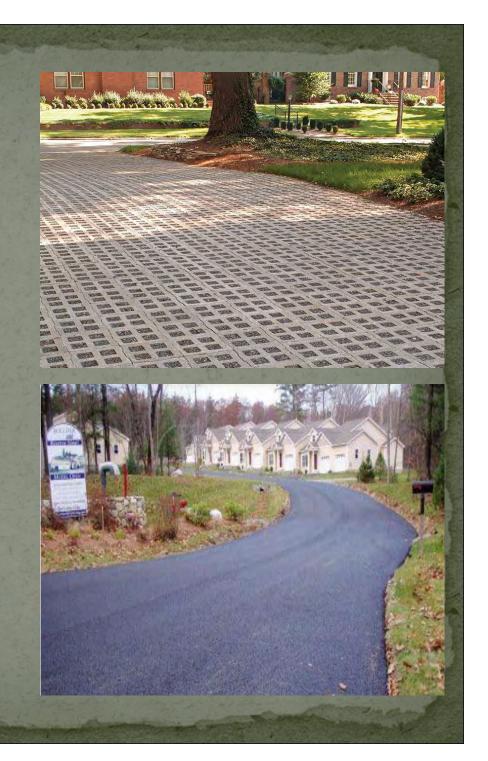
# Using Green Technology: Bioswales

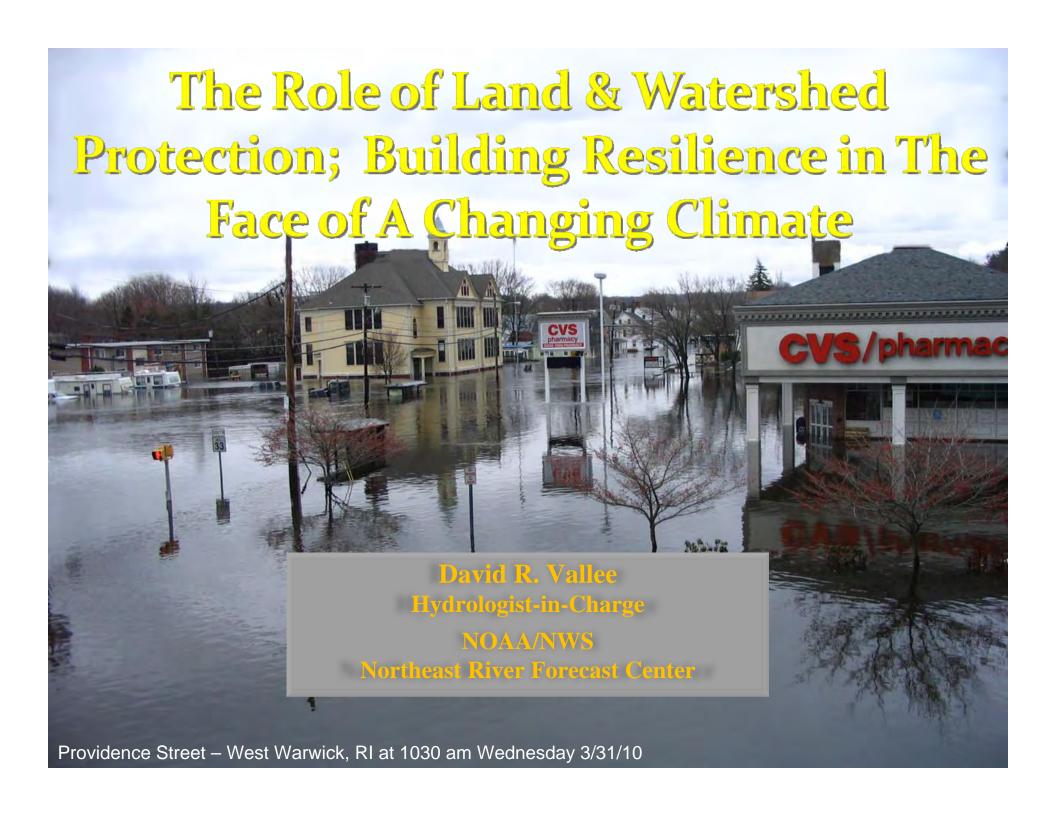
- Stormwater runoff best management practice
- Receives and slows runoff generated during small to medium sized storms
- Provides modest local flood storage
- Filters, traps and removes contaminants in stormwater runoff that would otherwise be carried downstream.



# Porous pavement

- Another best practice
- Reduces risk for ice formation on parking lots and walkways
- Slows arrival of stormwater into near by catchments
- Depending upon design, can also act as a filter mechanism





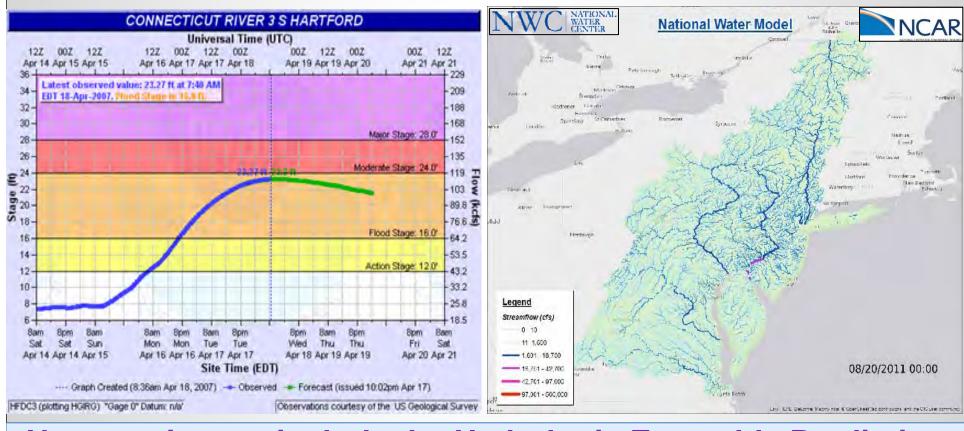
# Backup Slides



# A Look At Current & Future Water Prediction Services:



### Moving from Point Specific to Street Level Hydrologic Forecasting



New services to include the Hydrologic Ensemble Prediction System & the new National Water Model

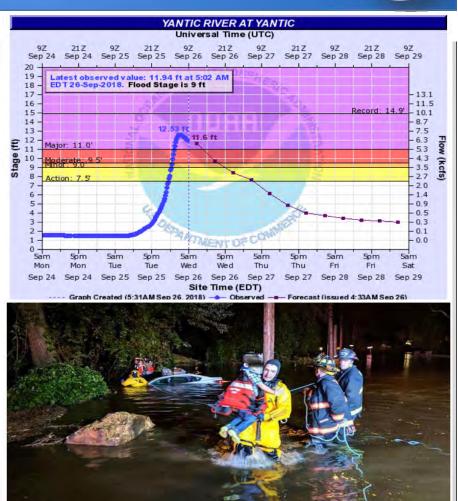


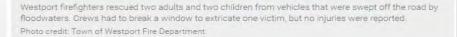


# **Current Hydrologic Services**

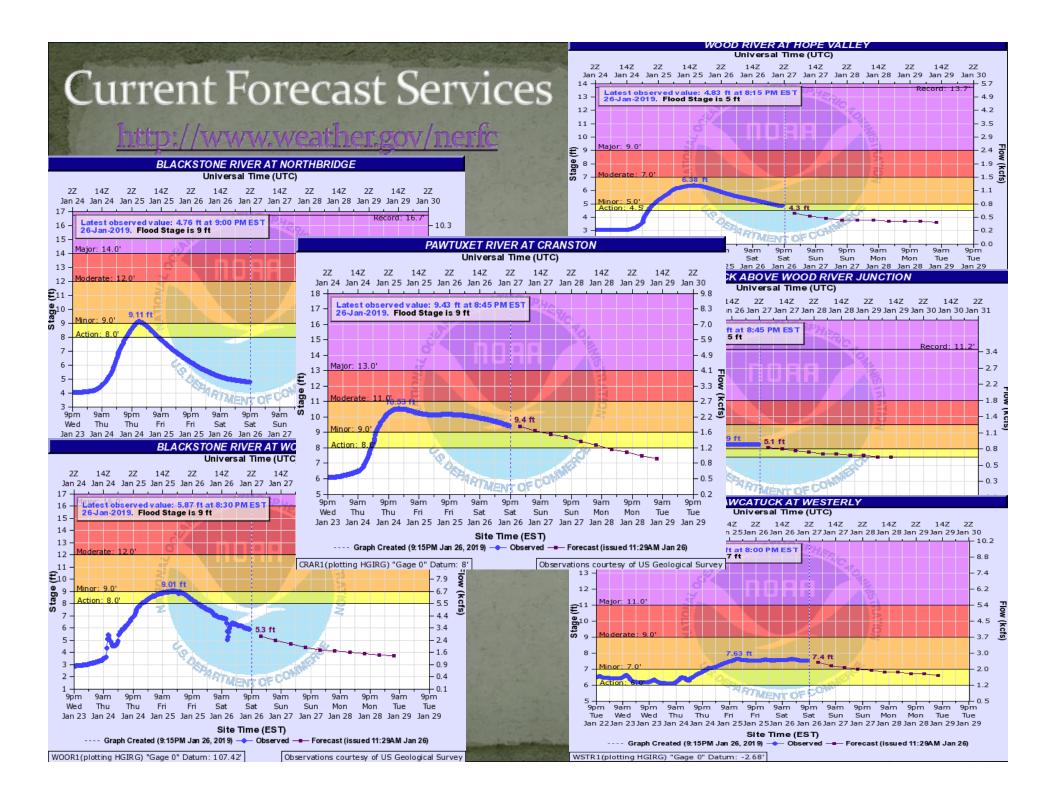


- For decades we have provided
  - Point specific deterministic river forecasts
  - County and storm based flood/flash flood warnings
- Partners have stated while services have been beneficial they lacked:
  - specificity with respect to timing, onset, exact locations
  - Detail as to potential local impacts including inundation





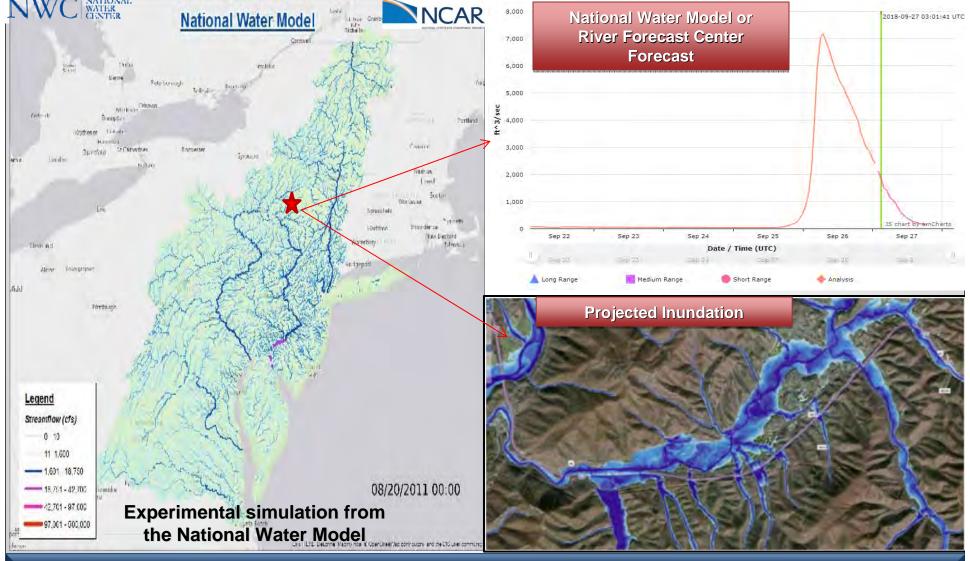




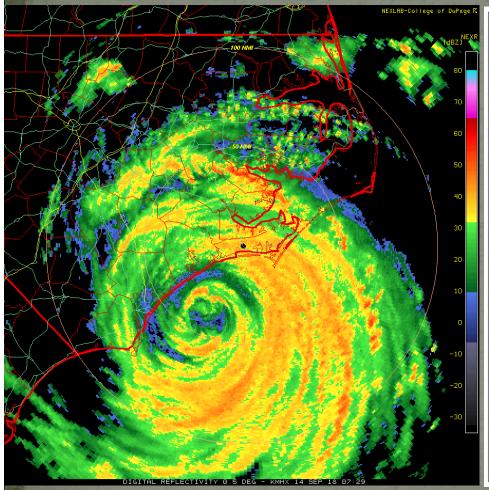


# Imagine if we could bring services down to the street level

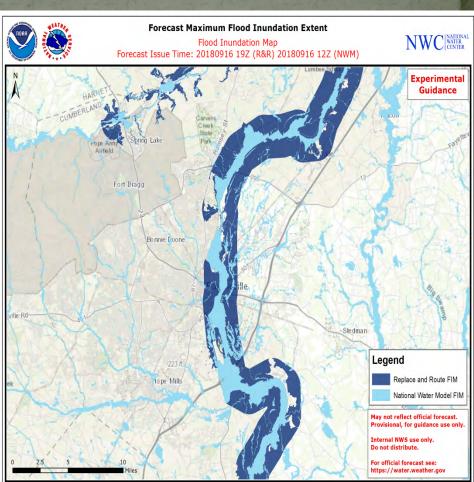




# A very recent example: Florence

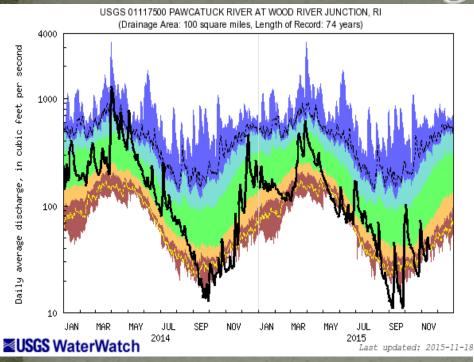


Hurricane Florence's Assault on the Carolinas Radar loop as she approached the coast



Areal extend of flood inundation experimental guidance mapping

# Closer look at drought characteristics



- Droughts of yesteryear:
  - **\*** 1964-66
- Prolonged record lows
  - Not as "record" as today's low minimum flows
  - But far longer in duration with little significant recharge

- ❖ Short/intense drought episodes:
  - **\*** 2014 and 2015
- \* Record daily flows
  - Exceeding minimums during the 1960s drought!
  - But...very short duration with long periods of significant recharge if not flood volumes

