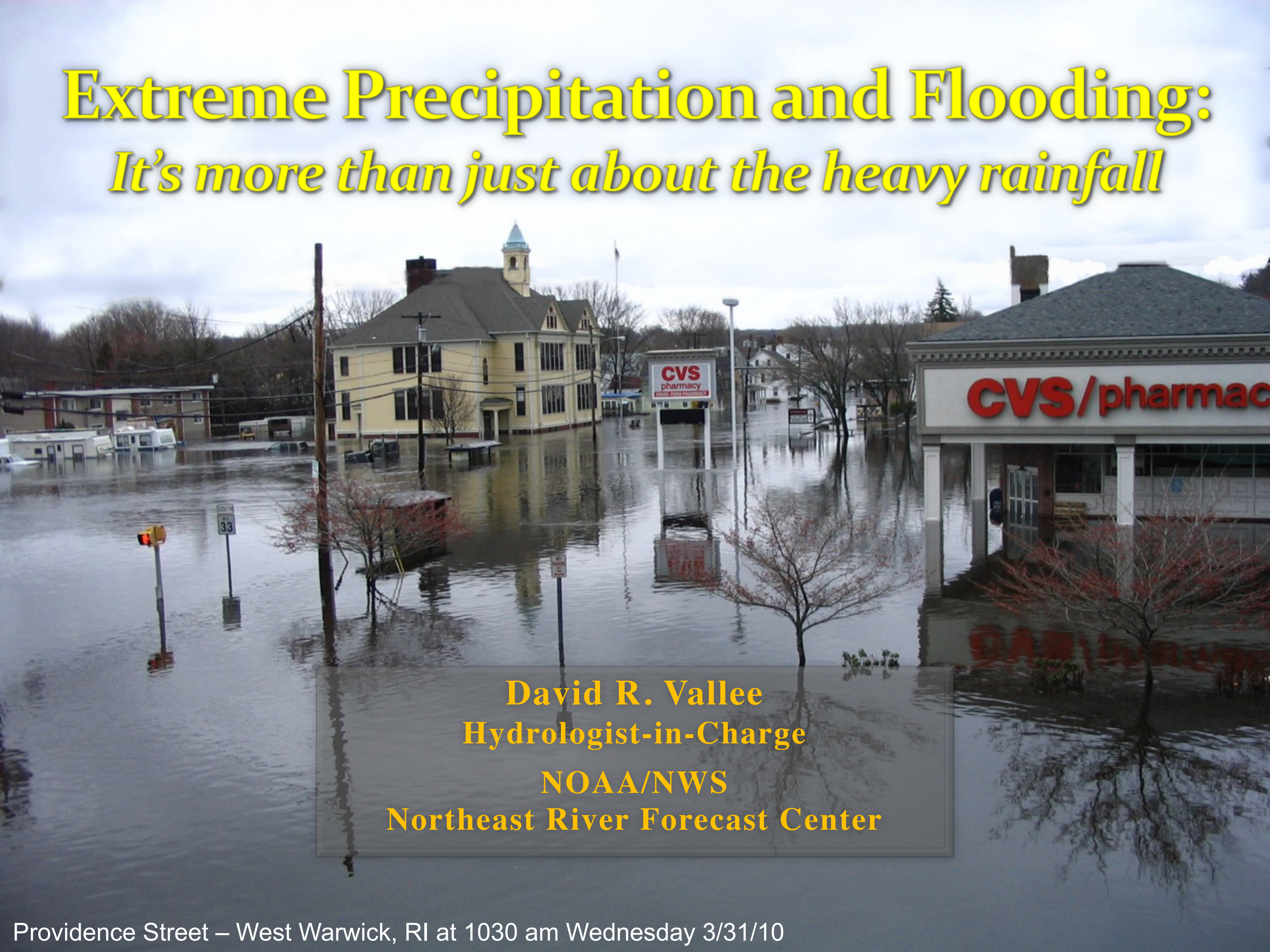
Extreme Precipitation and Flooding:
It's more than just about the heavy rainfall

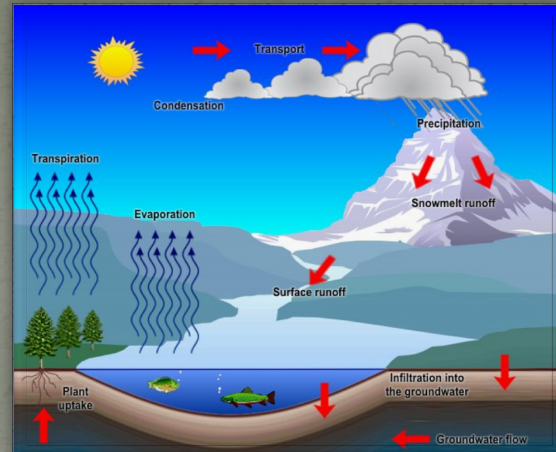


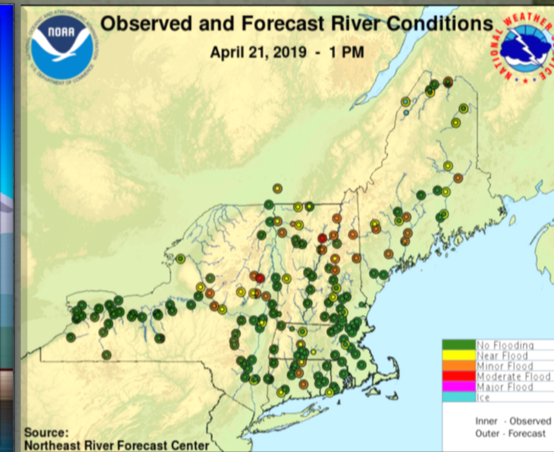
David R. Vallee
Hydrologist-in-Charge
NOAA/NWS
Northeast River Forecast Center

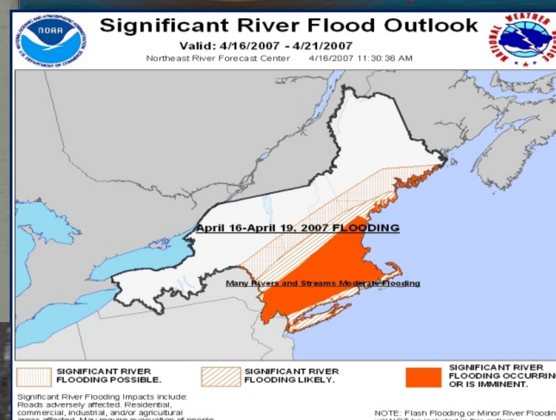
Providence Street – West Warwick, RI at 1030 am Wednesday 3/31/10

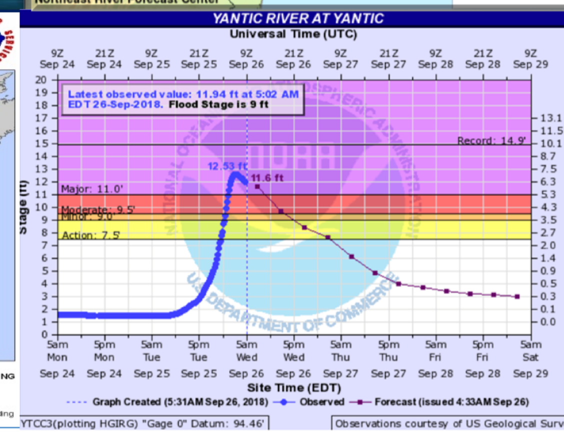
River Forecast Center Responsibilities

- 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

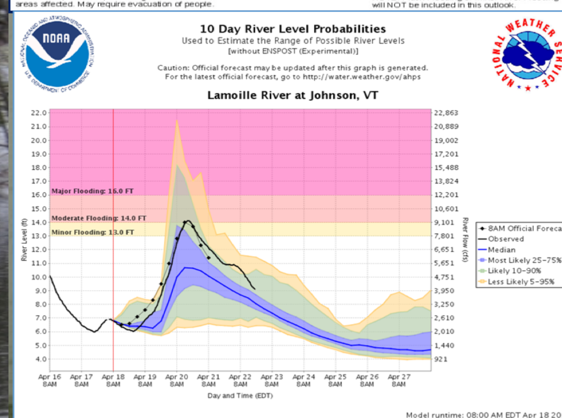


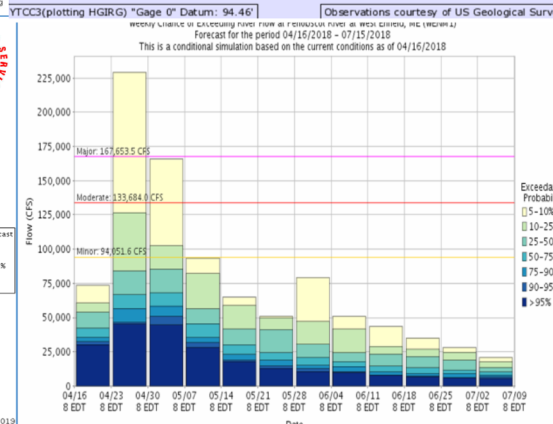






Moderate flooding - Connecticut River at Portland, CT.





NERFC Forecast Services

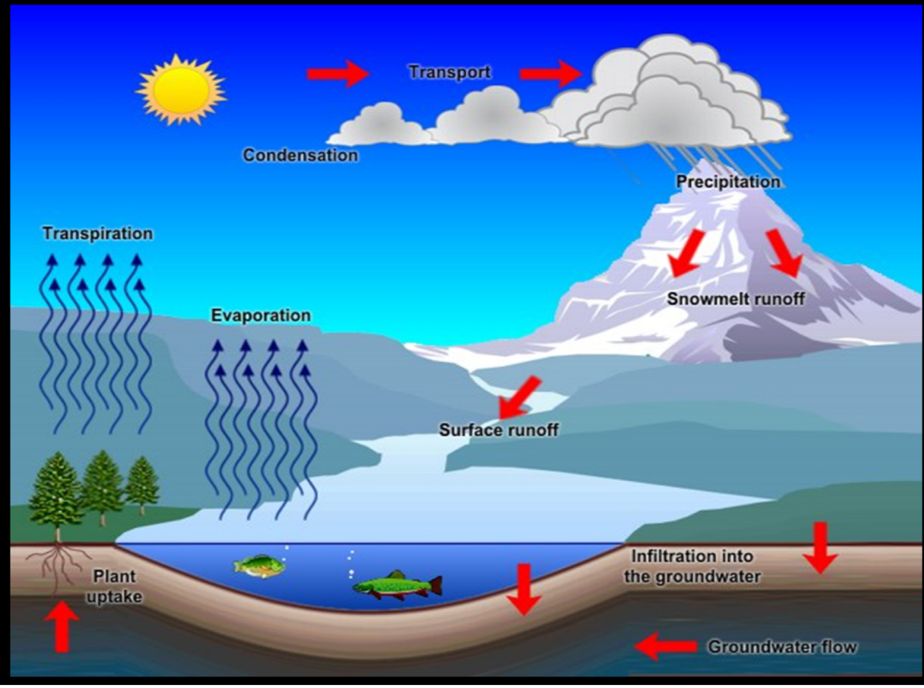
On A Watershed Scale

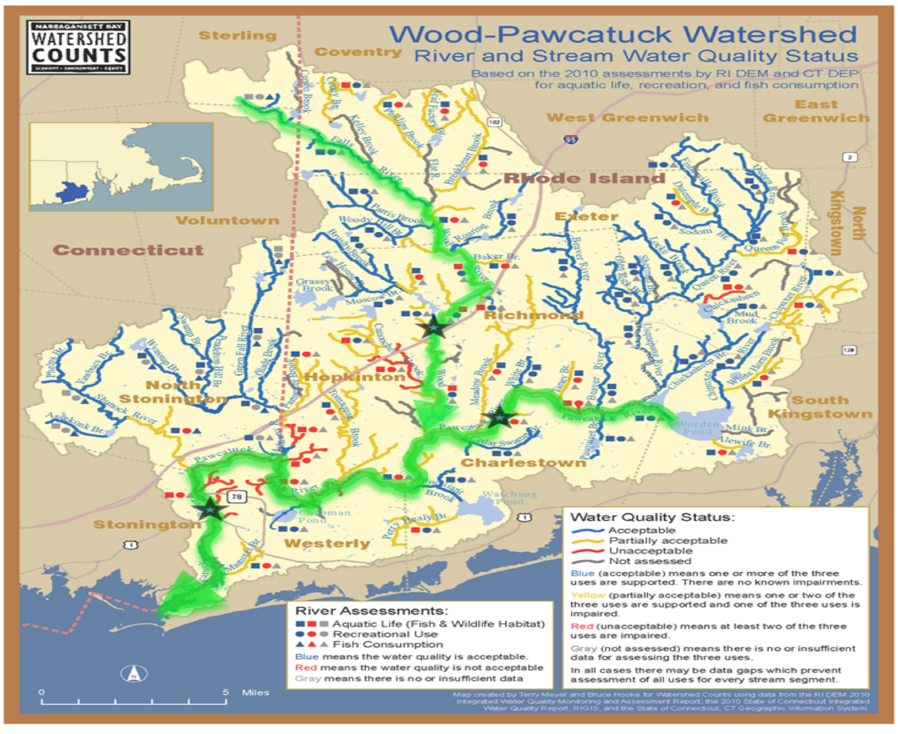
Requirements:

- Observed precipitation & temperatures
- Observed streamflows (USGS)
- Forecast temperatures and precipitation
- **Drainage area ≥100 sq mi**

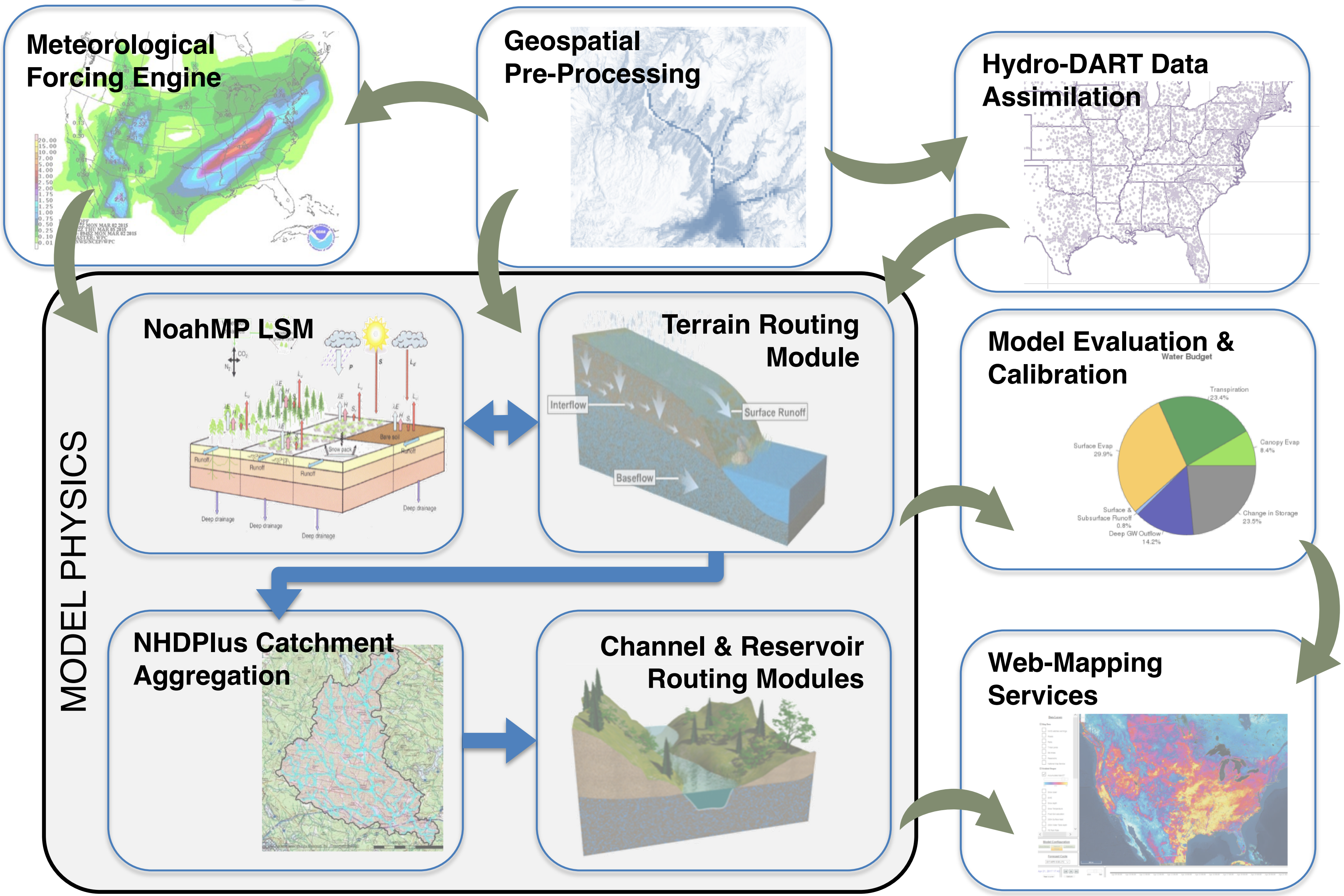
Our models help us forecast:

- The volume of water in the river & that's converted to stage/elevation
- Time of the peak elevation & duration
- Soil moisture & Snow melt
- Unit hydrograph theory
- Reservoir Operations
- Hydraulics (HES-RAS) for complex river systems
  - Tidal reaches
    - Combines tidal/storm surge with fresh water runoff on 5 tidal rivers
  - Lake Champlain, Farmington River



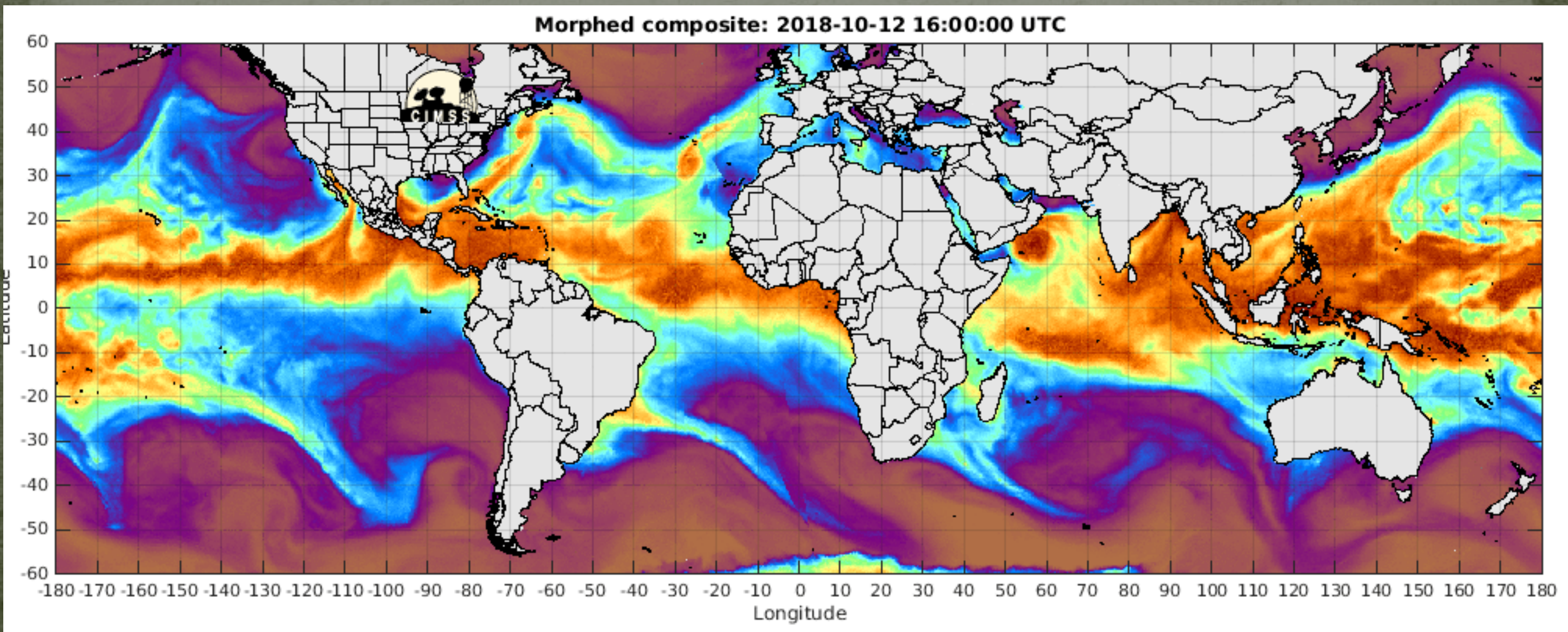


National Water Model : WRF-Hydro Modeling System
Forecasting for 2.7 million catchments across the nation!



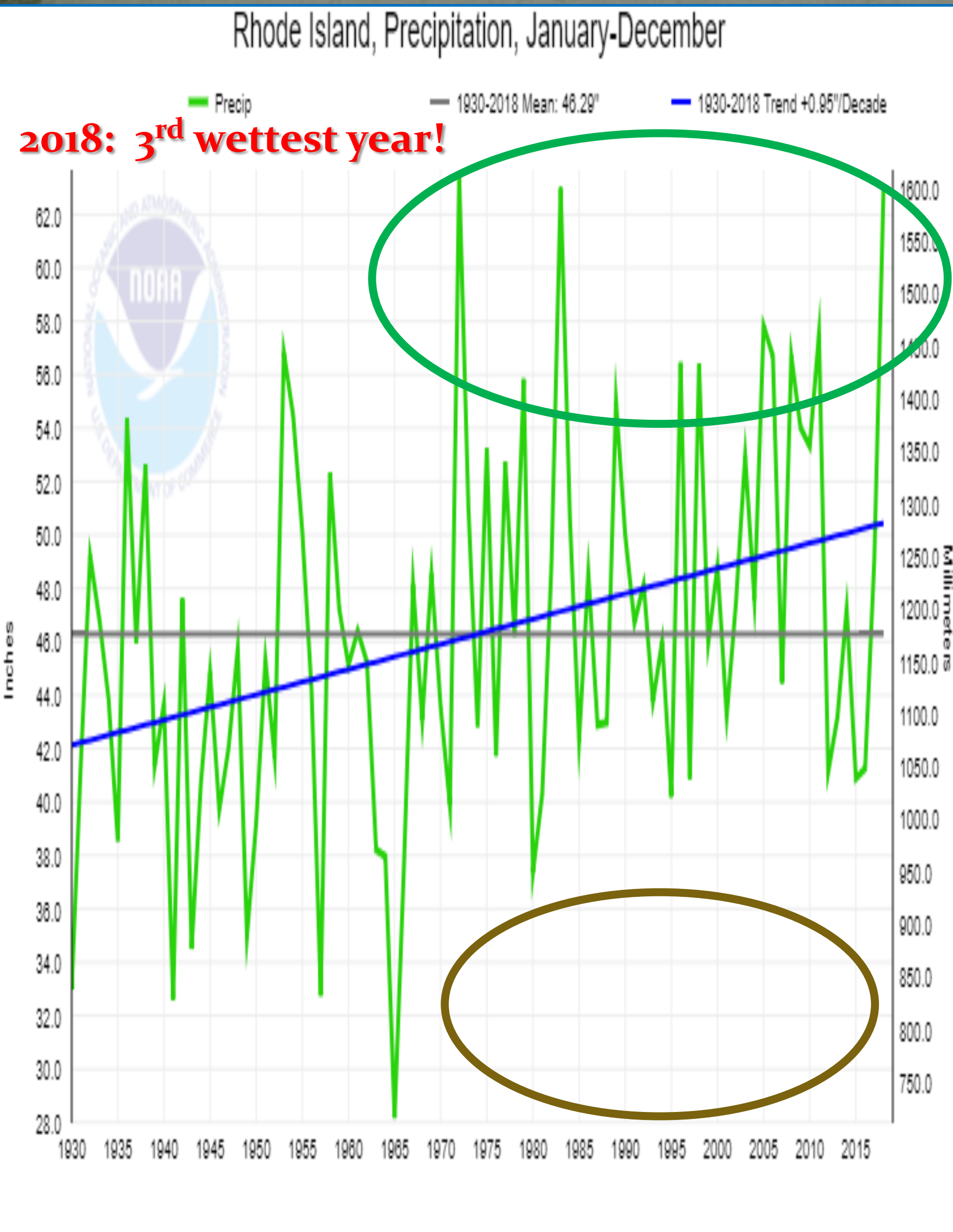
Ingredients for increased intense precipitation

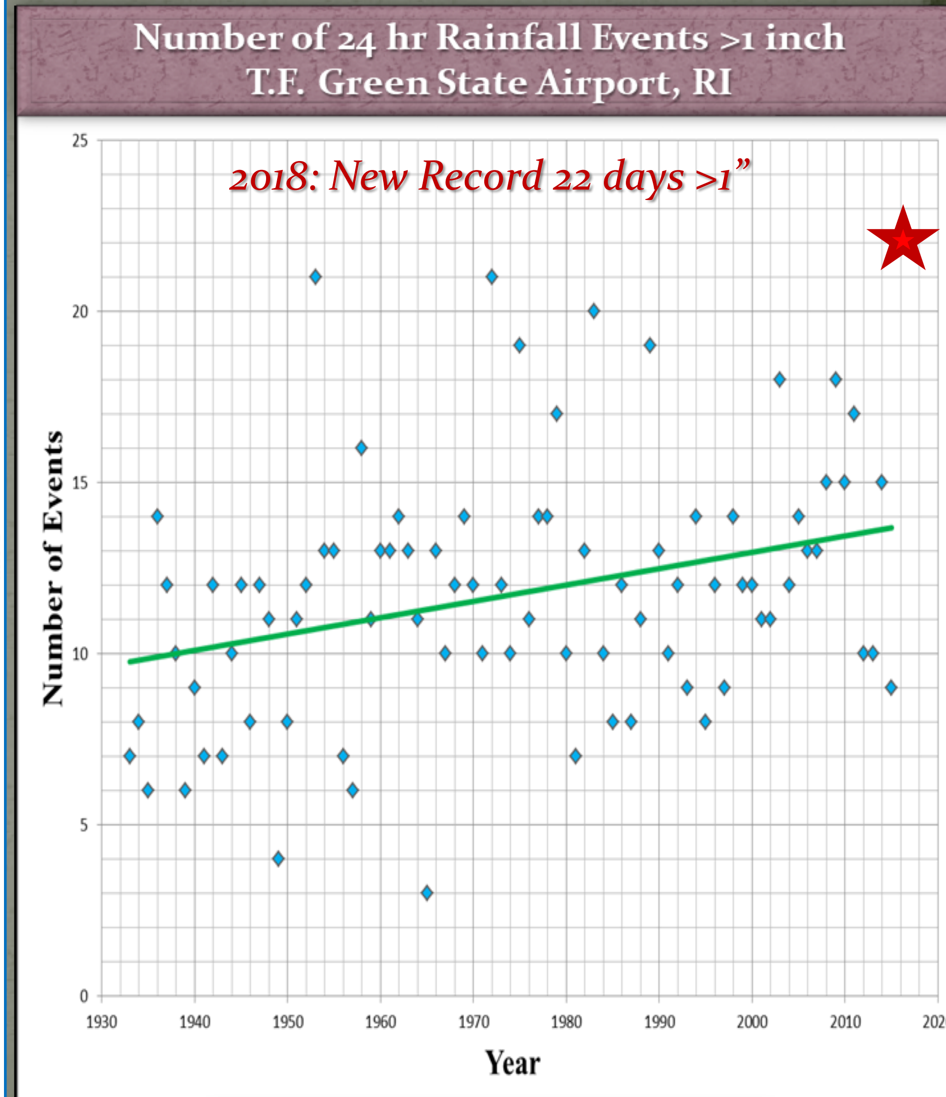
- Several:
  - Slow moving weather systems – a blocked up atmosphere
    - One slow mover or multiple events in close succession
  - Results in saturated antecedent conditions before “main event”
  - Each fed by a “tropical connection”
    - Plumes of deep moisture carrying 5 to 7% more water vapor



A Look at Temperature and Precipitation Trends

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



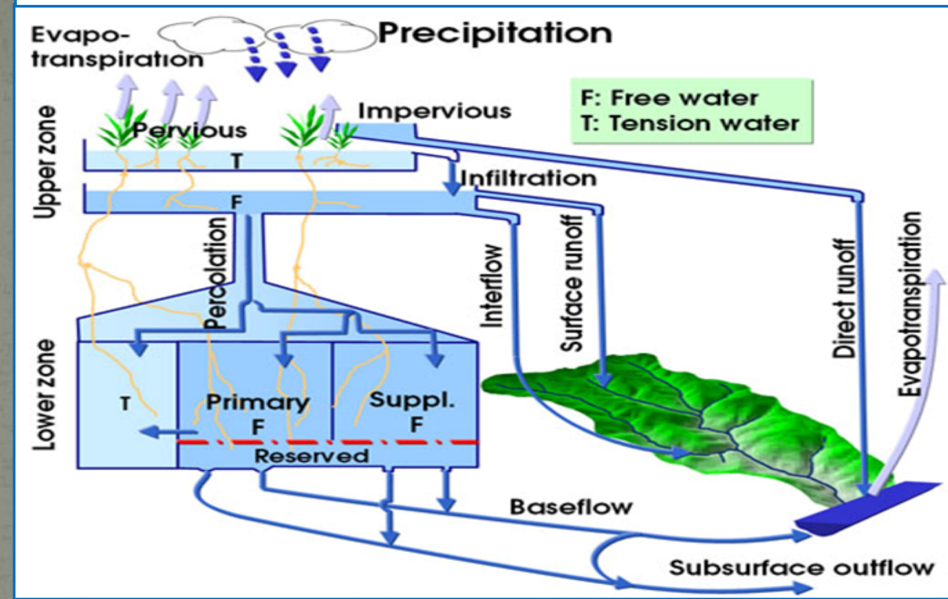


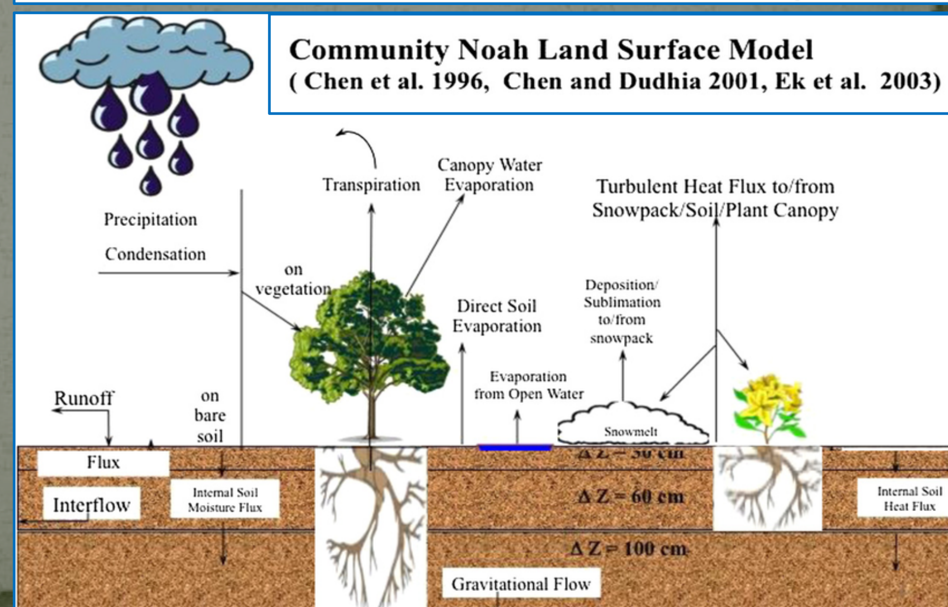
Source: N. Strauss, NERFC

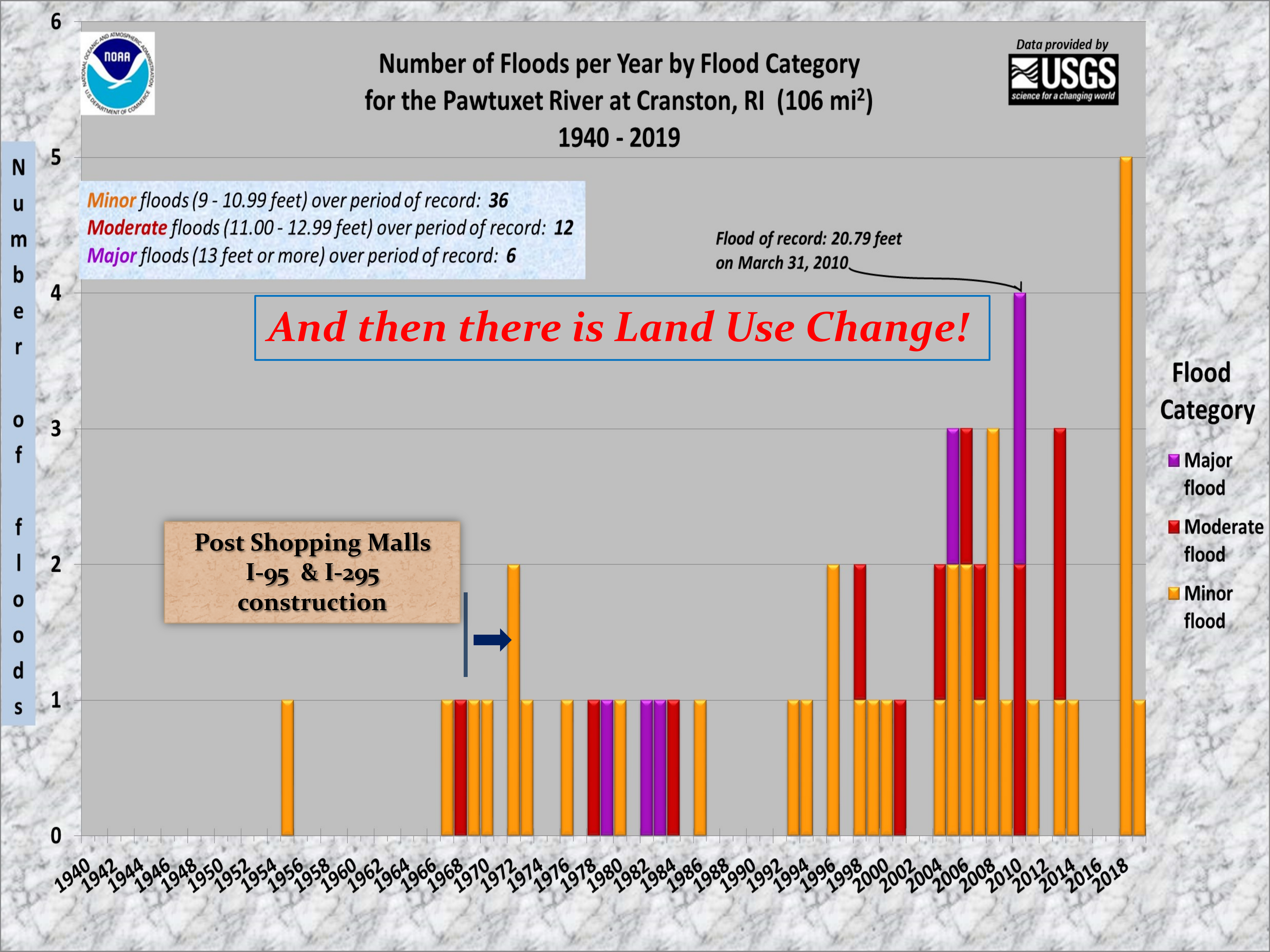
But it is not just about intense rainfall

- Antecedent soil moisture conditions
- Basin size
  - Small basins far more susceptible
- Footprint of the causative rainfall/runoff event
- One intense event or a sequence of events
- Seasonal considerations
  - Heavy rain and snowmelt
  - Heavy rain prior to green up or after leaf-off
- Flood control footprint
- Nature of the way the rain event moved across the basin

Sacramento Soil Moisture Accounting Model



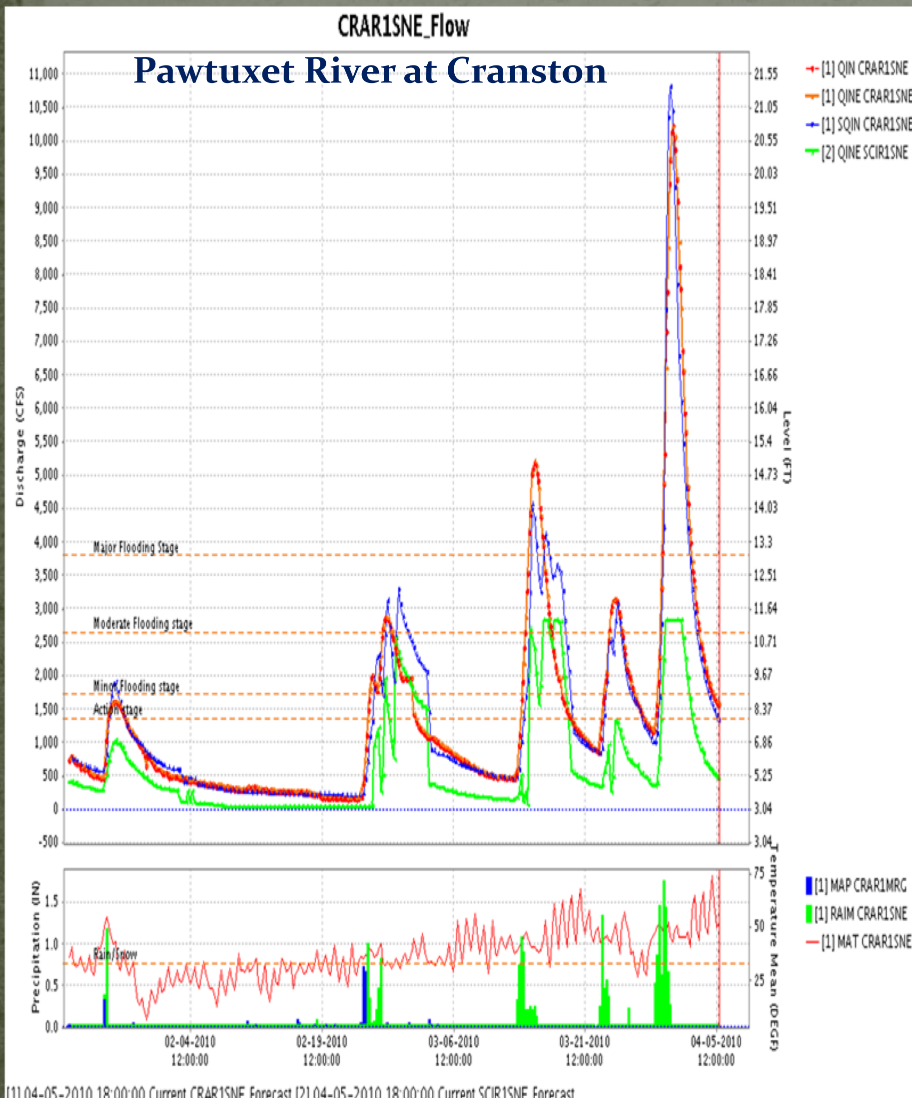


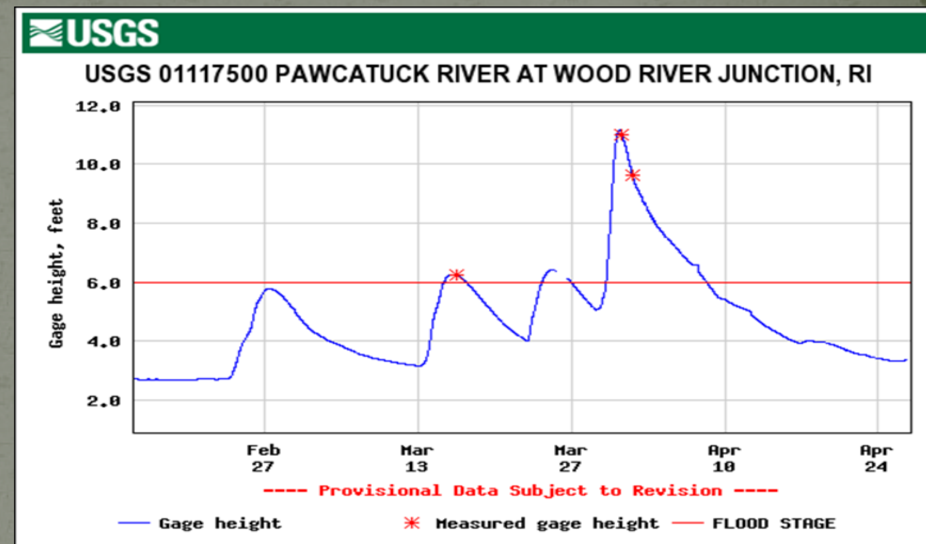


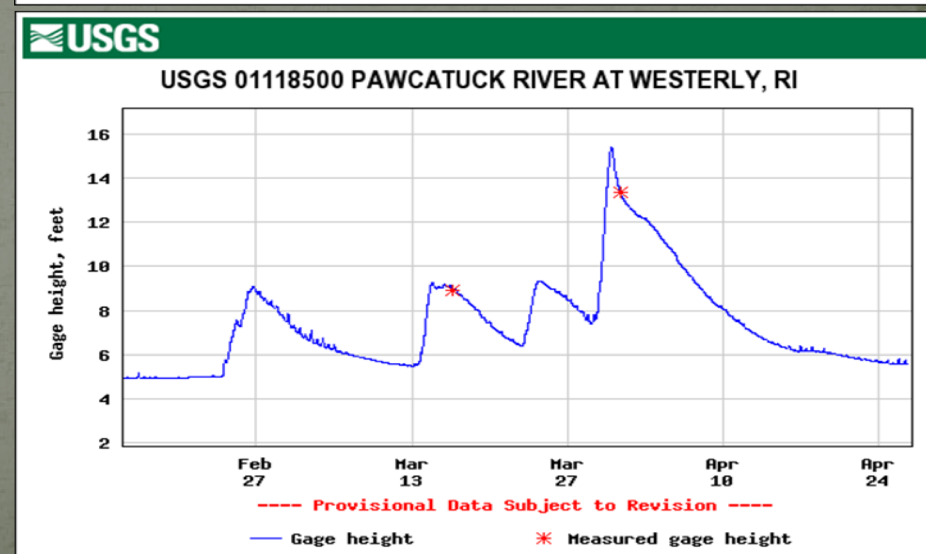
Number of Floods per Year by Flood Category
for the Pawtuxet River at Cranston, RI (106 mi²)
1940 - 2019
Data provided by
USGS
science for a changing world
NOAA
Minor floods (9 - 10.99 feet) over period of record: 36
Moderate floods (11.00 - 12.99 feet) over period of record: 12
Major floods (13 feet or more) over period of record: 6
Flood of record: 20.79 feet
on March 31, 2010
And then there is Land Use Change!
Post Shopping Malls
I-95 & I-295
construction
Flood Category
Major flood
Moderate flood
Minor flood
Number of floods
0
1
2
3
4
5
6
1940 1942 1944 1946 1948 1950 1952 1954 1956 1958 1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

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

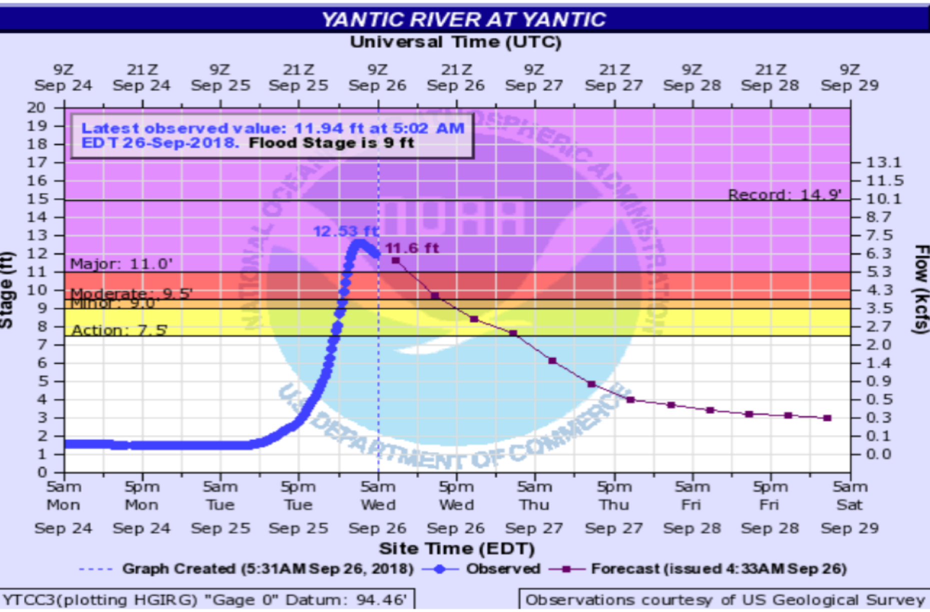




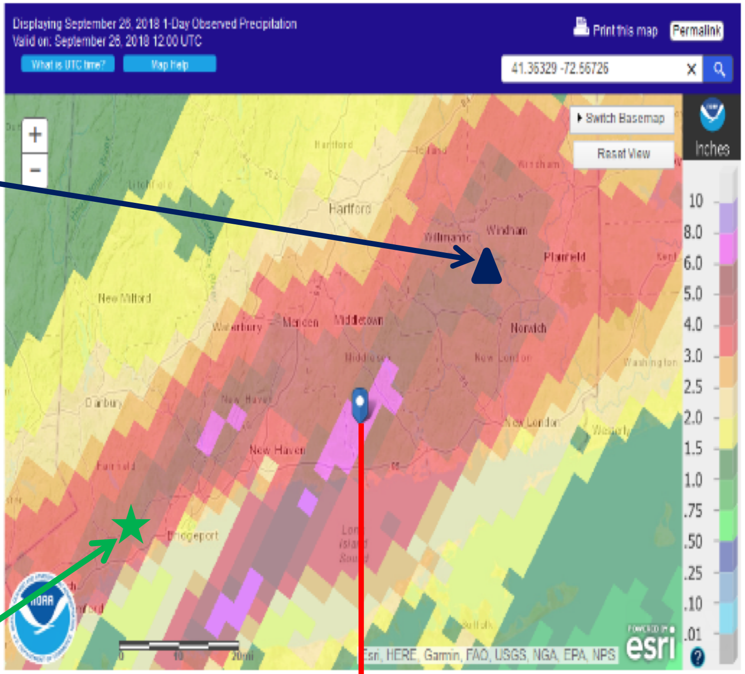


Small scale extremely intense event:

Coastal Connecticut – September 25^{th}, 2018



Westport firefighters rescued two adults and two children from vehicles that were swept off the road by floodwaters. Crews had to break a window to extricate one victim, but no injuries were reported.
Photo credit: Town of Westport Fire Department



Killingsworth, CT received 6.78 inches in ~ 12 hours 3hr ~ 50 yr event and the 6-12 hr ~ 75-100 yr event

Duration	Obs	Approx ARI	1	2	5	10	25	50	100
1h	1.56	~5-yr	0.993	1.2	1.53	1.81	2.19	2.49	2.78
2h	2.95	~25-yr	1.31	1.58	2.01	2.37	2.86	3.24	3.63
3h	3.74	~50-yr	1.53	1.83	2.34	2.75	3.32	3.76	4.21
6h	4.95	>50-yr	1.95	2.34	2.98	3.51	4.24	4.8	5.36
12h	6.21	>50-yr	2.42	2.91	3.71	4.38	5.29	6	6.7
24h	6.78	>25-yr	2.84	3.44	4.43	5.25	6.38	7.25	8.13

...But you cannot design for everything!

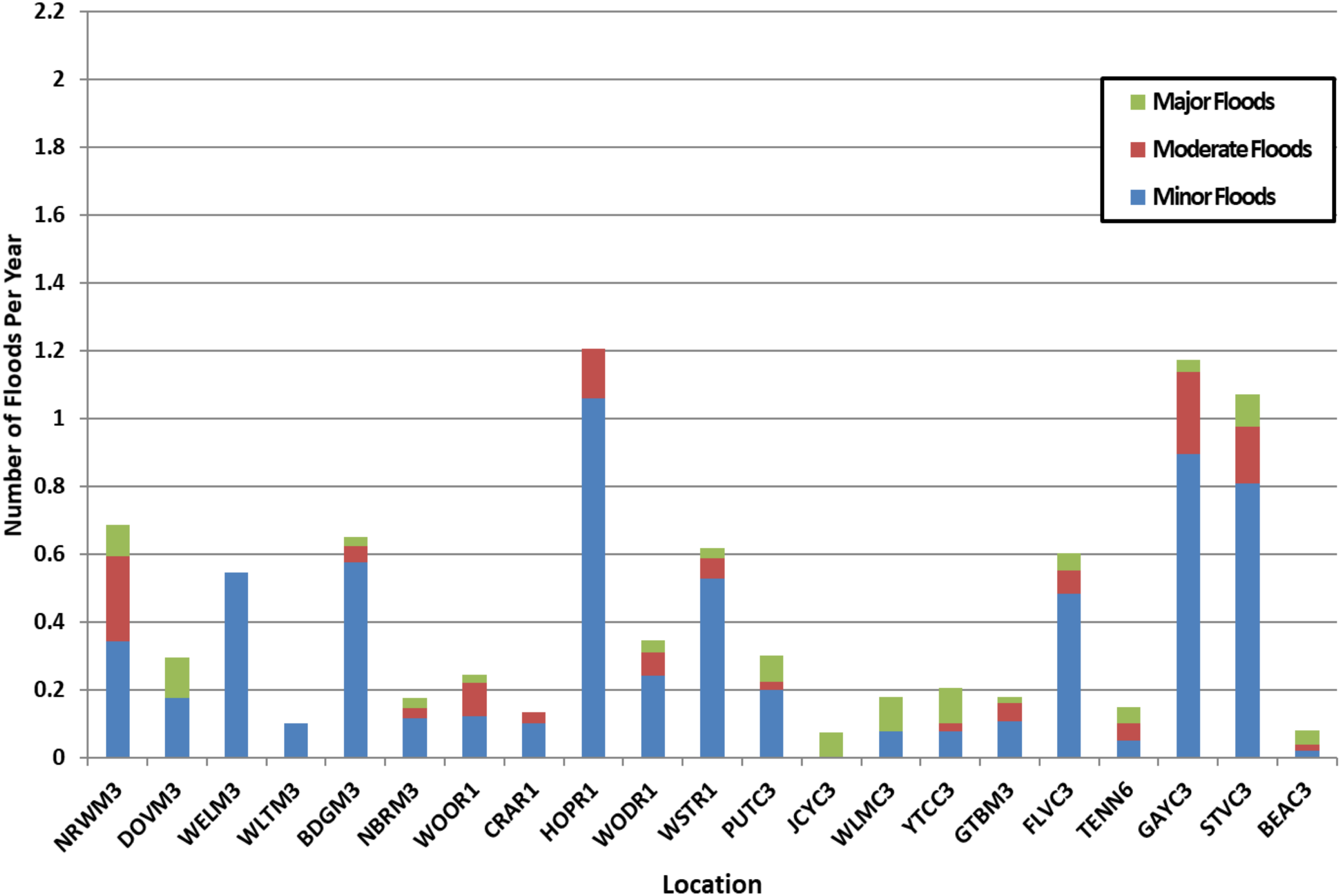
Example: August 13th, 2014 – Islip, NY – Rainfall 11 inches/3 hours

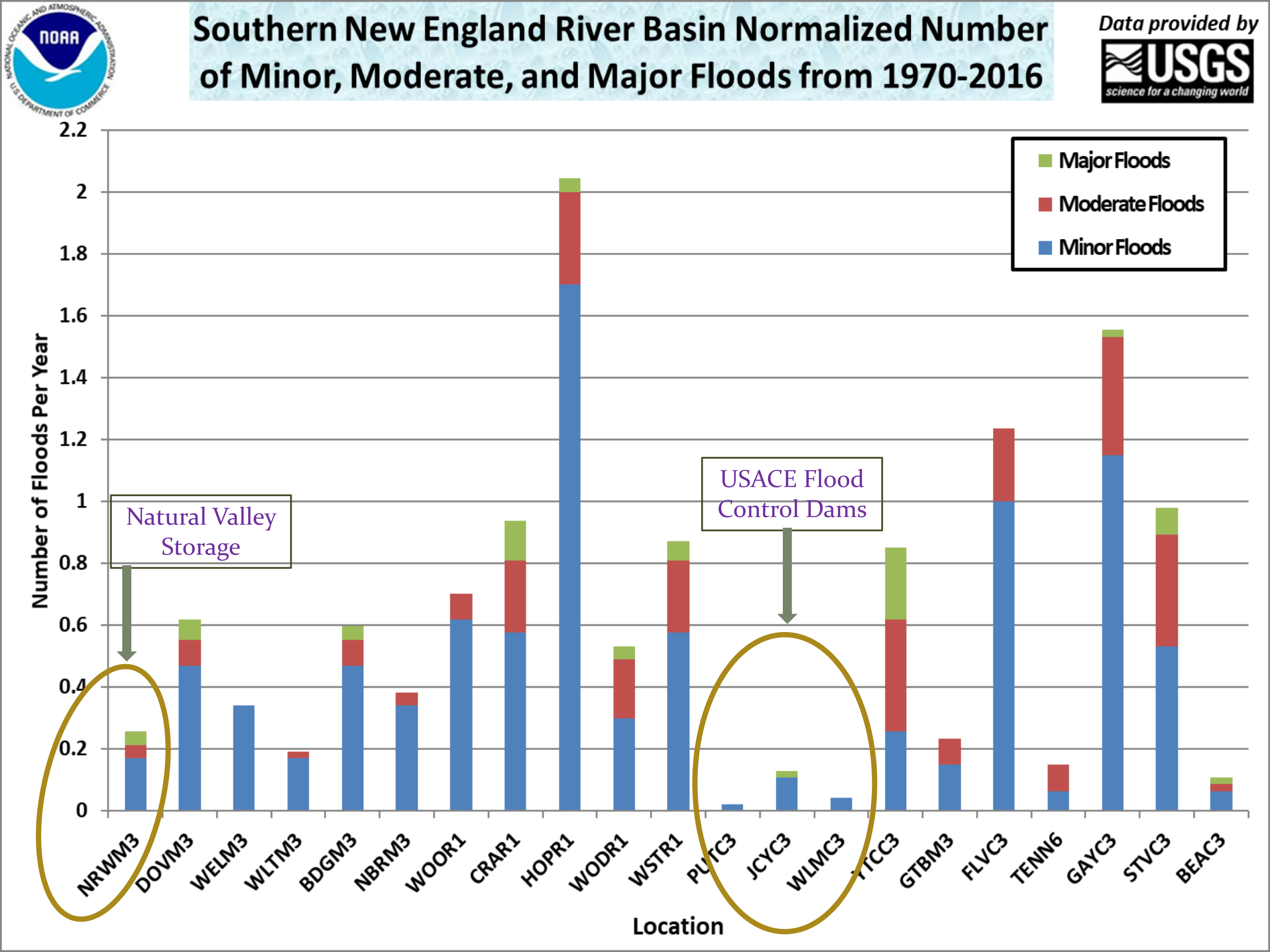
AMS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]									
Duration	Annual exceedance probability (1/years)								
	1/2	1/5	1/10	1/25	1/50	1/100	1/200	1/500	1/1000
5-min	**0.400** (0.312-0.507)	**0.544** (0.423-0.693)	**0.654** (0.505-0.836)	**0.798** (0.597-1.06)	**0.907** (0.666-1.23)	**1.02** (0.727-1.42)	**1.16** (0.784-1.65)	**1.36** (0.880-1.98)	**1.51** (0.953-2.23)
10-min	**0.566** (0.442-0.719)	**0.771** (0.599-0.981)	**0.926** (0.715-1.18)	**1.13** (0.846-1.50)	**1.29** (0.944-1.74)	**1.44** (1.03-2.02)	**1.65** (1.11-2.33)	**1.92** (1.25-2.80)	**2.13** (1.35-3.15)
15-min	**0.666** (0.520-0.846)	**0.907** (0.705-1.15)	**1.09** (0.842-1.39)	**1.33** (0.995-1.77)	**1.51** (1.11-2.05)	**1.69** (1.21-2.37)	**1.94** (1.31-2.74)	**2.26** (1.47-3.29)	**2.51** (1.59-3.71)
30-min	**0.938** (0.731-1.19)	**1.28** (0.992-1.63)	**1.53** (1.19-1.96)	**1.87** (1.40-2.49)	**2.13** (1.56-2.88)	**2.39** (1.71-3.34)	**2.73** (1.84-3.86)	**3.18** (2.06-4.63)	**3.53** (2.23-5.22)
60-min	**1.21** (0.942-1.53)	**1.65** (1.28-2.10)	**1.98** (1.53-2.53)	**2.42** (1.81-3.21)	**2.75** (2.02-3.72)	**3.08** (2.20-4.31)	**3.52** (2.37-4.98)	**4.11** (2.66-5.97)	**4.55** (2.88-6.72)
2-hr	**1.60** (1.26-2.02)	**2.21** (1.73-2.79)	**2.67** (2.08-3.39)	**3.28** (2.47-4.32)	**3.74** (2.76-5.02)	**4.20** (3.01-5.83)	**4.80** (3.25-6.74)	**5.59** (3.63-8.08)	**6.19** (3.93-9.09)
3-hr	**1.86** (1.47-2.33)	**2.58** (2.02-3.24)	**3.12** (2.44-3.94)	**3.84** (2.90-5.03)	**4.38** (3.24-5.86)	**4.93** (3.54-6.80)	**5.63** (3.81-7.87)	**6.55** (4.27-9.43)	**7.25** (4.61-10.6)
6-hr	**2.35** (1.86-2.93)	**3.25** (2.57-4.06)	**3.93** (3.09-4.93)	**4.84** (3.67-6.29)	**5.52** (4.11-7.32)	**6.20** (4.48-8.50)	**7.08** (4.82-9.83)	**8.24** (5.39-11.8)	**9.12** (5.82-13.3)
12-hr	**2.87** (2.30-3.55)	**3.95** (3.15-4.90)	**4.76** (3.77-5.93)	**5.84** (4.46-7.55)	**6.65** (4.98-8.78)	**7.47**	**8.55**	**9.97**	**11.1**
24-hr	**3.34** (2.69-4.10)	**4.64** (3.72-5.71)	**5.62** (4.48-6.95)	**6.92** (5.32-8.90)	**7.90** (5.96-10.4)				
2-day	**3.72** (3.02-4.54)	**5.31** (4.29-6.48)	**6.50** (5.22-7.98)	**8.09** (6.28-10.4)	**9.28** (7.07-12.2)				
3-day	**4.01** (3.26-4.86)	**5.72** (4.64-6.96)	**7.02** (5.66-8.58)	**8.74** (6.81-11.2)	**10.0** (7.68-13.1)				
4-day	**4.27** (3.49-5.16)	**6.05** (4.92-7.34)	**7.40** (5.98-9.01)	**9.18** (7.18-11.7)	**10.5** (8.09-13.7)				
7-day	**4.98** (4.09-5.99)	**6.84** (5.60-8.24)	**8.24** (6.70-9.98)	**10.1** (7.95-12.8)	**11.5** (8.89-14.9)				
10-day	**5.67** (4.68-6.79)	**7.58** (6.23-9.10)	**9.02** (7.36-10.9)	**10.9** (8.61-13.8)	**12.4** (9.56-15.9)				
20-day	**7.79** (6.47-9.26)	**9.85** (8.15-11.7)	**11.4** (9.37-13.6)	**13.5** (10.6-16.7)	**15.0** (11.6-19.0)				
30-day	**9.57** (7.98-11.3)	**11.7** (9.76-13.9)	**13.4** (11.1-16.0)	**15.6** (12.3-19.1)	**17.2** (13.3-21.5)				
45-day	**11.8** (9.88-13.9)	**14.1** (11.8-16.6)	**15.8** (13.1-18.8)	**18.1** (14.4-22.1)	**19.9** (15.4-24.7)				
60-day	**13.7** (11.5-16.0)	**16.1** (13.4-18.9)	**17.9** (14.9-21.1)	**20.3** (16.1-24.6)	**22.1** (17.1-27.2)				

>11"

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

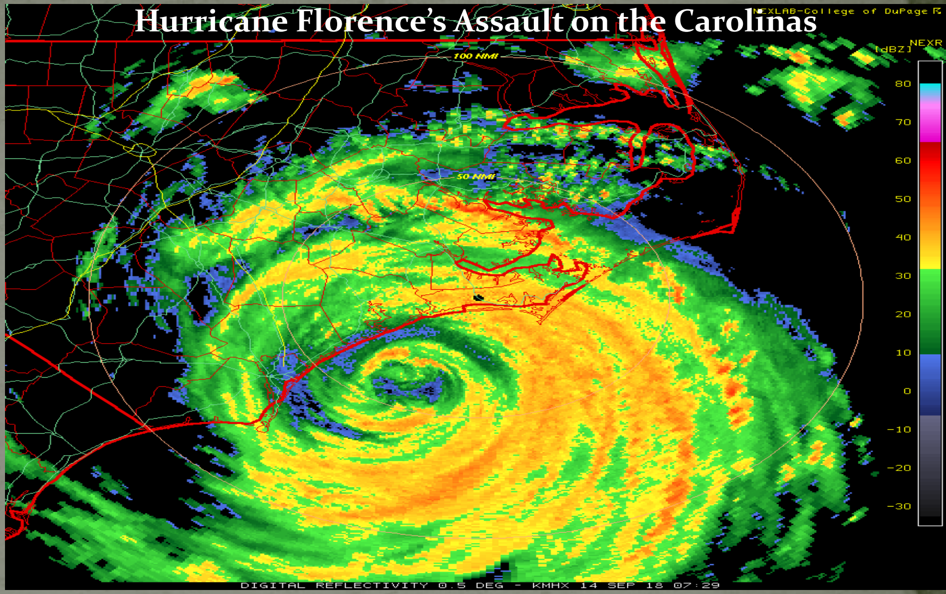
Data provided by USGS

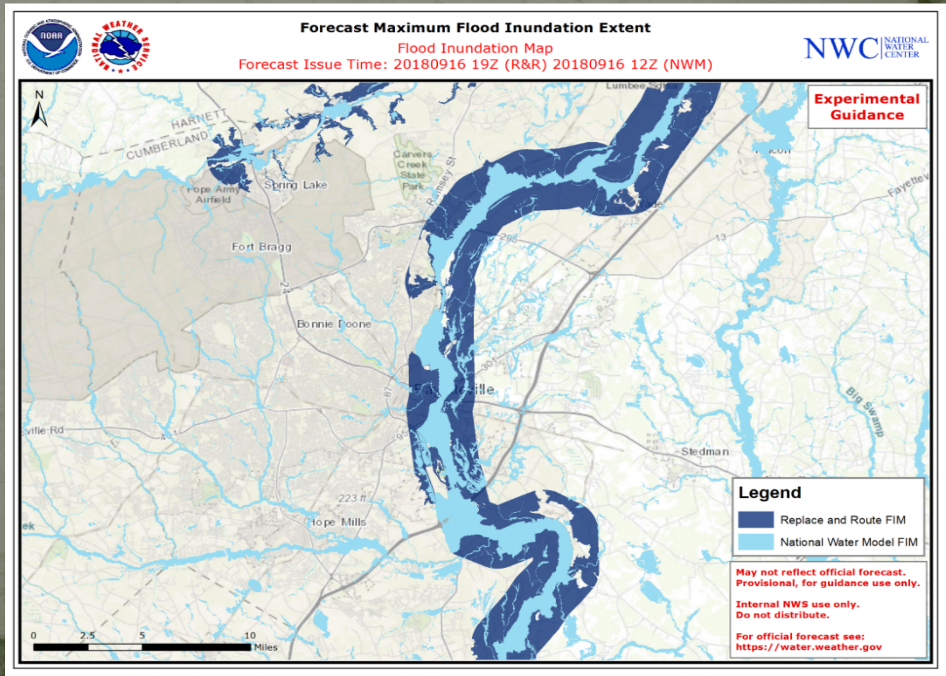



Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods from 1970-2016
Data provided by
USGS
science for a changing world
NOAA
Number of Floods Per Year
Location
Major Floods
Moderate Floods
Minor Floods
Natural Valley Storage
USACE Flood Control Dams
NRWM3
DOVM3
WELM3
WLTM3
BDGM3
NBRM3
WOOR1
CRAR1
HOPR1
WODR1
WSTR1
PUTC3
JCYC3
WLMC3
TTCC3
GTBM3
FLVC3
TENN6
GAYC3
STVC3
BEAC3

Real-time forecast based Flood Inundation Mapping

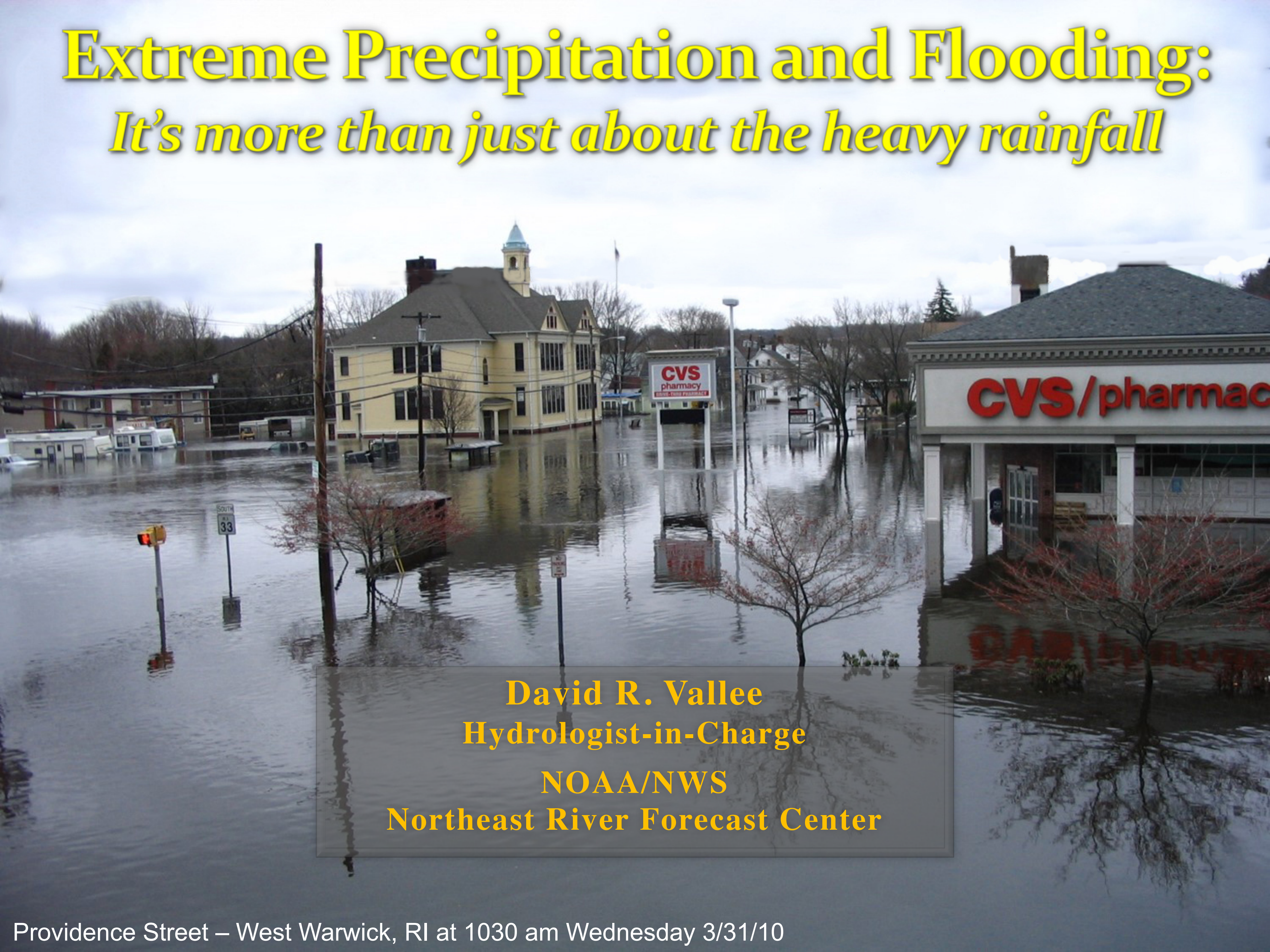
- For years partners via stakeholder engagements have asked for FIM services based on our forecasts
- Experiences with Harvey, Florence and the Midwest Floods illustrate utility
- Developed two approaches applying the Height At Nearest Drainage Method (HAND)
  - RFC forecast flows
  - NWM forecast flows
- “Don’t let perfection be the enemy of good”
- The journey will commence for New York and New England in FY20!





Extreme Precipitation and Flooding:

It's more than just about the heavy rainfall



David R. Vallee
Hydrologist-in-Charge
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Providence Street – West Warwick, RI at 1030 am Wednesday 3/31/10