The background image shows an aerial view of a dam breach at Blue Pond. A large circular area of water has been released from the dam, creating a distinct blue circle against the surrounding green landscape. The water is calm, reflecting the sky. The dam itself is visible as a white, curved structure at the top left.

# The Great RI Flood of 2010: A Hydrological Assessment

Dr. Tom Boving

University of Rhode Island

Member of the WPWA Board

# Overview

- A few words about statistics
- Preludes to a Disaster
- The 2010 Flood
- The Aftermath
- 2011 ...one year later
- The Future



WPWA Headquarters; Photo: Chris Fox

# 100 yr Rain event vs. 100 yr Flood

RI County	24-hour (Type III) Rainfall Amount (inches)						
	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Providence	<b>2.7</b>	<b>3.3</b>	<b>4.1</b>	<b>4.9</b>	<b>6.1</b>	<b>7.3</b>	<b>8.7</b>
	<b>2.7</b>	<b>3.3</b>	<b>4.2</b>	<b>4.8</b>	<b>5.6</b>	<b>6.2</b>	<b>7.0</b>
Newport	<b>2.8</b>	<b>3.3</b>	<b>4.1</b>	<b>4.9</b>	<b>6.1</b>	<b>7.3</b>	<b>8.6</b>
	<b>2.7</b>	<b>3.4</b>	<b>4.3</b>	<b>4.9</b>	<b>5.7</b>	<b>6.3</b>	<b>7.1</b>
Bristol	<b>2.8</b>	<b>3.3</b>	<b>4.1</b>	<b>4.9</b>	<b>6.1</b>	<b>7.3</b>	<b>8.6</b>
	<b>2.7</b>	<b>3.4</b>	<b>4.3</b>	<b>4.9</b>	<b>5.7</b>	<b>6.3</b>	<b>7.1</b>
Kent	<b>2.7</b>	<b>3.3</b>	<b>4.1</b>	<b>4.8</b>	<b>6.2</b>	<b>7.3</b>	<b>8.7</b>
	<b>2.7</b>	<b>3.4</b>	<b>4.3</b>	<b>4.9</b>	<b>5.7</b>	<b>6.3</b>	<b>7.1</b>
Washington	<b>2.8</b>	<b>3.3</b>	<b>4.1</b>	<b>4.9</b>	<b>6.1</b>	<b>7.2</b>	<b>8.5</b>
	<b>2.7</b>	<b>3.4</b>	<b>4.3</b>	<b>4.9</b>	<b>5.7</b>	<b>6.3</b>	<b>7.1</b>

Updated values  
Previous values

100 yr Rain

# A few words about Flood Statistics

- “100-year flood” is misleading!
- ***Recurrence interval:*** the probability that a given event will be equaled or exceeded in any given year.
  - Better: “...a flood having a 100-year recurrence interval.”
  - **Plain English:** “a flood of that magnitude has a 1 percent chance of happening in any year.”

# "100-year floods can happen twice in a year"

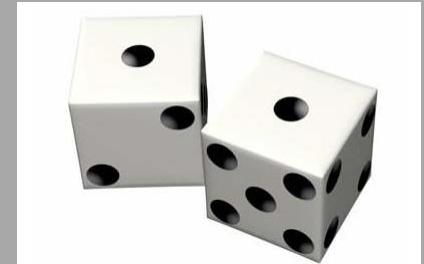
- What are the odds of that happening?
- Answer: 0.01% chance of recurrence

Example:  
Pawtuxet River at Cranston

Historical Crests	
(1)	20.79 ft on 03/31/2010
(2)	14.98 ft on 03/15/2010
(3)	14.50 ft on 06/07/1982
(4)	13.68 ft on 10/15/2005
(5)	13.26 ft on 01/26/1979

# "100-year floods can happen twice in a year"

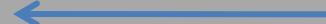
- Well,...2010 must have been RI's "lucky" year then!



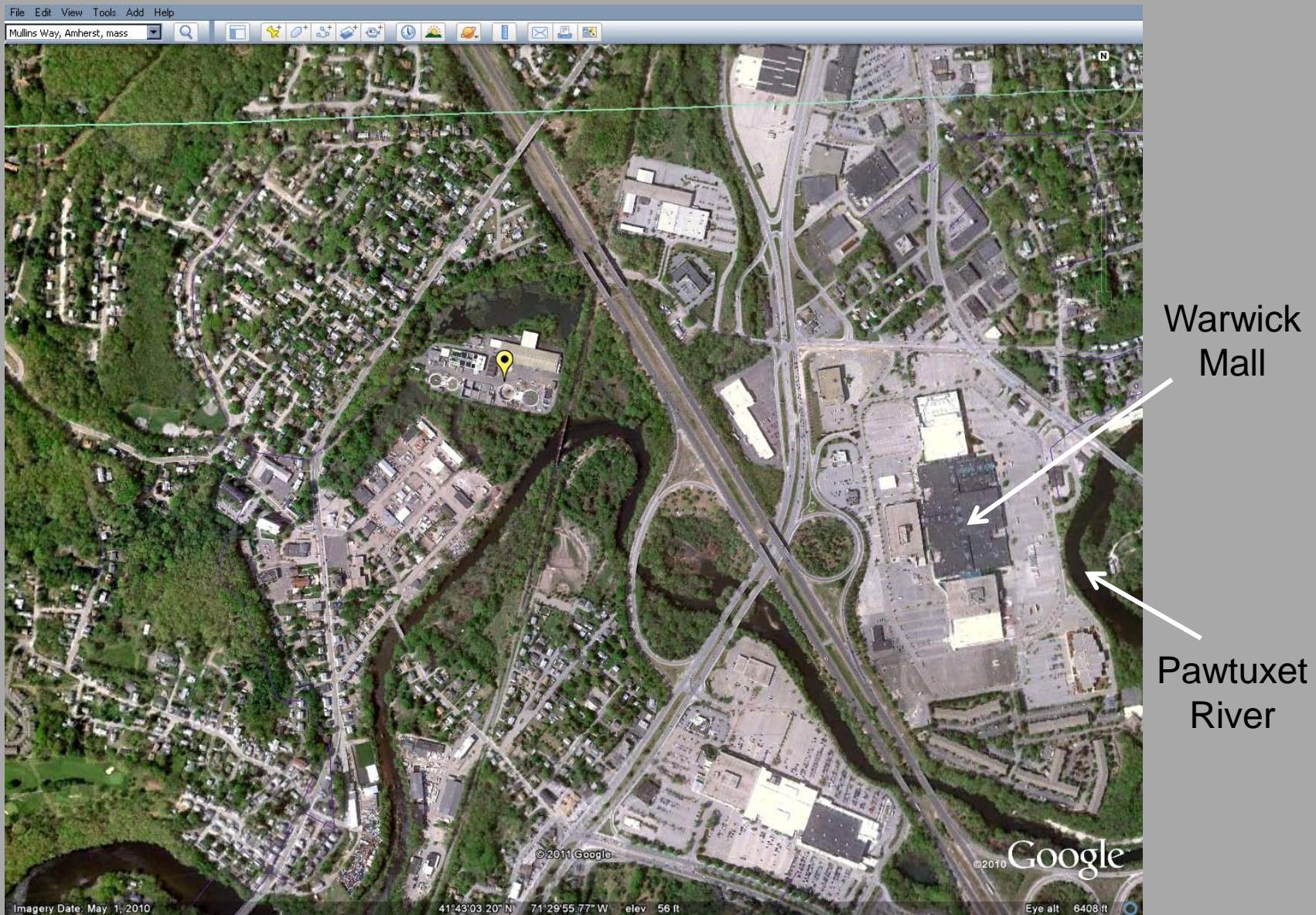
# What about a 500-year flood?

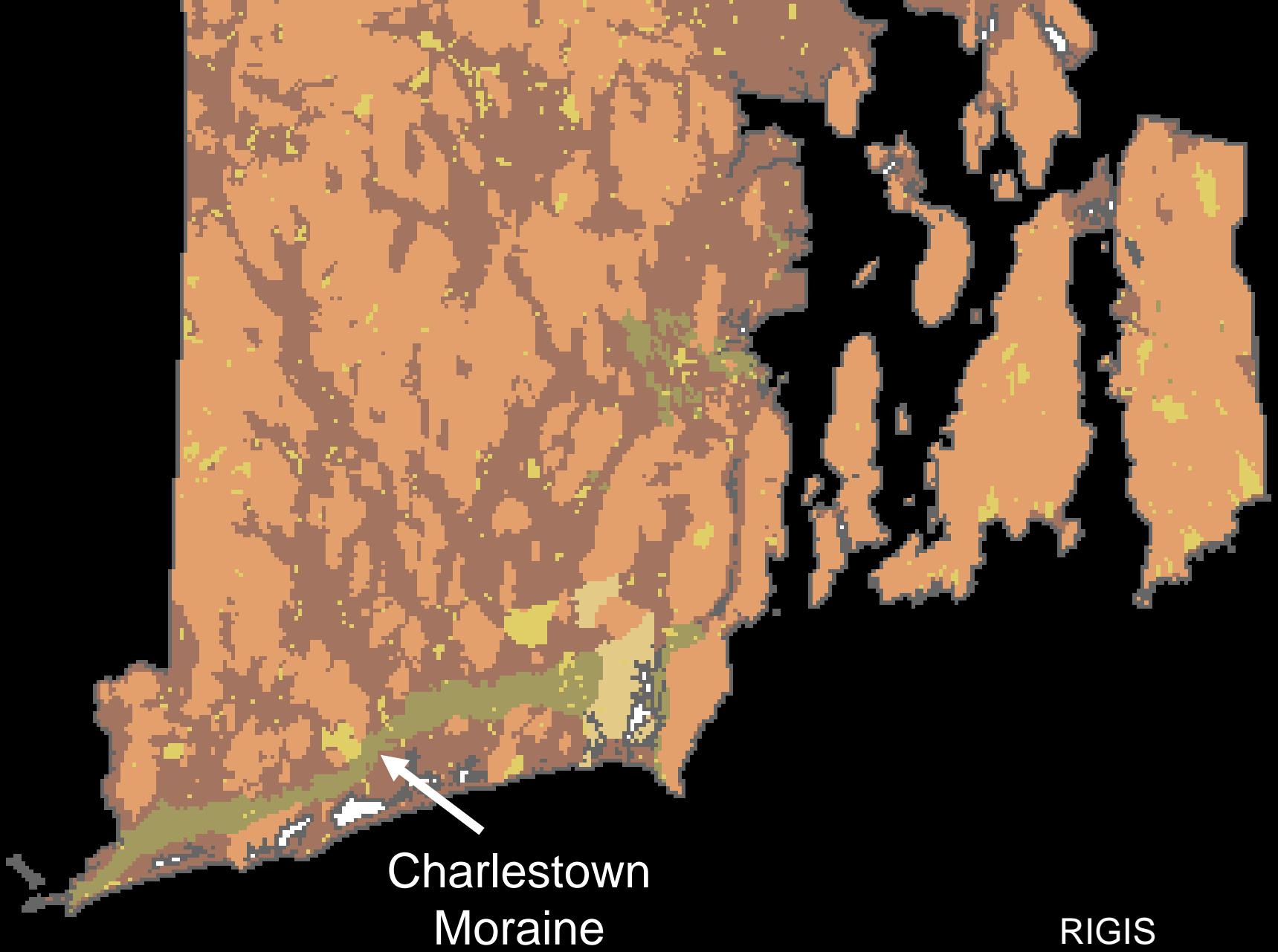
- The probability of a 500-year flood in any given year is 0.2 %.
- Compared to winning the lottery, those odds are actually pretty high...

$$P(a) = \left[ \frac{\sum_{i=0}^{a-1} \left( \frac{1-p}{p} \right)^i}{\sum_{i=0}^{a+b-1} \left( \frac{1-p}{p} \right)^i} \right]$$

 This will be on the test.

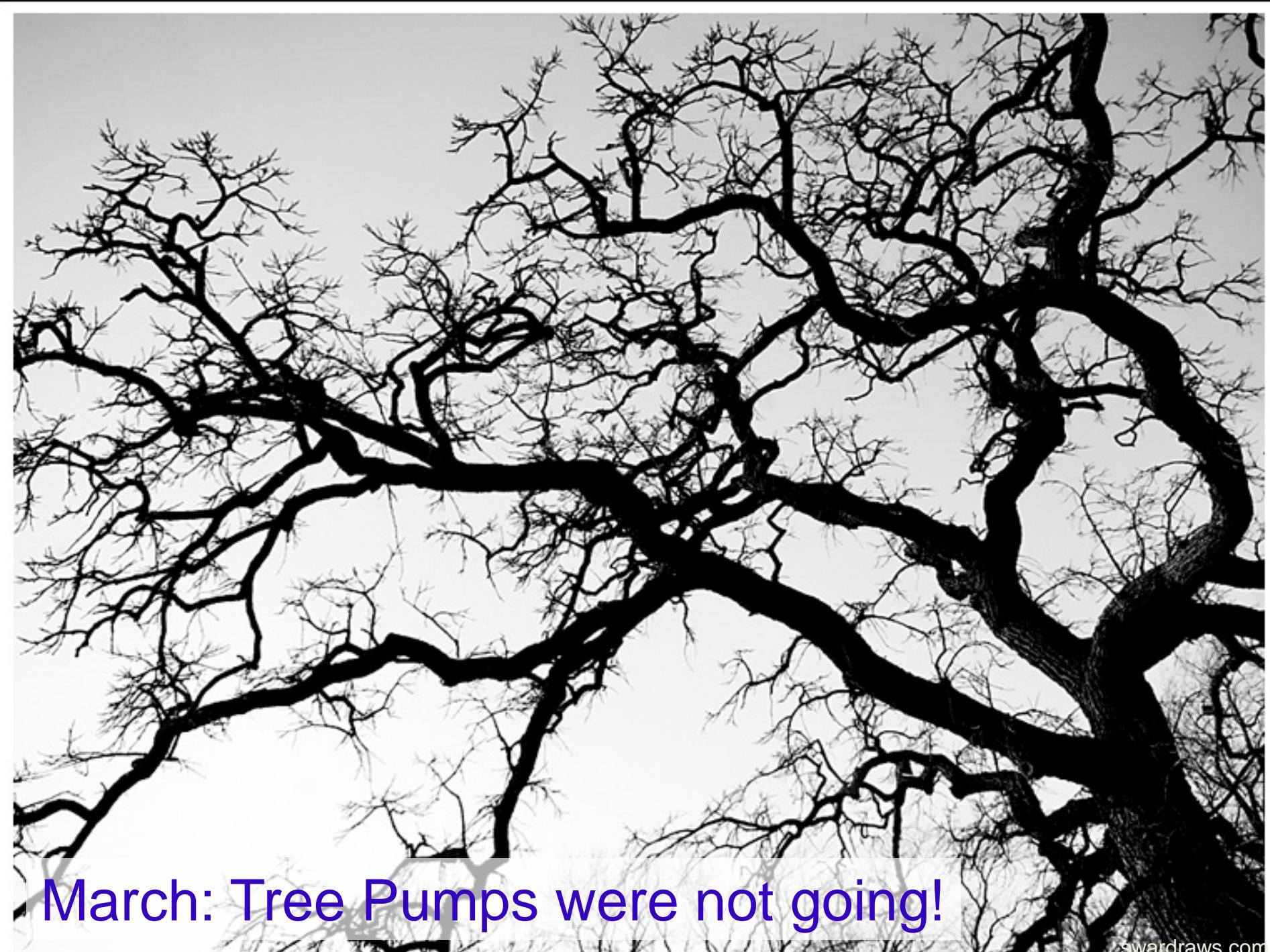
# But it's not all about rain amounts!





Charlestown  
Moraine

RIGIS  
Glacial Geology Map



March: Tree Pumps were not going!

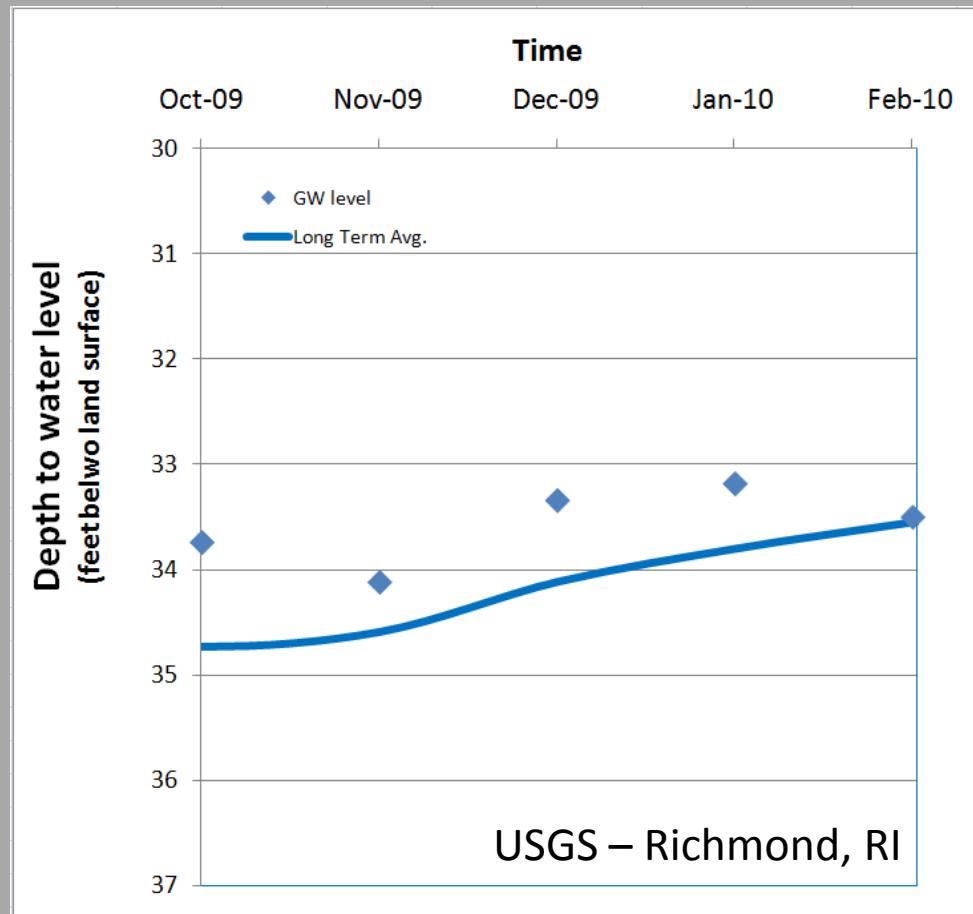
# Preludes

Horseshoe Dam, Pawcatuck River in Shannock; Photo: Chris Fox

# Groundwater Conditions

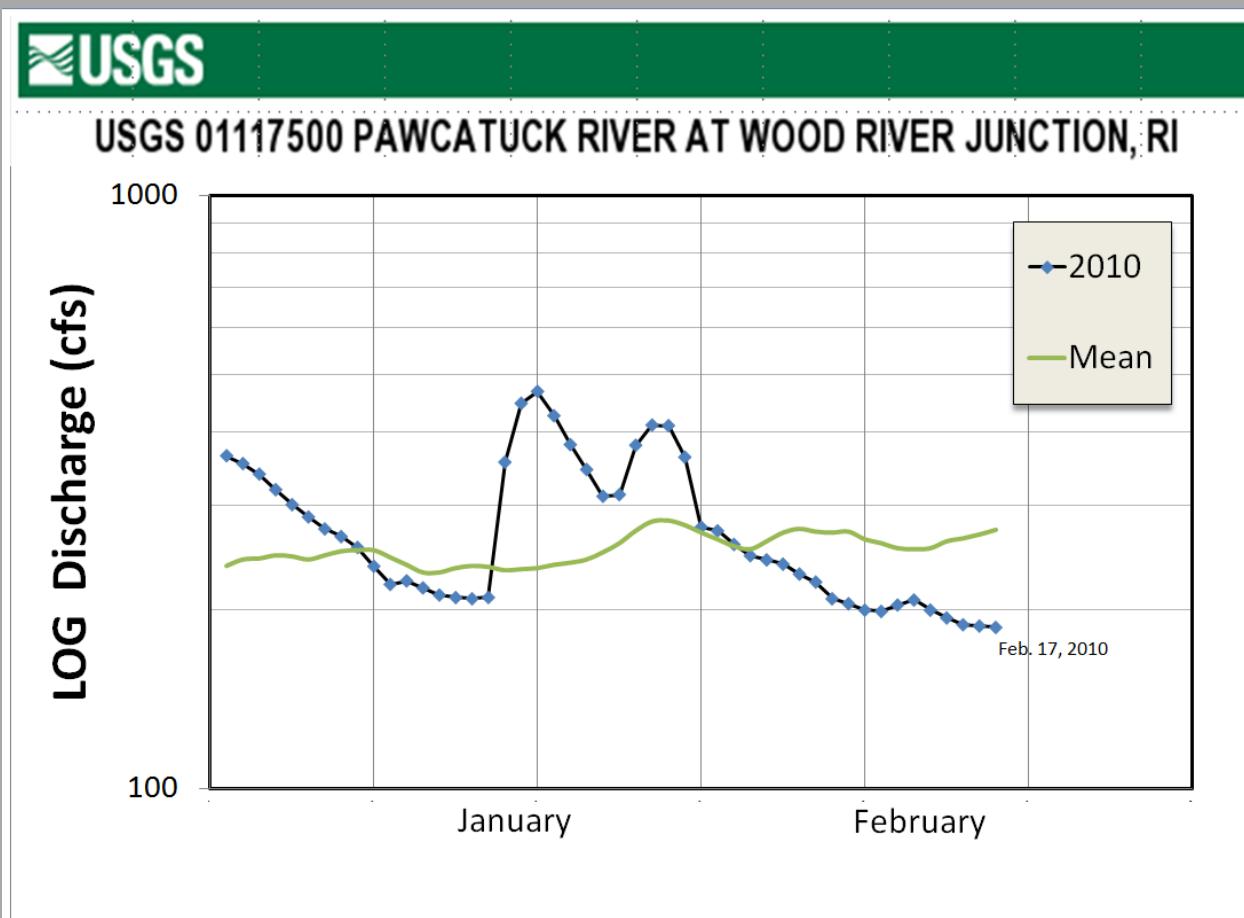
Feb. 2010:

USGS designated RI groundwater levels generally as above normal, with the exception of the eastern RI which was generally designated as normal.



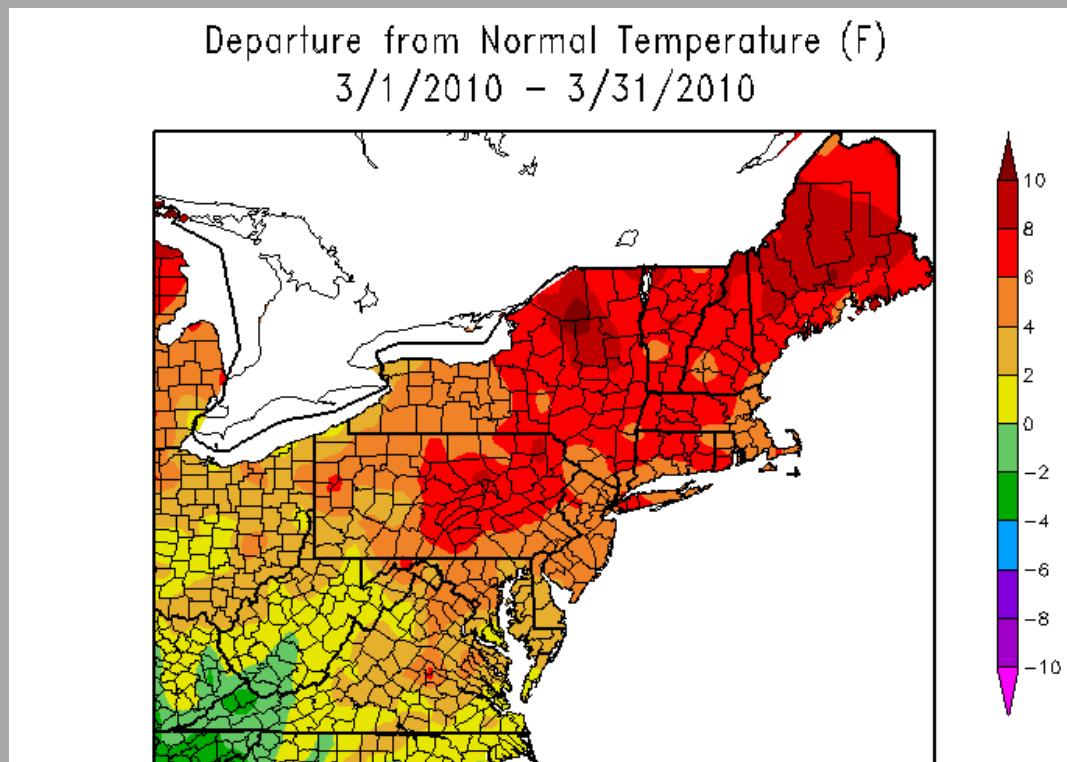
# Wood River

Mid Feb. 2010: RI rivers run near or blow normal



# Temperatures

March 2010 temperatures in the Northeast averaged 40.2 degrees F ( $4.6^{\circ}\text{C}$ ), which was 5.5 degrees F ( $3.1^{\circ}\text{C}$ ) **above** normal.

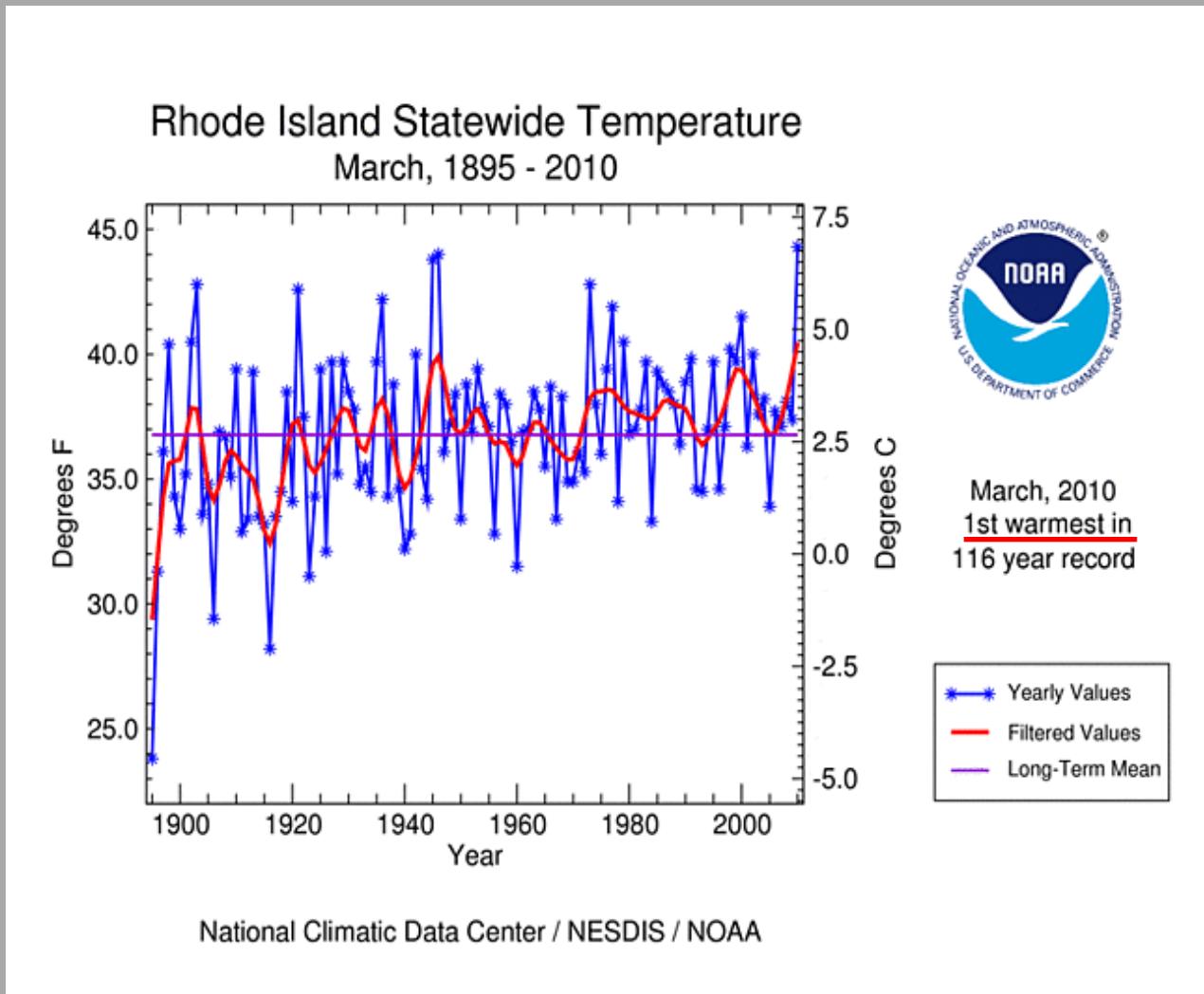


Generated 11/23/2010 at HPRCC using provisional data.

Regional Climate Centers

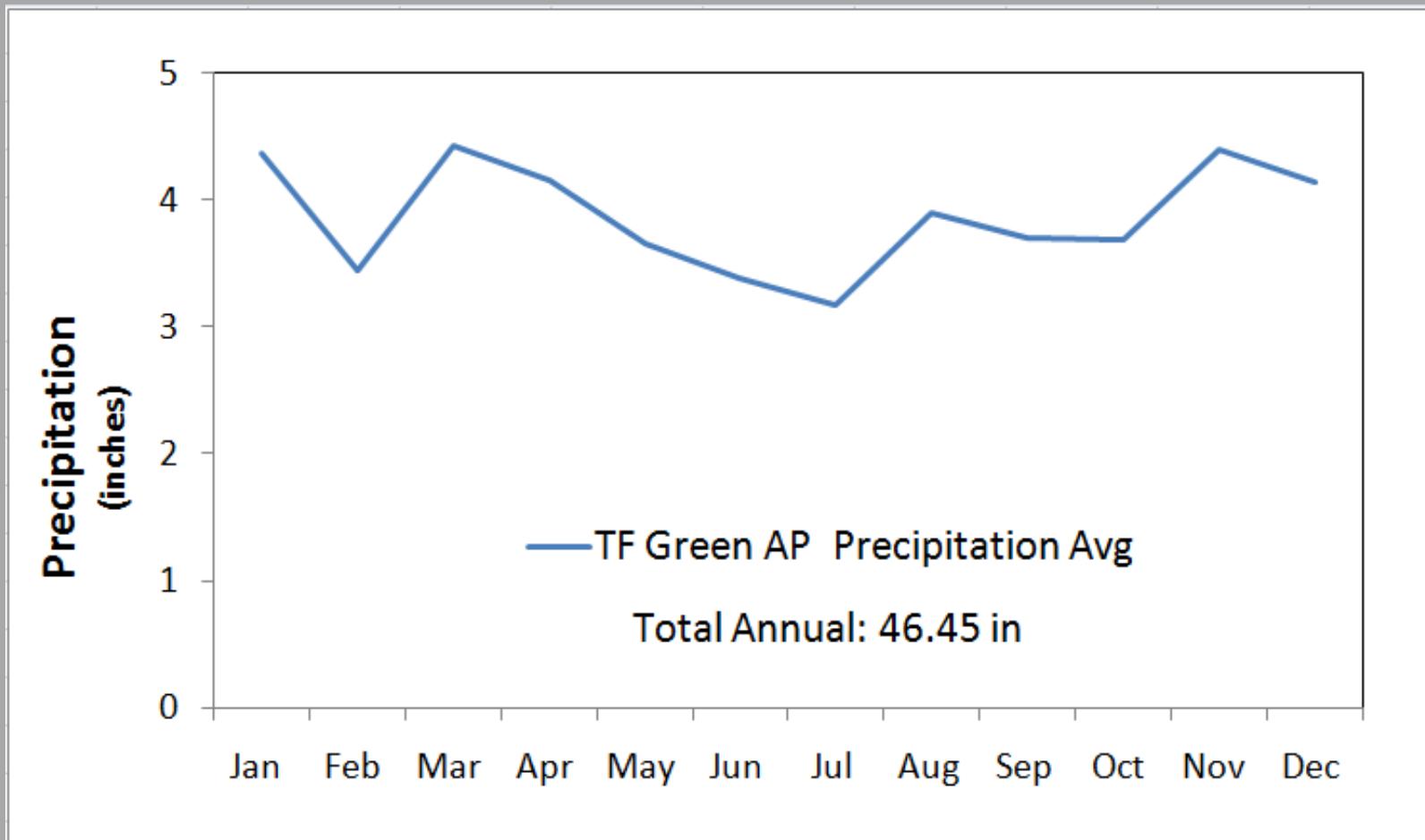
<http://www.hprcc.unl.edu/products/maps/acis/nrcc/Mar10TDeptNRCC.png>

# March 2010: Warmest on record in RI.



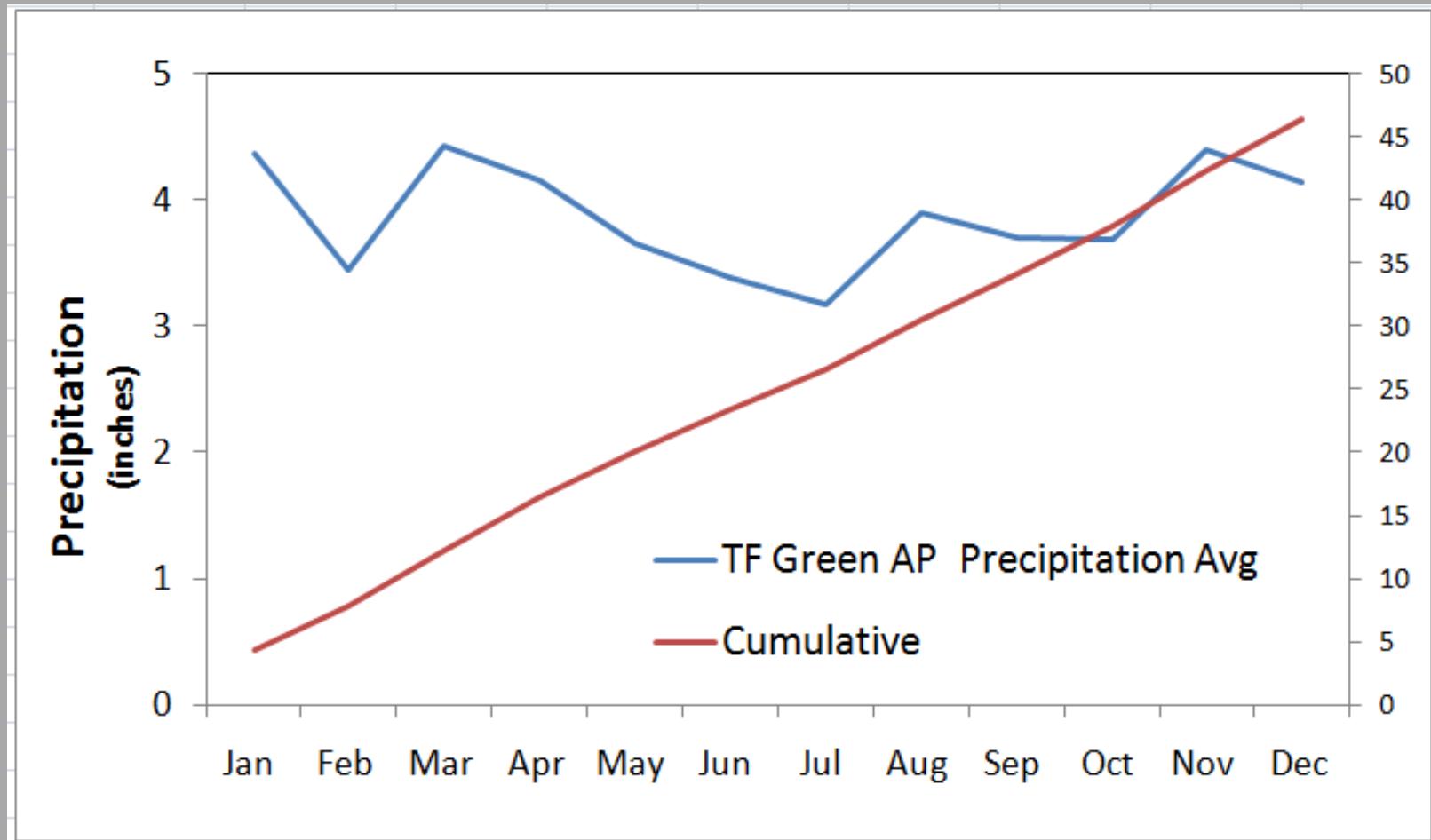
# “Normal” Precipitation

(Average per month: 3.87 in)



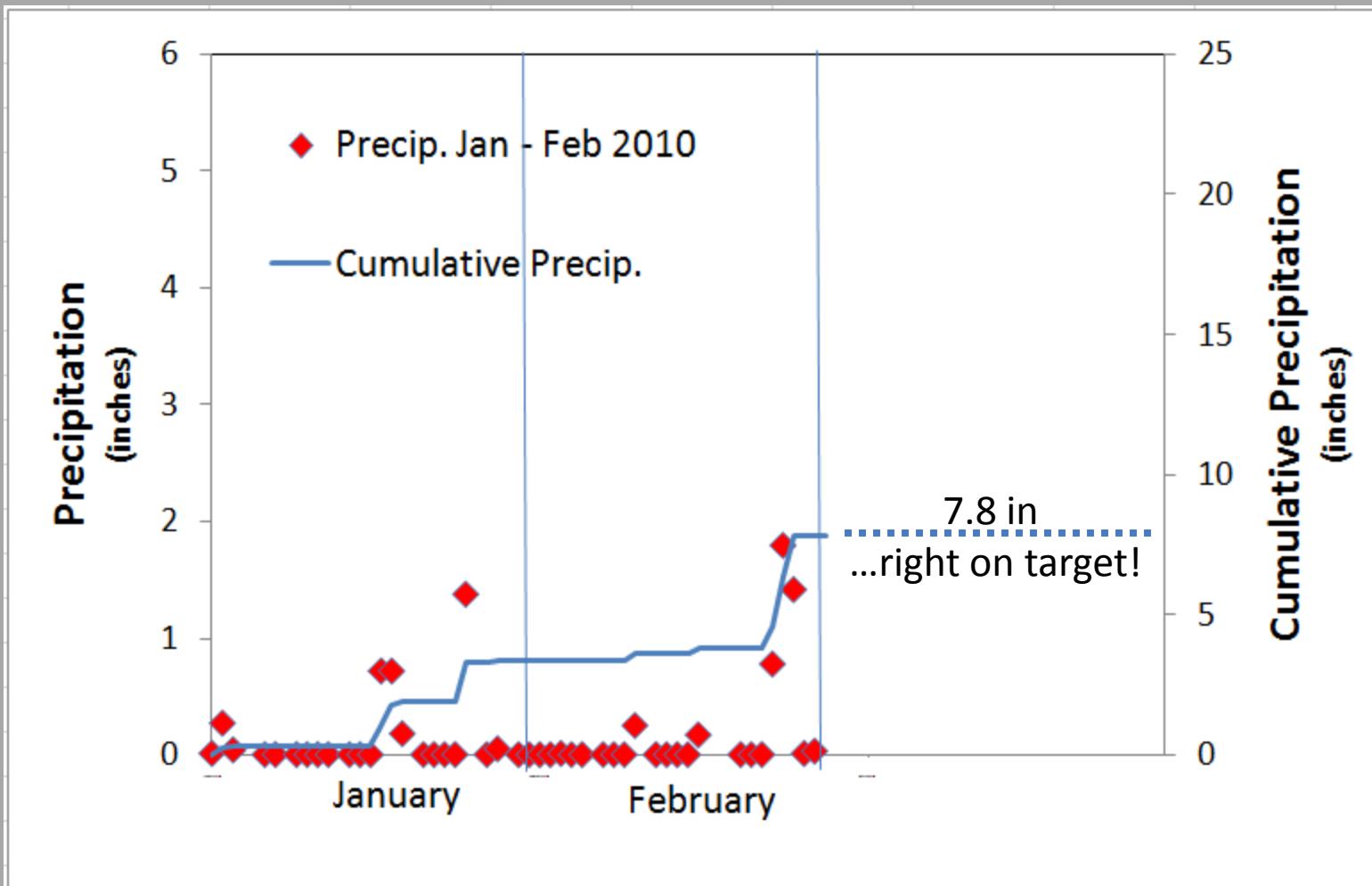
# “Normal” Precipitation

(Annual Total: 46.45 in)



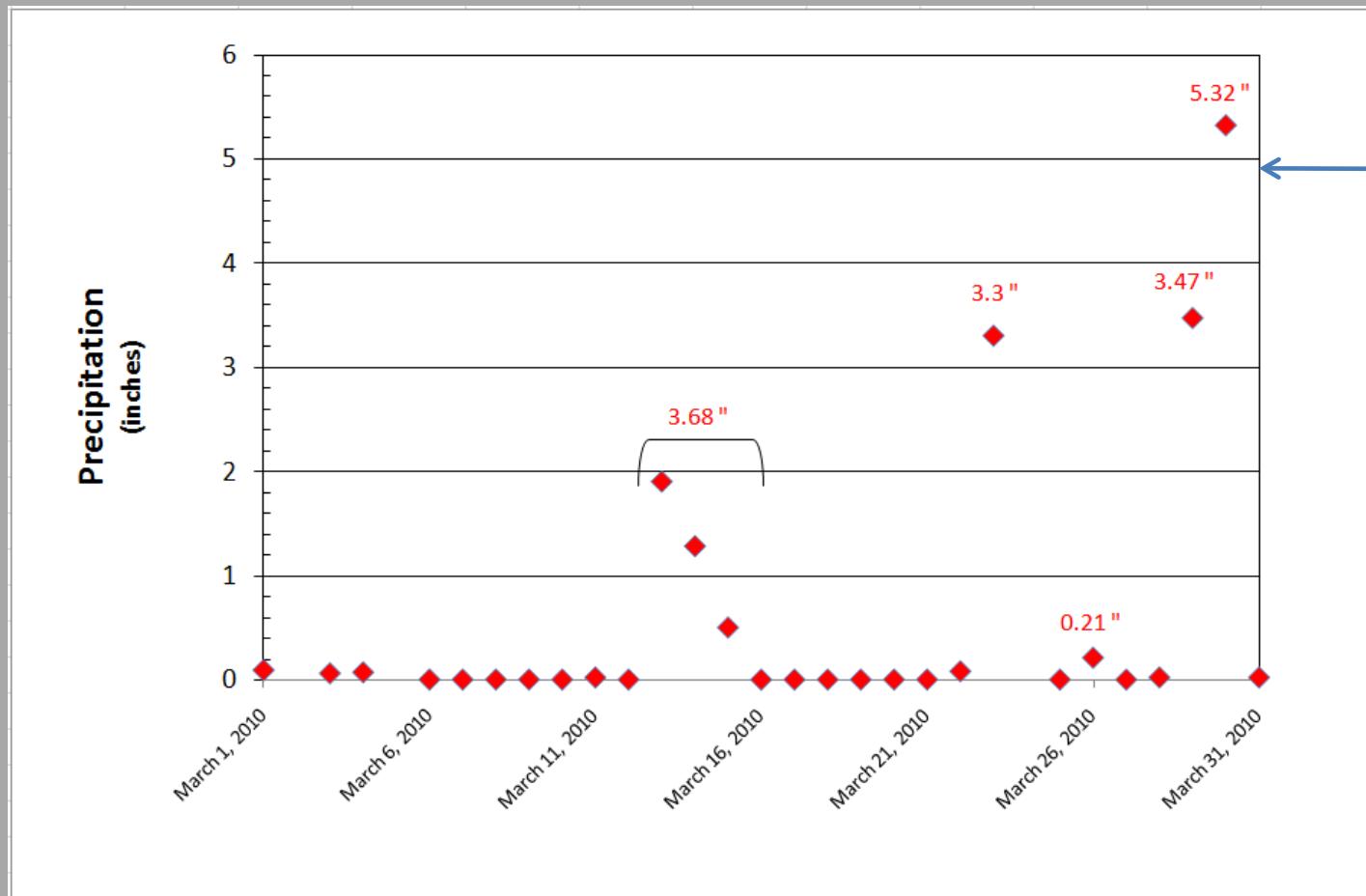
# 2010 Precipitation

## (TF Green AP)



...and then March '10 came around

# March 2010: ...nothing special, or?



Gage: TF Greene

Recall:

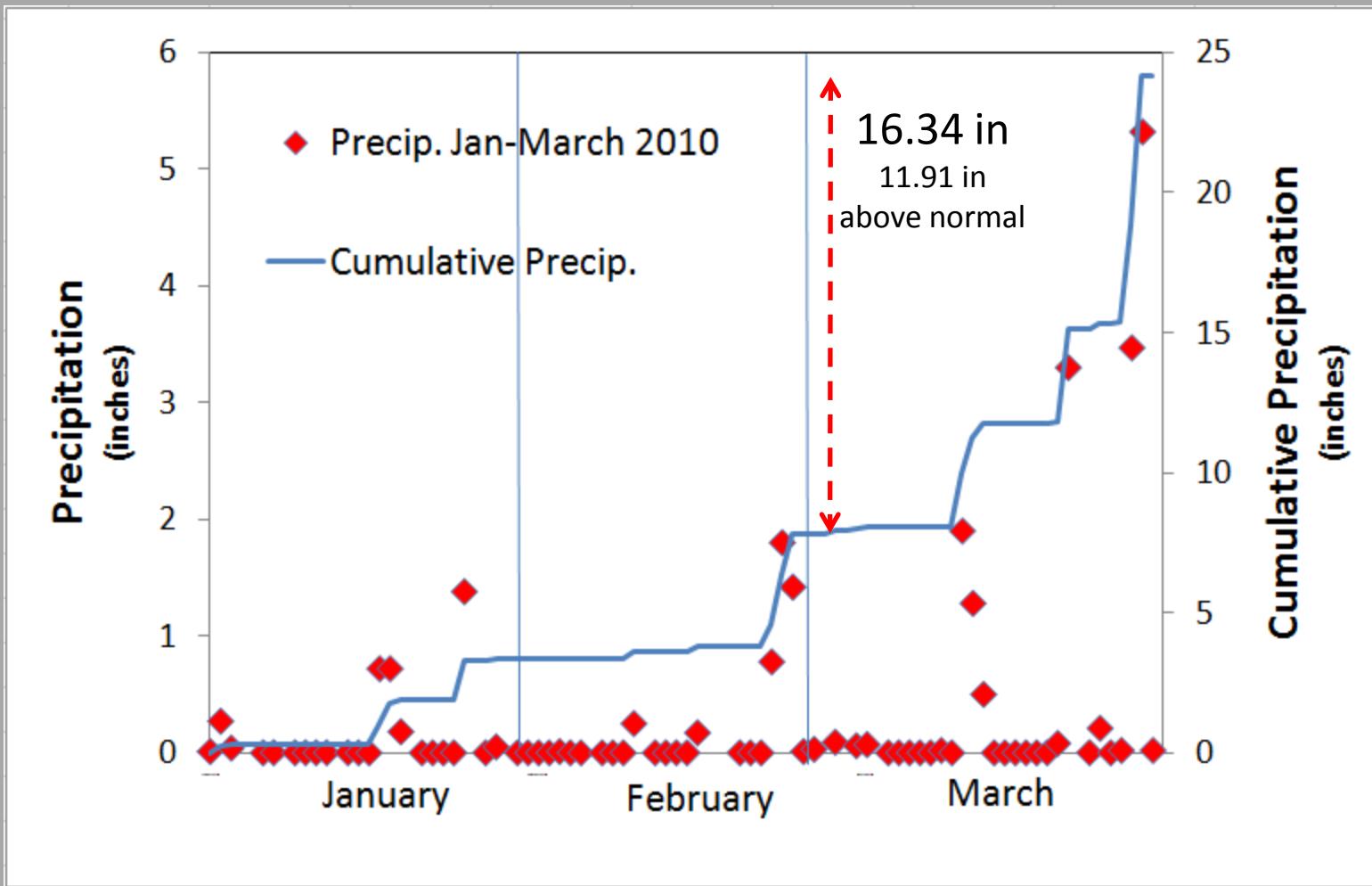
4.9" = 10 yr storm  
(Washington County)

March total

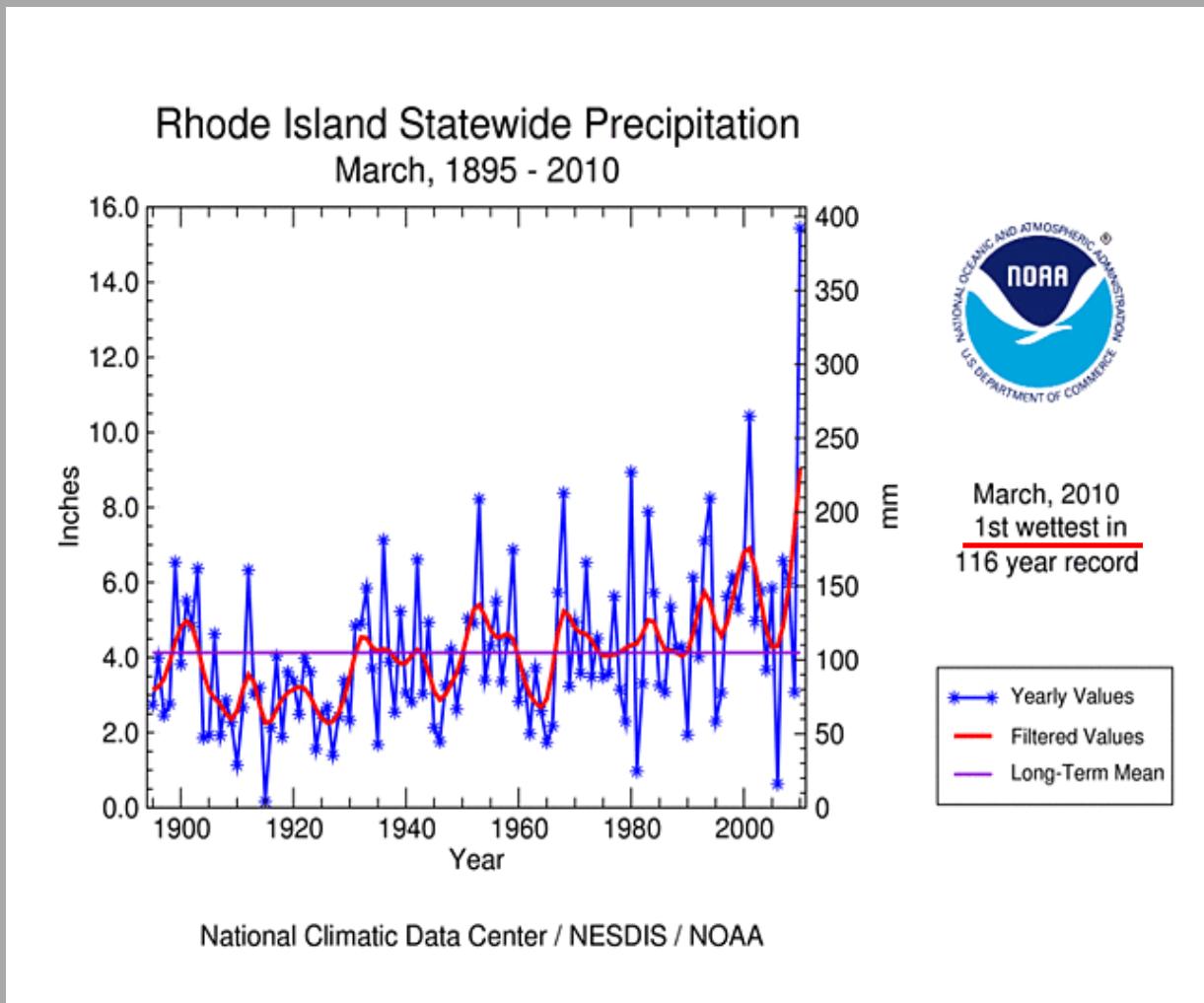
**16.34"**  
during three  
major storms

# 2010 Precipitation

## (TF Green AP)



# March 2010: Record Precipitation

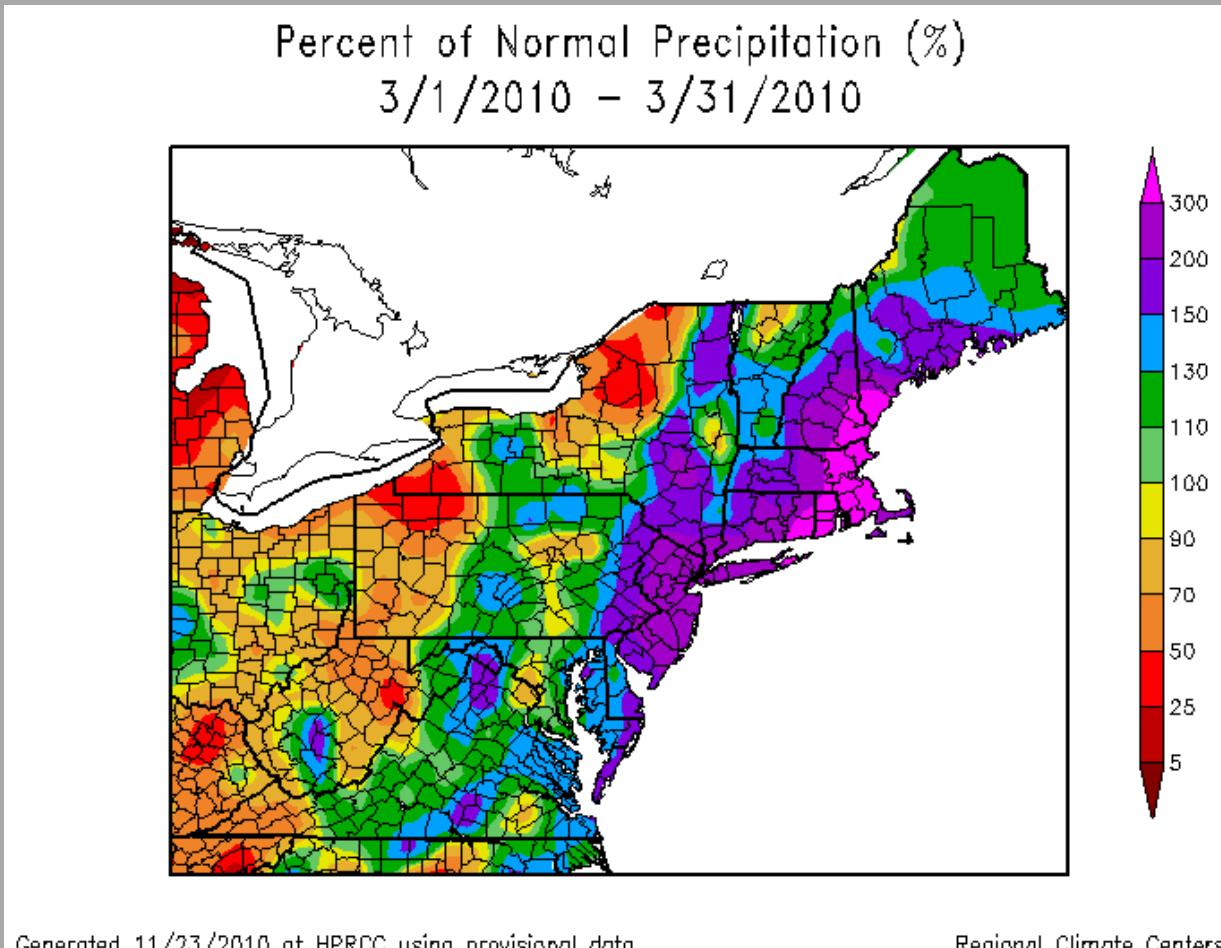


Precipitation departures for the month was **331% of normal** in Rhode Island.

# Northeast in March 2010

## 331% above normal precipitation

### ...that's not good!



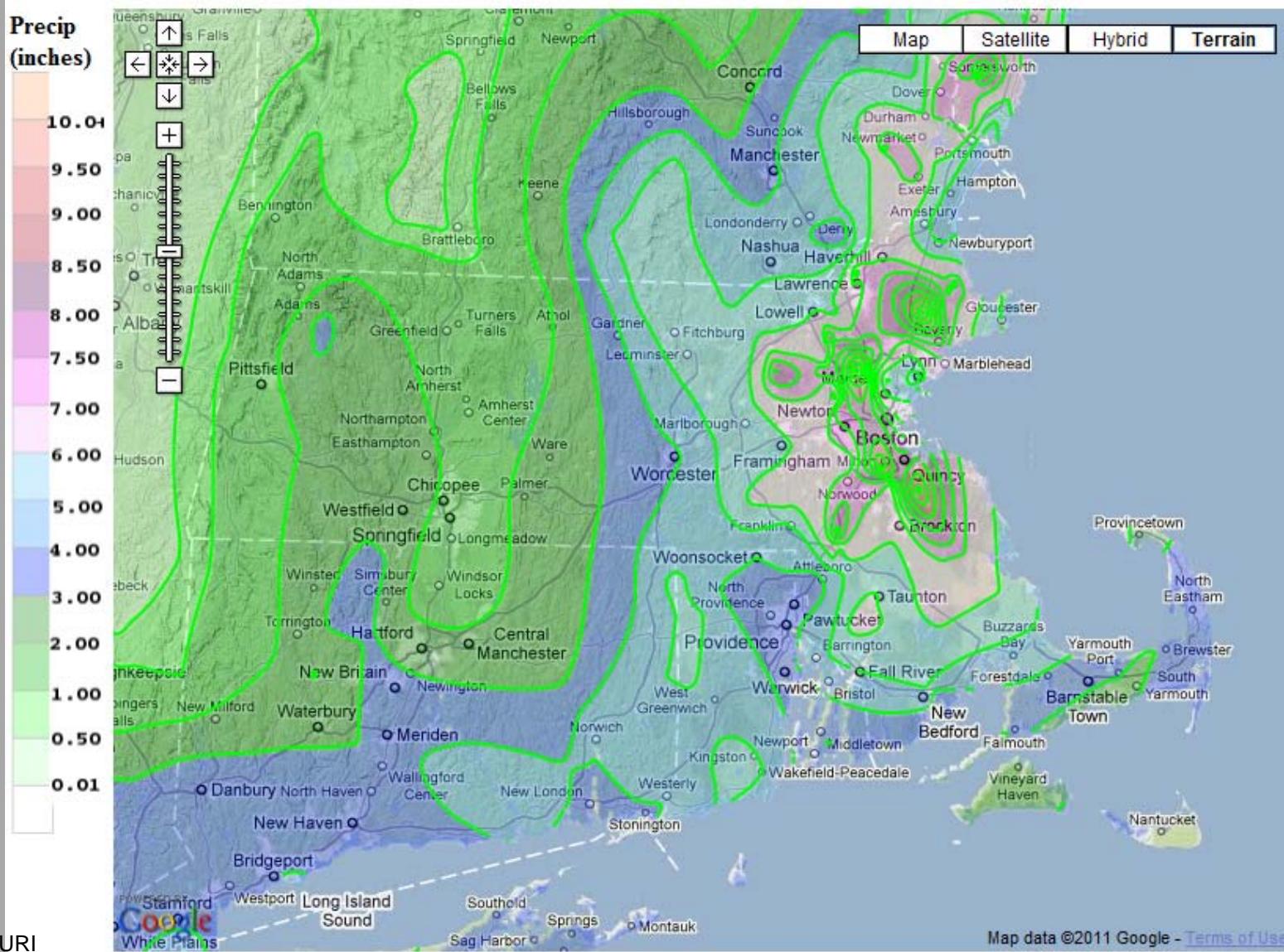
Three storms...one big disaster.

NWS Taunton, MA - Significant Weather Event

**Storm I** Mar 13-15, 2010

Source: NOAA

<http://www.erh.noaa.gov/box/pnsevents/wxeventsCalendar.php?month=12&year=2010>



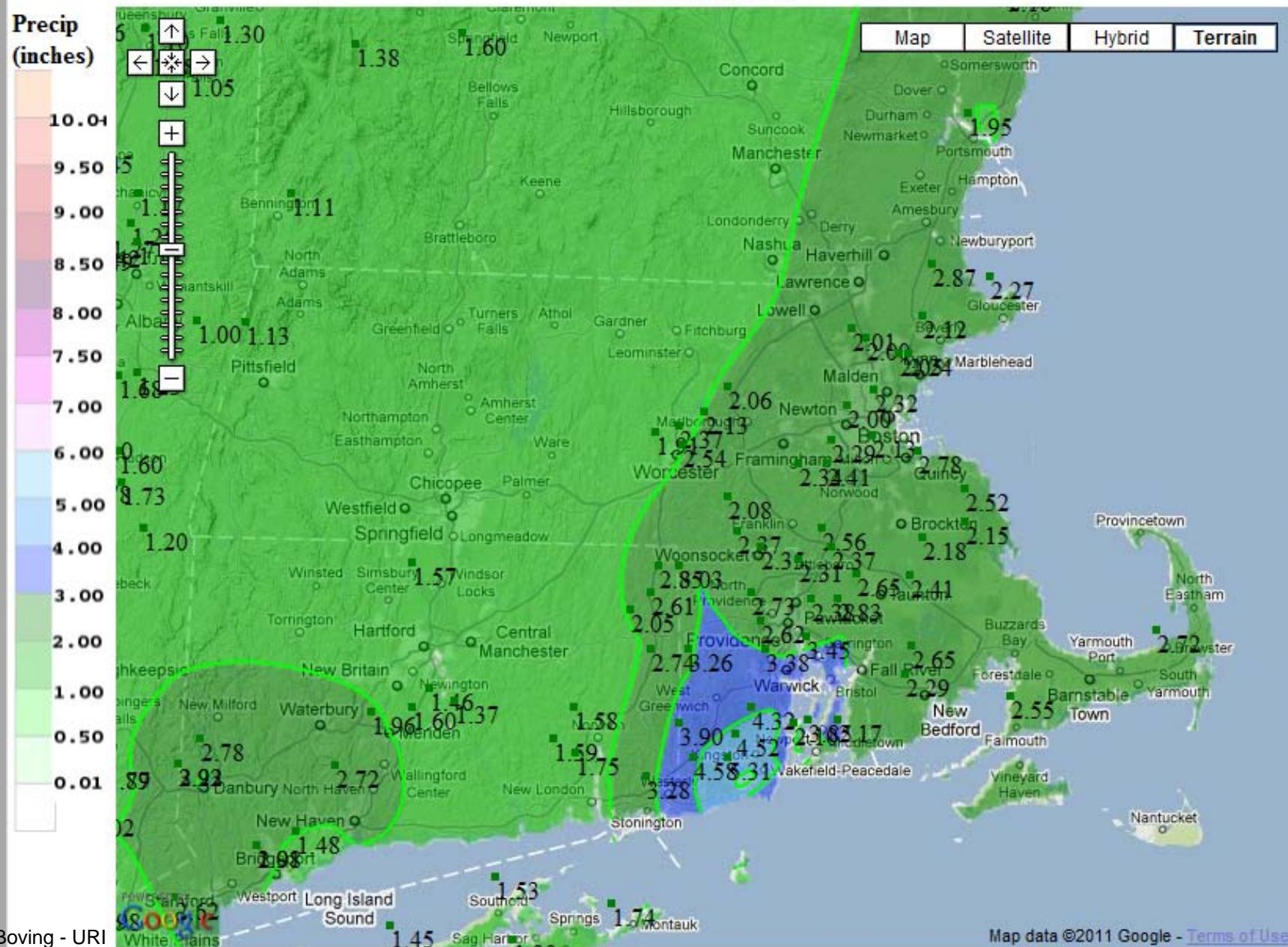
The first round of storms left Boston with a monthly total of 7.45 inches; Bridgeport, Conn. at 4.02 inches; and Portland, Maine reported 3.57 inches of rain.

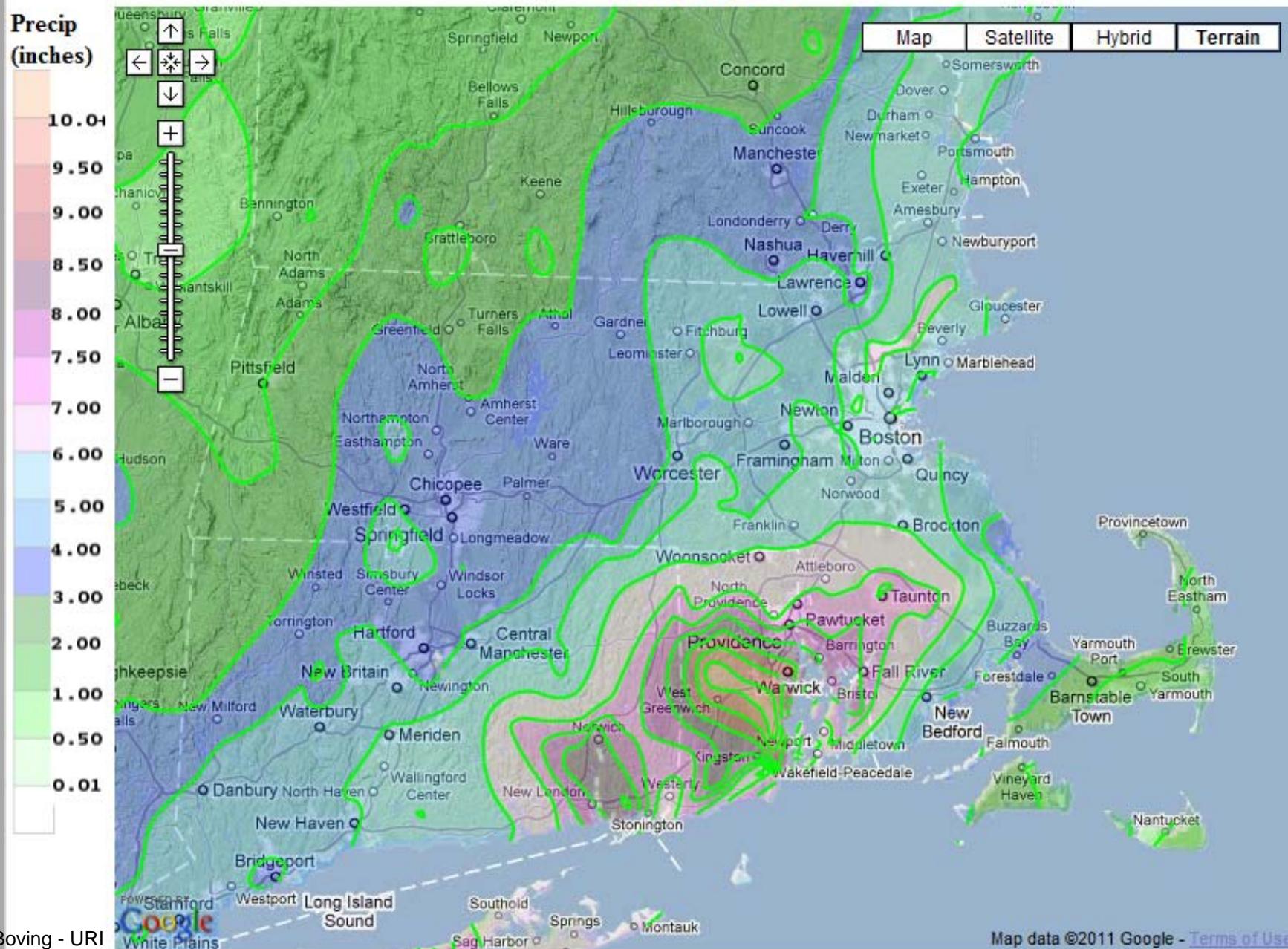
...but that was just the beginning!

# NWS Taunton, MA - Significant Weather Event

Source: NOAA

## Storm II Mar 22-23, 2010



**Storm III Mar 29-30, 2010**

# View from Space

- The video shows GOES observations from March 21 through 31, 2010.
- **Credit:** NASA/GOES Project



[http://www.nasa.gov/mp4/438231main\\_100321-31.floods.mp4](http://www.nasa.gov/mp4/438231main_100321-31.floods.mp4)



# The Flood

A photograph of a flooded street. The water covers the entire lower half of the frame, reflecting the clear blue sky above. In the background, a dense line of bare trees stands along the edge of the floodwater. On the far left, a utility pole with several wires is partially submerged. The overall scene conveys a sense of a major flooding event.

Route 91 @ Bradford  
Photograph by: Tom Tetzner

# USGS calls RI River Flows “Historic”

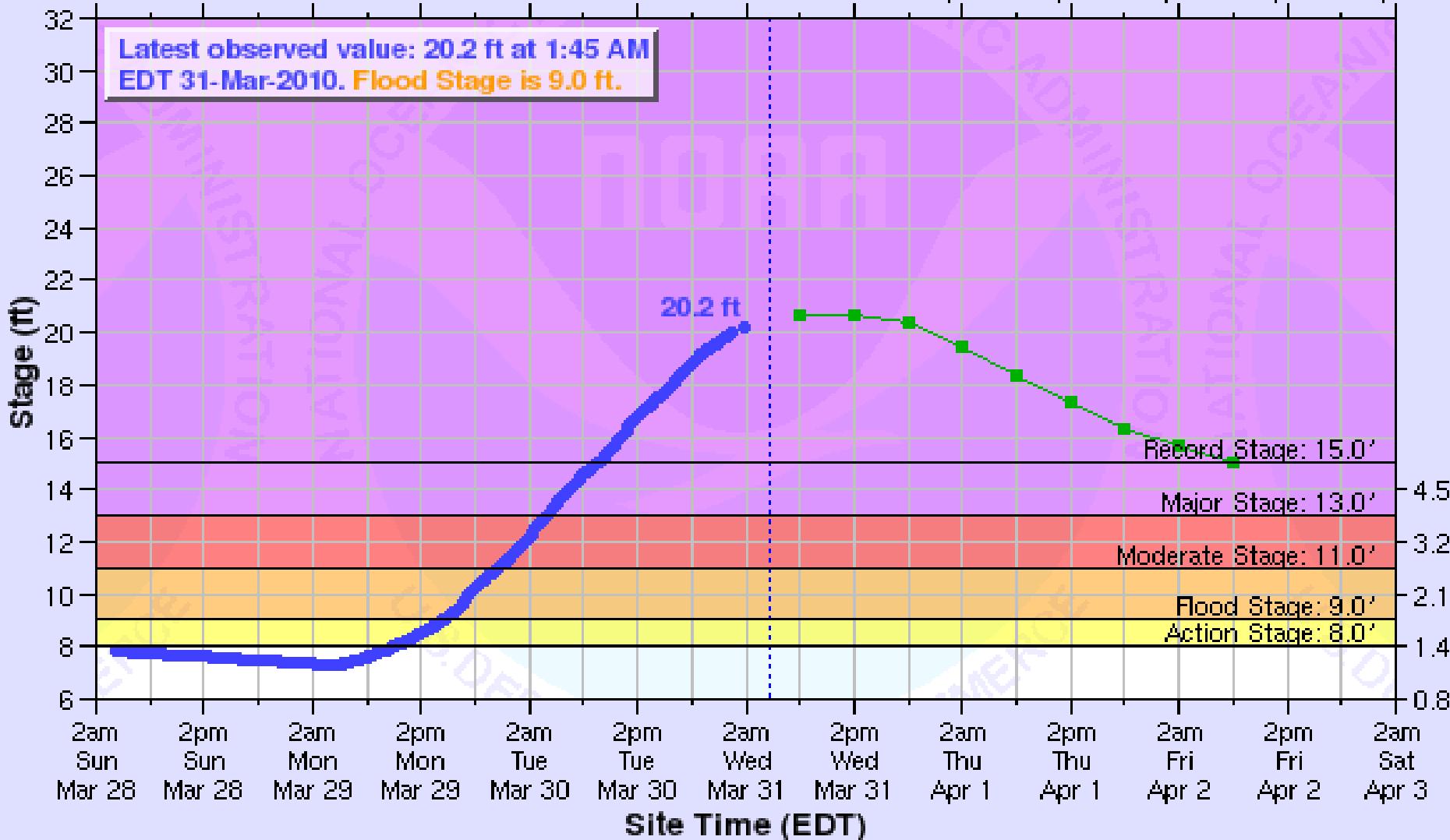
- 22 of the 27 long-term network streamgages that measure the state’s rivers and streams exceeded their previous period of record peaks.
  - The Pawtuxet River at Cranston sets new records, exceeding the 9.00 foot flood stage by 11.79 feet and flow (14,100 cfs) versus the previous records of 5.50 feet above flood stage and 5,440 cfs of flow set in 1982.
  - The Pawcatuck River at Westerly also set a new record for flow at 9,390 cfs versus the previous record of 7,070 cfs set in 1982.
  - The Blackstone River at Woonsocket exceeded its 9 foot flood stage by 5.5 feet and had a preliminary peak flow of 14,900 cfs.

# PAWTUXET RIVER AT CRANSTON

Universal Time (UTC)

Source: B Patenaude, RI DEM

06Z Mar 28	18Z Mar 28	06Z Mar 29	18Z Mar 29	06Z Mar 30	18Z Mar 30	06Z Mar 31	18Z Mar 31	06Z Apr 1	18Z Apr 1	06Z Apr 2	18Z Apr 2	06Z Apr 3
---------------	---------------	---------------	---------------	---------------	---------------	---------------	---------------	--------------	--------------	--------------	--------------	--------------



CRAR1 (plotting HGIRG) "Gage 0" Datum: 8.00'

Observations courtesy of the US Geological Survey

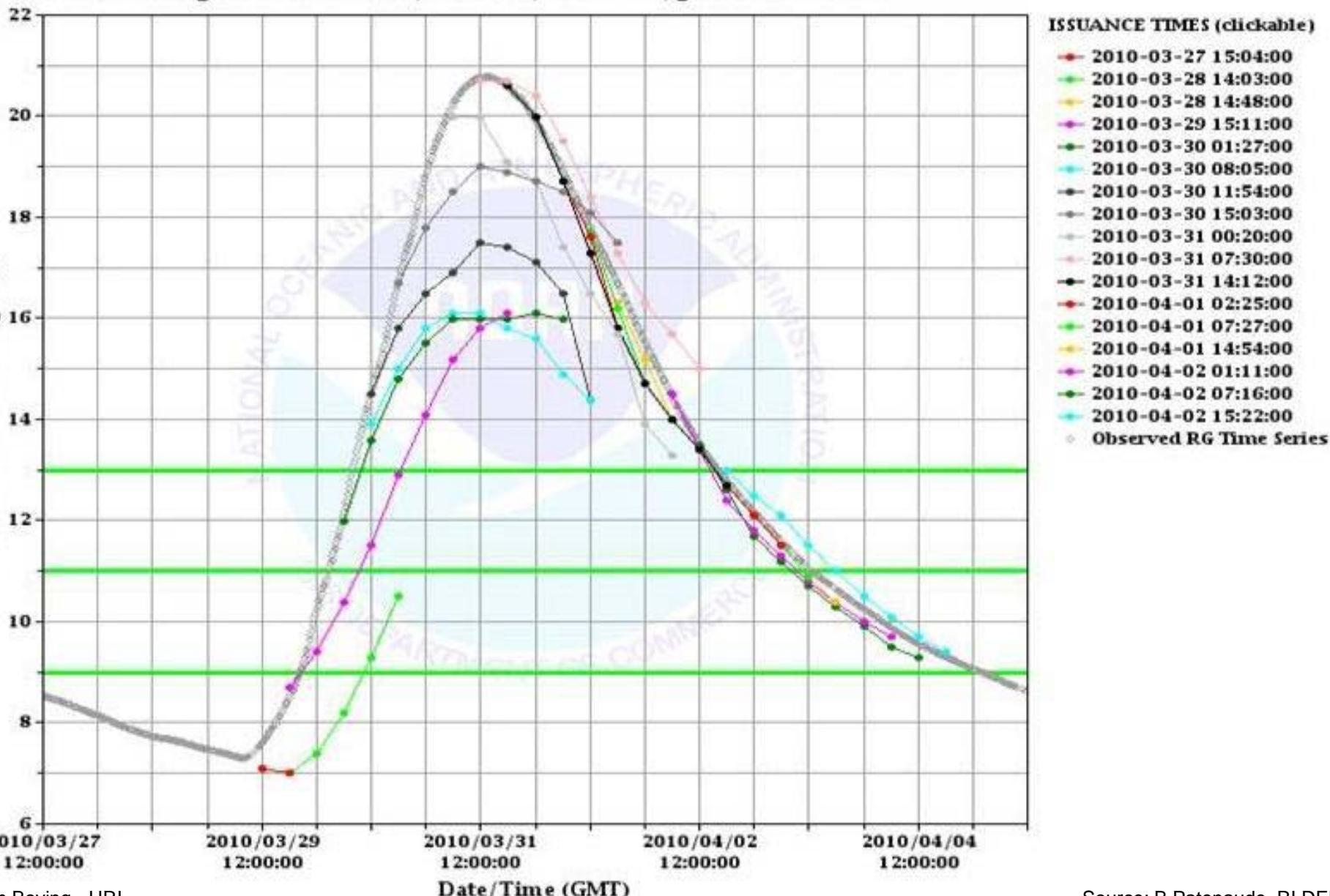
# Plot of Forecast and Observed Instantaneous Height Time Series for NERFC

Time Period: 2010-03-29 12:00:00 GMT – 2010-04-05 12:00:00 GMT

Lead times: ALL

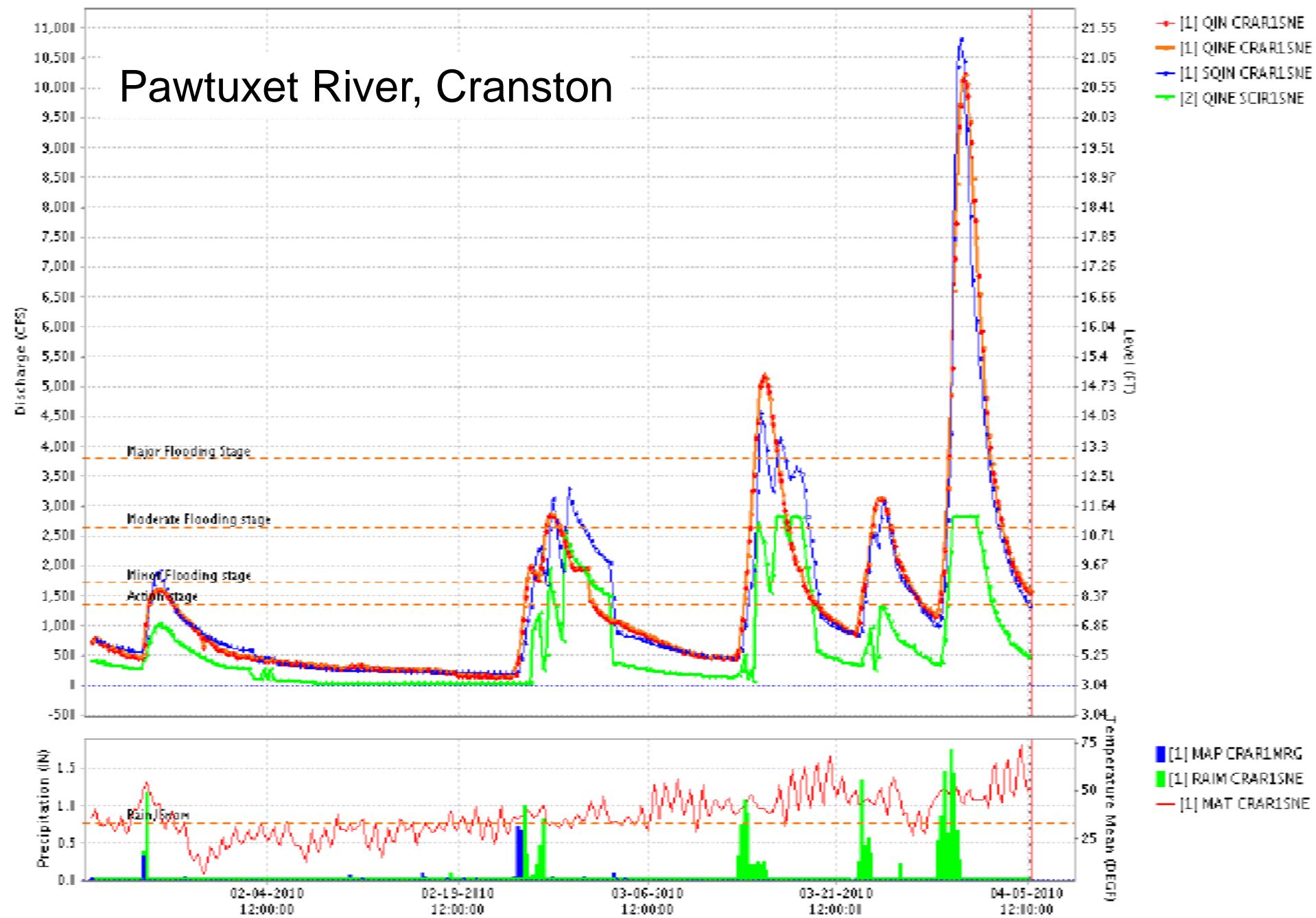
Location: Cranston [CRAR1(HGIFFZZ)]

Forecast Categories: less than 9.0, 9.0 - 11.0, 11.0 - 13.0, greater than 13.0 ft



# CRAR1SNE\_Flow

## Pawtuxet River, Cranston

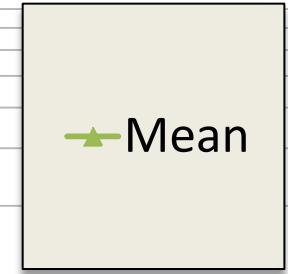
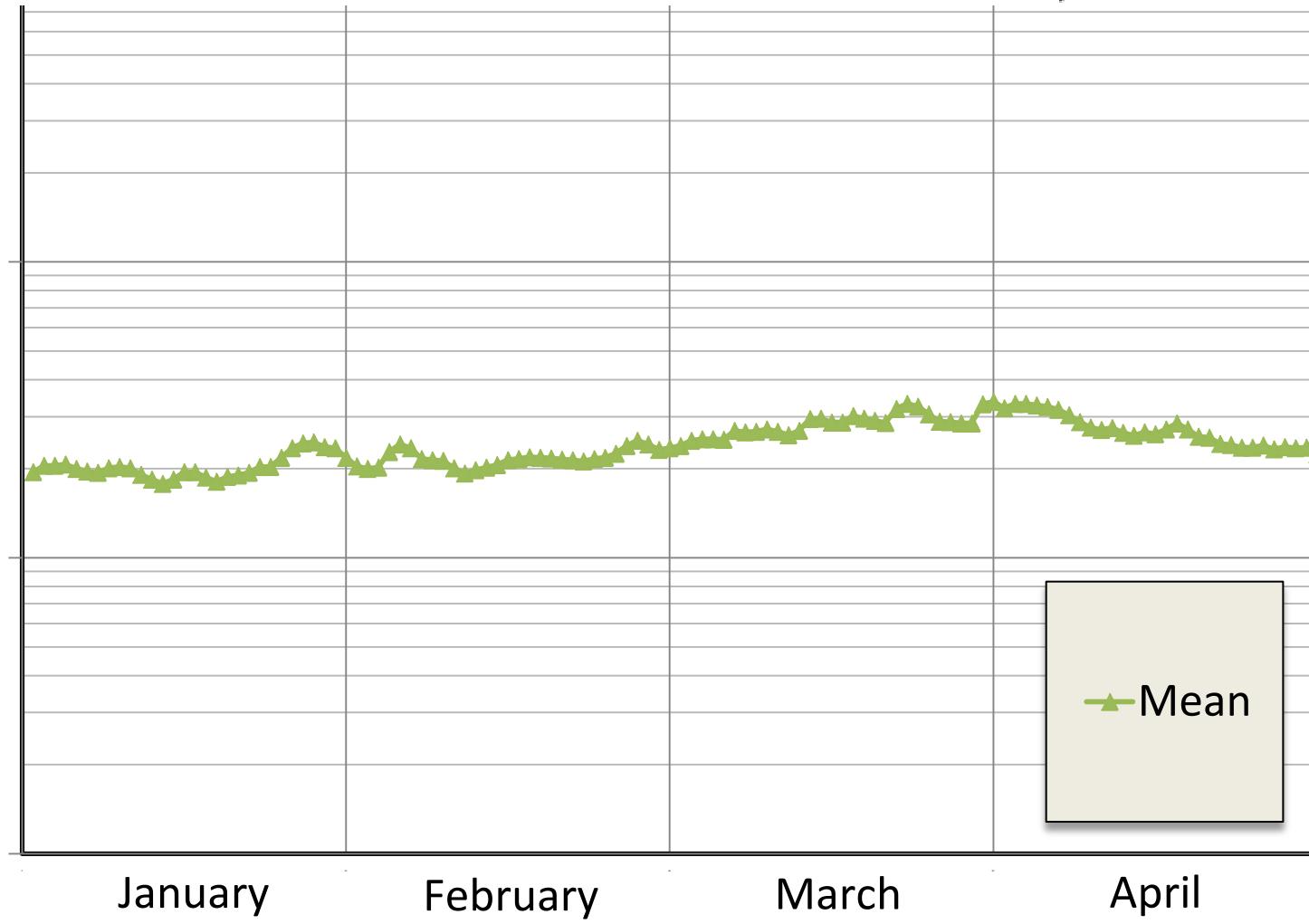


[1] 04-05-2010 18:00:00 Current CRAR1SNE\_Forecast [2] 04-05-2010 18:00:00 Current SCIR1SNE\_Forecast

Source: B Patenaude, RI DEM

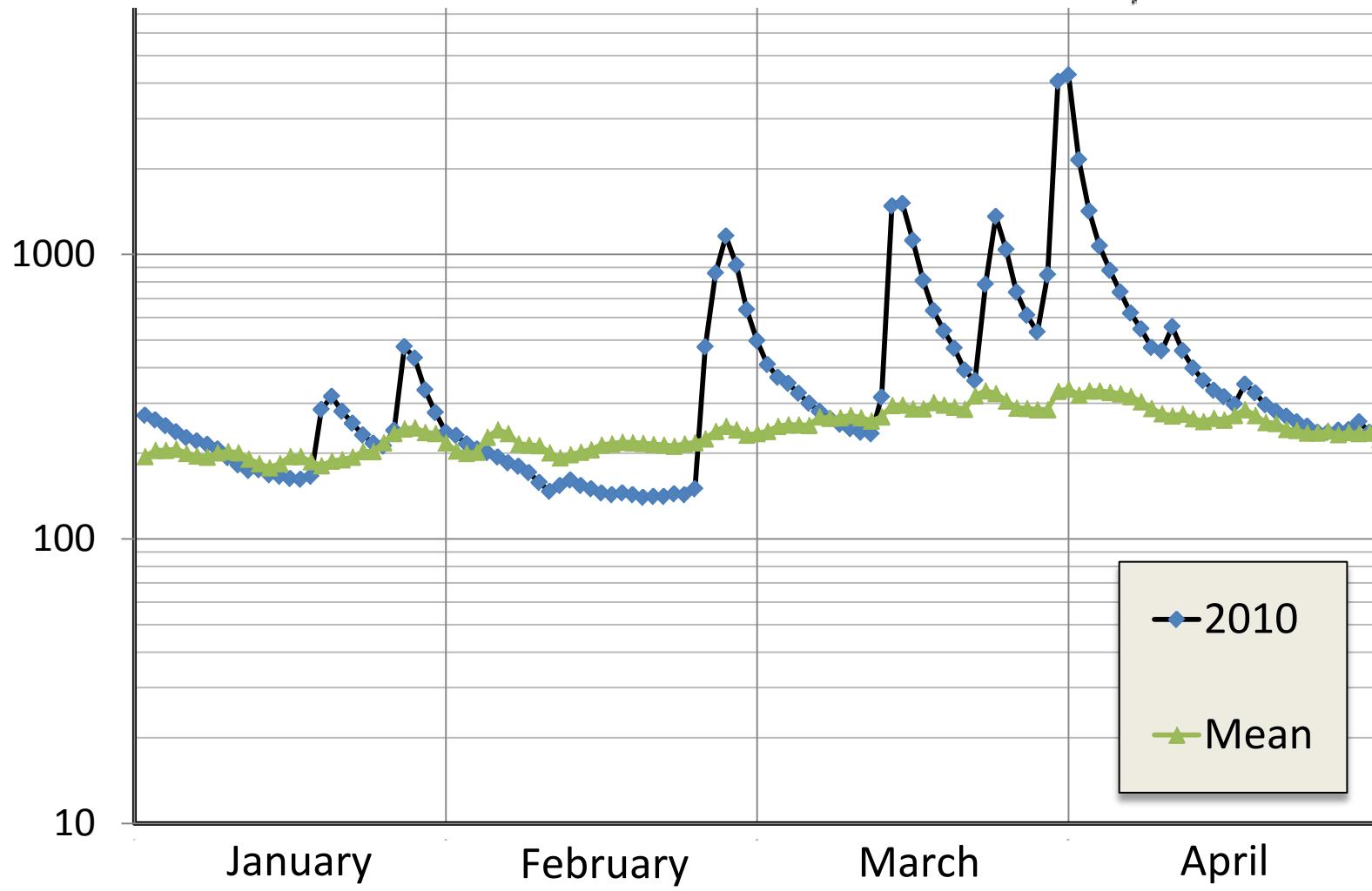
## USGS 01118000 WOOD RIVER AT HOPE VALLEY, RI

LOG Daily Discharge (cfs)

1000  
100  
10 Mean

## USGS 01118000 WOOD RIVER AT HOPE VALLEY, RI

LOG Daily Discharge (cfs)



# WOOD RIVER AT HOPE VALLEY, RI

- USGS Station 01118000
- Record: March 30, 2010: \*
  - Gage height: 13.72 ft
  - Discharge: 5,470 ft<sup>3</sup>/s
- Previous: June 06, 1982
  - Gage height: 10.26 ft
  - Discharge: 2,390 ft<sup>3</sup>/s



*Dam on the Wood River, Hope Valley  
(Source: RI DEM)*

\* **USGS: <0.2% = >500-year recurrence interval**



## Westerly

Photograph by: Michael Dolan

Date of Photograph: April 1, 2010

Rt. 91 underwater in Westerly can barely be seen crossing wetlands east of Chapman's Pond. This photo is taken from the north, with the Westerly coastline in the background.

[www.wpwa.org](http://www.wpwa.org)

## North Stonington/Westerly

[www.wpwa.org](http://www.wpwa.org)

Photograph by: Michael Dolan

Date of Photograph: April 1, 2010

View of the Pawcatuck River as it runs between Westerly, RI on the left and North Stonington, CT on the right. The river is running southwest. This photo was taken at the Historic Lewis Dairy Farm looking southwest. Boombridge Road crosses the river. The bridge has been closed for years.



# Switch Road, Hope Valley

Photo: Tom Boving



# Switch Road, Hope Valley

Photo: Tom Boving





Woodville Road, Wood River

Photo: Tom Boving



Woodville Road, Wood River  
Photo: Tom Boving

# Main St., Hope Valley

Photo: Tom Boving



# Main St., Hope Valley

Photo: Tom Boving



# Dow Baseball Field, Main St., Hope Valley

Photo: Tom Boving





**Woodville Road Bridge, Wood River**  
Photograph by: Valerie Parente  
Date of Photograph: March 31, 2010



Woodville Road, Wood River

Photo: Tom Boving



Woodville Road, Wood River

Photo: Tom Boving



Woodville Dam, Wood River

Photo: Tom Boving



I -95 near Exit 12

Source: B. Patenaude, RI DEM



WPWA Office, Wood River

Photograph by: Chris Fox

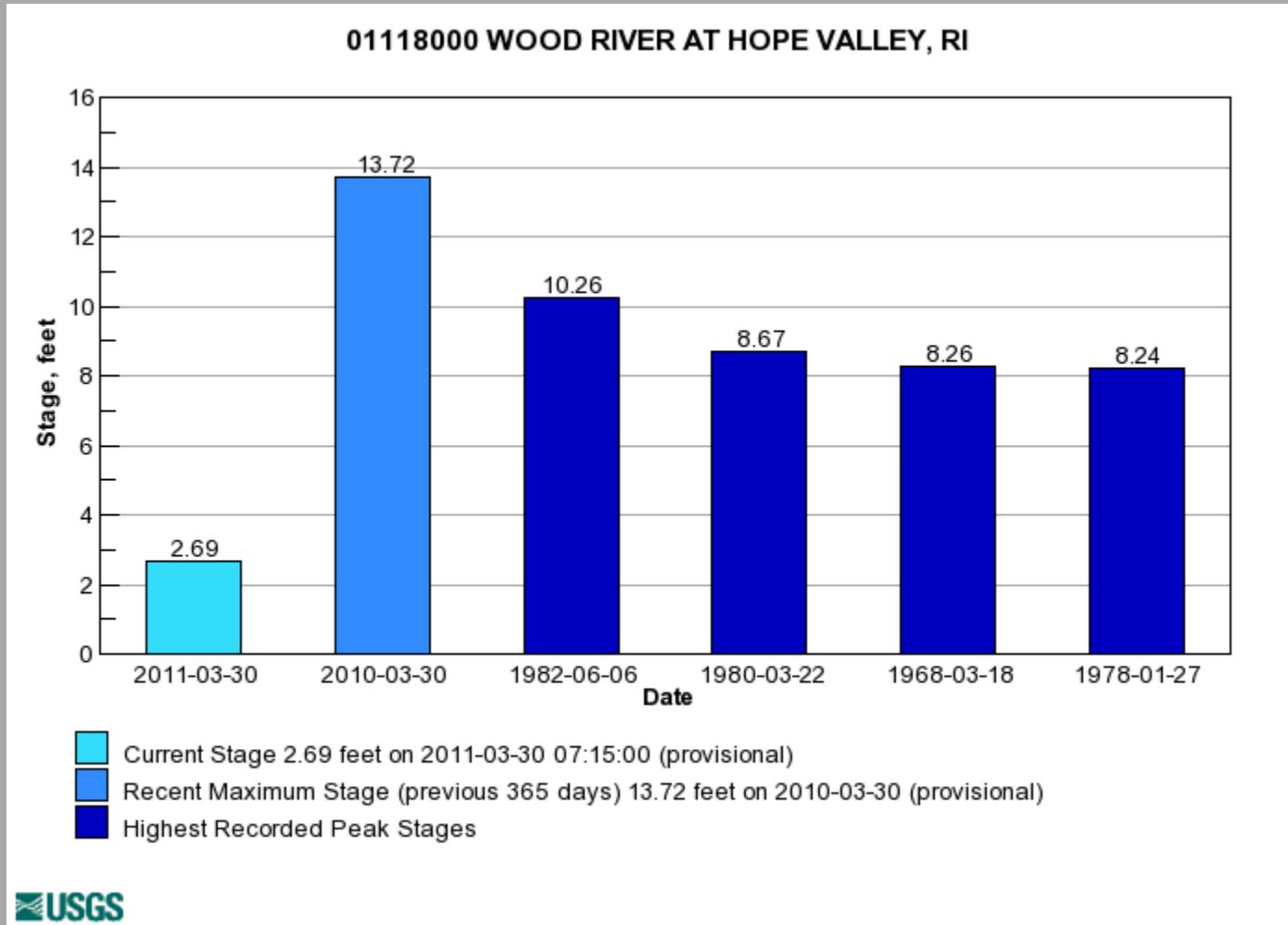
Date of Photograph: March 30, 2010

# Then and Now



Wyoming Dam, Wood River  
Photo: Tom Boving

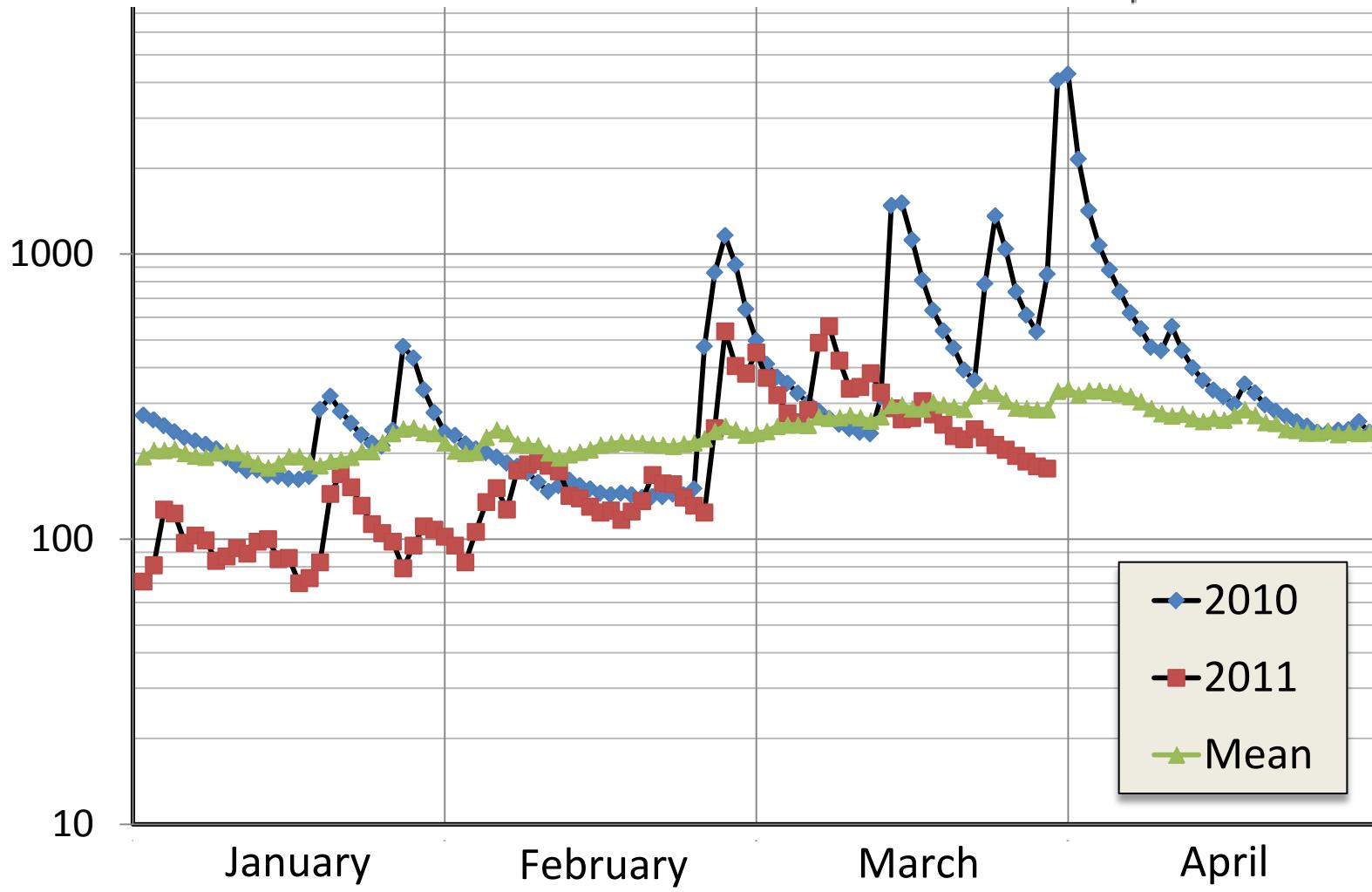
# Putting things into perspective



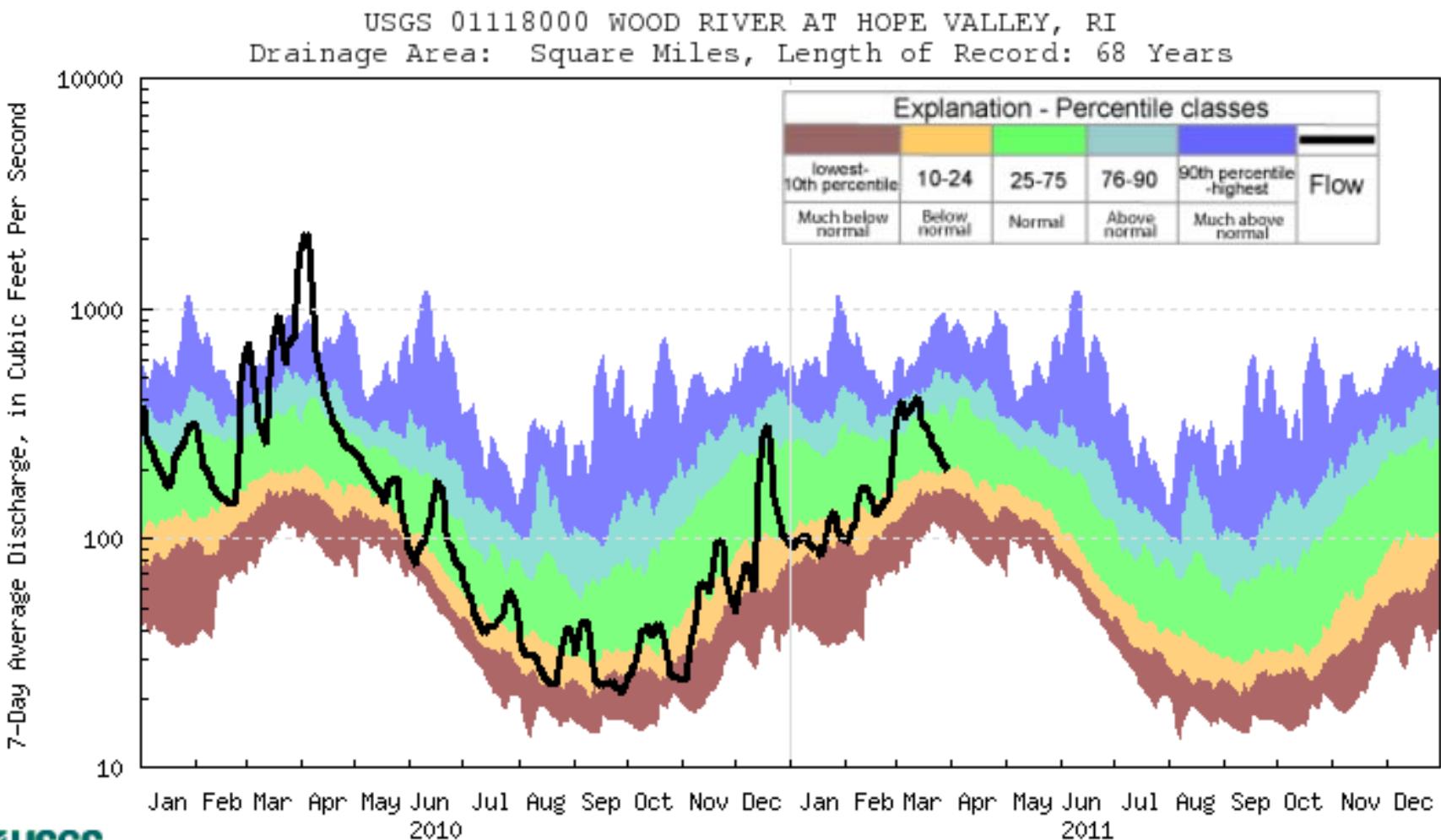
[http://waterwatch.usgs.gov/new/wwapps/ftc.php?site\\_no=01118000](http://waterwatch.usgs.gov/new/wwapps/ftc.php?site_no=01118000)

## USGS 01118000 WOOD RIVER AT HOPE VALLEY, RI

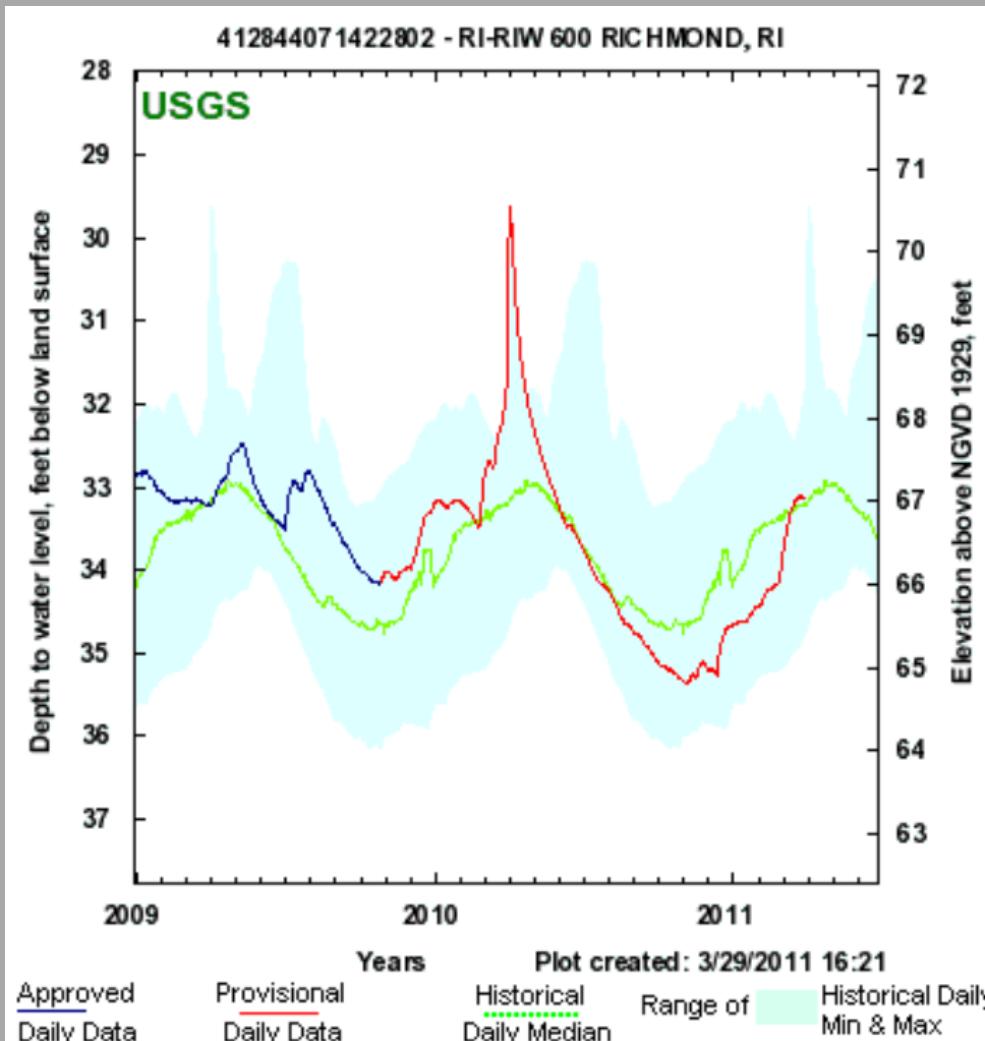
LOG Daily Discharge (cfs)



# USGS Streamflow Duration Hydrographs

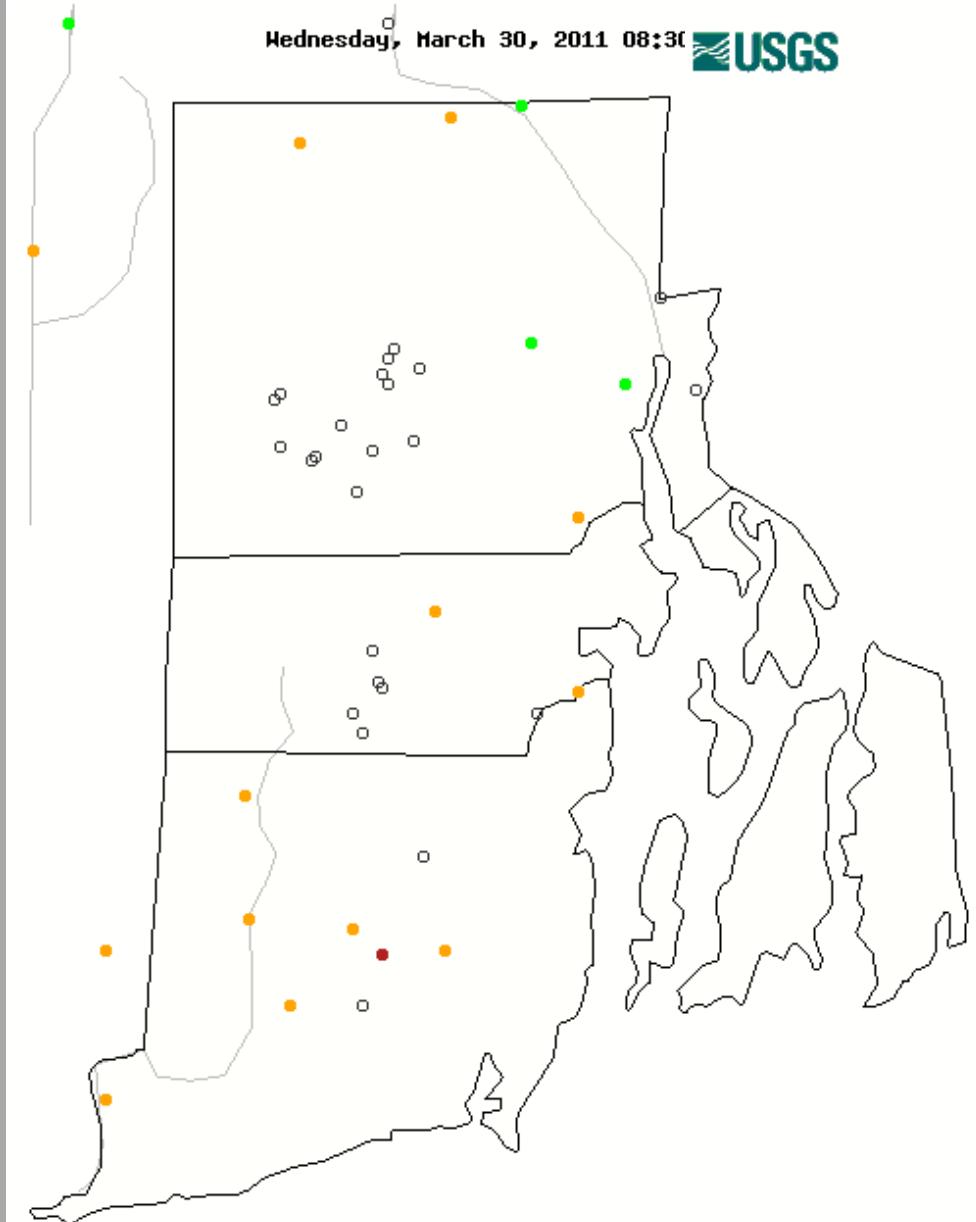


# Groundwater levels: Normal



<http://groundwaterwatch.usgs.gov/AWLSites.asp?S=412844071422802>

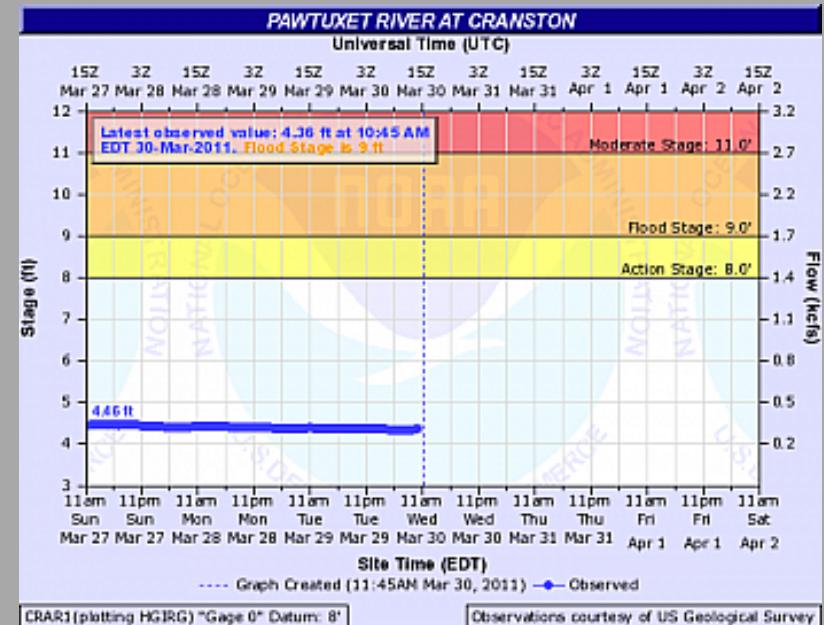
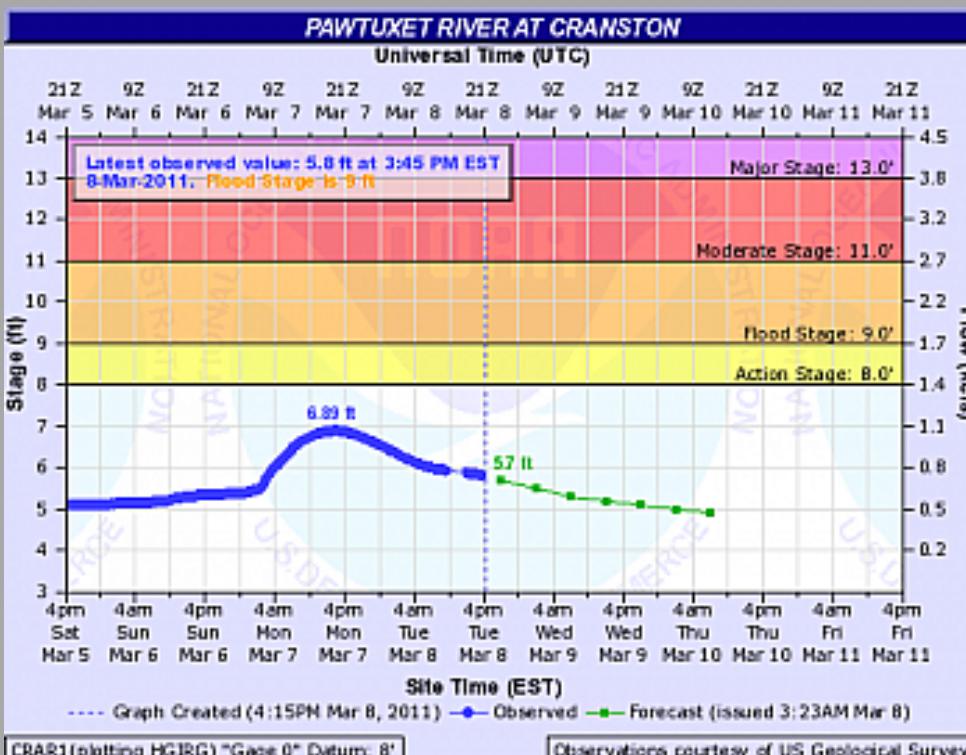
What a difference  
a year makes....



Explanation - Percentile classes							
Low	<10	10-24	25-75	76-90	>90	High	Not-ranked
	Much below normal	Below normal	Normal	Above normal	Much above normal		
●	●	●	●	●	●	●	○

# Advanced Hydrologic Prediction Service (AHPS) - River Forecast

<http://www.weather.gov/oh/ahps/>

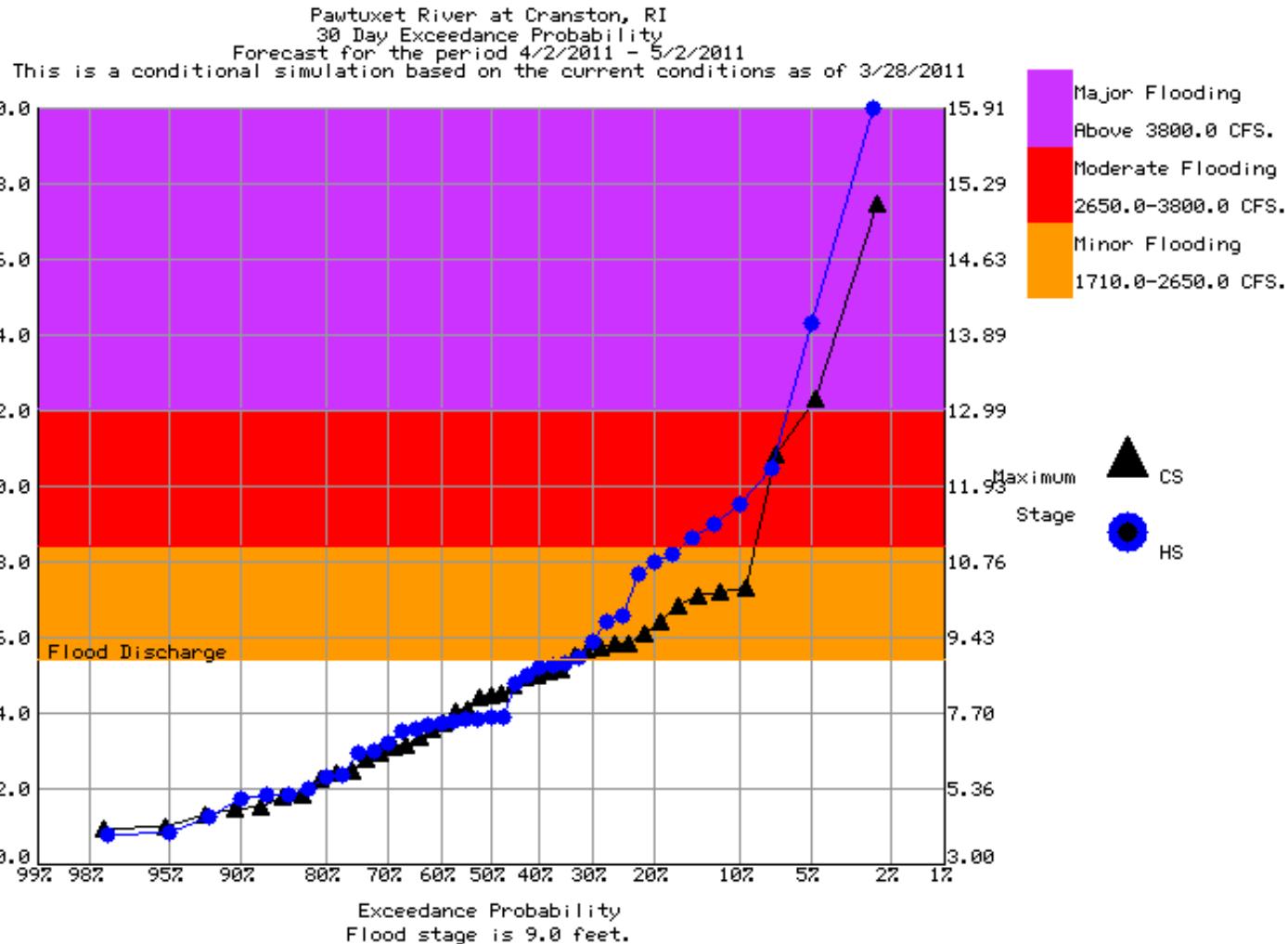


March 30, 2011

March 08, 2011: Snow melt

Pawtuxet River, Cranston

<http://water.weather.gov/ahps2/index.php?wfo=box>



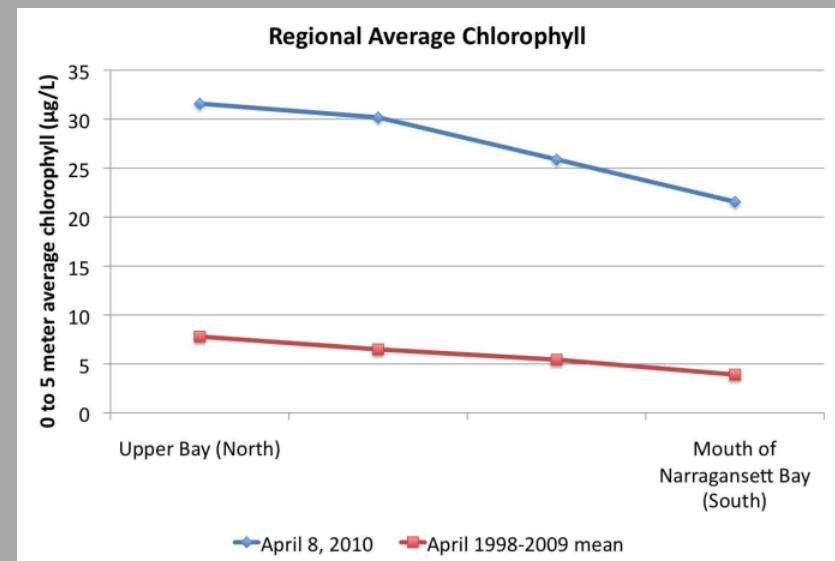
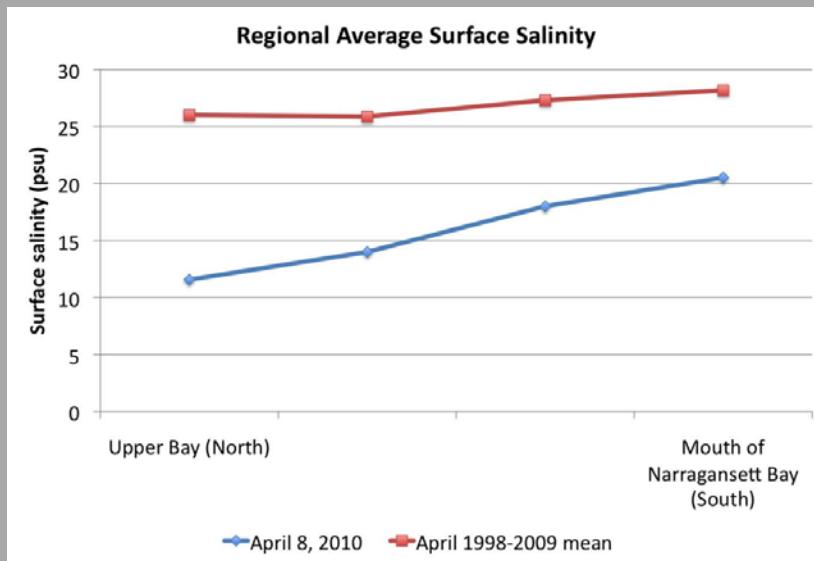
The conditional simulation (CS) line indicates chances of the river going above given levels based on current conditions. The historical simulation (HS) line indicates the chances of the river going above given levels based on the total range of past levels.

# Was all the news bad???

# Northeast Fisheries Science Center



- The flood runoff produced the lowest salinity surface water and the highest April concentrations of phytoplankton ever measured during the 12 years of a study in Narragansett Bay.



# R.I. Floods May Have Positive Impact on Commercial Fish, Shellfish Industries

- Perfect timing: When the water is cold, as occurred during the spring 2010 flood, the bacteria do not consume the phytoplankton quickly enough to deplete the dissolved oxygen in the water.”
- “The flooding is likely to benefit Narragansett Bay’s commercial finfish and shellfish industries for some time to come.”

Northeast Fisheries Science Center



# The Future

**...more of the same?**

# Climate Change: Effects in the Northeast

## Precipitation

- Rainfall is expected to become **more intense** and periods of heavy rainfall are expected to become **more frequent**.
  - Number of heavy-precipitation events is projected to increase 8 % by mid-century, and 12 % to 13 % by the end of the century.
  - In Maine, New Hampshire, and Vermont the probability of high-flow events may increase as much as 80 %, accompanied by an **increased risk of flooding**.

# Climate Change: Effects in the Northeast

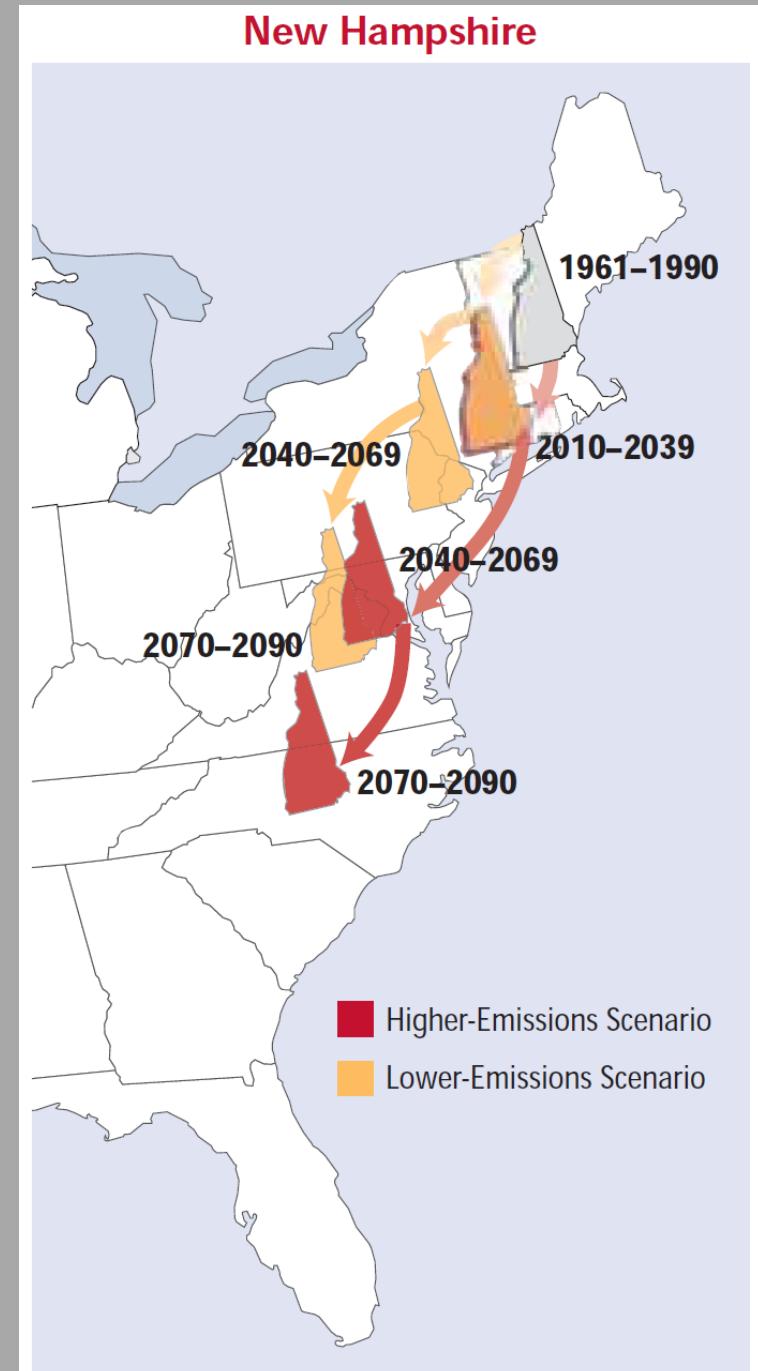
## Temperature

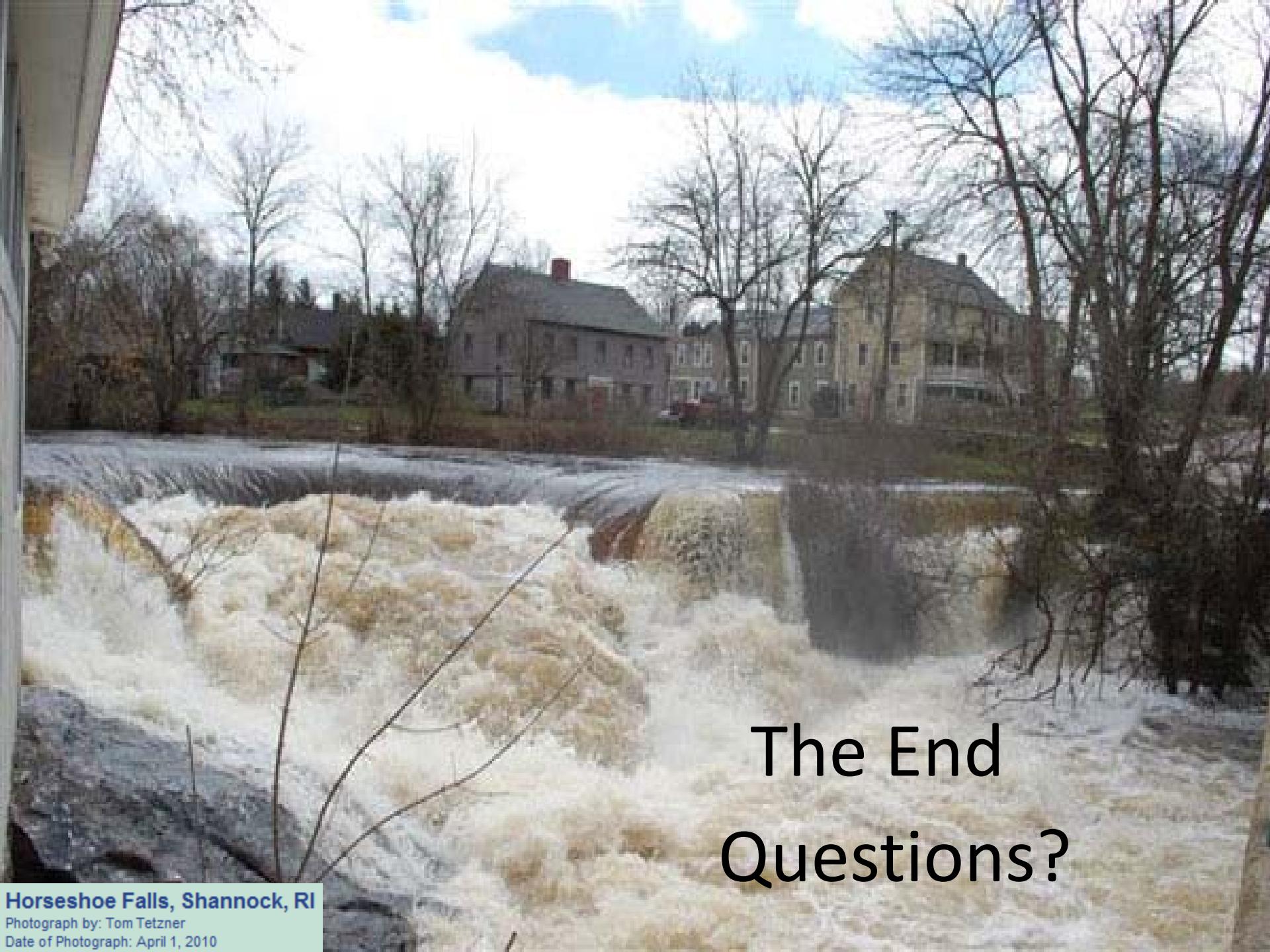
- Since 1970, the Northeast has been heating up at a rate of 0.5°F per decade. Winter temperatures have been rising even faster—1.3°F per decade between 1970 and 2000.
- Average temperatures are projected to rise another 2.5 to 4 °F in winter and 1.5°F to 3.5°F in summer above historic levels over the next several decades.

# Migrating State Climates

Citation: Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions*. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS).

My suggestion:  
Start planting palm trees!





The End  
Questions?

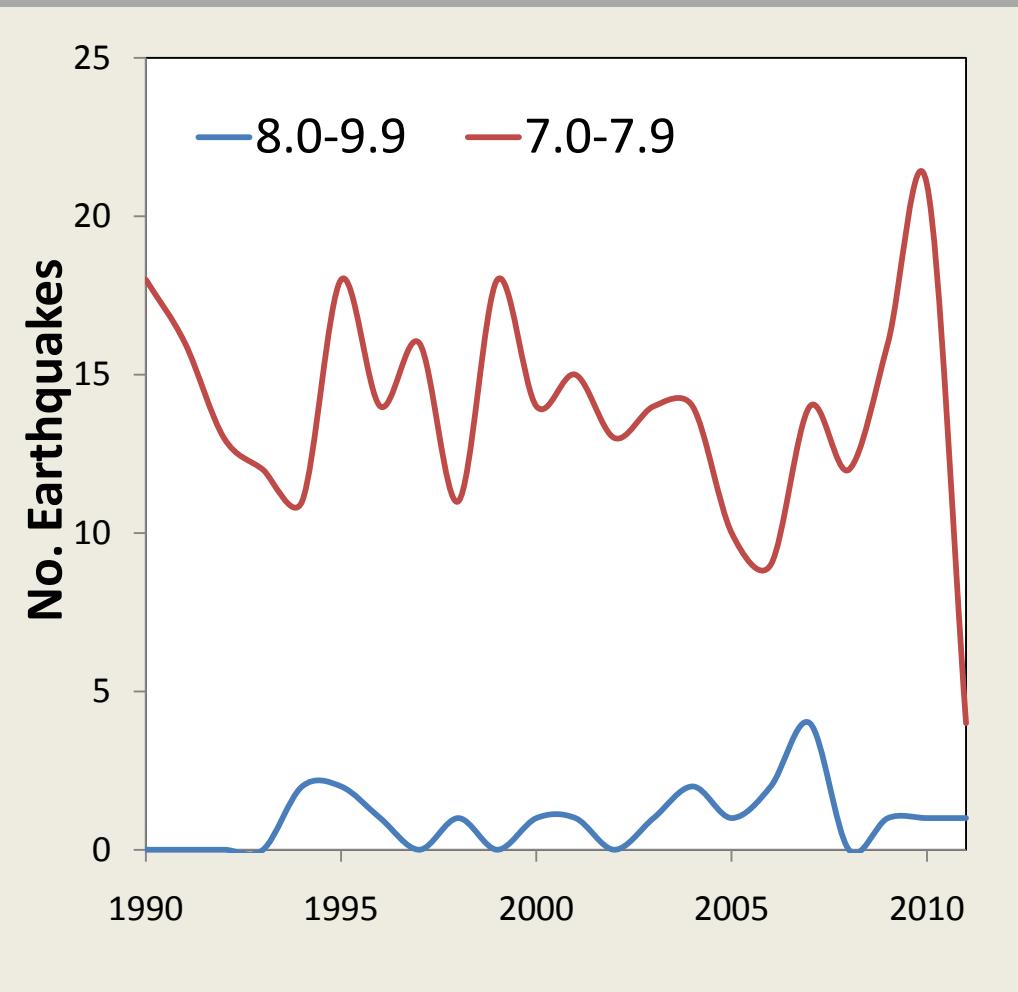
Horseshoe Falls, Shannock, RI

Photograph by: Tom Tetzner

Date of Photograph: April 1, 2010



# More Strong Earthquakes?



## Earthquake Facts and Statistics

### Frequency of Occurrence of Earthquakes

Magnitude	Average Annually
8 and higher	1 <sup>1</sup>
7 - 7.9	15 <sup>1</sup>
6 - 6.9	134 <sup>2</sup>
5 - 5.9	1319 <sup>2</sup>
4 - 4.9	13,000 (estimated)
3 - 3.9	130,000 (estimated)
2 - 2.9	1,300,000 (estimated)

<sup>1</sup> Based on observations since 1900.

These numbers have been recently updated, based on data from the [Centennial catalog](#) (from 1900 to 1999) and the [PDE](#) (since 2000).

<sup>2</sup> Based on observations since 1990.