Delaware River Basin Commission

Analyzing Climate Change Impacts to Water Resources in the Delaware River Basin: Big Picture Risks

Amy L. Shallcross, PE
Manager, Water Resource Operations

Water Resources Association of the Delaware River Basin
57th Annual Conference
the Nature and Nurture of a Working River

November 1, 2018

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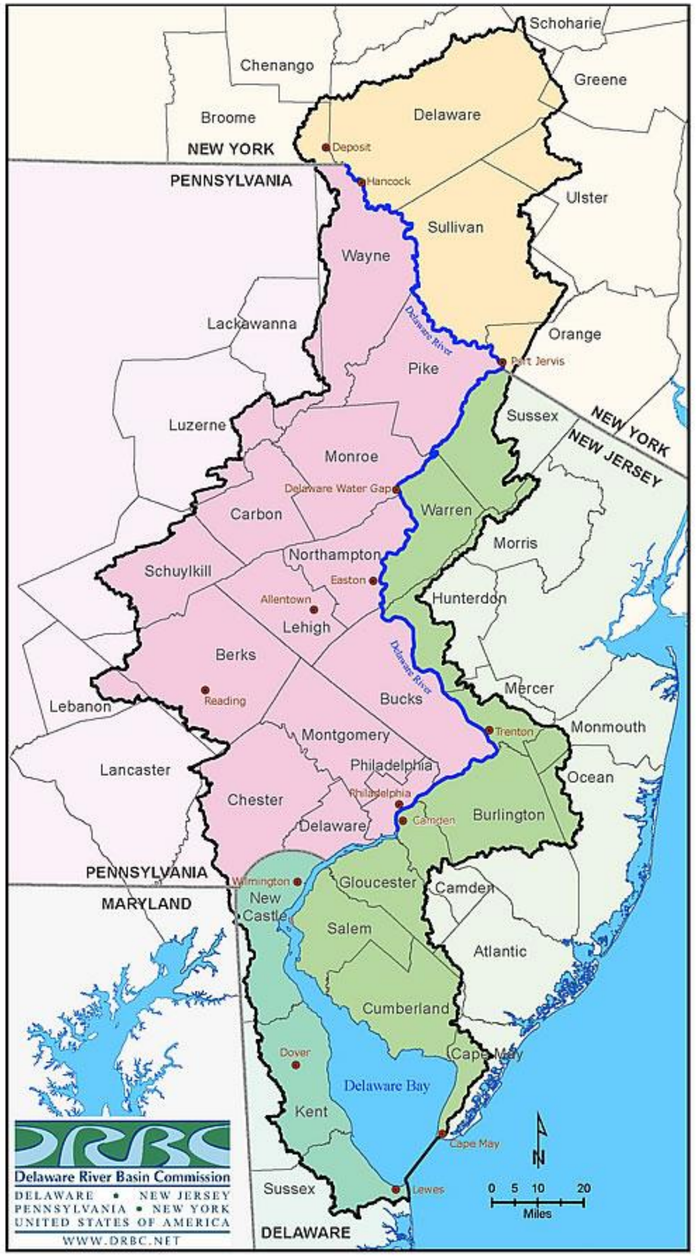
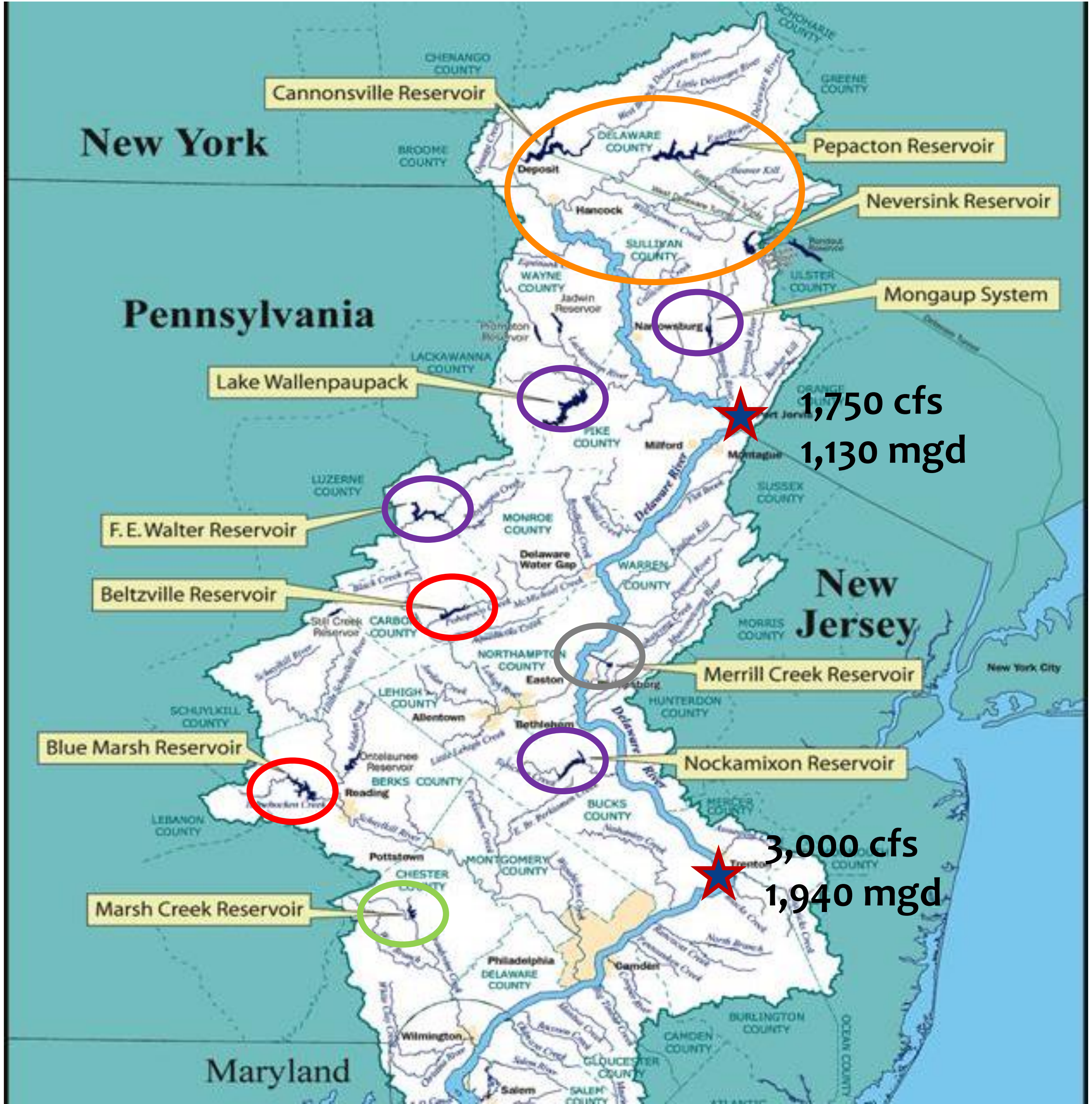


"A river is more than an amenity, it is a treasure"

-US Supreme Court Justice
Oliver Wendell Holmes

- Delaware River Main stem river is **330 miles long**
- Delaware River forms an interstate boundary over its entire length
- **15 million people** (about 5% of the U.S. population) rely on the waters of the Delaware River Basin
- **Drains 13,539 square miles** of watershed in 4 states.
- Water **withdrawal** in the Basin = **8.7 billion gallons a day**
- **Significant Exports: NYC (up to 800 MGD) and NJ (up to 100 MGD)**
- Longest, un-dammed U.S. river east of the Mississippi (dams are located on tributaries, not the main stem Delaware)
- **Contributes over $21B in economic value** to the Region.

Competing Objectives



Sources of Water

- NYC Decree
- DRBC Storage in USACE Reservoirs
- Emergency
- Consumptive Use Make – Up
- Dockets

Flow at Montague and Trenton can be 60 percent or more from reservoir releases in dry periods

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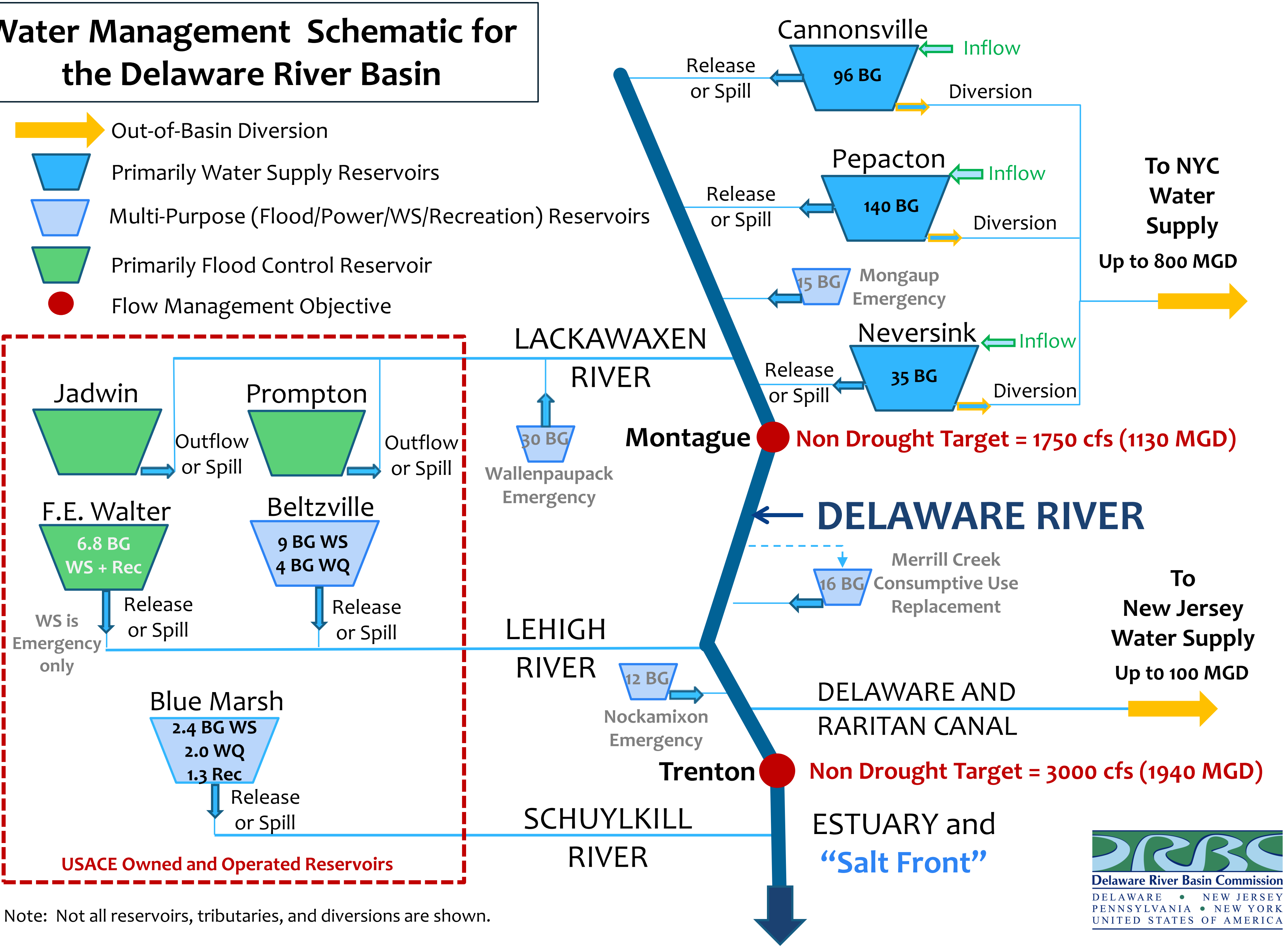
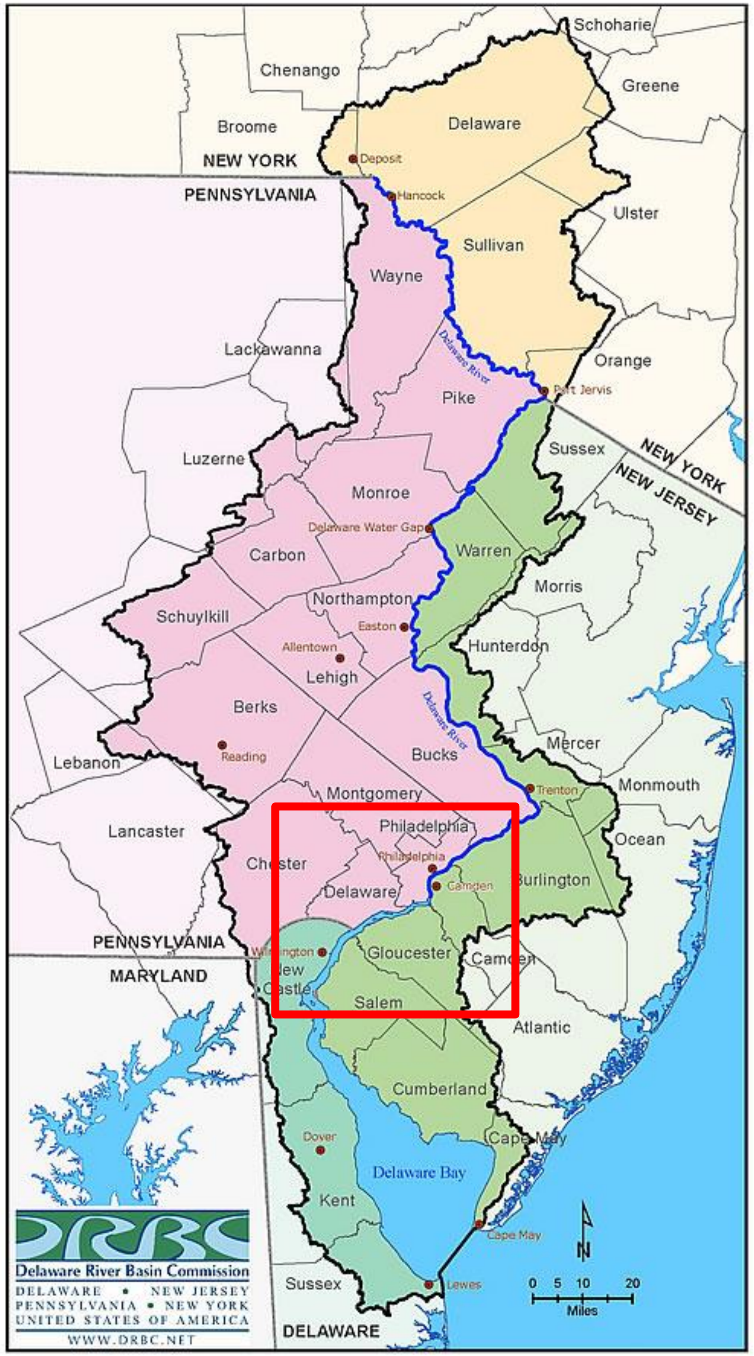
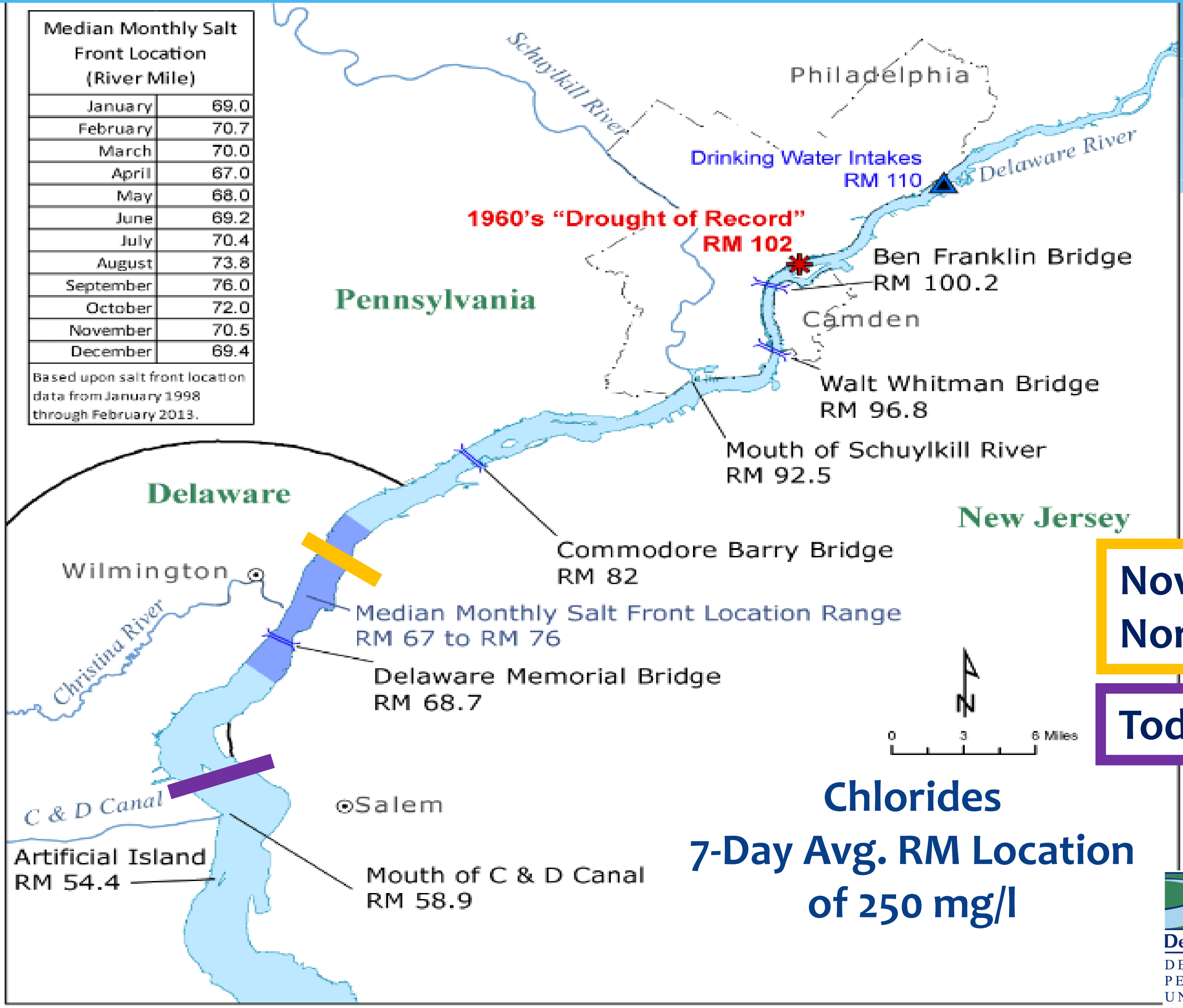
Water Management Schematic for the Delaware River Basin



Note: Not all reservoirs, tributaries, and diversions are shown.

Salt Front





Median Monthly Salt Front Location (River Mile)	
January	69.0
February	70.7
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April	67.0
May	68.0
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August	73.8
September	76.0
October	72.0
November	70.5
December	69.4

Based upon salt front location data from January 1998 through February 2013.

November Normal R.M. 70

Today R.M. 69

Chlorides 7-Day Avg. RM Location of 250 mg/l

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Assessing Climate Risks

Flooding

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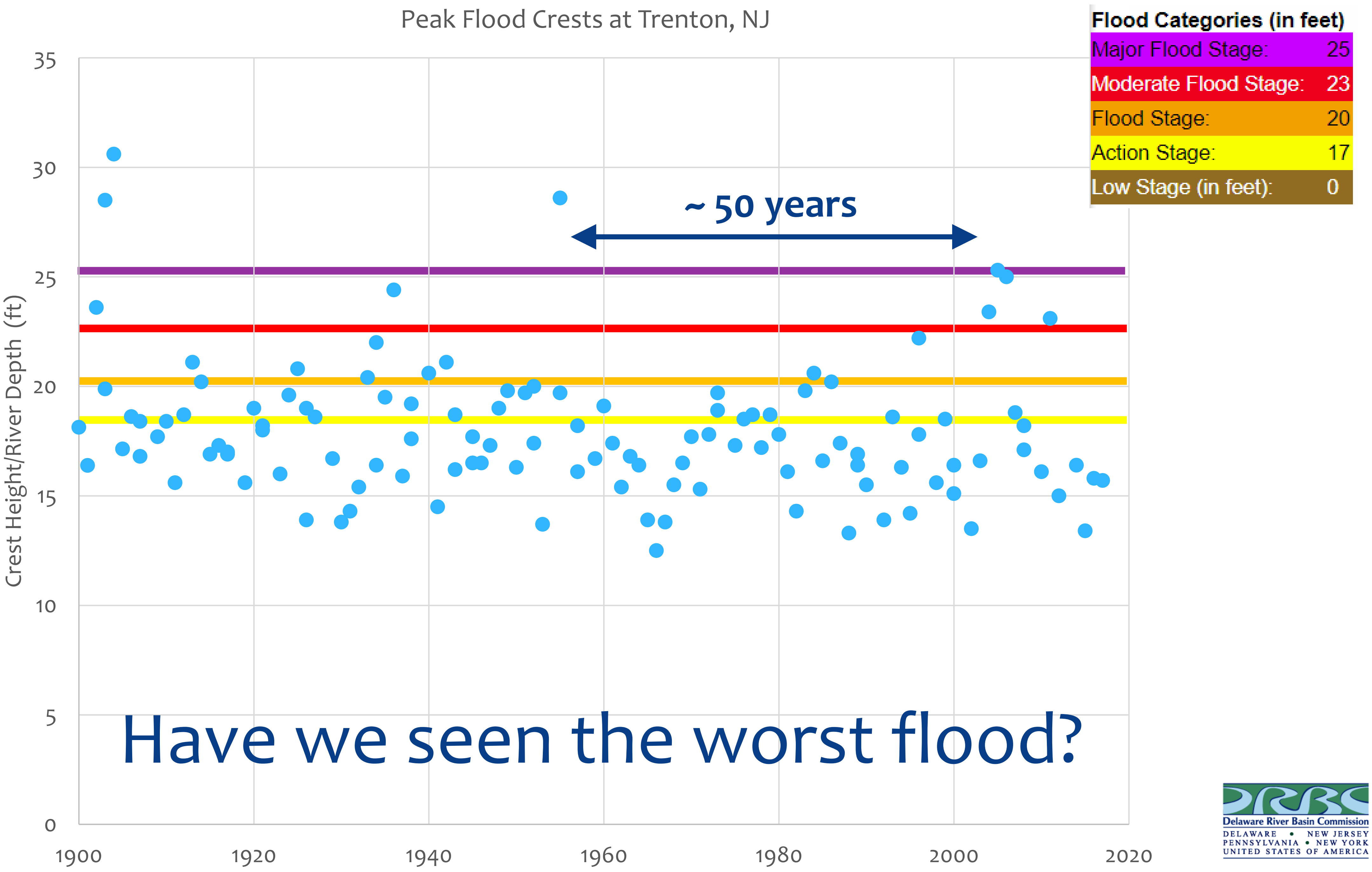

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August 1955

Morning Call

Hurricane Diane

Flood of Record

Free Bridge
Phillipsburg to Easton

Basinwide Droughts

	Enter Drought Watch	Enter Drought Warning	End Drought Watch/ Warning	Enter Drought	Declare Drought Emergency	End Drought Emergency
1960s					7/7/65	3/2/67
1980s	10/17/80	12/1/80		1/15/81	1/15/81	4/27/82
	11/13/82	12/8/82	3/27/83			
	11/09/83	--	12/20/83			
	1/23/85	2/7/85		5/13/85	5/13/85	12/18/85
	1/16/89	2/5/89		--	3/21/89 Conditional	5/12/89
1990s	9/13/91	11/7/91	4/25/92			
	9/21/93	--	12/6/93			
	9/15/95	10/13/95	11/12/95			
	10/27/97	--	1/13/98			
	12/14/98	12/23/98		--	8/18/99 (8)	9/30/99
2000s	10/29/01	11/4/01		12/1/01	12/18/01	11/25/02
	11/23/2016	--	1/18/2017			

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November 28, 2016
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Cannonsville Reservoir
October 20, 2016 – 35%
By December – as low as 19%
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Cannonsville Reservoir in December 2001

Storage in June = 96 BG (full). Storage in December = 5 BG = **6 %**

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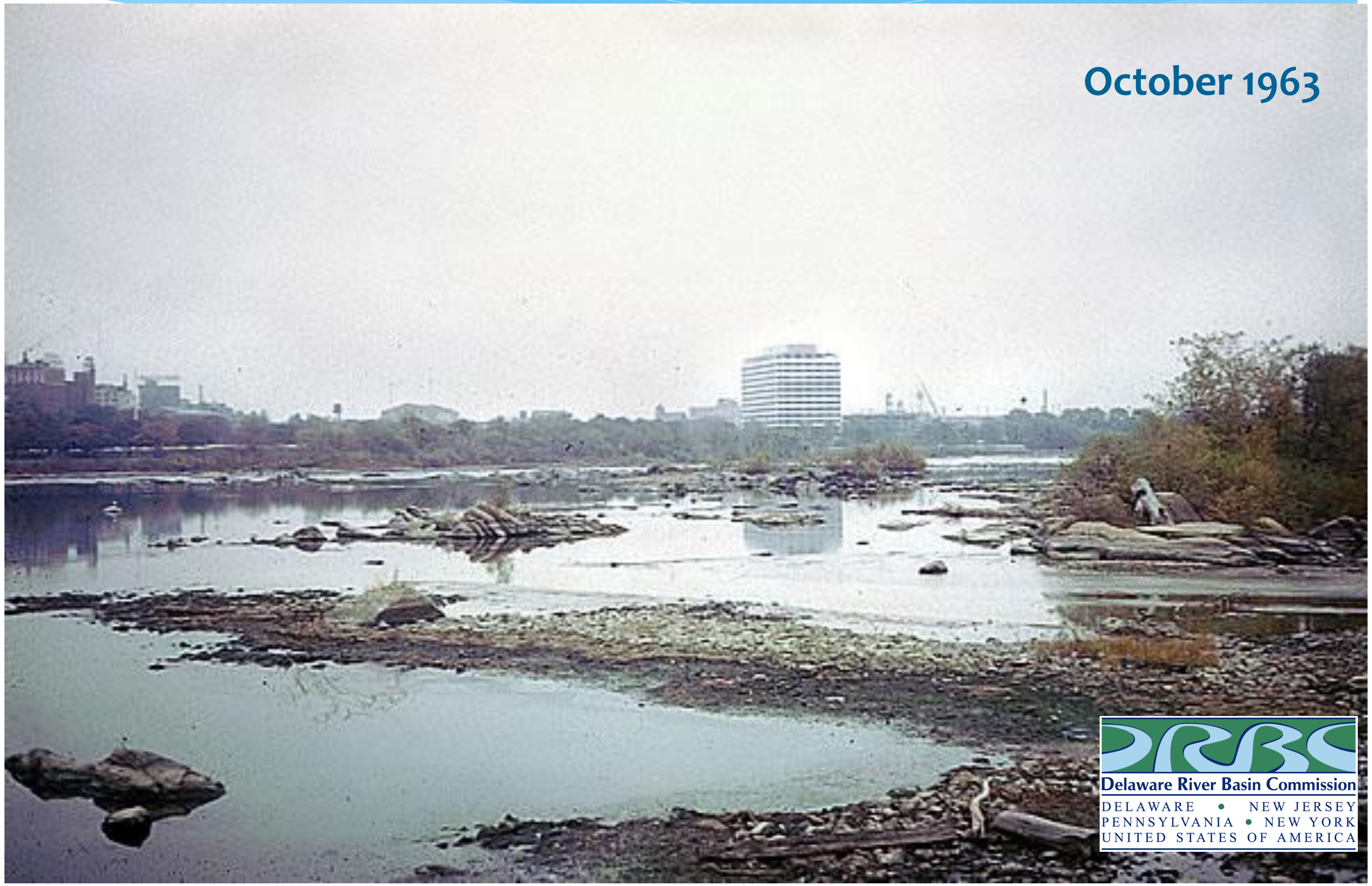
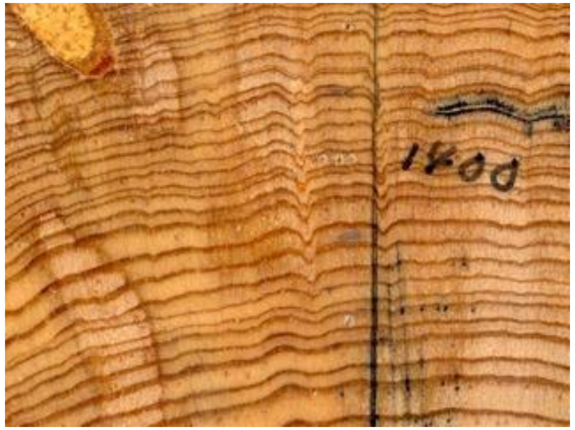
Drought of Record



Have we seen the Drought of Record?



Simulated **Storage** using dendro-derived hydrology

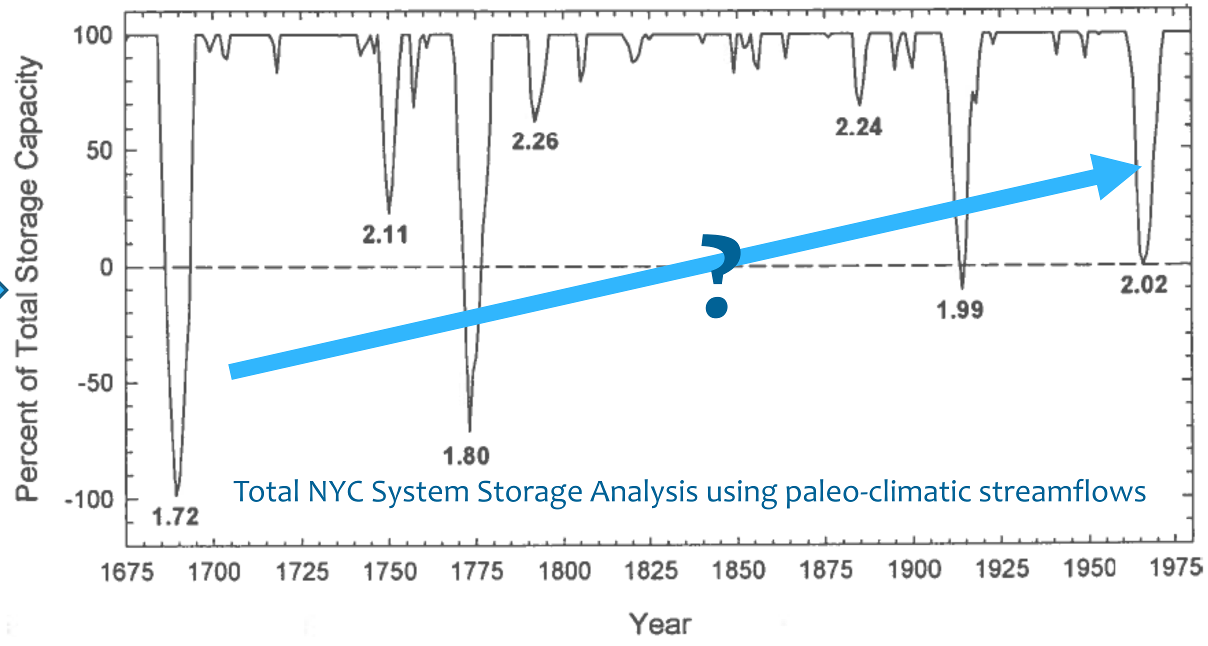


Figure 32. Annual Inflow Model – Tree-Ring Reconstructed Inflow Data (1675 – 1980)
The total storage capacity of the system is 547.5 BG. The bold numbers represent the total system yields associated with the selected droughts. The outflow from the system is set to that corresponding to the total system yield for the 1960s drought (2.02 BGD). Therefore, any droughts with a lower total system yield than 2.02 BGD will result in negative storage capacities.

Photo: Henri D. Grissino-Mayer
Department of Geography,
The University of Tennessee

Department of Environmental Engineering, Manhattan College, Kaitlin J. Bars, Kevin R. Ellenwood, Joseph J. Nemesh, Kevin J. Rader. Tree Ring Analysis as a predictor of pre-1927 reservoir inflows, April 26, 2004

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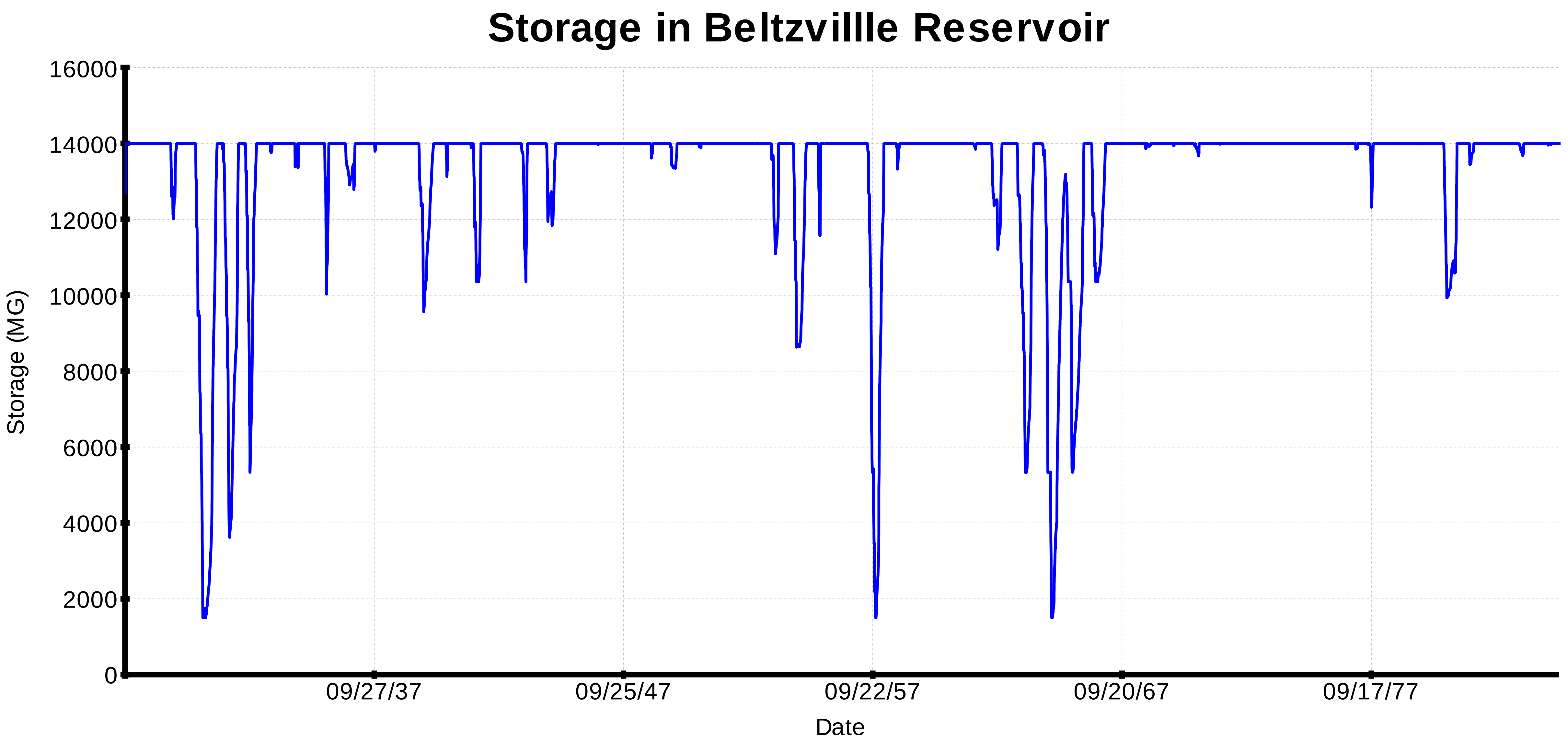
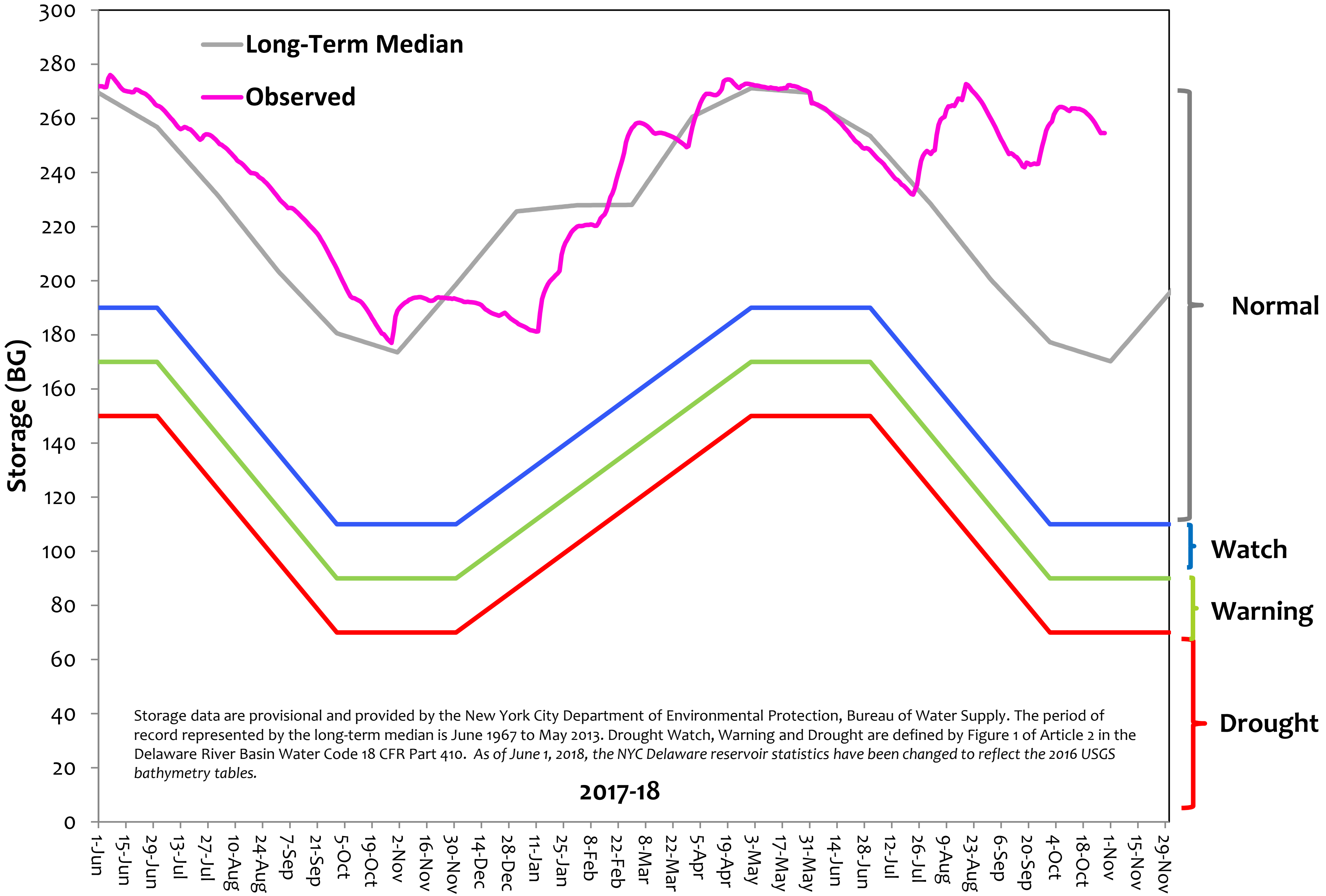


Simulation of Revision 1 Program and Maximum Diversions

New York City Delaware River Basin Storage



PHASED REDUCTIONS

Drought Status	Diversions NYC	Diversions NJ
Normal	800	100
Watch	680	100
Warning	560	90
Emergency	520	80

Drought Status	Flow Objectives Montague	Flow Objectives Trenton
Normal	1,750	3,000
Watch	1,650	2,700
Warning	1,550	2,700
Emergency	SF: 1,100 - 1,650	SF: 2,500 - 2,900

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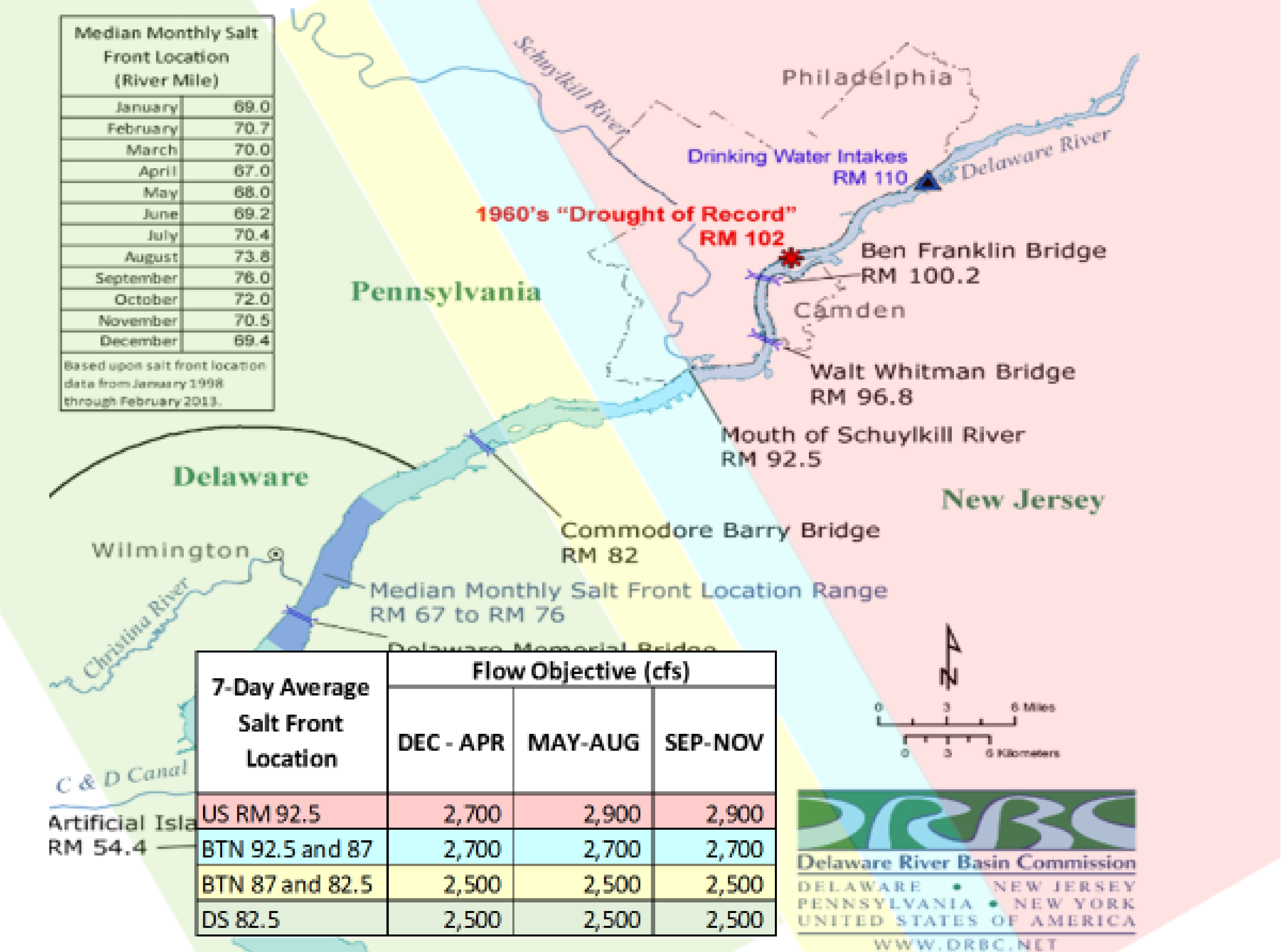

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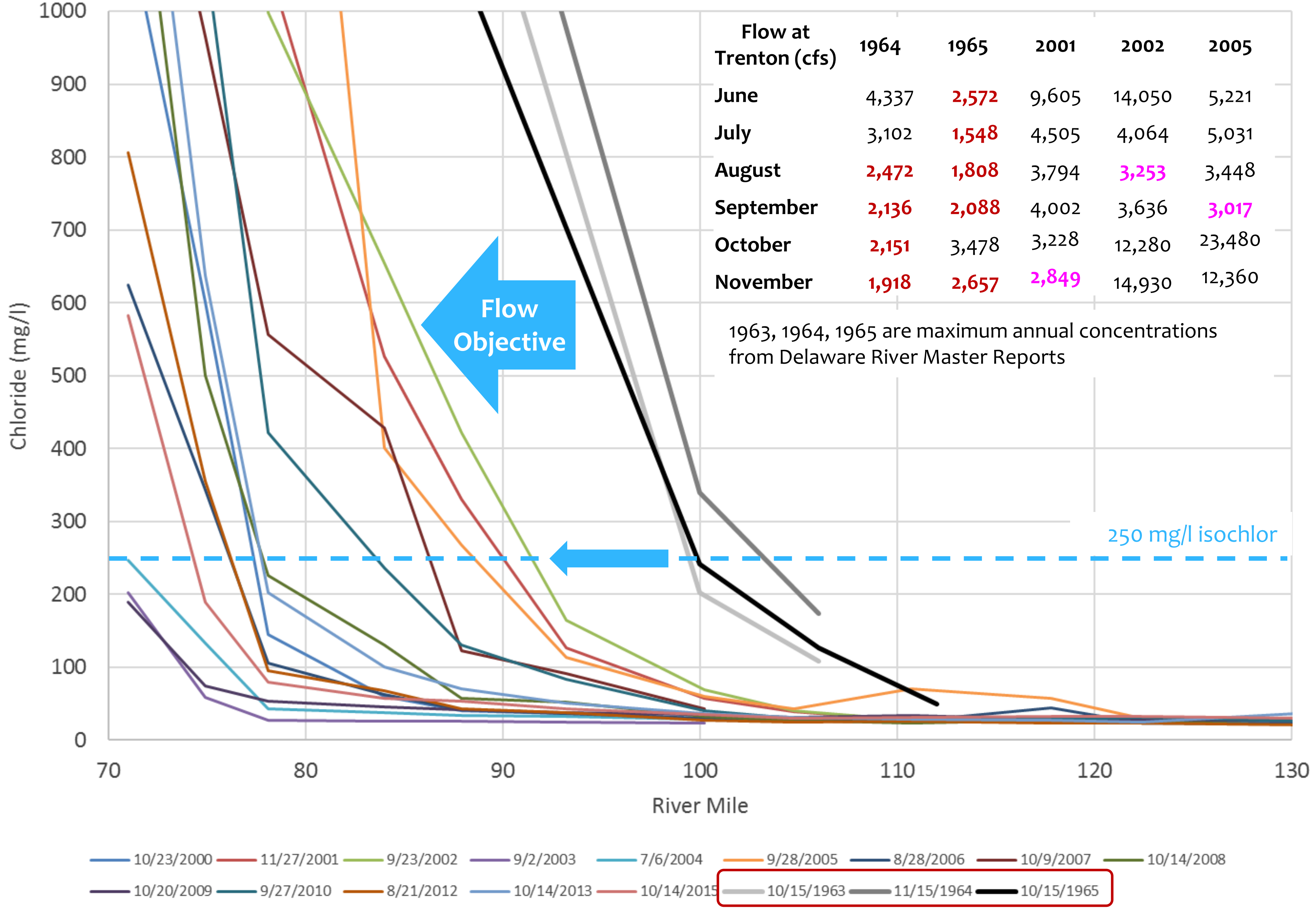
Based upon salt front location data from January 1998 through February 2013.

7-Day Average Salt Front Location	Flow Objective (cfs)		
	DEC - APR	MAY-AUG	SEP-NOV
US RM 92.5	2,700	2,900	2,900
BTN 92.5 and 87	2,700	2,700	2,700
BTN 87 and 82.5	2,500	2,500	2,500
DS 82.5	2,500	2,500	2,500

Boat Run Chloride Profiles



Flow at Trenton (cfs)	1964	1965	2001	2002	2005
June	4,337	2,572	9,605	14,050	5,221
July	3,102	1,548	4,505	4,064	5,031
August	2,472	1,808	3,794	3,253	3,448
September	2,136	2,088	4,002	3,636	3,017
October	2,151	3,478	3,228	12,280	23,480
November	1,918	2,657	2,849	14,930	12,360

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Evaluation of Climate Change

DRBC's goals during droughts:

Preserve regional storage for water supply and flow augmentation and salinity control

* Linked climate-driven hydrologic, water supply planning and salinity models
* Compare based on:
  * New Hydrology (deterministic)
  * Water use (existing and projected)
  * Land cover/Land use (existing and projected)
  * Flow management programs

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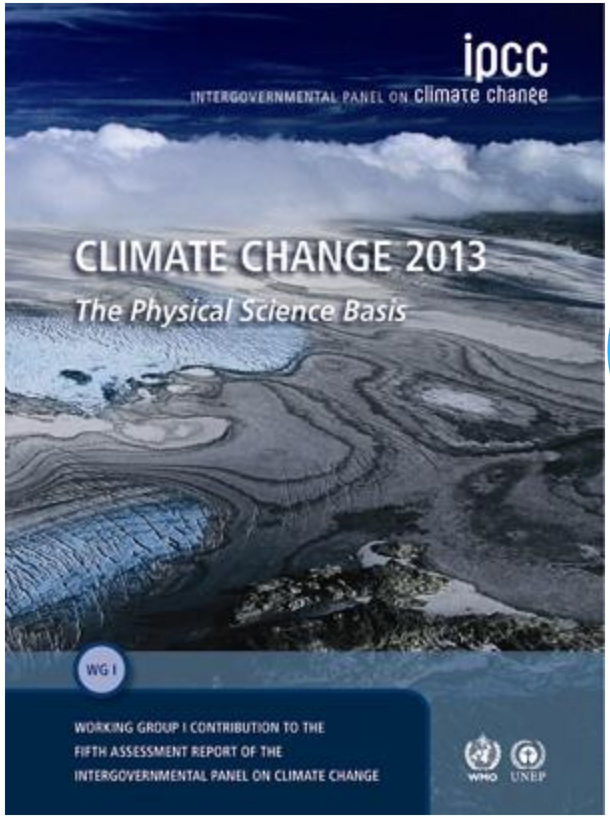
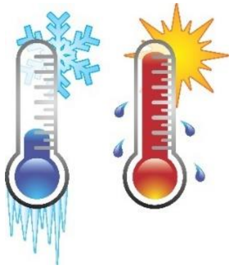
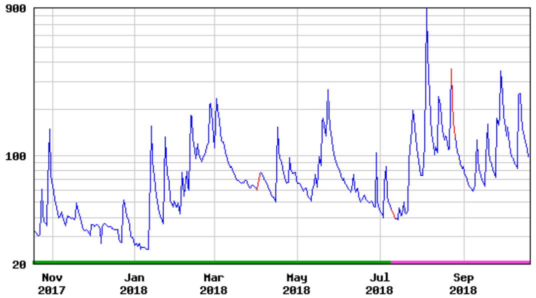
Climate Scenarios
Temperature and Precipitation



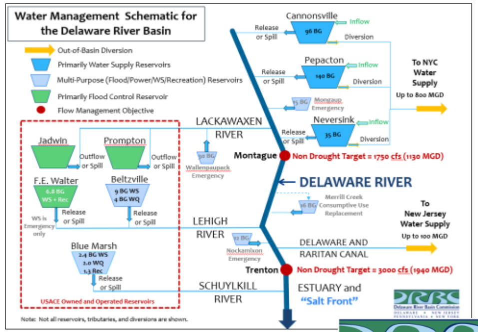
IPCC Emissions
- RCP 2.6
- RCP 4.5
- RCP 6.0
- RCP 8.5



USGS WATER
Runoff



DRBC Modeling
Water Availability



IPCC = Intergovernmental Panel on Climate Change
RCP = Representative Concentration Pathways

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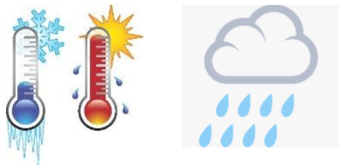
Models

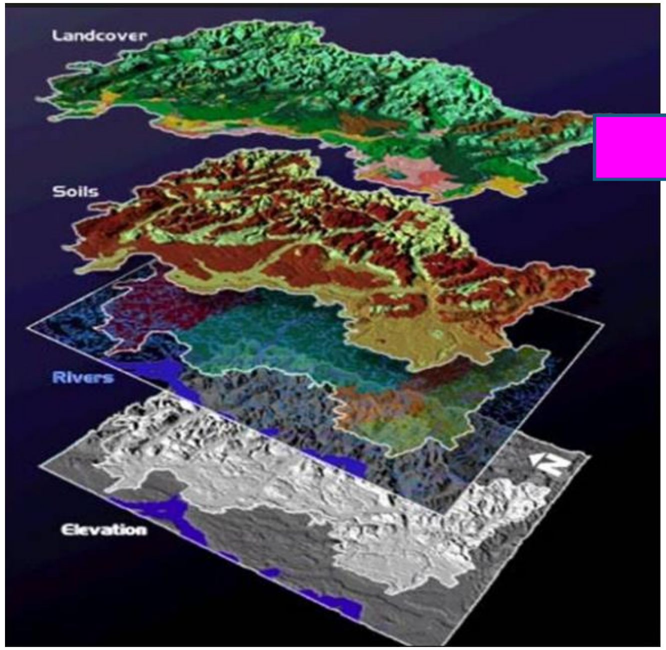
GCMs and RCPs

GFDL
GISS
NCAR
CanES



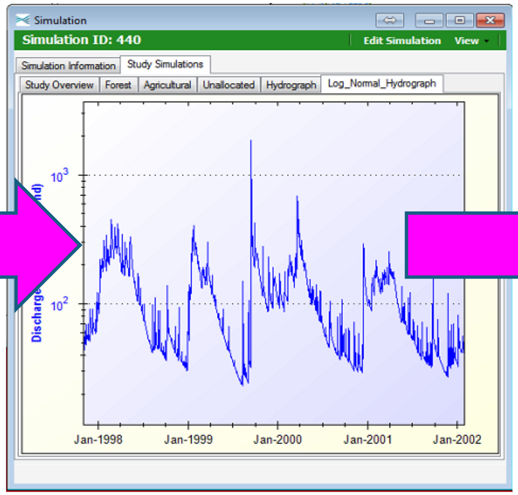
RCP2.6
RCP4.5
RCP6.0
RCP8.5

USGS WATER

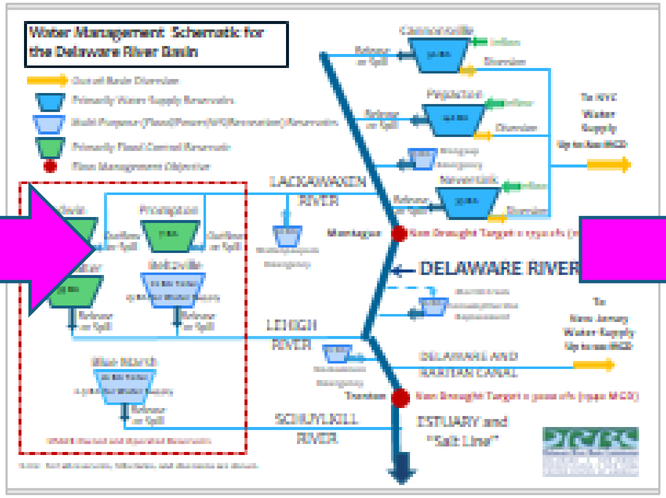


GCM: Global Circulation Model

Inflows

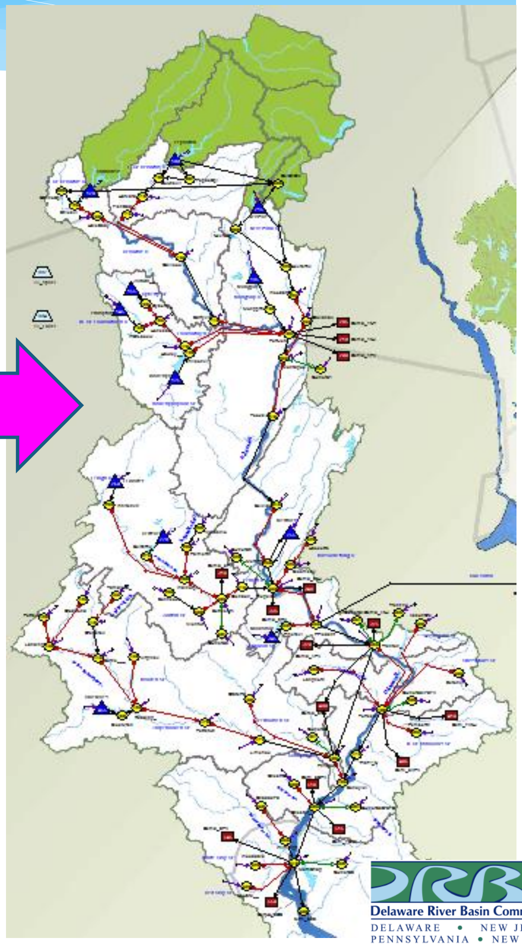


Flow Management Rules



Water Code, FFMP, Dockets

DRB-Planning Support Tool



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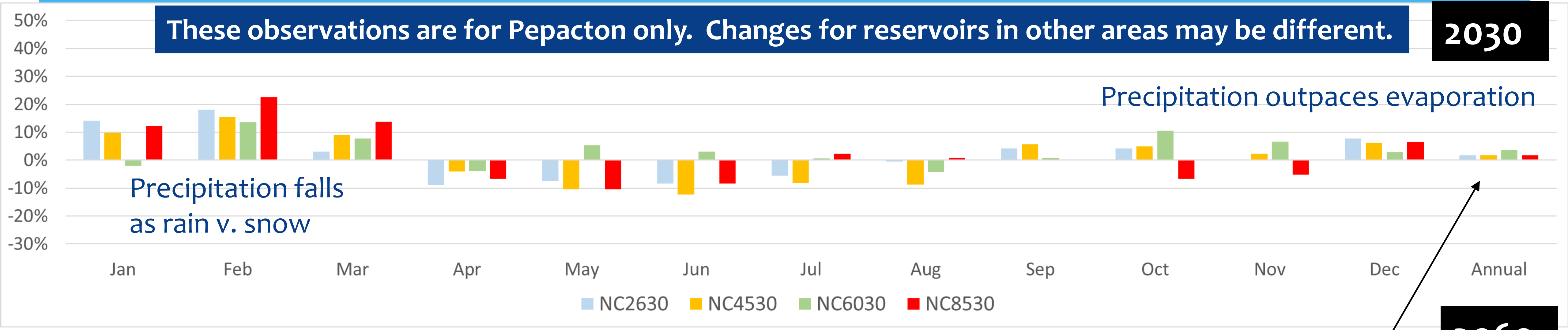
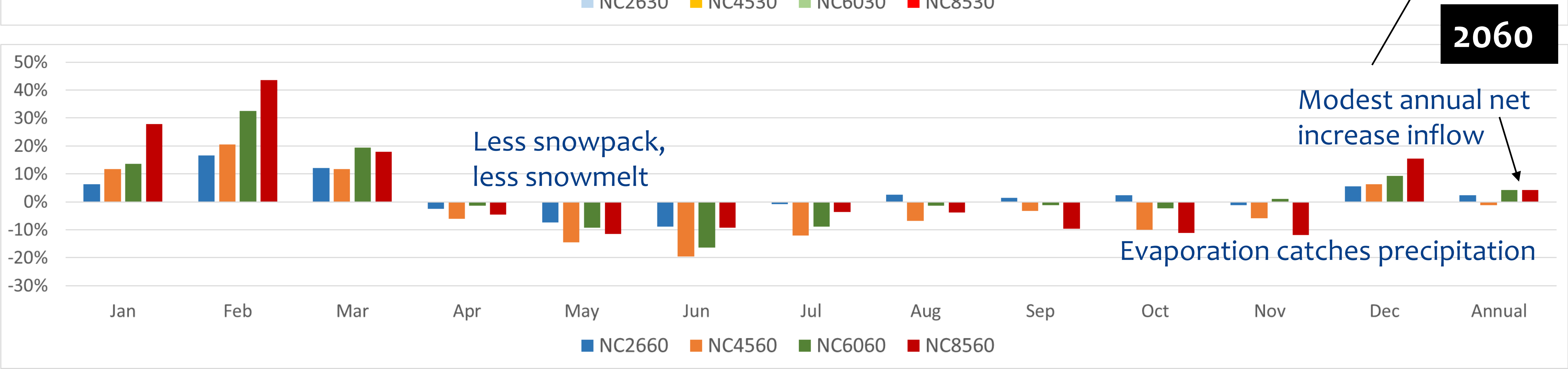
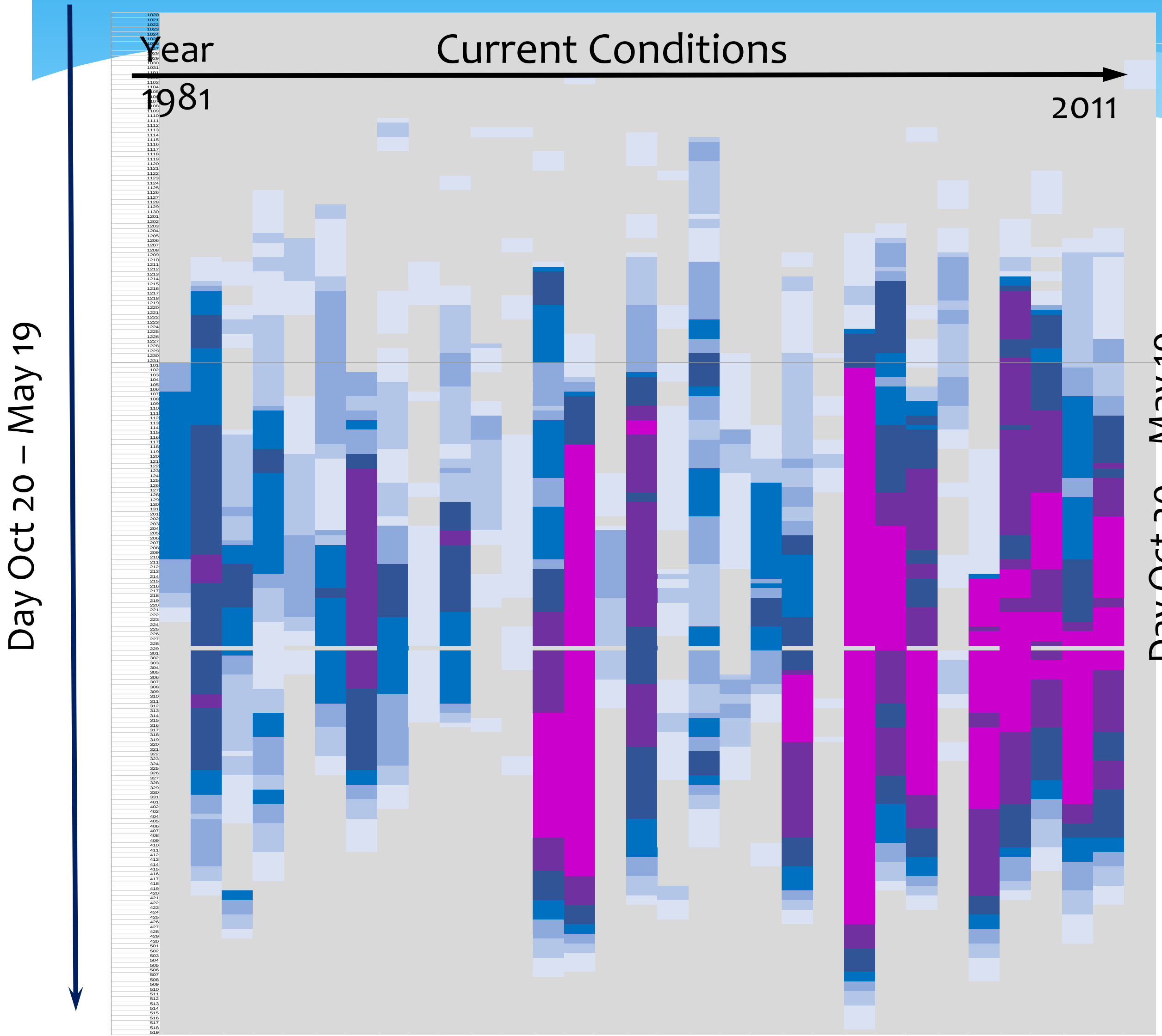
Changes in Reservoir Inflows (Pepacton)

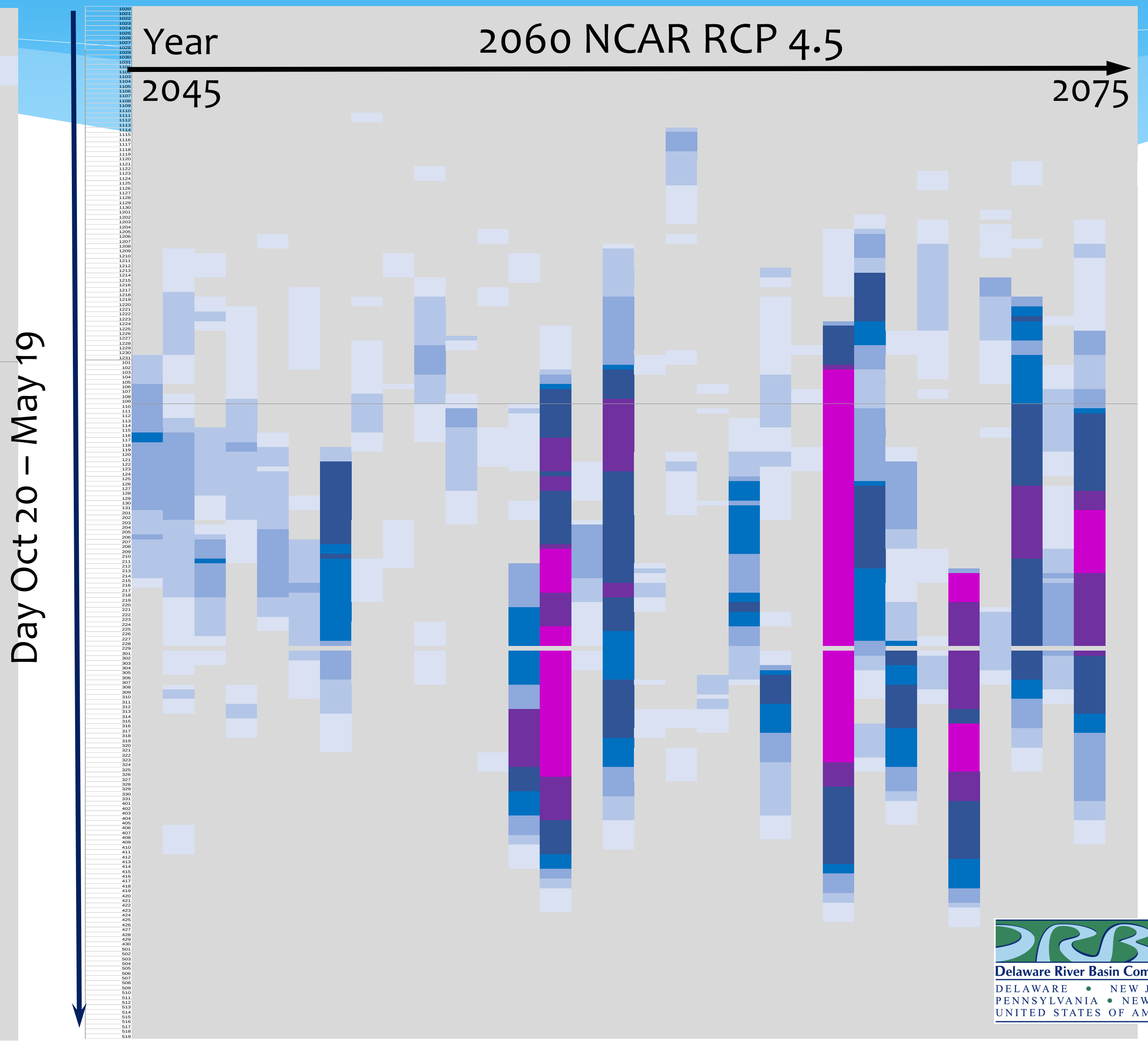




Snow Pack

PRELIMINARY





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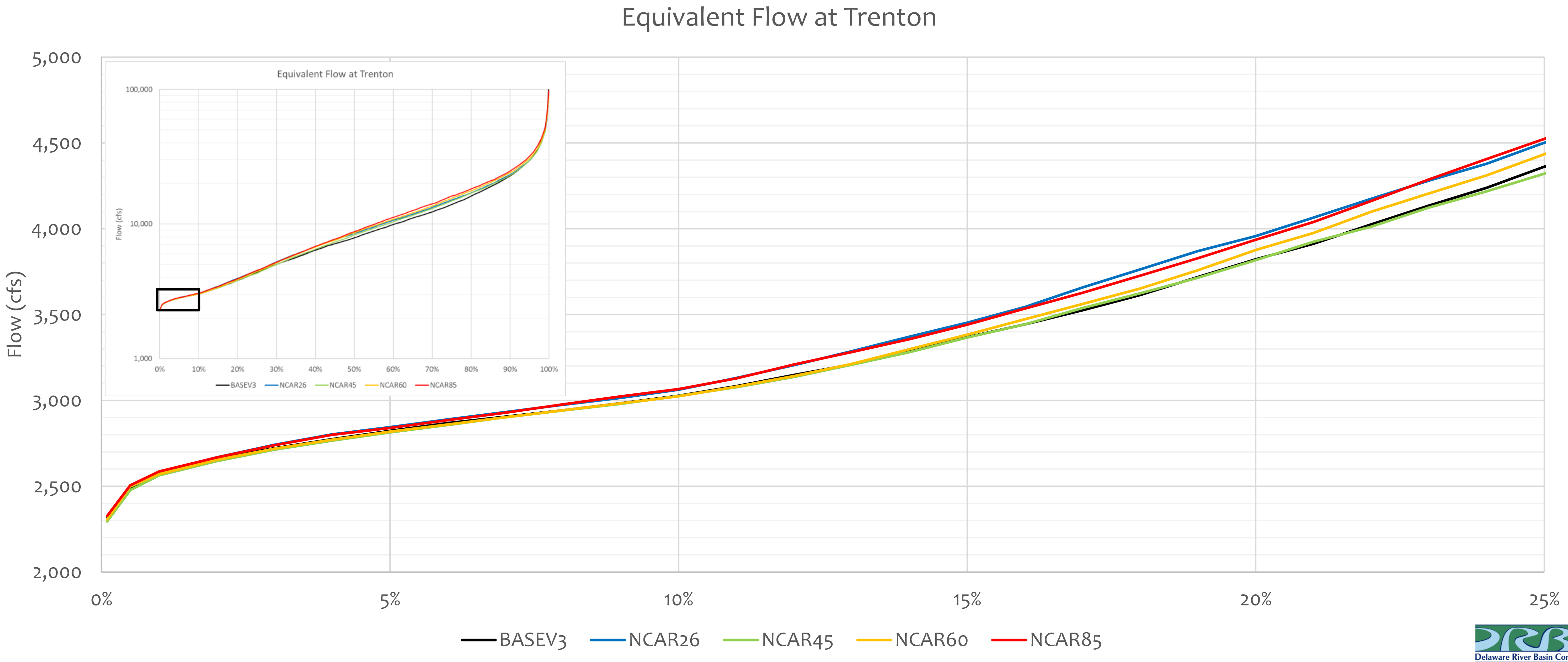
About the same?



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PRELIMINARY

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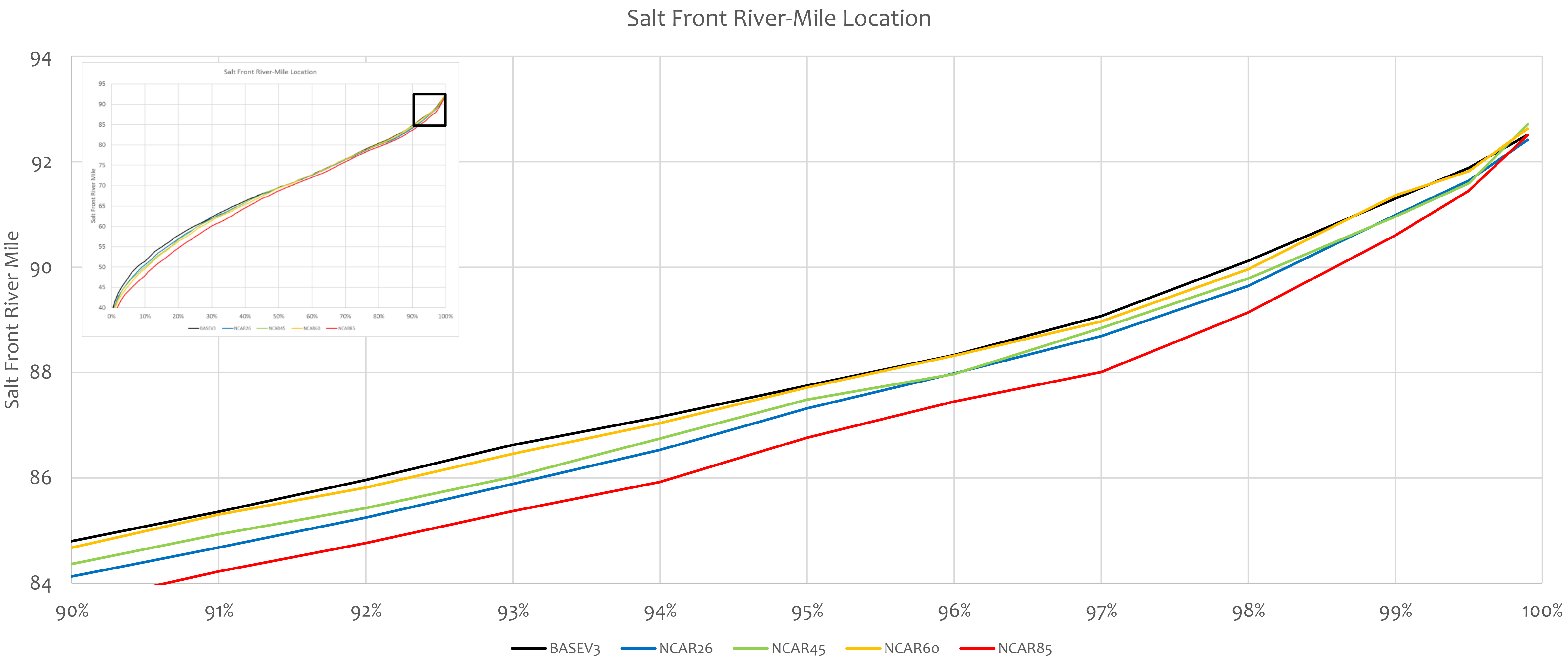

Results

- Changes in temperature and precipitation balance (warmer/wetter)
- Overall, flows increase slightly
- Seasonal changes in flow are likely
- Less snowpack, but water still reaches reservoirs
- Trends to flow similar among scenarios

Not the whole story …

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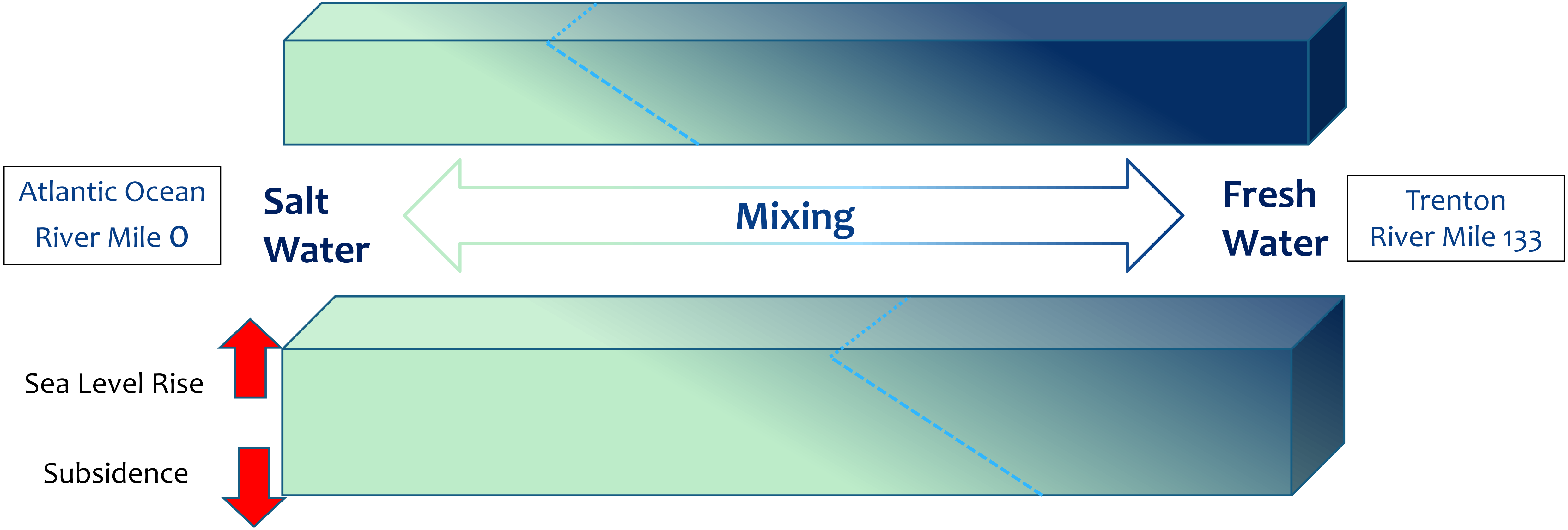
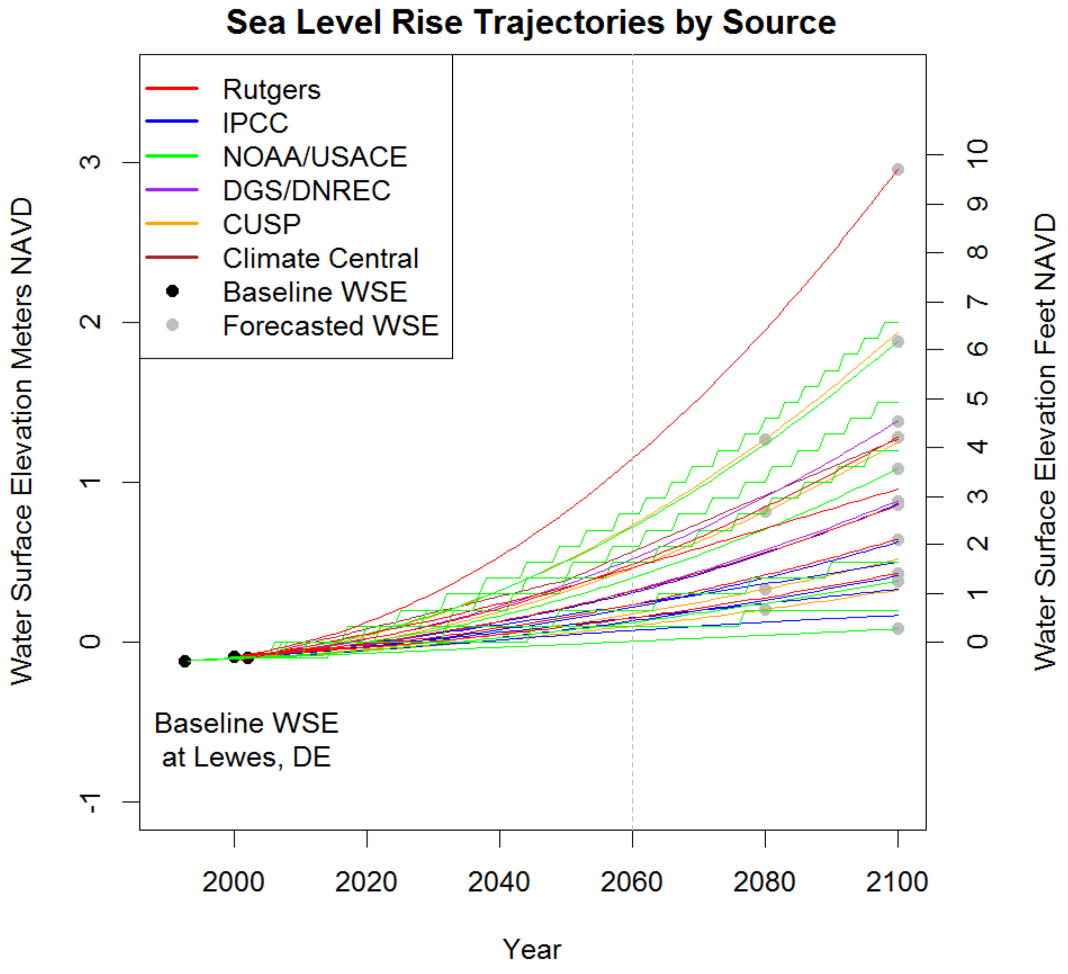
Sea Level Rise



Sea Level Rise Projections



Regional Projection Sources:

- Rutgers University
- Delaware GS and DNREC
- NOAA
- US Army Corps of Engineers
- Climate and Urban Systems Partnership (CUSP)
- Climate Central

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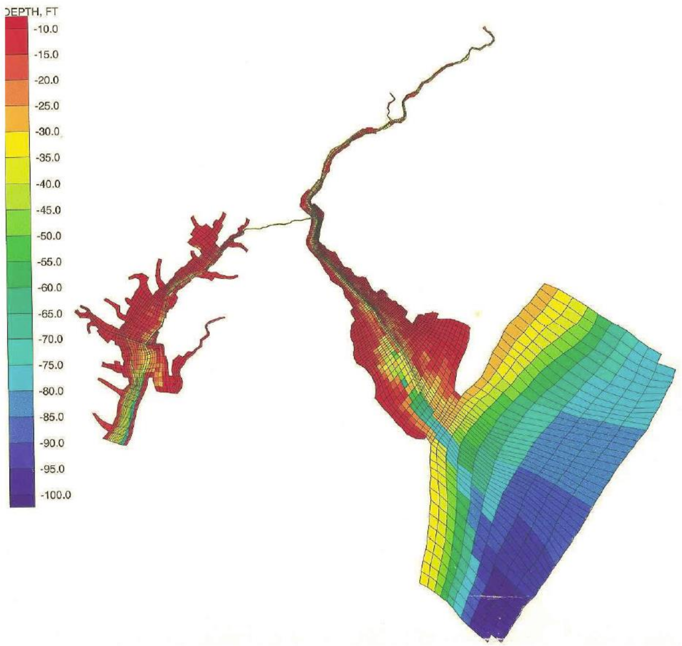
Sea Level Rise



June 2010 Report: Application of the Delaware Bay and River 3D Hydrodynamic Model to Assess the Impact of Sea Level Rise on Salinity

- USACE/Billy Johnson
- Two Channel Depths (40 and 45 feet)
- Rises of 1, 2 and 3 feet*
- Conclusions: SLR has a greater impact on salinity than channel deepening

* NOTE: Current indications are that Sea Level Rise may be 7 feet.
(NOAA SLR Viewer, Beta 3)

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Sea Level Rise and Salt Front River Mile for a Repeat of the 1960s Drought

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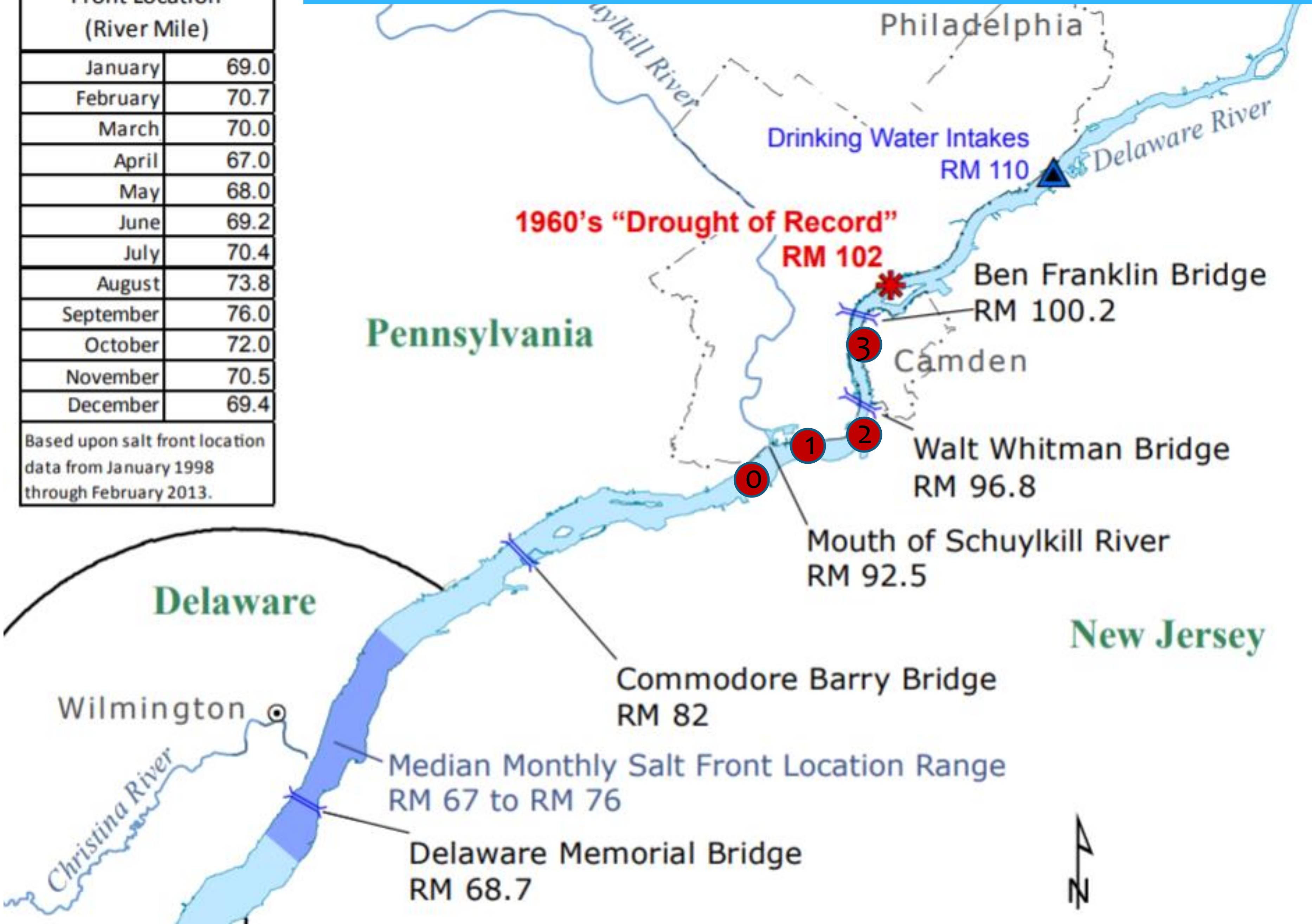

Rise	RM
0	90
1	93
2	95
3	98

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Summary

* The basin has experienced more severe droughts and floods than those seen in the past 50 years
* Predicted **trends** in climate indicate that the basin will experience **similar, but seasonally different,** flows
* More severe wet or dry flows are always a possibility
* The **drought of the 1960s** is a reasonable **planning criteria** for the basin
* Sea level rise poses the greatest threat to the basin during droughts

Delaware River Water Gap

Photo Courtesy of Samuel Vovsi

Questions

Contact:

Amy.Shallcross@drbc.gov

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