Delaware River Basin Commission

Climate Change in the Delaware Basin

Understand – Plan - Engage

Amy L. Shallcross, PE

Manager, Water Resource Operations

Water Utility Climate Alliance:
Building Resilience to Climate Change:
Decision Support and Adaptation
October 17, 2023

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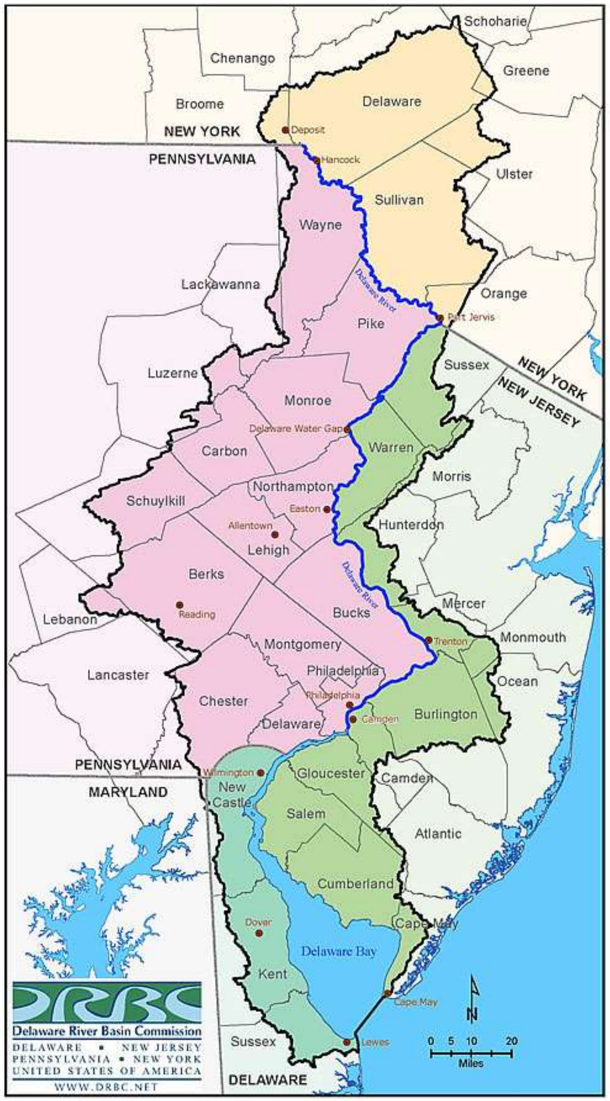


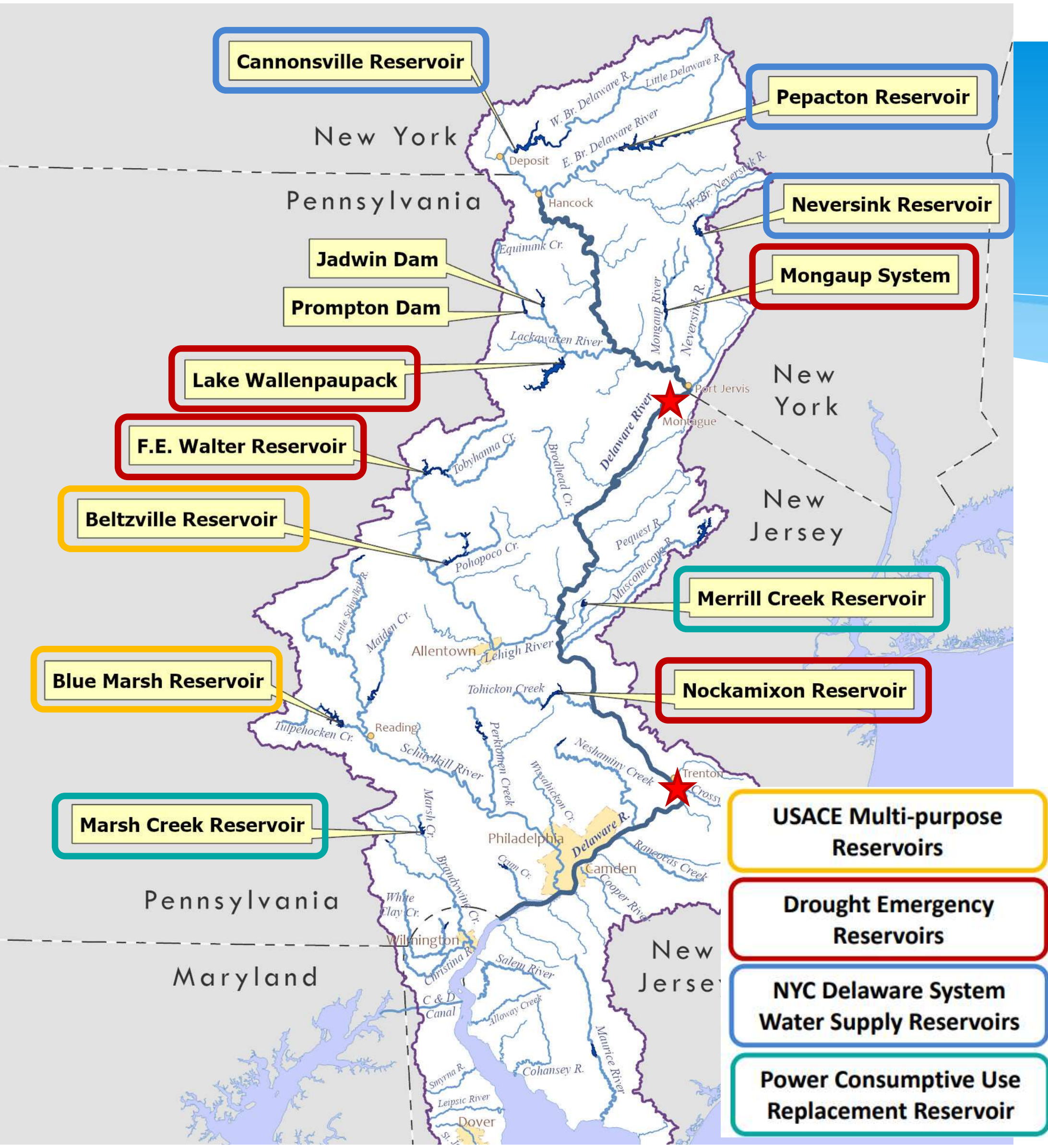
The Setting

- Delaware River Main stem 330 miles long
- Forms an interstate boundary along its entire length
- Drains 13,539 square miles of watershed in 4 states
- 14.2 million people (approximately 5% of the U.S. population) rely on the waters of the Delaware River Basin
- 150 miles designated by Congress as “Wild and Scenic” – remarkable scenic, recreational, geologic, fish, wildlife, historical and cultural values

Competing Goals for Basin Waters and Storage

- **Goals**
  - Recreation
  - Flood Risk/Damage Reduction
  - **Water Supply – Drinking Water**, Industry, Manufacturing, Cooling
  - Water Quality – Salinity, Temperature, Dissolved Oxygen, Fish and Wildlife
  - Power Generation – Hydropower, Thermoelectric
- **Resources** (**FINITE**)
  - Nature (precipitation)
  - Storage
  - Direct from river

LIMITED RESOURCES



Meeting Goals

- Mother Nature (precipitation)
- Storage (different types for different purposes) – 11 major reservoirs
- Minimum flow requirements (a.k.a. flow objectives★)
- Drought Management Programs
- Permitting programs
  - Water Use/Demand Mgmt
  - Water Quality

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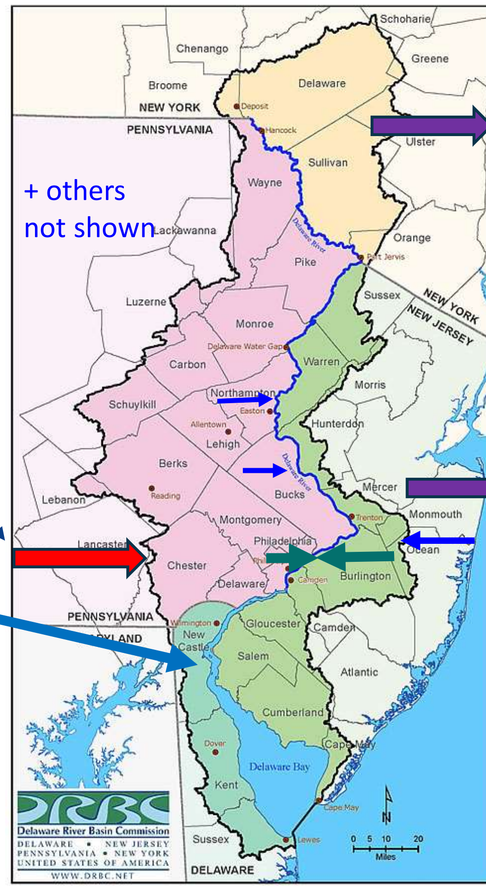
Water Purveyors and Supplies

- Pennsylvania (in-basin):
  - Non-tidal along mainstem
  - **Philadelphia** Tidal from estuary

  Chester (import) – *abandoned tidal intake in 1930s*
- Delaware
  - New Castle County – Tributary **inflatable dam** for salinity and drought protection

Export — Non-tidal
Import — Major Tidal
Tidal Tributary



- New York:
  - **New York City** aqueduct communities in headwaters
  - out-of-basin diversion (decree)
- New Jersey:
  - Non-tidal out-of-basin diversion (decree)
  - **Tidal (central and southern New Jersey)**

Green = Run-of-River

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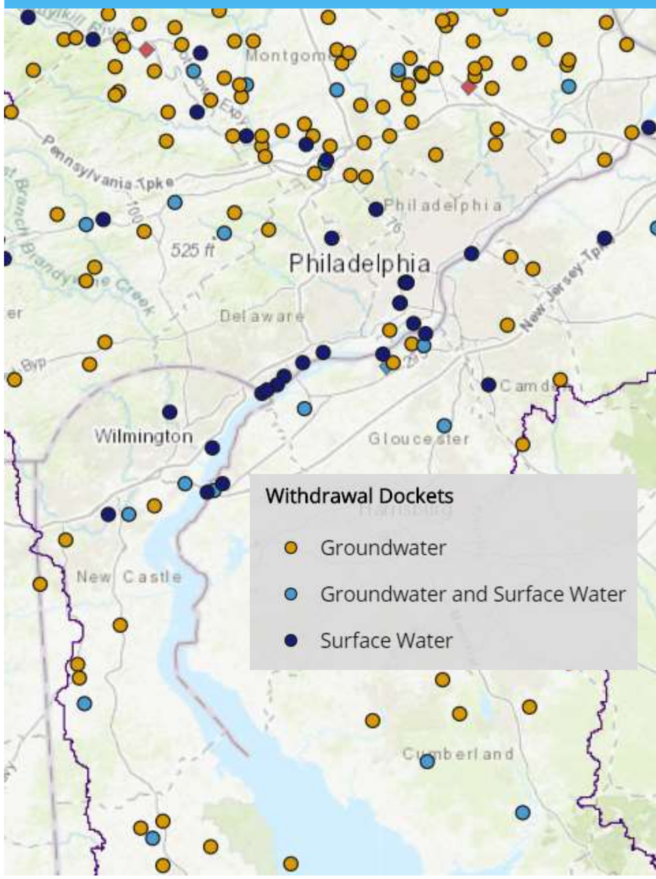
Water Users

Drinking Water Providers – Manufacturing – Refining – Energy Production



https://www.nj.gov/drbc/basin/map/interactive-map.html

Phila.gov

Suk

http://wikimapia.org/21274124/Kimberly-Clark-Inc-Chester-Papermill#/photo/1905408

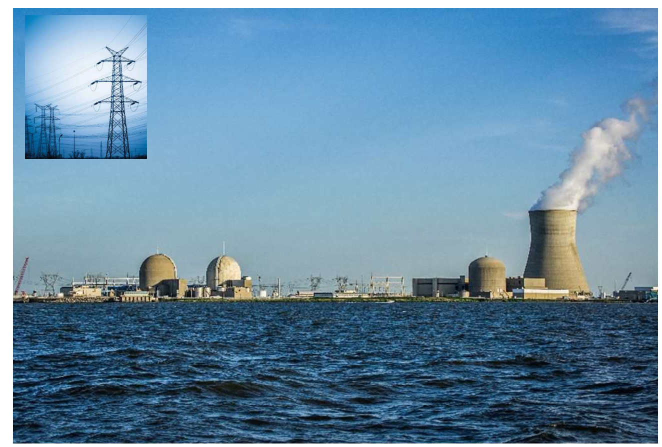


Photo: Peretz Partensky, https://www.flickr.com/photos/ifl/7238282472/in/album-72157629823114004/; unedited

1960s - Drought

- **Extreme** low flows (less than 2/3 of the minimum flows after regulation)
- Insufficient water for out-of-basin diversions to NYC
- High salinity damages equipment of estuary water users
- High salinity water was 8 miles from Philadelphia drinking water intake
- Some studies estimate it as the 250-year drought

Drought Management Plan

preserve regional storage and repel salinity (balance upper and lower basin water supplies)

- The drought of record is the planning standard
- Phased reductions in Flow Objectives, Exports, Conservation releases
- Increase flow objective when salinity it high
- Water Conservation
- Consumptive use permitting
- Additional Storage (only 1 of 5 projects developed)
- Developed **40 years ago**

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CLIMATE CHANGE
Habitat
High-Tide Flooding
Sea Level Rise
Snowpack and Ice
Drought
Welcome To REHOBOTH BEACH
Viewer
Sea Level Rise
Local Scenarios
Mapping Confidence
Marsh Migration
Vulnerability
High Tide Flooding
WATER LEVEL
10ft
9ft
8ft
7ft
5ft
4ft
3ft
2ft
1ft
Current MHHW
UNITS
Chester
Pennsville
Woodstown
Salem
NEW JERSEY

Climate Science for Drought Studies

Questions and what we need

* How will sea level rise affect salinity?
* How will water availability change?
* How will water demand change?
* How much more water do I need?
* How will water quality be affected?

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* Models (hydrologic, operational, hydrodynamic, water quality)
* Expertise\resources

What is problematic

* Generalizations (e.g., warmer/wetter; flash/worse droughts; tropical uncertainty)
* Stationarity - dead or un-dead?
* Models – GCMs/RCMs
* Hydrologic models/scale (13,600 sq. mi.)
* Uncertainty, risk, timelines
* Probability is math

} Communication fit for audiences

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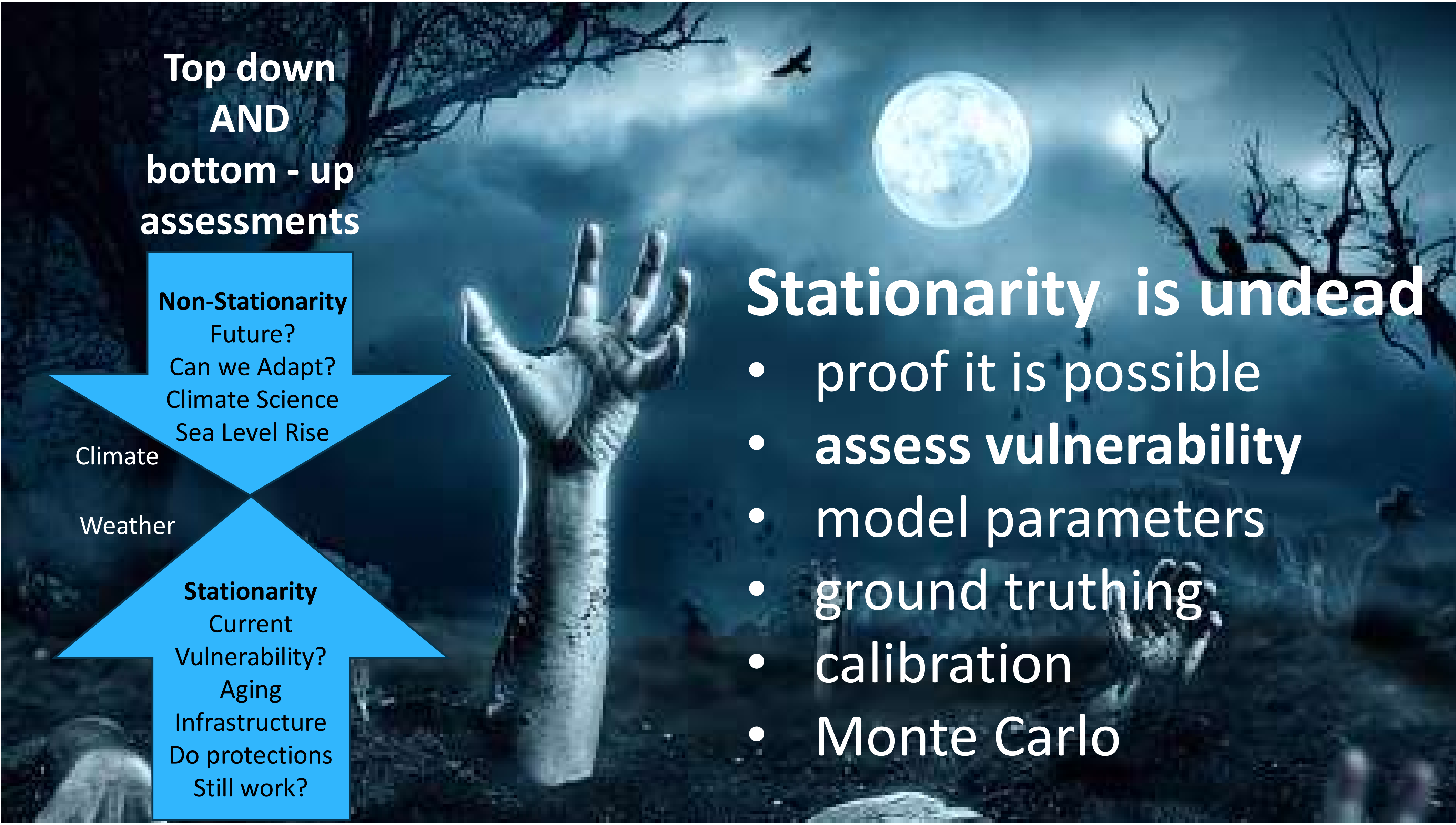


Top down AND bottom - up assessments

Non-Stationarity
Future?
Can we Adapt?
Climate Science
Sea Level Rise

Climate

Weather

Stationarity
Current
Vulnerability?
Aging
Infrastructure
Do protections
Still work?

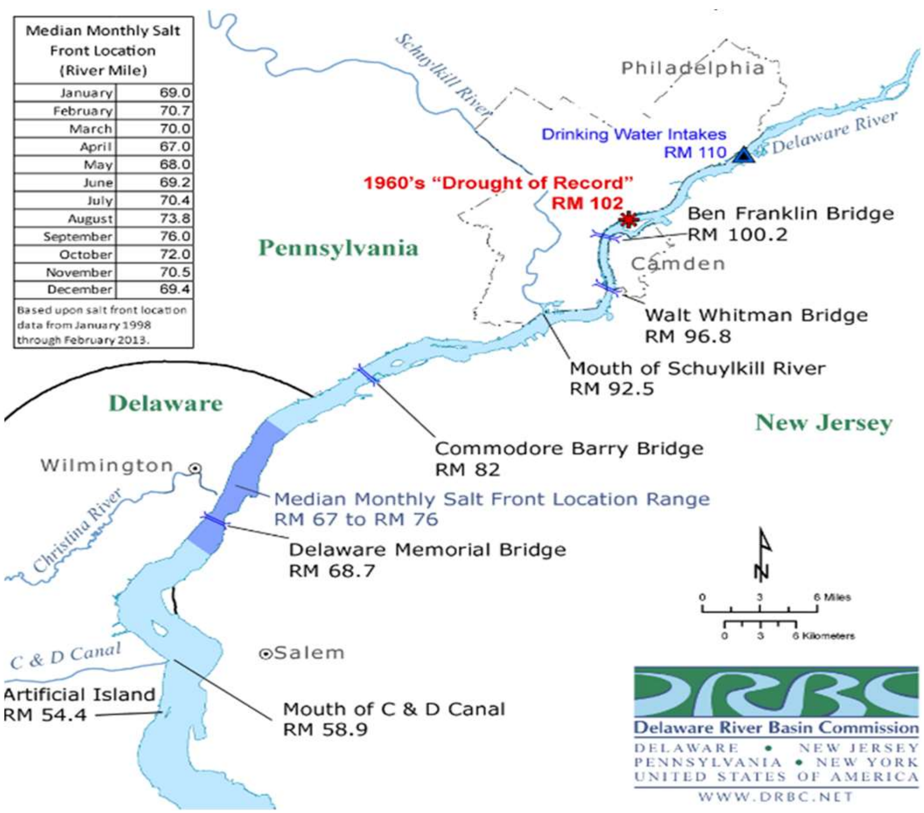
Stationarity is undead

- proof it is possible
- **assess vulnerability**
- model parameters
- ground truthing
- calibration
- Monte Carlo

The Salt Front and Sea Level Rise

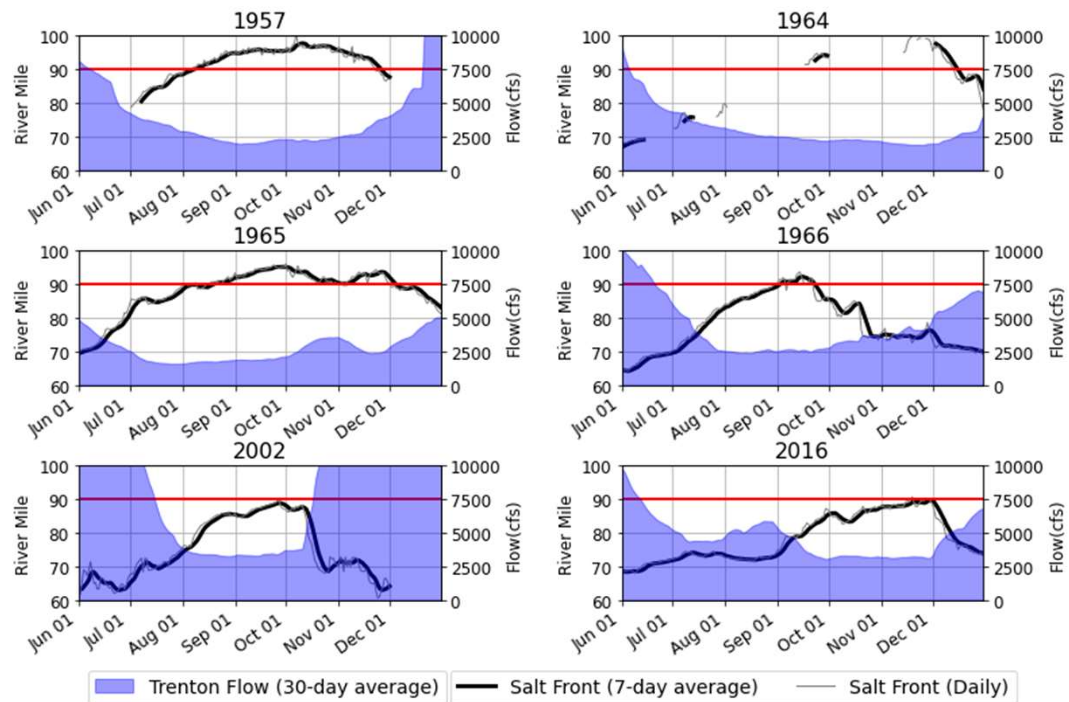
Median Monthly Salt Front Location (River Mile)	
January	69.0
February	70.7
March	70.0
April	67.0
May	68.0
June	69.2
July	70.4
August	73.8
September	76.0
October	72.0
November	70.5
December	69.4

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



Salt Front Location vs. 30-dma flow

Flow sets the location, the tide sets the variability



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Salinity and Sea Level Rise

largest factors are flow and tides

Water supply intakes were threatened by high salinity water during the drought of record

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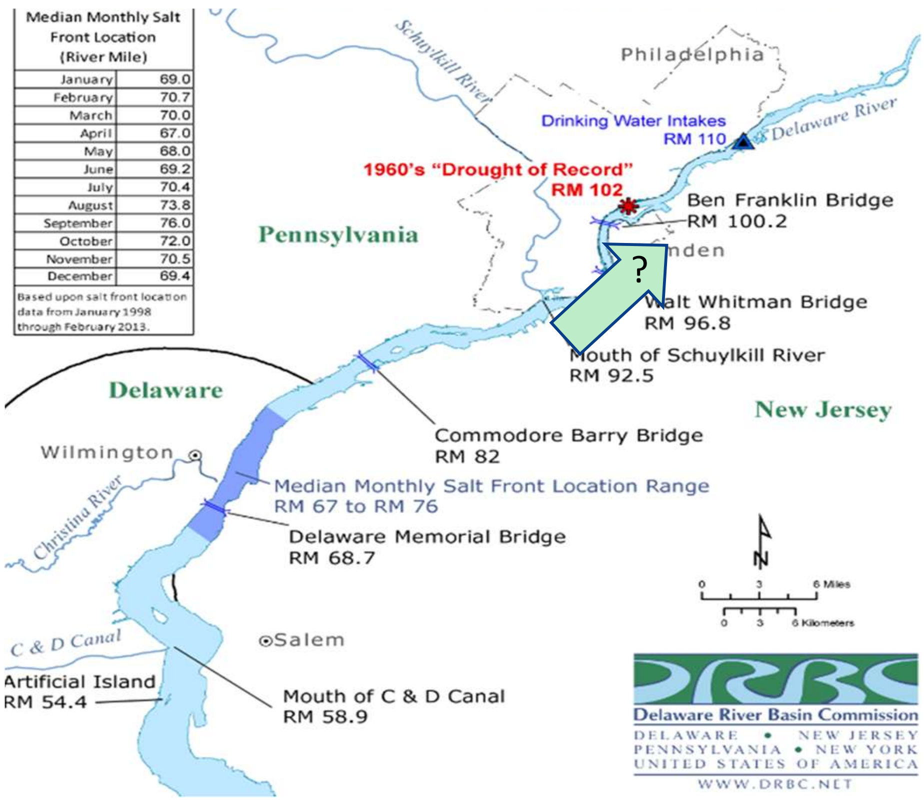

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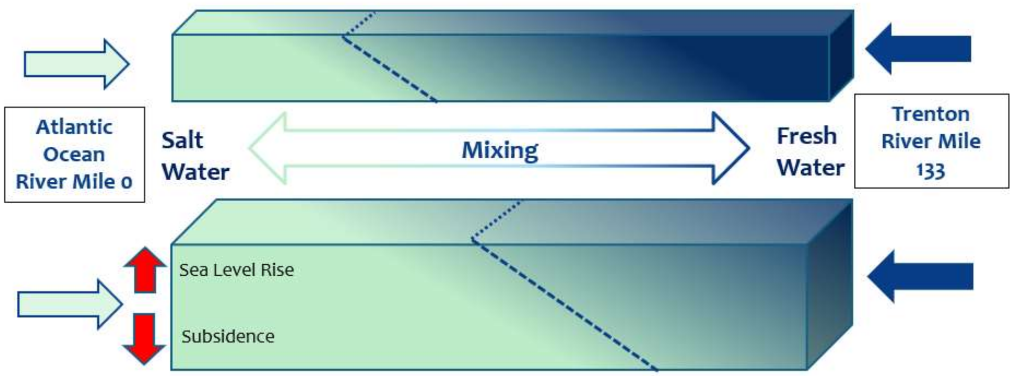
WWW.DRBC.NET

Risks of Sea Level Rise

Conceptual diagram of how SLR may affect the location of the salt front.

Location of high salinity water depends on the ocean pushing into the bay and the freshwater flow pushing out to the ocean



Mass (ocean) and kinetic energy (tide, gravitational pull) vs. Mass (river) and potential energy (gravity)

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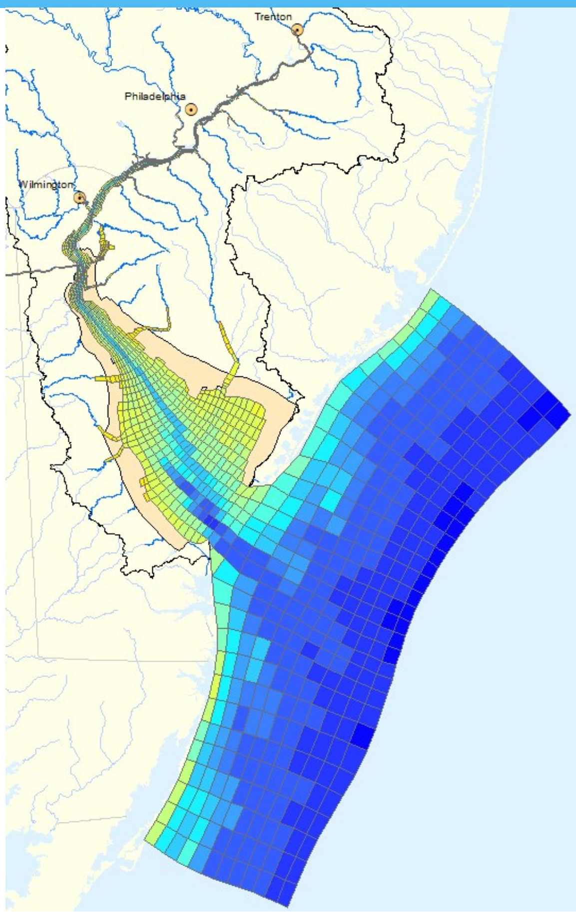
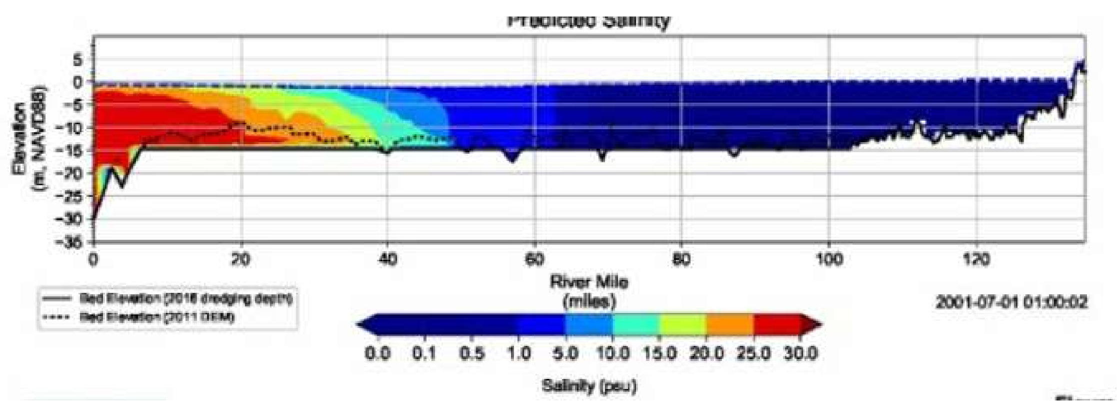
Three-dimensional Hydrodynamic Salinity Model (SM3D)

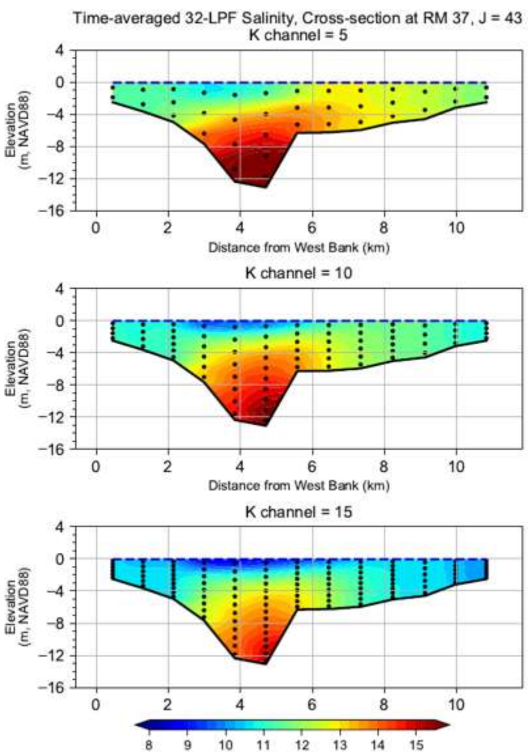


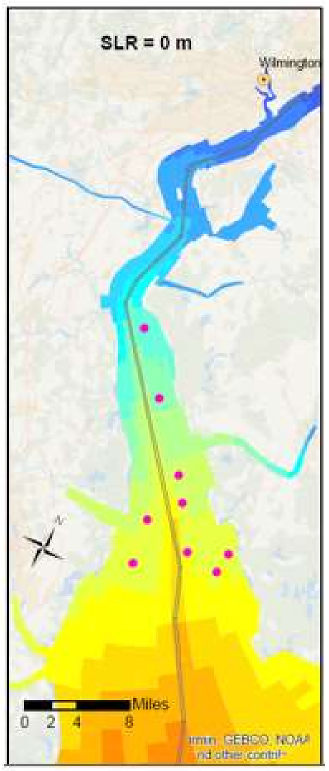
* Three-Dimensional Model Required
* Complex physics
* Environmental Fluid Dynamic Code (EFDC)
* “Living” model - refined as more data become available
* Computationally intensive

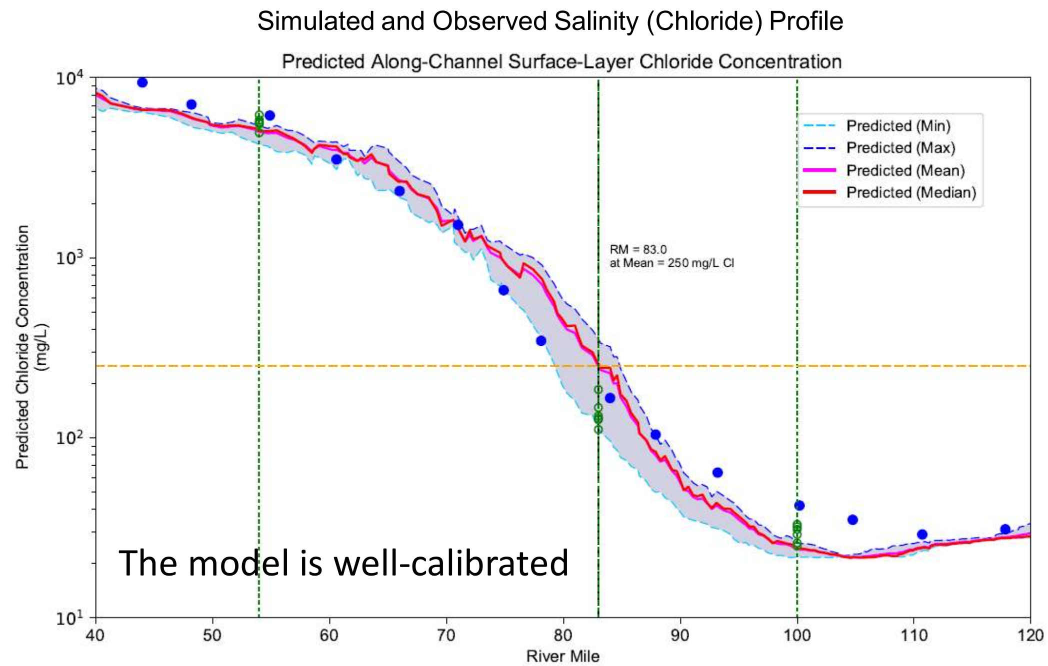


Three-dimensional Hydrodynamic Salinity Model (SM3D)

Sample Results

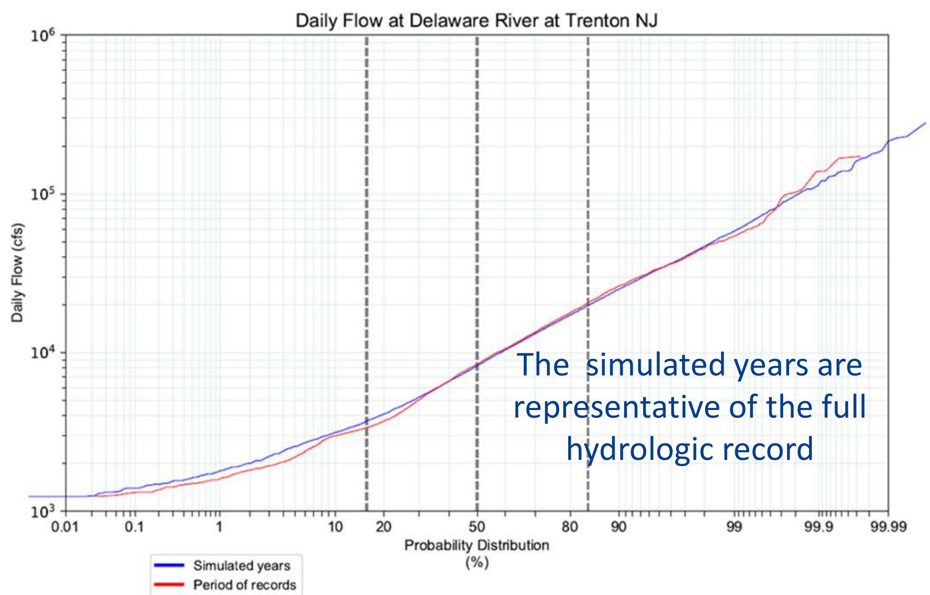






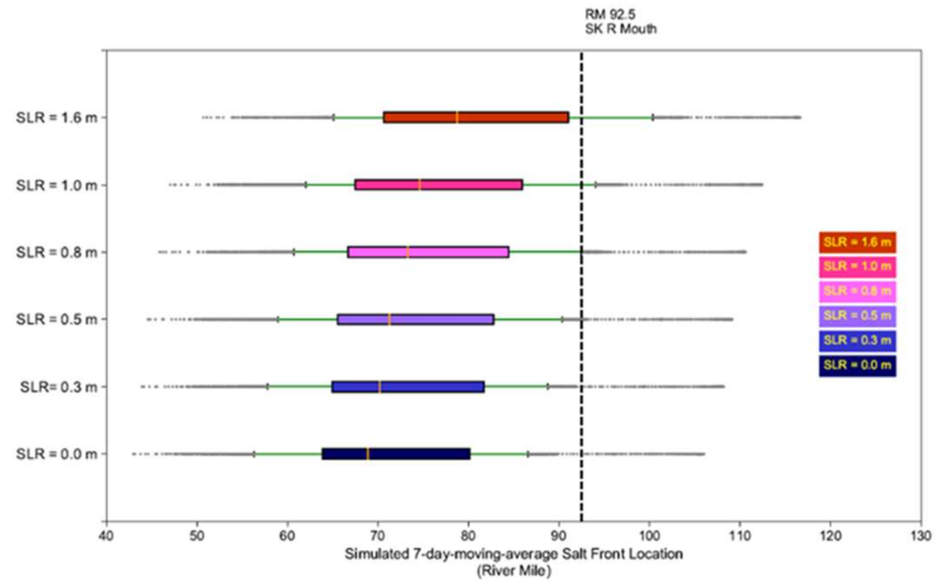
Sea Level Rise and Salinity

Cumulative Flow Distribution for the Full Historical Record and Only the Years Simulated



Years Simulated: 1965, 2001-2003, 2011-2013, 2016-2019

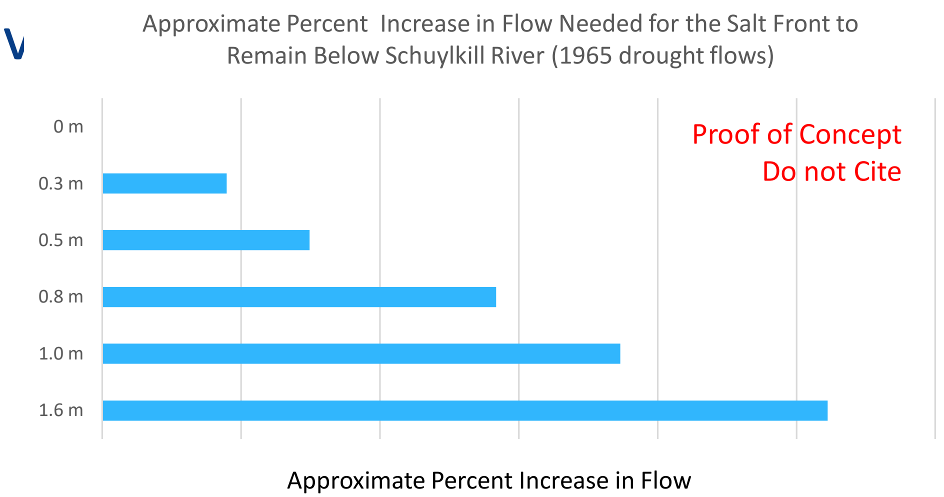
Range of Salt Front Location with a range of Sea Level Rise Projections (0 m - baseline, 0.3 m, 0.5 m, 0.8 m, 1.0 m, 1.6 m)

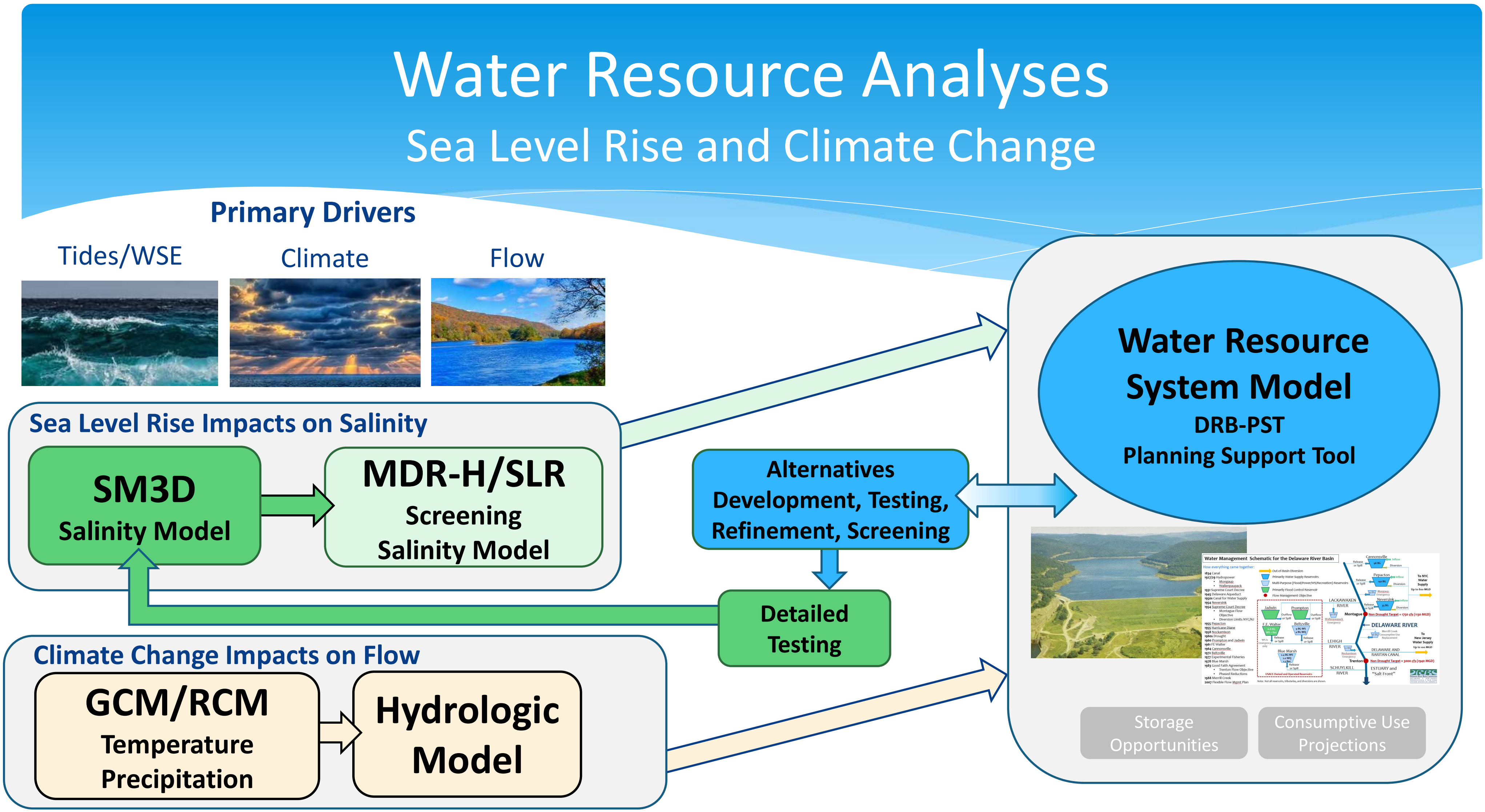


Sea Level Rise values simulated can represent multiple emission/planning horizon scenarios

Planned and Potential Future Analyses

- Effectiveness of Trenton Flow Objective
- Alternatives to Trenton Flow Objectiv
  - Flow/Pulses/Location Triggers
  - Sources
  - Timing
- Other conditions
  - Climate impacted flows
  - Tides
  - Incoming salinity



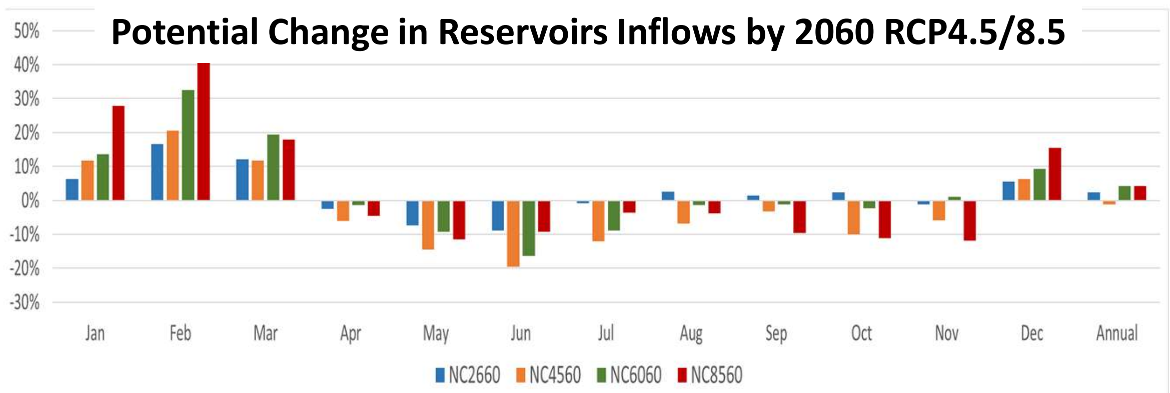

Water Resource Analyses
Sea Level Rise and Climate Change
Primary Drivers
Tides/WSE
Climate
Flow
Sea Level Rise Impacts on Salinity
SM3D
Salinity Model
MDR-H/SLR
Screening
Salinity Model
Alternatives
Development, Testing,
Refinement, Screening
Detailed
Testing
Climate Change Impacts on Flow
GCM/RCM
Temperature
Precipitation
Hydrologic
Model
Water Resource
System Model
DRB-PST
Planning Support Tool
Storage
Opportunities
Consumptive Use
Projections

Climate Assessment

First Analysis

* USGS Hydrologic Model
  * Developed for the Secure Water Act
  * Delta factor method/PET Adjustment
  * Based on availability of PRISM data
  * 4 GCMs, 4 RCPs, 4 periods, 2 land use
  * Number grid cells: 6-11
  * Model only ran on one computer*
* Water Supply Planning Model

* **Results:** anti-climatic
  * Inconclusive (some wetter/some drier)
  * No "worse" drought
* Conclusions:
  * Use GCMs with hindcasts inc. 1960s
  * Pursue analysis of Sea Level Rise



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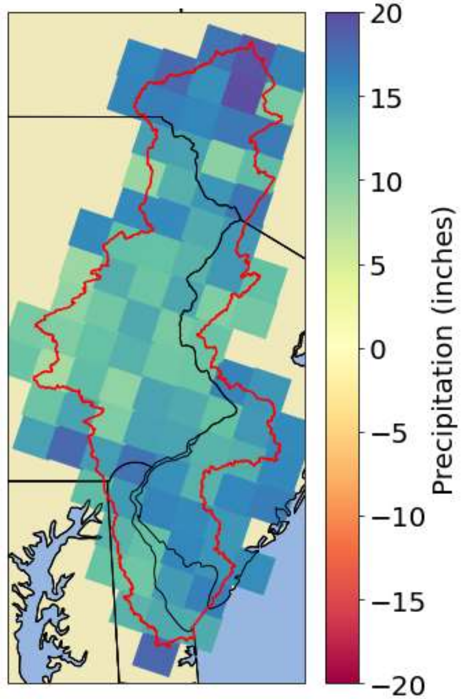
Current Analysis

Project Scope/Outline

- CMIP 5 Models: 1950 => 2100
- CORDEX: RCP 4.5 and RCP 8.5
- Bias Correction – Quantile Distribution Mapping
- New hydrologic model
- Results
- Develop a process for additional analyses

Precipitation
Observed – Raw GCM



Issues

- State of observed data
- Bias correction
- Hydrologic model

DRB Spatial Average

Observed	45.5 inches	30%
Raw GCM	59.4 inches	

Drizzle days only explain 3 inches

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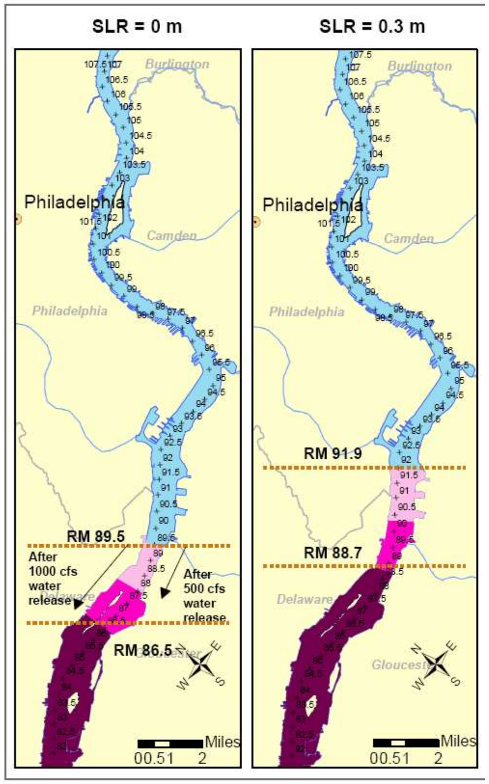
Water Resource Analyses – Next Steps



- Top-down and bottom-up analyses
- Tool Refinement
- Vulnerability/reliability assessments
- Uncertainty and defining risk
- Collaborate with stakeholders
- Establish planning assumptions with Advisory Committees

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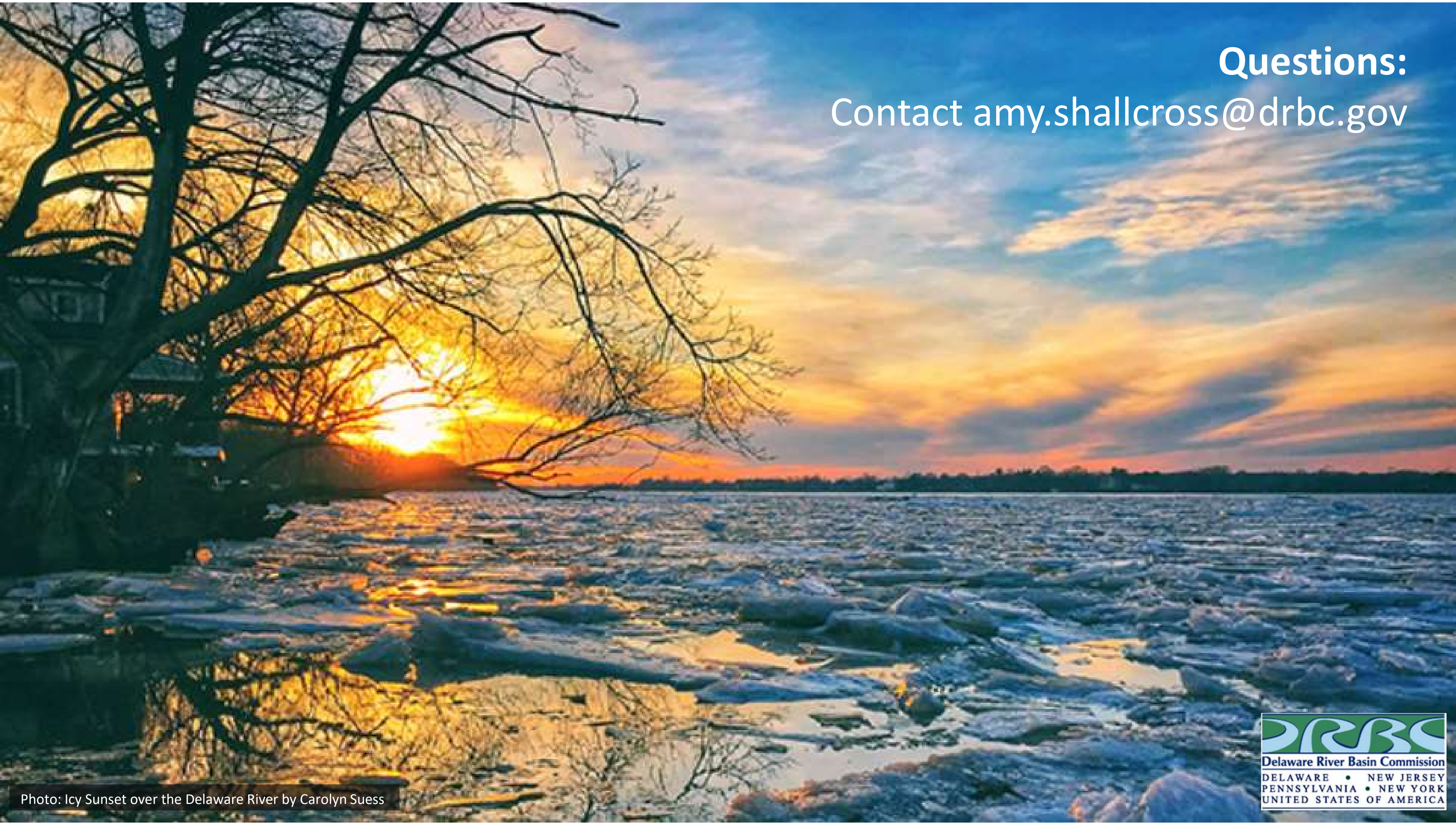

Photo: Icy Sunset over the Delaware River by Carolyn Suess