Climate Change in the Delaware Basin
Understand – Plan - Engage

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Water Utility Climate Alliance:
Building Resilience to Climate Change:
Decision Support and Adaptation
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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 Quality – Salinity, Temperature, Dissolved Oxygen, Fish and Wildlife
  - Power Generation – Hydropower, Thermoelectric

- **Resources (FINITE)**
  - Nature (precipitation)
  - Storage
  - Direct from river
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
* **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

* **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)

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**Green = Run-of-River**

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<thead>
<tr>
<th>Export</th>
<th>Non-tidal</th>
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<tbody>
<tr>
<td>Import</td>
<td>Major Tidal</td>
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<td>Tidal Tributary</td>
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Water Users
Drinking Water Providers – Manufacturing – Refining – Energy Production

Withdrawal Dockets
- Groundwater
- Groundwater and Surface Water
- Surface Water

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

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

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
This Photo by Unknown Author is licensed under CC BY-NC.
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?

What is problematic
* Generalizations (e.g., warmer/wetter; flash/worse droughts; tropical uncertainty)
* Stationarity - dead or un-dead?
* Models – GCMs/RCMs
* Hydrologic modelsSCALE (13,600 sq. mi.)
* Uncertainty, risk, timelines
* Probability is math
Stationarity is undead
- proof it is possible
- assess vulnerability
- model parameters
- ground truthing
- calibration
- Monte Carlo

Top down AND bottom-up assessments

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

Stationarity
- Current
- Vulnerability?
- Aging
- Infrastructure
- Do protections still work?
The Salt Front and Sea Level Rise

Salt Front Location vs. 30-dma flow
Flow sets the location, the tide sets the variability
Salinity and Sea Level Rise
largest factors are flow and tides

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)
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

The model is well-calibrated
Sea Level Rise and Salinity

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

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)

The simulated years are representative of the full hydrologic record


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 Objective
  - Flow/Pulses/Location Triggers
  - Sources
  - Timing
- Other conditions
  - Climate impacted flows
  - Tides
  - Incoming salinity

Approximate Percent Increase in Flow Needed for the Salt Front to Remain Below Schuylkill River (1965 drought flows)

Proof of Concept
Do not Cite

Approximate Percent Increase in Flow
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

Climate Change Impacts on Flow
- GCM/RCM Temperature Precipitation
- Hydrologic Model

Alternatives Development, Testing, Refinement, Screening

Detailed Testing

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
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

Issues

- State of observed data
- Bias correction
- Hydrologic model

DRB Spatial Average

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<td><strong>Raw GCM</strong></td>
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<td><strong>30%</strong></td>
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Drizzle days only explain 3 inches
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
Photo: Icy Sunset over the Delaware River by Carolyn Suess

Questions:
Contact amy.shallcross@drbc.gov