PWD Water Supply Planning: Salinity Intrusion in the Delaware River Estuary

Regulated Flow Advisory Committee April 9, 2019

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Salinity Intrusion in the Delaware Estuary

1. Utility and planning overview
2. Salinity intrusion
3. PWD modeling

Philadelphia Water Department

Drinking Water

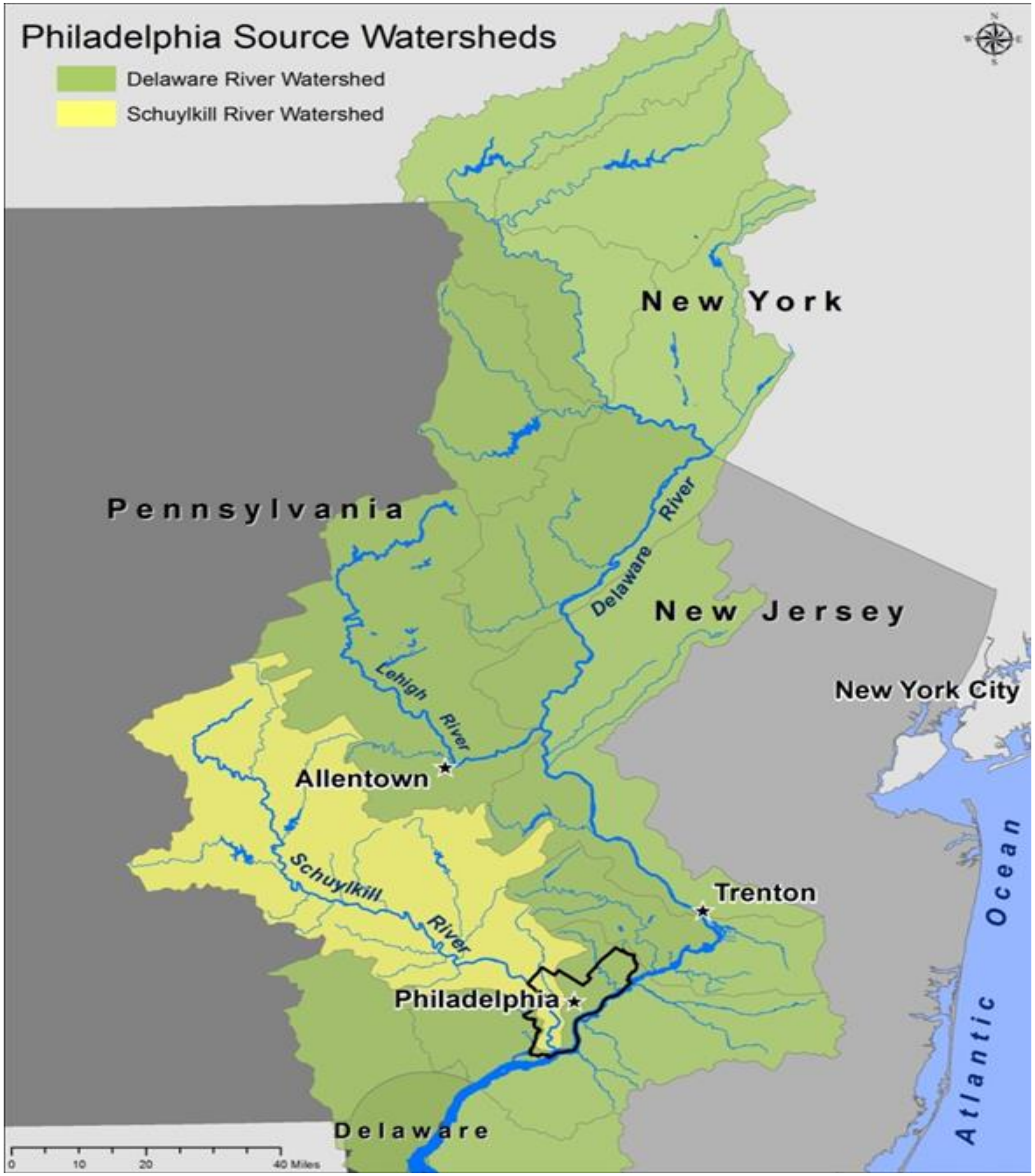
- 1.7 million drinking water customers
- 3 Water Treatment Plants

Wastewater

- 2.2 million wastewater customers
- 3 Water Pollution Control Plants

Stormwater

- 60% Combined, 40% Separate Sewers
- Large-scale green infrastructure pgm.



PWD Water Supply Planning

- Multi-year water supply planning effort
- Designed to support parallel water and wastewater infrastructure planning efforts
- Critical need to understand the potential risks to infrastructure, regulatory compliance and public health of current and future water quality and quantity
- Water supply planning, specifically, takes into consideration three critical drivers

  -Climate change

  -Ambient water quality changes

  -Policy changes

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Why is Water Supply Planning Needed?

- Climate changes
- Ambient water quality changes
- **Policy changes**
  - **The flow targets work, yet they are under consideration to be changed**

Pre-2017 FFMPs

- Same salinity policy since 1983 (35 yrs.)

Current FFMP

- Flow targets anticipated to be reduced in 5 years

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Critical Planning Baseline Observations

1. **Ambient chloride concentrations today are equivalent to the worst salinity intrusion of record in the 1960s**

2. **Current flow targets in the FFMP are critical to manage intrusion of ocean salt**

3. **Any attempt to alter current flow targets needs a carefully crafted assessment of intrusion impacts on public health and infrastructure**

What Does Water Supply Planning Entail?

Salinity Modeling

- Informs how changes to flow targets will influence salinity at the PWD drinking water intake

Watershed Modeling

- What reservoir policies optimize the use of limited water resources during drought

What Does Water Supply Planning Support?

Infrastructure Planning – PWD Water Master Plan

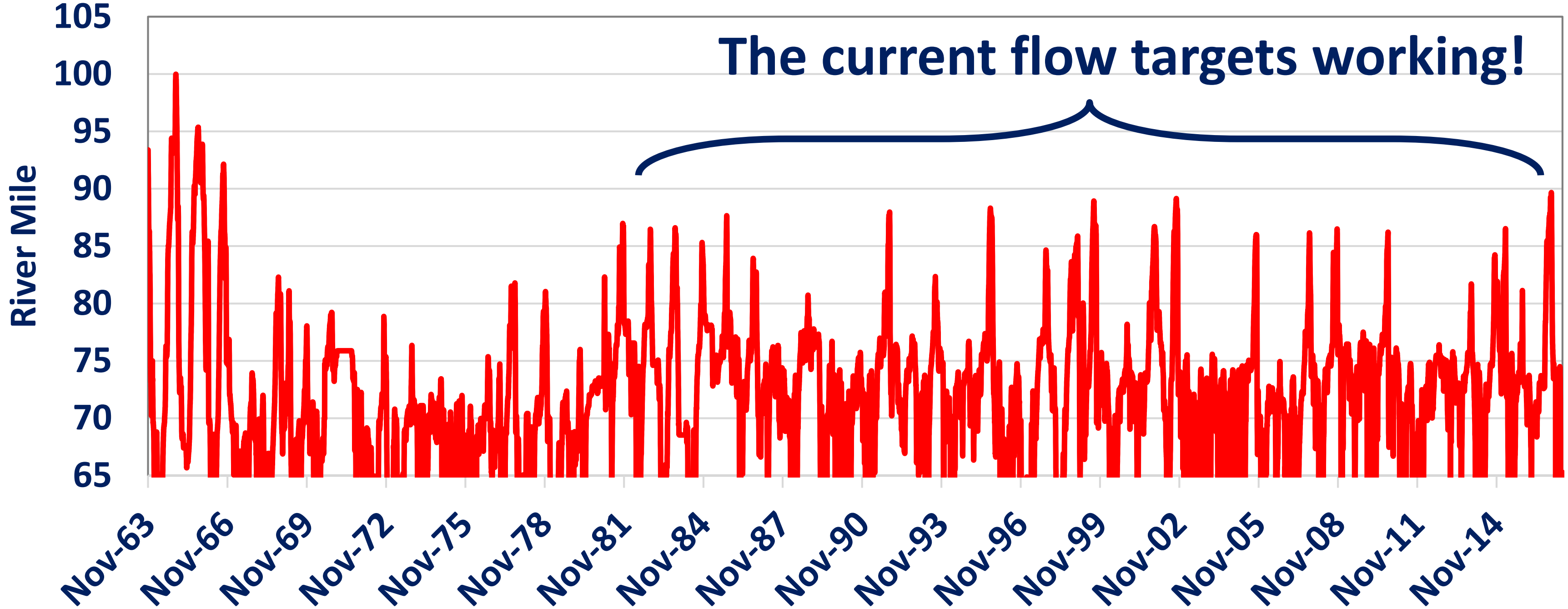
- Alignment of the life cycle of infrastructure, water quality and regulatory compliance

Why do the flow targets work?

Salinity Modeling

- Informs how changes to flow targets will influence salinity at the PWD drinking water intake
- Salinity is not removed by treatment process

Salt Line River Mile, 1963 – 2016, 7-day average 250 mg/L chloride

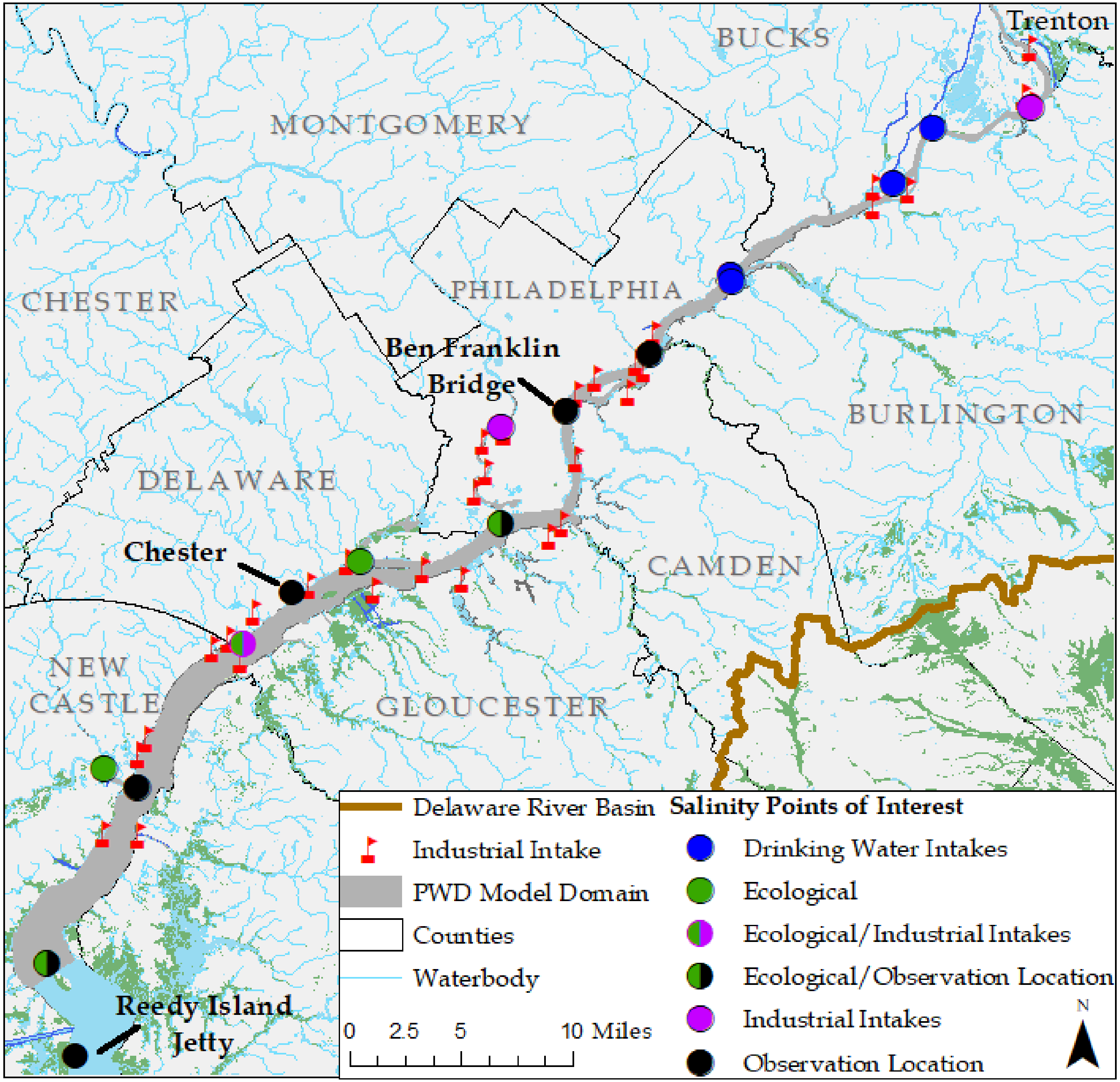


Salinity in the Delaware Estuary

- Salinity measured in Practical Salinity Units (PSU), also parts per thousand (ppt)
- Salinity is the total ionic salt concentration, includes chloride, sodium, sulphate, magnesium, calcium and potassium
- 250 mg/L chloride, approximately 0.52 PSU, is a secondary MCL
- Ocean is 35 PSU, Baxter WTP is typically <0.1 PSU

How can observed data inform salinity intrusion modeling?

- Critical influences on intrusion
- What capabilities are required of a model



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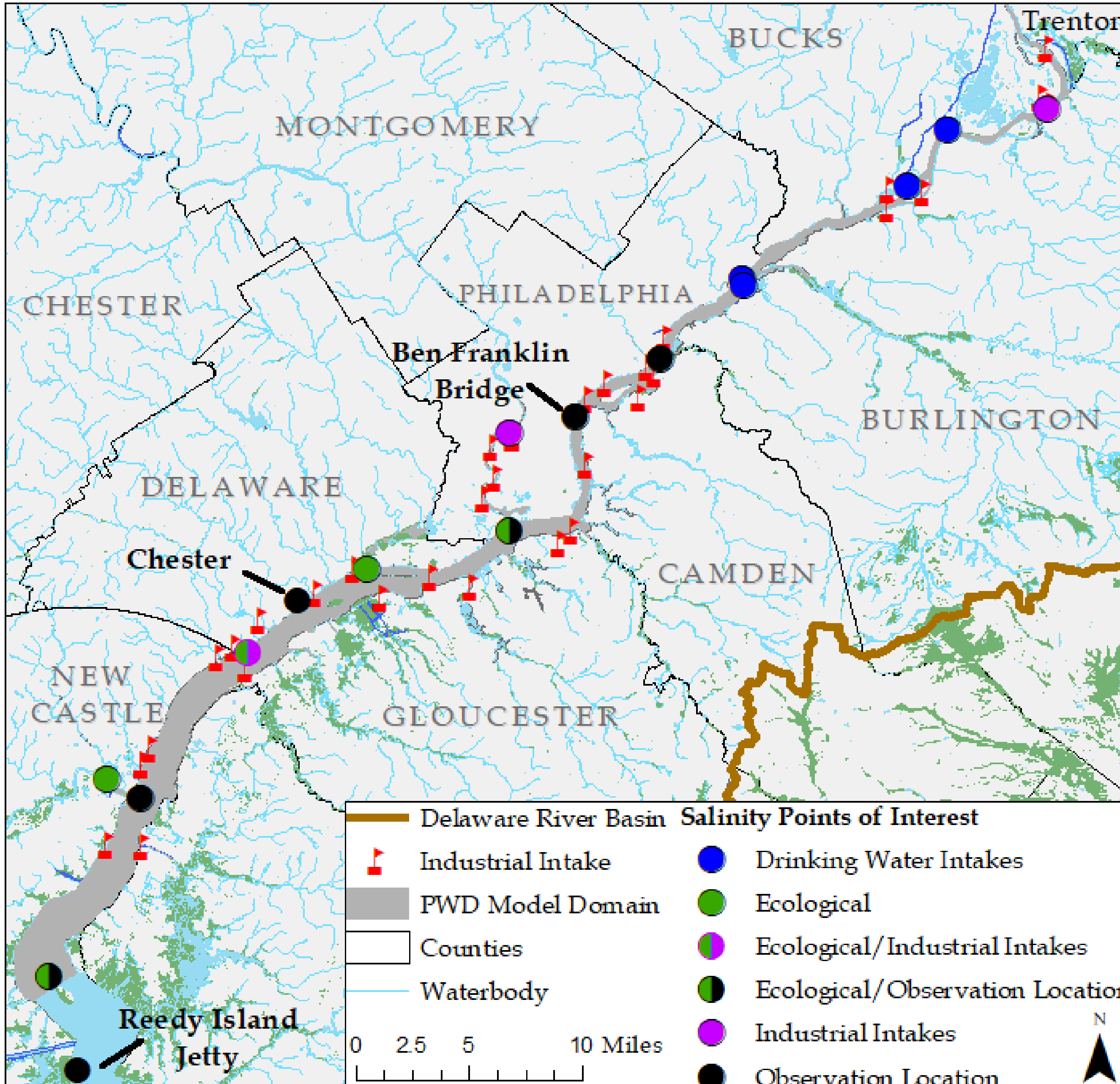
Observed Data Demonstration - Sources

- Salinity at Reedy Island Jetty, USGS
- Salinity at Chester, USGS
- Sea Level at Philadelphia, NOAA
- Streamflow at combined Trenton and Philadelphia, USGS



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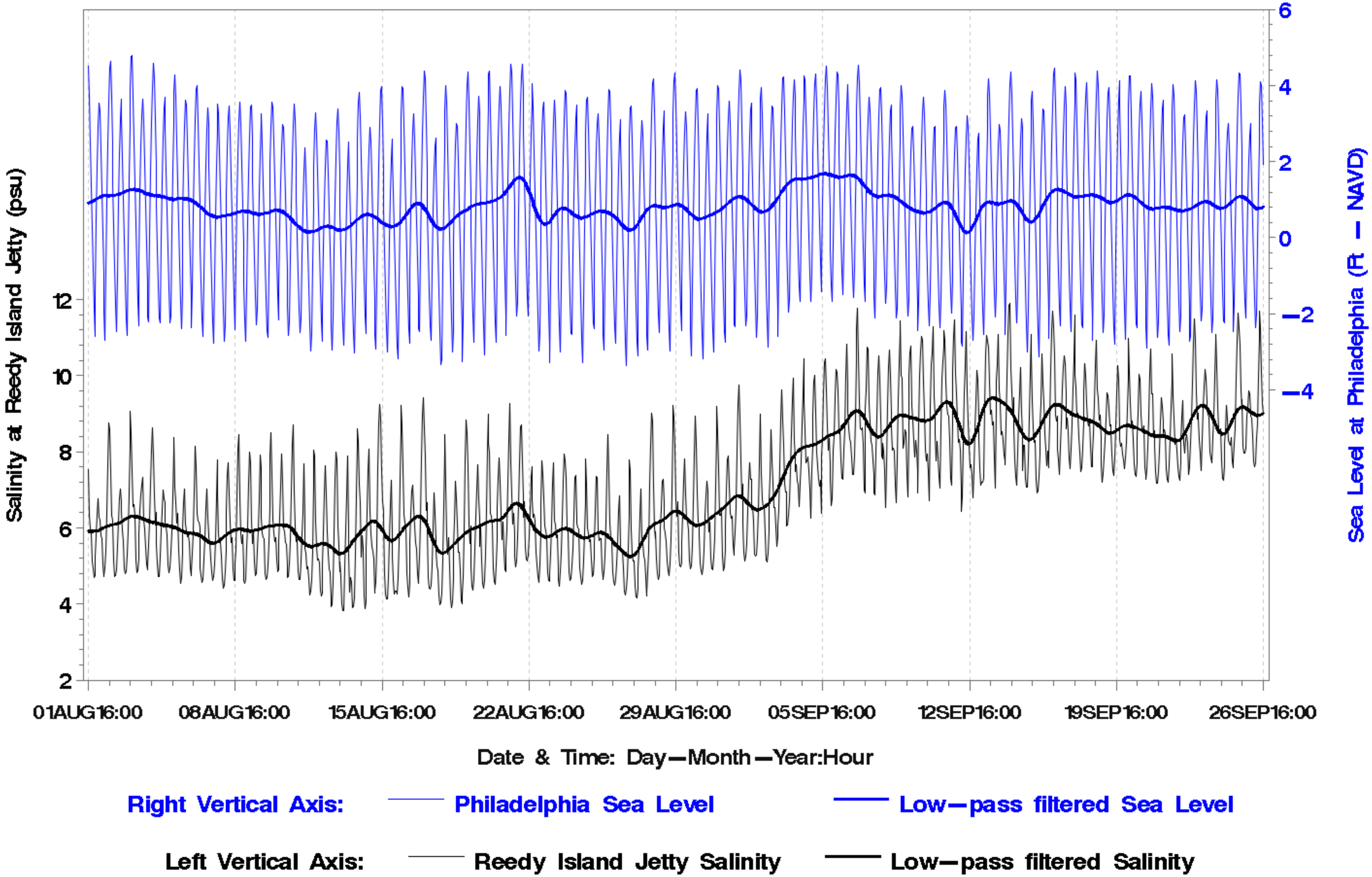
Quick Overview – Tidal Data Signal Filtering



Critical Influences on Salinity Intrusion

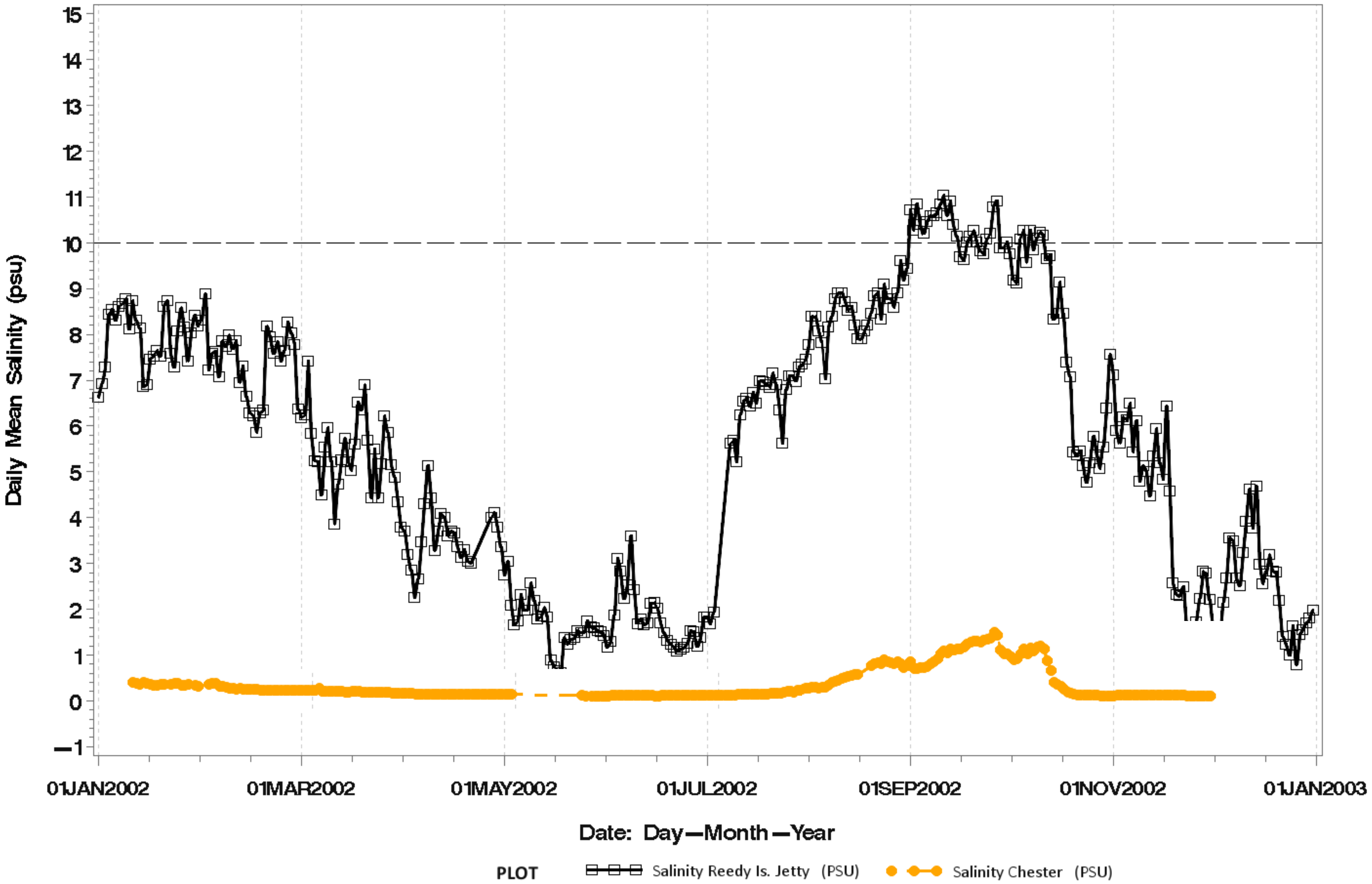
Streamflow – can cause salinity to rise and fall

Major Storms – can decrease salinity through advective transport

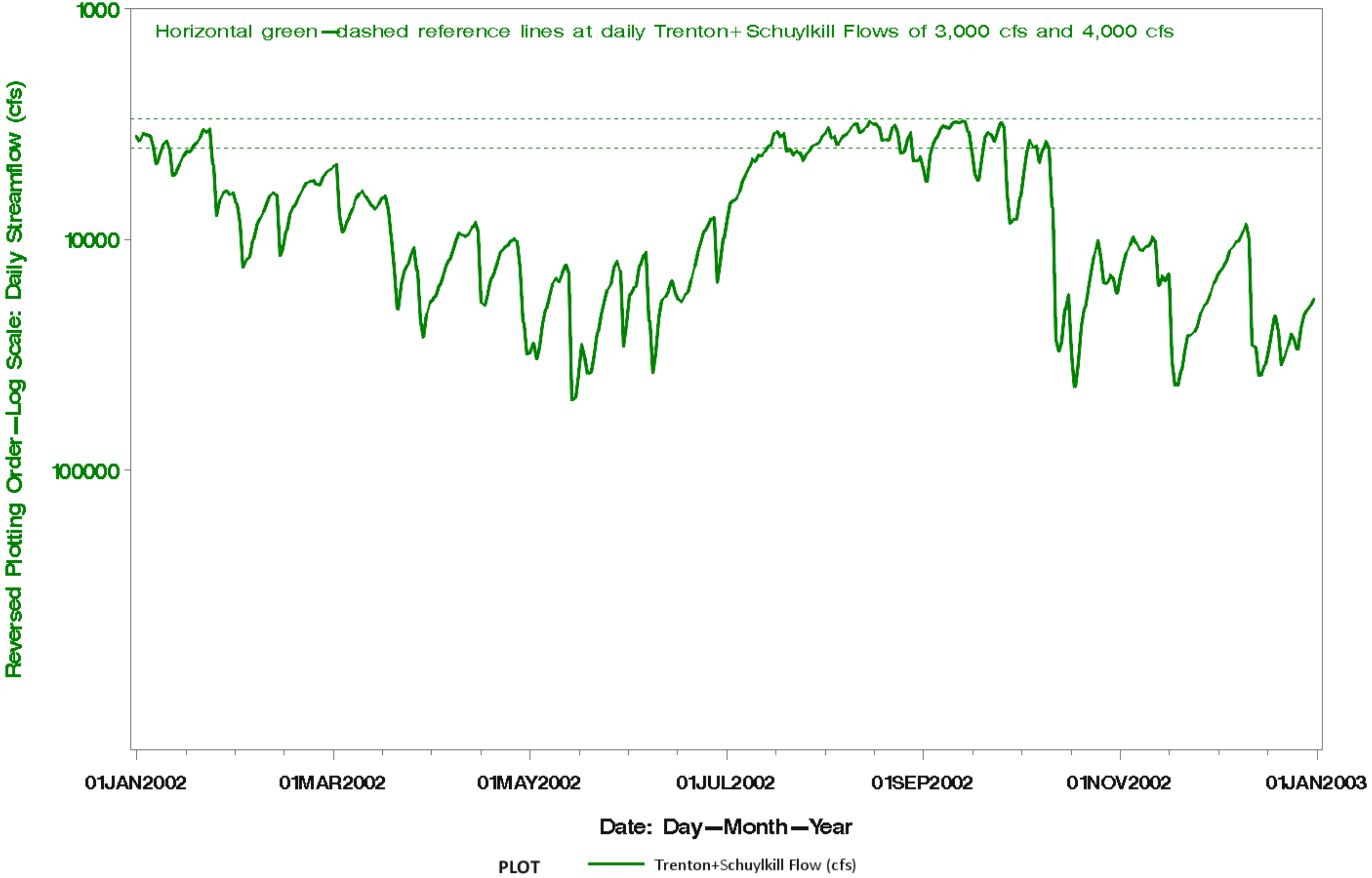
Sea Level – short-term subtidal fluxes cause significant increases or decreases in salt intrusion through advective transport

Estuarine Circulation – increases or decreases salt intrusion absent changes in freshwater inflow or subtidal fluxes. These are more three-dimensional hydrodynamic effects, not simple advective transport

2002 – Salinity at Reedy Island Jetty and Chester



2002 – Inverted Schuylkill + Delaware Streamflow



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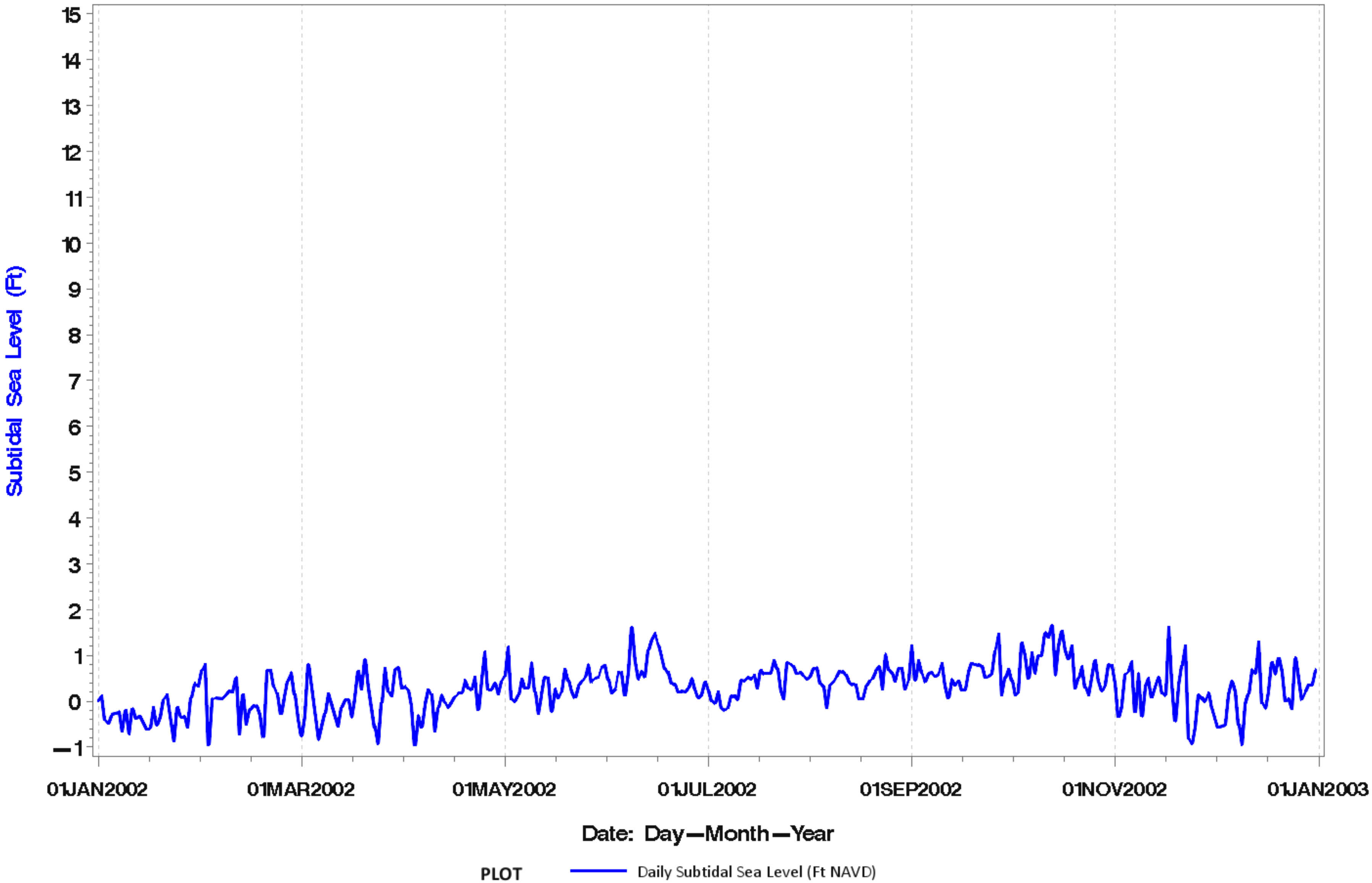
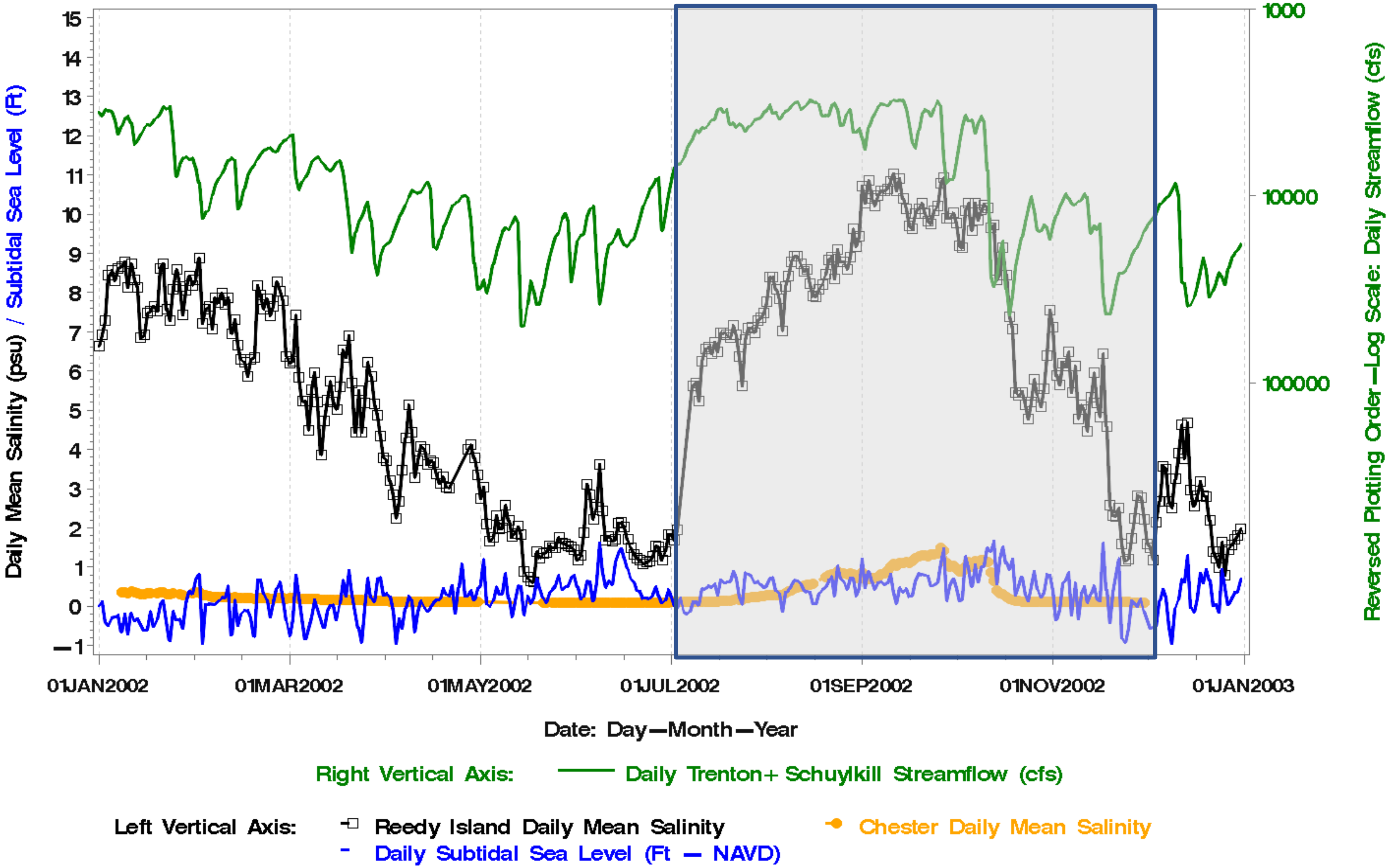
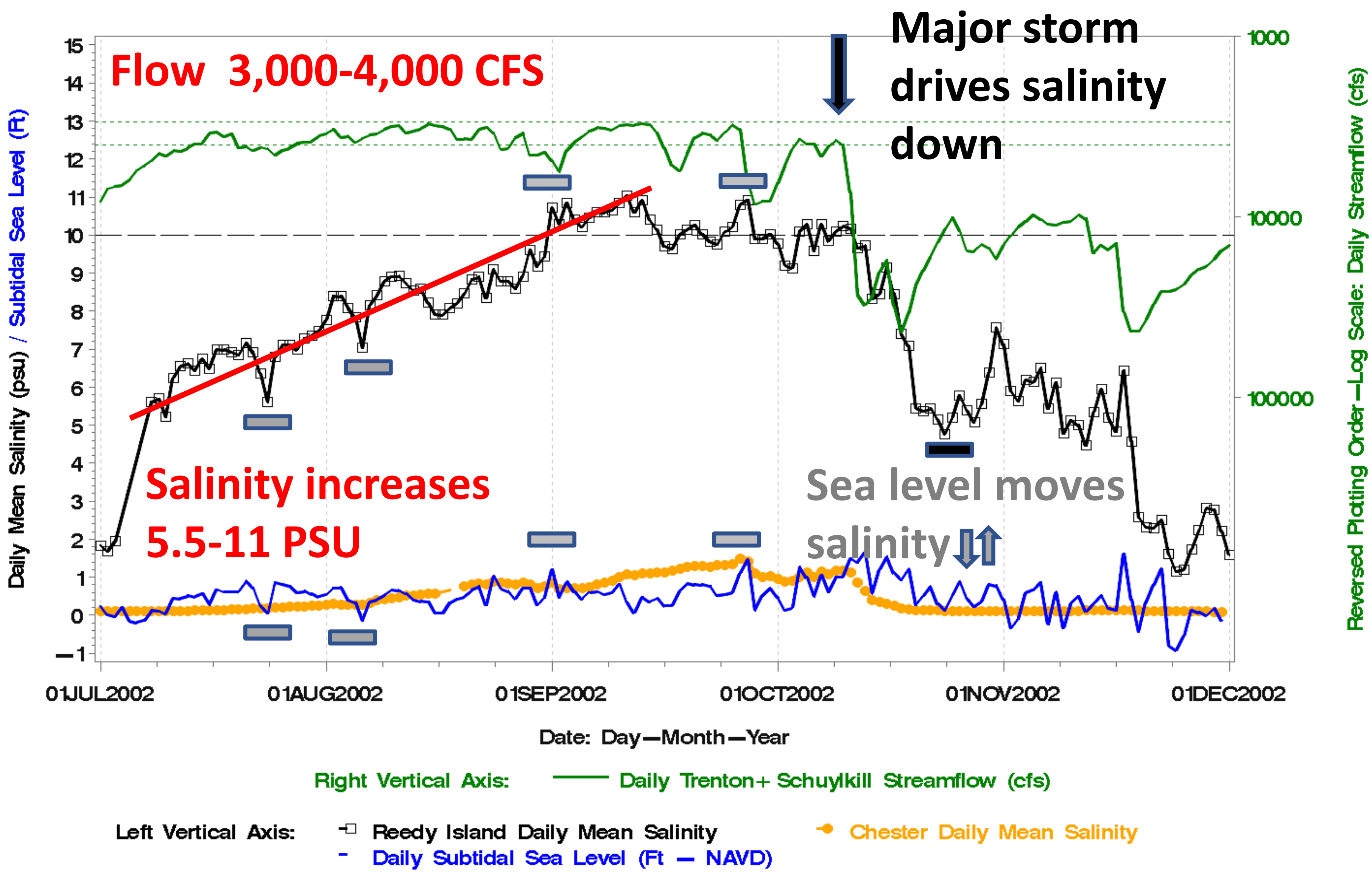
2002 – Sea Level at Philadelphia



2002 – Full Year Streamflow, Salinity and Sea Level



2002 Intrusion Event Characteristics



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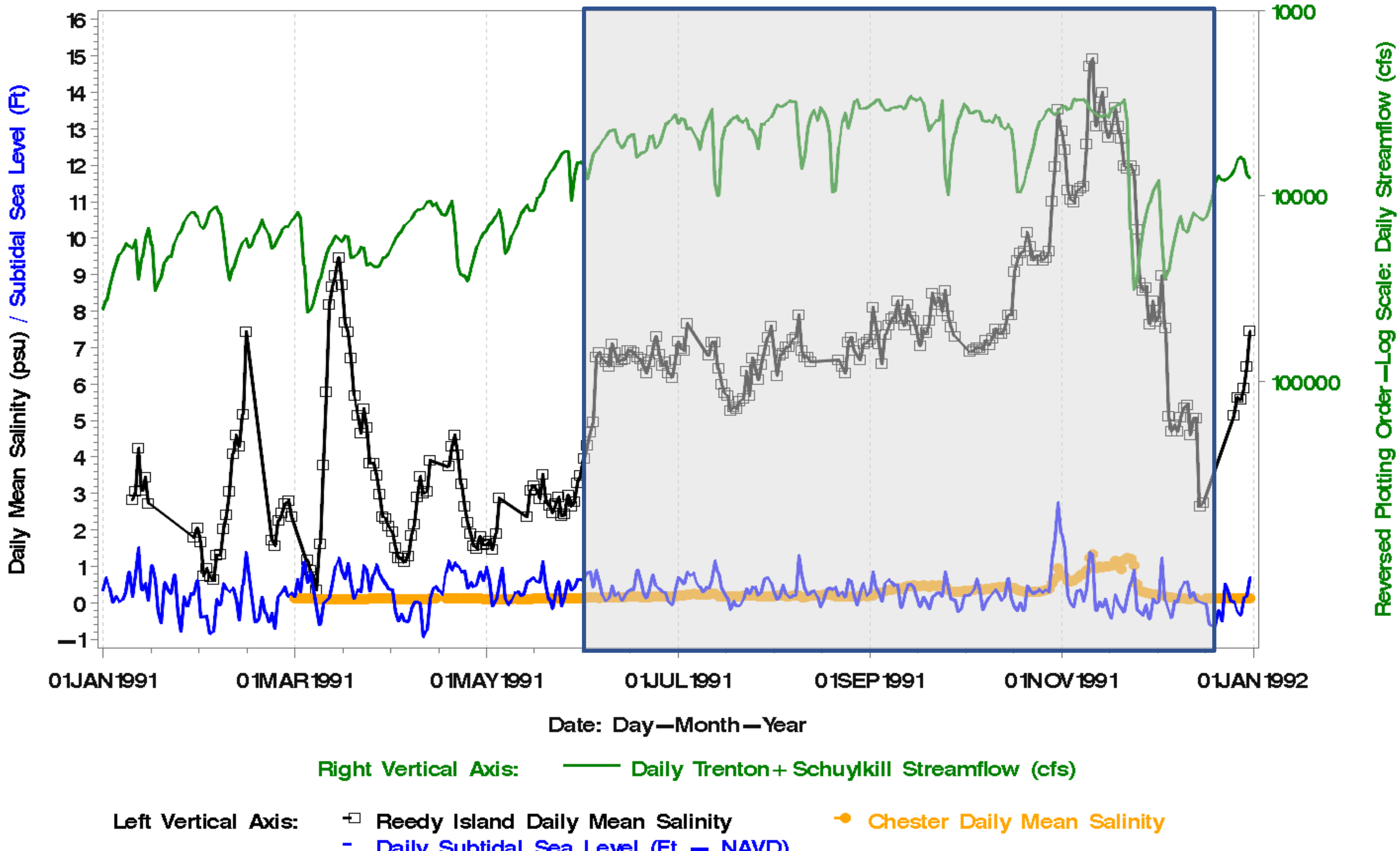
1991 – Full Year Streamflow, Salinity and Sea Level



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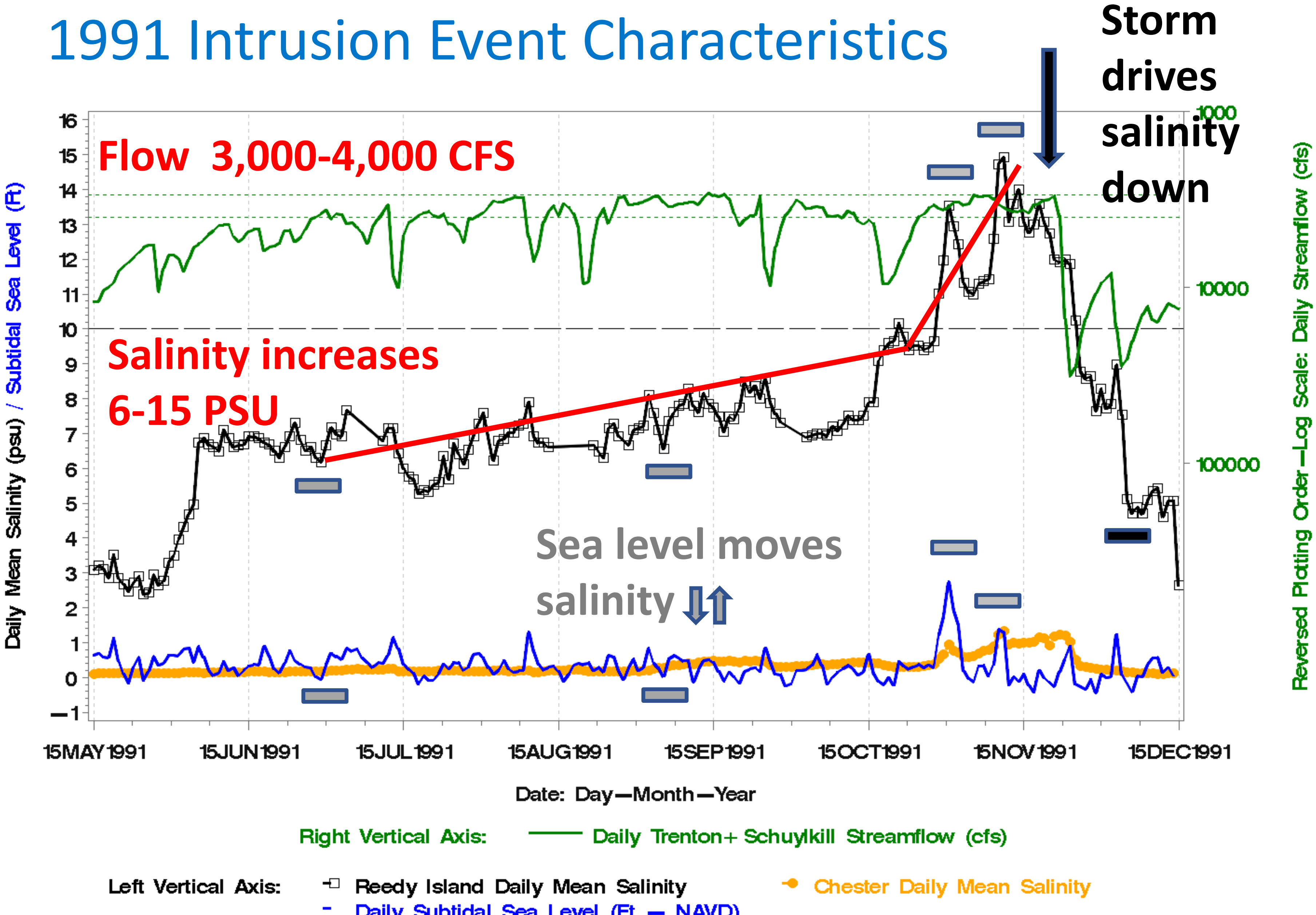
1991 Intrusion Event Characteristics



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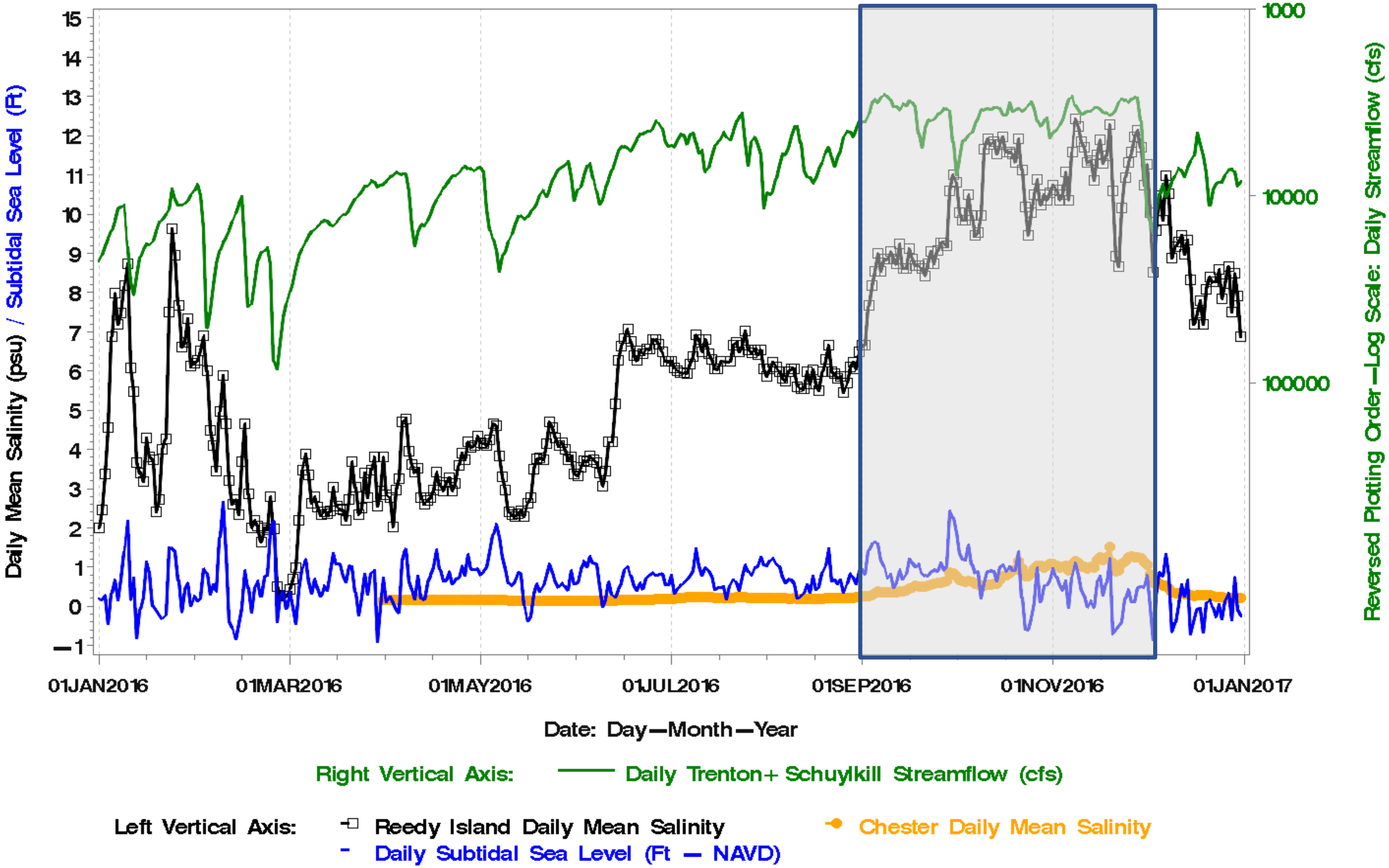
2016 – Full Year Streamflow, Salinity and Sea Level



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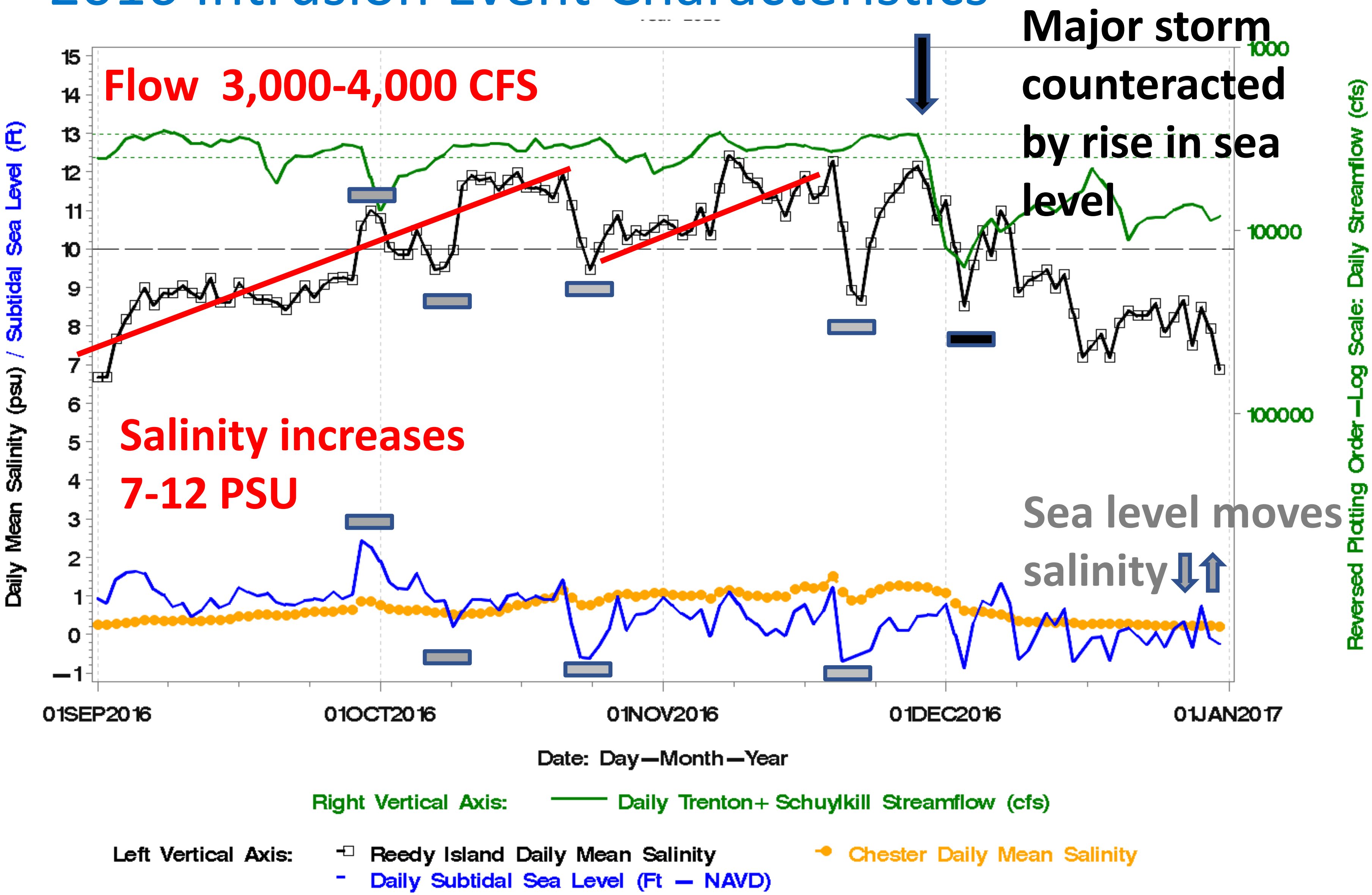
2016 Intrusion Event Characteristics



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Characteristics of Salt Intrusion Length from Observed Data

Streamflow - Trenton and Philadelphia cause salinity to intrude landward (during low flows) and to retreat seaward (during rising flows)

Major Storms - Large basin-wide rainfalls, often from tropical or extratropical storms, typically are needed to cause the salt intrusion to retreat seaward after prolonged periods of low streamflow (typically ~3,000-4,000 CFS)

Sea Level - Subtidal sea level variability, caused by meteorological conditions in the lower Bay and on the adjacent continental shelf, can impose significant influences on salt intrusion length up to and upstream of Reedy Island

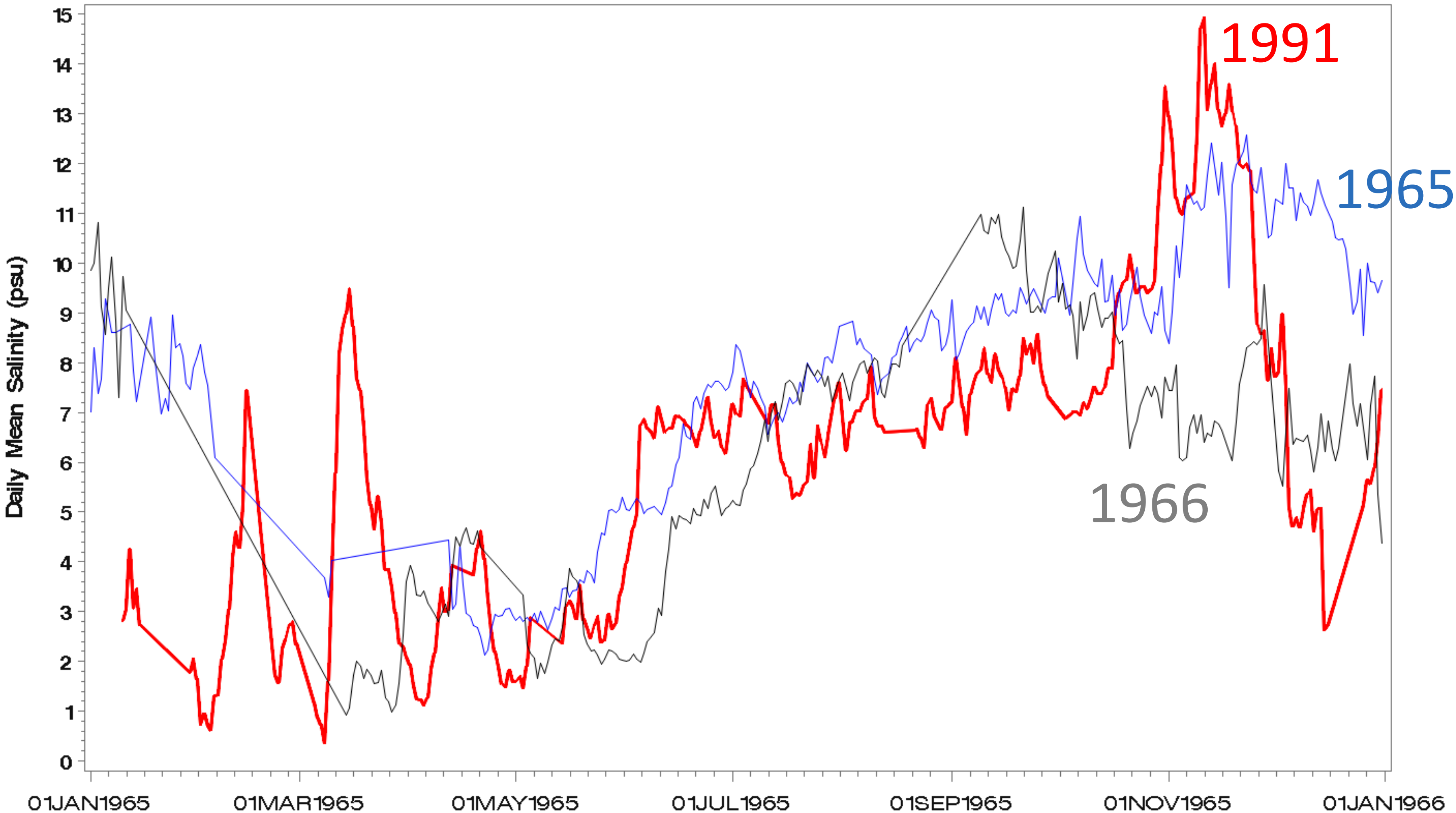
Estuarine Circulation - Beyond the one-dimensional advective effects of river flow and subtidal sea level conditions, the estuarine exchange flow, and concomitant secondary circulation, significantly modify salt intrusion length, with sensitivity to strain-induced periodic stratification, horizontal salinity gradient, channel width and depth, and tidal mixing/stirring. **These physical phenomenon are not one-dimensional in nature.**

Delaware Estuary Salinity Intrusion

Major Takeaway #1

A three-dimensional (3D) model is needed to simulate salinity in the Delaware Estuary

1991 vs. 1960s Salinity Intrusion at Reedy Island



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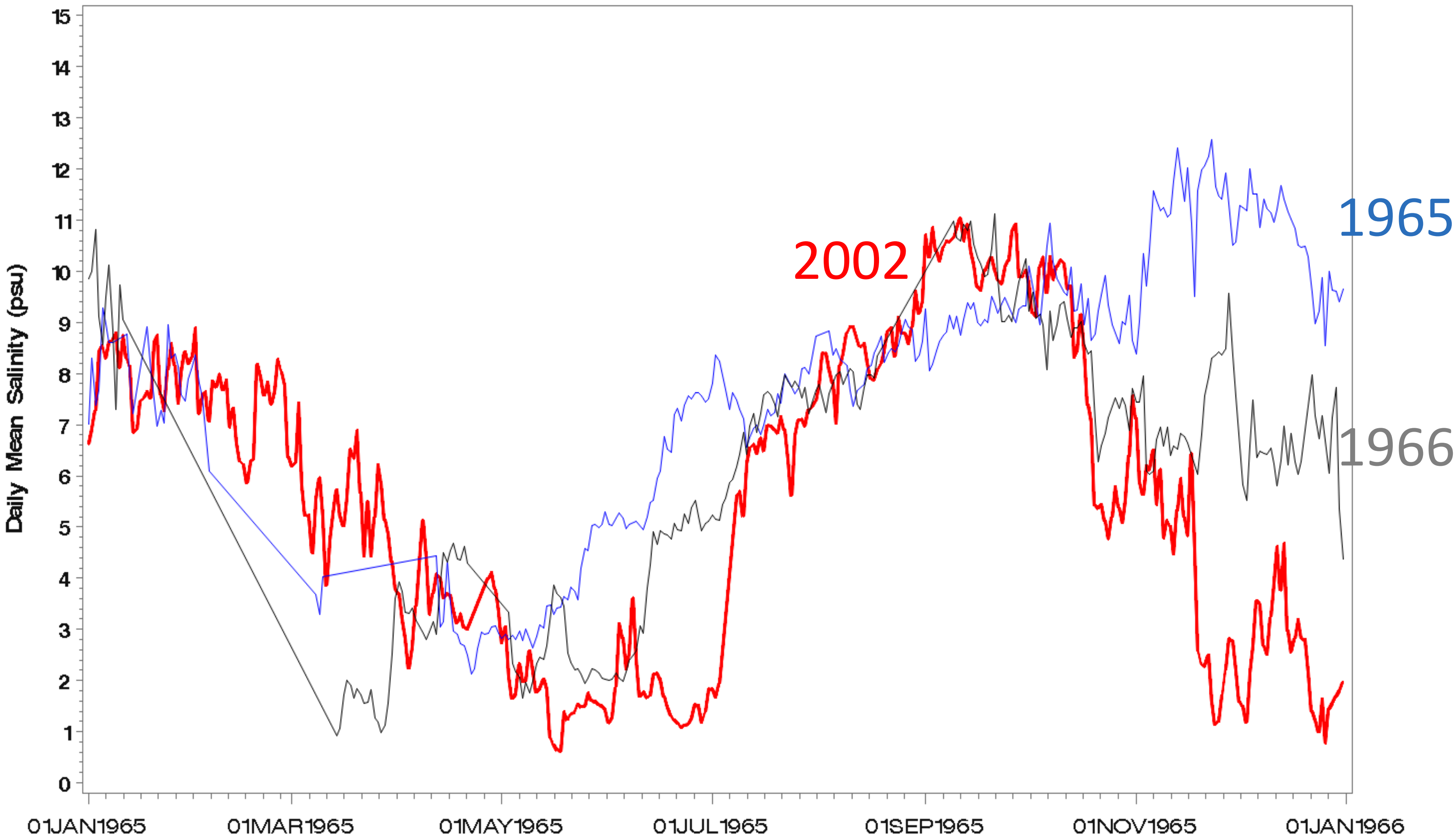
2002 vs. 1960s Salinity Intrusion at Reedy Island



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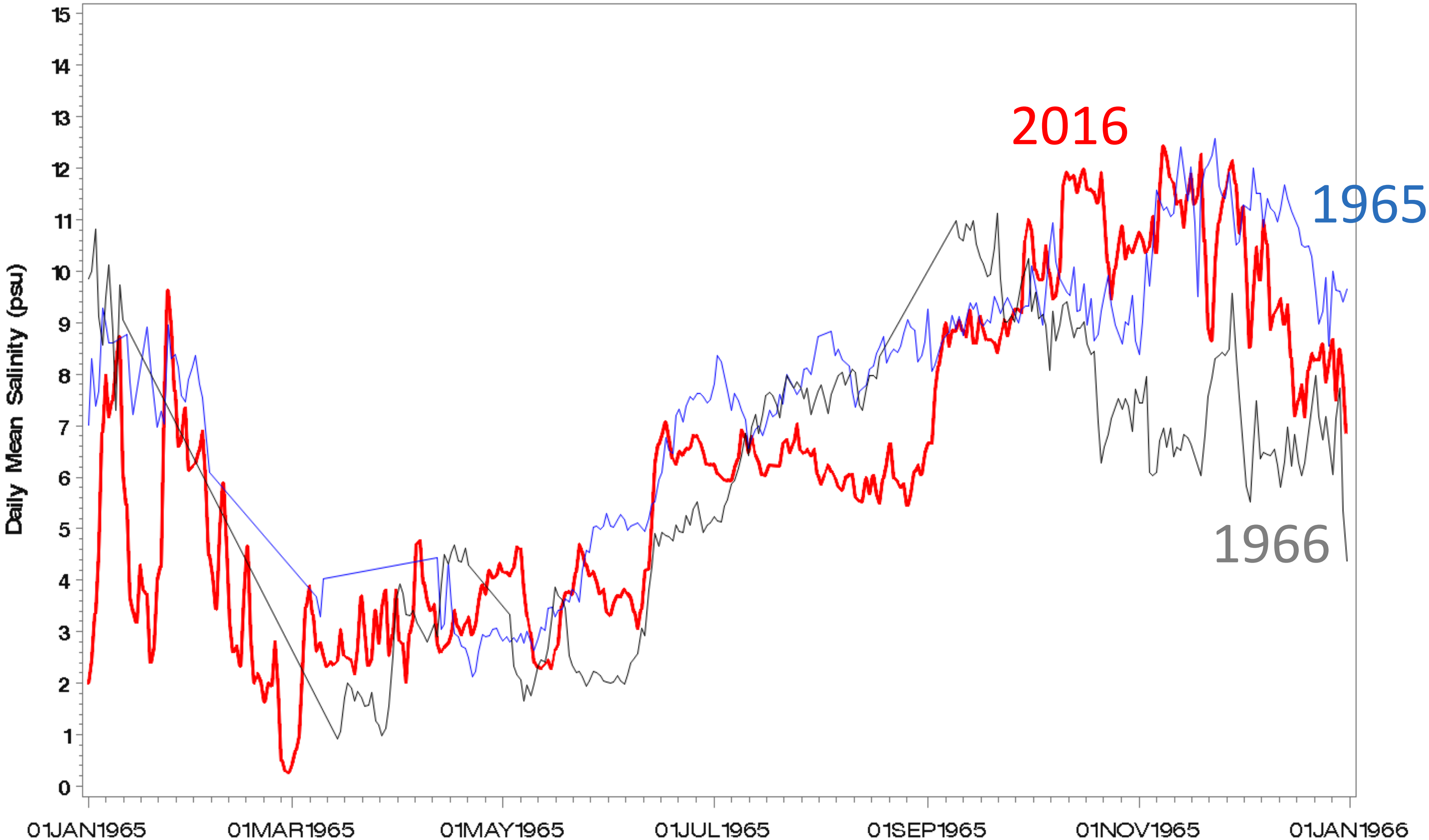
2016 vs. 1960s Salinity Intrusion at Reedy Island



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Delaware Estuary Salinity Intrusion

Major Takeaway #2

Salinity intrusion events at Reedy Island during recent droughts are comparable to salinity observed in the 1960s drought of record.

Main Takeaways from Observed Data that Inform Model Preparation

1. **A three-dimensional model is needed**
   - It is evident from observed data that the salt intrusion length to and upstream of Reedy Island is subject to a range of physical influences, and that to a not insignificant degree, the physics of those hydrodynamic influences are 3-dimensional in nature

2. **Salinity intrusion events at Reedy Island during recent droughts are comparable to salinity observed in the 1960s drought of record**
   - The FFMP flow targets are not intended to manage salinity as far downstream as Reedy Island, they are designed to manage salinity in the area upstream of Chester

PWD Modeling Team

PWD Programs

- Water Quality Compliance Modeling Group
- Watershed Protection Program
- Bureau of Laboratory Services
- Hydraulic & Hydrology Modeling Group

Consulting Support

- Woods Hole Group
- CDMSmith Inc.
- SciTek Consultants Inc.
- Tetra Tech
- Sage Services LLC
- Academy of Natural Sciences
- Rutgers University

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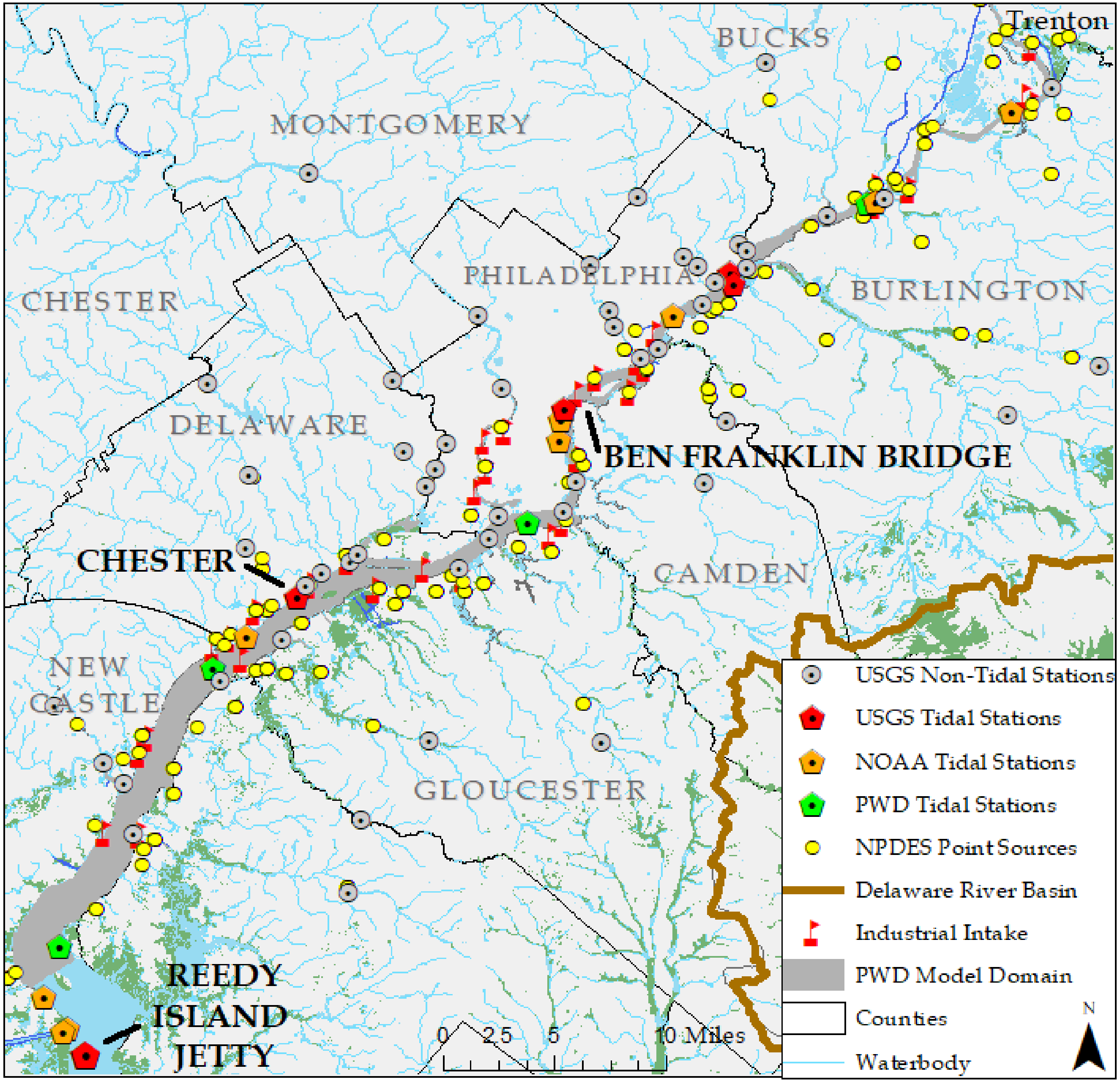
Model Development

- PWD/Woods Hole buoy deployment: water level, quality
- NOAA: water level, quality, velocity
- USGS: streamflow, water level, water
- Withdrawals and discharges
- OOW/BLS boat run
- DRBC boat run
- Bathymetry



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Model Development –

Modeling Process

Model Set-up

- Data Collection
  - Sampling
  - Gather inputs
  - QA/QC
  - Data preparation
  - Data formatting
- Model Building
  - Hydrodynamics
  - Salinity transport
  - Bacteria transport
  - Sediment diagenesis
  - Algae

Testing

- Calibration
- Sensitivity analysis
- Validation

EXTERNAL REVIEW

Analysis

- Production runs
- Post-processing

Salinity Modeling – Objectives

Support infrastructure planning

- Inform Baxter Water Treatment Plant capital planning initiatives exploring plant modifications and technology decisions

Support Pennsylvania PADEP and RFAC

- Provide high quality analyses of how FFMP policy changes will impact the supply to the largest drinking water utility in Pennsylvania
- Share findings and results with stakeholders interested in salinity impacts to aquatic and fishery resources

Project Timeline – Ongoing Work

June 2018

- Completion of calibration and validation

July 2018-June 2019

- Review and completion of validation report
- Numerical experiments, post processing
- Begin PST2 refinements, research into alternative policies

July 2019-June 2020

- Sea level rise salinity model set up and numerical experiments scheduled to begin

July 2020-June 2021

- Numerical experiments with PST2 and synthesis of findings

Series of Presentations

1. **Planning Introduction (given May 2018)**

2. **Salinity Intrusion in the Delaware Estuary (today)**

3. **Calibration Approach and Validation**

4. **Simulation Approach**

And much more to come!

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THANK YOU!

www.phila.gov/water/sustainability

FFMP 2017 Most Significant Section IV.3.b

“The studies identified in subdivision (a) above will evaluate the impacts to: the salt front, aquatic and fishery resources in the Basin, and projections of future sea level rise to salinity…

If studies by the Decree Parties or external entities on behalf of a Decree Party support that detachment provides comparable protection for existing resources and uses within the Basin and does not cause significant adverse impacts, then detachment will be implemented between June 1, 2023 and May 31, 2028… “

Comparable Protection vs. Significant Adverse Impacts…

- **A burden of proof in favor of detachment**