Studies to determine the attainability of aquatic life uses and associated enhanced dissolved oxygen conditions in the urbanized portion of the Delaware River Estuary

Delaware Watershed Research Conference

Academy of Natural Sciences of Drexel University (virtual)

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Delaware River Basin Commission

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Funding Support

Delaware Watershed Research Fund

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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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NATIONAL FISH AND WILDLIFE FOUNDATION
NFWF

DWRF Grant Studies

Modeling Eutrophication Processes in the Delaware Estuary

- Purpose
  - To evaluate impact of nutrient loads on water quality in Estuary
- Key Personnel
  - **Lead Investigators**
    - **Namsoo Suk, Ph.D.**
    - **Li Zheng, Ph.D.**
  - Modeling Team
    - Vince DePaul, USGS
    - Fanghui Chen, Ph.D., P.E.
    - Thomas Amidon, B.C.E.S.
  - Monitoring and Assessment Team
    - John Yagecic, P.E.
    - Elaine Panuccio
    - Jake Bransky

Engineering Evaluation and Cost Estimate of Wastewater Treatment Nitrogen Reduction

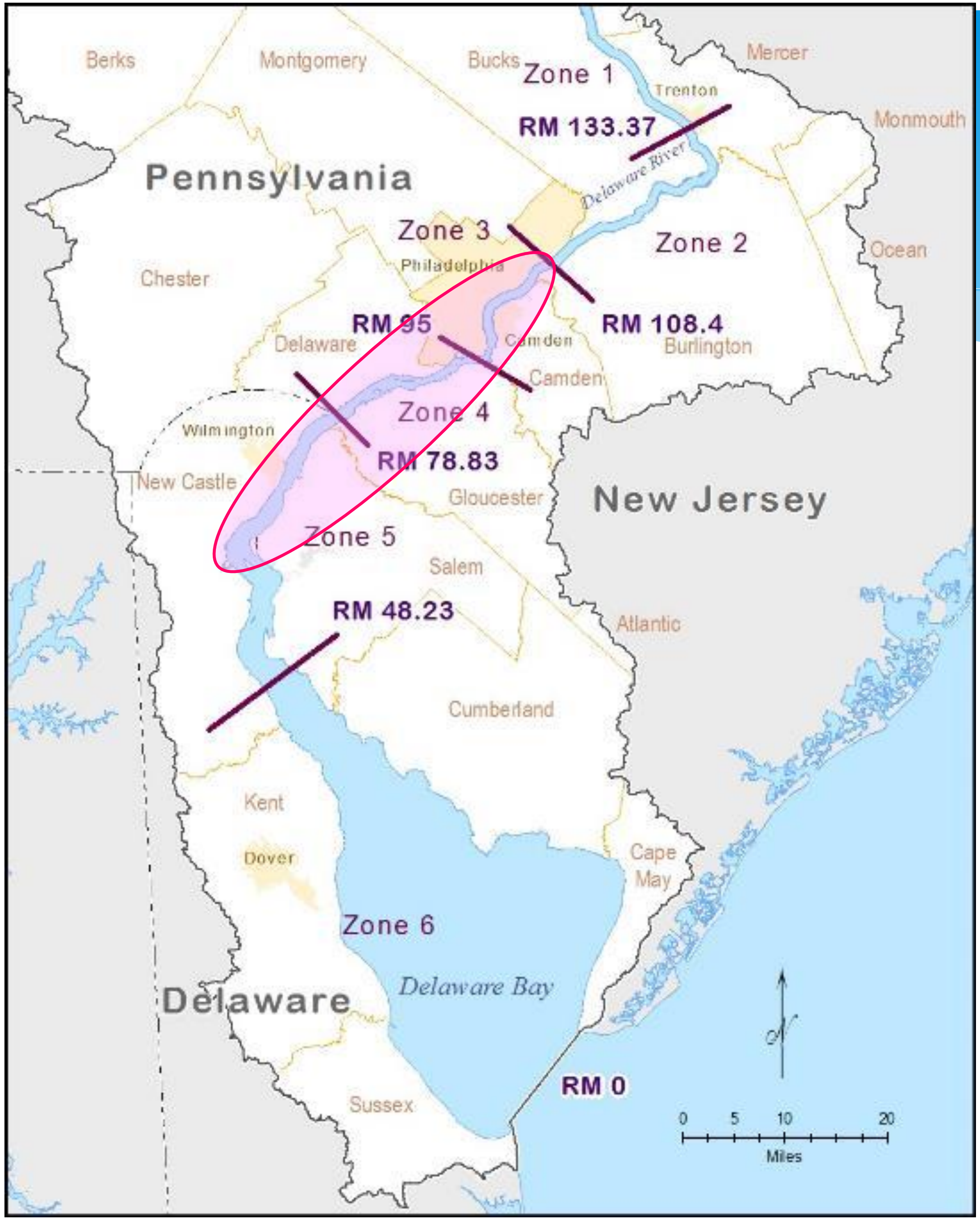
- Purpose
  - Estimate cost to achieve specific nitrogen levels in treated discharges
- Key Personnel

Project Manager

John Yagecic, P.E.
Manager, Water Quality Assessment

Lead Investigator

Timothy D. Bradley, P.E.
Vice President



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Delaware River Estuary

<u>WQ Assessment Units:</u>

Zone 1: Non-tidal (Upstream from Trenton)

Estuary:

Zone 2 - 5: Tidal Delaware River

Zone 6: Delaware Bay

<u>River Miles:</u>

RM 0.0 = Atlantic Ocean

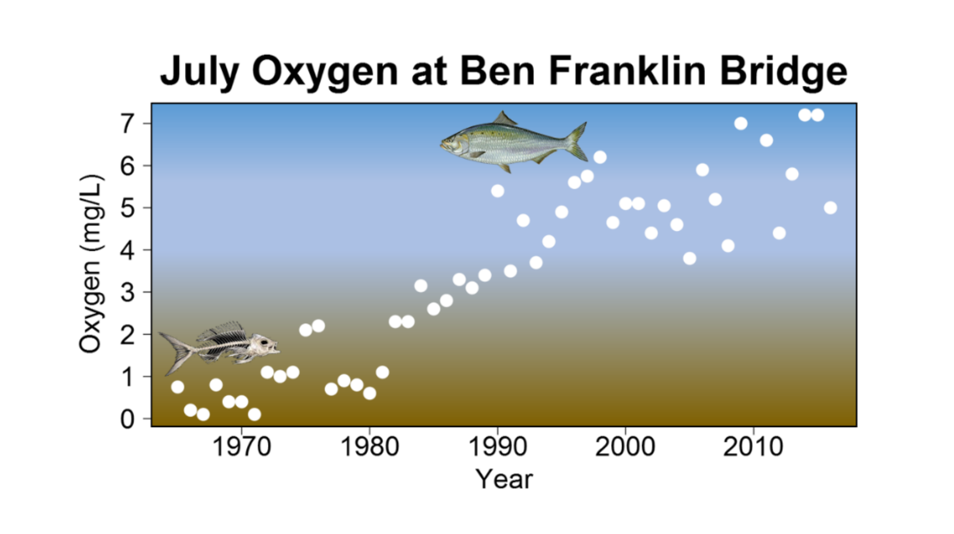
RM 70 = City of Wilmington

RM 100 = Ben Franklin Bridge, Philadelphia / Camden

RM 133 = “Head of Tide”, Trenton, NJ

Evaluation of Existing Use

- Fishery propagation
  - Some degree of propagation has been observed
  - Full attainment of propagation has not been demonstrated
- The goals established in 1967 have been exceeded
  - Dissolved oxygen exceeds 3.5 mg/L as a daily average concentration
  - Fisheries enhanced due to improved dissolved oxygen condition



- DO-sensitive species that currently exhibit some degree of propagation
  - American shad
  - Atlantic sturgeon
  - Channel catfish
  - Largemouth bass
  - Shortnose sturgeon
  - Striped bass
  - White perch
  - Yellow perch

DRBC Resolution 2017-04
Studies Required Before Rulemaking

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Fish/DO Studies

- 6(a). Input on the **dissolved oxygen requirements of aquatic species**
- 6(b). Field studies of the occurrence, spatial and temporal distribution of the life stages of Estuary fish species
- 6(c). Input from consultations pursuant to the **Endangered Species Act** ("ESA")

Modeling Studies

- 6(d). Development and calibration of a **eutrophication model** for the Delaware River Estuary and Bay;
- 6(e). Determination of the nutrient **loadings from point and non-point sources** necessary to support key aquatic species;

Cost/Feasibility Studies

- 6(f). Evaluation of the **capital and operating costs for treatment** capable of achieving higher levels of dissolved oxygen;
- 6(g). Evaluation of the physical, chemical, biological, **social and economic factors affecting the attainment of uses**,

6. "Analysis of Attainability"

6(h).

Preparation of a **draft report and final report** containing findings and conclusions.

What is an "Analysis of Attainability?

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What We Know

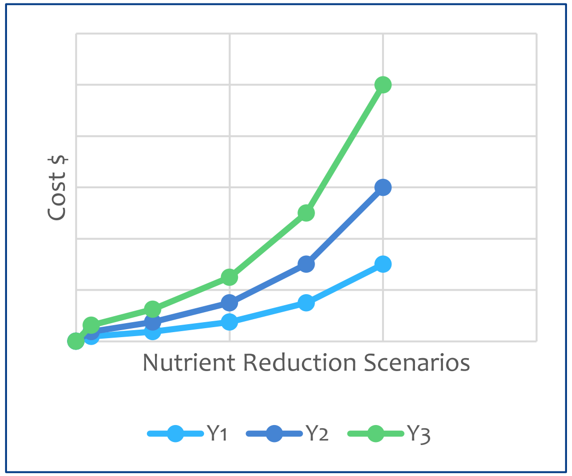
- Minimum Dissolved Oxygen conditions are critical to supporting fish propagation
- Existing DO condition supports some degree of propagation among resident fish
  - Since the degree of propagation associated with the existing DO condition is an Existing Use, it must be protected
  - Therefore, current minimum DO condition (3.7 mg/L) must be maintained or enhanced
- Higher minimum DO condition (i.e., more oxygen) will enhance the degree of fish propagation
  - Full propagation among resident fish would appear to be supported by a minimum DO of approximately 5 mg/L

What We Need to Determine

- How much can the DO condition be improved?
  - What would the DO condition be under "reference background" loading conditions?
  - What would the DO condition be under various levels of point and nonpoint source pollutant reductions?
  - Is it feasible to meet the minimum required DO to support propagation of all sensitive species?
- What would be the costs and benefits associated with the various point and nonpoint source reductions?
- DRBC must determine Highest Attainable Dissolved Oxygen (HADO) condition
  - Revised designated use will be the enhanced degree of propagation associated with the HADO condition

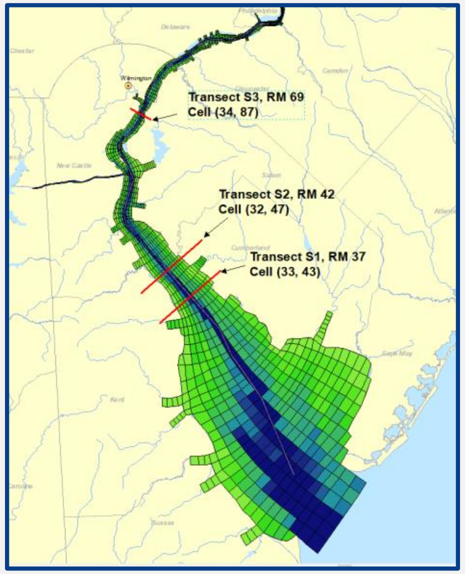
Elements of “Attainability Analysis”

Point Source Nutrient Reduction Cost Evaluation

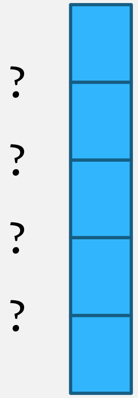


Effluent Level
NH_3-N – 10 mg/L
NH_3-N – 5 mg/L
NH_3-N – 1.5 mg/L
TN – 4 mg/L

Eutro Model

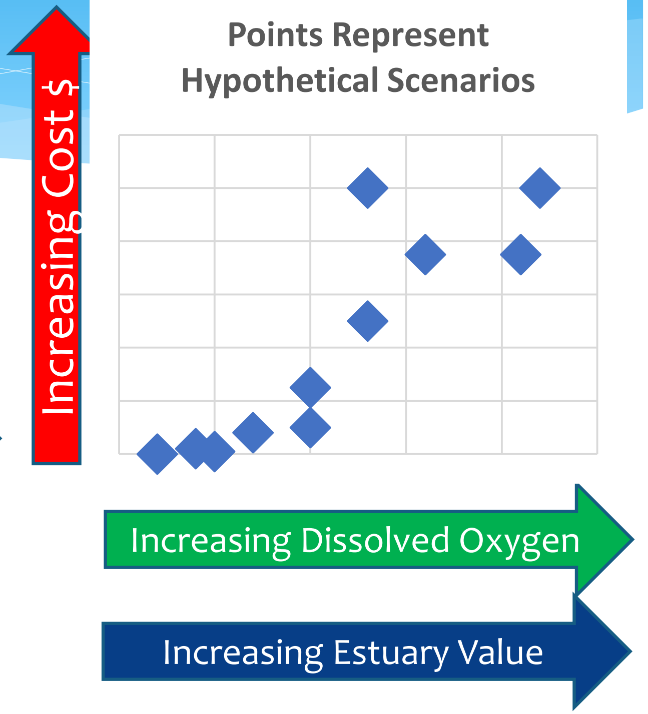


Refined Candidate Scenarios



How much would DO condition improve if:

- Each of the point source nutrient scenarios were implemented
- Tributary boundaries were reduced
- Nonpoint sources were reduced
- Various sources reduced



“Attainability”

- Natural condition
- Technological limitations
- Socioeconomic constraints and benefits

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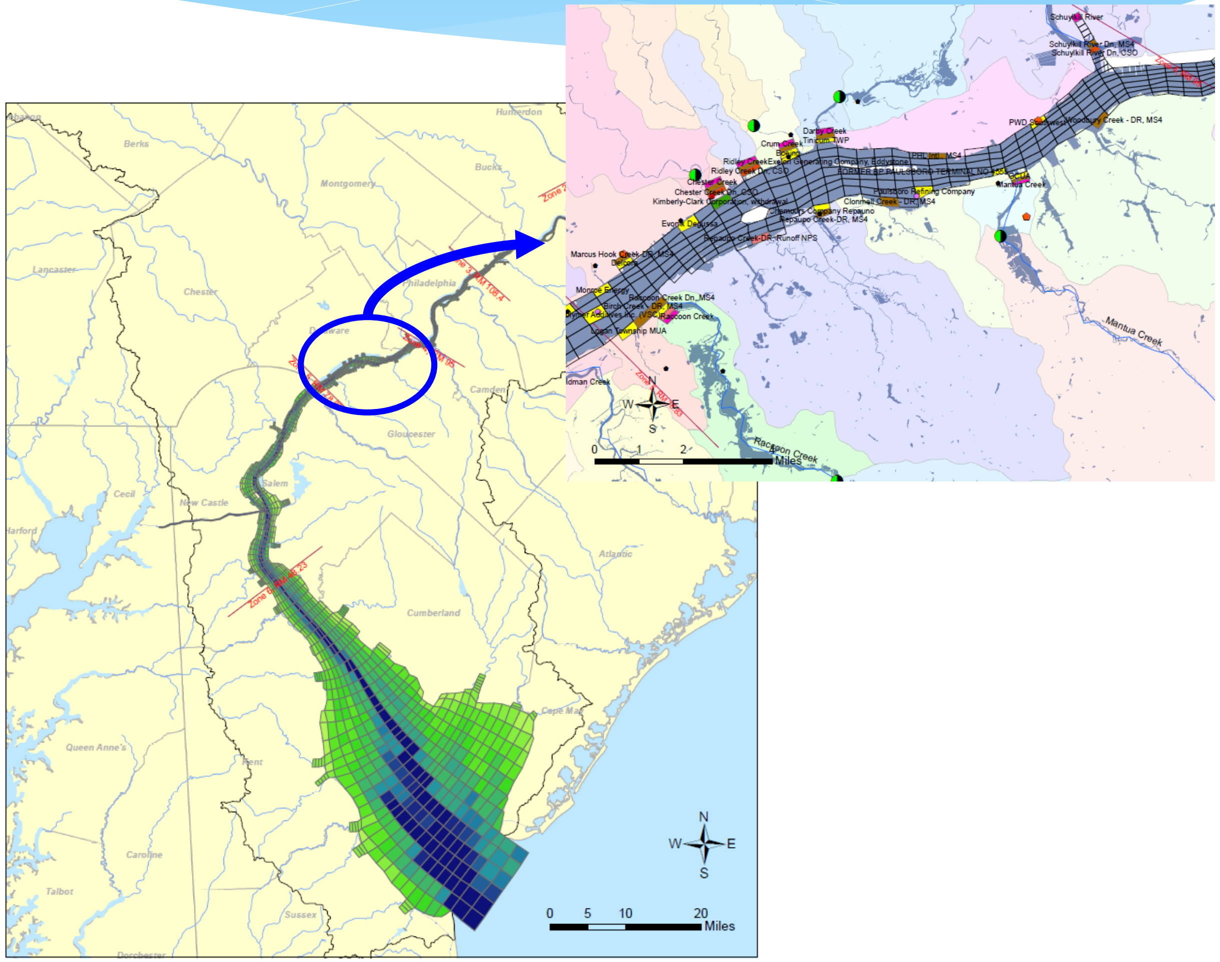
System-Wide Eutrophication Model

Modeling Approach

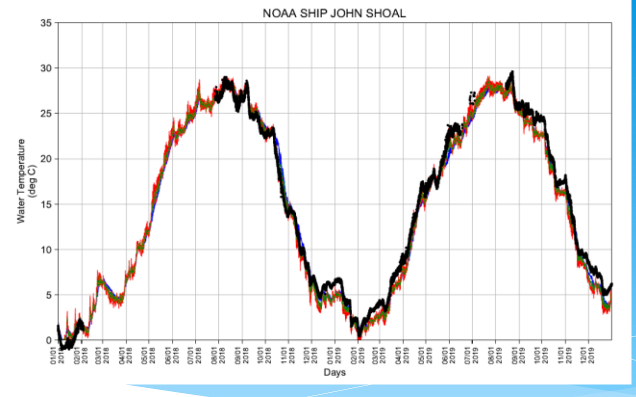
- Link hydrodynamic and water quality model
  - Environmental Fluid Dynamics Code (EFDC)
  - Water Quality Analysis Simulation Program (WAP8.x)
  - Develop model grid and vertical structure
  - Develop pre- and post-processing tools
  - Optimize model performance and simulation time
- Develop boundary conditions
  - Intensive monitoring period 2018-2019
  - Tidal forcing boundaries
  - Point source flows and water quality
  - Tributary flows and water quality
  - Stormwater, runoff, CSOs
- Perform hydrodynamic and water quality model calibration
- Conduct forecast simulations with calibrated model
  - Develop baseline condition and future scenarios
  - Determine levels of external sources required to achieve varying levels of ambient dissolved oxygen

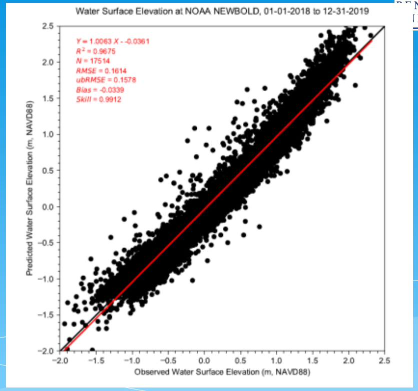
Model Grid

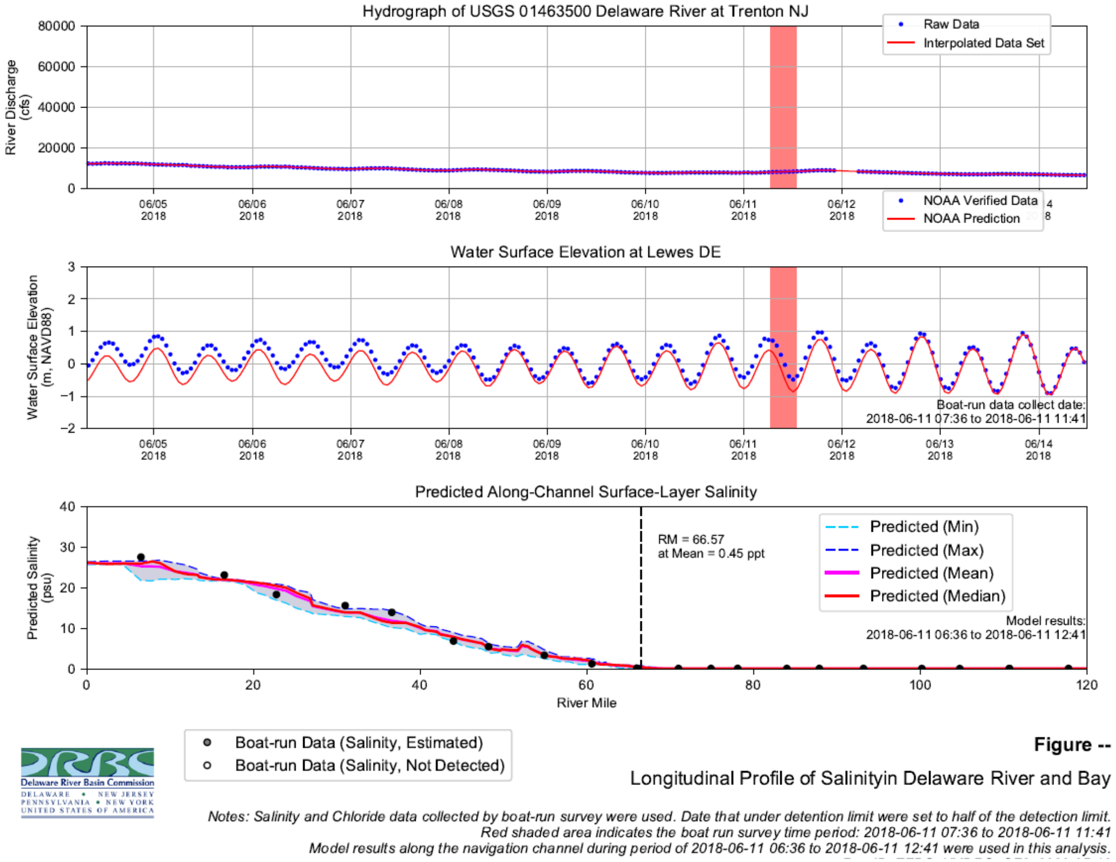


Hydrodynamic Model Calibration

- Calibration Periods
  - 2018, 2019
  - 2012 added to capture full range of hydrologic conditions
- Significant boundary improvements
  - Temperature assignments
    - Tributary temperatures
    - Point source temperatures
  - Minor flows
    - Ungaged tributaries, watersheds, stormwater
    - CSOs
- Expert Panel after May 2020 Meeting
  - **“Hydrodynamic model is adequately calibrated for use in water quality model”**

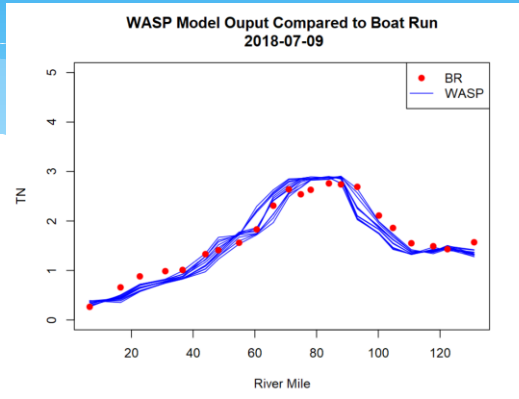


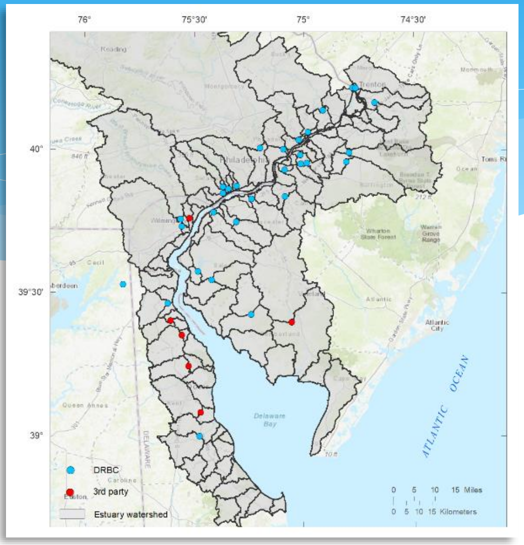


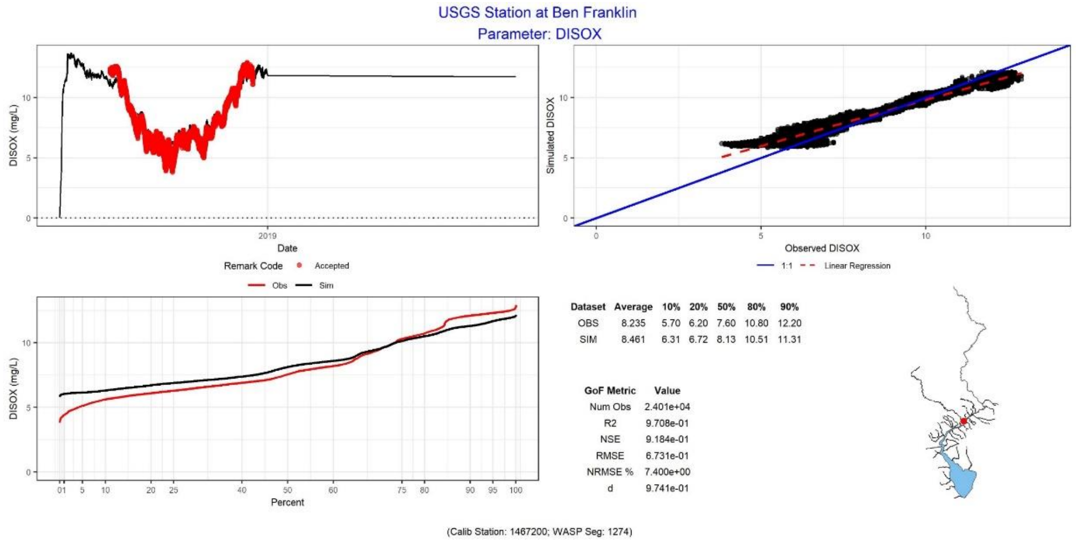


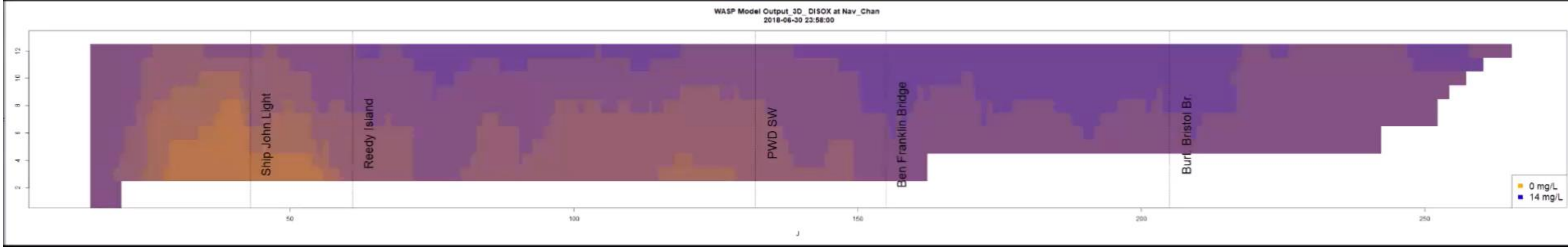
Water Quality Model Development

- Field sampling completed!
  - 3-year period 2017 - 2020
- Model Integration
  - Linkages between hydrodynamic and water quality model
  - Scale and complexity exposed limitations and inefficiencies
  - Diagnostic simulations, grid modifications, code modifications, and optimizations
- Evaluation of vertical resolution
  - Ensure adequate simulation of gradients and mass transfer
  - Need more than 5, but not more than 10, layers in navigation channel
- Boundary inputs developed for 2018-2019
  - Statistical submodel developed to estimate WQ at unmonitored tributaries and watersheds
  - Methodology developed to relate measured constituents to state variable assignments
- Light extinction function evaluated and re-formulated
- Model sensitivity simulations for key model coefficients and parameters performed to guide model calibration
- Pre- and Post-processing tools developed









WASP Model Output_3D_ DISOX at Nav_Chan
2018-06-30 23:58:00
Ship John Light
Reedy Island
PWD SW
Ben Franklin Bridge
Burl Bristol Br.
0 mg/L
14 mg/L
50
100
150
200
250
J

Nitrogen Reduction Cost Study

Table 1: Final Technology and Effluent Level Recommendations

Effluent Level	Generic Conventional Activated Sludge Plant	Generic Pure Oxygen Activated Sludge Plant	Generic Fixed Film (RBC and TF) Plant
NH_3-N – 10 mg/L	Replace process air system, construct additional final clarifiers and modify RAS system	Add downstream BAF sized for approximately 50% of plant flow	Add downstream BAF sized for approximately 45% of plant flow
NH_3-N – 5 mg/L	Conversion to IFAS with medium level of media addition to aeration tanks	Add downstream BAF sized for approximately 75% of plant flow	Add downstream BAF sized for approximately 70% of plant flow
NH_3-N – 1.5 mg/L	Conversion to IFAS with high level of media addition to aeration tanks	Add downstream BAF sized for 100% of plant flow	Add downstream BAF sized for 100% of plant flow
TN – 4 mg/L	Conversion to IFAS with high level of media addition plus downstream DF	Add downstream BAF sized for 100% of plant flow plus DF	Add downstream BAF sized for 100% of plant flow plus DF

IFAS – Integrated fixed film activated sludge

Photo courtesy of Hazen & Sawyer

· BAF – Biological Aerated Filter

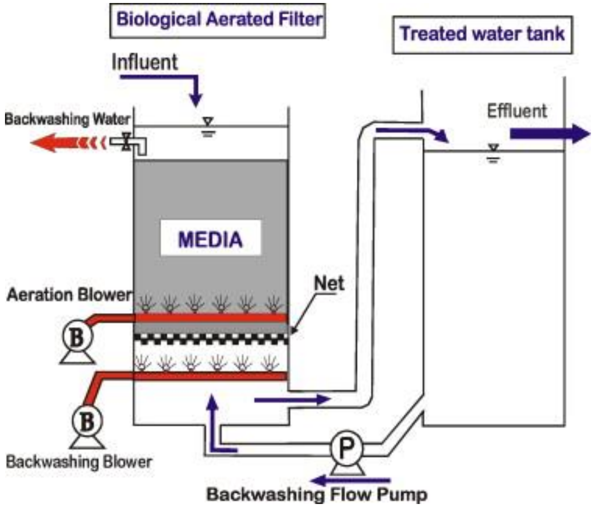


Photo courtesy of ScienceDirect

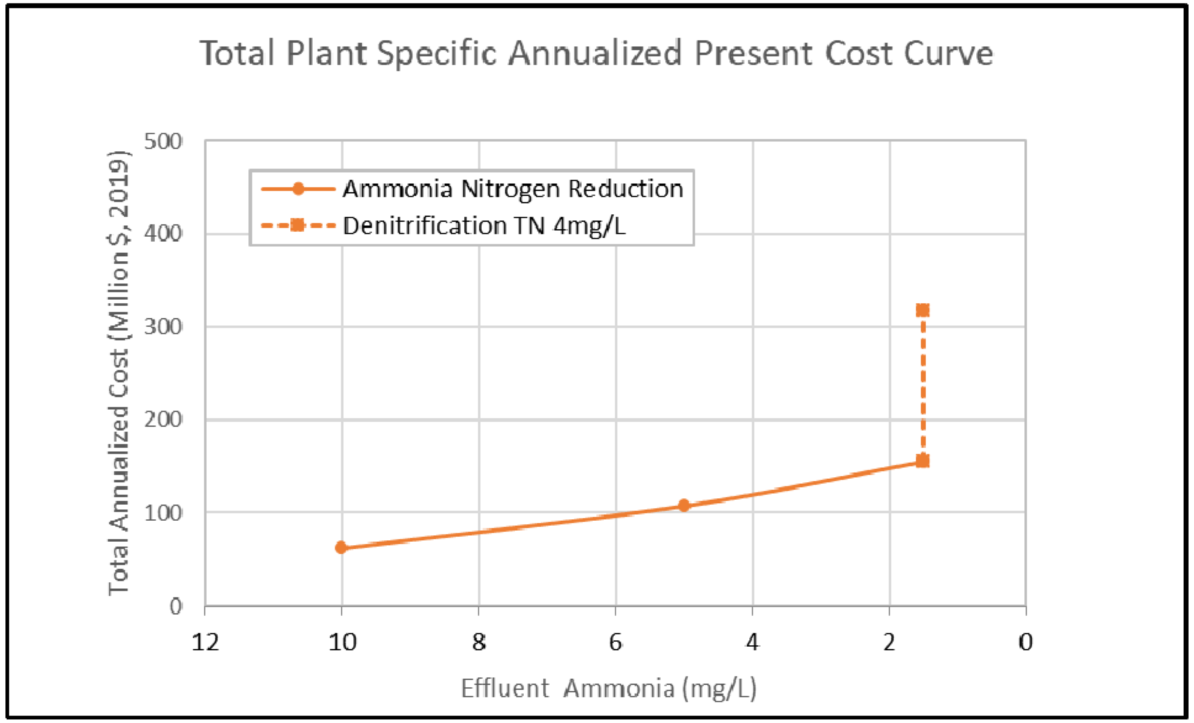
· DF – Denitrification Filter

Photo courtesy of AquariumFilterSetup

Nitrogen Reduction Cost Study

- 12 Plants (95% of load)
  - 6 activated sludge
  - 3 pure oxygen activated sludge
  - 3 fixed film reactors
- Cost factors
  - Capital costs
  - Operation & Maintenance
    - Staffing, chemicals, energy, sludge
  - Total present worth cost and annualized present cost

Figure 26: Overall Summary of Plant Specific Total Annual Cost Curve



- Total present worth costs (capital and O&M) for top 12 range from ~$1.1 to ~$5.5 billion
- Fairly linear for ammonia reductions
- Sharp increase to achieve TN target due to the addition of denitrification

Resources

DRBC's Water Quality Advisory Committee

https://www.nj.gov/drbc/about/advisory/WQAC_index.html

DRBC e-mail groups

https://www.nj.gov/drbc/contact/interest/index.html

Contacts

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Questions and Discussion

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