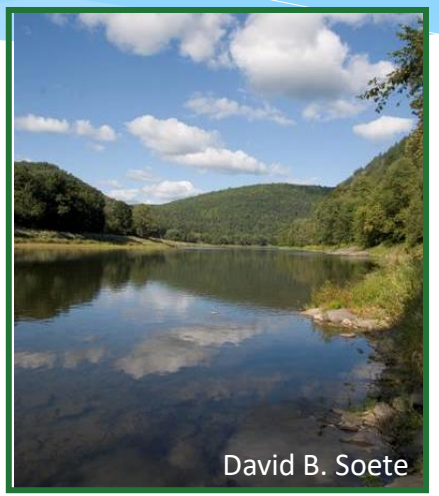
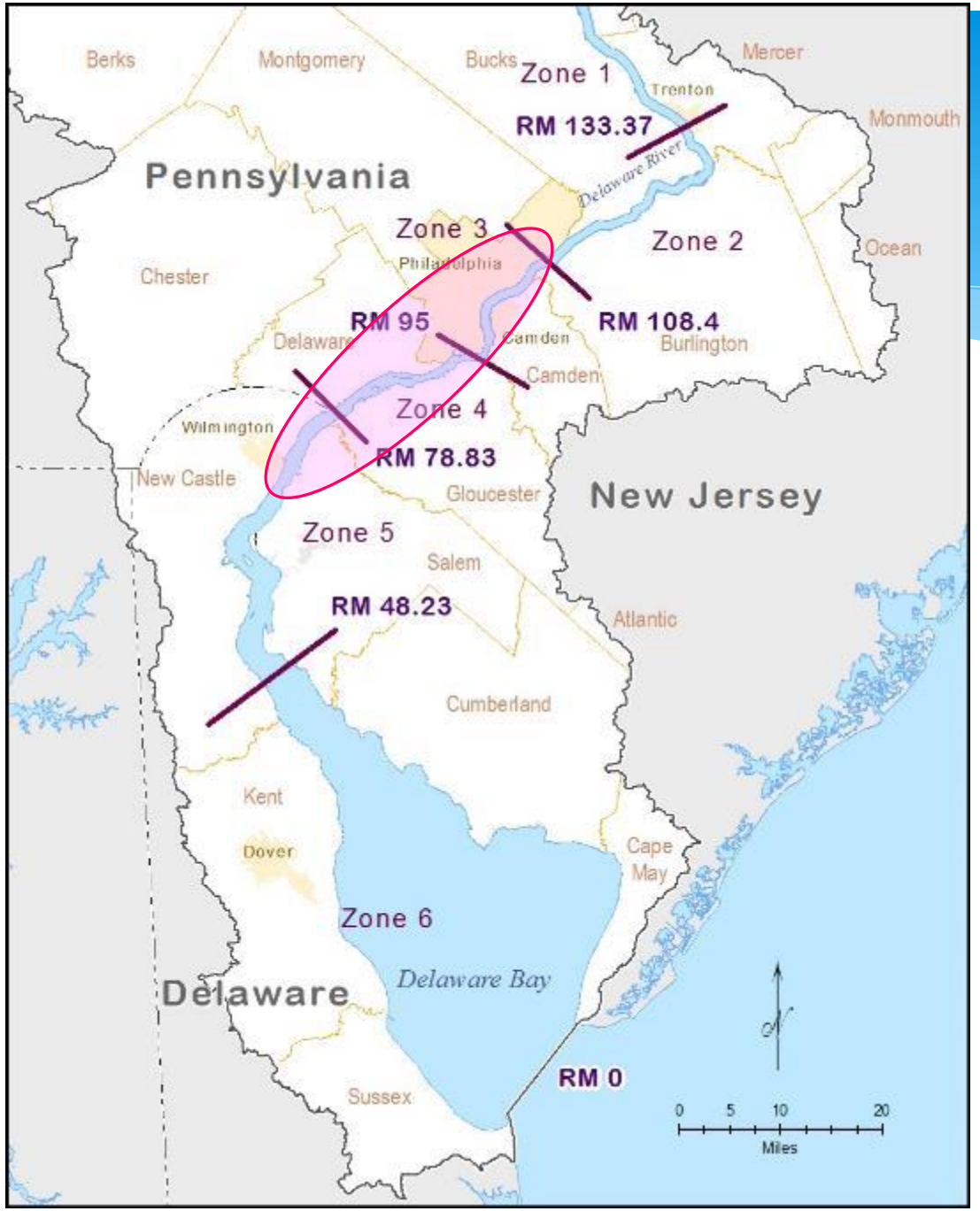
Application of eutrophication modeling to understand the potential to expand designated aquatic life uses in the Delaware River Estuary

Thomas Amidon
Manager, Water Resources Modeling
Delaware River Basin Commission

September 23, 2021
2021 AWRA Mid-Atlantic Conference
Water Data Summit Track, Session 3C



60 years
1961–2021
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA



Delaware River Estuary

WQ Assessment Units:

Zone 1: Non-tidal (Upstream from Trenton)

Estuary:

Zone 2 - 5: Tidal Delaware River

Zone 6: Delaware Bay

River Miles:

RM 0.0 = Atlantic Ocean

RM 70 = City of Wilmington

RM 100 = Ben Franklin Bridge, Philadelphia/Camden

RM 133 = "Head of Tide", Trenton, NJ

60 years 1961–2021

Delaware River Basin Commission

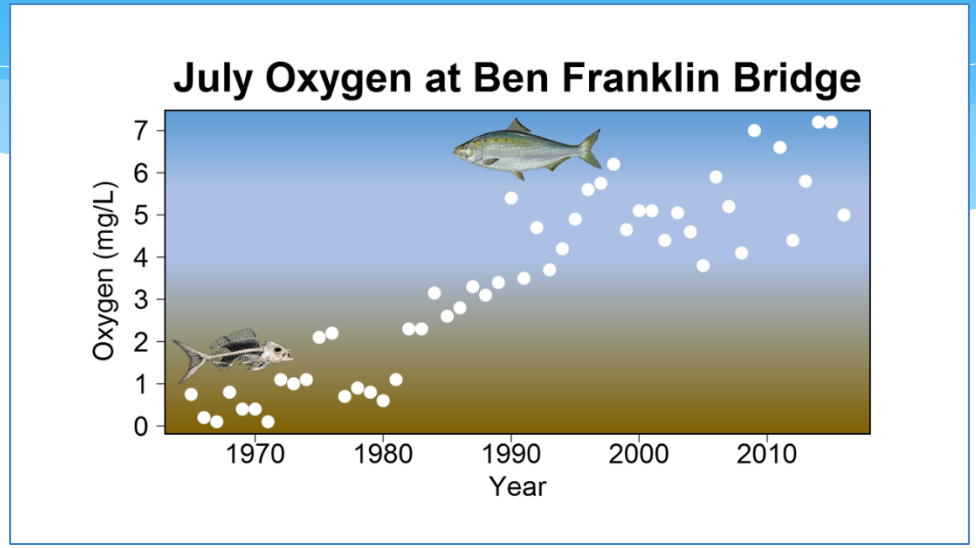
DELAWARE • NEW JERSEY PENNSYLVANIA • NEW YORK UNITED STATES OF AMERICA

Evaluation of Existing Use in Urbanized Area

- The water quality goals established in 1967 have been exceeded
  - Dissolved oxygen exceeds 3.5 mg/L as a daily average concentration
  - Use in urban area designated for “maintenance only”
- Fisheries enhanced due to improved dissolved oxygen condition*
  - Some degree of propagation has been observed
  - Full attainment of propagation has not been demonstrated

*

https://www.nj.gov/drbc/library/documents/ExistingUseRpt_zones3-5_sept2015.pdf



- 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

60 years 1961–2021
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DRBC Resolution 2017-04
Studies Required Before Rulemaking

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

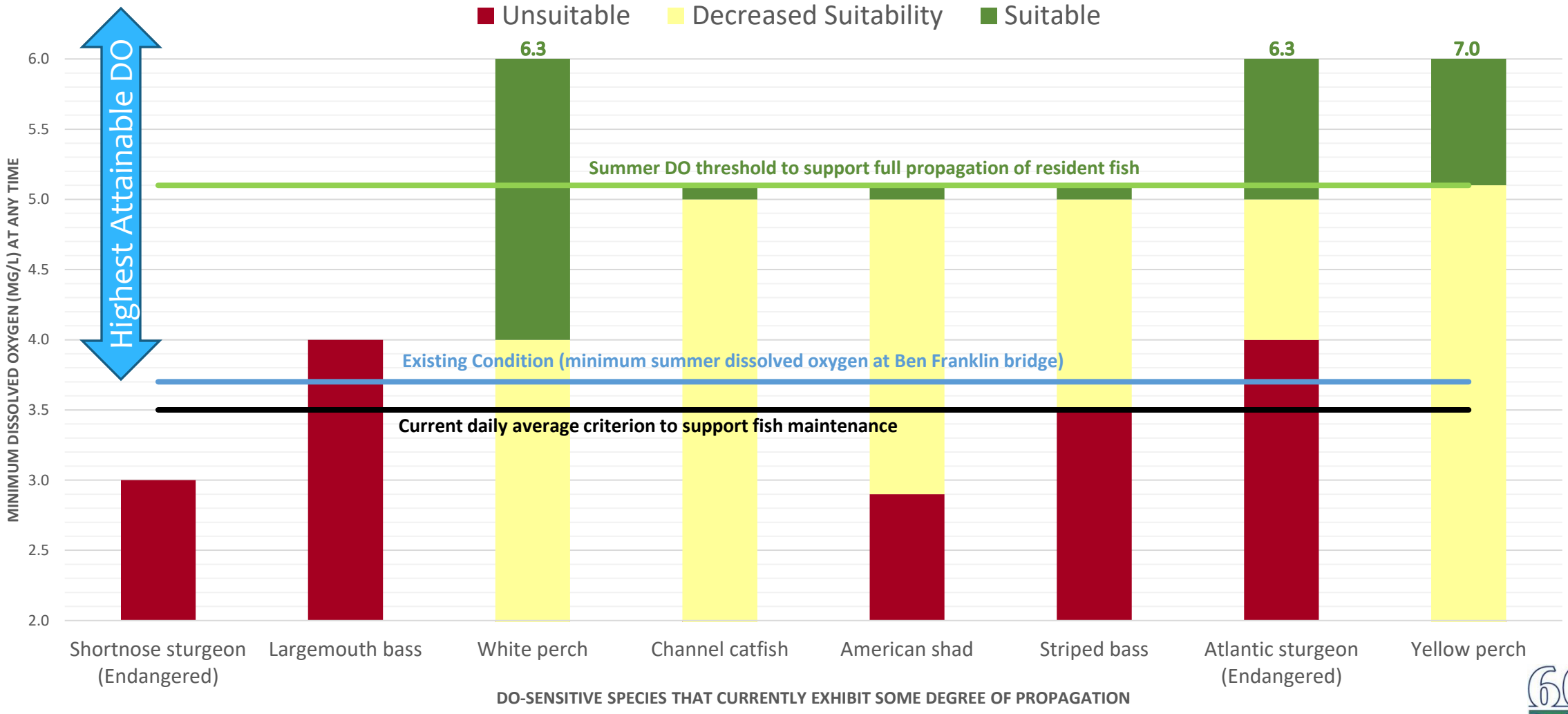
- 6(f). Evaluation of the **capital and operating costs for treatment** capable of achieving higher levels of dissolved oxygen;
- 6(g). Evaluation of the physical, chemical, biological, **social and economic factors affecting the attainment of uses**,

6. "Analysis of Attainability"

6(h). Preparation of a **draft report and final report** containing findings and conclusions.

60 years 1961–2021
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Conceptual Model Applied to Zone 3 in Summer



60 years 1961–2021
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

What is an "Analysis of Attainability?

What We Know

- Minimum Dissolved Oxygen conditions are critical to supporting fish propagation
- Existing DO condition supports some degree of propagation among resident fish
- 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

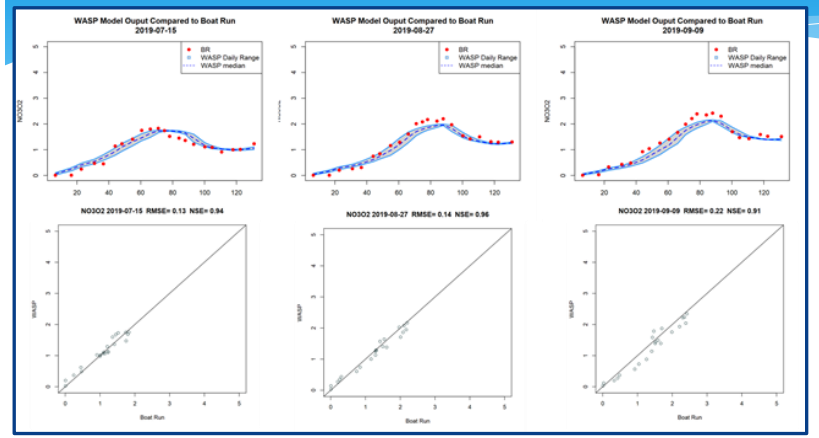
What We Need to Determine

- 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

60 years 1961–2021
DRBC
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

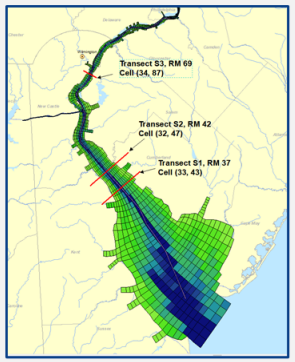
Elements of "Attainability Analysis"

Eutrophication Model Calibration



Design Condition / Future Scenarios

Eutro Model



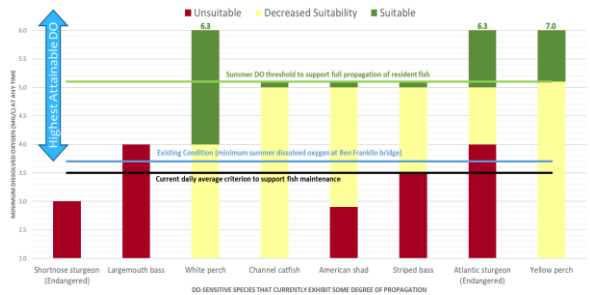
Refined Candidate Scenarios

? ? ? ?

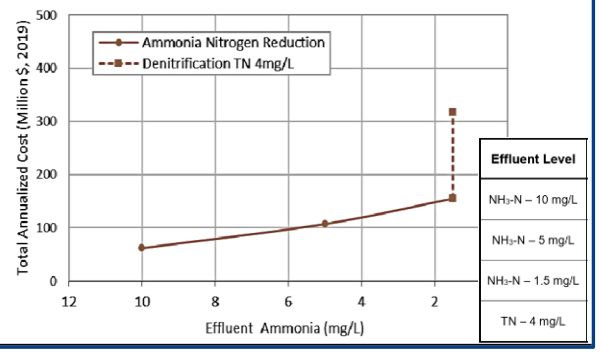
How much would DO condition improve if:

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

Aquatic Life Protection Levels and DO



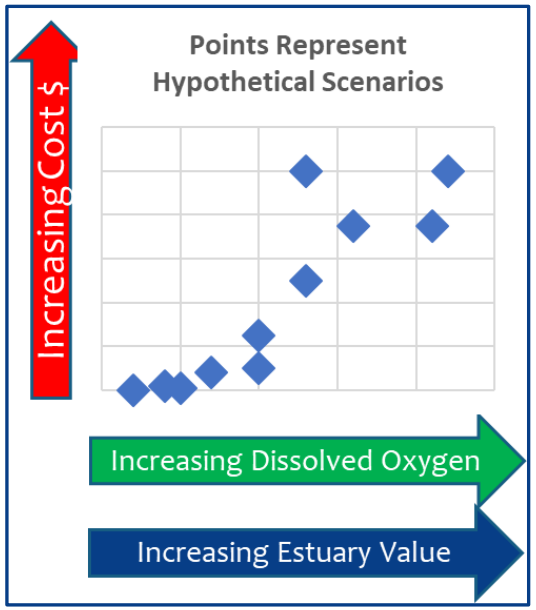
Treatability and Cost



Social and Economic Evaluation

- Impact of enhanced fisheries on estuary value
- Evaluation of affordability
  - Implementation schedule
- Consideration of equity

Analysis of Attainability

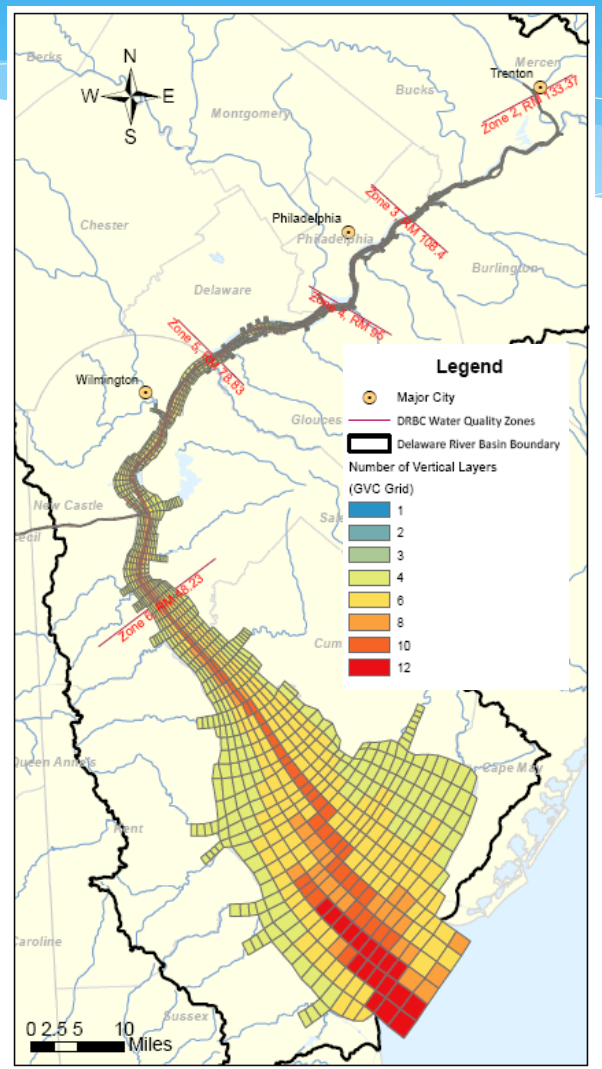


60 years 1961–2021
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

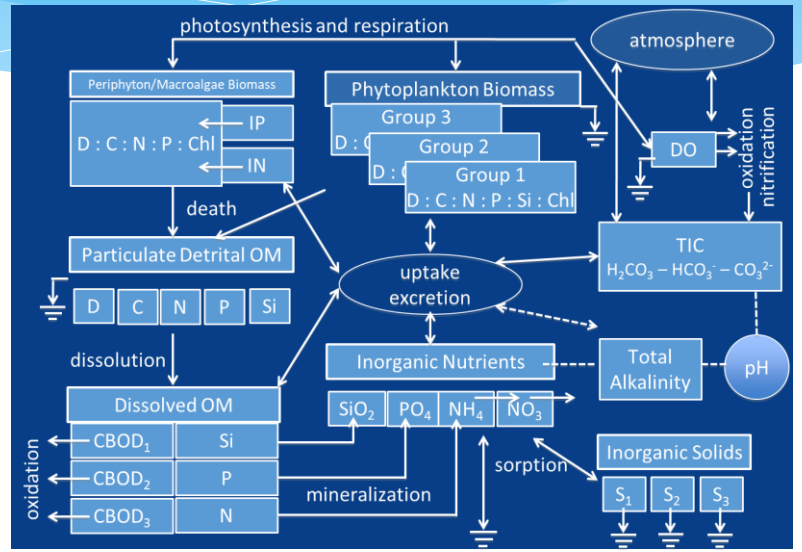
System-Wide Eutrophication Model

Hydrodynamic Model

- Provides transport information for WQ model
  - water depth
  - current velocity
  - salinity
  - water temperature
  - mixing coefficient
- 3D application of EFDC
  - 1,876 horizonal grid cells
  - 10 vertical layers in navigation channel (11,490 total cells)



Water Quality Model

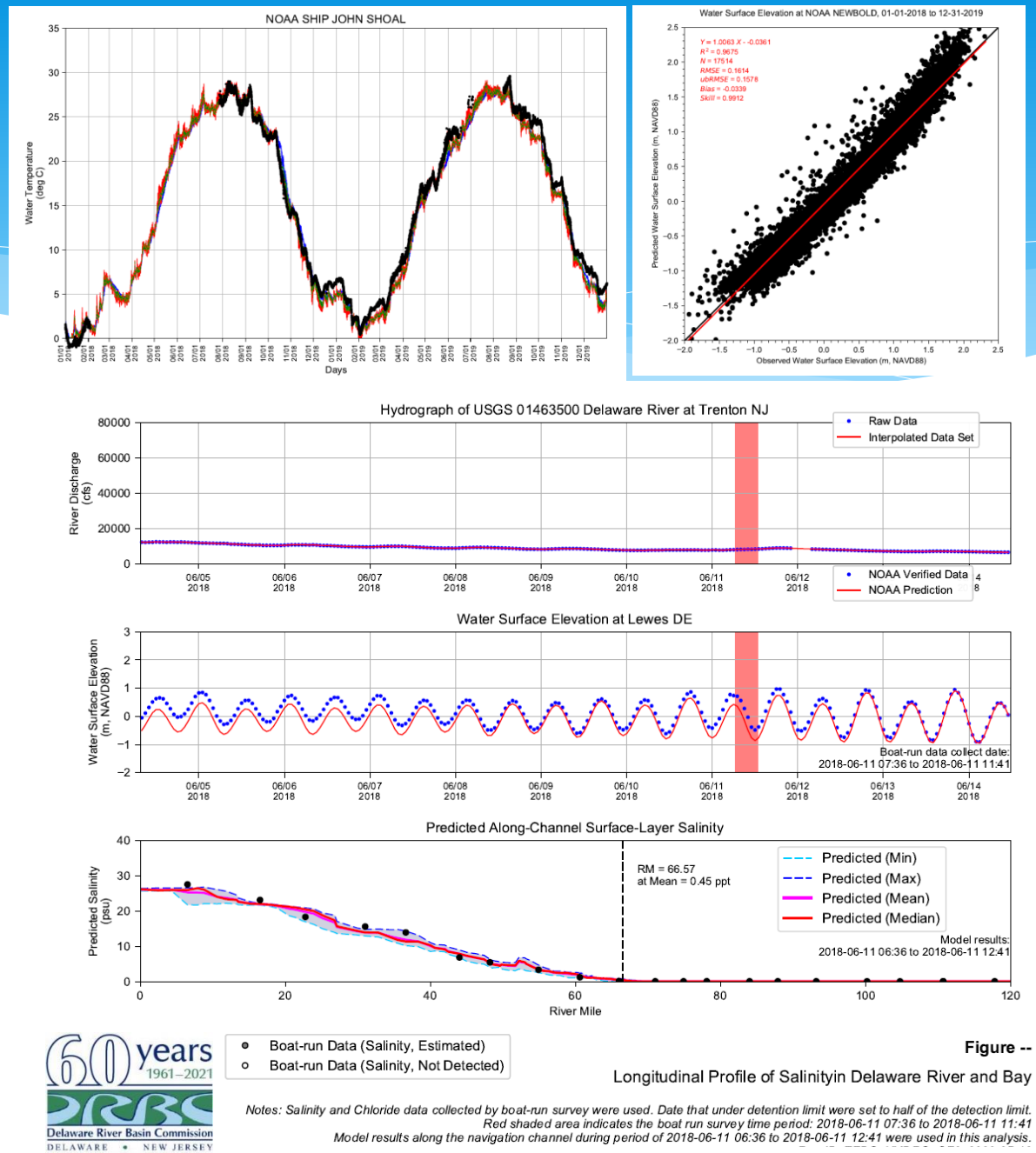


- Water Quality Analysis Simulation Program (WASP)
  - Linked to EFDC
  - ~32 hrs/year run time for 3D
  - ~1-2 hrs/year run time for 2D

60 years 1961–2021
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Hydrodynamic Model Calibration

- Calibration Periods
  - 2018, 2019
  - 2012 added to capture full range of hydrologic conditions
- Submodels developed to improve boundary conditions
  - Tributary temperature assignments
  - Flow at ungaged tributaries, watersheds, stormwater
- Calibration completed in 2020



60 years 1961–2021

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

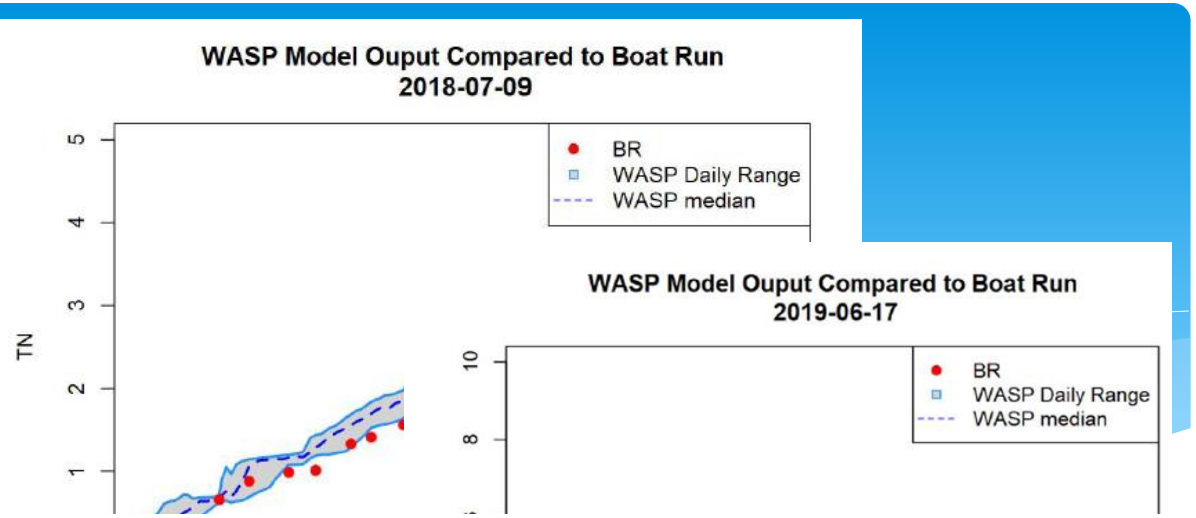
Figure --

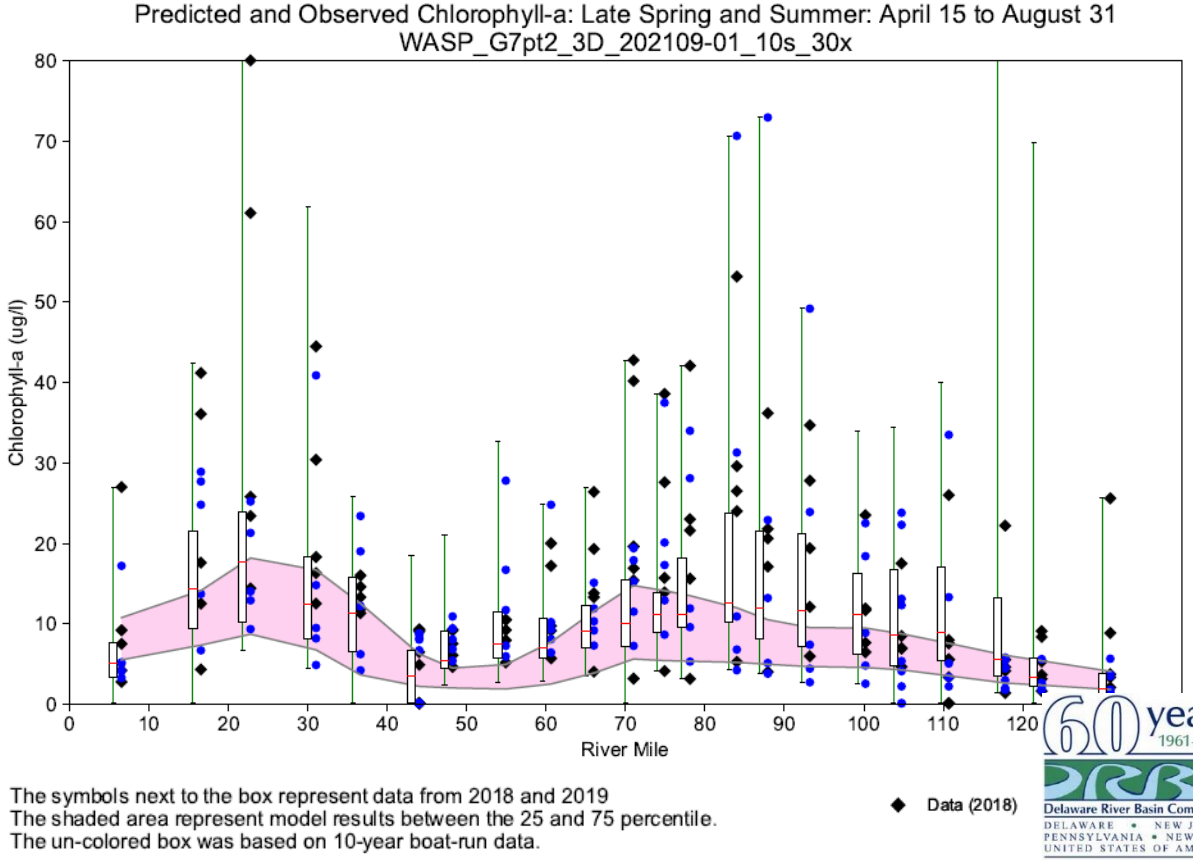
Longitudinal Profile of Salinityin Delaware River and Bay

Notes: Salinity and Chloride data collected by boat-run survey were used. Date that under detention limit were set to half of the detection limit.
Red shaded area indicates the boat run survey time period: 2018-06-11 07:36 to 2018-06-11 11:41
Model results along the navigation channel during period of 2018-06-11 06:36 to 2018-06-11 12:41 were used in this analysis.

Water Quality Model Calibration

- Significant advancements to state-of-the-art
  - EFDC-WASP Model Integration
    - Scale and complexity exposed limitations and inefficiencies
  - Statistical submodel for boundary assignments
    - Based on a regional analysis of shared features
    - Estimates flow and WQ at tributaries and watershed boundaries
  - Light extinction function re-formulated
    - Empirical Ke model f(RM, salinity, DOC, chl-a)
  - Reaeration formulation improvement
    - Mechanistic submodel incorporated
- Calibration to be completed in 2021

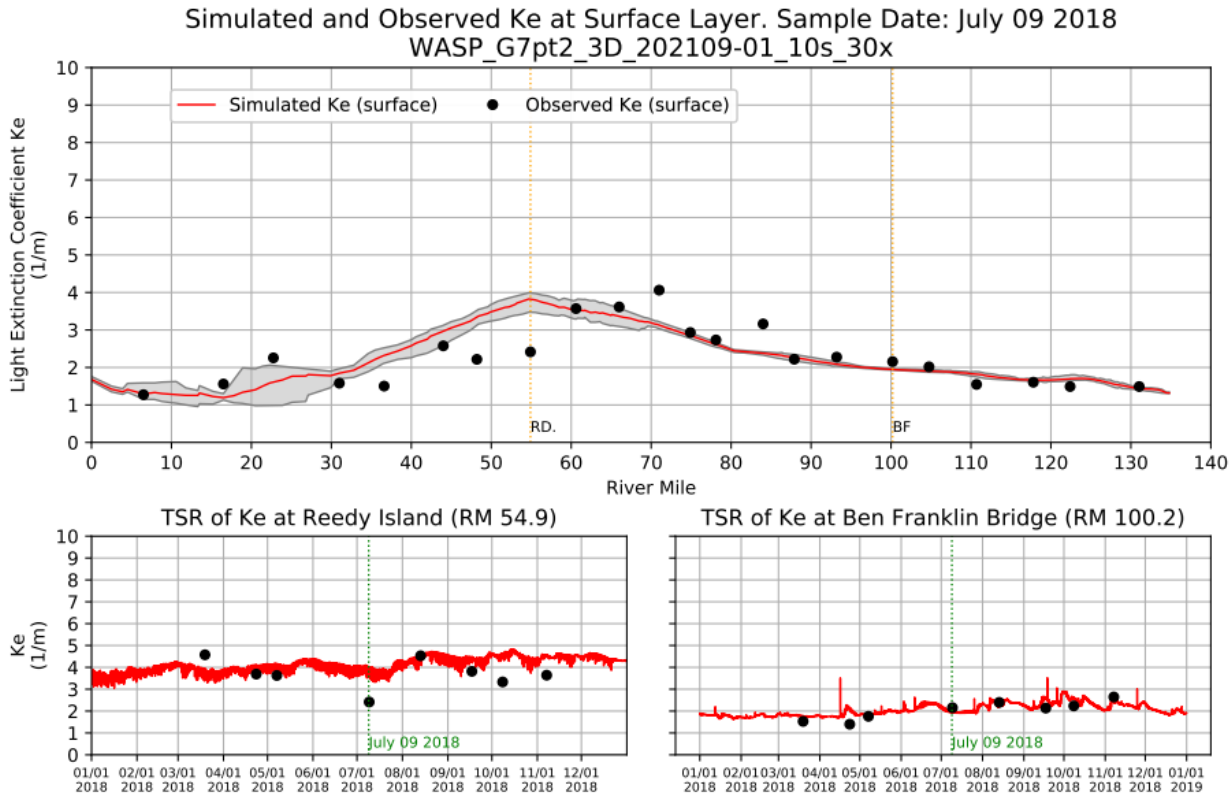




60 years 1961–2021
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Data to Knowledge: Light Extinction

- Ke is related to:
  - Scattering (solids)
  - Absorption (color)
  - Self-shading (phytoplankton)
- It all starts with DATA!
  - PAR measurements 2019-2019
- Insights applied to re-formulation
  - ETM disrupts relationships
    - Data outside ETM used for fitting
  - Salinity better than solids
- Intercept can be estimated as fRM)



Application of Systemwide Eutrophication Model

What have we learned?

- Very different than Chesapeake Bay!
  - High energy – tides and boundaries
  - More WWTP loads and less agriculture loads
  - DATA)inputs) extremely important
- Drivers of low dissolved oxygen episodes:
  - Temperature and flow
  - Sediment demand
  - Periods of low phytoplankton!
- The most critical DO events in urban estuary occur when phytoplankton does not bloom
  - In addition to the ammonia nitrification issue, there appears to be a natural condition component to the low DO issue

How can model be useful?

- Determining how much DO improvement can be achieved
  - What happens when sources are eliminated or reduced to max extent?
  - What DO benefits (and associated uses) can be achieved with various source reductions
  - What is highest attainable DO condition?
- Additional data needs exposed through study
  - Boundary phytoplankton matters!
- How can we expect model to evolve in the future
  - Dynamic sediment model
  - Exploration of future climatic scenarios

Thomas Amidon, Manager
Water Resources Modeling
Thomas.Amidon@drbc.gov
www.drbc.gov

60 years
1961–2021

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Managing, Protecting and Improving Our Shared Water Resources since 1961