Meeting of Model Expert Panel with DRBC Staff

Report to the Water Quality Advisory Committee

Delaware River Basin Commission

October 29, 2020

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DRBC Expert Panel Members

Name	Organization	Service
Carl Cerco	U.S. Army Corps of Engineers (Retired)	Panel Members
Bob Chant	Rutgers University	
Steve Chapra	Tuffs University	
Tim Wool	U.S. EPA Region 4	
Vic Bierman	LimnoTech	Consultant to DRBC
Scott Hinz	LimnoTech	

DRBC Participants

Name	Title	Specialty and Responsibility
Kristen B. Kavanagh	Deputy Executive Director	Project management / multi-task
Tom Amidon	Manager, Water Resource Modeling	Modeling general / algal speciation
Jacob Bransky	Aquatic Biologist	Primary productivity / ichthyoplankton / algal speciation
Fanghui Chen	Water Resource Engineer	Hydrodynamic modeling / data retrieval / post processing
Vince DePaul	Hydrologist (USGS)	WQ modeling / NPS load / atmospheric deposition
Elaine Panuccio	Water Resource Scientist	Data collection and management / load calculation
Namsoo Suk	Director, Science and WQ Management	Project management / multi-task / WQ modeling
John Yagecic	Manager, Water Quality Assessment	Data retrieval & analysis / post processor development
Li Zheng	Senior Water Resource Engineer	Hydrodynamic and WQ modeling

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Goal

- Develop a technically sound eutrophication model for the Delaware Estuary and Bay utilizing the current state of the science within a timeframe established by the Commission
  - Identify appropriate levels of source controls, especially in relation to dissolved oxygen

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Modeling Approach

- Develop a linked hydrodynamic and water quality model
  - Environmental Fluid Dynamics Code (EFDC)
  - Water Quality Analysis Simulation Program (WASP8)
- Develop flow and concentration inputs (boundary conditions)
  - Tributaries, point sources, tidal forcings, stormwater, air deposition, CSOs, etc.
  - Conduct intensive monitoring to supplement historical data
  - Develop methodologies and submodels as needed to assign boundaries
- Calibrate linked model
  - Intensive monitoring period 2018-2019
  - Historical data, primarily 2012
- Conduct forecast simulations with calibrated model
  - Develop baseline (design) conditions and future scenarios
  - Determine levels of external sources required to achieve varying levels of ambient dissolved oxygen

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Site-Specific Challenges

- Scale and complexity of this EFDC-WASP application to Delaware River Estuary are much greater than typical applications at other sites
  - For example, Neuse River application had 4 vertical layers and 1,620 spatial grid cells
  - Delaware River Estuary application has 10 vertical layers and 11,490 spatial grid cells
- Since December 2019, numerous technical limitations and computational challenges became apparent in the linked EFDC-WASP models
- Resolution of these unexpected issues caused delays in the overall schedule

Key Tasks Performed since December 2019

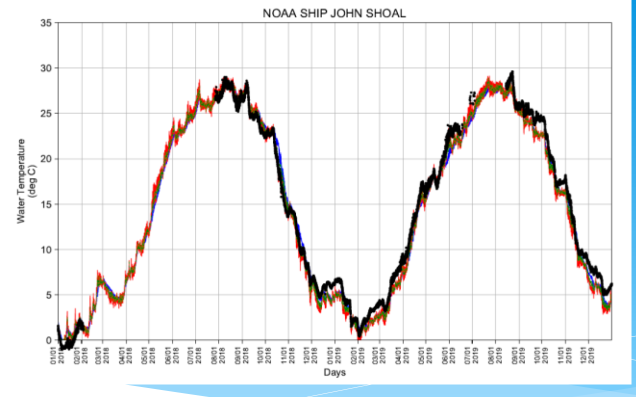
- Optimization of model simulation times by testing multiple model grids, each of which required:
  - Re-calibration of EFDC
  - Mass balance checks
  - EFDC-WASP linkage time step optimization
- Tested sensitivity of EFDC and DO to vertical grid resolution
- Tested sensitivity of tracer concentrations and DO to vertical mixing coefficients
- Incorporation of site-specific options for WASP, with support from Tim Wool, EPA Region 4 and Model Expert Panel
  - New light extinction formulation based on site-specific data
  - Revised reaeration formulation for estuarine environments

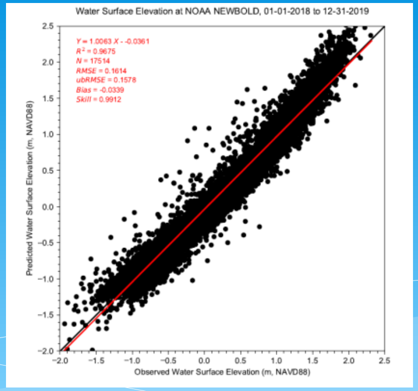
Key Accomplishments since December 2019

- EFDC Model
  - Finalized calibration of a full 3D, 10-layer model
  - Developed a 2D (horizontal) production version to optimize WASP8 calibration runs
- WASP Model
  - Completed 2018-2019 boundary assignments
  - Conducted systematic sensitivity analyses and preliminary calibration runs with the 2D production version
  - Developed and tested the full operational 3D version
  - Developed post-processing tools
- Completed the 2018-2019 field sampling program

EFDC 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”**





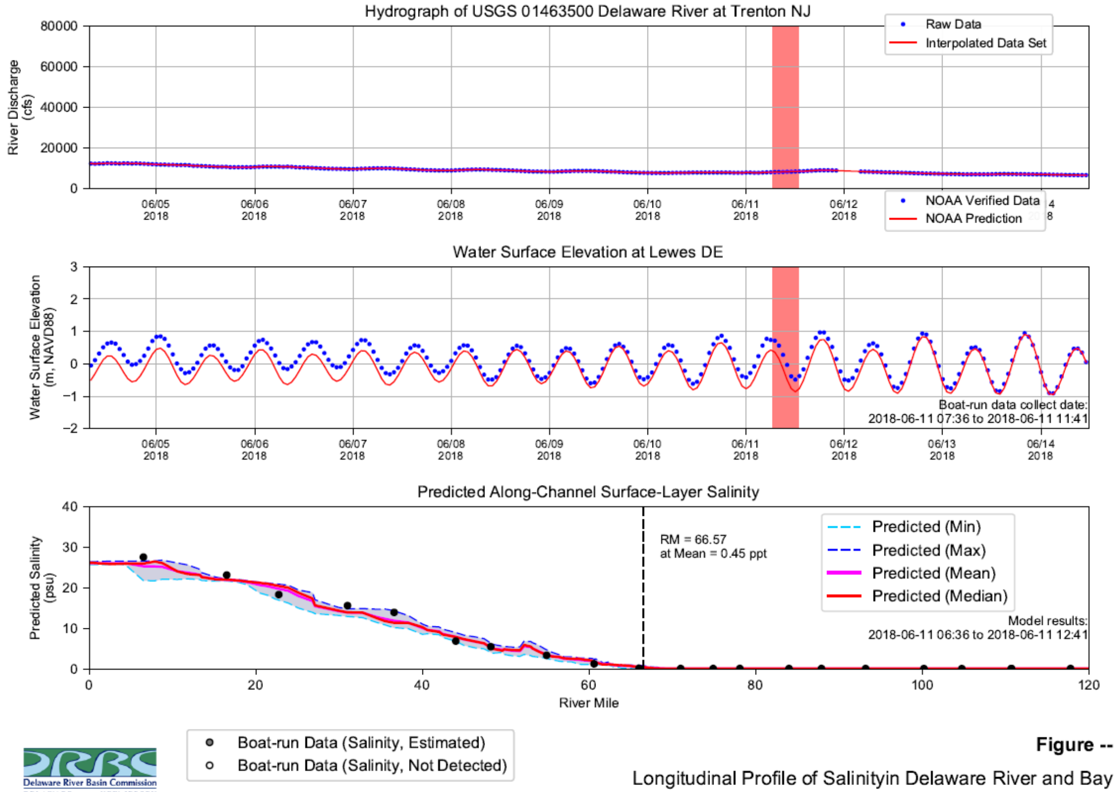


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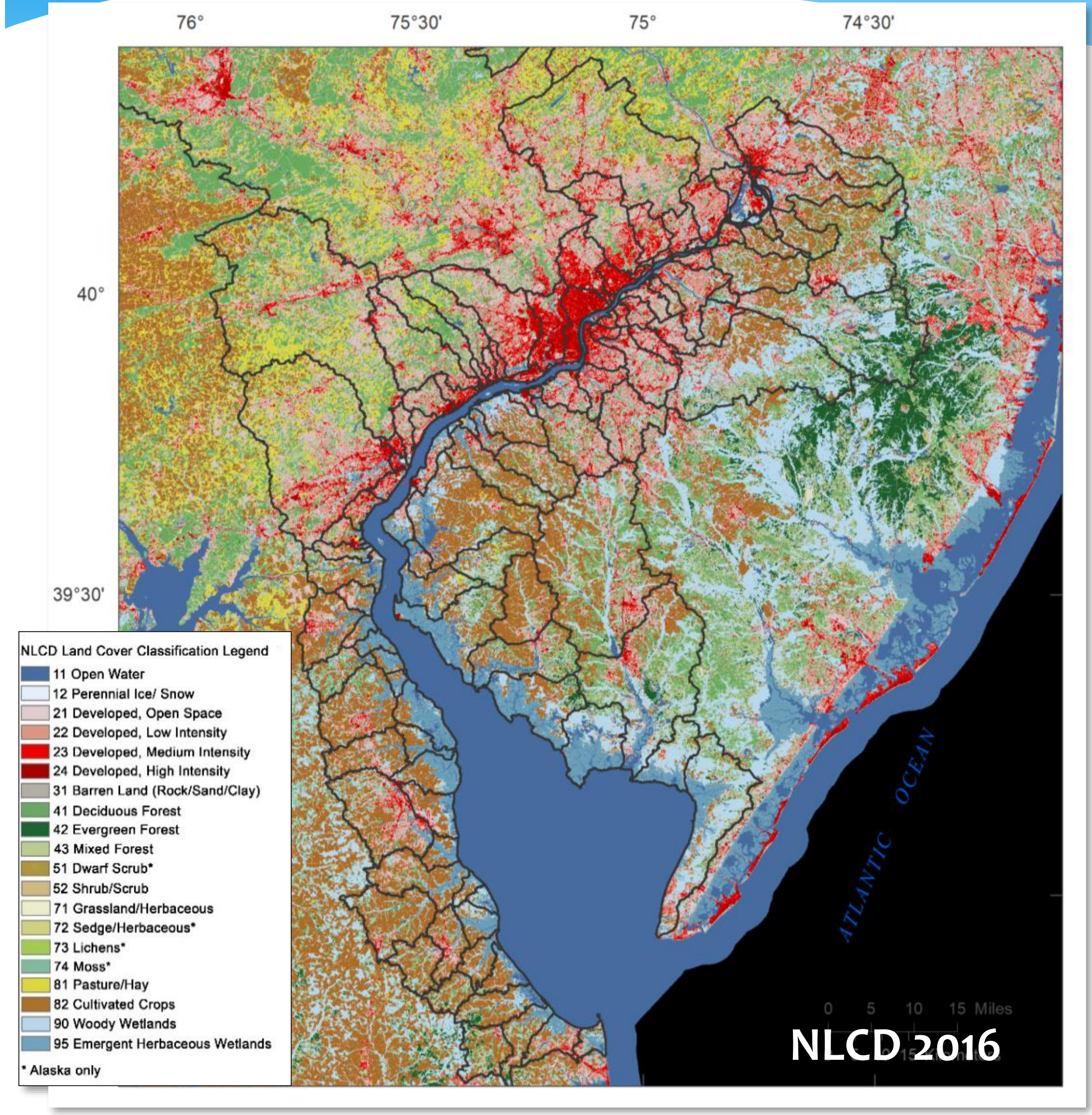
Figure --

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.

Environmental Classification
Unmonitored Basin Assignment



- Suite of physical and hydrologic characteristics extracted by watershed using a GIS
- Characteristics chosen among categories known to influence streamflow or water quality (morphology, soils, geology, land use/land cover, climate, atmospheric deposition, other factors)
- Group 124 sub watersheds with potential reference stations using multivariate analysis
- Hierarchical agglomerative clustering (HACA) using Ward's algorithm to group basins sharing similar environmental factors

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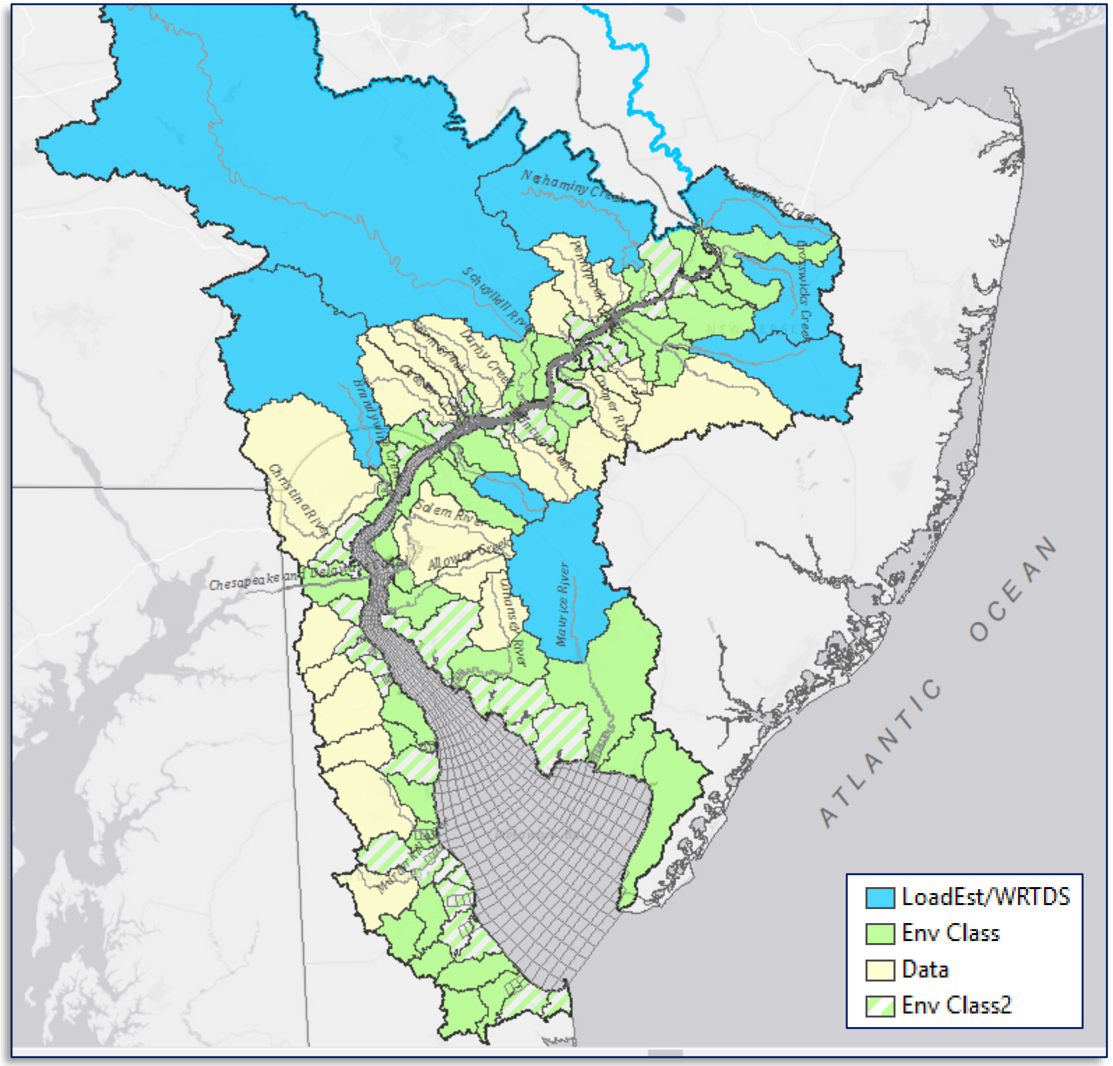
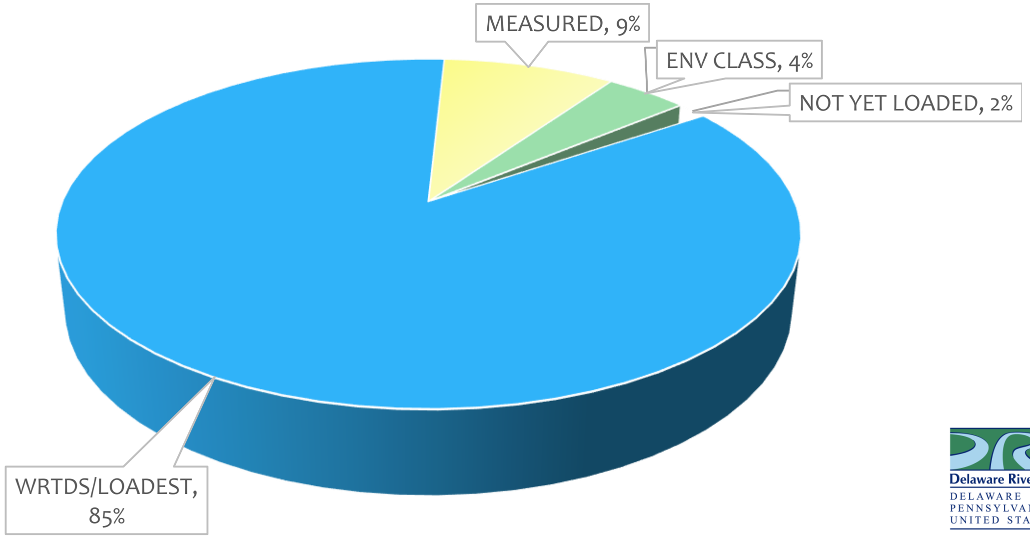
Loading Method Summary



- LOADEST/WRTDS models and continuous monitoring data in selected tributaries – paired with 85% of watershed inflows
- Measured data -- some substitution – 9% of watershed inflows
- Environmental classification and data assignment - ~6% of watershed inflows



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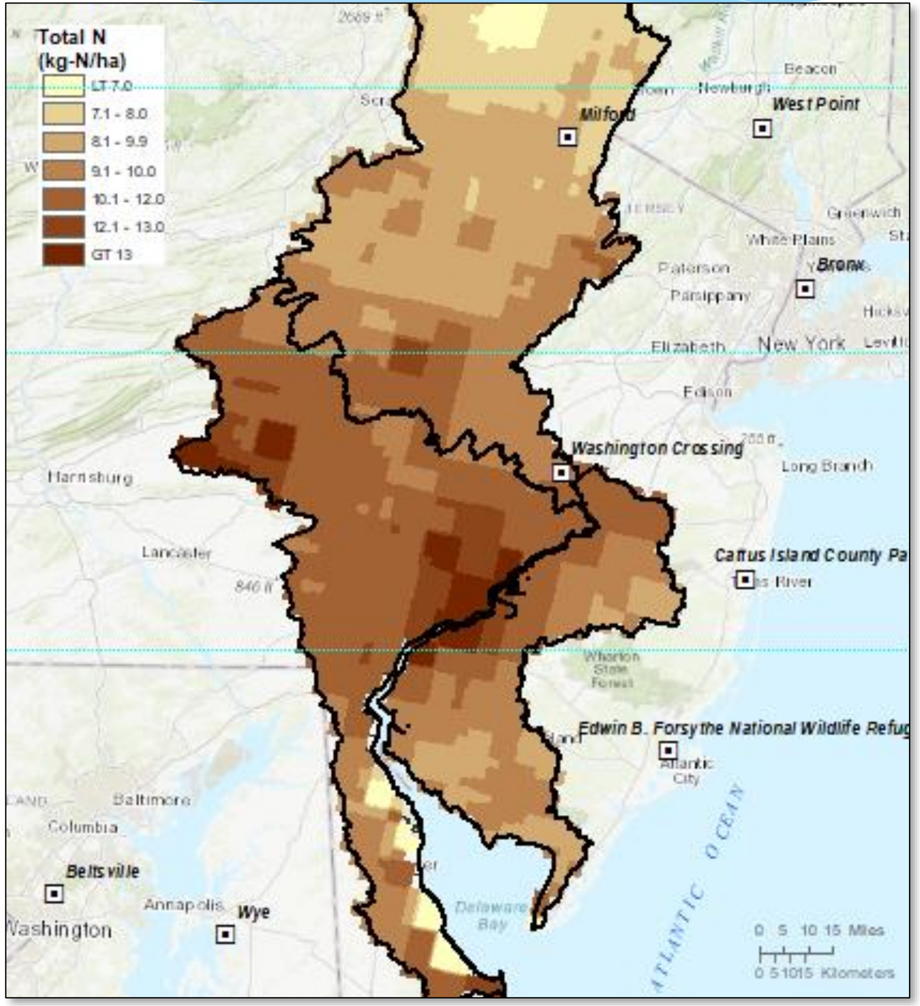
Atmospheric Deposition

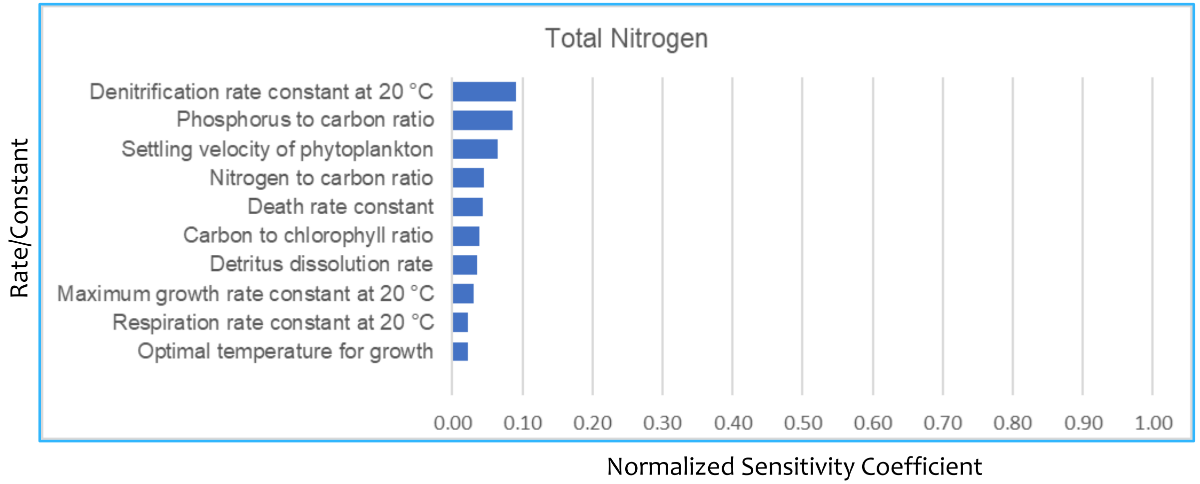
- Wet deposition rates determined from precipitation chemistry following methods of Ullman and others (2010). Wash Crossing, NJ; Wye, MD, EBF NWR
- Dry deposition estimated from NADP Total Dep maps
  - Hybrid mapping approach utilizes monitoring and modeled data (*Schwede, D.B. and Lear, G.G., 2014)*
- Extrapolate north-south using NADP deposition grids (wet-dry, reduced-oxidized)
- Weekly deposition rates are applied to all surface model segments using time function utility
  - Substantial WASP code upgrade
  - 2,268,059 Kg/yr DIN to water surface -- <5% of watershed TN loading.

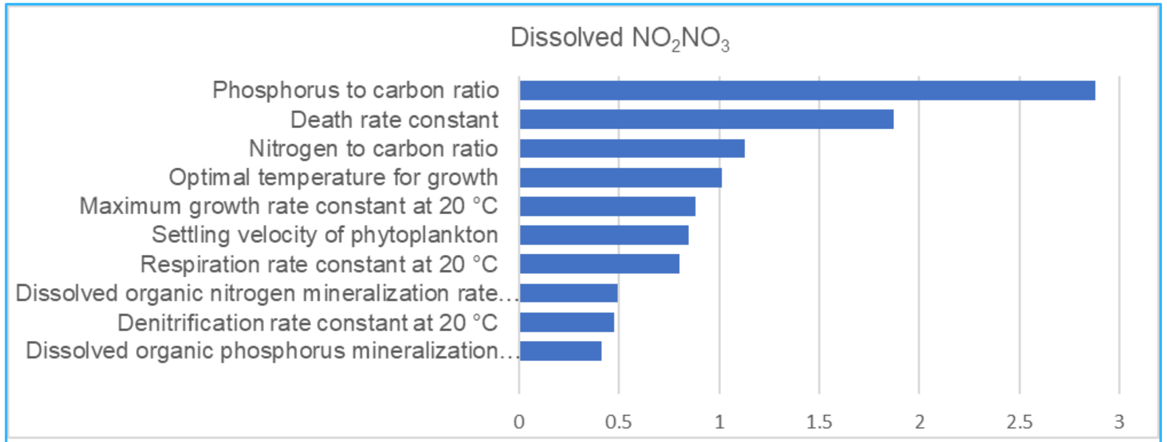


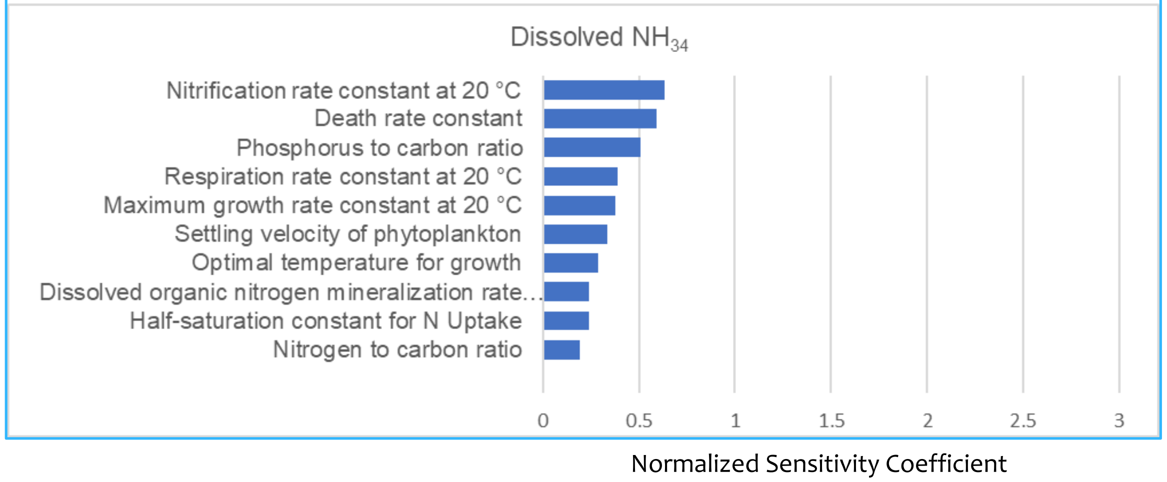
WASP Calibration Approach

- Specify starting values for all internal model parameters and coefficients based on:
  - Other similar estuarine modeling studies (e.g., Chesapeake Bay)
  - Scientific literature
  - Best professional judgment
- Conduct sensitivity analyses for 30 model parameters using 2D production version
  - Change one input at a time by +/- 25 percent
  - Screening approach to guide model calibration
  - Understand relative influence of each parameter on principal model outputs
  - Novel in that typically conducted after an optimal calibration is obtained
- Conduct preliminary model-data comparisons for 2D production version
  - Boat run data for 2019
- Compare results for 2D production version and full 3D version
  - Low-flow period only (9/7 to 10/7 19)
  - Mean values of observed data along navigation channel
  - Assess utility of 2D version for production calibration runs

Nitrogen Sensitivity







Low flow conditions at all stations

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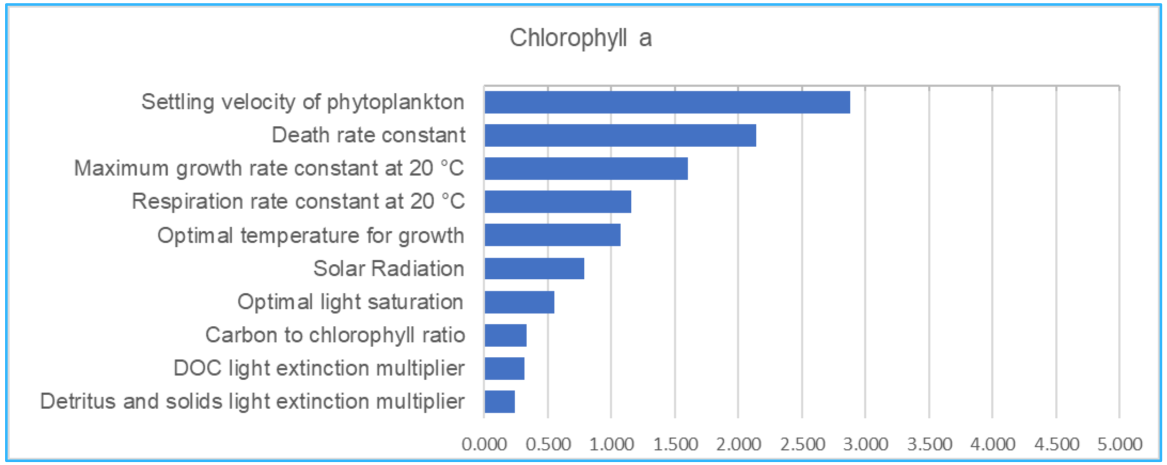
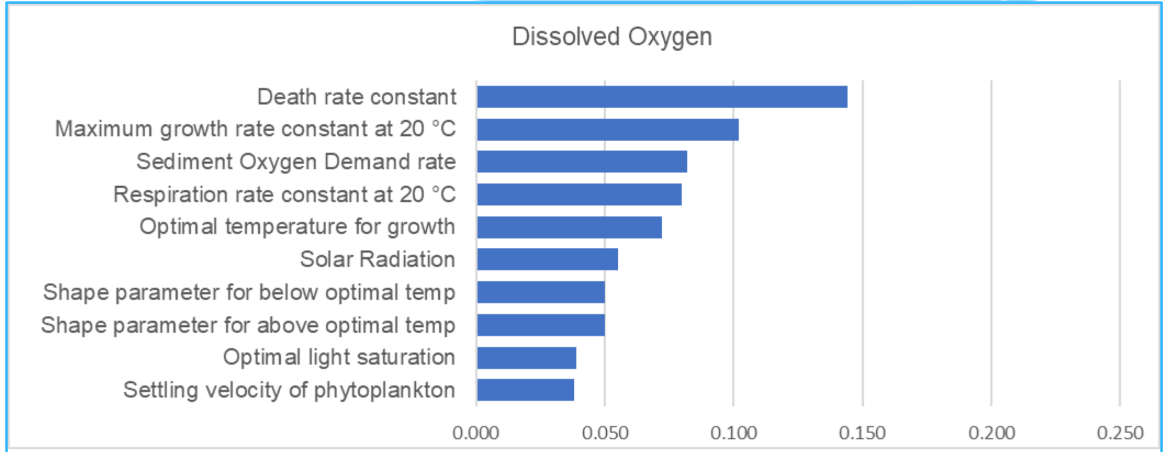
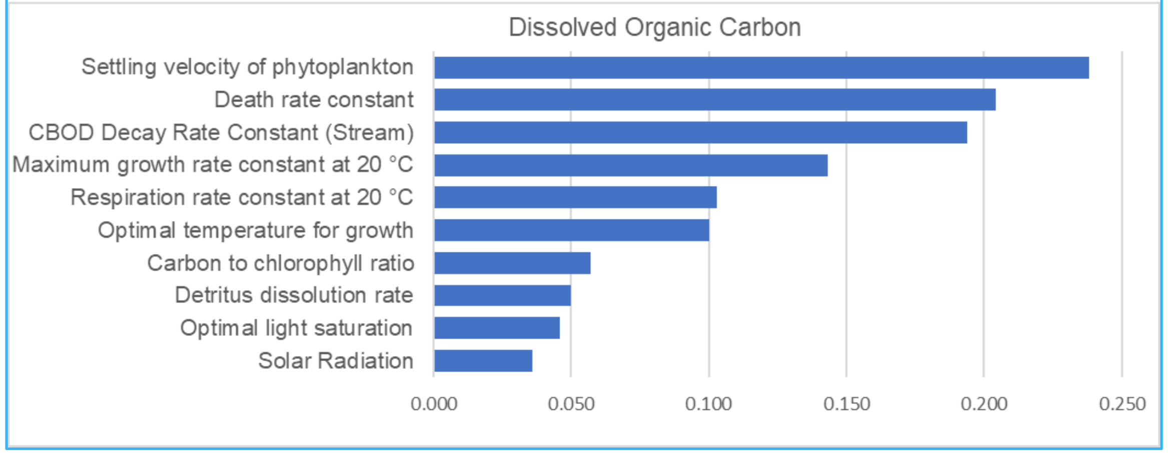
Organic Carbon, Oxygen, CHLA







Low flow conditions
All Stations

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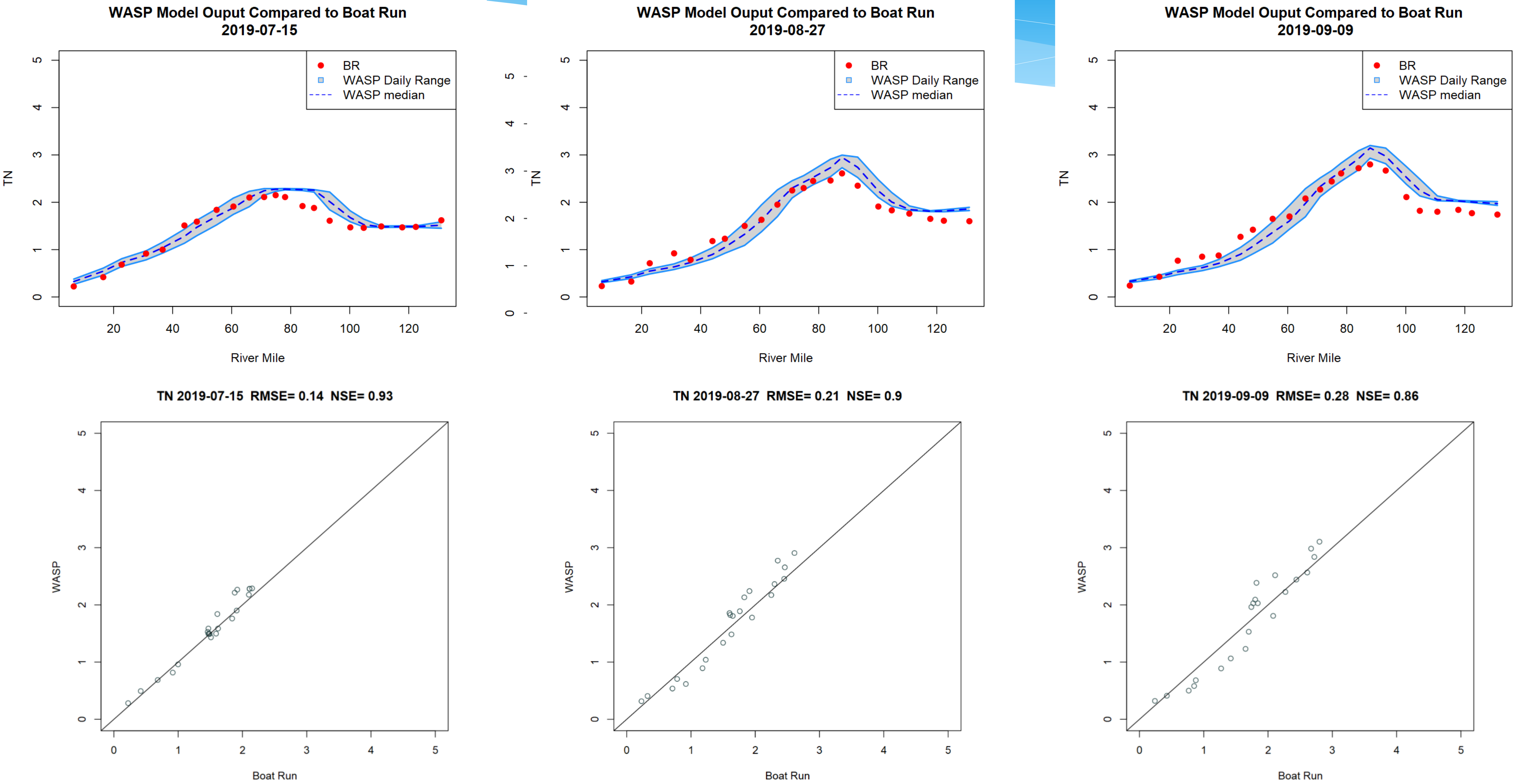
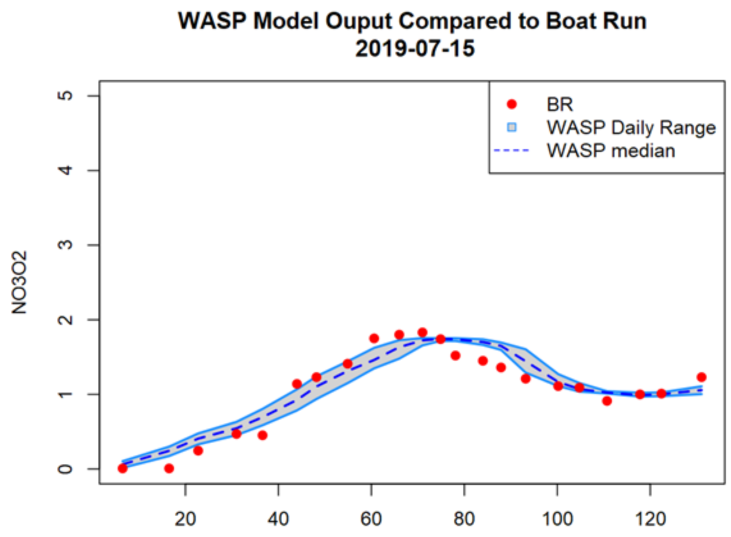
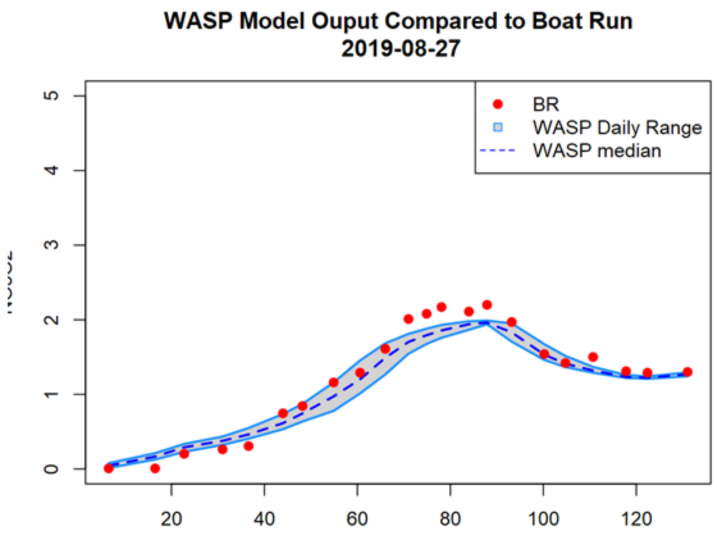
Total Nitrogen

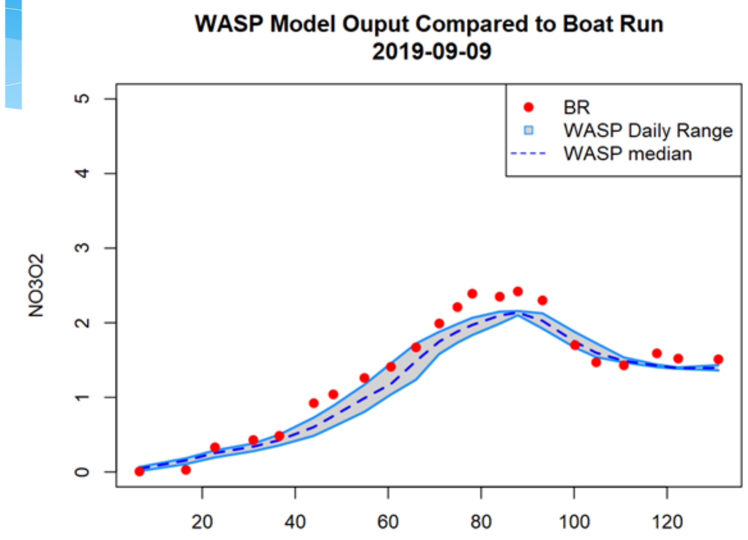


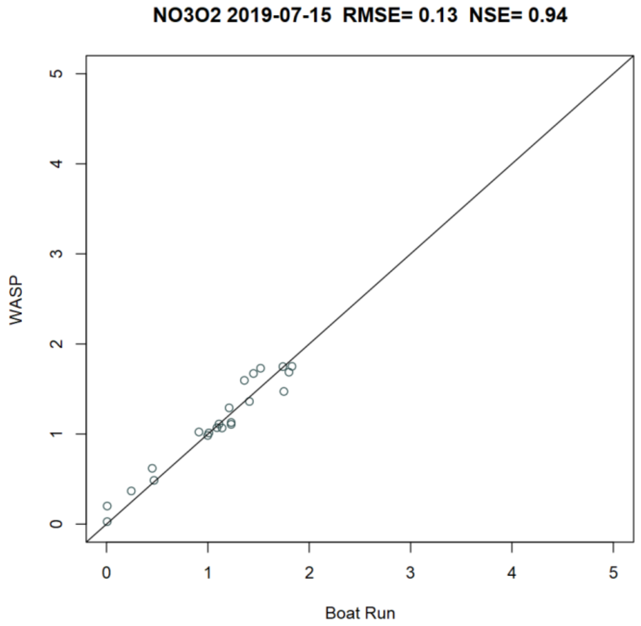
RUNID: WASP_G7pt2_2D_2020-10-15_6_10s_60x_YR2019

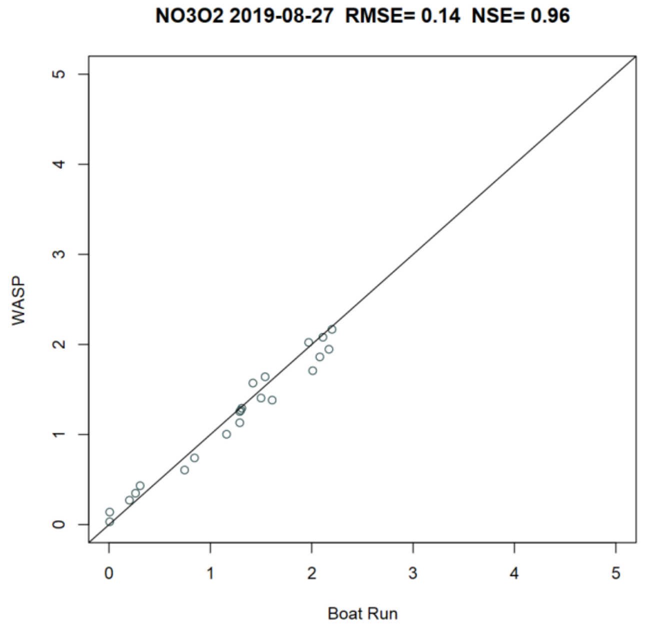
NO3NO2

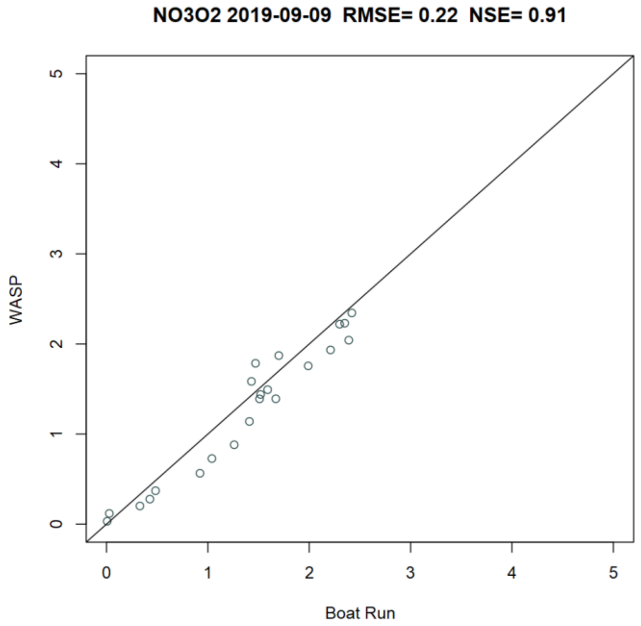












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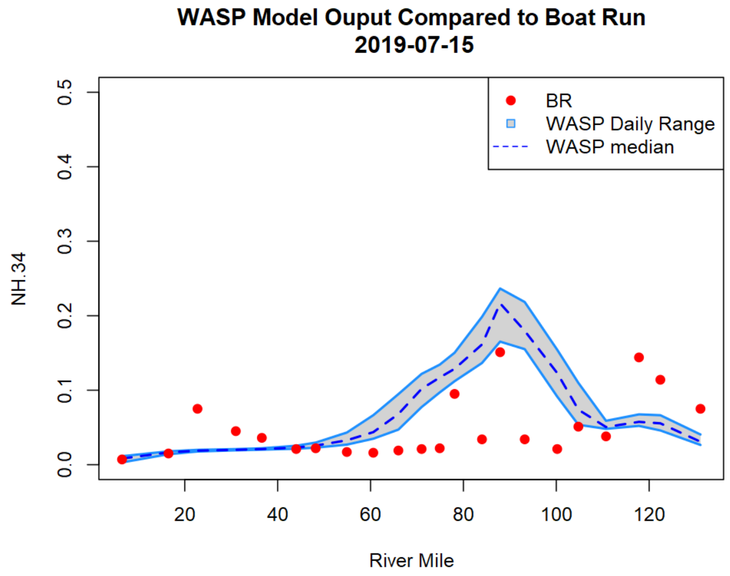
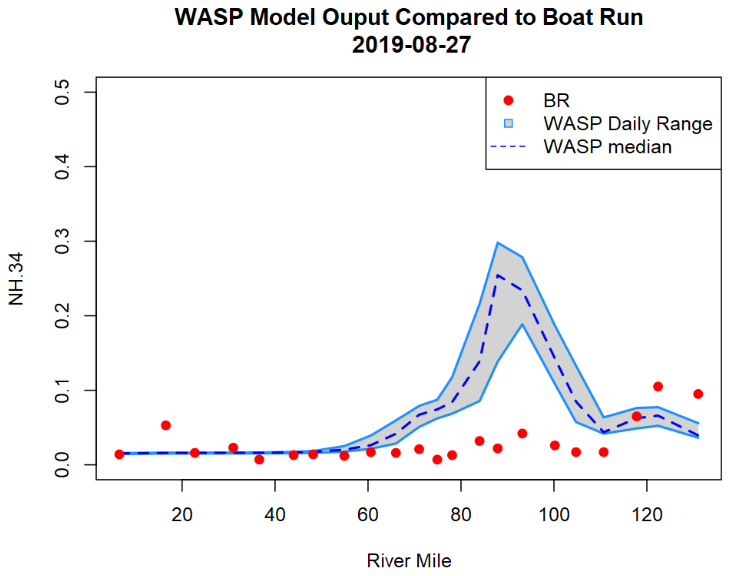
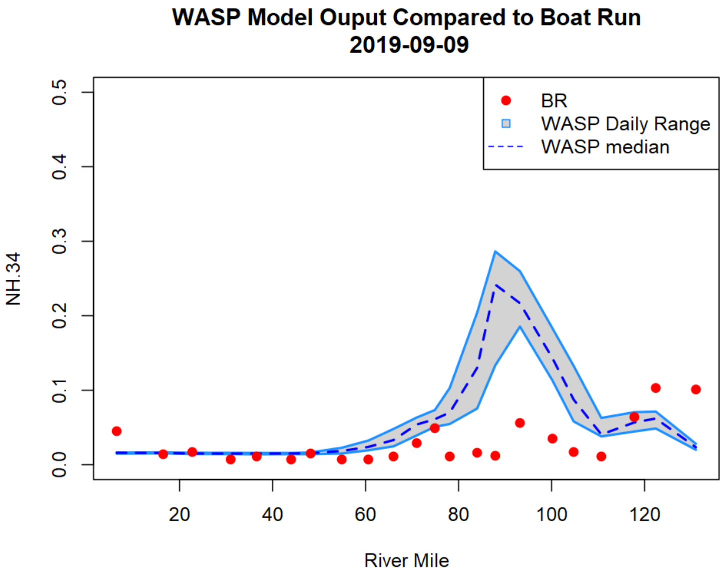
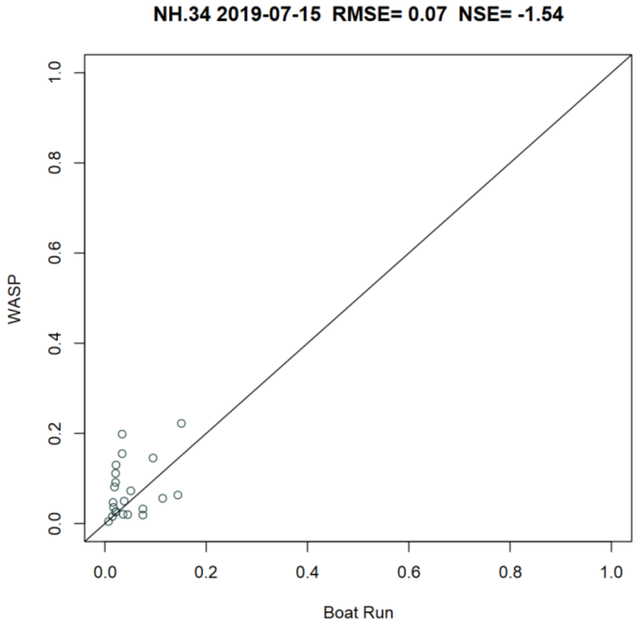
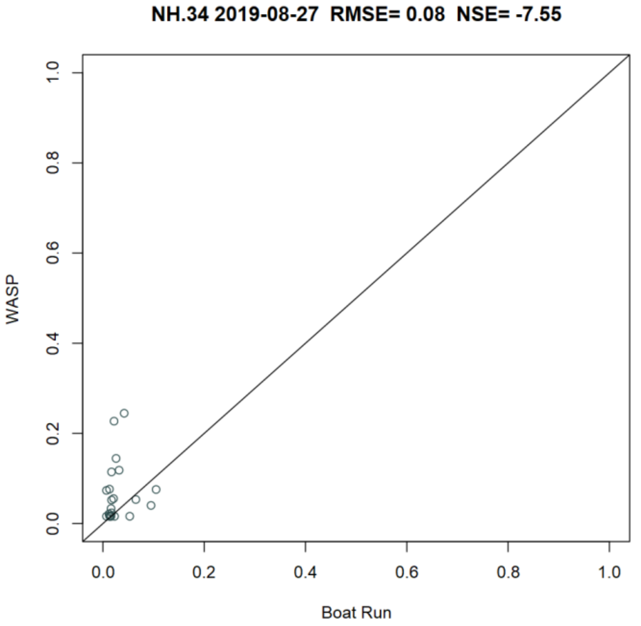
NH34

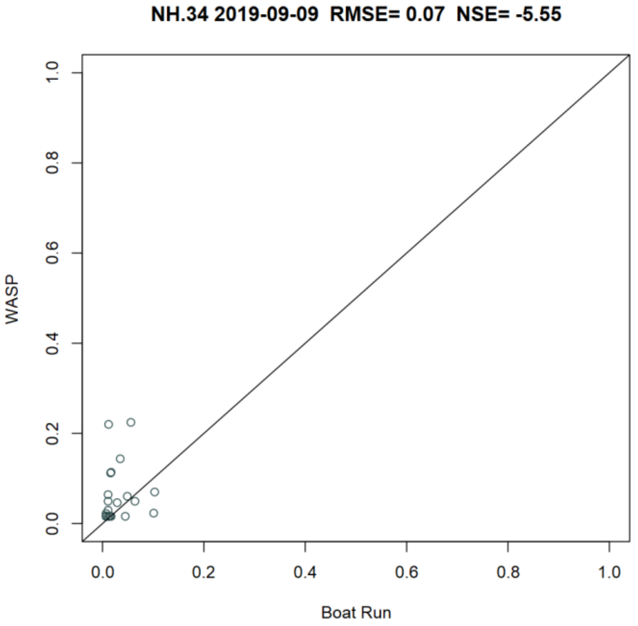

WASP Model Ouput Compared to Boat Run
2019-07-15
BR
WASP Daily Range
WASP median
NH.34
River Mile
0.0
0.1
0.2
0.3
0.4
0.5
20
40
60
80
100
120


WASP Model Ouput Compared to Boat Run
2019-08-27
BR
WASP Daily Range
WASP median
NH.34
River Mile
0.0
0.1
0.2
0.3
0.4
0.5
20
40
60
80
100
120


WASP Model Ouput Compared to Boat Run
2019-09-09
BR
WASP Daily Range
WASP median
NH.34
River Mile
0.0
0.1
0.2
0.3
0.4
0.5
20
40
60
80
100
120

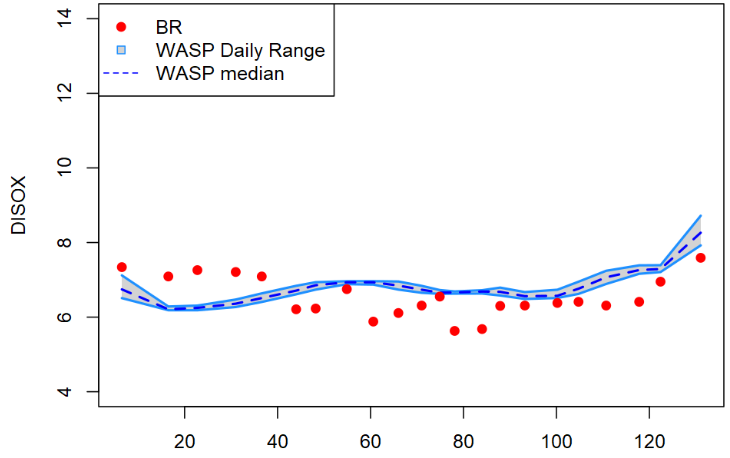

NH.34 2019-07-15 RMSE= 0.07 NSE= -1.54
WASP
Boat Run
0.0
0.2
0.4
0.6
0.8
1.0


NH.34 2019-08-27 RMSE= 0.08 NSE= -7.55
WASP
Boat Run
0.0
0.2
0.4
0.6
0.8
1.0

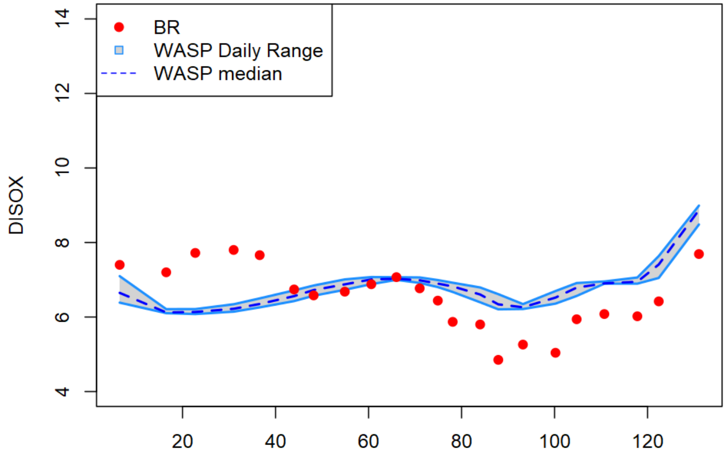

NH.34 2019-09-09 RMSE= 0.07 NSE= -5.55
WASP
Boat Run
0.0
0.2
0.4
0.6
0.8
1.0

DISOX

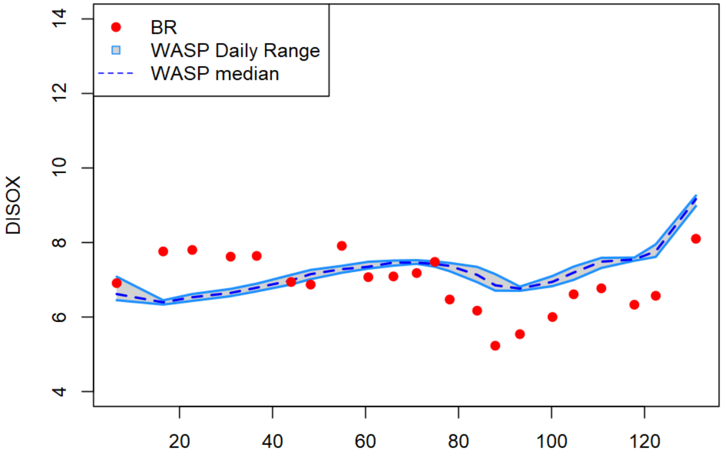
WASP Model Ouput Compared to Boat Run
2019-07-15



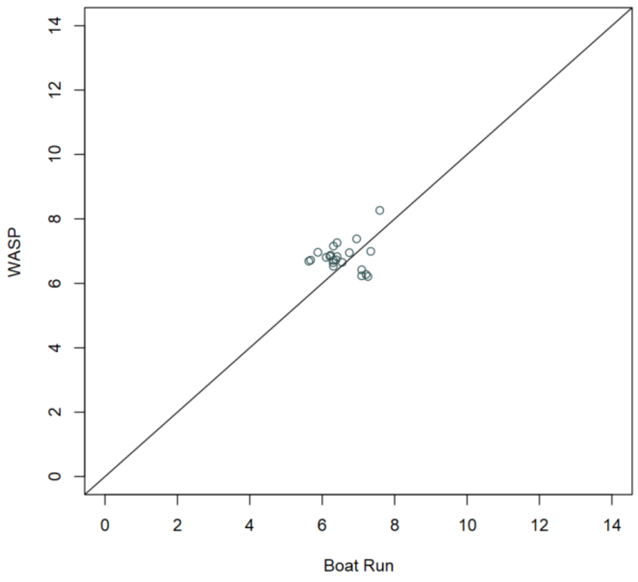
WASP Model Ouput Compared to Boat Run
2019-08-27



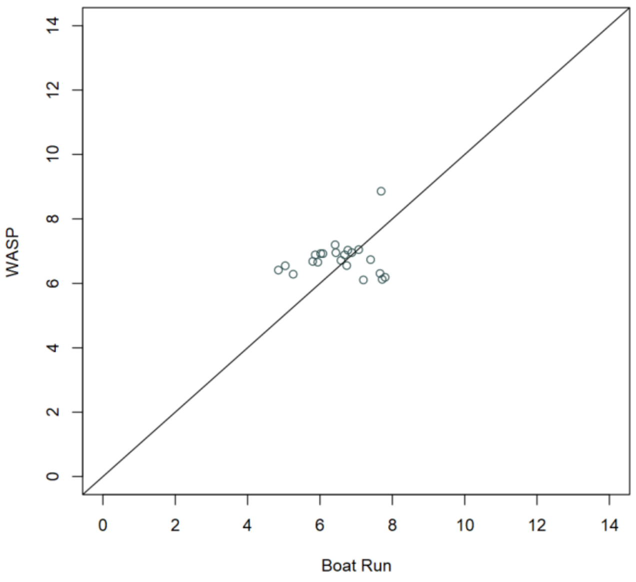
WASP Model Ouput Compared to Boat Run
2019-09-09



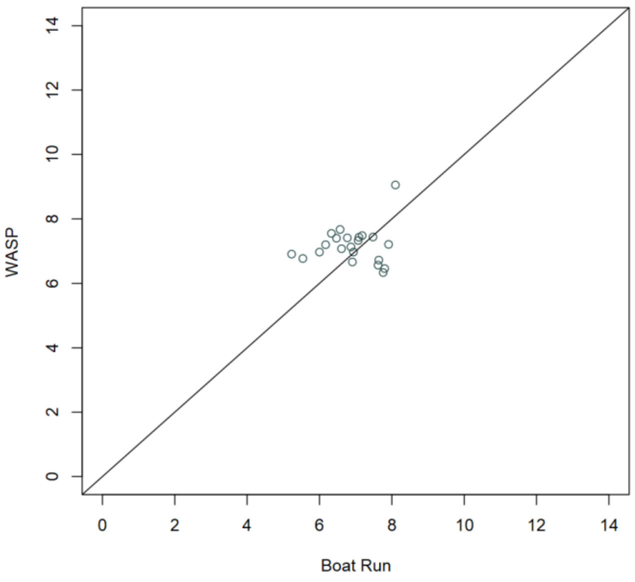
DISOX 2019-07-15 RMSE= 0.7 NSE= -0.73



DISOX 2019-08-27 RMSE= 0.97 NSE= -0.3



DISOX 2019-09-09 RMSE= 0.91 NSE= -0.48



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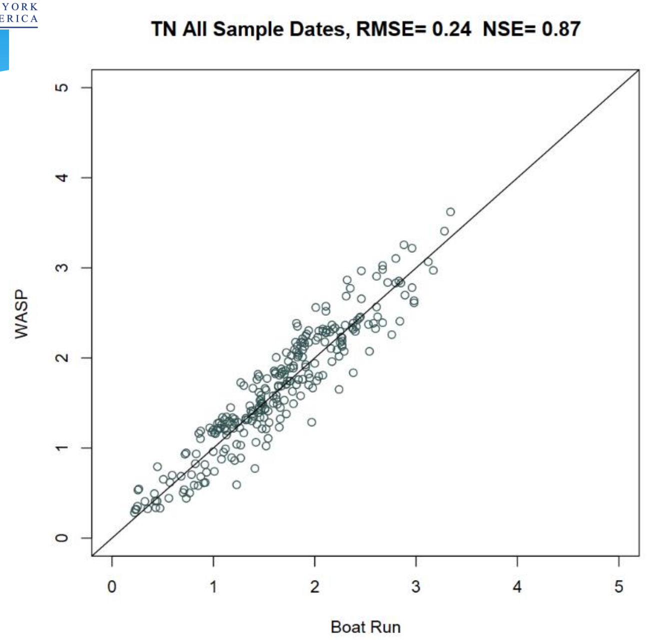
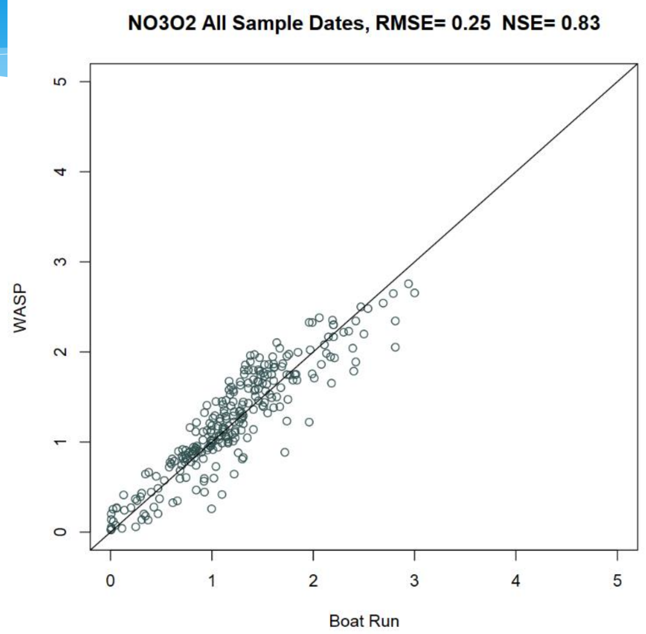
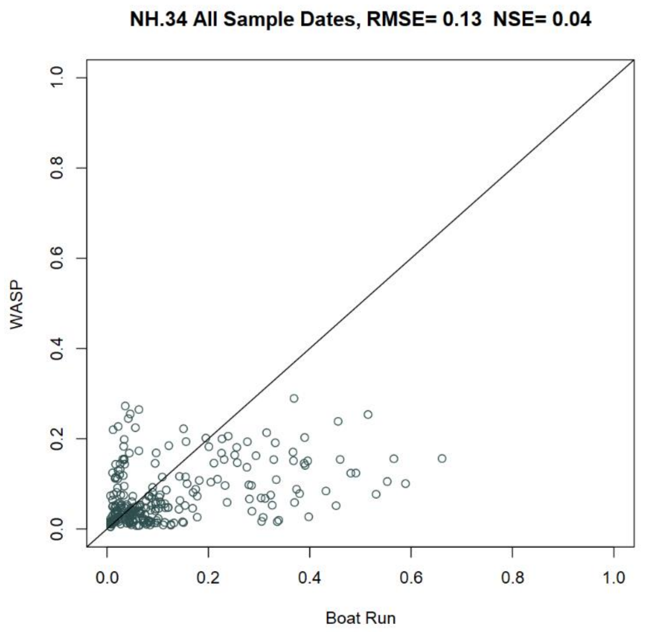
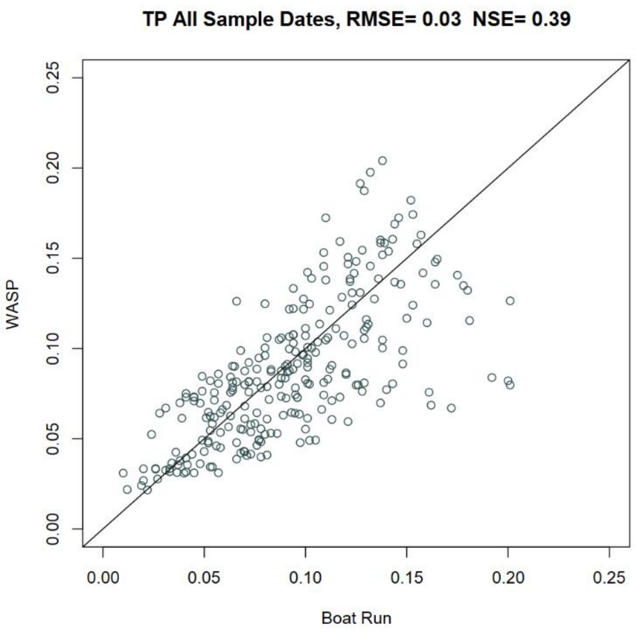
Bivariate Plots

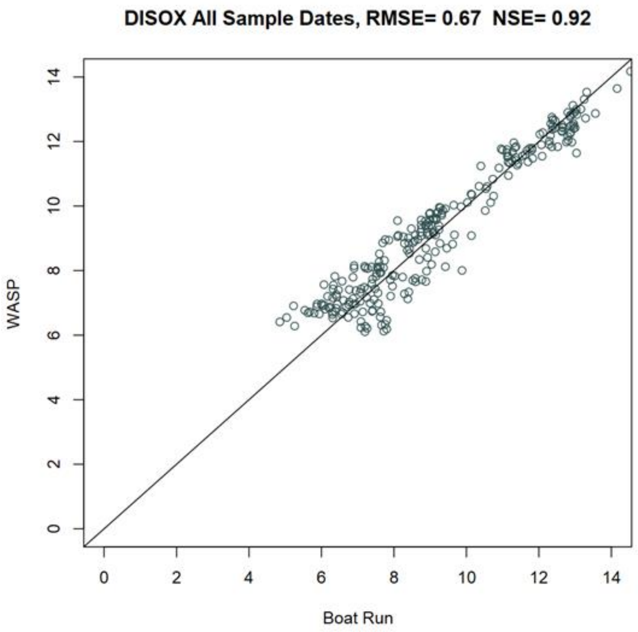




All sample dates – 2019 only





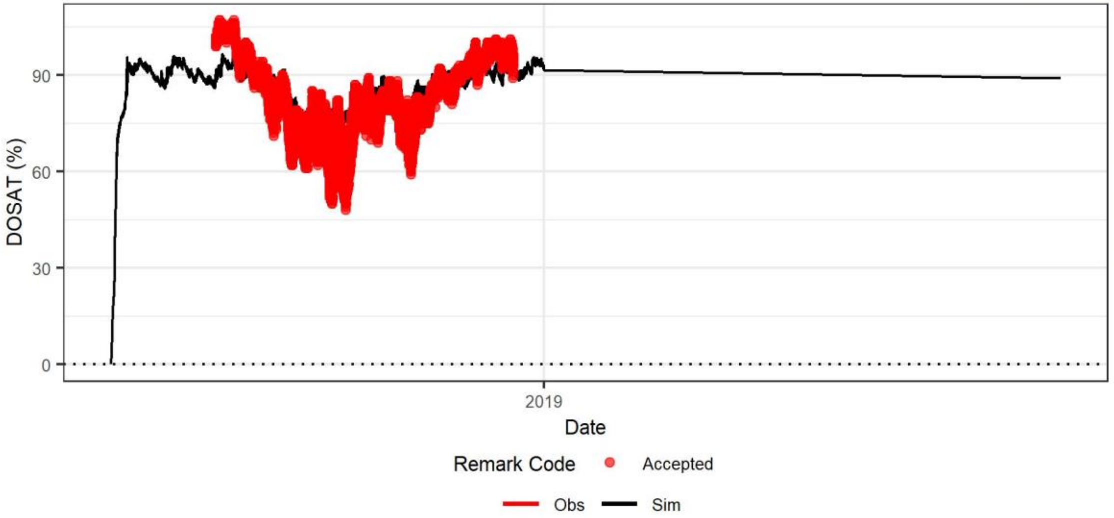


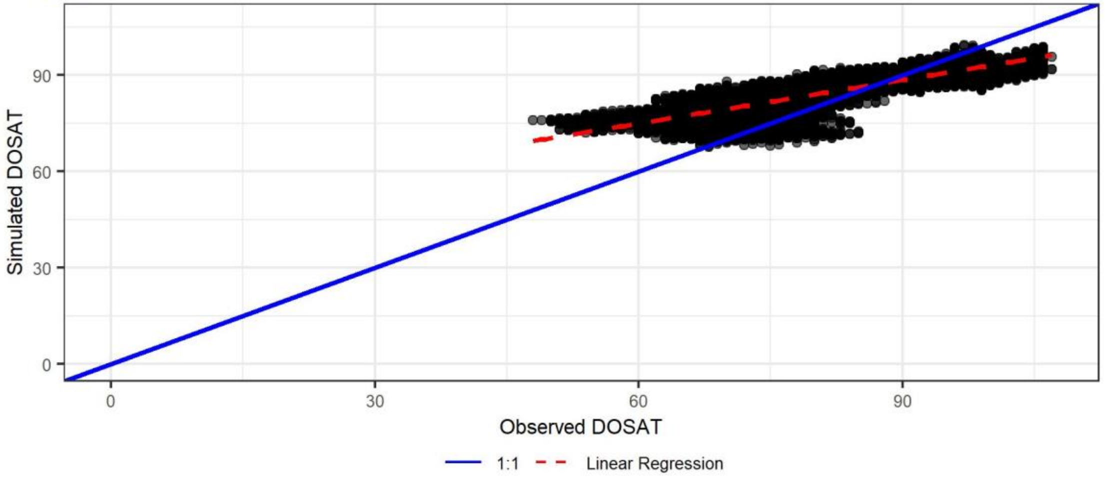
RUNID: WASP_G7pt2_2D_2020-10-15_6_10s_60x_YR2019

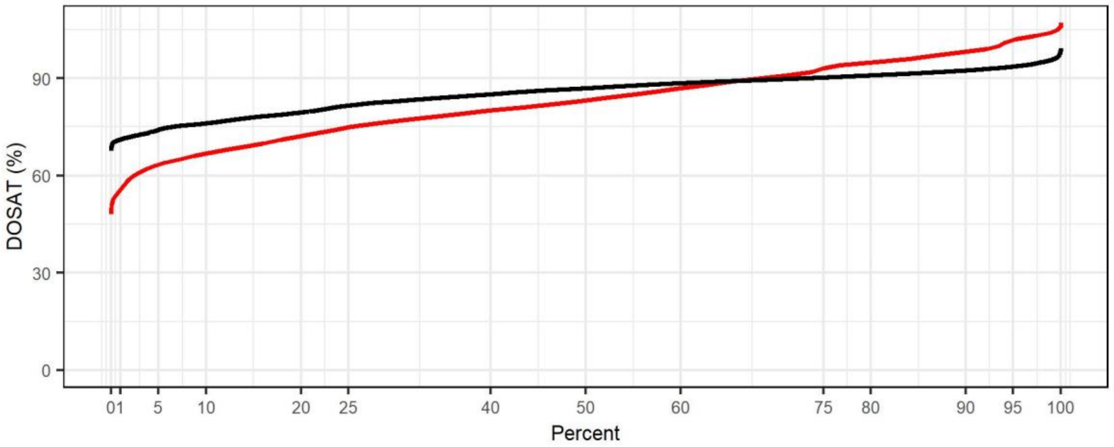
Multi-panel Calibration Figure USEPA tools

USGS Station at Ben Franklin

Parameter: DOSAT







Dataset	Average	10%	20%	50%	80%	90%
OBS	83.590	67.00	73.00	84.00	95.00	99.00
SIM	85.587	76.13	79.47	86.95	90.91	92.42

GoF Metric	Value
Num Obs	23978.0000
R2	0.7630
NSE	0.6075
RMSE	7.3877
NRMSE %	12.5000
d	0.8247

(Calib Station: 1467200; WASP Seg: 1274)

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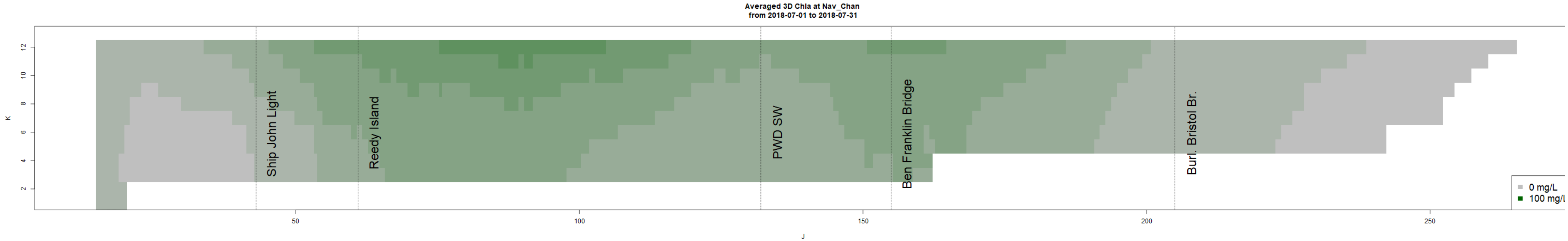
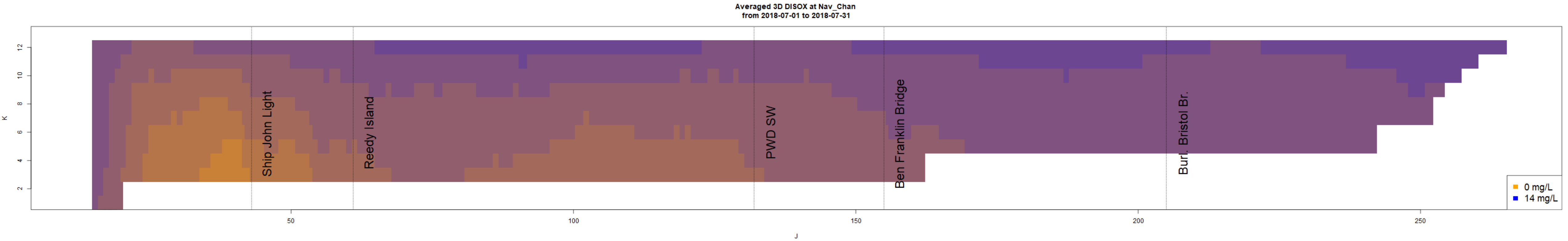
Other Profile Plots DRBC Tools





Heat maps for average a) chlorophyll-a and b) dissolved oxygen along the navigation channel, July 2018.

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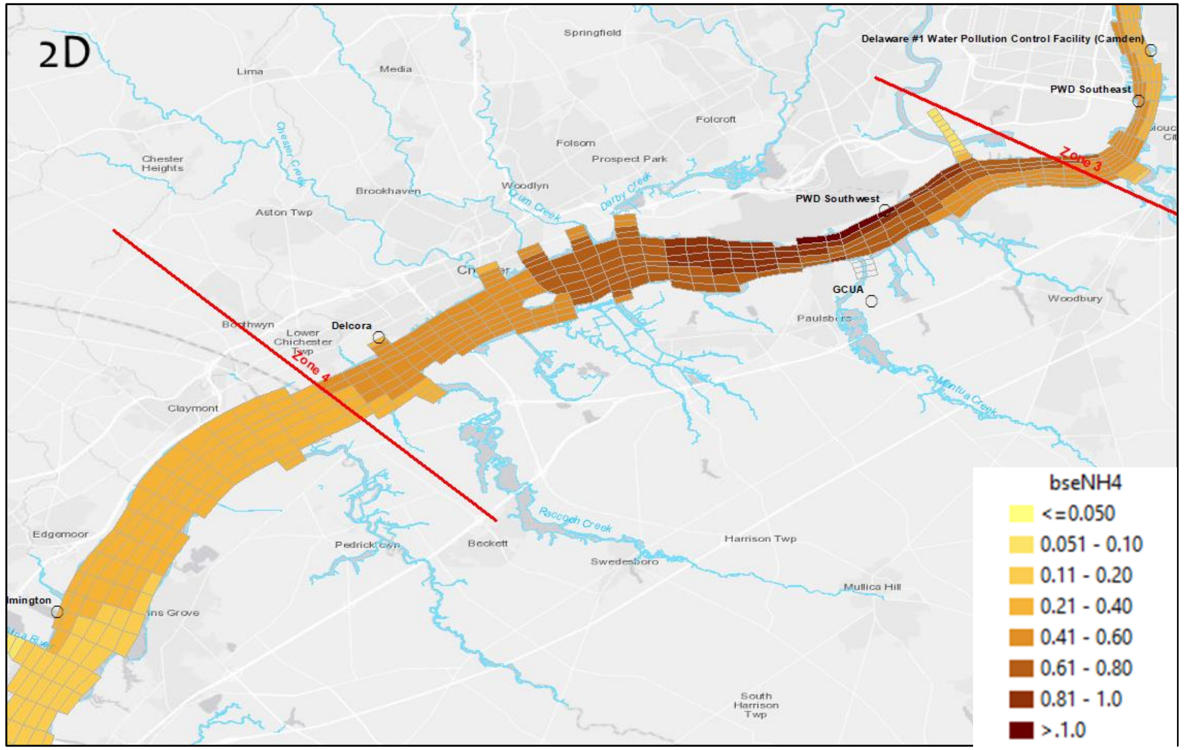
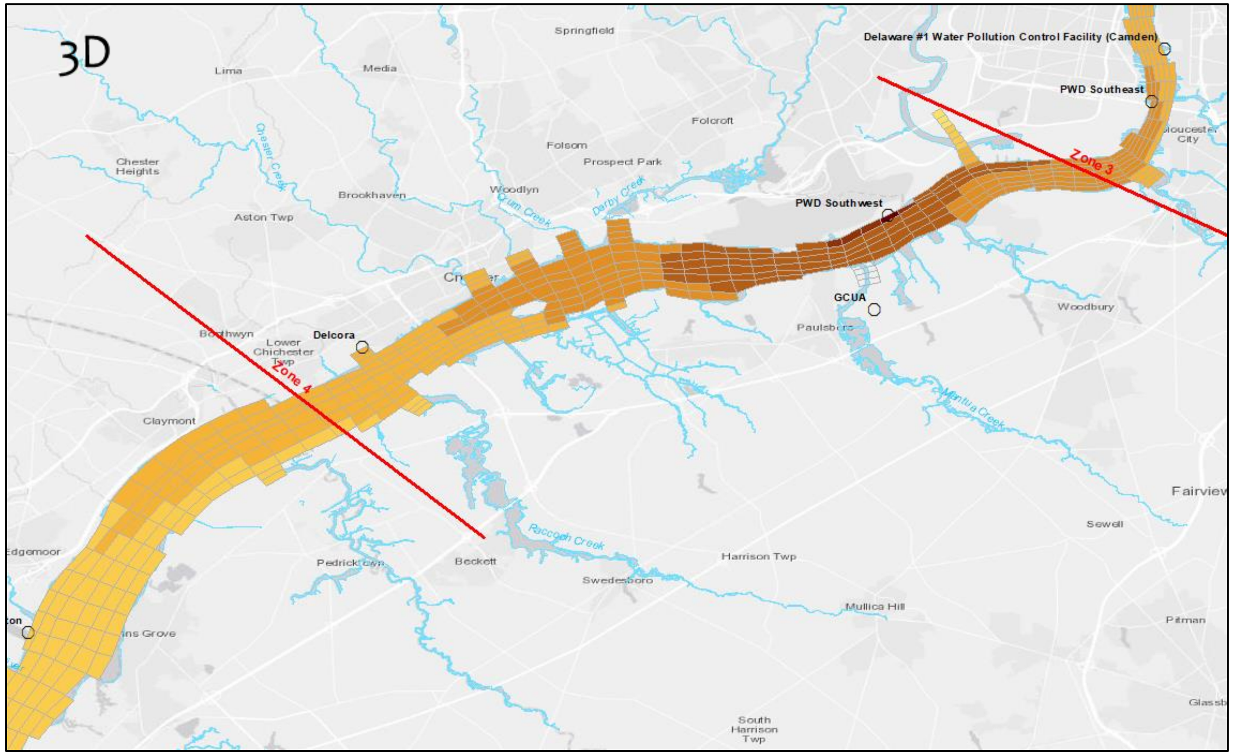
NH34 – Zn 4

2D & 3D Baseline





Comparison of simulated dissolved ammonia between 2D & 3D model versions.
(Period of 9/7 – 10/7/2019)

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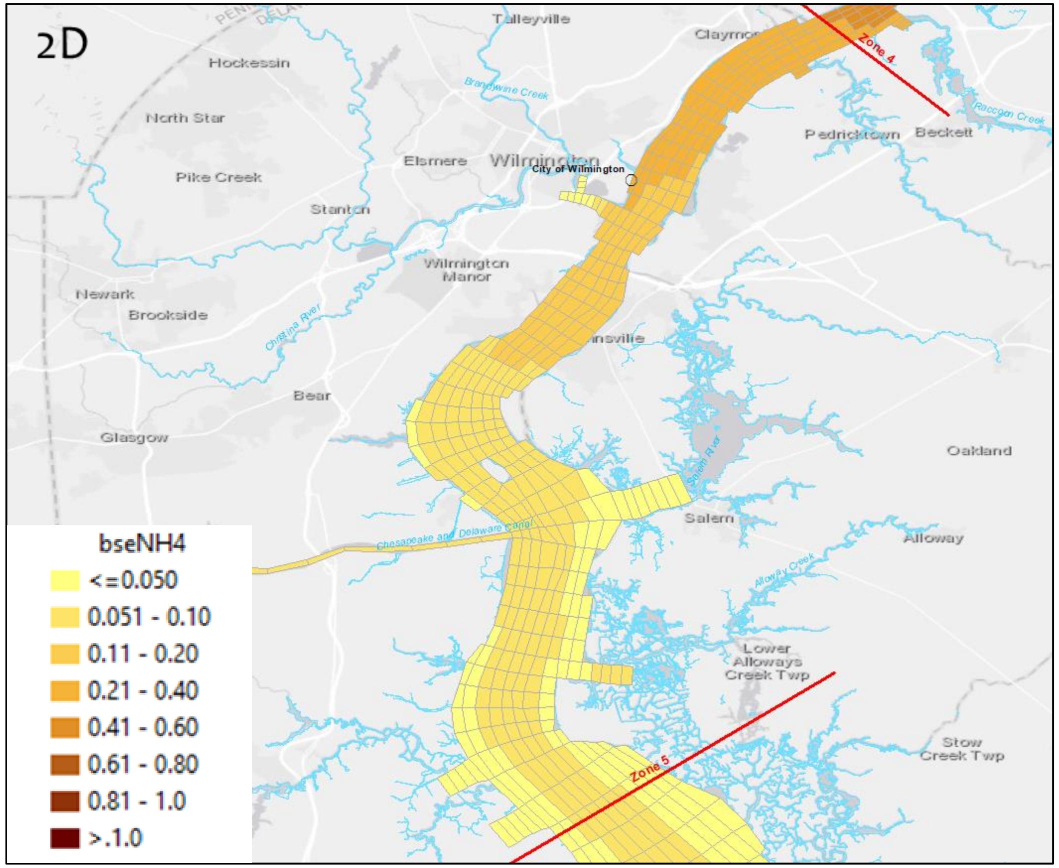
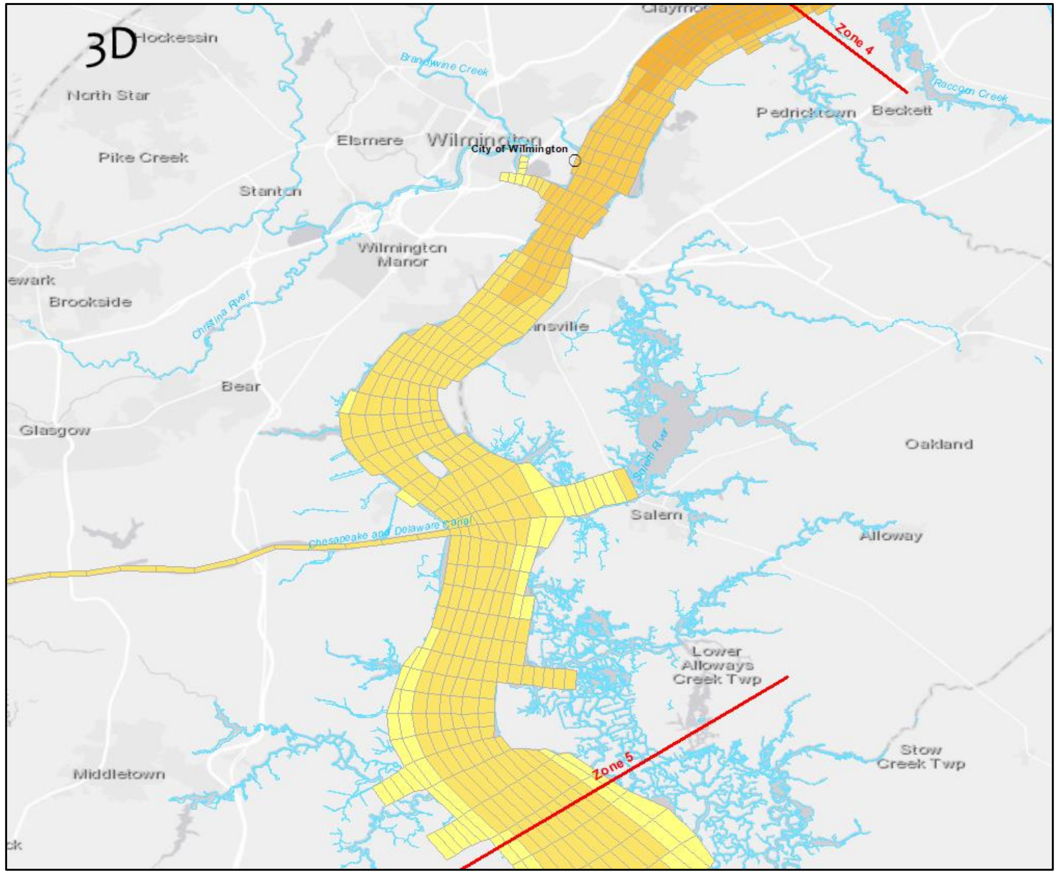
NH34 – Zn 5

2D & 3D Baseline





Comparison of simulated dissolved ammonia between 2D & 3D model versions.
(Period of 9/7 – 10/7/2019)

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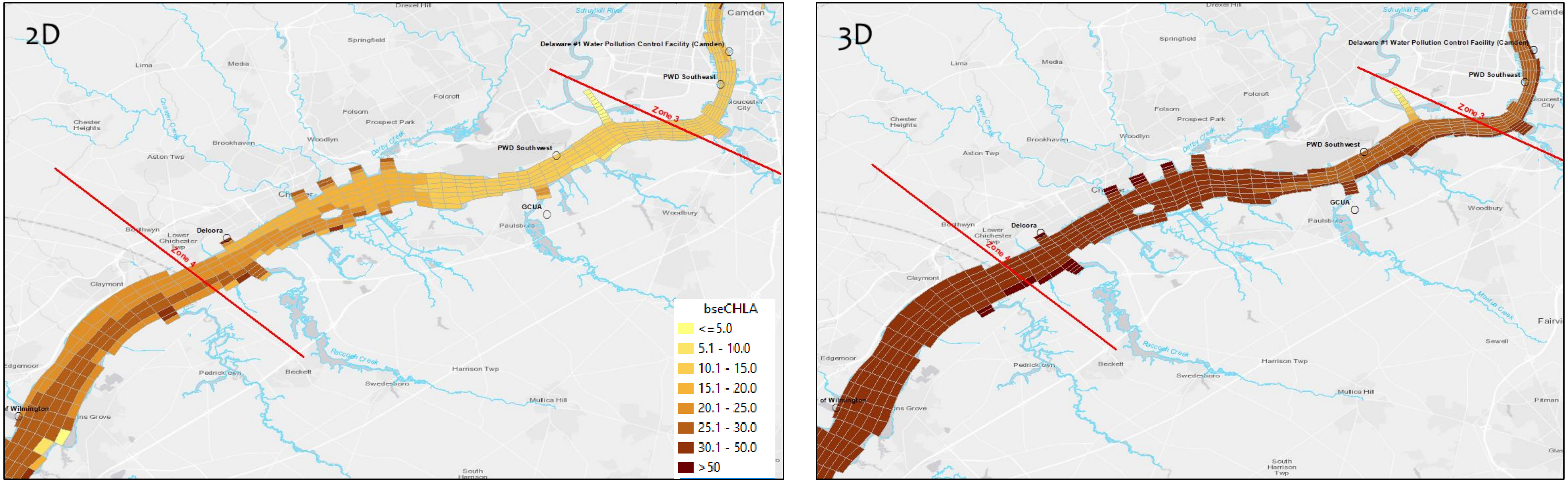
Chlorophyll a

2D & 3D Baseline



Comparison of simulated chlorophyll a between 2D & 3D model versions.
(WQ zone 4; Period of 9/7 – 10/7/2019)

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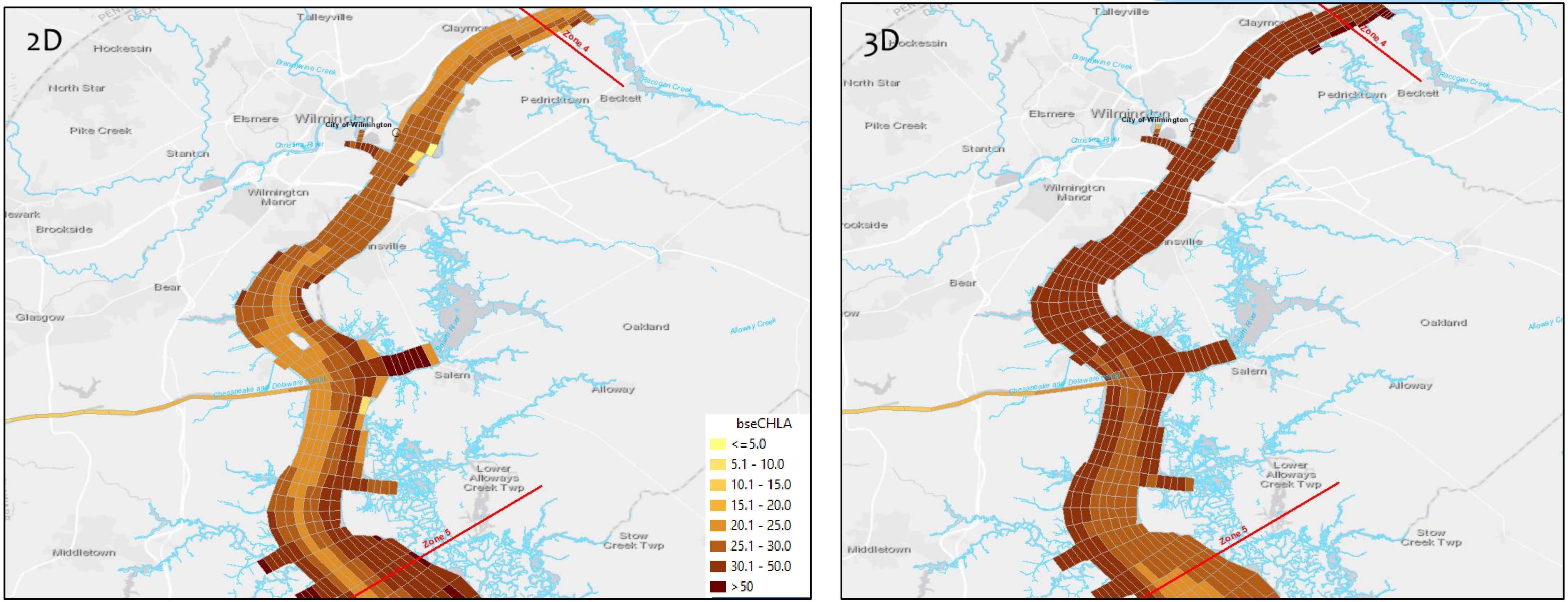
Chlorophyll a

2D & 3D Baseline



Comparison of simulated chlorophyll a between 2D & 3D model versions.
(WQ zone 5; Period of 9/7 – 10/7/2019)

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Path Forward

- Activate sediment diagenesis submodel in WASP
  - Current simulations use externally-specified SOD
- Continue efforts to reduce model simulation times
  - Vertical grid resolution
  - EFDC-WASP linkage optimization
- Finalize calibration of EFDC-WASP model
- Explore baseline (design) conditions and future scenarios

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