Assessing 2035 Climate Change Risks to TMDL in the Rappahannock River using SCHISM

(co-)PIs: Qubin Qin, Jian Shen, Zhengui Wang, and Pierre St-Laurent

Advisory team: Joseph Zhang and Marjorie Friedrichs

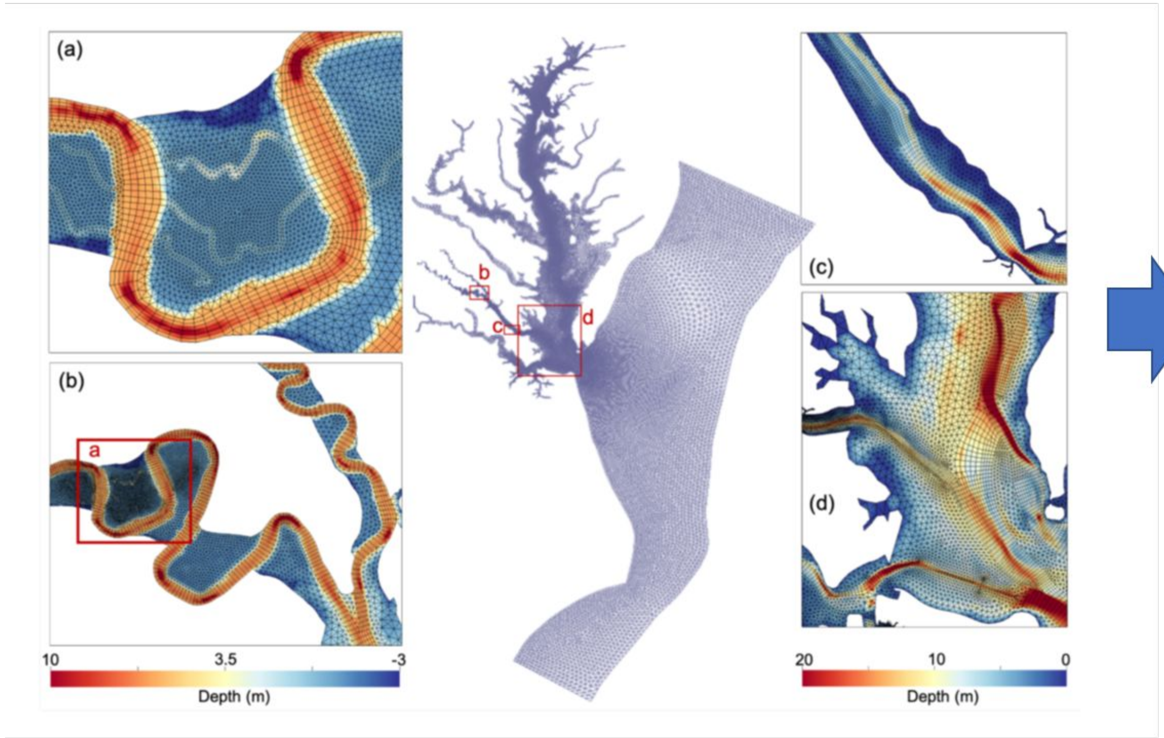
Objectives and tasks

- **Goal**: to develop and calibrate a high-resolution hydrodynamic-water quality model for the Rappahannock River, which will enable us to investigate and assess the water quality of the river.
- Specifically, we aim to use the model to forecast the potential risks to TMDL due to climate change by the year 2035.

- Task 1: revise the current MBM grid of the Rappahannock River and increase the resolution in accordance with Modeling Workgroup's recommendations and important dynamic properties of the river to ensure sufficient spatial coverage and resolution to represent the true geometry and bathymetry of the river.
- Task 2: work with the MBM team to transfer of the latest version of the SCHISM-ICM model code and the open boundary conditions generated by the MBM. We will setup the model and test the tributary model. We will also provide feedback to MBM for any issues and required changes in tools used for model setup.
- Task 3: work closely with watershed, airshed, hydrological modeling groups to ensure proper execution of coupling, scaling, and interface mechanisms, as well as incorporating information on climate change and model biochemical parameters for the water quality model.
- Task 4: conduct full calibration and verification of hydrodynamic and water quality model.
- Task 5: understand the physical-biogeochemical processes in the Rappahannock River and conduct management and climate change scenarios.
- Task 6: document the findings and recommendations in the final report.
- Task 7: transfer of the software package to CBPO for operational testing. During this phase, we will collaborate with CBPO personnel to conduct tests on the model package in operational environments and address any issues that may arise.
- Task 8: disseminate our research findings and experiences via 1-2 journal papers each year.

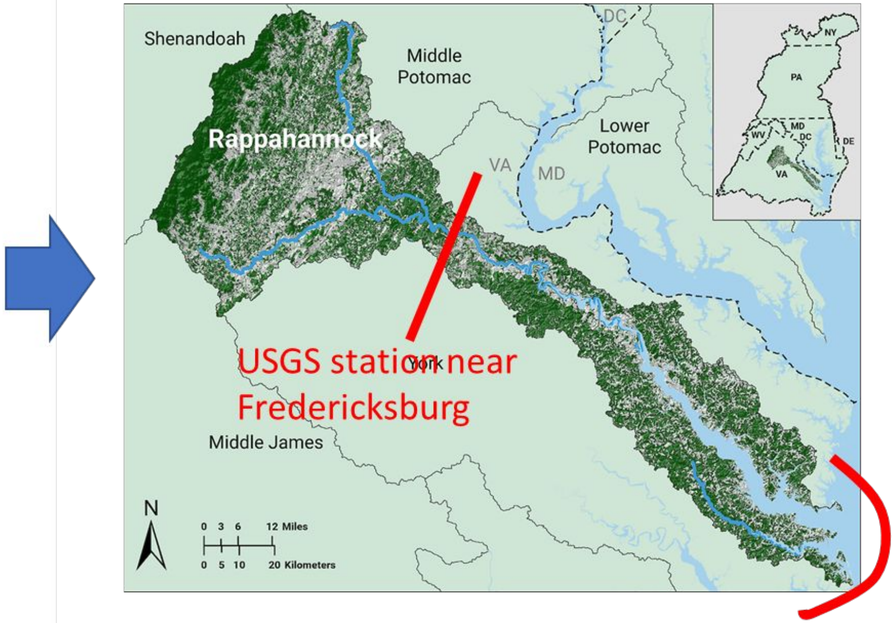
- Task 1: revise the current MBM grid of the Rappahannock River and increase the resolution in accordance with Modeling Workgroup's recommendations and important dynamic properties of the river to ensure sufficient spatial coverage and resolution to represent the true geometry and bathymetry of the river.

Chesapeake Bay Model



Cai et al. 2022

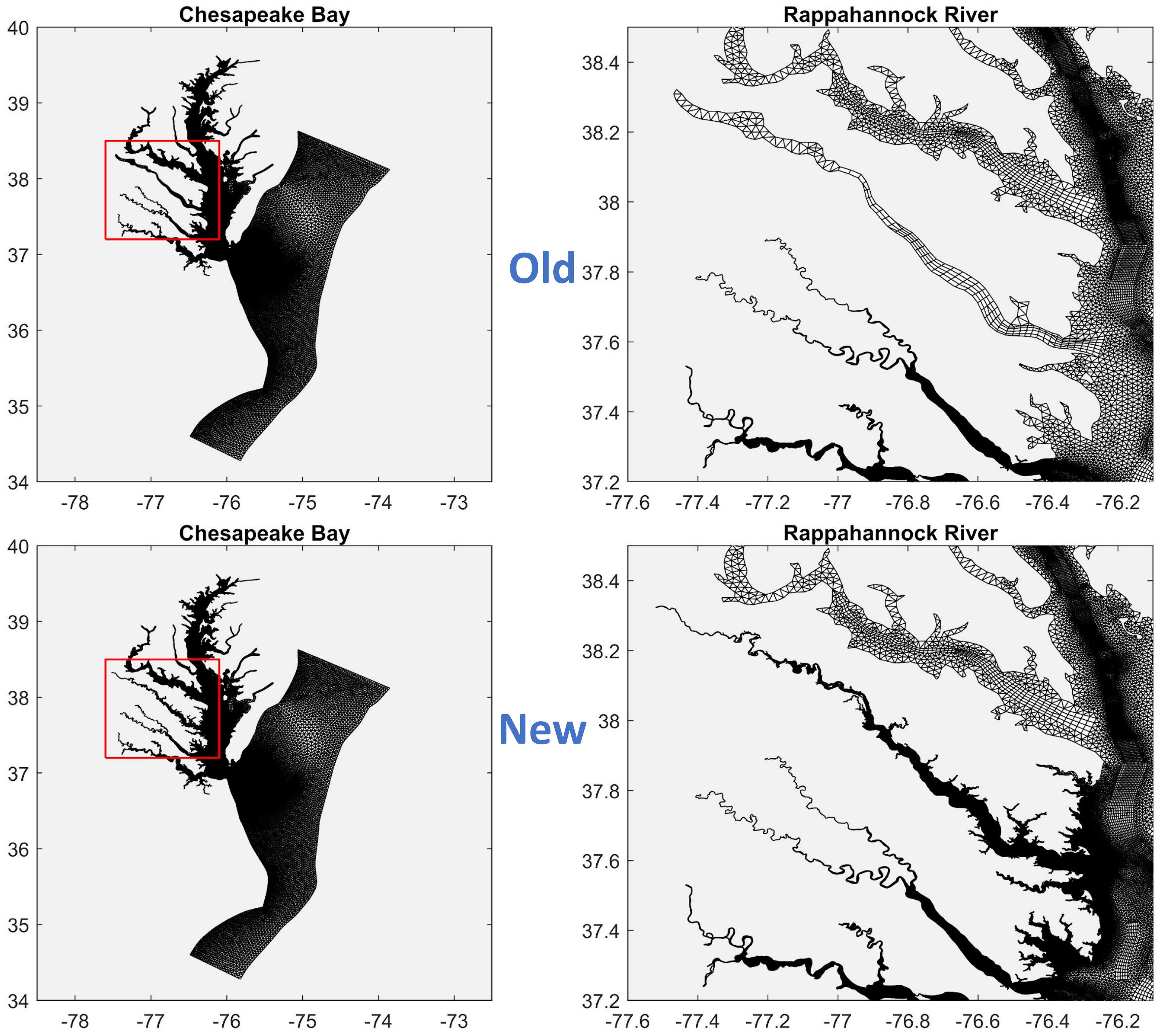
Rapp. River Model



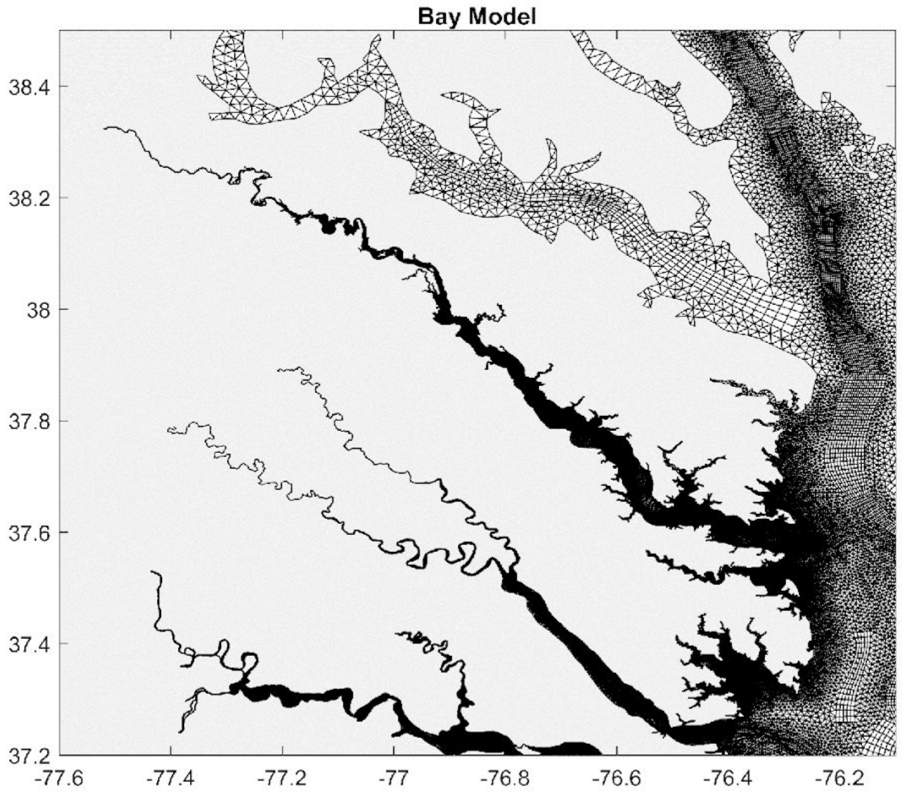
https://ecoreportcard.org/report-cards/chesapeake-bay/watershed-regions/rappahannock/

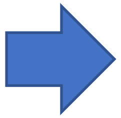
First, refine the Rappahannock River in the Bay model

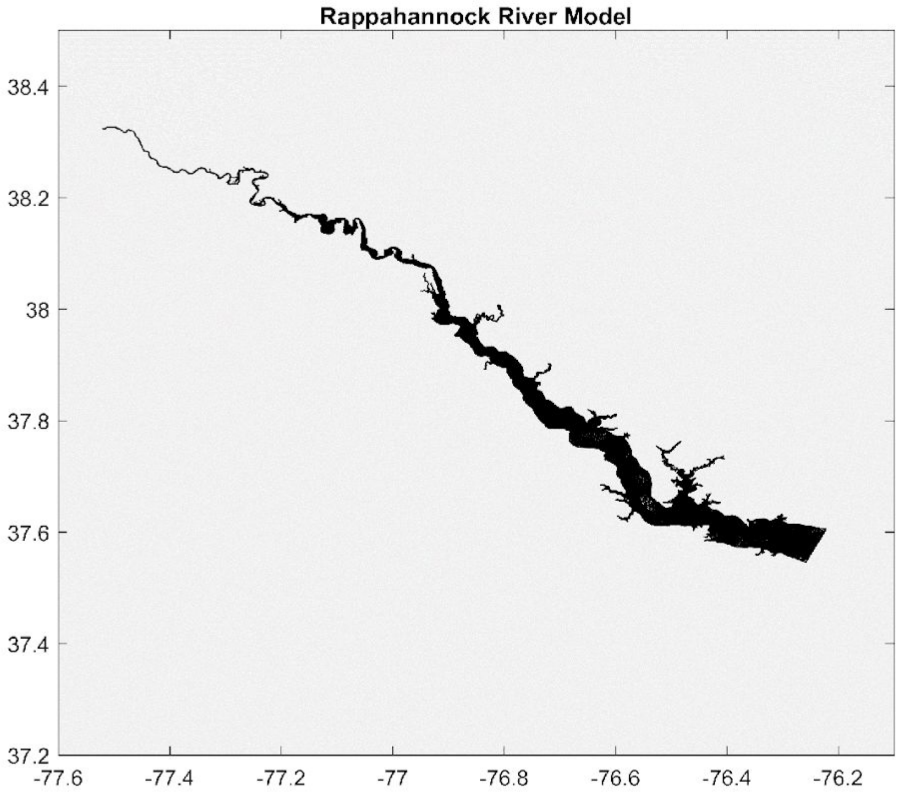
Run and calibration



Second, cut out the Rappahannock River and use the large bay model to provide the boundary conditions



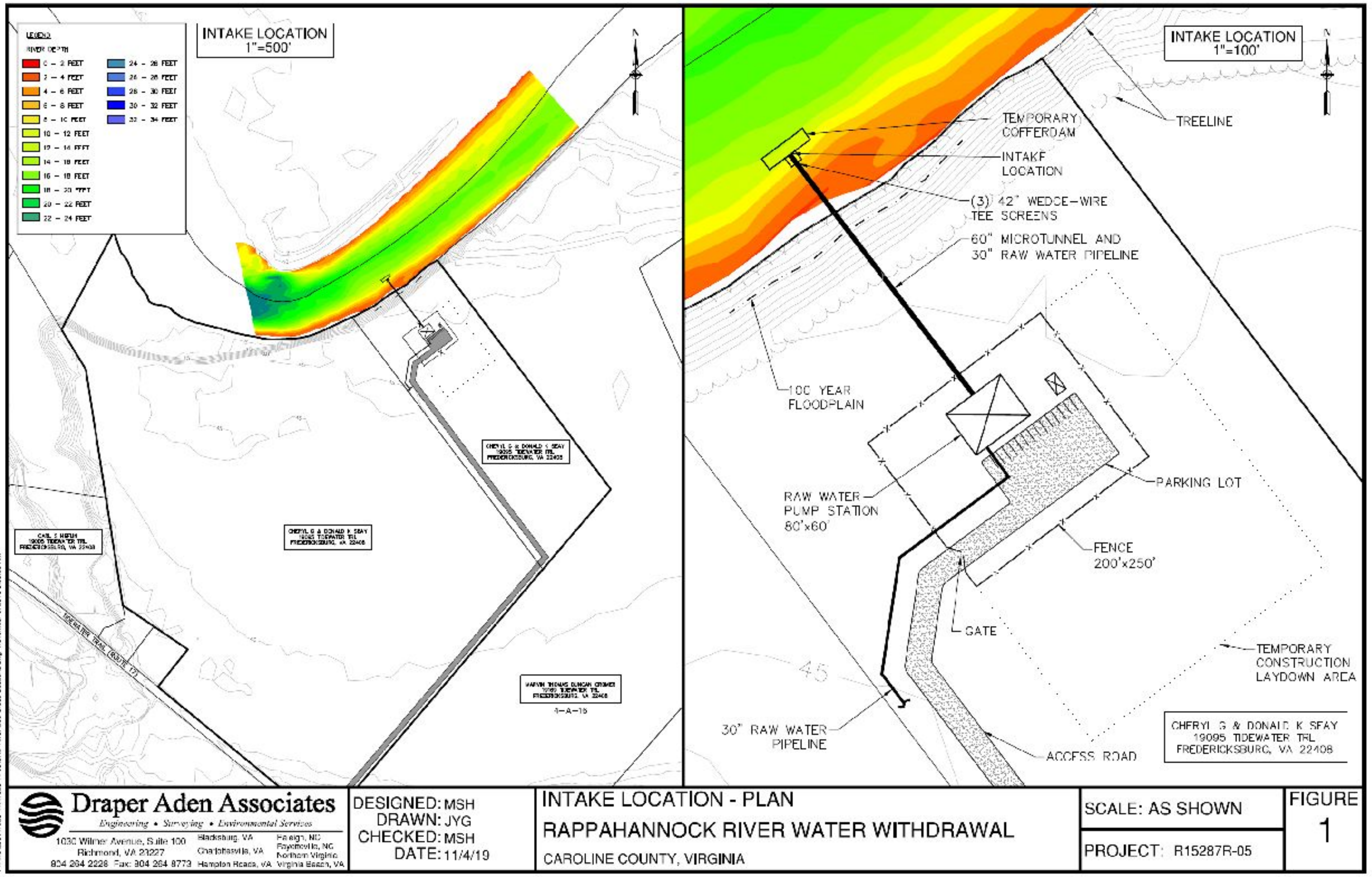


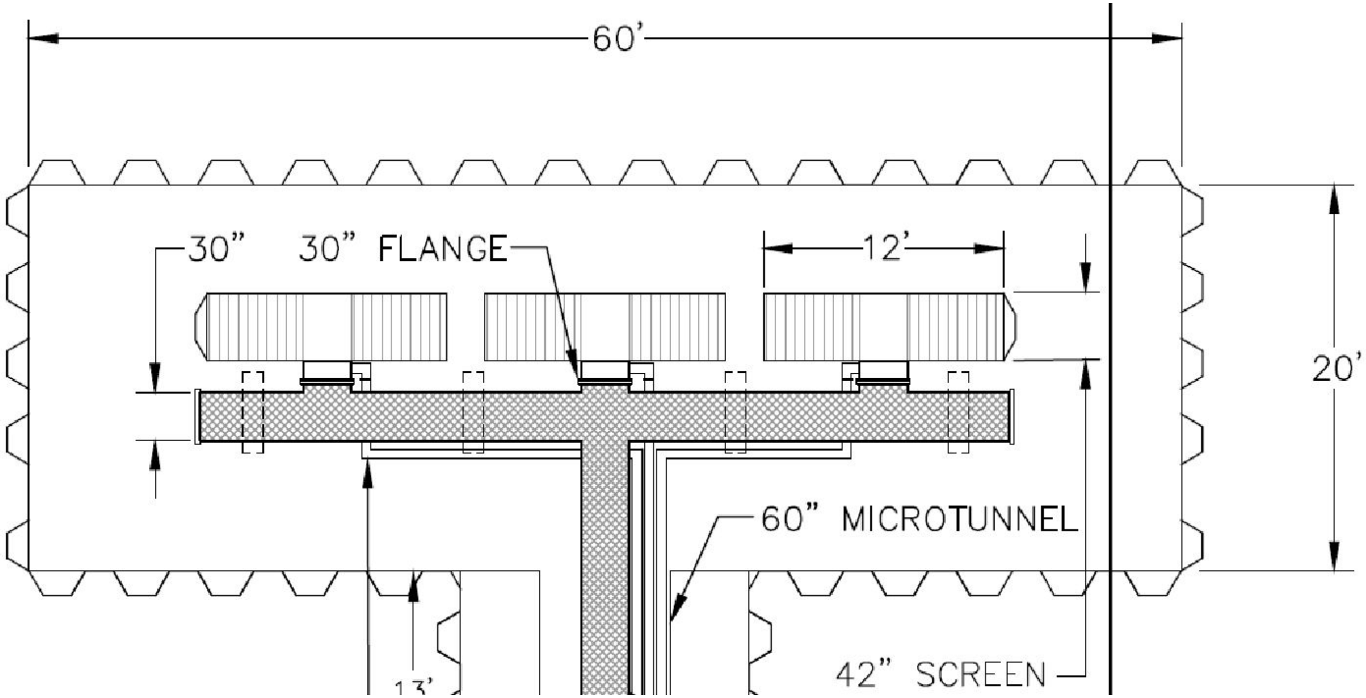


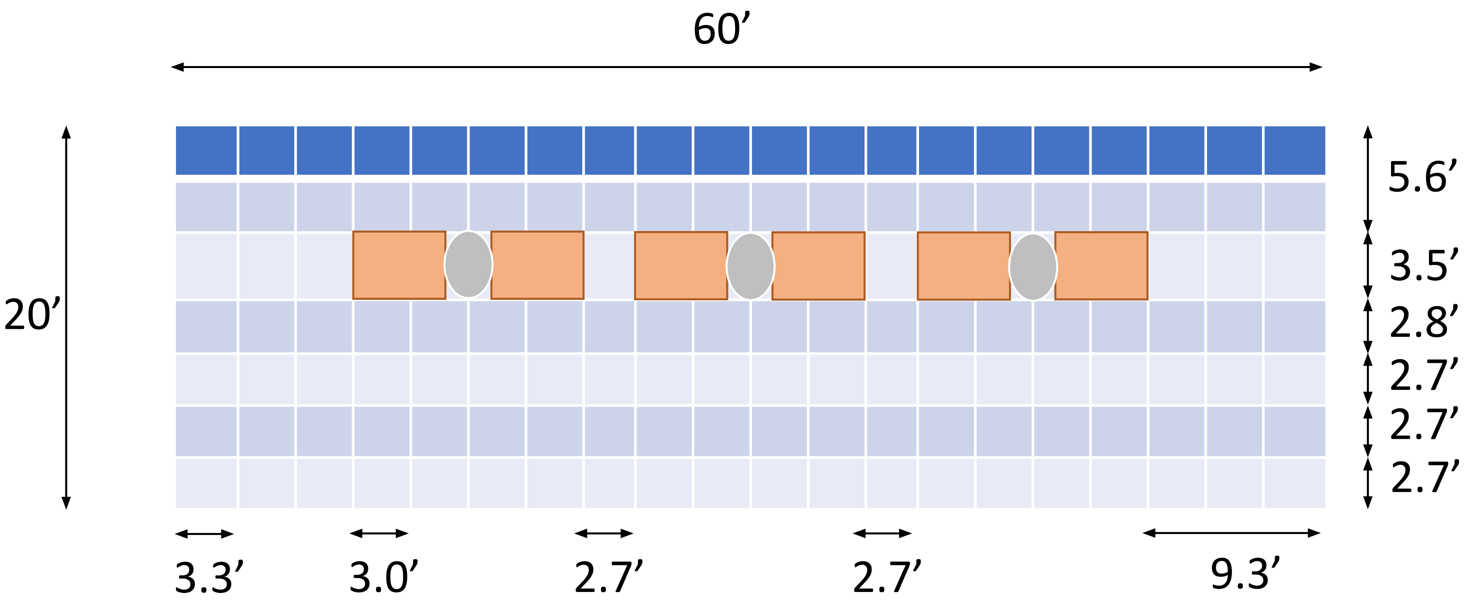
Apply a Particle Tracking Model to Analyze Impacts of Water Intake on Ichthyoplankton Mortality in Tidal Freshwater Region of the Rappahannock River

Qubin Qin, Jian Shen, and Troy D. Tuckey

model refined near the intake area

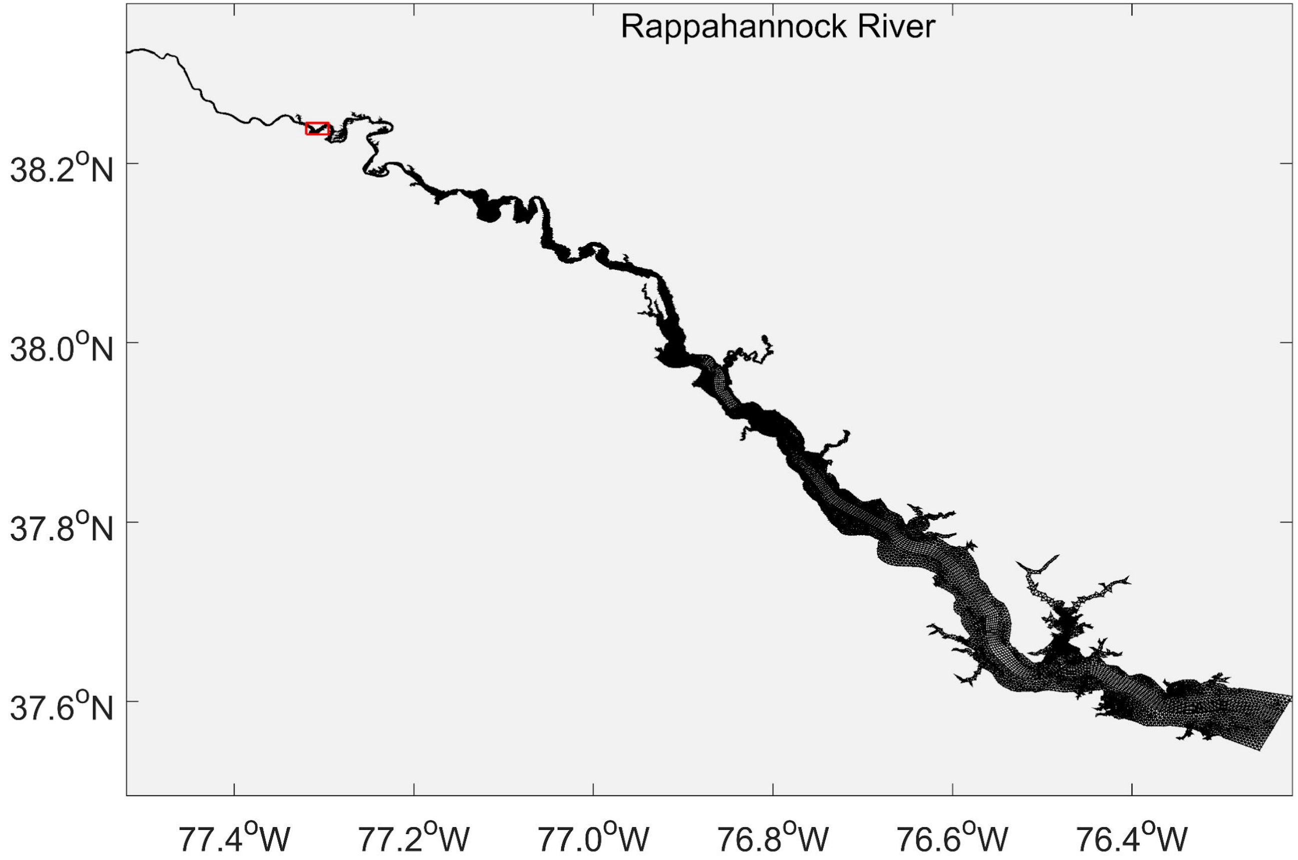


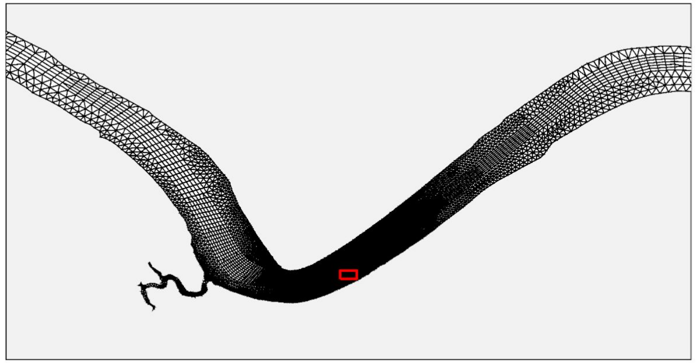


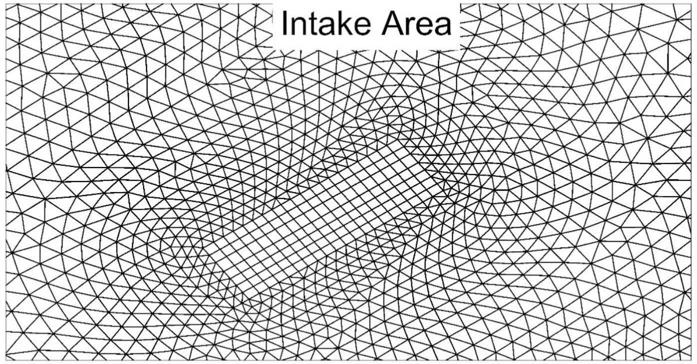


3 intake screens

12 grid elements (= 4*3)







Refined near the intake

Fine resolution: size is as small as 2 feet

Bottom is set to be 12.5 feet MLW

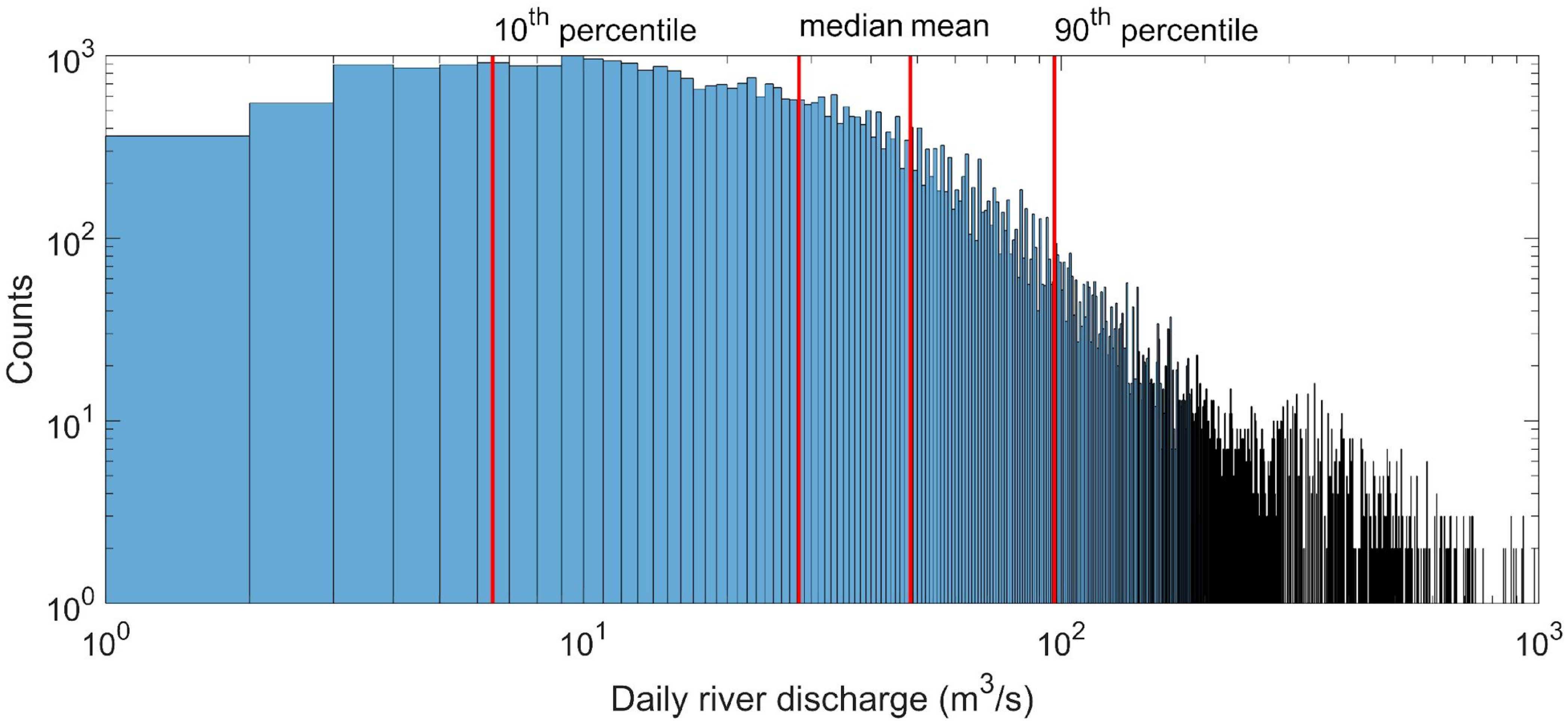
5 vertical layers

Water is withdrawn from the bottom

13.9 mgd

Run hydrodynamic model for a selected year

Statistics of daily river discharge of the Rappahannock River over 1907 to 2022

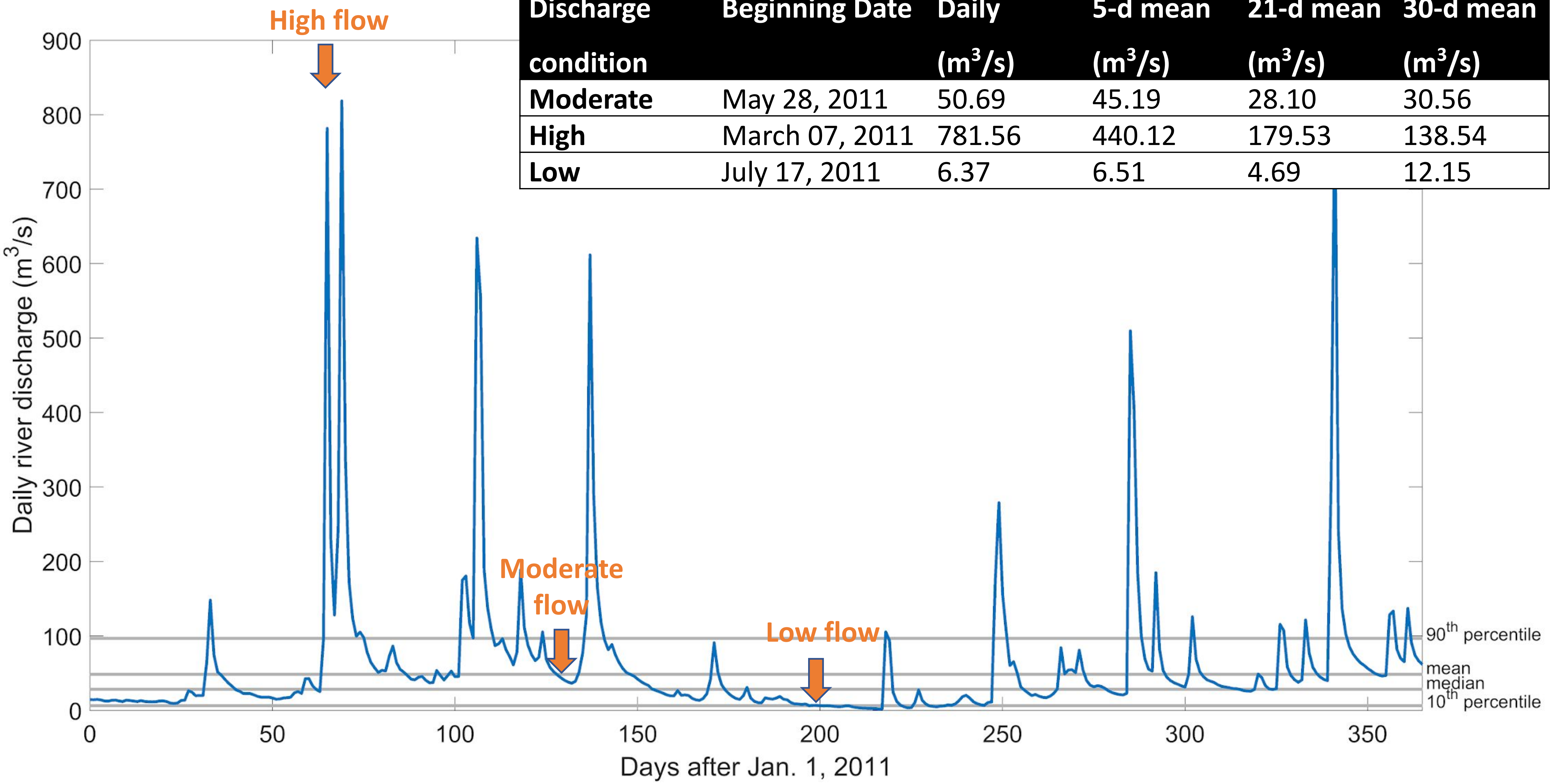


The mean and median flows are 48.3 and 28.3 m^3/s respectively. Moderate condition

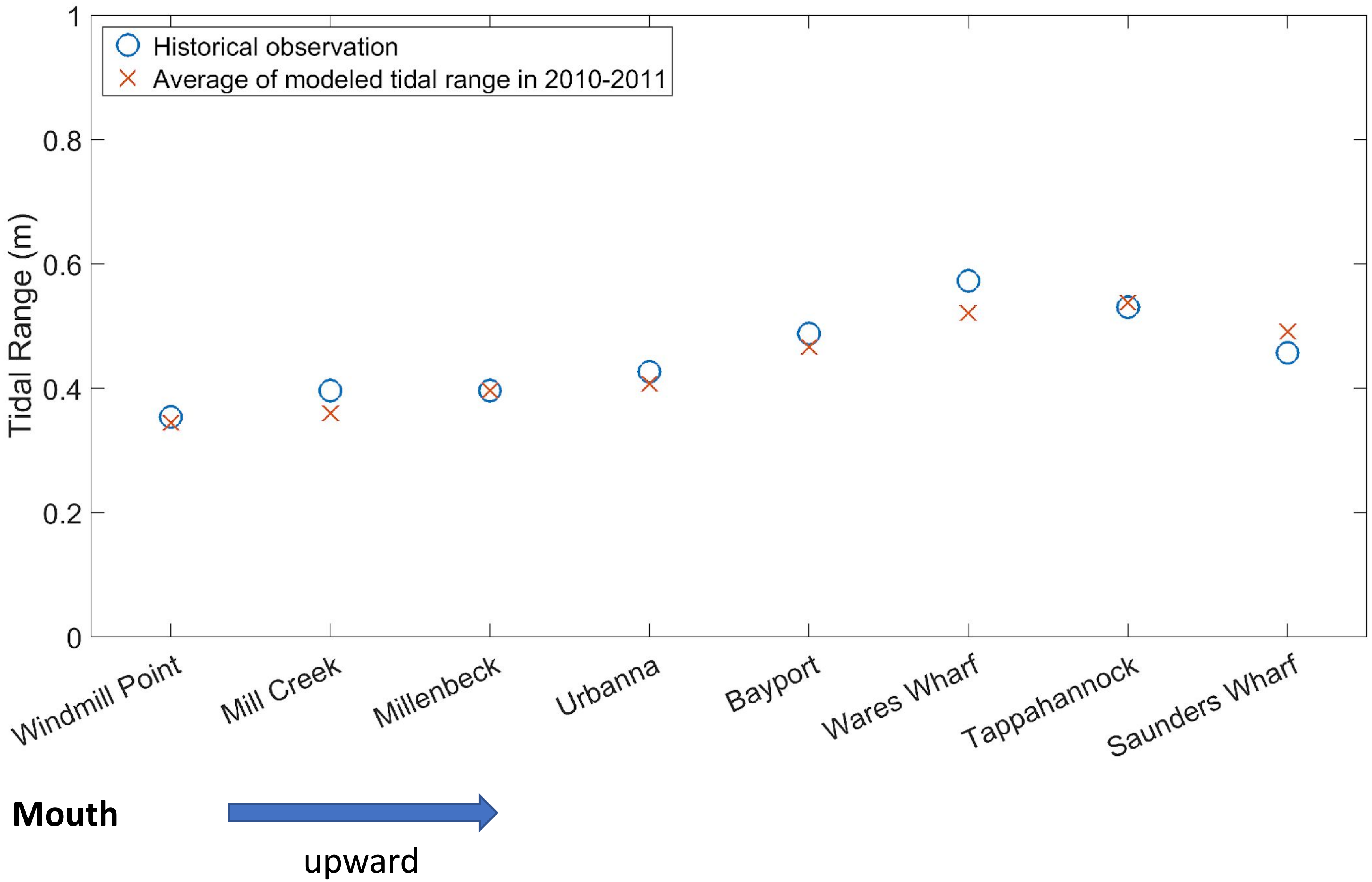
The 10th and 90th percentiles are 6.5 and 96.8 m^3/s, respectively. Low and high condition

Daily river discharge of the Rappahannock River in 2011

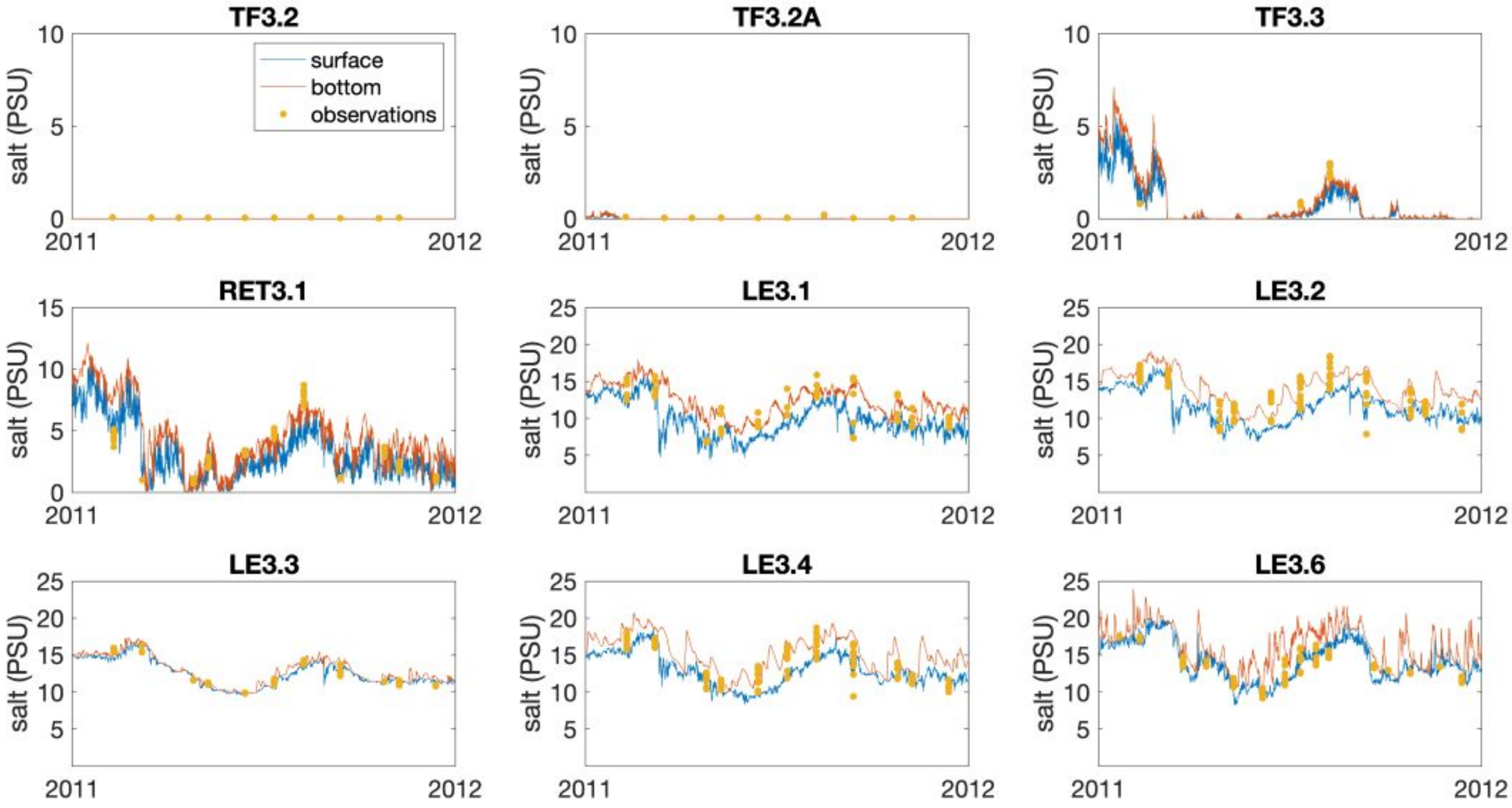
Discharge condition	Beginning Date	Daily (m^3/s)	5-d mean (m^3/s)	21-d mean (m^3/s)	30-d mean (m^3/s)
Moderate	May 28, 2011	50.69	45.19	28.10	30.56
High	March 07, 2011	781.56	440.12	179.53	138.54
Low	July 17, 2011	6.37	6.51	4.69	12.15



Calibration of tidal range along the river



Calibration of salinity along the river for the selected year

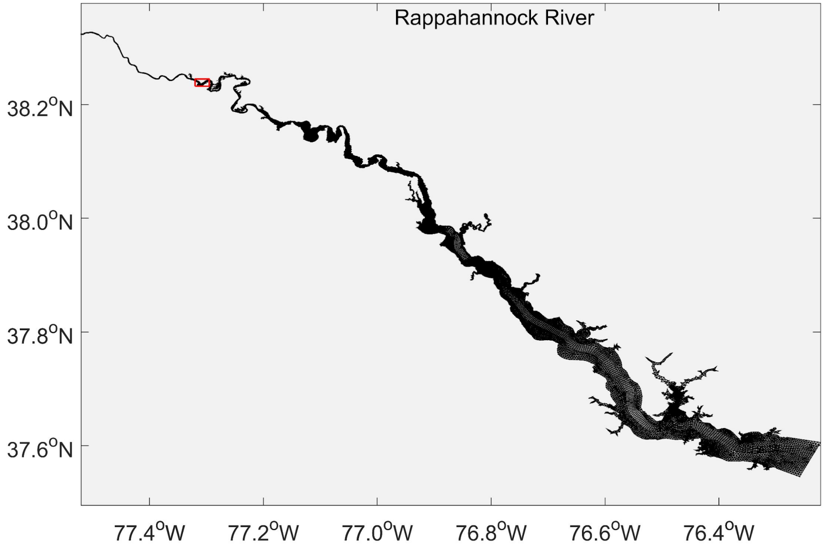


Particle tracking scenarios

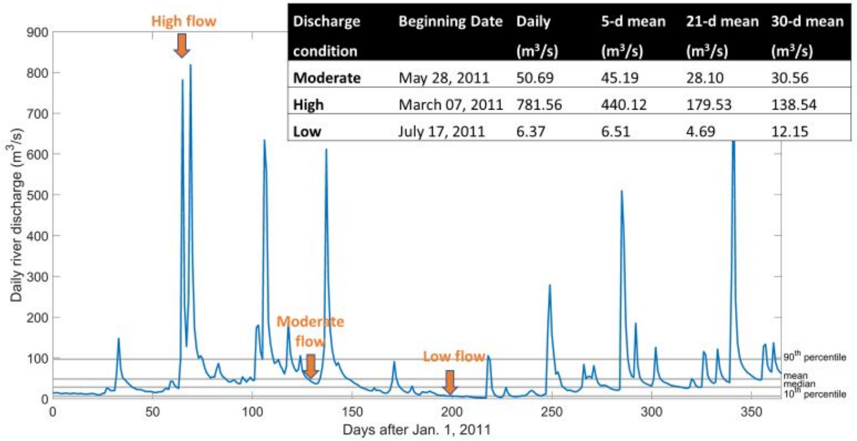
Forward tracking scenarios

- Different locations: near, upstream, downstream the intake
- Different release methods: one-time vs. continuous
- Different flow conditions: moderate, high, low
- Different vertical velocities: passive vs. active

Backward tracking scenario



Daily river discharge of the Rappahannock River in 2011



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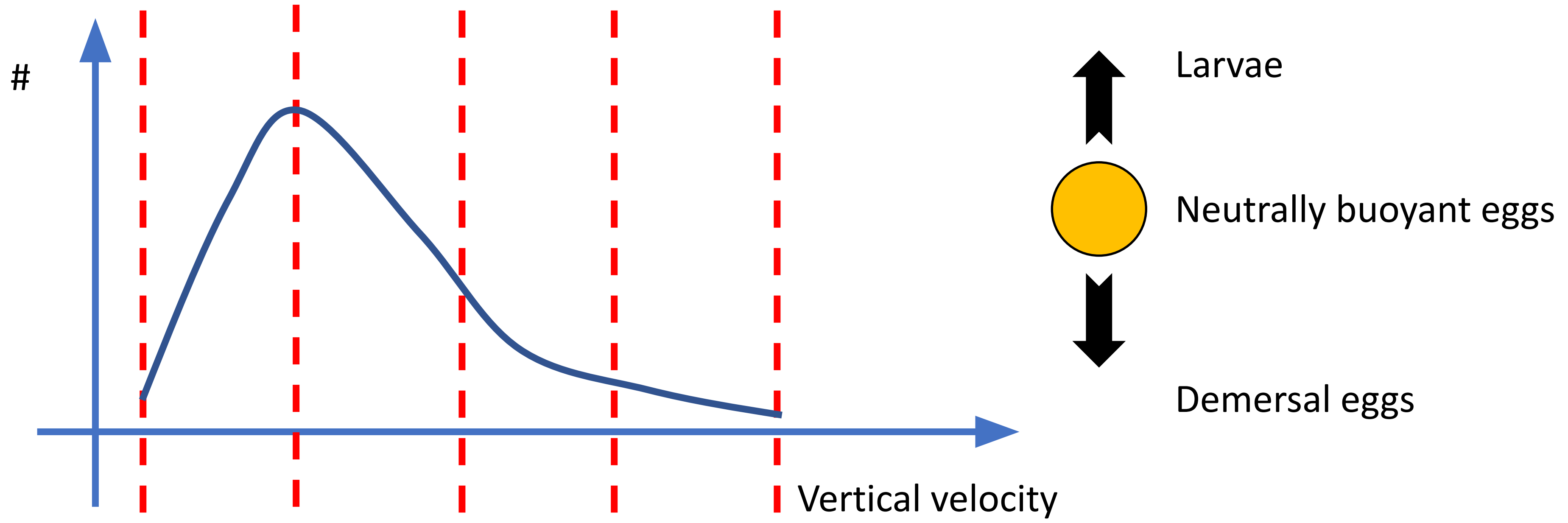
Particle Tracking model

Particles represent fish eggs or larvae

Passive particles: neutrally buoyant fish eggs or larvae

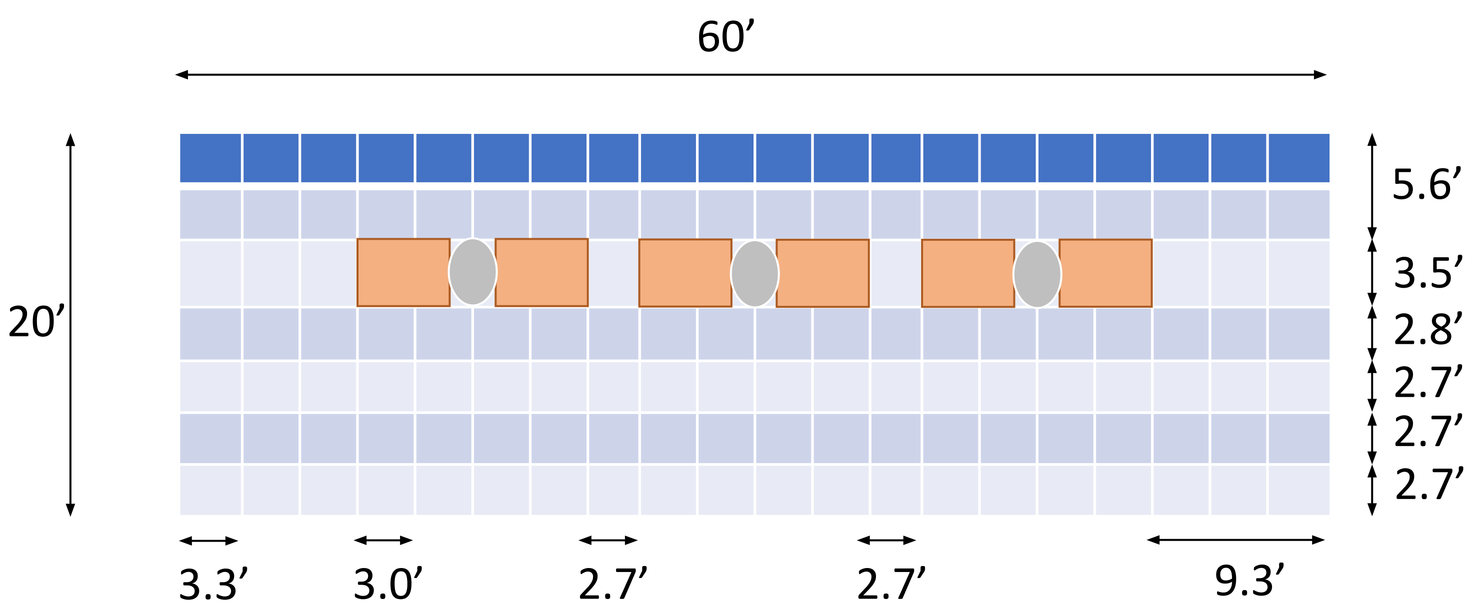
Active particles: demersal eggs or buoyant eggs, or fish larvae that can swim



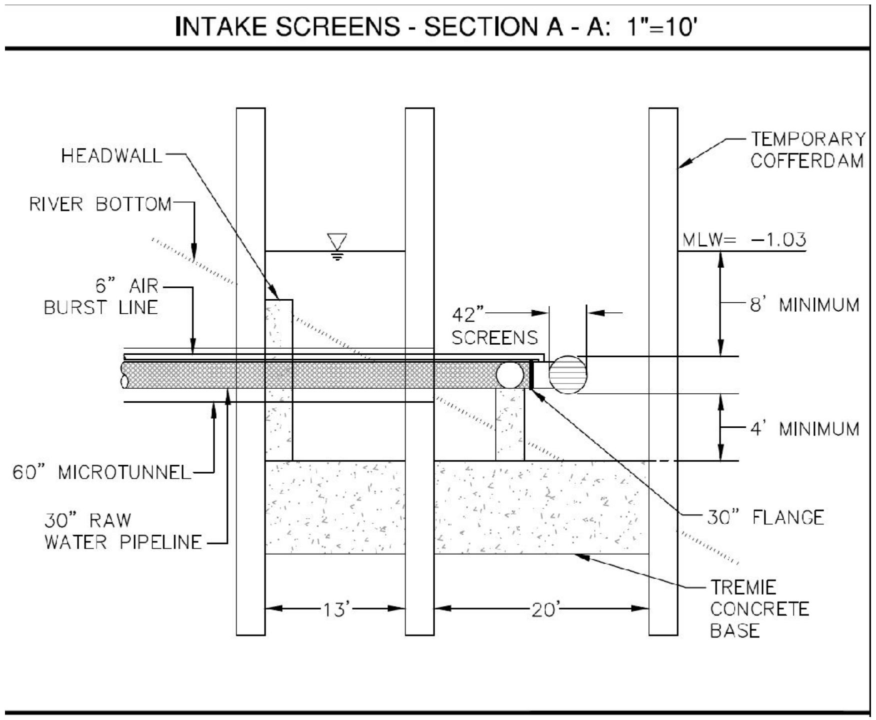
Scenarios for fish ichthyoplankton

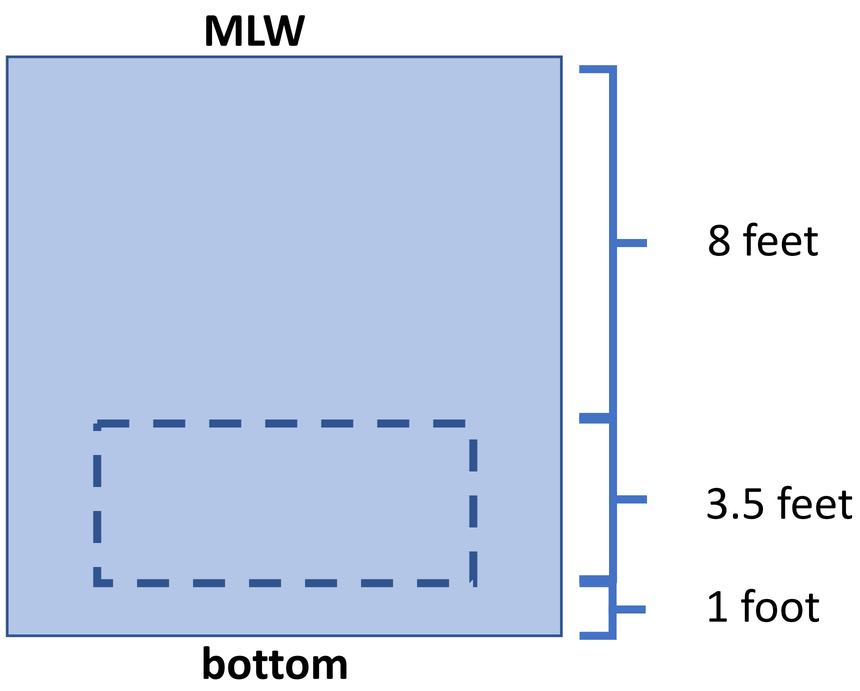
Table. Particles, vertical velocity, and the representatives. Upward (+); downward (-).

Particle	Vertical velocity (cm/s)		Representative
Passive	0		Neutrally buoyant eggs
Active	-1	= -860 m/d	Demersal eggs
Active	-0.3		Demersal eggs
Active	-0.1	= -86 m/d	Demersal eggs
Active	-0.01	= -8.6 m/d	Demersal eggs
Active	-0.001	= -0.86 m/d	Demersal eggs
Active	1		Larvae
Active	10		Larvae



Particles are removed when they enter the area of the intake screens





Particle tracking scenarios

Forward tracking scenarios

- Different locations: near, upstream, downstream the intake
- Different release methods: one-time vs. continuous
- Different flow conditions: moderate, high, low
- Different vertical velocities: passive vs. active

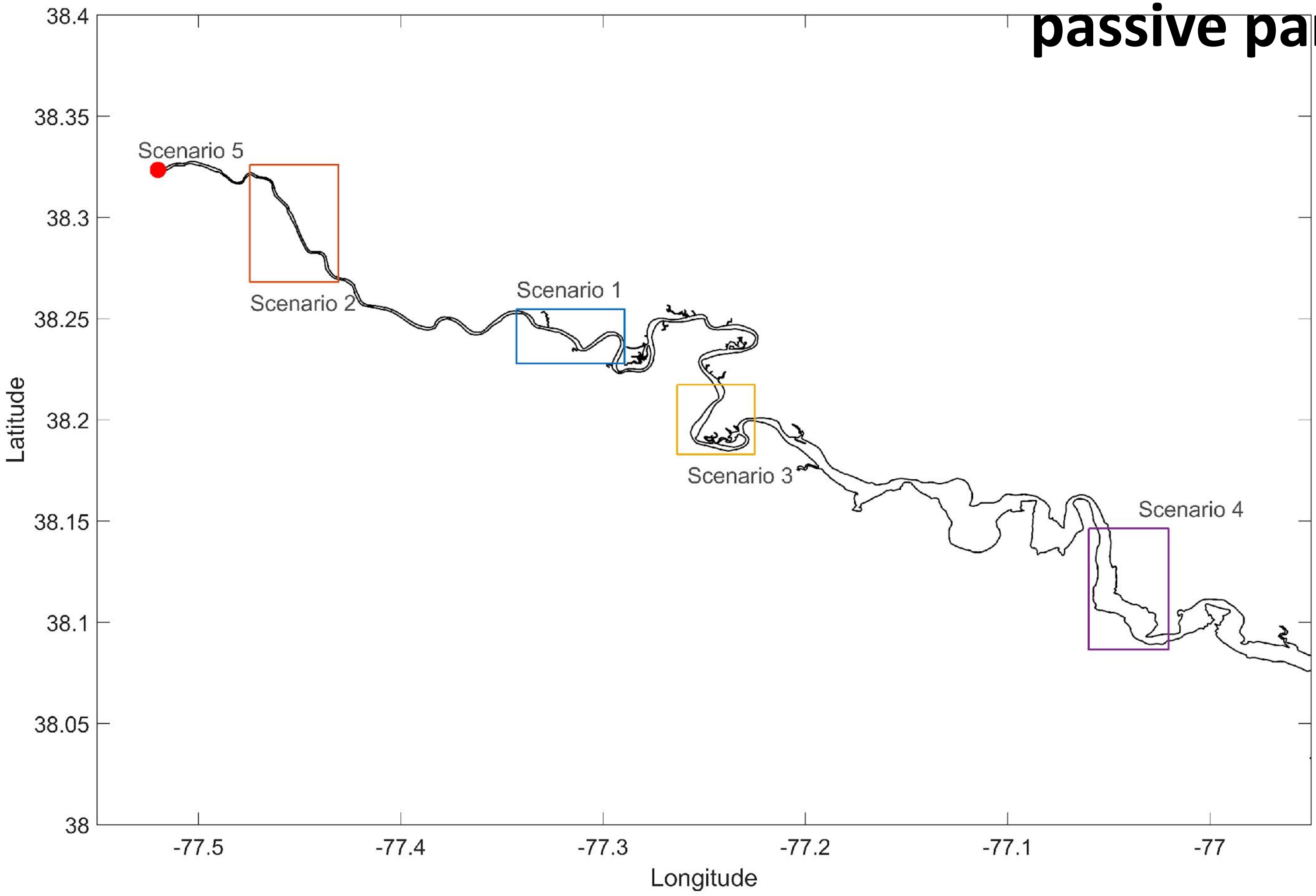
Backward tracking scenario

Scenarios 1-5: location and release methods

Release locations and methods

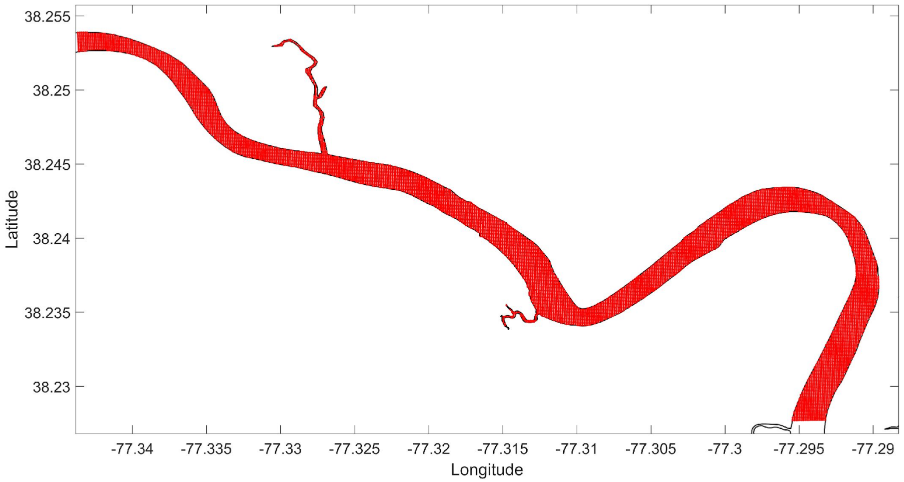
Scenarios 1-5:

passive particles, moderate flow condition



One-time release

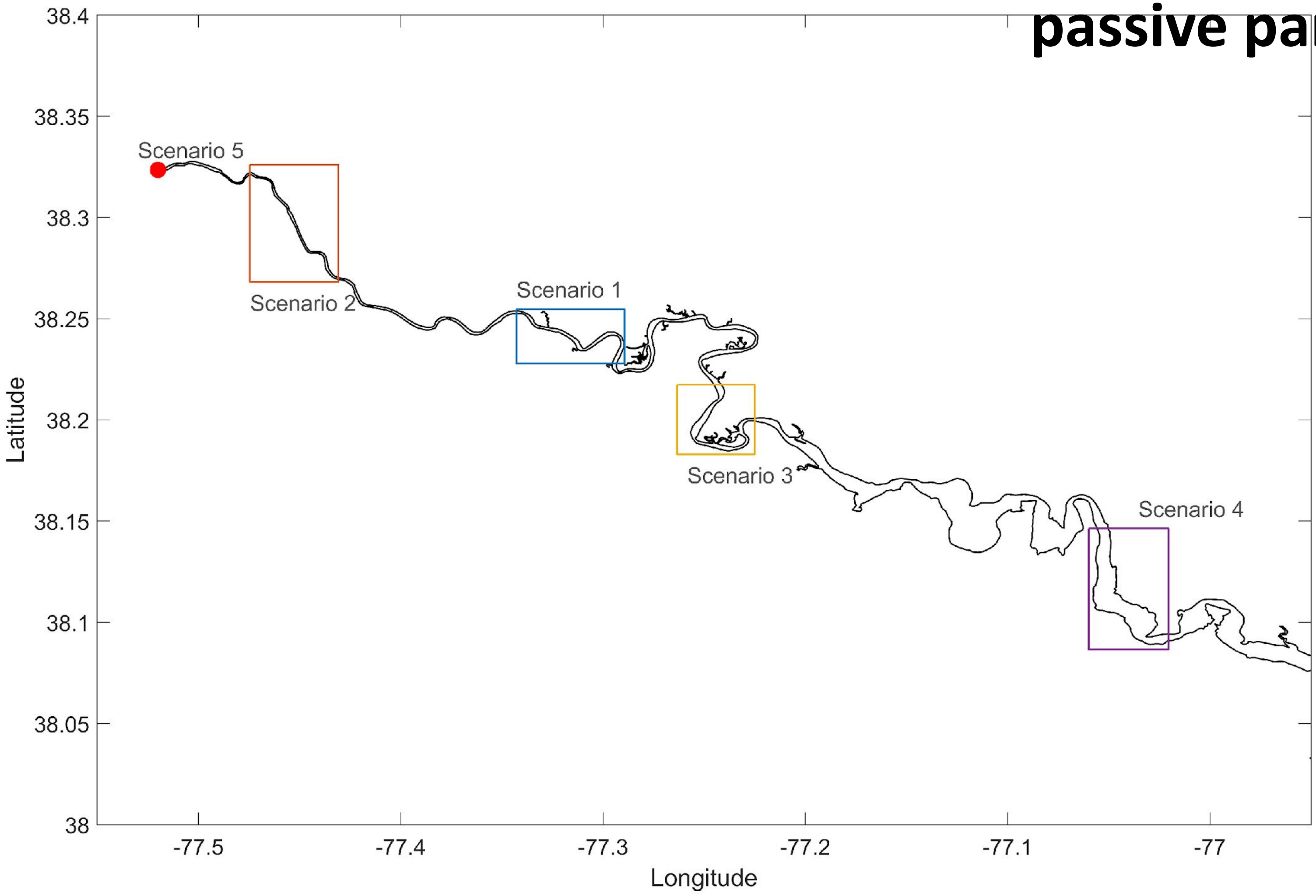
Scenario 1 (particle # = 10,190)



Release locations and methods

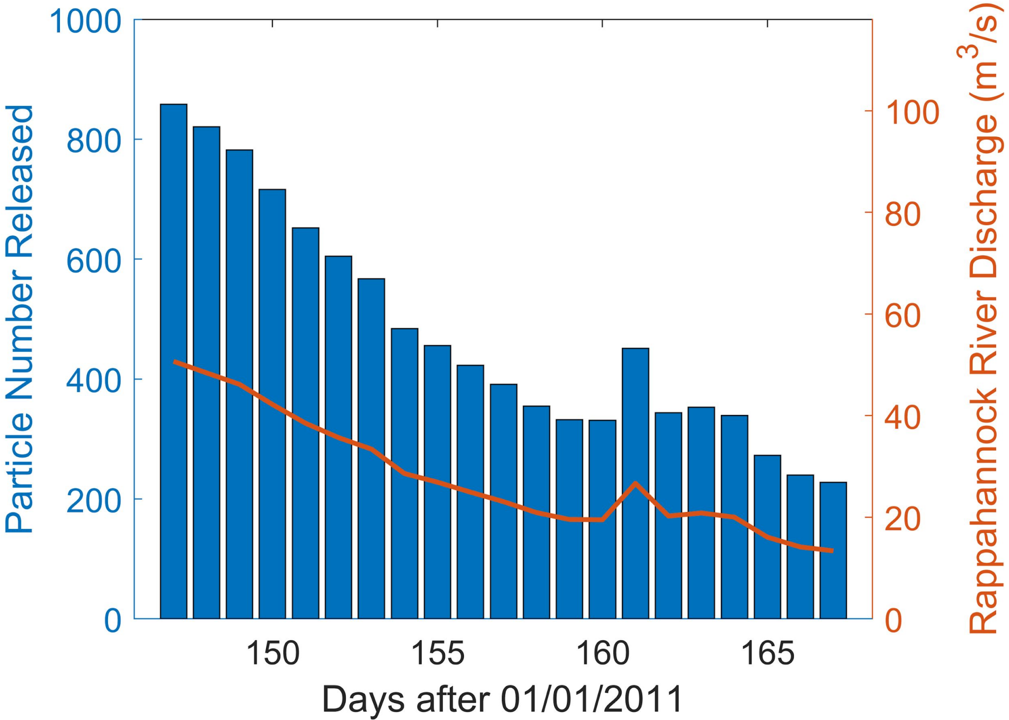
Scenarios 1-5:

passive particles, moderate flow condition



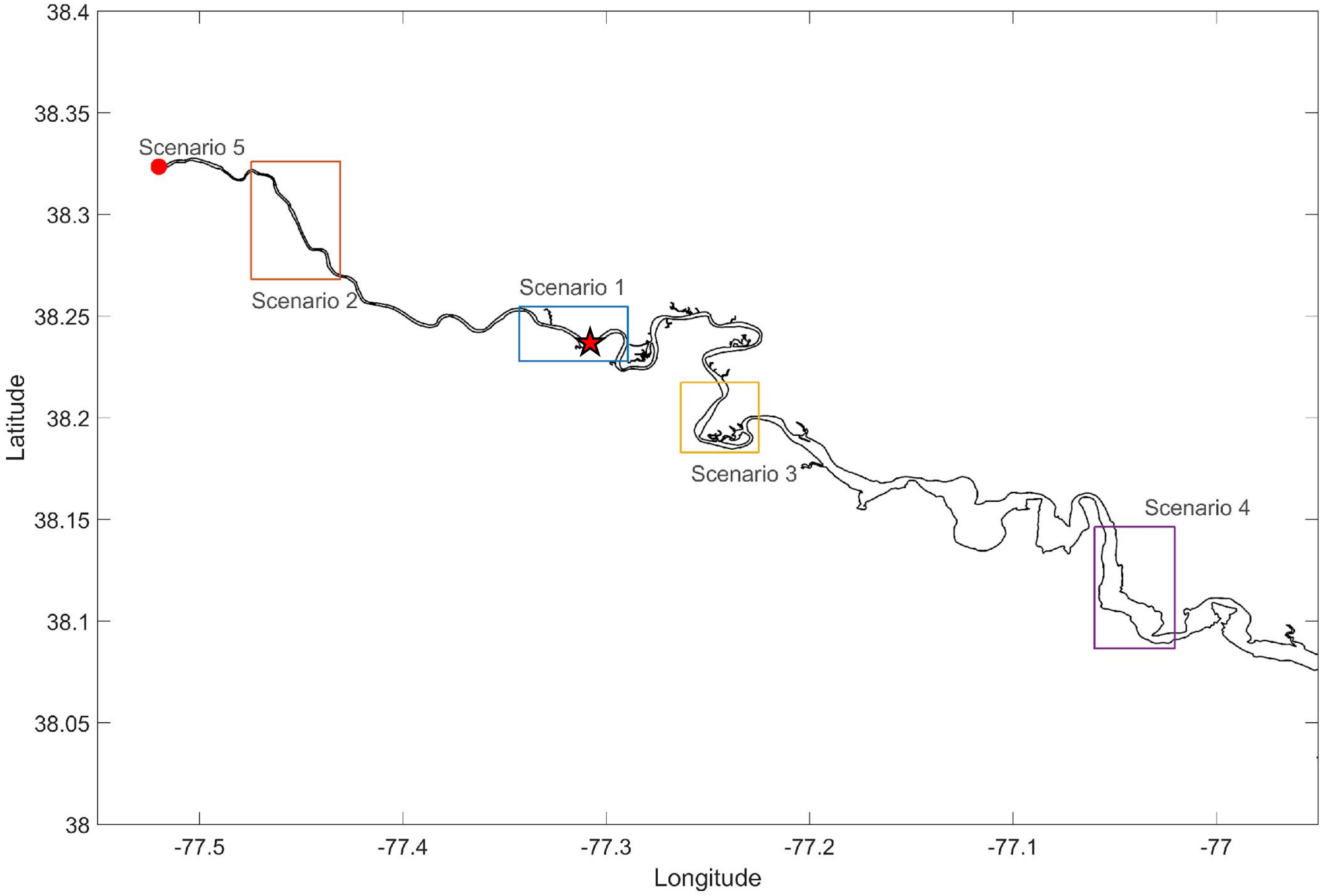
Continuous release for 21 days

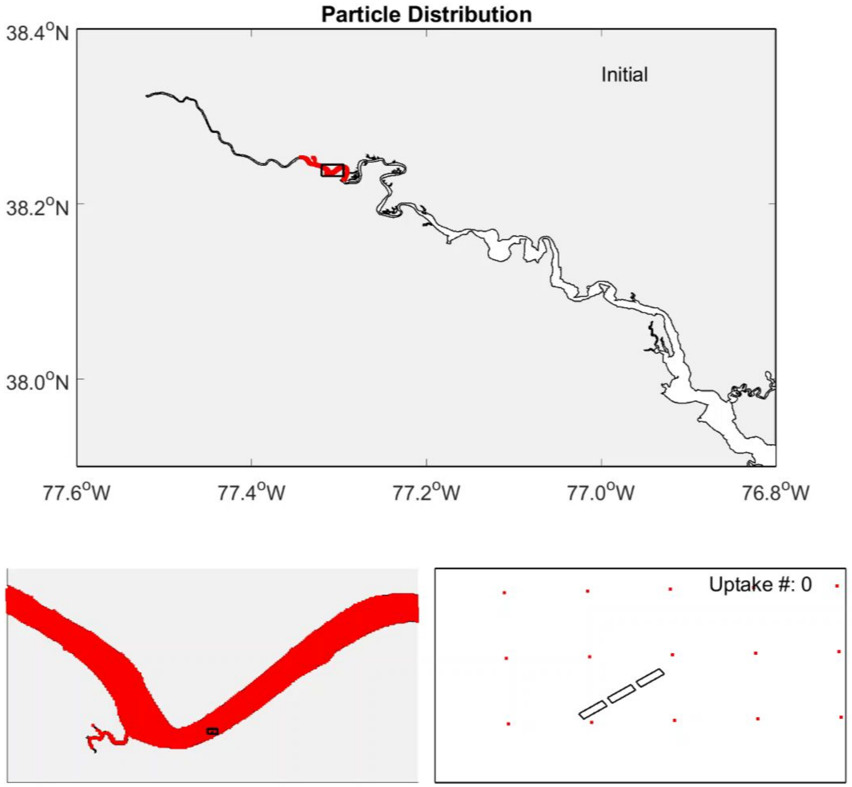
Scenario 5 (particle # = 10,001)



Scenario 1

One-time release, moderate flow condition, passive particles

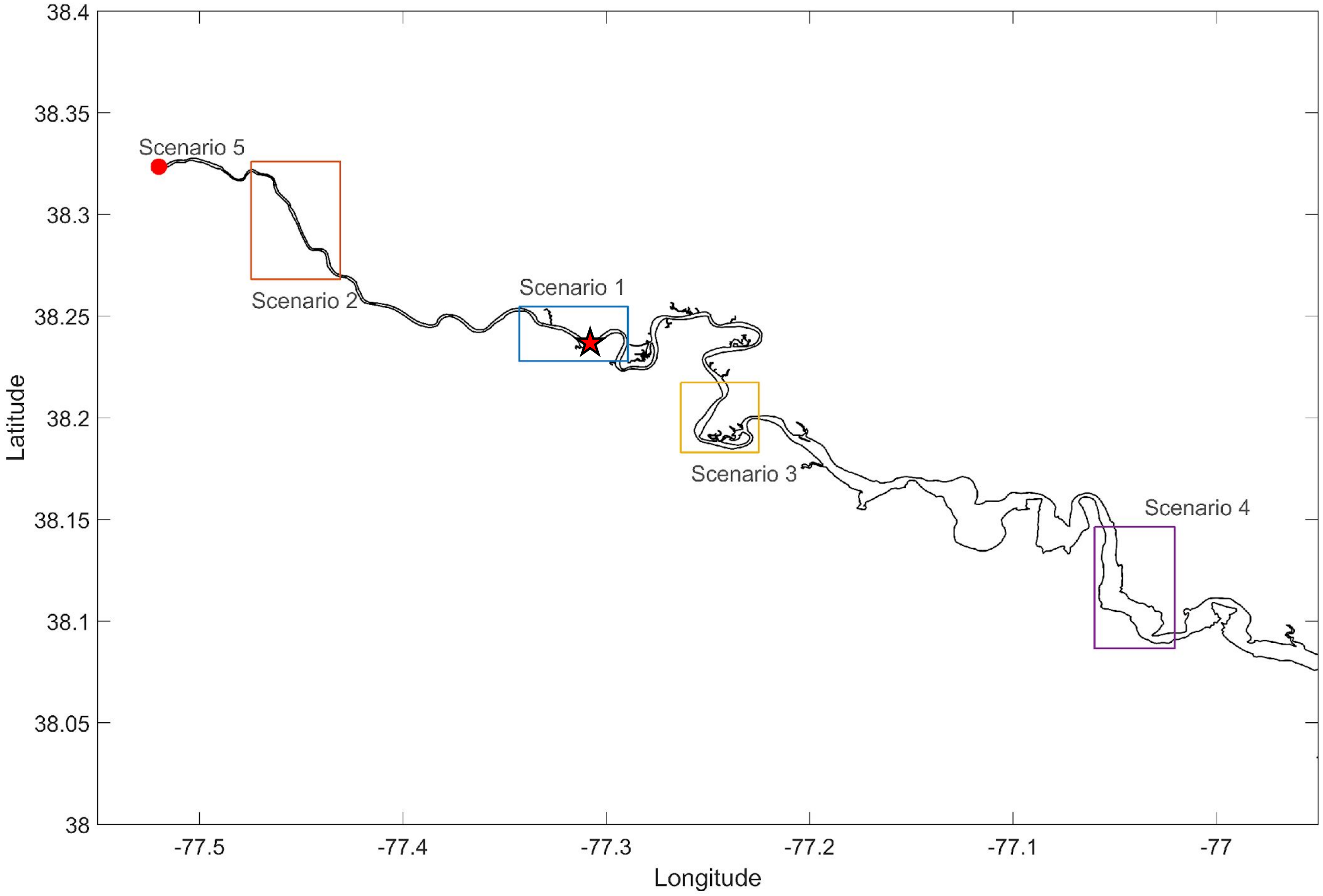


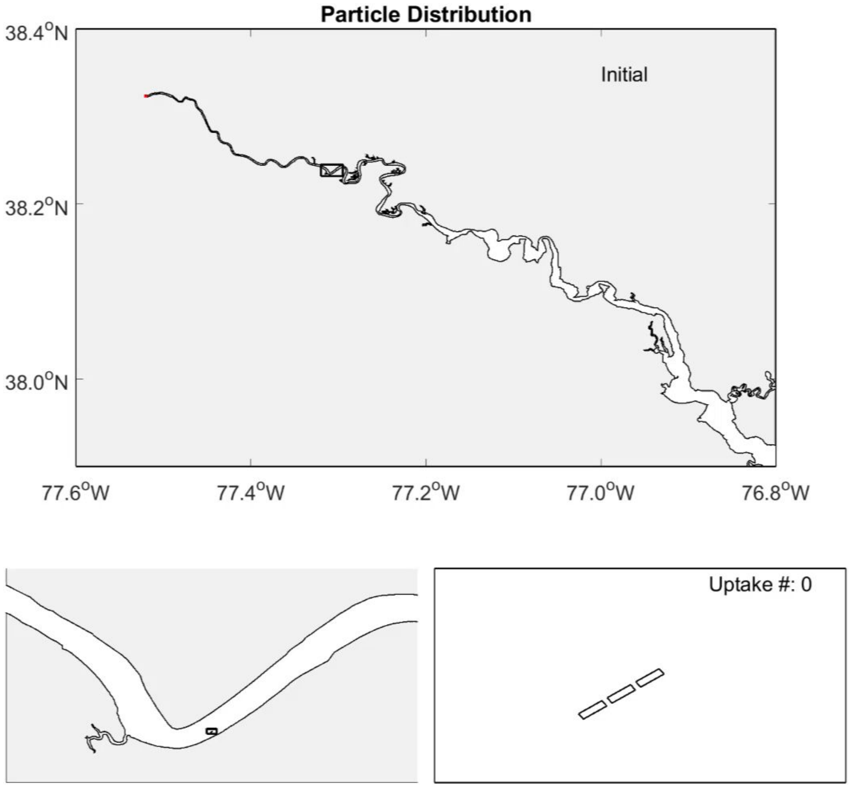


Video

Scenario 5

Continuous release, moderate flow condition, passive particles

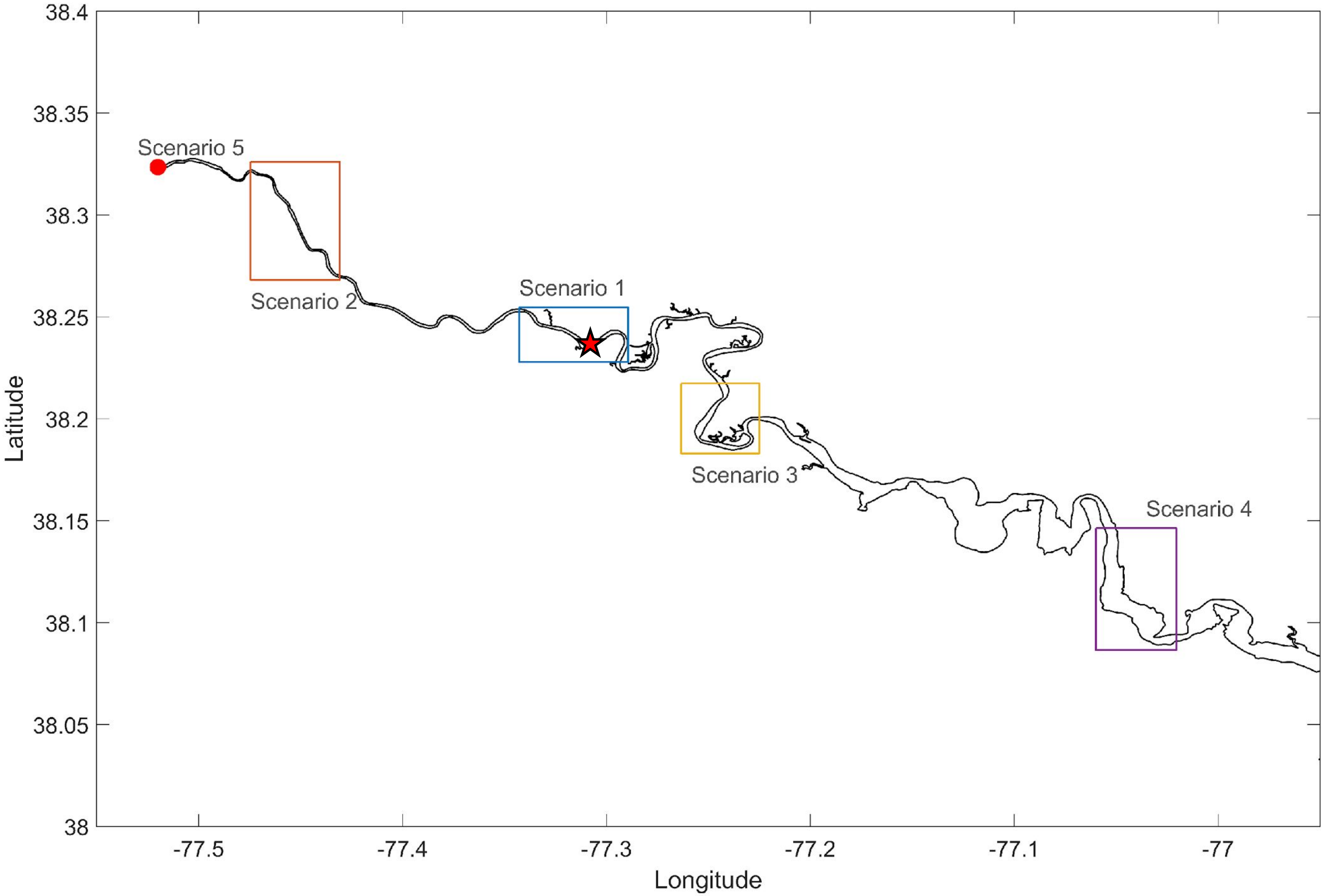


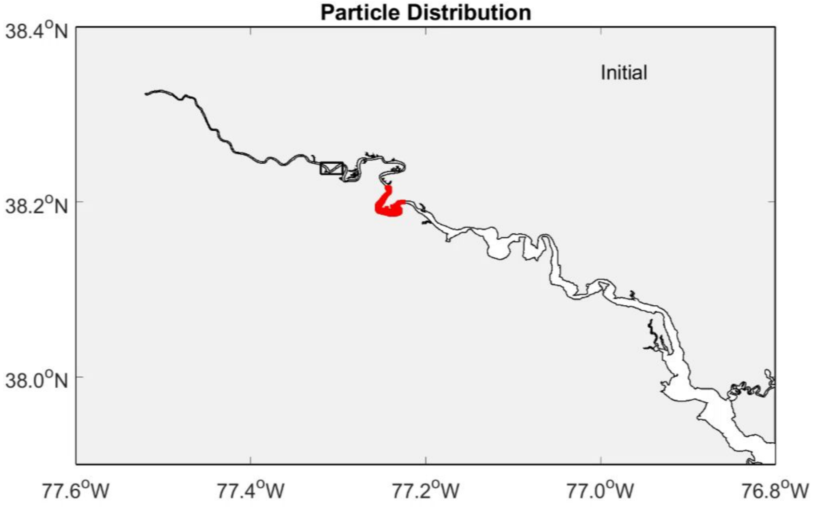


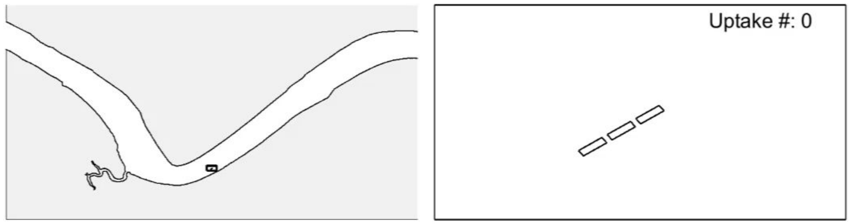
Video

Scenario 3

One-time release, moderate flow condition, passive particles







Video

Particle tracking scenarios

Forward tracking scenarios

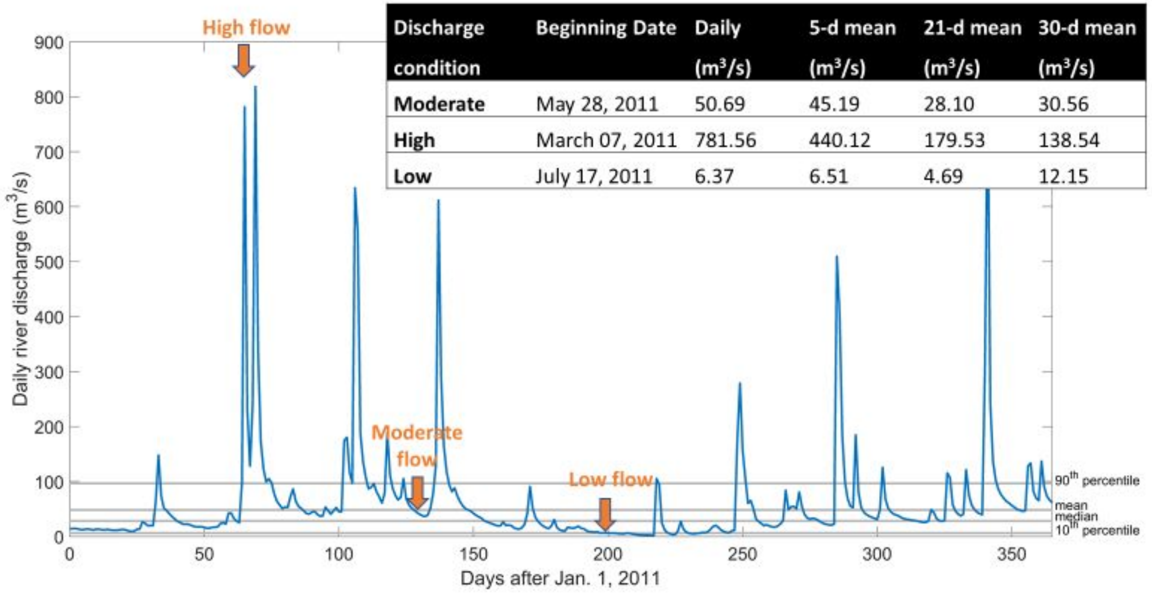
- Different locations: near, upstream, downstream the intake
- Different release methods: one-time vs. continuous
- ➡ Different flow conditions: moderate, high, low
- Different vertical velocities: passive vs. active

Backward tracking scenario

Scenarios 1-5: location and release methods

Scenarios 6-13: flow conditions

Daily river discharge of the Rappahannock River in 2011



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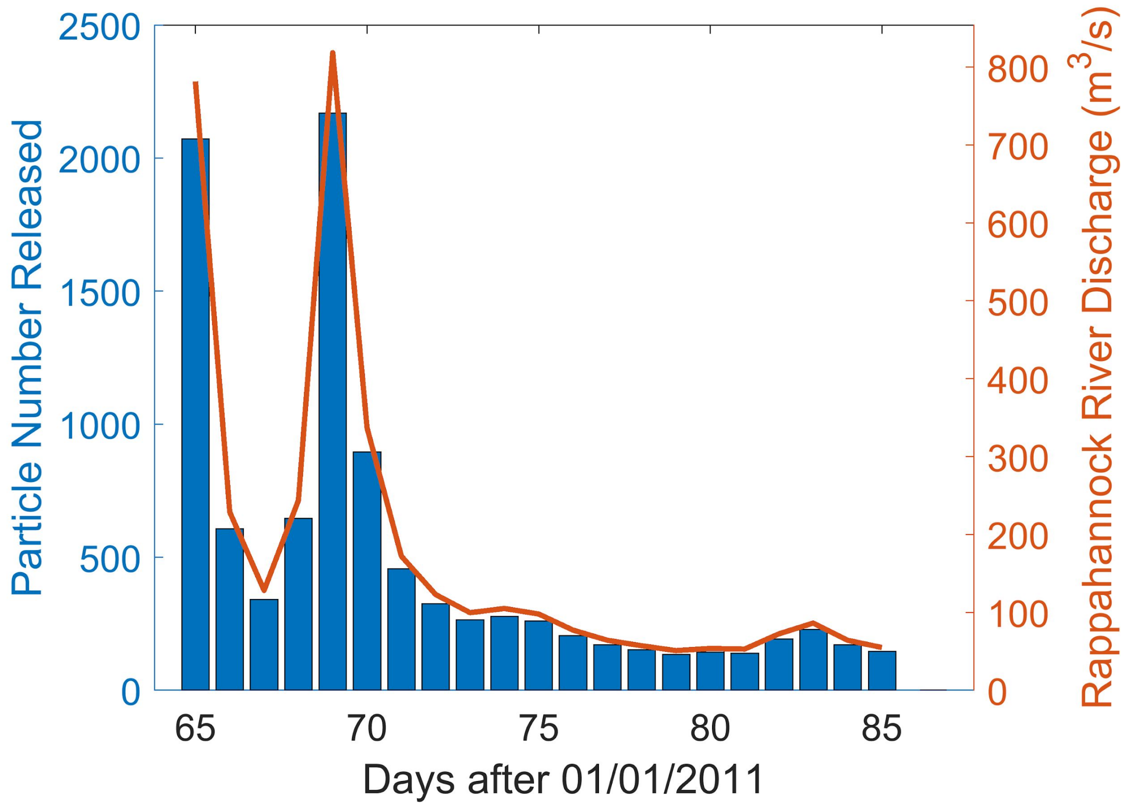
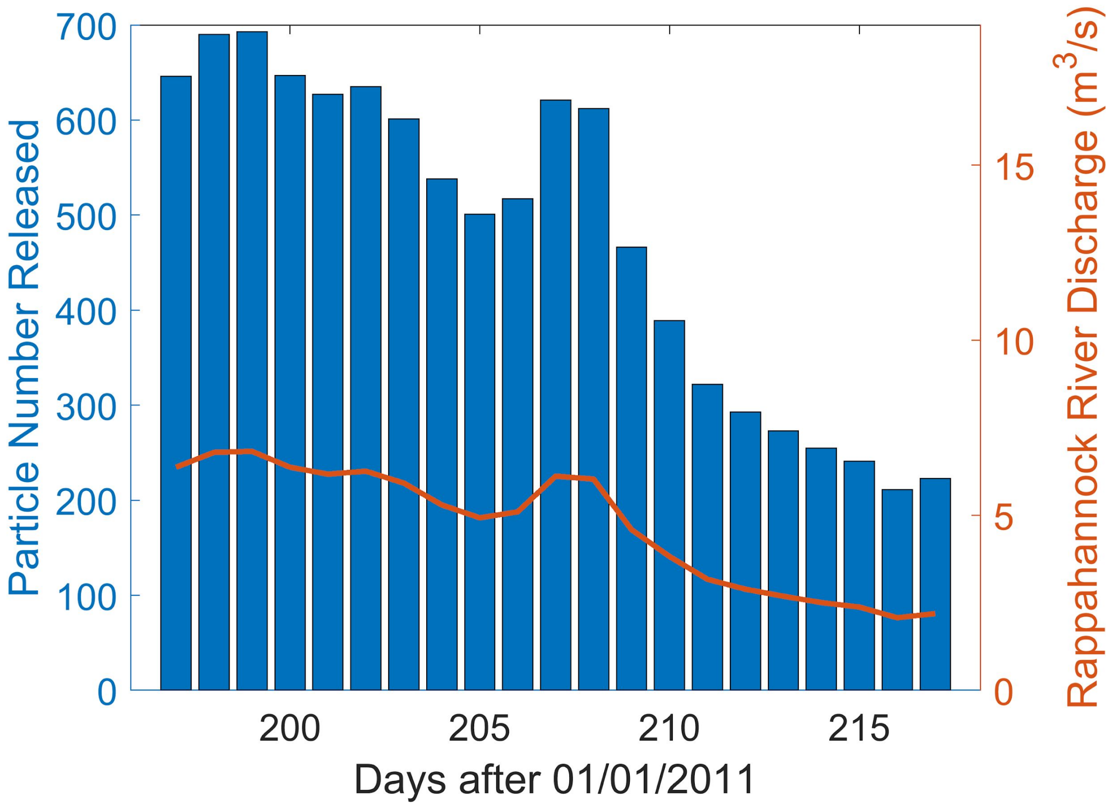
Continuously released scenarios

High flow



Scenario 12

Low flow



Scenario 13

Particle tracking scenarios

Forward tracking scenarios

- Different locations: near, upstream, downstream the intake
- Different release methods: one-time vs. continuous
- Different flow conditions: moderate, high, low
- Different vertical velocities: passive vs. active

Backward tracking scenario

Scenarios 1-5: location and release methods

Scenarios 6-13: flow conditions

Scenarios 14-34: vertical velocities

Particle tracking scenarios

Number of released particles?

~10,000 and also 10-fold scenarios

Forward tracking scenarios

- Different locations: near, upstream, downstream the intake
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- Different flow conditions: moderate, high, low
- Different vertical velocities: passive vs. active

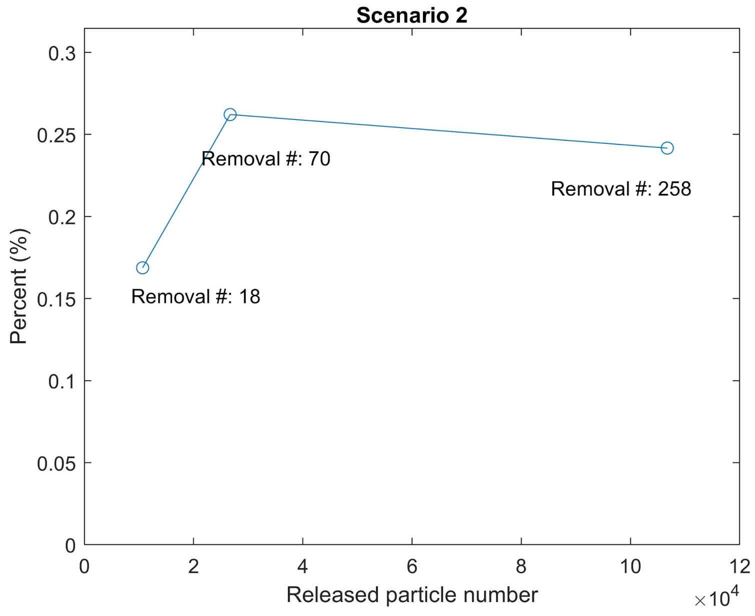
Backward tracking scenario

Scenarios 1-5: location and release methods

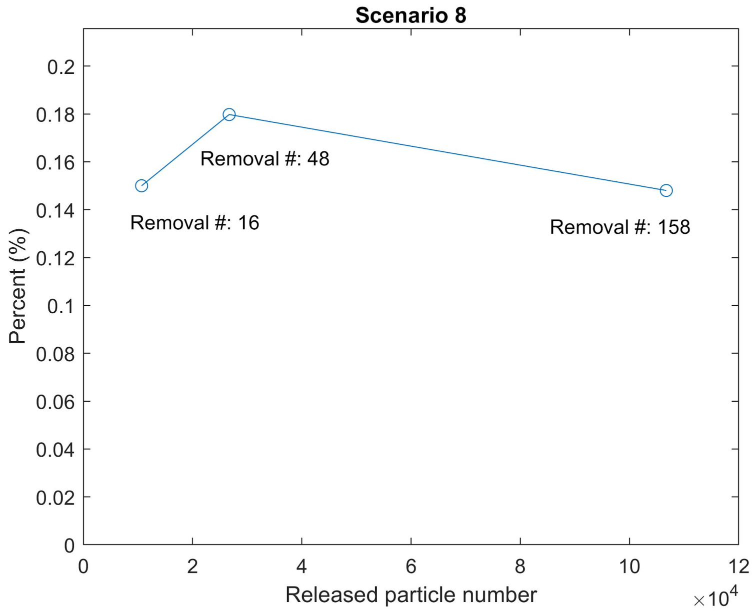
Scenarios 6-13: flow conditions

Scenarios 14-34: vertical velocities

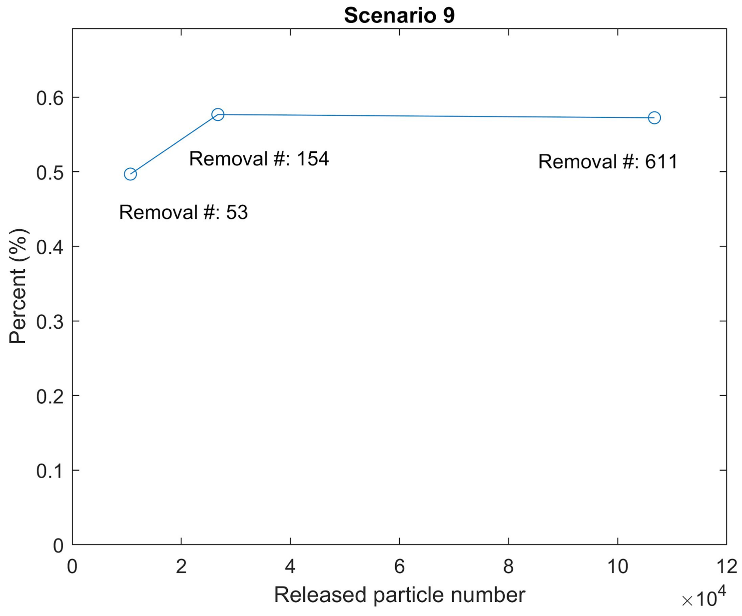
Moderate flow



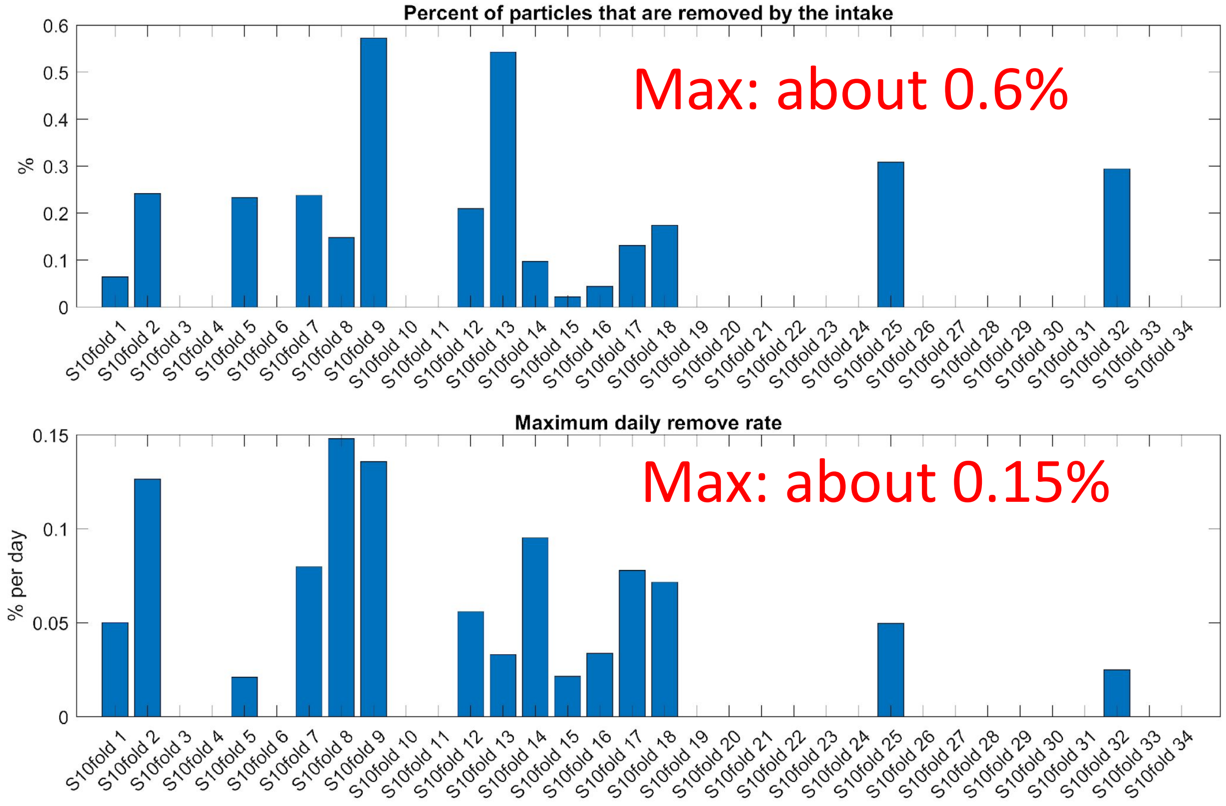
High flow



Low flow



Results of forward tracking scenarios



Natural daily mortality rate: (on average) ~20%

Particle #: about 100,000

Qin, Shen, Tuckey, Cai, and Xiong (2022). J. Mar. Sci. Eng