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Preliminary Assessment of Whatcom and Skagit Shellfish Bed Exposure to Fecal Bacteria using the Salish Sea Model

Catherine Gockel

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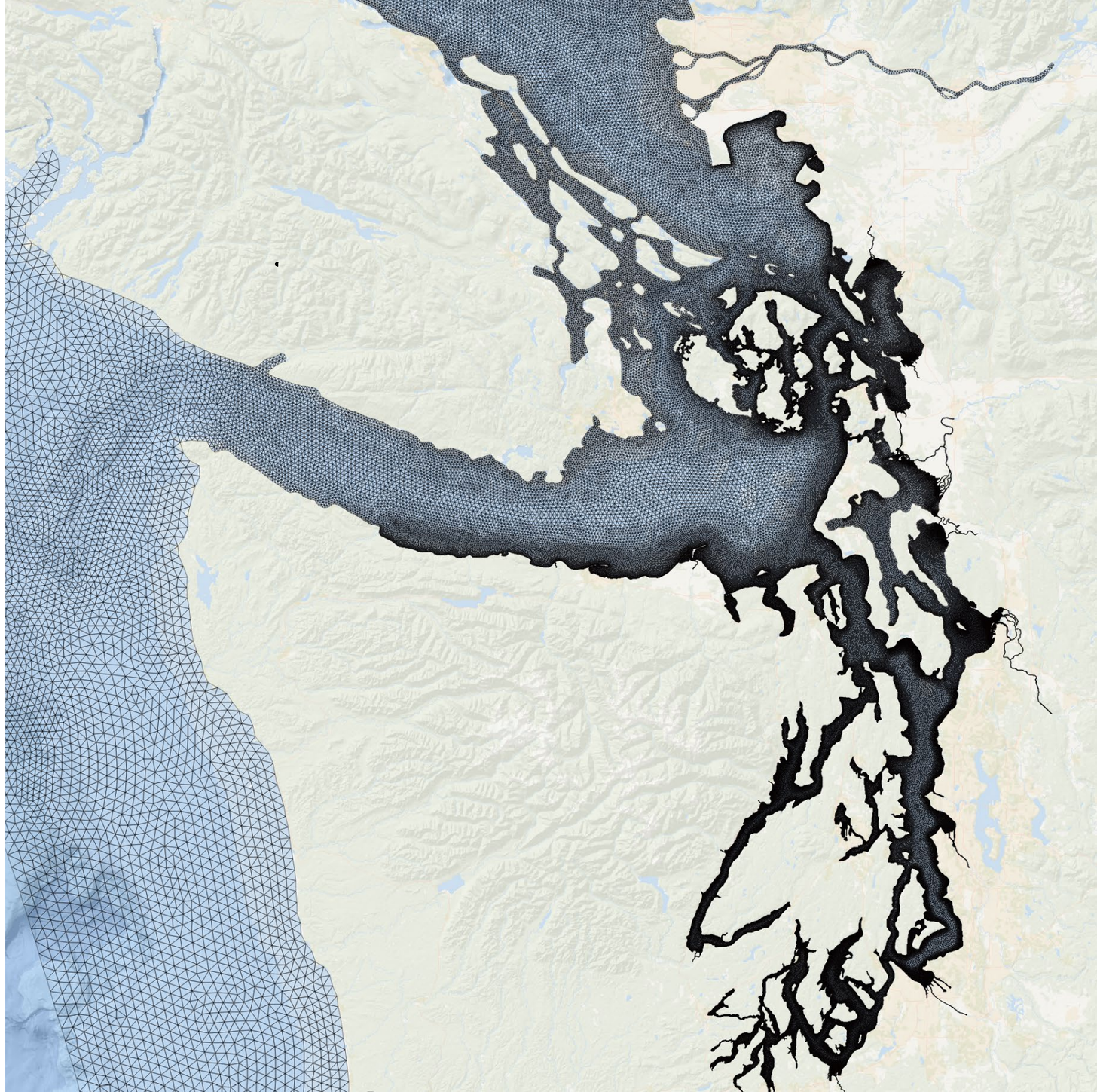
Pacific Northwest
NATIONAL LABORATORY

Preliminary Assessment of Whatcom and Skagit Shellfish Bed Exposure to Fecal Bacteria using the Salish Sea Model

April, 2022

CATHERINE GOCKEL / EPA
TARANG KHANGAONKAR / PNNL
LAKSHITHA PREMATHILAKE / PNNL
WENFEI NI / PNNL



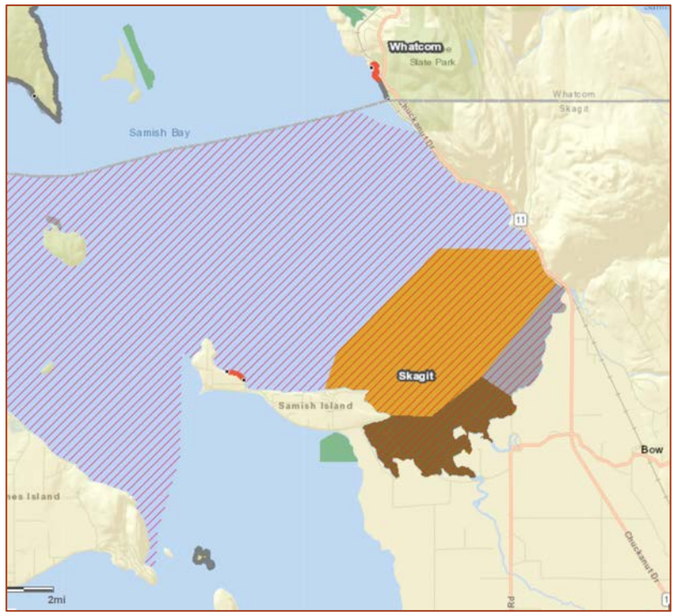
U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

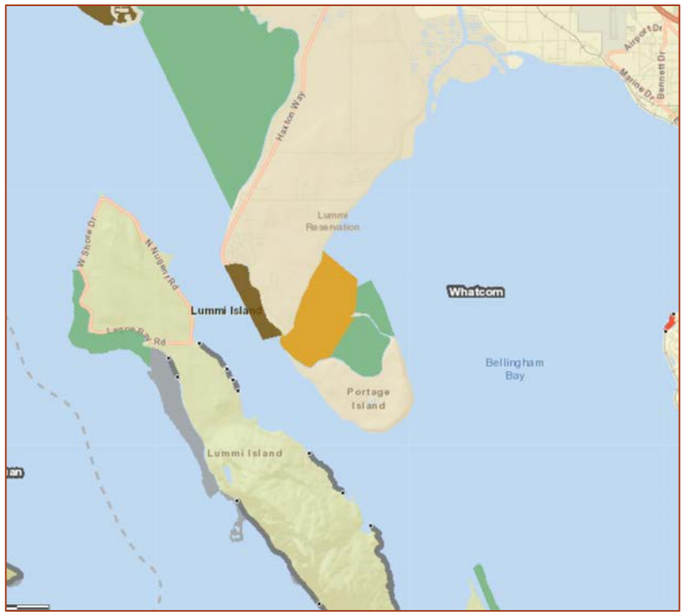
EPA United States Environmental Protection Agency

Background and Motivation for the Study

- Shellfish growing areas in the Salish Sea are impacted by poor water quality
  - Despite restoration efforts, numerous shellfish beds remain impacted
- Whatcom and Skagit Pollution Identification and Correction (PIC)
  - Need to better understand how currents driven by tides and winds move freshwater and fecal bacteria from rivers, streams, and outfalls.



Samish Bay



Portage Bay

Drayton Harbor

Project Team

- EPA Oversight/Funding
  - Catherine Gockel
  - Ben Cope
  - Angela Adams

EPA United States Environmental Protection Agency

- Project Management
  - Tarang Khangaonkar (PI)
  - Lakshitha Prematilake
  - Wenfei Ni

Pacific Northwest NATIONAL LABORATORY

SALISH SEA MODELING CENTER UNIVERSITY of WASHINGTON

- Collaborators/
  - Andrea Hood (DOH)
  - Scott Berbells (DOH)
  - Clara Hard (DOH)
  - Jean Frost (DOH)
  - Mark C Troy (DOH)
  - Trevor Swanson (DOH)
  - Jean Frost (DOH)
  - Michael See (Skagit)
  - Karen DuBose (Skagit)
  - Kevin Jackman (Skagit)
  - Erika Douglas (Whatcom)
  - Meagan Harris (Whatcom)
  - Kara Kuhlman (Lummi)
  - James Kardouni (Ecology)
  - Scott Bohling (Ecology)
  - Eric Grossman (USGS)

Washington State Department of Health

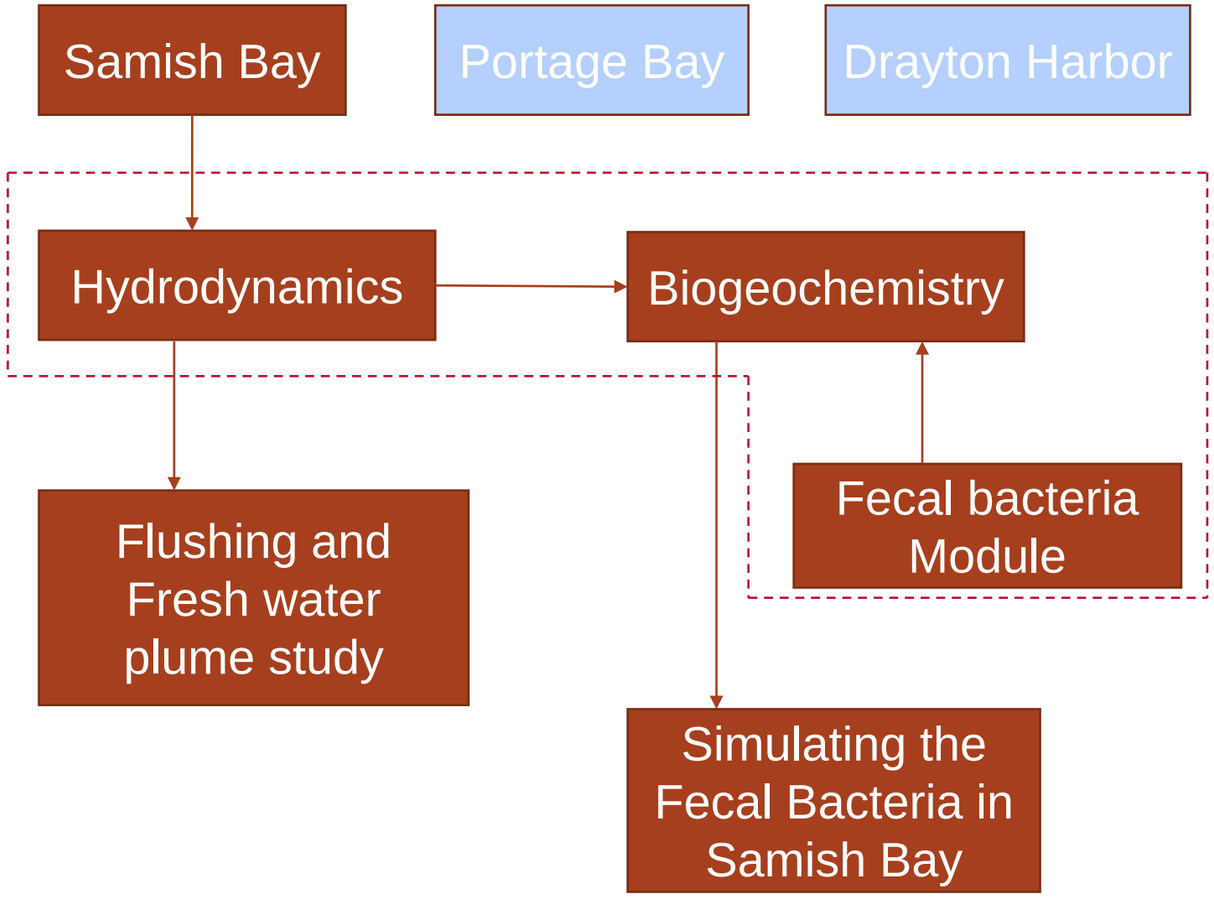
WHATCOM COUNTY WASHINGTON

SKAGIT COUNTY Serving With Pride WASHINGTON

DEPARTMENT OF ECOLOGY State of Washington

Study Fecal Bacteria Fate and Transport using the Salish Sea Model

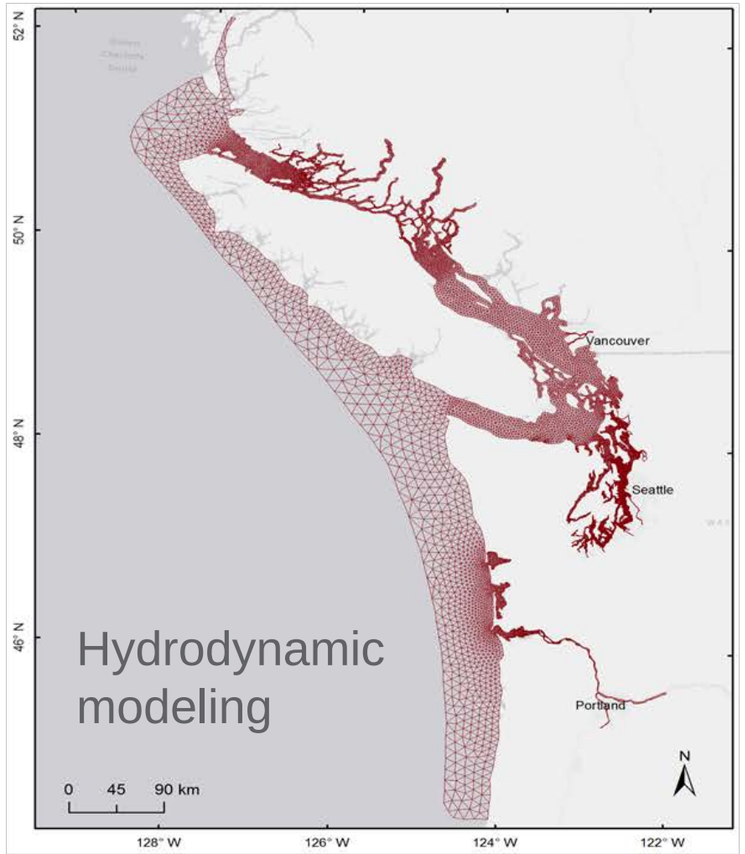
- Objectives
  - Identify the temporal and spatial variation of fecal bacteria at impacted region
  - Identify the sensitivities of potential fresh water sources on fecal bacteria
  - Revalidate the current TMDL limits
- Task
  - Conducting simulations with Salish Sea Model to produce hydrodynamics and water quality of the impacted region



Salish Sea Model and Development of Fecal Bacteria Module

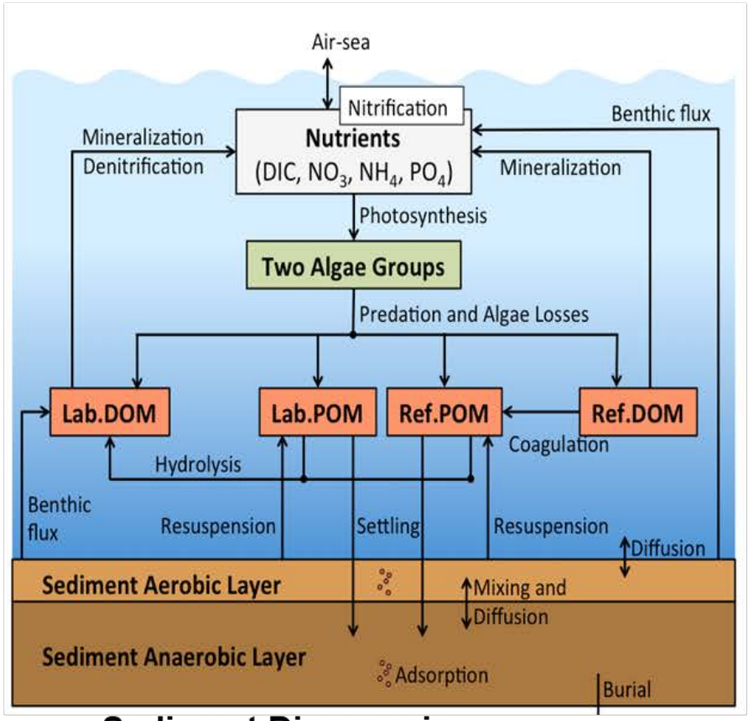
- **Salish Sea Modeling Framework**

Salish Sea Model (SSM) - Grid



Biogeochemical Component

Water Quality Modeling



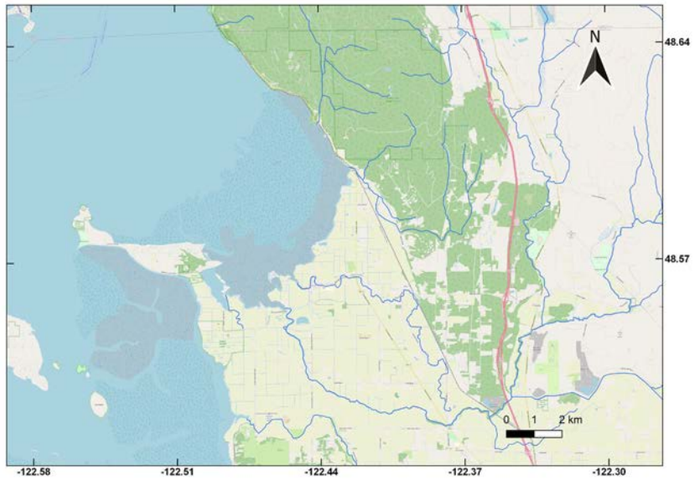
- **Sediment Diagenesis**
- **Carbonate Chemistry & pH**

Model Specifications

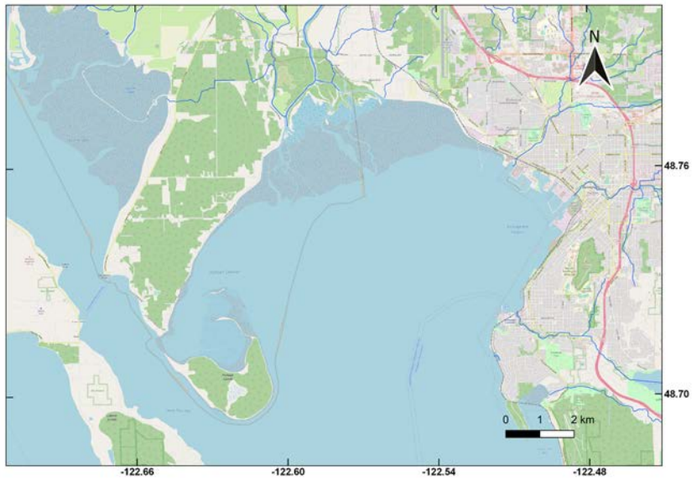
- **Hydrodynamic Model**
  - **FVCOM (Chen et al 2003)**
  - **3-D Baroclinic**
  - **10-layers, sigma coordinates**
  - **Boundaries**
    - **Strait of Juan de Fuca**
    - **Strait of Georgia**
    - **S, T, and Elevation**
  - **Meteorology**
    - **UW – WRF Model**
  - **Hydrology**
    - **River flows**
    - **Watershed models**
- **Water Quality Model**
  - CE-QUAL-ICM / USACE
  - **FVCOM-ICM (Kim and Khangaonkar 2012)**
  - **Nutrients, phytoplankton/algae, carbon, DO, …. 19 variables**
  - **Benthic fluxes, pH**
  - **Boundary loads based on DFO monitoring data / HYCOM**
  - **Point source loads (99)…**

Data for Modeling - Fecal Bacteria Monitoring Data, & Loading Characterization

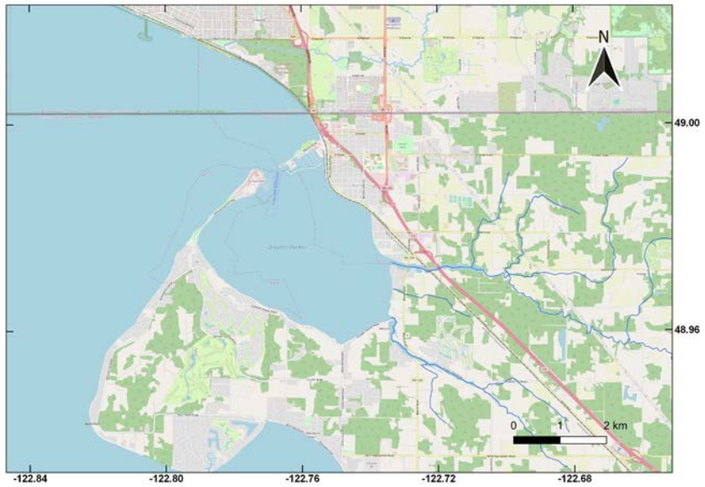
- **Data and the sources:**
  - Gather data to characterize Fecal Bacteria loading
    - Fecal coliform Concentrations
    - Flow measurements in watershed
    - Land use information of the watershed
  - Obtain watershed and nearshore bathymetry for model grid development
    - USGS/Lidar Survey data
  - Gather monitoring data for model validation/calibration
    - County/DOH monitoring Data
    - Data from Tribes in the regions



Samish Bay



Portage Harbor/Bellingham Bay

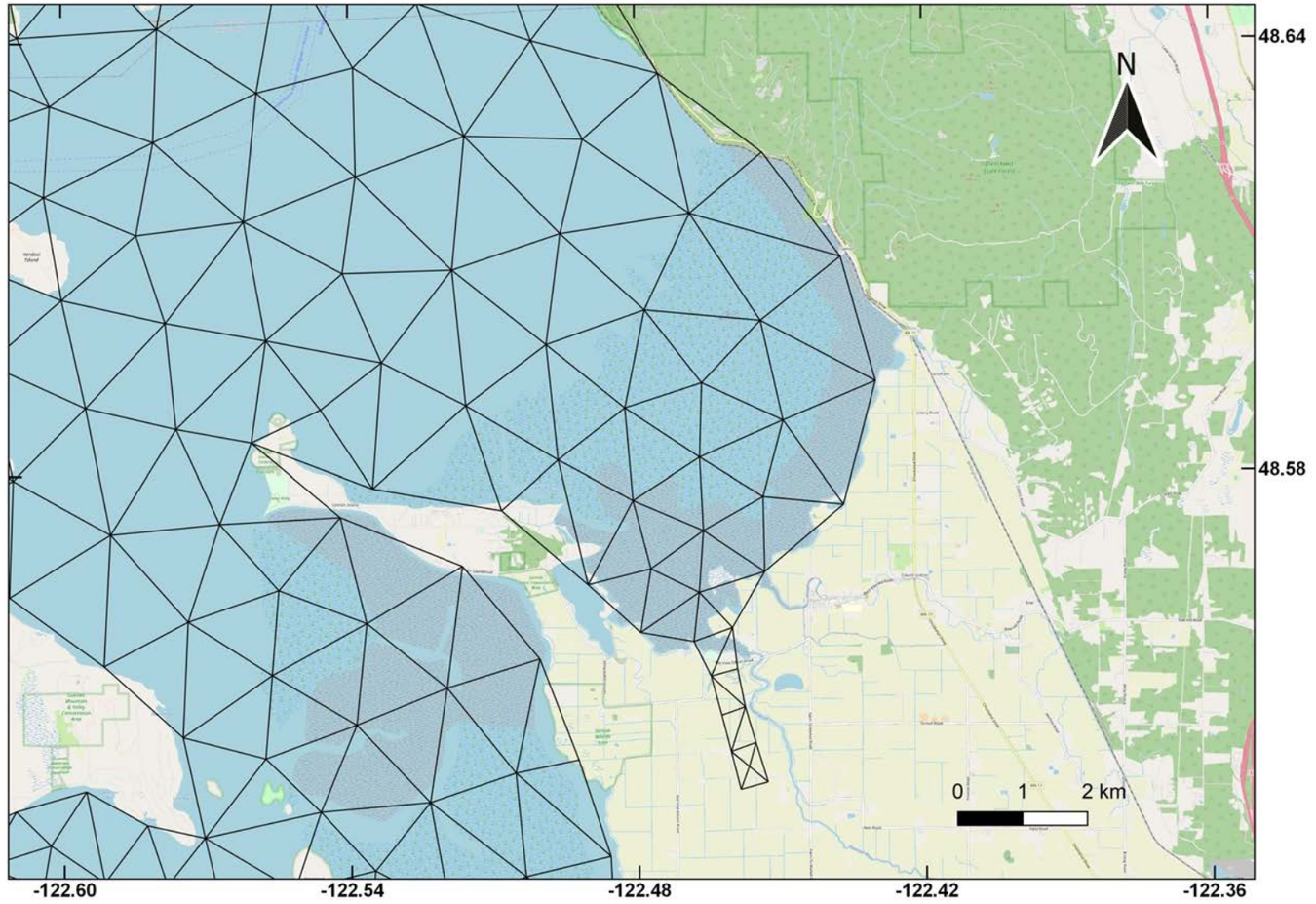


Drayton Harbor

Embedded Refinement of SSM Grid - Samish, Portage Bays, Drayton Harbor

- Standard Salish Sea Model resolution of ≈ 800m
- Detailed, refined grids were developed for domains of study

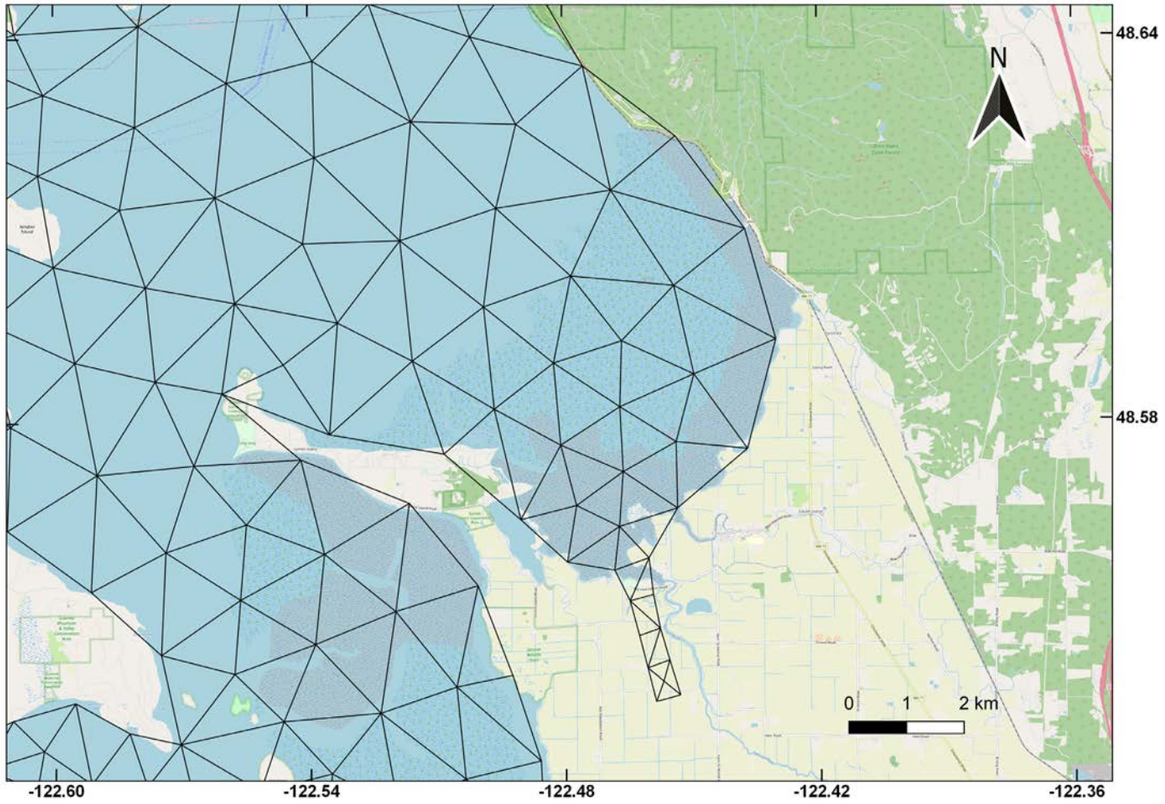
Regular SSM grid



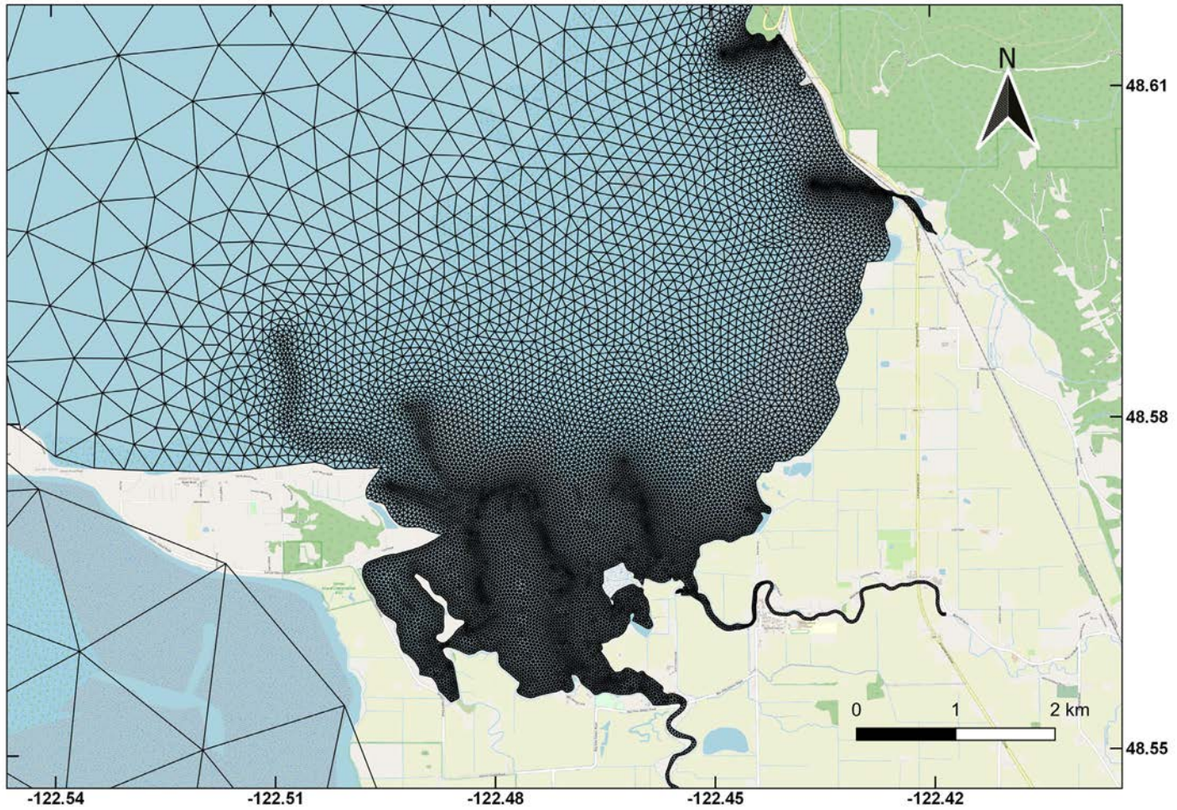
Samish Bay in regular SSM grid

Refining the Grid - Samish, Portage Bays, Drayton Harbor

Samish Bay



Regular SSM shoreline grids ≈ 400-600 m

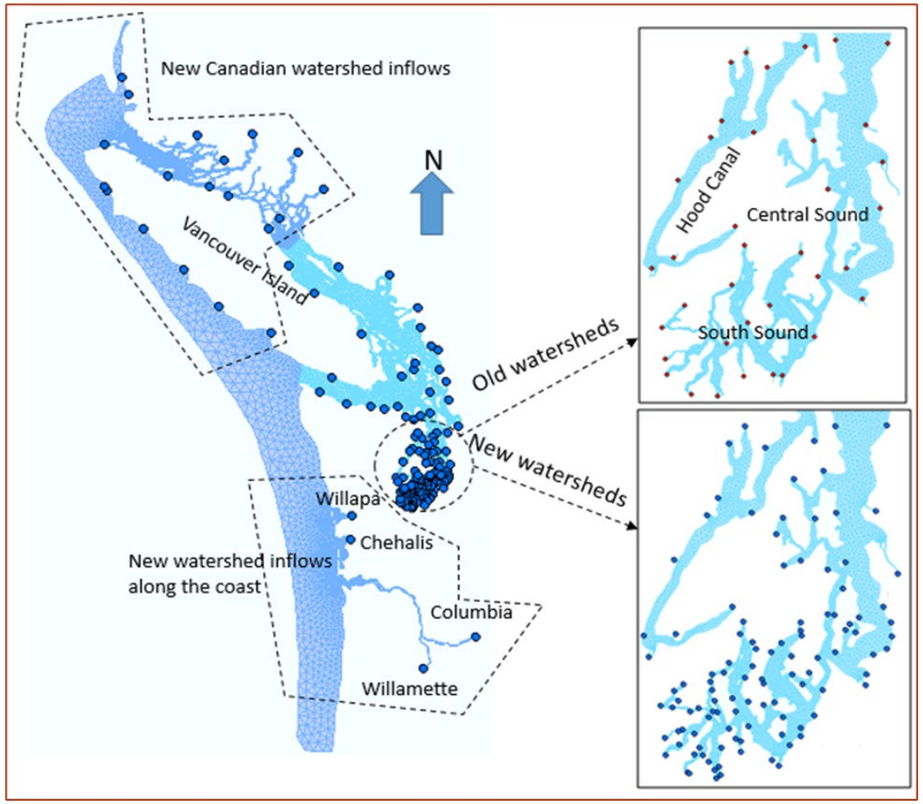


Refined Samish Bay shoreline grids ≈ 10-15 m
(Completed)

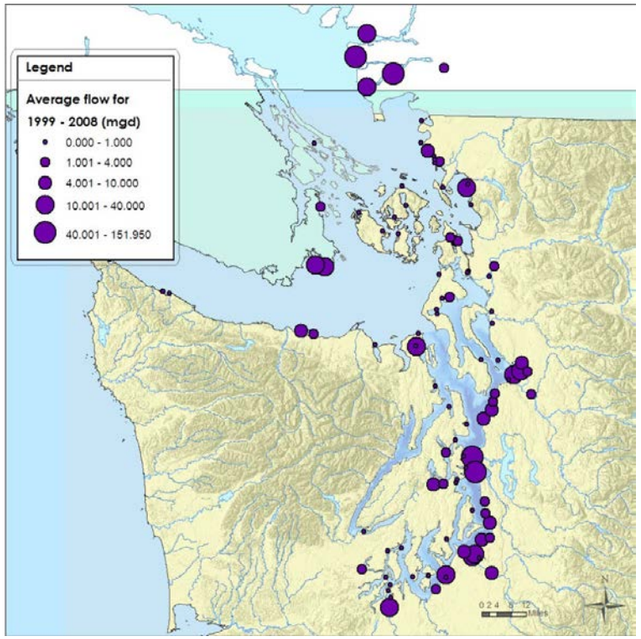
Model setup for hydrodynamic simulations

Model forcing; River flows, Open Ocean boundary

- **Samish Bay – Model: Setup for Hydrodynamics**
  - Highest fecal bacteria related beach closures for Samish Bay – 2012, 2013 and 2014
  - Higher fecal bacteria detected in Samish Bay - ***2012***

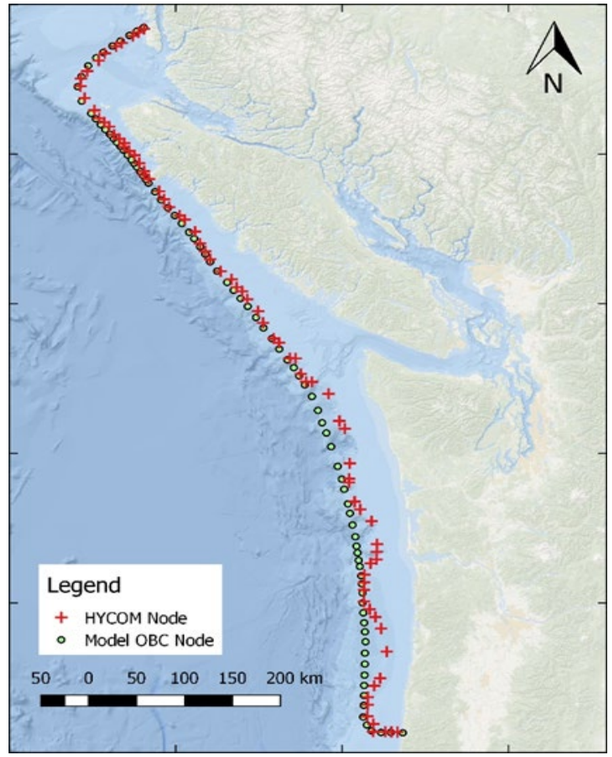


99 WWTPs



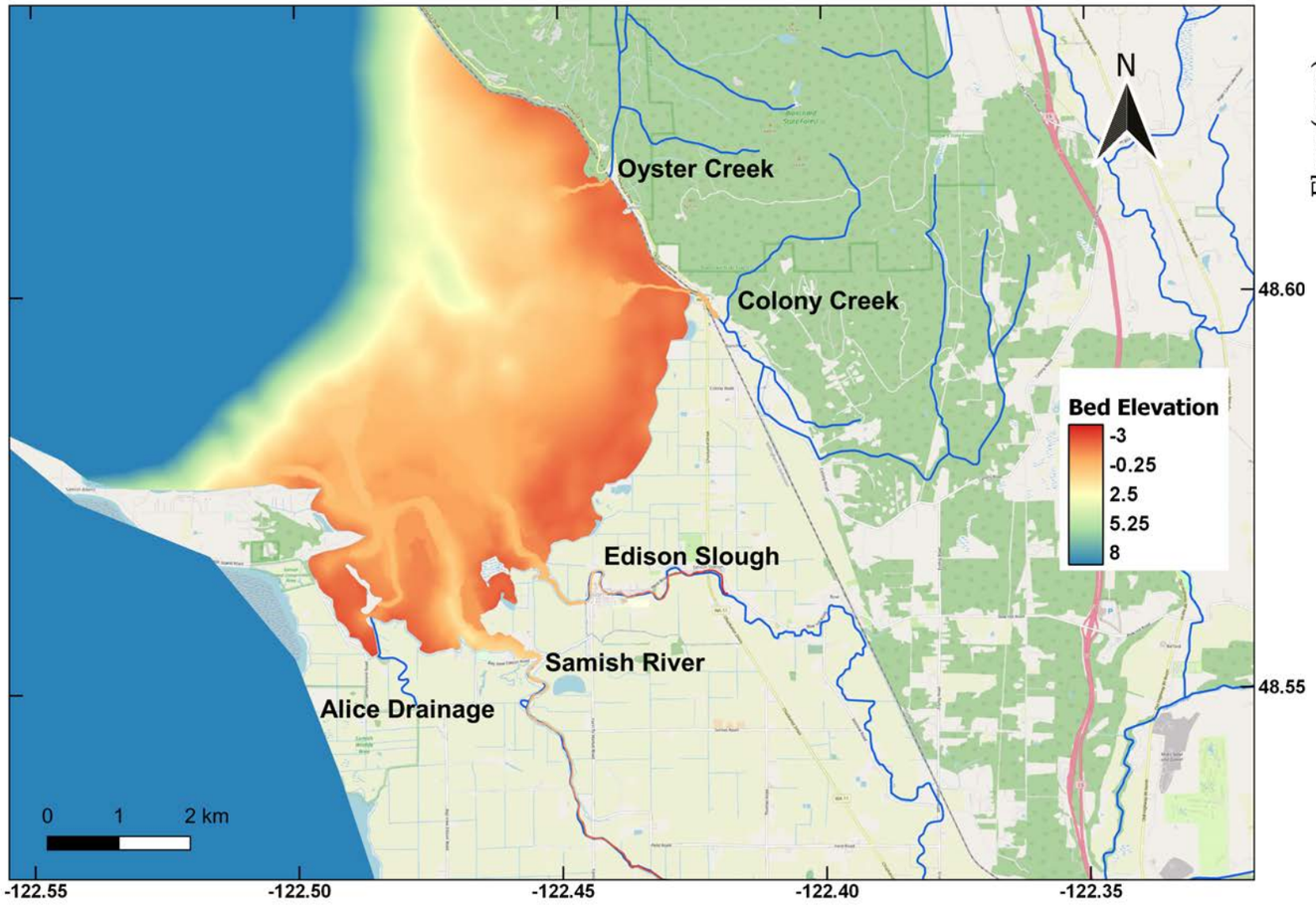
135 ungaged watershed streams (1 node/stream)
26 gaged major rivers (2 nodes/stream)

Open Ocean Boundary – HYCOM model data for year 2012

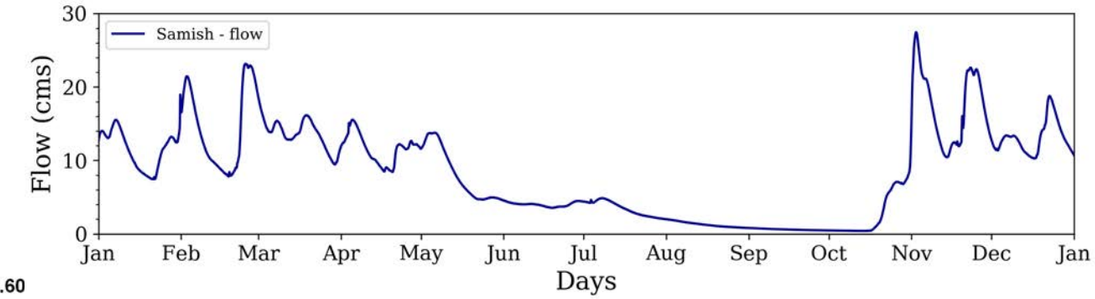


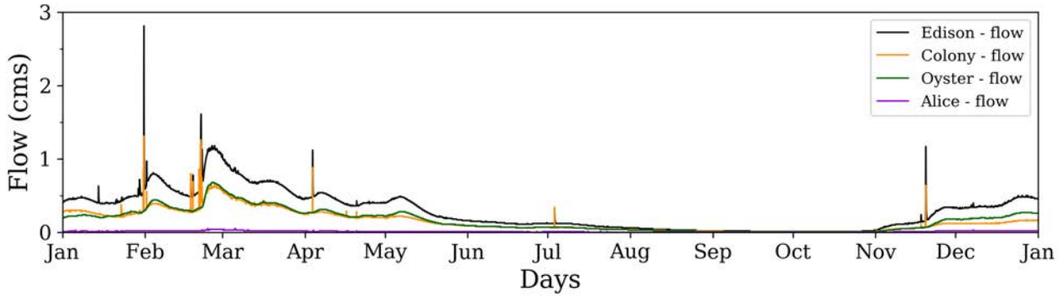
Model setup for hydrodynamic simulations

➢ Samish Bay – Model: bathymetry and additional river flow



Year 2012



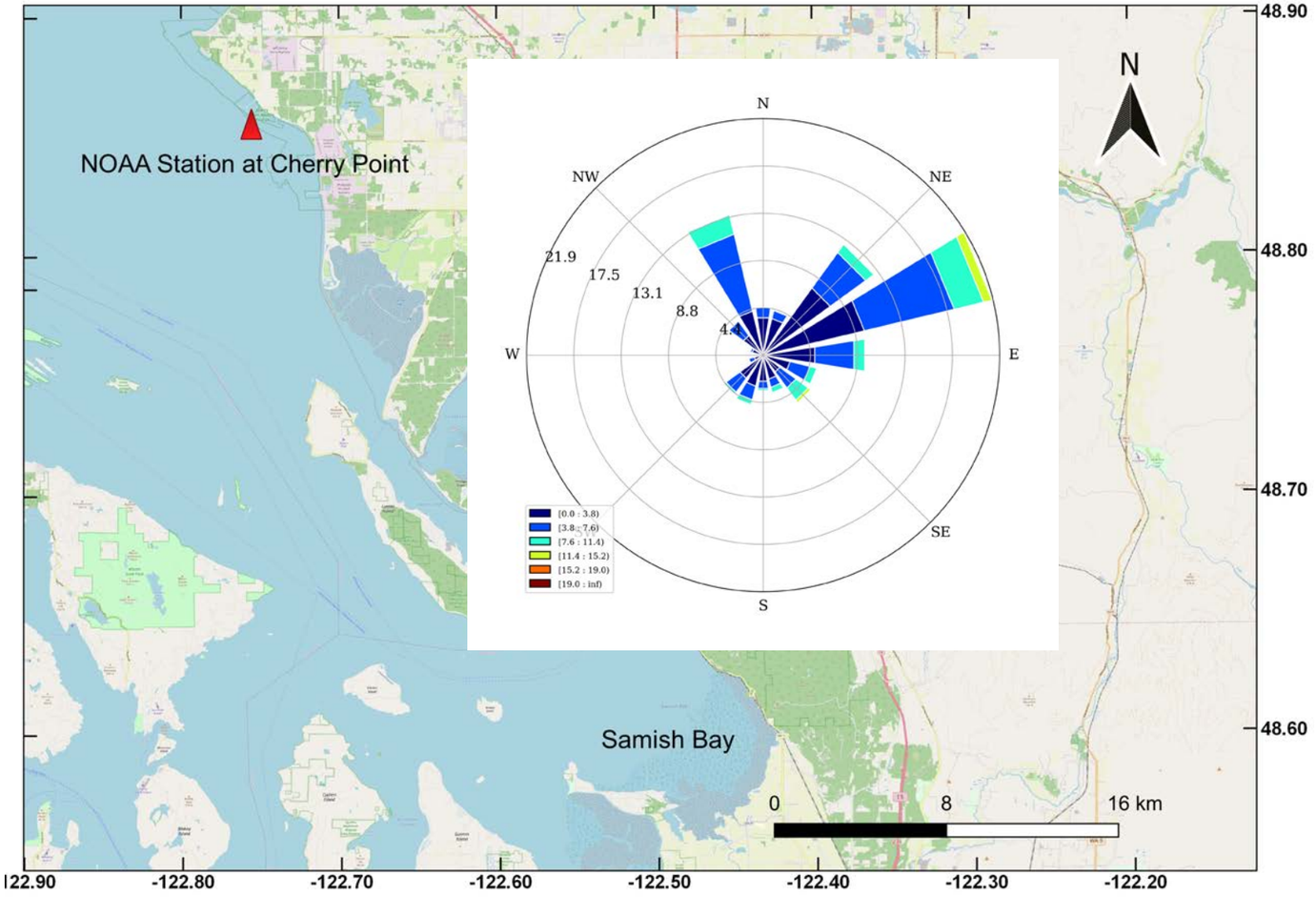


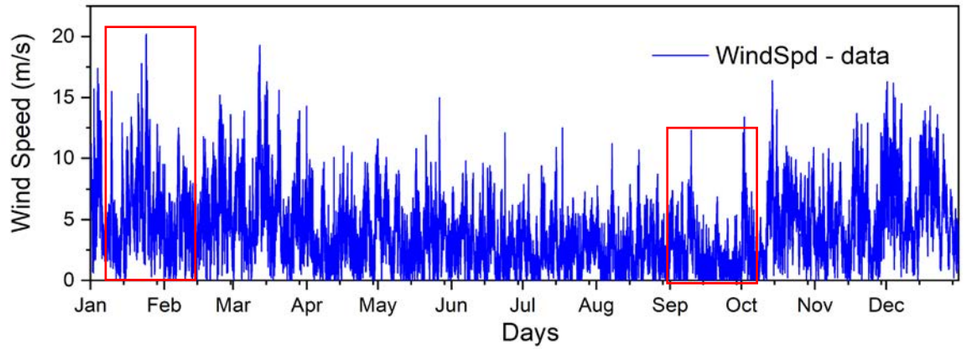
In addition to Samish River, Edison Slough, Colony Creek, Oyster Creek and Alice Drainage were added to SSM river inputs.

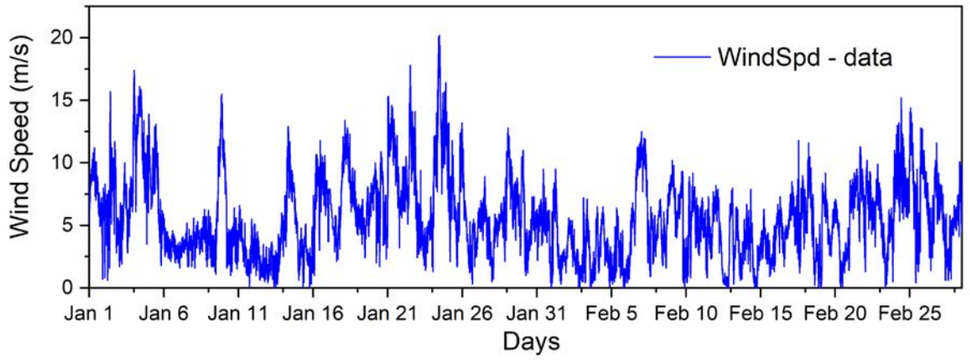
Flow estimates were obtained from National Water Model (NWM)

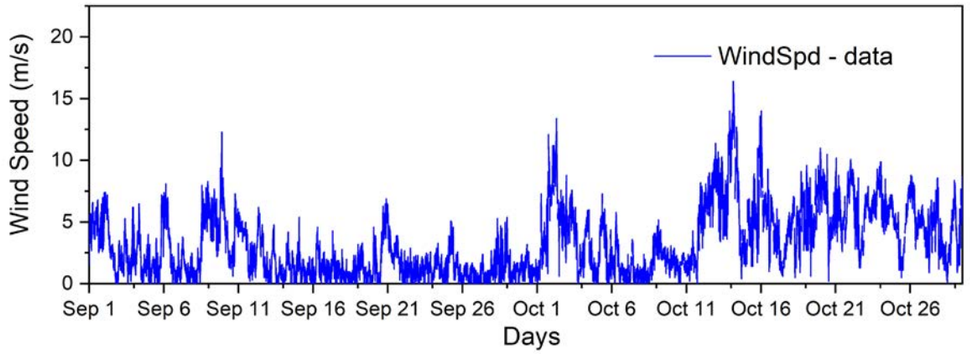
Model setup for hydrodynamic simulations

➢ Samish Bay – Model: Meteorological input





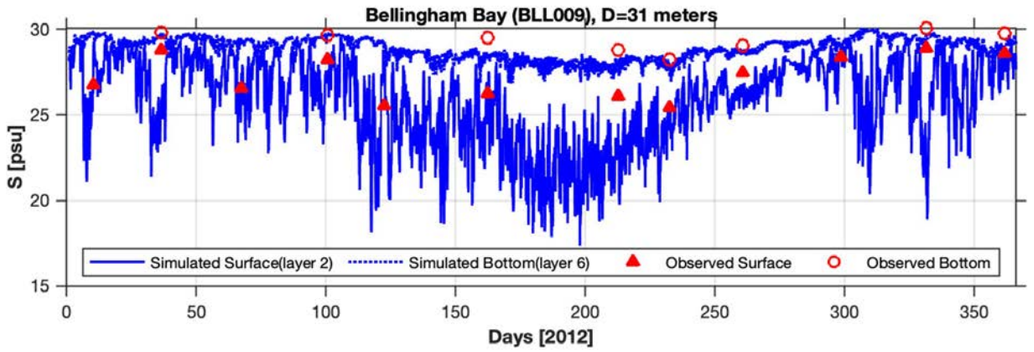


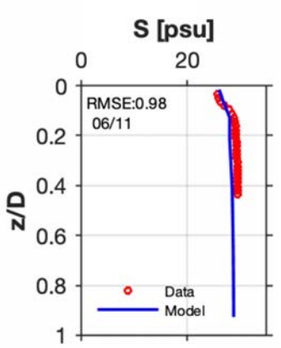


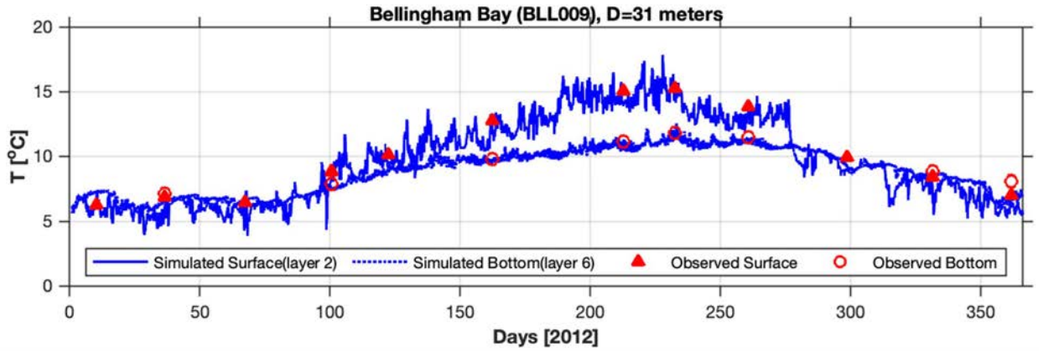
BUSINESS SENSITIVE

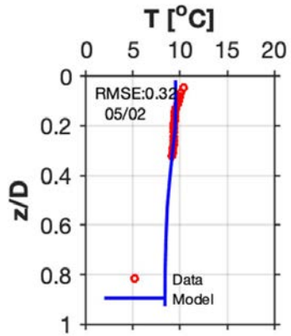
Re-validation of SSM and Development of Fecal Bacteria Module

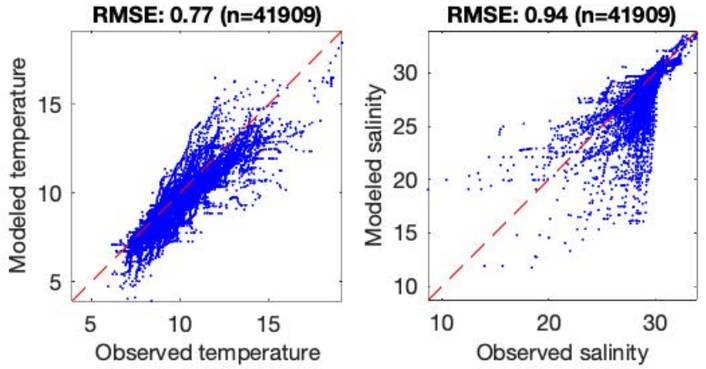
- Validation of SSM Hydrodynamics for Year 2012
  - Temperature and Salinity

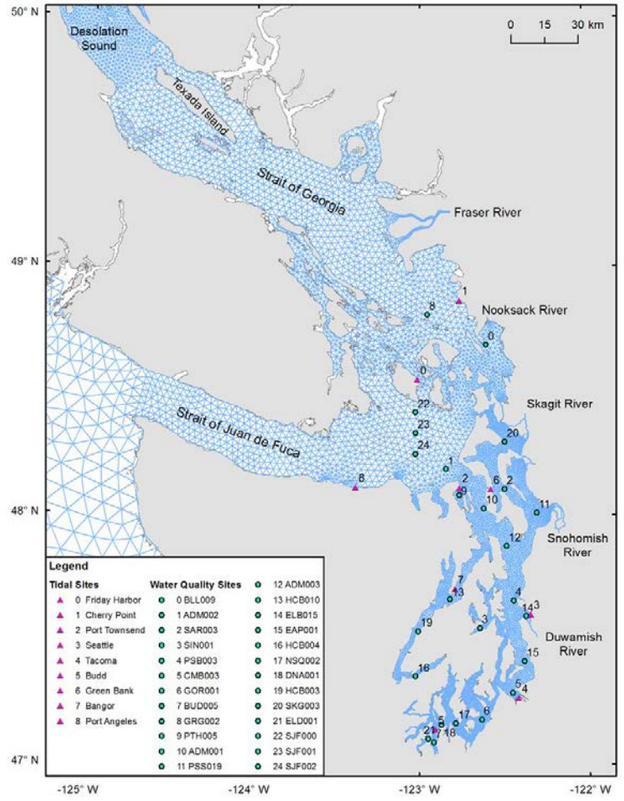








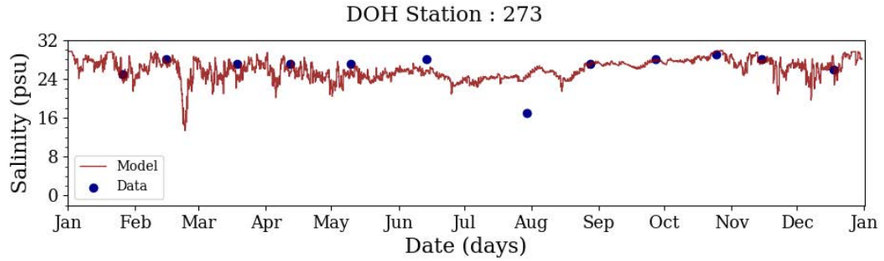


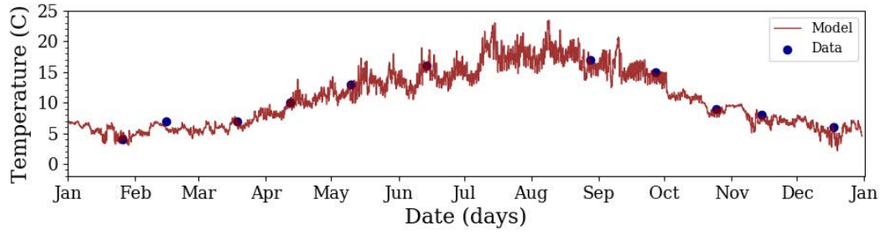


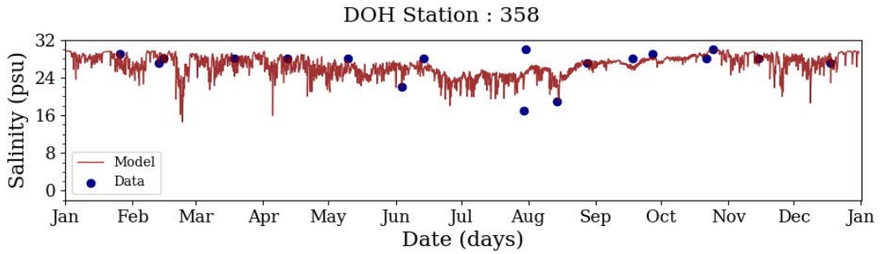
Ecology monitoring stations

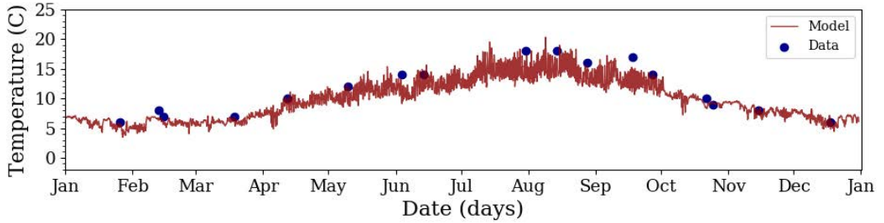
Re-validation of SSM and Development of Fecal Bacteria Module

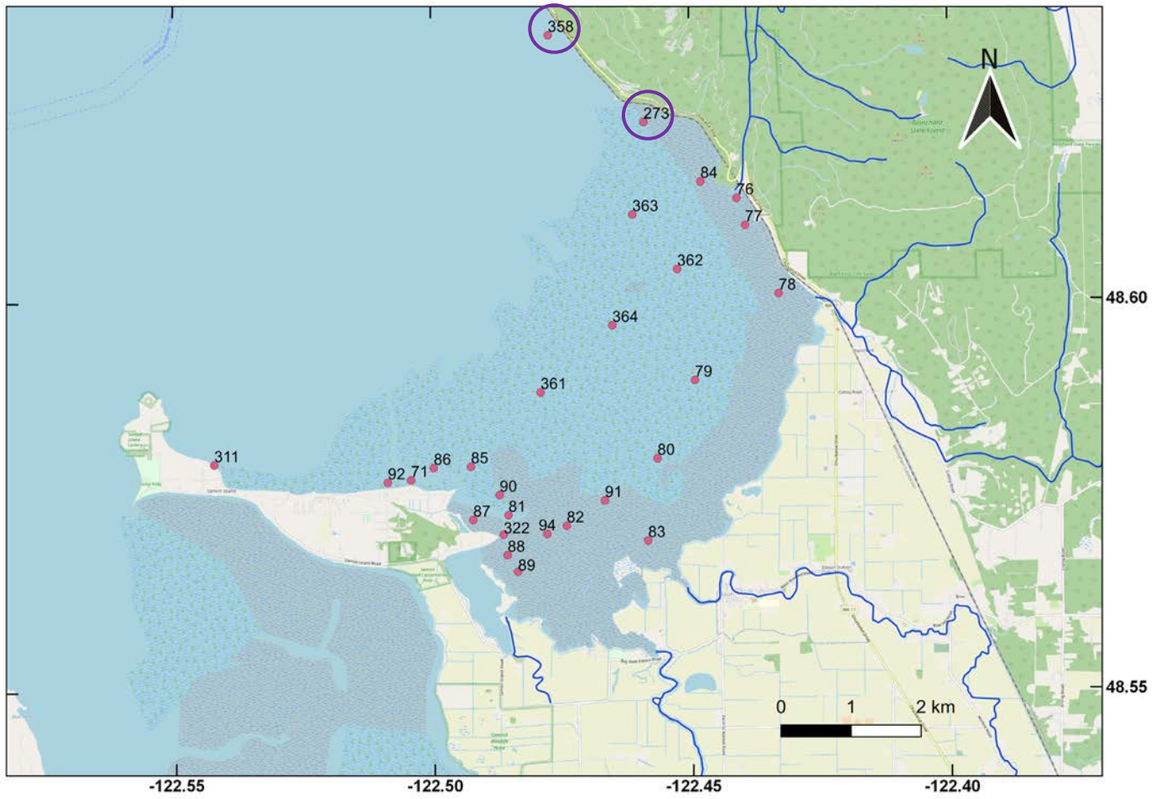
- **Validation of SSM Temperature and Salinity predictions in Samish Bay for Year 2012:**







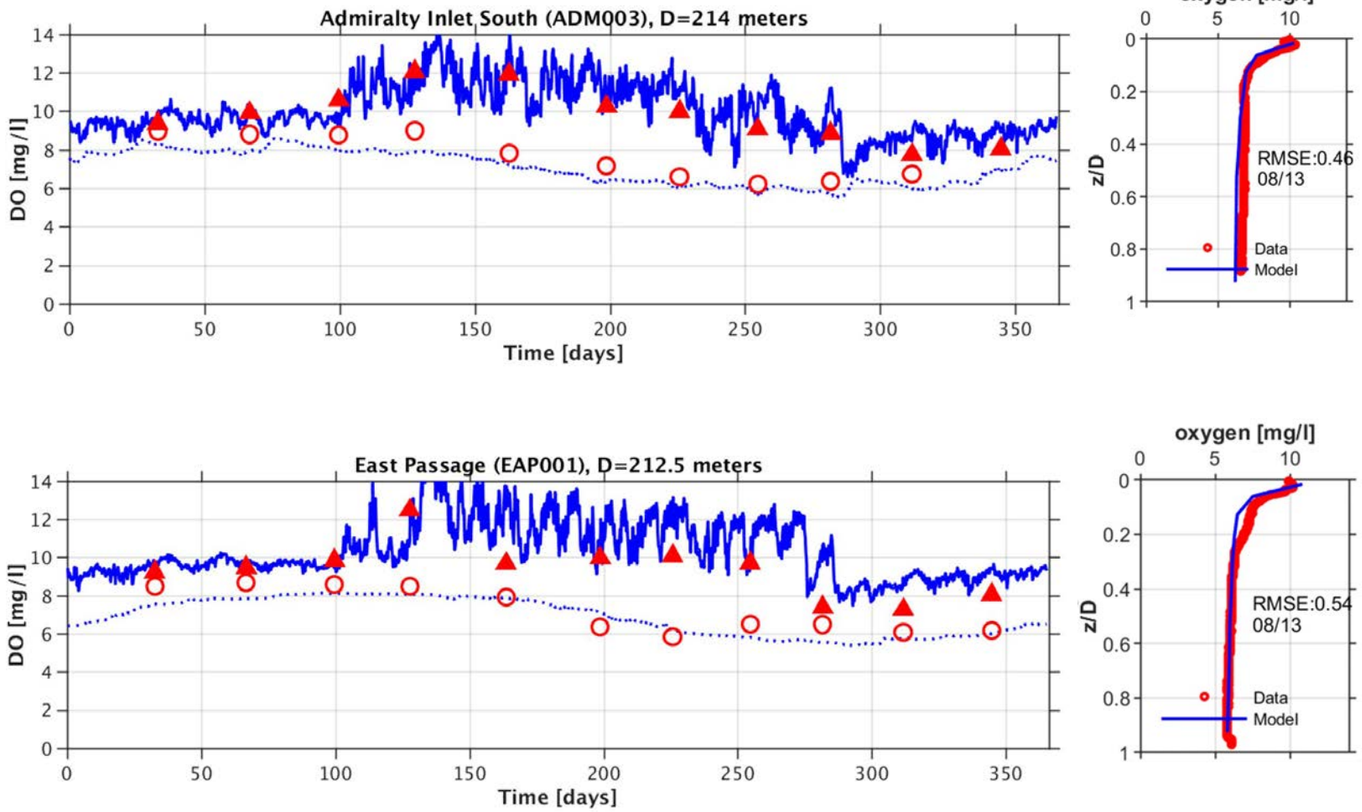


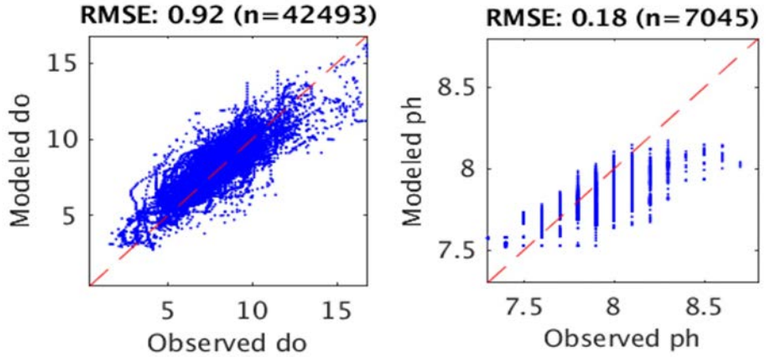


DOH monitoring stations

Re-validation of SSM and Development of Fecal Bacteria Module

➢ SSM – Validation Biogeochemistry for Year 2012:



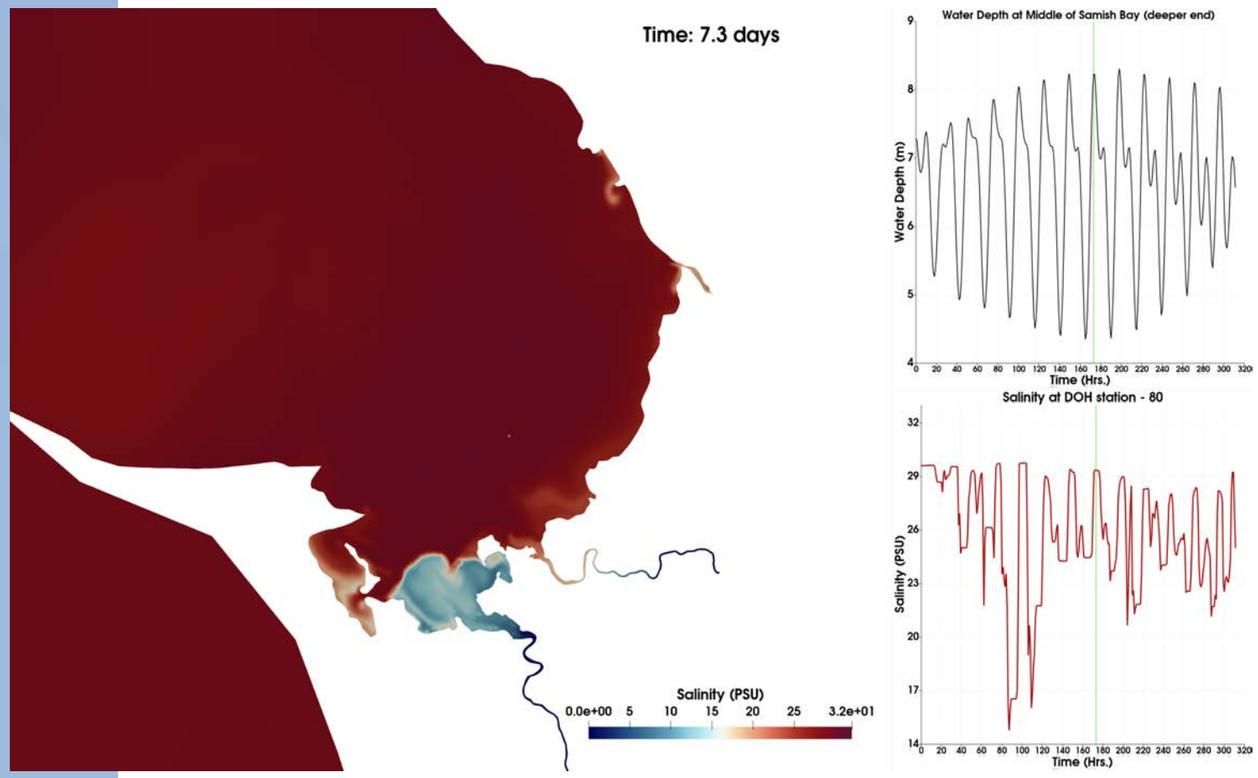


	Standard Y2012 Validation Typical simulation using inputs derived from 2012 data		
	ME	**RMSE**	**WSS**
T (°C)	-0.27	0.76	0.96
S (ppt)	-0.12	0.97	0.84
DO (mg/L)	-0.07	**0.92**	0.91
Nitrate NO_3+NO_2 (µ mol/L)	-0.83	7.55	0.88
Chlorophyll a (µg /L)	0.19	2.63	0.74
Phosphate PO_4 (µ mol/L)	-0.06	0.61	0.79
pH	-0.09	**0.14[a]**	0.67

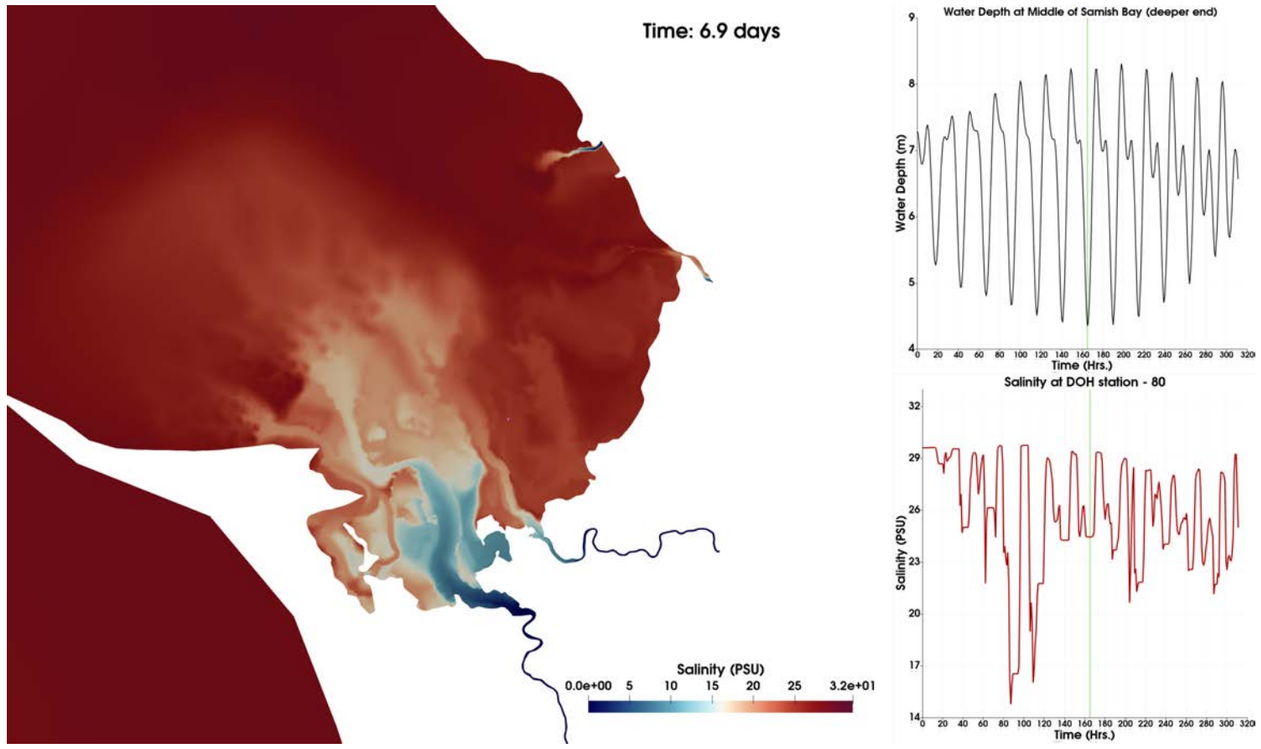
ME **= Mean error (bias)**
AME **= Absolute mean error**
RMSE **= Root-mean-square error**
WSS **= Willmott (1982) Skill Score**

Samish Bay - Circulation, Freshwater Plumes Simulations, and Flushing Analysis

- **Samish Bay – Simulation of Freshwater Plumes in Samish Bay - high flow spring tides:**



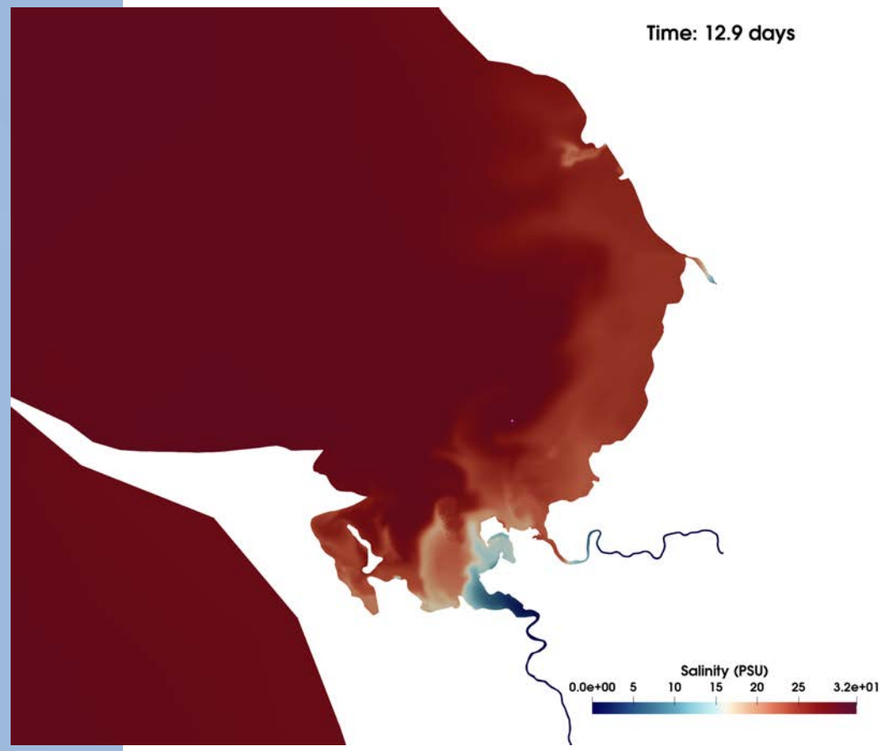
Spring Flood - January

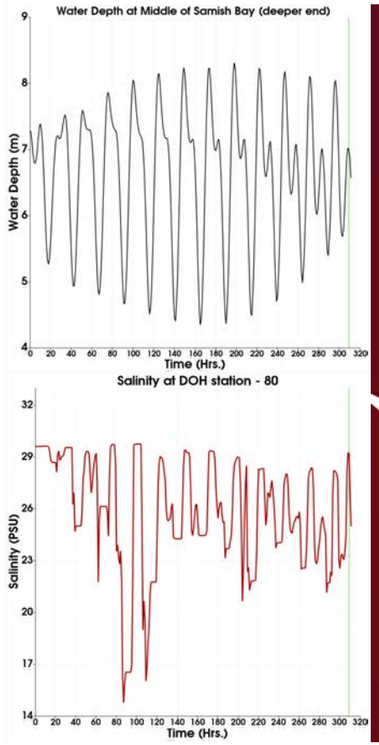


Spring Ebb - January

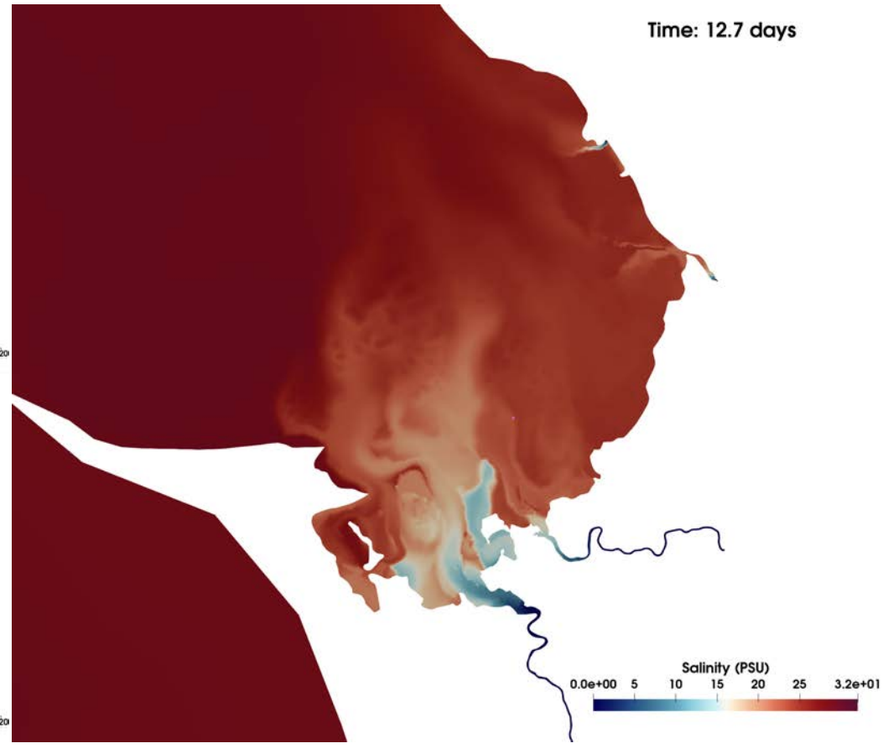
Samish Bay - Circulation, Freshwater Plumes Simulations, and Flushing Analysis

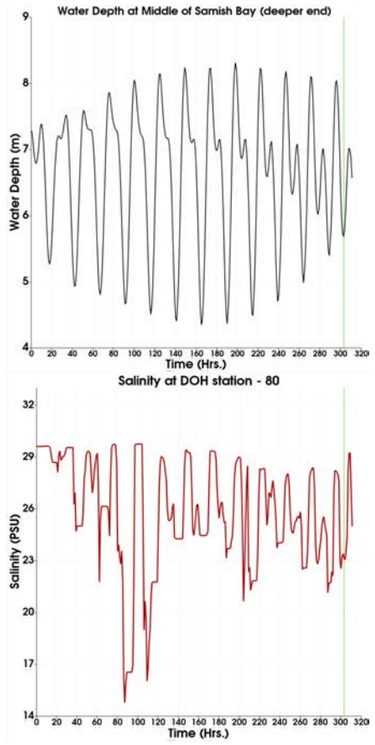
- **Samish Bay – Simulation of Freshwater Plumes in Samish Bay high flow neap tides:**





Neap Flood - January

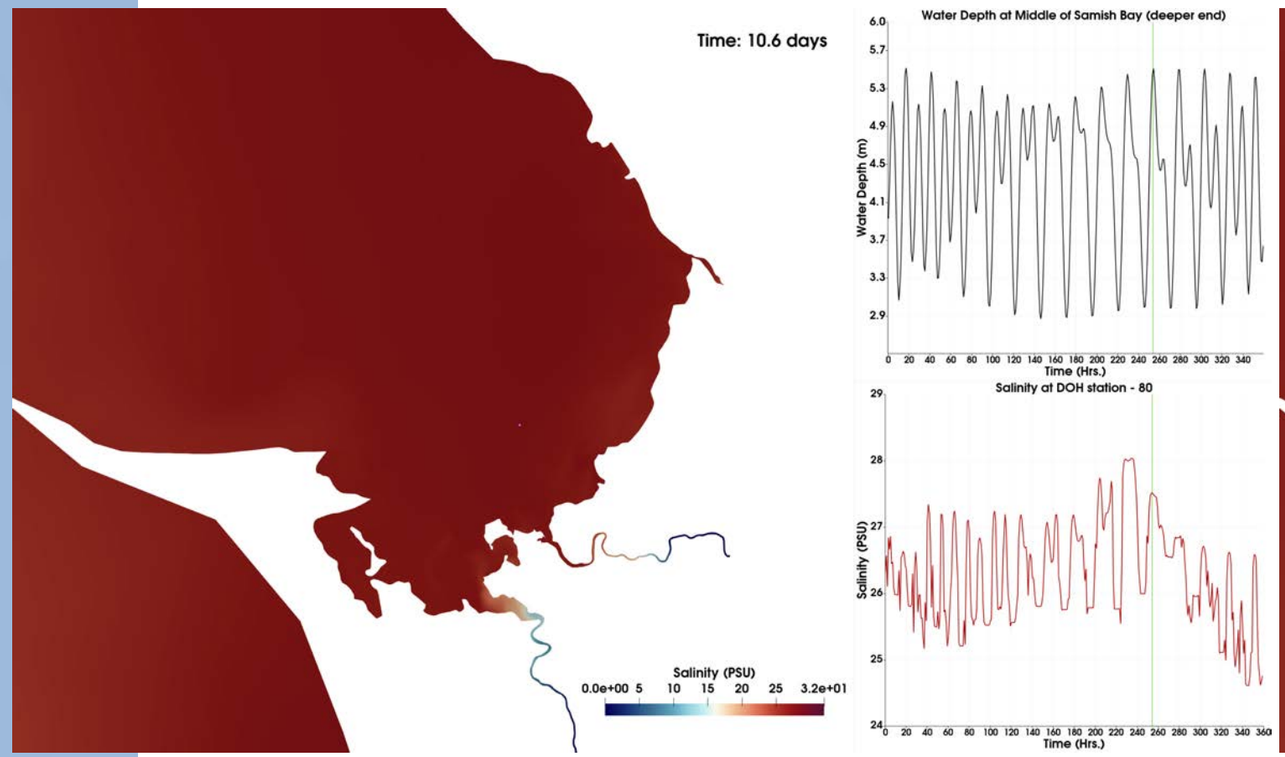




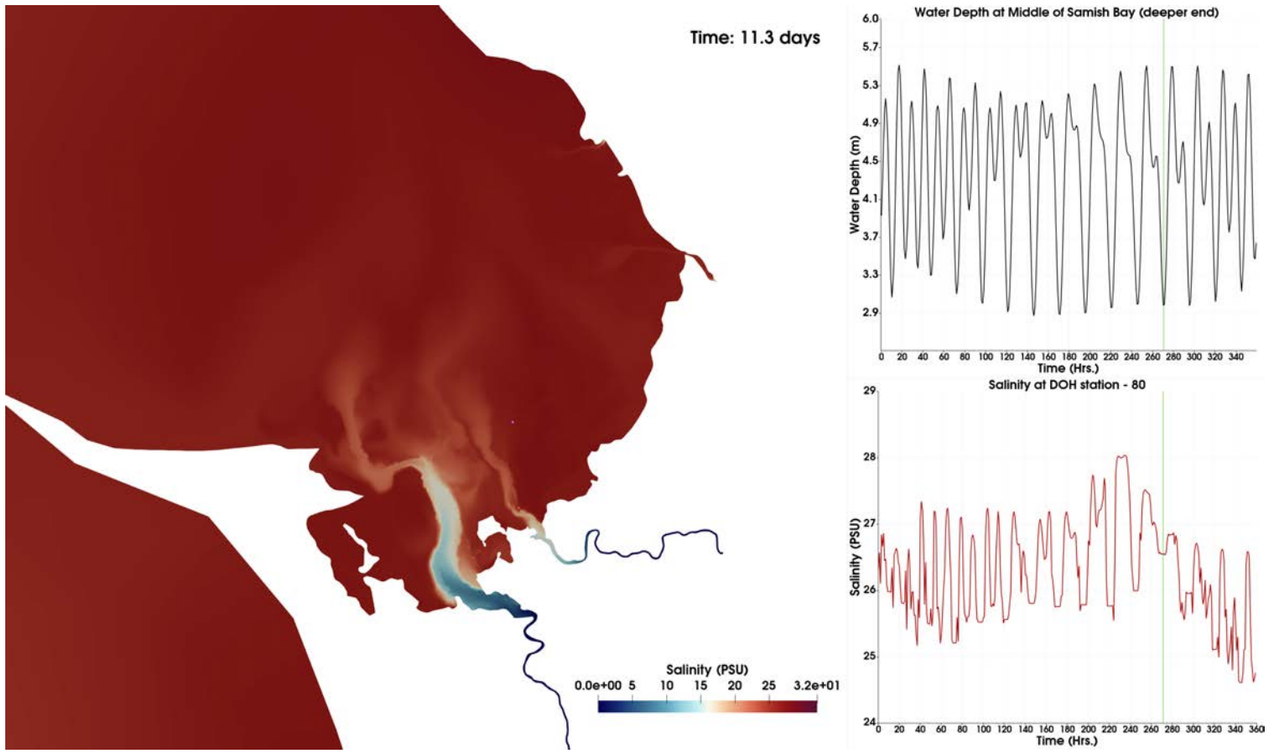
Neap Ebb - January

Samish Bay - Circulation, Freshwater Plumes Simulations, and Flushing Analysis

- **Samish Bay – Simulation of Freshwater Plumes in Samish Bay low flow spring tides:**



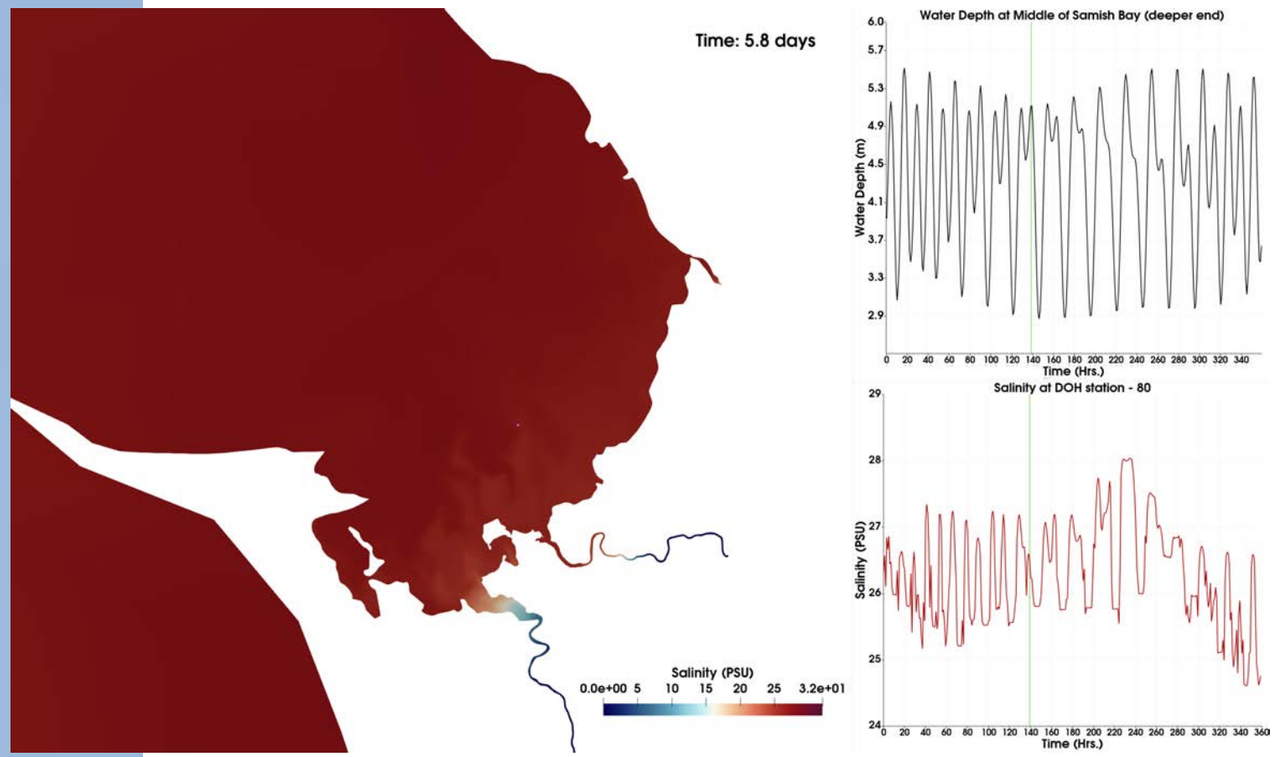
Spring Flood - September



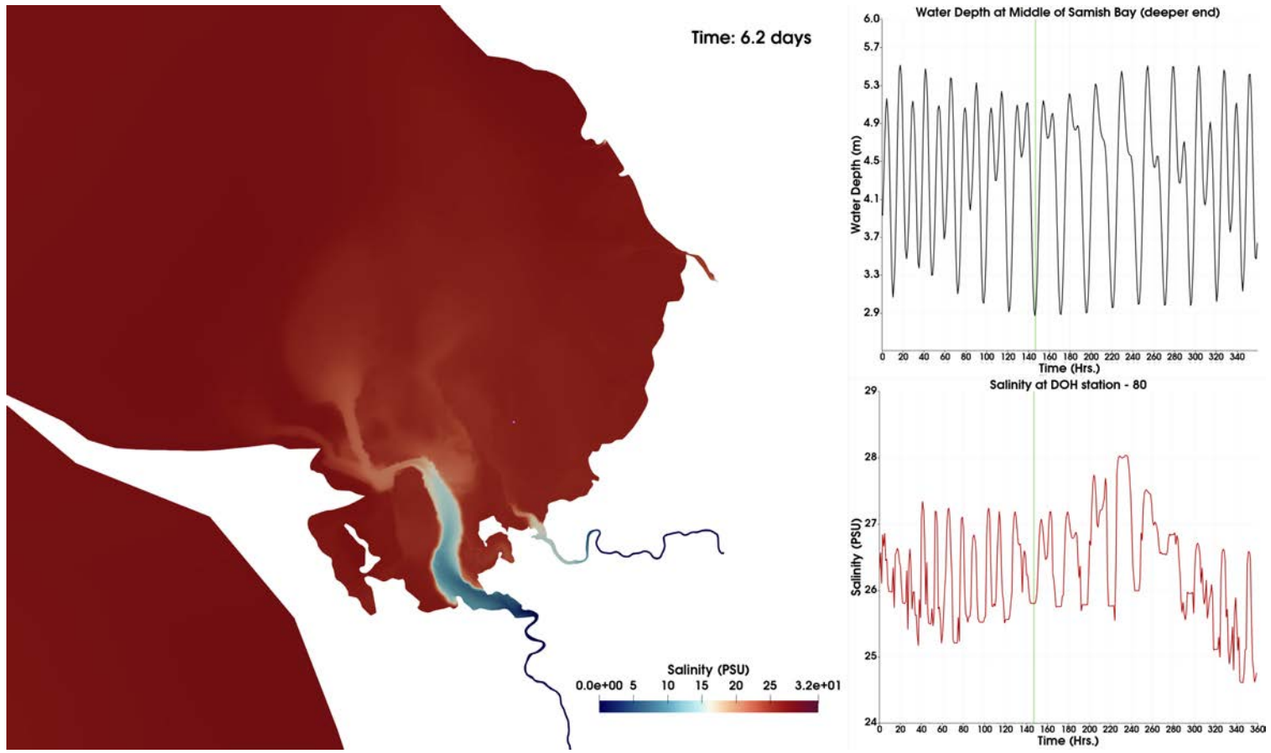
Spring Ebb - September

Samish Bay - Circulation, Freshwater Plumes Simulations, and Flushing Analysis

- **Samish Bay – Simulation of Freshwater Plumes in Samish Bay low flow neap tides:**



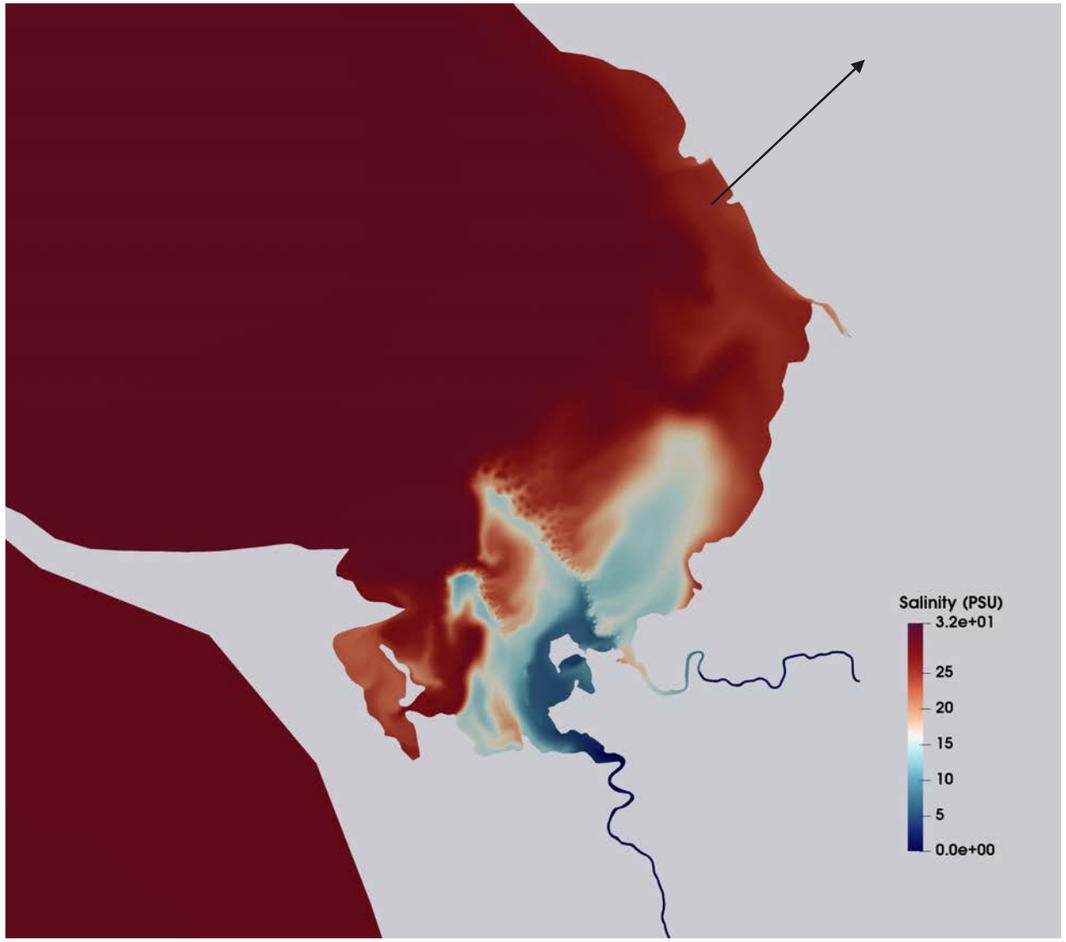
Neap Flood - September

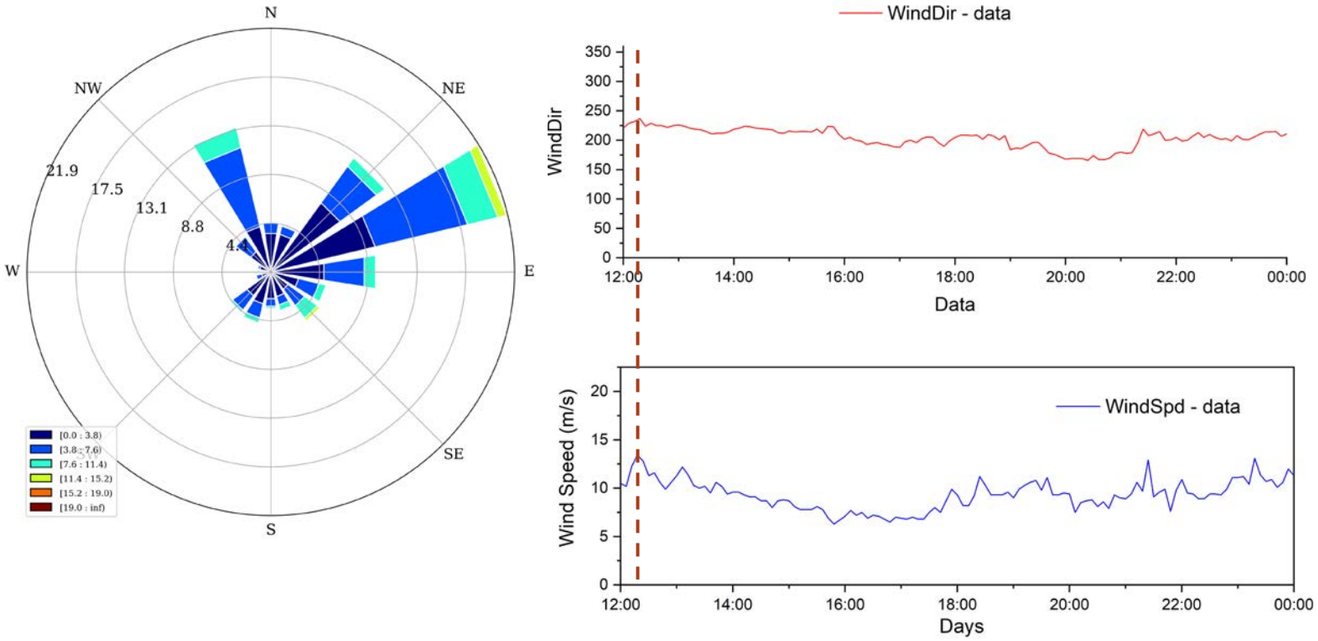


Neap Ebb - September

Samish Bay - Circulation, Freshwater Plumes Simulations, and Flushing Analysis

- **Samish Bay – Simulation of freshwater plumes in Samish Bay under different Winds:**
  - **Southwesterly winds**

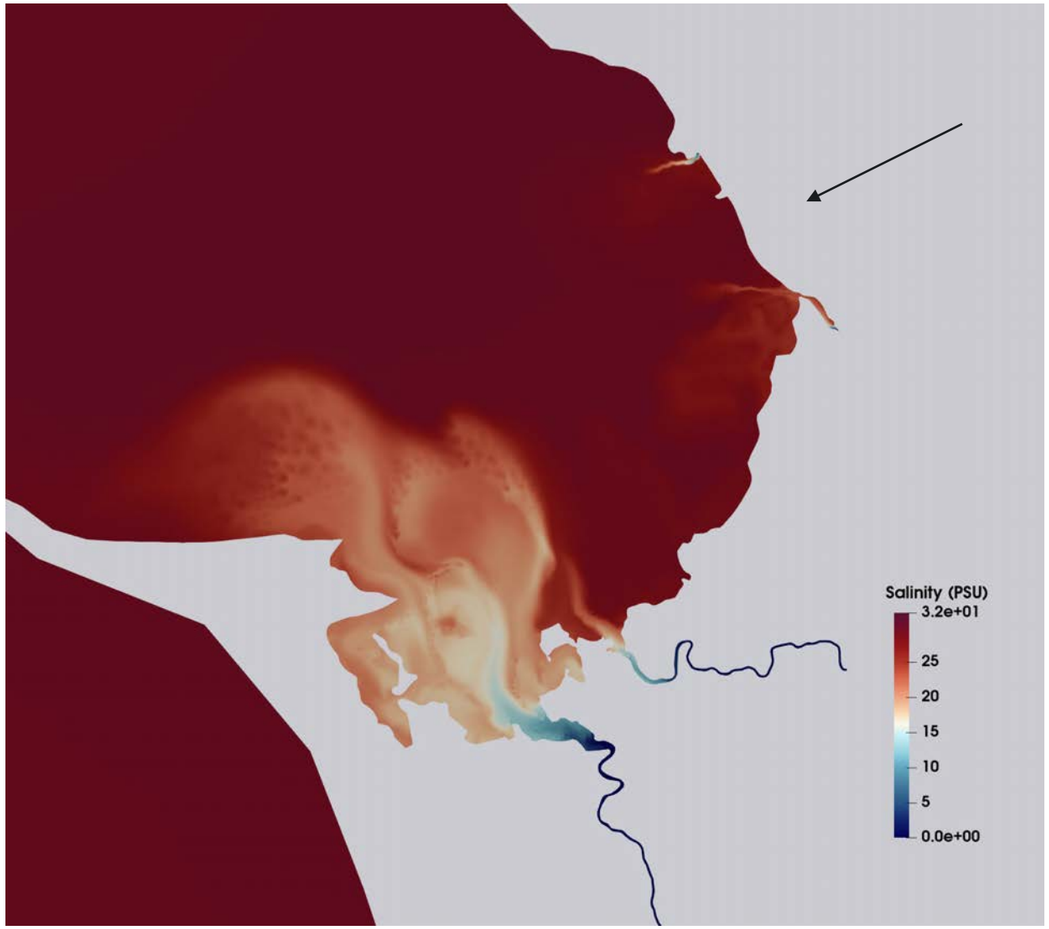


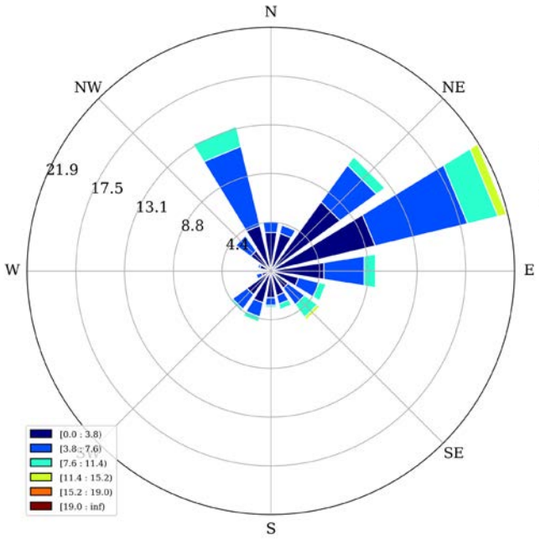


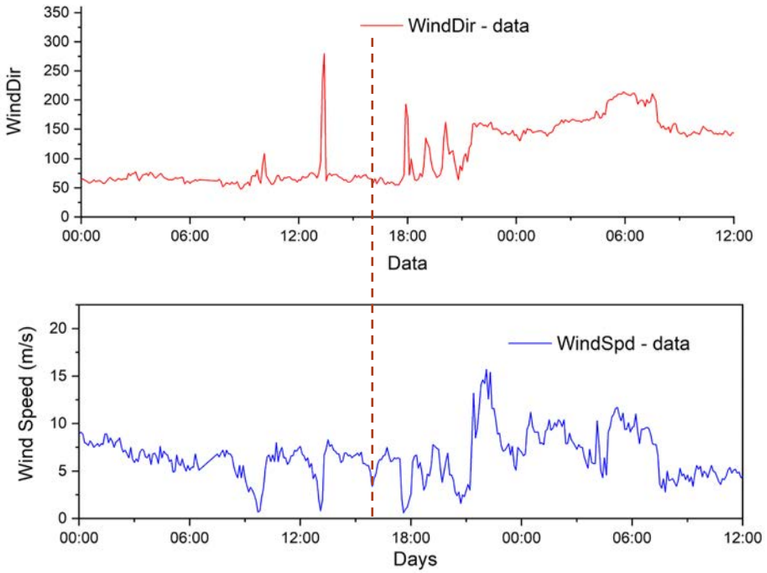
Wind effect on the freshwater plume on January 5th

Samish Bay - Circulation, Freshwater Plumes Simulations, and Flushing Analysis

- **Samish Bay – Simulation of freshwater plumes in Samish Bay under different Winds:**
  - **Northeasterly winds**







Wind effect on the freshwater plume on January 2nd

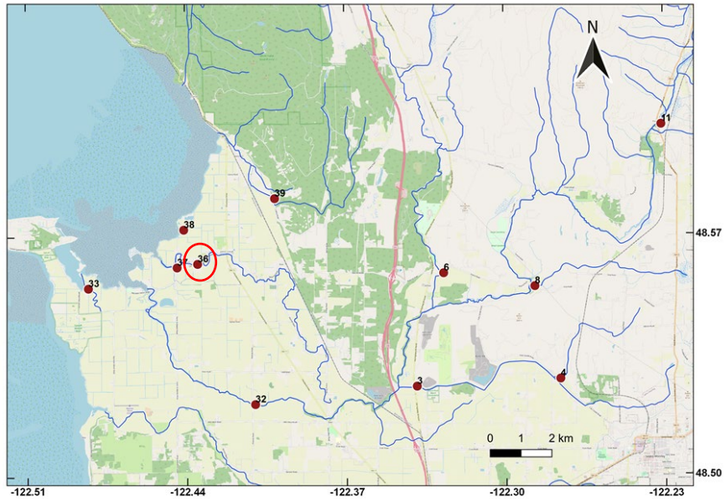
Conclusions and Next Steps

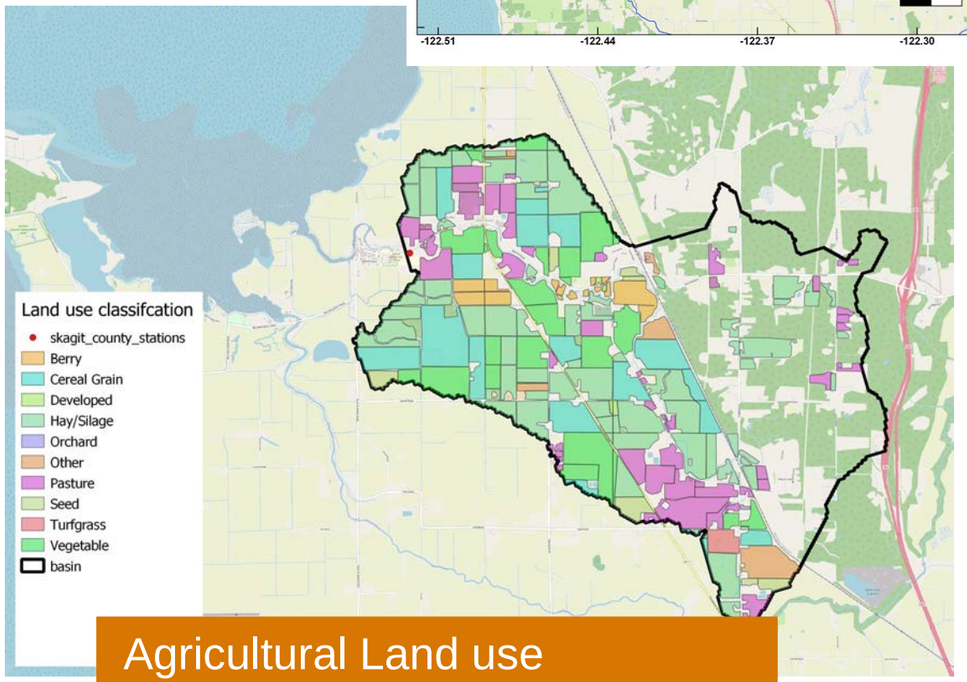
Conclusions from the study so far:

- Successfully simulated the water circulation in Samish Bay
- The freshwater plumes from Samish river is significantly affected by tides and winds

Next Steps:

- Fecal bacteria loading estimate using land use characterization
- Simulate fecal bacteria fate and transport inside Samish Bay
- Do the same for Portage Bay and Drayton Harbor





Agricultural Land use Characterization for estimate fecal bacteria loading

Pacific Northwest
NATIONAL LABORATORY

Questions