The Salish Sea Model:

A tool to test nutrient reduction options in Puget Sound

Developed for the September 20, 2018
Puget Sound Nutrient Forum

Purpose of the Salish Sea Model

The Salish Sea model (SSM) is the tool we use to test the potential for nutrient reduction options in Puget Sound to meet our water quality standards for DO. It simulates complex interactions between the ocean, climate, and circulation impacts between the Puget Sound and the rest of the Salish Sea. We use it to evaluate the water quality response to different nutrient reduction scenarios while accounting for complex factors, including: water circulation, incoming ocean conditions, watershed inflow and quality, regional climate and weather, and estimated human contribution of nutrients.

The model was developed by Pacific Northwest National Laboratory, in collaboration with Ecology, and with funding support from the U.S. Environmental Protection Agency. We have switched to using the Salish Sea model from an older model that was used for the South/Central Puget Sound dissolved oxygen (DO) study completed in 2014 (Roberts et al, 2014). The following improvements have increased the model's ability to accurately predict marine water quality:

- Addition of sediment diagenesis (allowing for dynamic oxygen flux between sediments and bottom waters).
- Addition of the carbonate system (to improve how carbon is represented in the model).
- Expanded model domain to include coastal waters from the Columbia River to the northern tip of Vancouver Island.
- Refinement of existing river and stream inputs, updated surface flows and water quality, and updated marine point source flows and water quality.

For more information on the Salish Sea Model, visit our website blog at:
http://ecologywa.blogspot.com/2017/11/puget-sound-nutrient-watch-salish-sea_8.html.

Targets used to assess the Salish Sea model results

Targets for evaluating the Salish Sea model results are based on achieving compliance with the marine water quality standards for DO. There are two parts to Washington's DO water quality standards for marine water that are set to protect aquatic life:

1. Numeric criteria for the designated uses of the waterbody range between 4 to 7 mg/L for daily minimum DO, and

2. When a waterbody DO is naturally lower than the numeric criteria, there is an allowance for the sum of human sources to not reduce DO by more than 0.2 mg/L below the waterbody's natural condition, so that effects on aquatic life from further decreased DO are minimal.

We will assess the effect of various nutrient reductions in Puget Sound with a target of achieving numeric standards, or where that is not possible, achieving a human-caused DO deficit that is within 0.2 mg/L DO of estimated natural reference conditions.

Process to assess nutrient reductions

We are using series of model runs to test the marine water quality response to a variety of hypothetical nutrient reductions from Washington human sources in the Salish Sea, including:

1. Evaluate existing conditions for individual years with actual flows, nutrient loading, climate, and ocean boundary conditions.

2. Define the background reference condition with nutrient loads from human sources removed.

3. Evaluate the significance of large categories of human nutrient sources and to establish a range of potential improvements that could be achieved using bounding scenarios.

4. Use what we learn from the bounding scenarios to model more detailed nutrient reductions that optimize potential solutions and their benefits.

Objectives for modeling phases

1. Existing Conditions

Existing conditions are modeled using actual flow data from marine and watershed sources, as well as actual nitrogen and carbon levels (where available) to measure DO depletion. Regression based estimates and extrapolations will be used to fill data gaps. We have calibrated the model with extensive marine datasets, and computed model performance statistics to make sure it accurately predicts water quality. The Salish Sea model is ready to be used to predict marine water quality changes due to changes in human nutrient sources.

In order to understand how annual variability affects Puget Sound, model years were chosen to represent "above average" and "average" years according to the residence time index for the Central Puget Sound basin. Model year 2006 represents an "above average" year condition because it exhibited warmer than average climate conditions and longer than average residence time during summer months. Model year 2008 represents an "average" year condition because it exhibited average climate and residence time conditions according to the index.

2. Reference Conditions

The reference condition is defined as the water quality conditions for a given model year that we would expect if Washington marine and watershed human sources were not present. The reference condition includes the ocean-boundary condition at its existing levels.

The existing ocean-boundary condition is included in the reference conditions. Global human and natural sources influence the quality of deep ocean waters in the North Pacific. Variability in the ocean-boundary condition is affected by multiple oceanic process that control the magnitude of upwelling from the North Pacific Ocean waters, bringing low oxygen and high nitrogen loading into the Straits of Juan de Fuca and into the Puget Sound. We can calculate the change in DO due to human sources (reference condition minus existing condition) because the ocean condition is the same between the existing and reference scenarios.

3. Bounding scenarios

To understand the relative importance of different nutrient sources in Puget Sound, we need to isolate the effect of large categories of human nutrient sources and predict the system's ability to achieve water quality standards. We call these bounding scenarios.

We designed these scenarios to understand the significance of land-based loadings (rather than oceanic or atmospheric sources) and how Puget Sound water quality might improve if there are nutrient reductions from large categories of sources. The two major categories of sources are:

1. **Marine point sources.** This category includes wastewater treatment plants and industrial facilities discharging either in close proximity to, or directly into, estuarine waters.

2. **Watershed sources.** This category is characterized by loadings estimated at the mouths of rivers and streams flowing into the Salish Sea. Estimated loadings from each watershed that enters the Salish Sea represent the sum of point (wastewater, stormwater, and other permitted dischargers) and nonpoint source pollution, as well as natural sources.

A separate issue paper titled "Bounding Scenarios: A first step in testing nutrient reduction scenarios using the Salish Sea model" provides further details on what specific model runs were conducted for the bounding scenarios.

4. Optimization scenarios

Optimization scenarios are detailed nutrient reduction scenarios to predict the water quality response to a variety of marine and watershed source reductions in the next modeling phase. We expect the bounding scenario outputs to help us understand which sources we must focus on for reductions.

During this phase we will further analyze scenarios with different combinations of source reductions, levels of efficiency, seasonal reductions, or other ideas. Finding a set of point and nonpoint source reductions, balancing cost and feasibility that meets the water quality improvement target is the goal. We will conduct up to four iterative periods of model runs, with each consecutive period further refining the nutrient reduction preferred options.

We will test nutrient reduction options to form the basis of a Puget Sound Nutrient Management Plan. The plan will be an alternative to a Total Maximum Daily Load (TMDL) that will include: specific nitrogen and carbon load reduction targets, a monitoring and adaptive management strategy, and a prioritized list of actions needed to restore and protect Puget Sound water quality.

Coming up with questions for optimization scenarios

Results from the bounding scenarios will be shared with the public during fall 2018 and discussed with members of the Puget Sound Nutrient Forum (Ecology's stakeholder advisory group) and the Puget Sound Partnership's Marine Water Quality Implementation Strategy (MWQ IS). These two groups will use the bounding scenario results along with other information they develop to propose questions and scenarios for testing with the model.

We will seek input from these groups throughout this modeling phase, and discussing the results so we benefit from their ideas and expertise as well as increasing stakeholder understanding of potential nutrient reduction solutions.

Timeline for the Salish Sea model run phases

Project Task	Who is Involved	Status of project task	Estimated Timeline
Bounding scenarios for initial model runs	• Ecology	A suite of model run scenarios to inform the more detailed modeling of nutrient reductions during the optimization phase.	Fall 2018
Development of Optimization Scenario model runs	• Ecology • Nutrient Forum Participants • MWQ-IS Core & IDT	Conduct up to four iterative periods of optimization scenario model runs from approximately May 2019 through April 2021.	Spring 2019 – Spring 2021
Draft Puget Sound Nutrient Management Plan	• Ecology	Ecology will draft a nutrient management plan that will go out for public review and be finalized in 2022.	Mid-2021 to mid-2022

Where can I find more Information?

Ecology's website on reducing nutrient in Puget Sound has access to resources and documents related to this project: https://ecology.wa.gov/Water-Shorelines/Puget-Sound/Helping-Puget-Sound/Reducing-Puget-Sound-nutrients

The Quality Assurance Project Plan for the Salish Sea modeling effort: McCarthy, S. et al. 2018. Quality Assurance Project Plan: Salish Sea Model Applications. WA Department of Ecology, Publication #18-03-111. https://fortress.wa.gov/ecy/publications/SummaryPages/1803111.html

Roberts, M., T. Mohamedali, B. Sackmann, T. Khangaonkar, and W. Long. 2014. Puget Sound and the Straits Dissolved Oxygen Assessment: Impacts of Current and Future Human Nitrogen Sources and Climate Change through 2070. WA Department of Ecology, Publication #14-03-007. https://fortress.wa.gov/ecy/publications/SummaryPages/1403007.html