Calibration of a three-dimensional model of water quality in South Puget Sound

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Abstract

South Puget Sound, west of the Tacoma Narrows, experiences low dissolved oxygen (DO) levels. Budd Inlet is one of the critical areas within South Puget Sound, and it is surrounded by a relatively large population center that contributes point and nonpoint sources of nutrient loading. Other critical areas do not have adjacent population centers with large point or nonpoint sources of nutrient loading (e.g. Carr and Case Inlets). A primary question is the extent to which human sources of nutrient loading to South Puget Sound, including sources from adjacent areas as well as indirect sources originating further away in South Puget Sound or from the main basin of Puget Sound, influence DO levels in the various sensitive areas of South Puget Sound.

A numerical model was considered to be a critical tool to quantify the relationships between human sources of nutrient loading at many different locations and the response of DO concentrations in the various sensitive areas. A three-dimensional hydrodynamic and water quality model of South Puget Sound was developed for this purpose. The water quality model simulates the concentrations of DO in response to primary production of phytoplankton, which is limited by light, temperature, and nutrient concentrations. Other important processes that affect DO are also included in the model (e.g. oxidation of organic material, reaeration, sediment oxygen demand, and nitrification). The model includes 15 water quality state variables and over 50 kinetic processes among these variables.

The model was calibrated to data collected over a 16-month period from July 2006 through October 2007. Calibration of the model involved running batches of up to 70 model runs at a time with a matrix of critical parameter estimates. The parameter estimates were constrained to be within the ranges of prior distributions of expected reasonable values. The results of each batch of runs were examined to compare the relative model skill with different combinations of parameter values. Information about which combinations of parameters improved skill was used to guide the selection of parameter combinations for the next batch of runs. This process was repeated numerous times and resulted in continuous improvement of the skill of the model from one batch to the next.

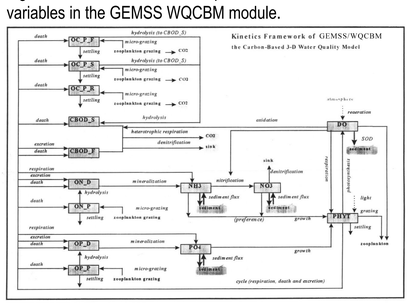
Model characteristics

- ERM GEMSS modeling framework (www.erm-smg.com)
- Curvilinear grid with 2558 cells with typical 600 m horizontal resolution (300-1300m resolution)
- Vertical layering using Z-level method with variable layer thickness and wetting/drying with up to 17 vertical layers with 4 to 29 m vertical resolution, gradually increasing thickness from surface to bottom
- Bathymetry based on Finlayson (2005)
- Tidal forcing time series of water levels from the pstides Puget Sound Tide Channel Model (Finlayson, 2004) prescribed as Dirichlet open boundary condition
- Freshwater boundaries for 75 watersheds and 33 NPDES wastewater discharges with estimated time-varying daily flows and loads
- Wind stress using Wu (1983) method
- Bottom friction using Chezy method
- Vertical diffusivity turbulence model uses Prandtl's mixing length approach.
- QUICKEST-ULTIMATE transport modeling scheme
- Water quality kinetics with 15 state variables and over 50 kinetics processes (Table 1 and Figure 1)
- Automated output post-processing and visualization using Matlab scripts (Figure 2).

Table 1. List of the water quality state variables in the GEMSS WQCBM module.

ID	Variable	Notation	Unit
C1	Ammonia Nitrogen	NH3	g N/m3
C2	Nitrate Nitrogen	NO3	g N/ m3
C3	Inorganic Phosphorus	PO4	g P/ m3
$C4_{DA}$	Phytoplankton Carbon (diatoms)	PHYT_DA	g C/ m3
$C4_{DF}$	Phytoplankton Carbon (dinoflagellates)	PHYT_DF	g C/ m3
$C5_F$	Fast-Reacting Dissolved Carbonaceous BOD	CBOD_F	g O2/ m3
$C5_S$	Slow-Reacting Dissolved Carbonaceous BOD	CBOD_S	g O2/ m3
C6	Dissolved Oxygen	DO	g O2/ m3
$C7_D$	Dissolved Organic Nitrogen	ON_D	g N/ m3
$C7_P$	Particulate Organic Nitrogen	ON_P	g N/ m3
$C8_D$	Dissolved Organic Phosphorus	OP_D	g P/ m3
$C8_P$	Particulate Organic Phosphorus	OP_P	g P/ m3
$C9_F$	Fast-Reacting Particulate Organic Carbon	OC_P_F	g C/ m3
$C9_S$	Slow-Reacting Particulate Organic Carbon	OC_P_S	g C/ m3
$C9_R$	Refractory Particulate Organic Carbon	OC_P_R	g C/ m3

Figure 1. Flow chart of kinetics processes between variables in the GEMSS WQCBM module.



General information about the South Puget Sound Dissolved Oxygen Study can be found at our project Web site:
www.ecy.wa.gov/puget_sound/dissolved_oxygen_study.html

This poster is Department of Ecology publication number 11-03-059, and can be found online at
www.ecy.wa.gov/biblio/1103059.html

Figure 2. Predicted and observed water quality from January through October 2007 at six sentinel stations in South Puget Sound.