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Memorandum

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Subject: Puget Sound Model Review Approach
Date: September 22, 2009
Revised December 14, 2009

This document outlines the general approach for review of various models developed by Washington Department of Ecology (ECY) for simulating circulation and water quality in Puget Sound and adjoining water bodies at multiple spatial scales. The outlined approach provides a proposed sequence of steps or tasks to be followed for each model or model component as well as defining certain activities specific to the circulation and water quality model components.

1. Review Appropriateness of Selected Models

This task will review and evaluate the appropriateness of selected models to determine that the models include the fundamental physical and biogeochemical processes necessary to simulate circulation and dissolved oxygen and nutrient dynamics in the corresponding physical domains consistent with project objectives. The task will briefly review the reasons for model development, the model selection process, identification of principal study questions, and associated modeling objectives as summarized in the project QAPP and related documents. This will provide the context for the review of the appropriateness of selected models. It will also provide important information relative to the degree of accuracy required in different aspects of the model configuration, calibration, and validation.

In addition to material provided by ECY, secondary material including model documentation and reports and papers describing previous model applications may be reviewed. Model source code will be reviewed only to the extent necessary to clarify insufficient detail or uncertainty in reviewed material. Model formulation and process representation limitations that could impact model performance relative to meeting project objectives will be identified and short- and long-term resolution strategies proposed.

2. Summarize Observational Data to Support Model Configuration, Calibration and Validation, and Scenario Simulation

The purpose of this task to summarize and obtain documentation as necessary for observational data sources used for model configuration, calibration and validation, and scenario simulation development. It is designed to streamline subsequent tasks, which will look more closely at specific data types and usage, by ensuring that appropriate information is available.

3. Review Model Configuration

Model configuration is defined as the sequence of steps leading to an operational model and includes selection of spatial resolution and grid development, selection of temporal simulation periods and assembly of corresponding forcing functions, boundary and initial conditions, and preliminary selection of adjustable model parameters. This task evaluates the forcing functions, boundary, and initial conditions from a general perspective as to suitability and use of appropriate processes. Detailed quality review of model input data is addressed separately in optional task 8. Subtasks include:

3.1. Model Spatial Resolution and Grid Development

The selection of model spatial resolution generally involves balancing trade offs between spatial resolution of important physical and biogeochemical processes, spatial data density, overall model accuracy and model computational performance. For example extremely fine spatial resolution may not be supported by corresponding dense data and could yield an operational model having high computational requirements and excess run time relative to desired simulation duration. Spatial resolution or grid sensitivity analysis, with respect to both horizontal and vertical resolution, is often appropriate to optimize between these competing requirements. This task will review and evaluate how these issues are addressed and consider associated topics of grid quality and bathymetric data and its interpolation to the model grid.

3.2. Selection of Model Temporal Simulation Period

The rationale for selection of the overall model simulation period, including identification of subintervals for calibration, validation, and scenarios simulations, will be reviewed and evaluated relative to the temporal density of supporting observational data and the computational requirements imposed by the combination of spatial and temporal resolution.

3.3. Circulation Model Boundary Conditions and Forcing Functions

This task will review the major groups of boundary conditions and forcing functions required by the hydrodynamic and circulation model components. Emphasis will be placed on evaluating model

boundary condition and forcing function formulations and options, selection of boundary condition locations, and use of observational data to define the boundary conditions and forcing functions. Specific groups of boundary conditions and forcing functions to be reviewed and evaluated will include:

3.3.1 – Hydrodynamic open boundary conditions for water surface elevation and/or inward-outward wave propagation

3.3.3 – Open boundary conditions for salinity and temperature

3.3.4 – Point and distributed fresh water inflows and associated temperatures

3.3.5 – Surface wind stress forcing functions and its spatial representation

3.3.6 – Atmospheric forcing including surface wind stress and thermal forcing functions and water column-sediment bed thermal coupling

Additional groups will be considered as appropriate. This subtask will evaluate the appropriateness of or identify any deficiencies in specification of boundary conditions and forcing functions and methods for resolution proposed.

3.4. Circulation Model Initial Conditions

Circulation models are relatively insensitive to initial conditions after an appropriate initialization period. However, for salinity this period can be long and can be eliminated with initial conditions which are approximately dynamically balanced. Circulation model initial conditions will be reviewed relative to these considerations and methods for refining initial conditions recommended if appropriate.

3.5. Circulation Model Options and Parameters

Circulation and transport models have a variety of options and parameters that require initial specification and possible subsequent adjustment during calibration. Areas to be reviewed include, but are not necessarily limited to:

3.5.1 – Numerical solution options and time step size, which influence model accuracy and stability.

3.5.2 – Bottom boundary resistance and wind stress parameter specification.

3.5.3 – Adjustable turbulence closure and mixing parameters

3.5.4 – Adjustable atmospheric thermal forcing and heat exchange parameters

As appropriate, various model parameters will be compared with accepted by ranges for similar water body and geographic locations.

3.6. Water Quality Model State Variable Selection

Current water quality models typically allow for custom configuration of water column state variables as well as the choice between using observed or predicted sediment flux.

This task will review the procedure used to select the state variable set relative to perceived variable importance, supporting observational data, and ultimate water quality management objectives.

3.7. Water Quality Model Boundary Conditions and Forcing Functions

This task will review the major groups of boundary conditions and forcing functions required by the water quality components. Emphasis will be placed on evaluating model boundary condition and forcing function formulations and options, selection of boundary condition locations, and use of observational data to define the boundary conditions and forcing functions. Specific groups of boundary conditions and forcing functions to be reviewed and evaluated include:

3.7.1 – Open boundary conditions for water quality constituents

3.7.2 – Point source loads for water quality constituents

3.7.3 – Land based non-point source loads for water quality constituents

3.7.4 – Atmospheric deposition

3.7.5 – Sediment oxygen and nutrient flux (if the sediment diagenesis formulation is not used)

Additional groups will be considered as appropriate. Particular attention will be given to reviewing methodologies used to predict loads and split total loads into different reactive and phase classes such as the splitting organic material into labile and refractory and particulate and dissolved classes or splitting total nitrogen loads between organic and inorganic variables. The extent to which uncertainty in load estimates are evaluated will be reviewed and evaluated.

3.8. Water Quality Model Initial Conditions

Observational data and methods used to establish water quality model initial conditions will be evaluated. Although water column concentration fields can come into dynamic equilibrium on seasonal time scales, achieving initial conditions representing an approximate dynamic equilibrium between the water column and sediment when the sediment diagenesis formulation is used for sediment flux prediction is much more problematic. In the event that the predictive sediment flux formulation is utilized, specific attention will be directed toward how sediment bed initial conditions are developed.

3.9. Water Quality Model Parameters

State of the art water quality models have a vast number of parameters defining reaction kinetics, including base reaction rates and associated physical and biogeochemical limiting effects, particulate settling, and water-column bed exchange processes. Current practice suggests that these parameters be preliminarily set using past experience for similar water bodies and geographical settings in conjunction with what are considered acceptable ranges. Methods for preliminary specification of

parameters and their appropriateness will be reviewed and evaluated. Parameters will be organized by groups as follows:

3.9.1 – Algae parameters, including growth rate, light and nutrient limitations, and optimal temperature ranges and geographical preferences

3.9.2 – Organic carbon parameters

3.9.3 – Organic and inorganic phosphorous parameters

3.9.4 – Organic and inorganic nitrogen parameters

3.9.5 – Micro-nutrients such as silica

3.9.6 – Dissolved oxygen parameters

3.9.7 – Sediment diagenesis model parameters or externally specified sediment fluxes including spatial variations

4. Review Model Calibration

Model calibration is defined as the adjustment of model boundary conditions and forcing functions and selected model parameters to achieve a desired or defined level of agreement between model predictions and observations of circulation and water quality state variables. Procedures to measure of the level of agreement range from qualitative visual comparison to a range of rigorous quantitative measures. The purpose of this task is to determine if calibration methods and parameters were appropriately selected, their adjustment constrained to remain within acceptable ranges, and the resulting levels of agreement between predicted and observed state variables are consistent with intended model use. Defining acceptable levels of agreement is often difficult, however results for similar modeling studies that have undergone extensive independent peer review provides a generally accepted basis and will be summarized in this review for comparison with results obtained in this study. Model calibration will also be evaluated in relation to the modeling objectives identified in the QAPP.

4.1. Circulation Model Calibration

Circulation model state variables used for calibration include water surface elevation, horizontal current velocities, salinity concentration, and temperature. These variables respond to changes in boundary conditions, forcing functions, and adjustable model parameters. Adjustments to boundary conditions and forcing functions to improve the level of agreement must be soundly supported in relation to the observational data used. Appropriate quantitative measures include time series error measures such as mean absolute error and root mean square error, linear regression, least squares harmonic analysis, and empirical orthogonal function analysis. Variables, observational data, and quantitative measures used for calibration will be reviewed and compared with published calibration performance from similar model studies.

4.2. Water Quality Model Calibration

All observed water quality model state variables are typically used for calibration. These variables respond to changes in boundary conditions, loads and adjustable model parameters. Adjustments to boundary conditions and loads should be consistent with uncertainty in observational data upon which they are based. Adjustments to reaction parameters, including physical and biogeochemical limiting effects, should keep parameters within acceptable ranges. For current water quality models utilizing multiple algae classes and multiple reactive classes of organic carbon, phosphorous, and nitrogen, the number of tabulated model parameters in calibration reports typically ranges from 80 to 120. Appropriate quantitative measures include time series error measures such as mean absolute error and root mean square error and linear regression. State variables, observational data, and quantitative measures used for calibration will be reviewed and compared with calibration performance from similar model studies.

5. Review Model Validation and Sensitivity and Uncertainty Analysis

This task will evaluate the validation of the models and also consider sensitivity and uncertainty analyses if they were conducted during the modeling study.

5.1. Model Validation

Model validation is defined as the evaluation of the level of agreement between model predictions and observations of circulation and water quality state variables over a time interval not used in the calibration process. The model is considered validated if a similar level of agreement similar to that obtained during calibration is achieved. Strict separation of calibration and validation is often difficult to achieve in practice as limitations in the extent of the observational dataset necessitates the use of the entire dataset in a combined calibration and validation activity. In this mode, high variability of conditions during the combined interval and corresponding consistent model performance is an important consideration. This subtask will evaluate validation of the circulation and water quality models or, if independent validations were not conducted, address the appropriateness of the calibration with respect to level of variability during the calibration period.

5.2. Sensitivity and Uncertainty Analysis

Sensitivity analysis is also important in demonstrating that the model is sufficiently calibrated, particularly in the absence of an independent validation period. Sensitivity analysis is also important in demonstrating that the model will be responsive to the range of load variations anticipated in management scenario simulation. Sensitivity analysis can also contribute to understanding the propagation of uncertainty in the water quality model when perturbations in loads and parameters represent the range of uncertainty in these variables. This subtask will evaluate the extent to which sensitivity and uncertainty analysis were incorporated into this study and make recommendations for further analysis if deemed appropriate as applicable to specific study components.

6. Review Model Scenario Selection and Results

This task will review and evaluate the procedures used to define model scenarios if applicable to the specific study components. As applicable, modifications to model configurations necessary to simulate the scenarios would be evaluated. Results of the scenarios will be evaluated for reasonableness and consistency with sensitivity and uncertainty analyses in the event that these

analyses were performed. Methods for quantifying the management effectiveness of the scenarios will be reviewed and alternate methods proposed if necessary.

7. Review Model Report and Associated Documentation

This final task will evaluate the model report and associated supporting documentation and software. It is assumed that draft reports will provide the primary source of information upon which the overall review will be based and reference readily available supporting documents necessary of completeness.

7.1. Model Report

The final review of the model report will validate that all issues identified in subsequent steps of the review have been addressed. The final review will also focus on ensuring that modeling objectives, limitations, findings, and conclusions are clearly stated.

7.2. Supporting Documentation

This sub-task will confirm that adequate support documentation for the model study and model are available. Documents to be considered would include data reports, work plans, QAPPs, model theory reports, and model user manuals.

7.3. Links to Modeling Software and Input Files

If public domain modeling software was utilized, links to source code, executables, and input files should be provided or explanations as to why they are not available should be provided.

8. Optional Task: Conduct Quality Assurance Review of Input Data

Draft questions developed by Ecology for the peer review include detailed review of model input data, focused on the general question, “Are there errors in the model input files?” A thorough quality assurance review of individual data elements in all the input files falls outside the scope envisioned in the development of the cost proposal, but can be considered. Potential ways to address this task short of a comprehensive examination include automated outlier detection using control charts and regression to flag possibly suspect data points and review of a statistical subsample of individual data points. The approach for a quality assurance review of all or a portion of the model input and output files and the associated scope and budget implications will need to be discussed further with the EPA TOM.