DEPARTMENT OF
ECOLOGY
State of Washington

Addendum to
Quality Assurance Project Plan

South Puget Sound Water Quality Study Phase 2: Dissolved Oxygen for Evaluation of Shellfish Harvesting near Joint Base Lewis-McChord and Chambers Creek

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Author and Contact Information

Skip Albertson
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

For more information contact:

Communications Consultant
Phone: 360-407-6834

DEPARTMENT OF ECOLOGY
Environmental Assessment Program

January 17, 2013

TO: Mark Toy, Washington State Department of Health

THROUGH: Carol Maloy, Unit Supervisor, Environmental Assessment Program
Robert F. Cusimano, Section Manager, Environmental Assessment Program

FROM: Skip Albertson, Environmental Assessment Program

SUBJECT: Addendum to Quality Assurance Project Plan for South Puget Sound Water Quality Study, Phase 2: Dissolved Oxygen.
Publication No. 07-03-101.

This Quality Assurance Project Plan (QAPP) covers the work that the Washington State Department of Ecology (Ecology) will do for farfield modeling of wastewater discharge plume from the Chambers Creek Wastewater Treatment Plant into the South Puget Sound basin. The work covers modeling a dye release experiment and 8-12 related scenarios.

Ecology prepared this QAPP Addendum for the U.S. Environmental Protection Agency (EPA).

cc: Melissa Gildersleeve, Section Manager, Water Quality Program
Helen Bresler, Unit Supervisor, Water Quality Program
Andrew Kolosseus, Water Quality Program
Kim McKee, Southwest Regional Office, Water Quality Program
Kevin Fitzpatrick, Northwest Regional Office, Water Quality Program
Dave Garland, Northwest Regional Office, Water Quality Program
Mindy Roberts, Environmental Assessment Program
Greg Pelletier, Environmental Assessment Program
Julia Bos, Environmental Assessment Program
Karol Erickson, Unit Supervisor, Environmental Assessment Program
Will Kendra, Section Manager, Environmental Assessment Program
Joel Bird, Director, Manchester Environmental Laboratory
Bill Kammin, Ecology Quality Assurance Officer

Distribution List

The following organizations and individuals are involved in this study:

Washington State Department of Health, Office of Shellfish and Water Protection, 111 Israel Road SE, Tumwater, WA 98501

- Mark Toy, Project Manager, Environmental Engineer; 360.236.3321; mark.toy@doh.wa.gov
- Andrew Jones, Environmental Engineer, 360.236.3323; andrew.jones@doh.wa.gov

Washington State Department of Health, Office of Environmental Health, Safety, and Toxicology, 111 Israel Road SE, Tumwater, WA 98501

- Lenford O'Garro, Toxicologist; 360.236.3376; lenford.o'garro@doh.wa.gov

Nisqually Indian Tribe, Natural Resources, 12501 Yelm Highway SE, Olympia, WA 98513

- Margaret Homerding, Shellfish Biologist; 360.456.5221x2138; homerding.margaret@nisqually-nsn.gov
- David Troutt, Fisheries Biologist; 360.438.8687x2134; troutt.david@nisqually-nsn.gov.

Washington State Department of Ecology, Marine Modeling Group, 300 Desmond Drive SE, Lacey, WA 98503

- Carol Maloy, Supervisor; 360.407.6675; cfal461@ecy.wa.gov
- Skip Albertson, Marine Modeler; 360.407.6676; salb461@ecy.wa.gov

Chambers Creek Wastewater Treatment Plant, 10311 Chambers Creek Road West, University Place, WA 98467-1040

- Larry Ekstrom, Plant Superintendent; 253.798.3032; lekstro@co.pierce.wa.us

Joint Base Lewis-McChord, IMWE-LEW-PWE MS 17, Box 339500, Joint Base Lewis-McChord, WA 98433-9500

- Joseph Gibbens and Martin Burris, Drinking Water and Wastewater Program Manager, Environmental Division DPW; 253.967.2837and 253.966.1768; joseph.gibbens@us.army.mil and martin.j.burris.civ@us.army.mil

U.S. Environmental Protection Agency, Region 10, 1200 Sixth Avenue, Suite 900, Seattle, WA 98101

- Gina Grepo-Grove, Quality Assurance Manager; 206.553.1632; Grepo-Grove.Gina@epa.gov
- Jonathan Pavy, Project Officer; 206.553.17611828; Pavy.Jonathan@epamail.epa.gov
- Jo Henszey, Technical Monitor; 360.753.9469; Henry.Jo@epamail.epa.gov

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Abstract

The Washington State Department of Ecology (Ecology) will apply an existing three-dimensional model of circulation and water quality for South Puget Sound (Albertson et al., 2007) to investigate shellfish harvest closure zones around the Chambers Creek Wastewater Treatment Plant (WWTP), the Joint Base Lewis-McChord WWTP, and other outfalls. The Washington State Department of Health received a grant to study the potential to open shellfish harvesting in Pierce County from south of Joint Base Lewis-McChord to north of Chambers Creek (including Ketron Island). Historically, this area has been closed to shellfish harvest due to numerous outfalls, both municipal and industrial, along its shores. Many point sources have ceased discharge over the years, and the major WWTPs in this area are in the process of evaluating options for upgrading their facilities. Therefore, this is an opportune time to assess shellfish resources, review pollution sources, and conduct studies to inform the decision process on WWTP upgrades.

Under separate funding, Ecology has been developing computer models of South Puget Sound to simulate circulation and water quality and to evaluate whether human contributions of nutrients are contributing to low dissolved oxygen levels. This is an addendum to the existing Quality Assurance Project Plan (Albertson et al., 2007) and addresses the application of the calibrated South Puget Sound model to a dye release field study (November 12, 2012) and selected scenarios for future planning and possible adjustment of the sanitary lines. The project period is May 1, 2012 through March 13, 2014.

Introduction

The U.S. Environmental Protection Agency (EPA) Region 10 awarded the Washington State Department of Health (WDOH) Office of Shellfish and Water Protection (OSWP) a Puget Sound Scientific Studies grant to evaluate the potential for restoring shellfish harvest to a study area stretching from just north of Chambers Creek to Sequalitchew Creek to the south. This Quality Assurance Project Plan (QAPP) Addendum describes the proposed development of predictive numerical models planned as part of the Chambers Creek Restore Shellfish project (WDOH, 2011). The study evaluates the potential to open shellfish harvesting in Pierce County from south of Joint Base Lewis-McChord (JBLM) to north of Chambers Creek (including Ketron Island). This work will help fulfill the Puget Sound Action Agenda priorities in the South Puget Sound Action Area, restoring ecosystem functions, reducing sources of water pollution, and working effectively and efficiently together on priority actions. The project will be done in collaboration with WDOH and the Nisqually, Puyallup and Squaxin Tribes and in consultation with JBLM and Pierce County.

Historically, this Pierce County area has been closed to shellfish harvest due to numerous outfalls, both municipal and industrial, along its shores. Because of this closure, little has been done to assess shellfish resources or the status of pollution in the area. In recent years, many sewage flows, such as for the towns of Steilacoom and DuPont, and industrial flows have been rerouted to other locations such as Chambers Creek or have ceased operation. The two major wastewater treatment plants (WWTPs) in this area, JBLM and Chambers Creek, are currently in the process of upgrading their facilities. Therefore, this is an opportune time to assess shellfish resources, review pollution sources, and inform the decision process on treatment plant upgrades.

We will model circulation and dilution of wastewater discharge into South Puget Sound near shellfish closure zones near Chambers Creek and JBLM as it might relate to upgrades for treatment and/or outfall design. We will model the dilution ratios of wastewater using an existing, calibrated (for 2006-7), three-dimensional marine hydrodynamic model after estimating initial vertical plume stratification with a nearfield model such as CORMIX or EPA-Plumes. The expected outcome of the development of these models is a management tool capable of evaluating worst-case fecal concentrations along existing sanitary lines maintained by WDOH during an upset condition in the winter. If found conservative, these sanitary lines may be repositioned based on a better assessment of the dilution effects in the farfield three-dimensional hydrodynamic model than was previously available without it. Outcomes might include better-designed WWTP improvements, improved water quality, and increased shellfish access for commercial, recreational, and tribal harvest.

Problem Definition and Background

The National Shellfish Sanitation Program Model Ordinance requires that a *Prohibited* area (closure zone) be established adjacent to each WWTP outfall or any other point source outfall of public health significance (USFDA, 2007). WDOH establishes shellfish closure zones around marine outfalls in Puget Sound to protect public health in the event that plant upsets occur. While WDOH considers effluent monitoring data required under National Pollutant Discharge

Elimination System (NPDES) permits, the closure zone presumes that disinfection ceases to function properly and secondary effluent reaches Puget Sound. WDOH develops a high bacteria concentration estimate based on the maximum or the 90th percentile of secondary effluent data prior to disinfection. The information and results obtained are used in assessing the shellfish closure zone for geoduck tracts 11250 and 11260.

Once wastewater reaches Puget Sound, the outfall diffuser characteristics, effluent buoyancy, and marine circulation affect how far up into the water column the plume rises and defines the nearfield conditions. The plume entrains ambient water as it rises, eventually reaching a density that matches the density at a particular depth in the water column. Once the plume is trapped, marine currents and density patterns influence where and how fast the trapped plume disperses and dilutes.

Description of Study Area

As shown in Figure 1, the study area stretches from just north of Chambers Creek to Sequalitchew Creek to the south. It includes two major WWTPs: The Solo Point WWTP for Joint Base Lewis-McChord and the Chambers Creek Regional WWTP. Other major historical sources of pollution include particulate contamination from the former ASARCO plant, the Abitibi (formerly Boise Cascade) pulp mill facility, an armament factory in DuPont, Joint Base Lewis-McChord activities, and the Steilacoom Marina. Constituents of concern include heavy metals, organics associated with pulp mill processes (such as dioxin), and other persistent organics such as PCBs.

Figure 1. Map of study area.

Farfield Modeling Goals and Objectives

WDOH has several criteria for establishing the closure zones. Generally, the most conservative of the following criteria are used to set the closure zone. These include at minimum a 300-yard exclusion area, regardless of plume transport and fate. The Food & Drug Administration (FDA) provisionally recommends a closure zone of 1000:1 dilution under normal operating conditions, in part to address viral risk. Finally, WDOH can establish a closure zone to the region where the combined effect of nearfield and farfield processes result in a concentration that meets the water quality standards of 14 fecal coliform bacteria per 100 mL. To evaluate the latter option, WDOH must evaluate farfield dilution effects that may have been underestimated in the past.

Ecology will evaluate farfield dilution using the South Puget Sound model as described in this QAPP Addendum after WDOH establishes plume characteristics with its nearfield modeling. The South Puget Sound model dilution estimates will be evaluated using the field program (dye study) data and the WDOH model applied to selected scenarios. The model performance and scenario application results will be documented in project reports. Since the model is already calibrated with data from 2006-2007, the dye results act as a confirmation that forcing conditions for 2012 have been sufficiently updated. WDOH will process the field data (dye results) through the nearfield model as specified below.

Modeling Objectives

The objectives of the proposed modeling effort for the Chambers Creek Shellfish Evaluation Study are as follows:

- Establish shellfish closure zones around existing WWTPs using an existing calibrated three-dimensional hydrodynamic model.
- Evaluate future alternatives for upgrades to optimize shellfish harvest opportunities.
- Evaluate alternative methods of establishing shellfish closure zones around point sources of pollution.

The nearfield model dye results from WDOH will be passed to the farfield model covered by this QAPP Addendum as a time series of dye[1] loading with sufficient temporal detail to resolve the tidal cycle and thereby fully characterize the trapping depths (if not at the surface) of the effluent from the WWTP discharge.

[1] surrogate for fecal coliform bacteria

Modeling Approach and Selection

Modeling is an essential component of the Chambers Creek Shellfish Evaluation Study. Historically, WDOH used the CORMIX computer model to assess the dilution and dispersion of effluent from WWTP outfalls.

Historical Modeling Effort

The prior CORMIX-only computer results indicated that it would take a very long distance of effluent transport to achieve sufficient dilution to meet the shellfish water quality standard of 14 fecal coliforms per 100 mL. The highest fecal coliform levels in the treated wastewater occurred during a summer visit to the Chambers Creek WWTP at 49,000 fecal coliforms per 100 mL, used in the CORMIX input parameters along with a monthly maximum flow rate of 18.0 million gallons per day (mgd; Ecology, 1994). Actual monthly average flows in the summer months at Chambers Creek have been several mgd less than this design flow, although some daily summer flows have approached this rate.

The distance required to meet the water quality standard predicted by the old model is approximately 6500 meters (21,000 feet). One reason for this extremely long distance is the fact that very little dilution was predicted to occur in the far field. The receiving water near the outfall is often turbulent and contains eddy formations and tiderips, with very little slack water occurring between tidal cycles as discussed in the March 1994 Mixing Ratio Study Report for the Chambers Creek WWTP by the Pierce County Department of Utilities. The report states that Puget Sound modeling studies showed tidal flows near the outfall are relatively strong compared to other principal channels in Puget Sound. Slack water, or weak currents, is brief during tidal reversal, markedly reducing the probability of effluent accumulation in the locality of the outfall or subsequent transport of high effluent concentration patches into contiguous areas.

These observations indicate that stratification of the water column generally should be minimal. This is consistent with results from Ecology's long-term monitoring (monthly via seaplane) station GOR001 (Gordon Point). The water column salinity and temperature results indicate that, even in summer months, the entire water column at this station is relatively well mixed with the occasional exception of the top few meters of water.

From both field and model studies, it is evident that the discharge lies in an area of strong tidal currents and high turbulence. Strong currents, combined with relatively deep waters near shore, result in rapid dilution of effluents under both neap and spring tidal currents (Collias and Sullivan 1975).

Another consideration by WDOH is the performance of the WWTP and its capacity to detect critical upset conditions. At the Chambers Creek WWTP, UV replaced chlorine as the disinfection agent in 2002. This is a low-pressure, high-intensity UV system. Combined effluent from the secondary clarifiers is split between two inlet chambers. Each chamber is fitted with two channels containing two banks of 16 modules, containing 18 lamps in each module for a total of 864 lamps (four channels). Two spare channels at each chamber are designed for future expansion. The first bank of lights is used for disinfection with the second bank used as a backup in case of failure or for maintenance. UV dosage is set by the operator (currently set at 40 mJ/cm2) and is paced with the combined total primary effluent flow entering the aeration basins in service. Transmissivity levels are read at the head of the process. Alarms alert operators when the adjacent lamp is out, when UV dosage drops below 40 mJ/cm2.

Previous studies have shown that a rare upset condition, where a disinfection system problem occurs for several hours at the WWTP, the effluent would be transported approximately 3000 feet an hour (0.25 m/s) at the current speed assumed in the modeling. If the discharge of non-treated effluent occurred undetected for three hours, the total distance traveled by the plume would be 9000 feet (2740 m). However, the closest portion of geoduck tract 11260 is approximately 10,000 feet (3050 m) from the WWTP outfall. Even if the effluent plume could travel rather directly towards the tract and avoid eddies or gyres around Toliva Shoal, the problem would be detected in the plant before the plume could reach the tract.

The outfall pipe is 750 feet (230 m) long, with an additional diffuser length of 112 feet (34 m). The depth of the diffuser is 110 feet (33.5 m) at mean lower low water (MLLW). The diameter of the ports is 11.9 inches (0.302 m), with 16 feet (0.41 m) between each of the eight ports. Each port is on a vertical riser, and the risers alternate in direction along the axis of the 60-inch (1.52-m) diameter pipe. An examination of the drogue trajectories released near the outfall (Pierce County, 1994) showed that, on the ebb tide, the effluent will move directly toward the Narrows, and accelerate as the Narrows is approached.

Over various tidal cycle releases, average drogue speeds were 0.12 knot (0.062 m/s), 0.5 knot (0.26 m/s), 1.5 knots, (0.77 m/s) and 0.6 knot (0.31 m/s). The water was never truly “slack” during this study, but moving slowly even as the tidal direction changed. On a flood tide, movement is to the southwest. The Puget Sound Current Guide also provides current speed information in the general area of the WWTP outfall. Station 1280 is located 0.8 mile (1,290 m) east of Gibson Point, which actually places it in the passage between Fox Island and the mainland, over a mile north of the WWTP outfall site. Current measurements at Station 1280 indicate a maximum flood tide speed of 2.1 knots (1.1 m/s) and a maximum ebb tide speed of 1.8 knots (0.93 m/s). These results affirm that the outfall lies in an area of strong tidal currents and turbulence.

The current meter information collected in the 1975 study measured a 50th percentile current speed at 15 feet (4.6 m) of 0.59 knot on a spring tide series. These measurements also showed that current speeds at a 15-foot depth were about 17% of those predicted for the Narrows. In the Current Guide, maximum flood tide speeds for the north and south end midstream stations in the Narrows are 3.2 (1.65 m/s) and 3.8 knots (1.95 m/s) respectively, and maximum ebb tide speeds are 2.8 (1.4 m/s) and 3.1 (1.6 m/s) knots respectively. Average bottom current in the 1975 study was approximately 0.4 knot (0.21 m/s).

Historically, a current speed of 0.5 knot (0.26 m/second) was assumed as representative of average measured current speeds in the water column as the plume arose from the bottom (0.4 knot; 0.21 m/s) towards the surface (0.59 knot; 0.30 m/s). This speed also is close to the median two (of the four) reported average drogue study speeds [0.5 and 0.6 knot (0.26 and 0.31 m/s)], discussed previously.

Modeling Approach

In theory, modeling should be an iterative approach that involves initial conceptualization, implementation based on management information needs, and available resources followed by testing and model refinement. However, the application of models as an aid in management decision making typically requires a finite project timeline. Ideally, modeling and management decision making would be a coupled iterative process that allows for additional data collection, model testing, model refinement, and re-evaluation of model results and management decisions based on them.

A relatively finite timeline will be achieved through the following steps:

- Use existing calibrated GEMSS model of South Puget Sound. Update tides, wind, and river inflow conditions for Dye Study conditions (November 12, 2012). Use some of the ocean boundary conditions from the 2006-7 study used to calibrate the GEMSS model.
- WDOH does nearfield modeling using CORMIX or EPA PLUMES. The function of the nearfield model is to apportion dye to layers in the GEMSS farfield model within the cell where the diffuser is located.
- Nearfield modeling results will be used as initial conditions for Ecology farfield modeling using GEMSS to simulate how dye disperses from the diffuser location.
- 8-12 scenarios may be run to demonstrate the effects of different diffuser options or meteorological conditions.

Model Selection

The project was developed because GEMSS was previously selected and applied to South Puget Sound. CORMIX is often selected by WDOH because they have considerable expertise in-house to use it effectively. EPA PLUMES is widely used elsewhere and is supported by EPA.

For the South Puget Sound Dissolved Oxygen Study, Albertson et al. (2007) selected GEMSS (an integrated 3-dimensional hydrodynamic and water quality model) based on comparisons with two other models (EFDC and ROMS). GEMSS was selected due to the successful application of an earlier version of the model to a portion of South Puget Sound (Budd Inlet), the inclusion of model code to simulate the diel migration of dinoflagellates, the availability of initial parameter settings from the Budd Inlet model as a starting point for model calibration, and the availability of pre- and post-processing graphical user interface.

Separate hydrodynamic and water quality models were selected by Sackmann (2009) to simulate the hydrodynamics and water quality of Puget Sound. FVCOM, an unstructured 3-dimensional model was chosen to simulate Puget Sound Circulation, which would be coupled through a hydrodynamic output file as input to the unstructured 3-dimensional CE-QUAL-ICM model. Separate models were chosen to provide the ability to run multiple water quality scenarios without the need to simulate Puget Sound circulation (if unchanged).

The most important criteria for selecting the GEMSS modeling framework for this project include:

1. The error by using a calibrated model with lower (500-m) resolution will likely be lower than using a higher-resolution submodel with high (50-m) resolution because of unknown conditions along the high-resolution model boundary.
2. The framework uses algorithms and solution techniques that are appropriate for the intended application.
3. Peer review of model theory and past applications has occurred.
4. Technical documentation is available.
5. Active development of the framework is ongoing, and technical support is available.

In addition to these key criteria, other considerations that would be beneficial include the following:

- Successful past applications in the Puget Sound region have occurred.
- Program source code is available for review as part of program documentation.
- Graphical user interface (GUI) utilities that facilitate model setup, execution, and input and output management and analysis will be used.
- Team members responsible for modeling tasks are familiar with the selected model(s)

Based on these considerations, adapting the GEMSS model for development for the Chambers Creek Shellfish Evaluation Study was selected.

Marine Hydrodynamic Model Setup

Development of the Chambers Creek hydrodynamic model will consist of three steps:

- Model setup involving specification of boundary conditions for the selected evaluation period.
- Evaluation of dye study results and sensitivity analysis
- Running of management scenarios.

Grid Development

This project will not change the existing South Puget Sound model grid. The South Puget Sound grid (Figure 2) is inherent with our decision that using a previously calibrated model, despite its lower resolution, will give better results than a higher resolution submodel because of uncertainty in the boundary conditions for the latter. There is also a tradeoff between desired detailed grid resolution and model run time.

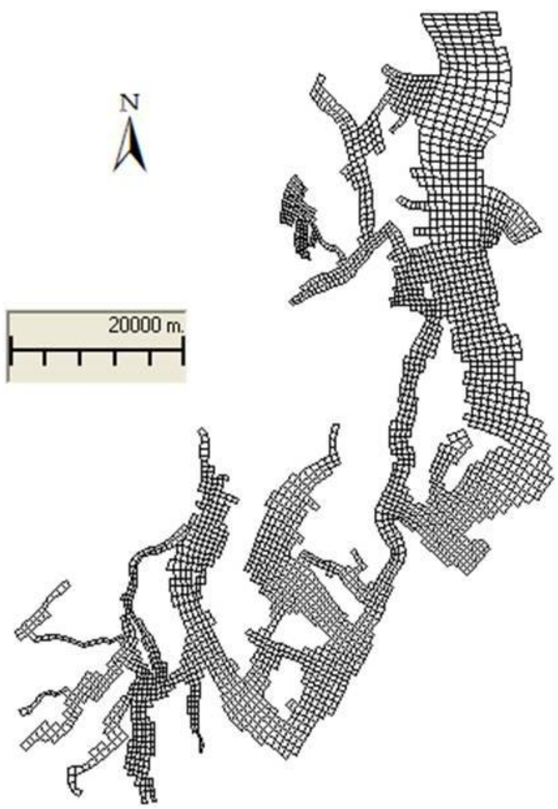

Figure 2. Full-scale South Puget Sound model grid.

Under the current model grid setup, the Chambers Creek WWTP outfall discharges to a grid cell next to shore at I=66, J=69 (Figure 3). This grid cell has a depth of -44 m relative to the NAVD88 vertical datum. The most recent mixing zone analysis for this outfall lists the outfall depth as -110 ft (-33.5 m) MLLW, which is approximately -34.2 m NAVD88. Because the grid-cell depth is greater on average than the outfall, the dye release from the nearfield model will not be on the bottom even though the diffuser is located there. In this grid cell, the model has 10 layers, and the plume traps between layers 4 and 7 (Hoffman, personal communication).

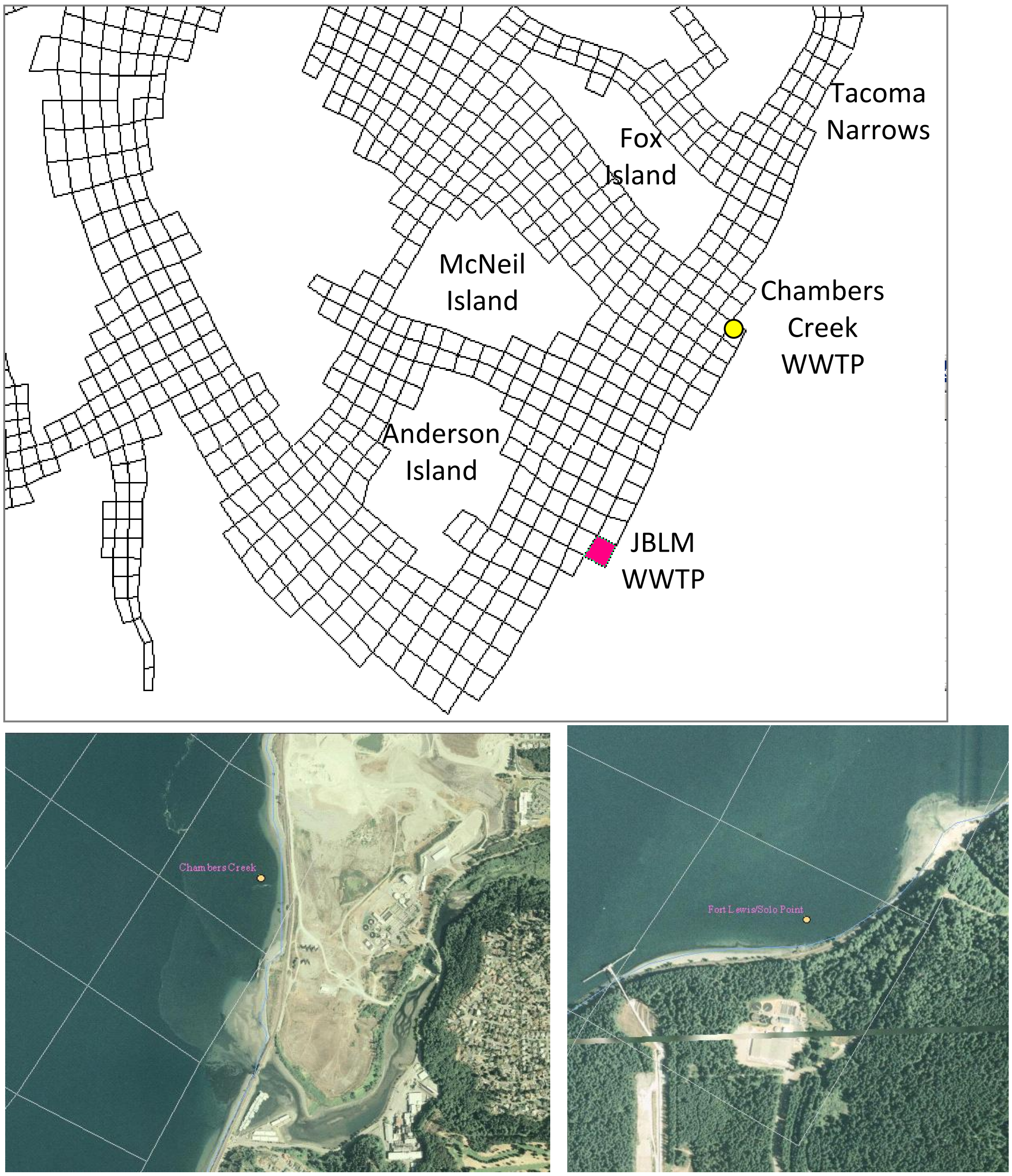

Figure 3. Location of the Chambers Creek and Joint Base Lewis-McChord wastewater treatment plant outfalls and the existing South Puget Sound model grid cells used for circulation and water quality.

WDOH will transmit the results of the field program and nearfield modeling to Ecology in a mutually agreeable format following initial compilations and quality assurance. Ecology will set up the South Sound model to simulate the conditions during the field program. The first report will summarize model performance for the winter field data program and dye study.

In a subsequent and separate modeling report, Ecology will develop draft and final reports for model performance and scenarios application. The reports will follow Ecology publication guidelines, but Ecology will consult with WDOH on the outlines and review process. The draft reports will be submitted to WDOH and others as appropriate for review. Ecology will finalize the report based on comments received.

The 8-12 scenarios that will be evaluated will be determined at a later time but will primarily focus on the potential benefit of various nitrogen management scenarios or potential future conditions if no action is taken (e.g., population growth).

Boundary Conditions and Meteorological Forcing

Tidal elevation at the open boundary will be specified using predictions from PSTIDES, tide predictions generated from the Puget Sound Tide Channel Model. At the water surface, wind stress will be specified. Meteorological forcing, including air and dew point temperature, wind speed, cloud cover, and solar radiation, will be specified using direct measurements collected as previously applied to the South Puget Sound model (e.g., SeaTac Airport)

Flow and temperature for the major rivers will be based on U.S. Geological Survey (USGS) gauge records collected during the calibration period, although estimations of river and stream input temperature may be necessary if those are unavailable. Surface water contributions from the ungauged drainages will be estimated by scaling inputs from the gauged basins.

Model Calibration and Evaluation

Methods Overview

Once the model setup is completed, the model will be evaluated through comparison with observed dye-release data collected in the Chambers Creek region. The term *calibration* is defined as the process of adjusting the model parameters within physically defensible ranges until the resulting predictions give the best possible match with observed data. In some disciplines, calibration is also referred to as parameter estimation. Model *evaluation* is defined as the process used to generate information to determine whether a model and its analytical results are of a quality sufficient to serve as the basis for a decision and whether the model is capable of approximating the real system of interest (USEPA, 2008). In some disciplines, evaluation is also referred to as validation, confirmation, or verification.

Since the model is already calibrated, the hydrodynamics will not be re-tuned. The tide, wind, and river forcing will be updated for 2012 conditions, and summary statistics will be calculated showing goodness-of-fit. The dye field data will need to be composited by tidal stage because the data are discrete points in space and time. The nearfield model will provide a time series of dye versus depth at agreed-upon intervals suitable for aggregating into the existing GEMSS layers. At the very least, dye flow volumes and concentrations (possibly near constant) should be output from the nearfield model at low slack, flooding, high slack, and ebbing tidal states. An example of this for a four-layer model is given in Table 1. In this example, only plume inflow varies because the concentration of dye/fecal bacteria is approximately constant in the waste stream. At each time-step, the flow across all layers sums to 0.1138 m^3/s (2.6 mgd). The concentrations of dye input into each layer change by layer and by model time.

To compensate for numerical dispersion, as-collected dye concentrations will need to be reduced by a factor related to the volume in each grid cell over which no dye was present.

Table 1. Example of a plume outflow time series for a four-layer model over the tidal cycle.

Model time (day)	layer1 (deep)	layer2	layer3	layer4 (shallow)	tide
45.2113	0	0	0	0	
45.2114	0	0.0569	0.0569	0	high
45.2844	0	0.0569	0.0569	0	
45.2845	0	0.0569	0.0569	0	
45.3573	0	0.0569	0.0569	0	
45.3574	0	0.0569	0.0569	0	ebb
45.4302	0	0.0569	0.0569	0	
45.4303	0	0	0.0569	0.0569	
45.5031	0	0	0.0569	0.0569	
45.5032	0	0	0	0.1138	low
45.5676	0	0	0	0.1138	
45.5677	0	0	0.0569	0.0569	
45.6235	0	0	0.0569	0.0569	
45.6236	0	0.0569	0.0569	0	flood
45.6794	0	0.0569	0.0569	0	
45.6795	0	0.0569	0.0569	0	
45.7353	0	0.0569	0.0569	0	
45.7354	0	0.0569	0.0569	0	high
45.7531	0	0.0569	0.0569	0	
45.7532	0	0	0	0	

Both calibration and evaluation of the model will rely on a combination of quantitative statistics for goodness-of-fit and visual comparison of predicted and observed time series and depth profiles (Krause et al., 2005). This methodology is consistent with the standard practice that has been established for similar modeling programs and other detailed studies. These include the following:

- Hood Canal Dissolved Oxygen Program.
- University of Washington PRISM Modeling Program.
- Budd Inlet Scientific Study (Aura Nova Consultants et al., 1998).
- Deschutes River/Capitol Lake/Budd Inlet Water Quality Study (Roberts et al., 2012).
- South Puget Sound Dissolved Oxygen Study (Roberts et al., 2008).

- Quartermaster Harbor Nitrogen Management Study (King County., 2010)

Bias will be assessed by calculating the average residual of paired values [mean (predicted - observed)]. A poor fit between modeled and observed data can sometimes yield a near-zero bias if the positive and negative deviations in a data set are of a similar magnitude. Therefore, measurements of precision will be used to further quantify and refine the goodness-of-fit between the model predictions and observations. Precision will be assessed by calculating the root mean square error (RMSE) of paired values [sqrt (mean ((predicted - observed)^2))]. We aim to decrease both bias and RMSE between predictions and observations but will predominantly focus on reducing bias, which may be related to the way in which dye results are collected and the numerical dispersion in the model as mentioned previously.

Since the South Puget Sound model is already calibrated with data from 2006-7, the dye results will provide a confirmation that the model works in a year with different meteorological conditions; the tidal conditions between years is not that different. Since South Puget Sound typically has a flushing time of 60 days, the model run will begin on 1 June 2012, and meteorological data will be gathered from nearby airports (e.g., McChord, SeaTac) and compared with any data collected during the dye experiment in November for consistency. A slight onshore component of the wind was observed during the experiment, and the final wind input to the model should be evaluated for that.

The meteorological forcing for 2006-7 will be updated to 2012 conditions, which had a cooler, wetter spring followed by a dry period from 15 July – 10 October. The tides and river input will be updated as well, but the boundary conditions (e.g., at Edmonds) will remain “as is”. The grid cell that contains the diffuser will be deepened to the depth of the diffuser so that the dye can be injected at the correct location in the model.

Targets and Goals

Hydrodynamic model calibration targets for this project are an average bias of less than ±10 cm for model vs. observed tidal height, ±1 ^{o}C for temperature, ±1 psu for salinity, and within 10% on average from the observed velocity observations reported in cm/s. The primary objective is to evaluate farfield plume transport to get at both the 1:1000 dilution and 14/100 mL concentration. The actual dye concentration is not as important for the dilution line, but numerical dispersion for the large grid cell size must be addressed.

Matching the dye field results will be highly dependent on how those results are collected as truly representative of each entire grid cell. Allowing for any possible bias due to numerical dispersion in the model, obtaining a high correlation and replicating the dye pattern over the tidal cycle, should be sufficient.

Sensitivity and Uncertainty Analysis

To evaluate model performance and the variability of results, sensitivity and uncertainty analyses will be carried out for temperature, salinity, and wind effects. Uncertainty can arise from a number of sources that range from errors in the input data used to calibrate the model, to imprecise estimates for key parameters, to variations in how certain processes are parameterized in the model domain. Regardless of the underlying cause, it is good practice to evaluate these uncertainties and reduce them, if possible (USEPA, 2008; Taylor, 1997; Beck, 1987).

A model's sensitivity describes the degree to which results are affected by changes in a selected input parameter. In contrast, uncertainty analysis investigates the lack of knowledge about a certain population or the real value of model parameters. Although sensitivity and uncertainty analyses are closely related, uncertainty is parameter-specific, and sensitivity is algorithm-specific with respect to model variables. By investigating the "relative sensitivity" of model parameters, a user can become knowledgeable of the relative importance of parameters in the model. By knowing the uncertainty associated with parameter values and the sensitivity of the model to specific parameters, a user will be more informed regarding the confidence that can be placed in the model results (USEPA, 2008).

During the evaluation process, the responsiveness of the model predictions to various assumptions and rate constants specified will be evaluated. The model setup will likely include parameters based on literature recommendations and best professional judgment, as well as estimates of loads in the absence of data. Specific areas to address with sensitivity and uncertainty analyses include boundary conditions, meteorological forcing, and process rate parameters. Fundamental parameters will be varied by (1) increasing and decreasing by a factor of 2 or an order of magnitude, and (2) the resulting predictions compared to understand whether a factor has a discernible effect on dye study predictions. The final report will document the parameters that are varied and will identify any parameters that have great uncertainty and strongly influence the results.

Evaluation of Model Scenarios

After sensitivity analyses have been performed, the calibrated model will be used to evaluate water quality conditions observed in Chambers Creek during the 2012 dye study and to simulate the effects of various alternative discharge scenarios.

Scenario results will be evaluated both as predicted patterns for that scenario and as differences between the base case (or natural conditions) and any particular scenario. Examples could be as follows:

- Summer vs. winter conditions (e.g., minimum and maximum stratification, effluent pollution loads, currents.
- What-if scenarios with WWTP upgrade options (ultimate buildout).
- Single vs. multiple tidal cycles.
- Concurrent pollution inputs from Chambers and Sequalitchew Creeks. How to include input from these sources has yet to be resolved and is an important factor in moving forward. One possible approach is to use the dilution factors from the South Puget Sound model and scale these other inputs proportionately.

Model Output Quality (Usability) Assessment

Final assessment of model performance will be conducted and summarized in the final report. This summary will evaluate whether the outcomes have met the project's original objectives. Criteria to be evaluated include whether or not the water quality model:

- Behaves in a manner that is consistent with the current understanding of processes known to affect water quality in the Puget Sound estuary system.
- Realistically reproduces variations in dye concentration during the field study, allowing for effects of numerical dispersion due to 500-m grid cell size.

Reconciliation with User Requirements

Reports generated for this project will include identification of any data limitations determined through application of the Data Quality Objectives described in the overall project plan. This information will be communicated through a project report and will include an evaluation of model versus dye from the field study and evaluation of 8-12 scenarios as previously described.

Organization and Schedule

Project Management and Oversight

This project will be managed by WDOH and includes collaborators. Funding will be provided by the EPA grant described above. In addition to direct grant support, staff time and resources, primarily in the form of field equipment and laboratory services are also being provided to match a portion of the grant. The project team plans to meet at least quarterly to communicate progress, problems, and plan future activities. Although no formal technical advisory committee has been formed, the project team and technical reviewers will review work plans and products (including this QAPP Addendum) assigned by EPA Region 10, primarily the EPA Project Monitor assigned to this grant.

Project Staff List and Roles

The modeling component of the project involves staff from Ecology and WDOH:

Core Project Team

- Mark Toy, WDOH project manager: responsible for (1) supervising project implementation; (2) coordinating and tracking work, budgets, and personnel; and (3) preparing and presenting presentations and written reports.
- Skip Albertson, Ecology project manager: responsible for all aspects of the modeling tasks.
- Andrew Jones, WDOH, provided technical assistance.

This stakeholder list includes the following agency representatives and is summarized in Table 2.

Table 2. Stakeholder group distribution list.

(as of April 30, 2011)

Stakeholder	Representing	E-mail Address
Alam, Mahbub	Washington Department of Ecology	Mala461@ecy.wa.gov
Albertson, Skip	Washington Department of Ecology	Salb461@ecy.wa.gov
Barton, Celia	Washington Department of Natural Resources	Celia.Barton@dnr.wa.gov
Crawford, Phil	Joint Base Lewis-McChord	Philip.b.crawford@us.army.mil
Ekstrom, Larry	Pierce County Public Works	lekstro@co.pierce.wa.us
Fait, Laurie	Sequalitchew Creek Watershed Council	lauriefait@gmail.com
Fyfe, David	Northwest Indian Fisheries Commission	Dfyfe@nwifc.wa.gov
Gibbens, Joseph	Joint Base Lewis-McChord	Joseph.gibbens@us.army.mil
Hanenburg, Steven T.	Pierce County Public Works	shanenb@co.pierce.wa.us
Hanowell, Ray	Tacoma Pierce County Health District	RHanowell@tpchd.org
Henszey, Jo	U.S. Environmental Protection Agency	Henry.jo@epa.gov
Julin, Kip	Pierce County Public Works	kjulin@co.pierce.wa.us
Kyte, Michael	Nisqually Indian Tribe	kyte.michael@nisqually-nsn.gov
Lane, Tonya	Washington Department of Ecology	Tlan461@ecy.wa.gov
Lowe, Rob	Pierce County Public Works	rlowe@co.pierce.wa.us
Marek, Steve	Tacoma Pierce County Health District	smarek@tpchd.org
Matthews, Cris	Washington Department of Ecology	Crim461@ecy.wa.gov
O'Garro, Lenford	Washington Department of Health	Lenford.O'Garro@doh.wa.gov
Pavy, Jonathan	U.S. Environmental Protection Agency	Pavy.Jonathan@epamail.epa.gov
Sizemore, Robert E.	Washington Department of Fish & Wildlife	Robert.sizemore@dfw.wa.gov
Slape, James Jr.	Nisqually Indian Tribe	Slape.jamesjr@nisqually-nsn.gov
Sparkman, Eric	Squaxin Indian Tribe	esparkman@squaxin.us
Troutt, David	Nisqually Indian Tribe	Trout.david@nisqually-nsn.gov
Weakland, Sandra	Washington Department of Ecology	Sgei461@ecy.wa.gov
Winfrey, David	Puyallup Indian Tribe	David.winfrey@puyalluptribe.com
Wright, Wynnae	Washington Department of Natural Resources	Wynnae.wright@dnr.wa.gov
Wrye, Dan	Pierce County Public Works	dwrye@co.pierce.wa.us

Major Activities and Timelines

Table 3 outlines the modeling activities and timelines. This project has three major phases as well as ongoing activities that will occur every year of the study. Modeling activities, other than the development of this modeling QAPP Addendum, begin in Phase 2 (2013) of the project. Deliverables include a working model of dye release study, 8-12 alternate scenarios, and a final report documenting the project. Table 4 presents the project timelines.

Table 3. Modeling timeline.

Ongoing activities	Timeline	Organization	Description
Phase 1 activities			
Modeling QAPP document	2012	Ecology	Write and approve a QAPP Addendum that includes documentation of models selected for use in this study
Phase 2 activities			
Marine hydrodynamic modeling	2013	All	Develop selected marine hydrodynamic model runs for dye study & scenarios
Phase 3 activities			
Modeling report	2014	Ecology	Write report of modeling work

Table 4. Project timeline.

Field and laboratory work	Due date	Lead staff
Field work completed	November 2012	Mark Toy, WDOH
Laboratory analyses completed	November 2012	
Final report		
Author lead / support staff	Skip Albertson	
Schedule		
Draft due to supervisor	December 2013	
Draft due to client/peer reviewer	January 2014	
Draft due to external reviewer(s)	January 2014	
Final (all reviews done) due to publications coordinator	February 2014	
Final report due on web	March 2014	

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