DEPARTMENT OF ECOLOGY
Water Quality Program
Memorandum

January 27, 2016

TO: Mark Henley, Amy Jankowiak

FROM: Laura Fricke

SUBJECT: Addendum to December 21, 2015 Memorandum from Teizeen Mohamedali and Mindy Roberts, "Tracer simulations to investigate how waters move in Puget Sound and the Salish Sea to address questions related to the draft proposed No Discharge Zone petition" – CORMIX Modeling for NDZ Scenarios, Location 5

I. Purpose and summary of results

This modeling was done as a follow-up to the hydrodynamic modeling using the Salish Sea model. CORMIX is a smaller-scale model that predicts dilution in an effluent plume under constant conditions. CORMIX is used by Ecology and EPA to support environmental impact assessment of regulatory mixing zones. A simulated discharge at Location 5, near the entrance to Samish Bay and Bellingham Bay, with an evaluation of dilution inside Samish Bay (node #002231 from the hydrodynamic model) is the focus for this project. This location was chosen for the "pulse" model because continuous simulation results showed some of the highest concentrations of the tracer at sensitive areas. Therefore, the distance and ambient conditions for the CORMIX model represent this location.

Under worst-case conditions (density stratification and high current speed), the CORMIX model predicts fecal coliform concentrations higher than the marine water quality standard for fecal coliform of 14/100 ml at the target location for all modeled discharge concentrations except the Type 1 laboratory study results.

II. Inputs for CORMIX model

A. Effluent data

1. Effluent density: I assumed fresh water effluent at a temperature of 20°C (typical of wastewater treatment plant effluent).

2. Effluent flow rate: Similar to the “pulse” model done with the hydrodynamic model, this model used a flow rate of 3000 gal/hour, or 50 gal/min. CORMIX is a steady state model; this is not a “pulse” model, but the time to reach the shore is just over one hour at maximum current conditions.

3. Decay rate: The die-off rate for fecal coliform bacteria used was k = -1.4/day, the low end of the range from Sargeant et al. (2006).

4. Discharge concentrations: Five discharge concentrations of fecal coliform bacteria were modeled, as follows:

a) 10^9 ppm (represents the high end of untreated household wastewater)

b) 2.04×10^7 ppm (average for traditional Type II MSDs, from Cruise Ship Discharge Assessment Report, EPA 2008)

c) 1,950,000 ppm (average for traditional Type II MSDs, from Netherlands tugboat study)

d) 720,000 ppm (average for traditional Type II MSDs, from Alaska small passenger vessels, 2012)

e) 820 ppm (laboratory only study for type I MSDs, from Evaluation of Improved Type 1 Marine Sanitation Devices: Performance Evaluation Report, EPA 2010)

B. Ambient conditions

1. Ambient depth: The depth at Location 5 is approximately 26 m.

2. Ambient velocity: I used a maximum current speed of 1.5 m/s (from DeepZoom Nautical Charts, www.deepzoom.com, for Chuckanut Bay). I also modeled an average current speed of 0.75 m/s (one-half the maximum speed).

3. The range of wind speeds allowed is from 0 m/s to 15 m/s. The default value suggested by CORMIX is 2 m/s, representing a breeze.

4. The Manning’s n coefficient represents the bottom friction. Because the surface level discharge does not interact with the bottom, I used a low value of 0.01.

5. Ambient density: I used the salinity and temperature profiles from the hydrodynamic model for Location 5 to determine an average uniform density characteristic of unstratified conditions, and a stratified profile (Type A) based on the most stratified daily profile.

C. Discharge geometry

1. Specific discharge geometry for individual vessels is not available, so I used the lower end of the range of discharge sizes from EPA’s fact sheet (General Permit 2013DB0004) for Large Commercial Passenger Vessel Wastewater Discharge. I used a discharge pipe diameter of 0.1 m, located 0.5 m below the surface. I assumed a horizontal discharge (vertical angle 0°) oriented 90° to the current direction. These parameters are only significant in the initial mixing zone, close to the vessel, so they are not important to the dilution factors at the sensitive area/shoreline.

2. The distance from Location 5 to the Samish Bay shellfish area is 4.66 miles, or approximately 7500 m.

D. Water quality standard

The marine water quality standard for fecal coliform is a mean of less than 14/100 mL, which is equivalent to 140 ppm. For the model cases with large enough dilution, I determined the distance and time from the discharge point to meet a target of 140 ppm.

E. CORMIX Model scenarios

There are three sets of modeled cases, with varying stratification conditions and current speeds. Each scenario is modeled for each of the five effluent concentrations.

1. Uniform ambient density, high current speed.

2. Stratified ambient density, high current speed (this is the most conservative case, “critical conditions”).

3. Stratified ambient density, average current speed.

III. CORMIX Model results

CORMIX Modeling for NDZ scenarios Location 5

Case #	Effluent concentration (ppm)	Effluent flow rate (gal/min)	Ambient velocity m/s	Ambient density	Concentration at Samish Bay (ppm)	Dilution factor at Samish Bay	Time (hours)	Distance to meet WQ standard of 140 ppm
1A	1.00E+09	50	1.5	uniform	1600	630000	1.39	not met at shoreline
1B	2.04E+07	50	1.5	uniform	33	630000	1.39	5256 m (58 min)
1C	1,950,000	50	1.5	uniform	3.10	630000	1.39	3387 m (38 min)
1D	720,000	50	1.5	uniform	1.15	630000	1.39	2265 m (25 min)
1E	820	50	1.5	uniform	0.0013	630000	1.39	1 m (0.5 sec)
2A	1.00E+09	50	1.5	stratified	215000	4287	1.39	not met at shoreline
2B	2.04E+07	50	1.5	stratified	4390	4287	1.39	not met at shoreline
2C	1,950,000	50	1.5	stratified	419	4287	1.39	not met at shoreline
2D	720,000	50	1.5	stratified	155	4287	1.39	not met at shoreline
2E	820	50	1.5	stratified	0.176	4287	1.39	7 m (4.7 sec)
3A	1.00E+09	50	0.75	stratified	121000	7022	2.78	not met at shoreline
3B	2.04E+07	50	0.75	stratified	2470	7022	2.78	not met at shoreline
3C	1,950,000	50	0.75	stratified	236	7022	2.78	not met at shoreline
3D	720,000	50	0.75	stratified	85	7022	2.78	5649 m (2.1 hours)
3E	820	50	0.75	stratified	0.099	7022	2.78	19 m (25.5 sec)

IV. Discussion

Under worst-case conditions (Case #2, density stratification and high current speed), the CORMIX model predicts fecal coliform concentrations higher than the marine water quality standard for fecal coliform of 14/100 ml at the target location for all modeled discharge concentrations except the Type 1 laboratory study results. The CORMIX model incorporated a conservative die-off rate for fecal coliform bacteria.

When the ambient water is not stratified (Case #1), the CORMIX model predicts much higher dilutions, such that the water quality standard is met at the target location for all but the most concentrated discharges.

The worst-case dilution factor is approximately 4300. In the hydrodynamic model the minimum dilution for this location using a pulse release was 14.2, and the maximum was 6.9×10^7. All the CORMIX results fall within this range. One significant difference between the CORMIX model and the hydrodynamic model is the predicted travel time. The time for the effluent plume to travel from the discharge point to the target location in the CORMIX model is 1-3 hours, while the hydrodynamic model predicted 18-24 hours for this location.