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Date: November 3, 2019
To: Nordic Aquafarms
From: Nathan Dill, P.E.
Subject: Far-field Dilution of Proposed Discharge – Supplemental Information

This memorandum is being provided as a supplement to our memorandum dated October 2, 2018 regarding far-field dilution analysis of the proposed Recirculating Aquaculture System (RAS) wastewater discharge into Belfast Bay. Our October 2, 2018 memorandum provides a description of the technical approach used to evaluate far-field mixing and dilution and provides estimates of the spatial and temporal distribution of the dilution resulting from a continuous discharge during typical tidal conditions.

This memorandum expands on the previous analysis by evaluating dilution characteristics while also considering how long the diluted effluent has been present in the bay after it's discharge. Consideration of diluted effluent age in this way may help provide insight into dilution processes that occur at time scales relevant to bio-chemical processes affected by nutrients and Bio-Chemical Oxygen Demand (BOD) associated with the discharge.

A time scale of approximately two days post-discharge was evaluated as a reasonable timeframe that would be required for bio-chemical processes to become important. Particle tracking output from the modeling described in our October 2, 2018 memorandum were analyzed to evaluate dilution characteristics at this time scale.

To perform this analysis triangular elements from the ADCIRC model finite element grid were used as control volumes to estimate the average age of the diluted effluent. Within each control volume the average age of diluted effluent is estimated by determining the median age of particles found within the element. For example, an element that contains diluted effluent with a median age of two days contains as many particles that are younger than two days post-discharge as it does particles that are older than two days post-discharge. Median particle age was determined for each triangular control volume that contained at least one particle, and for each hourly snapshot in the model simulation output. Once the median age was determined, control volumes containing diluted effluent with median age ranging from 1.5-days to 2.5-days were identified for further analysis. Figure 1 shows a reproduction of Figure 5 from our October 2, 2018 memorandum showing snapshots of the dilution over the course of a typical tidal cycle, but with an additional area indicated in yellow to show where the median diluted effluent age is between 1.5-days-old and 2.5-days-old. It is noteworthy that the area defined this way tends to lag the tidally averaged centroid of the total diluted effluent area. Furthermore, the dilution in this

region varies considerably from the lowest values of dilution associated with the leading edge of the region, to practically negligible values on the trailing edge of the region.

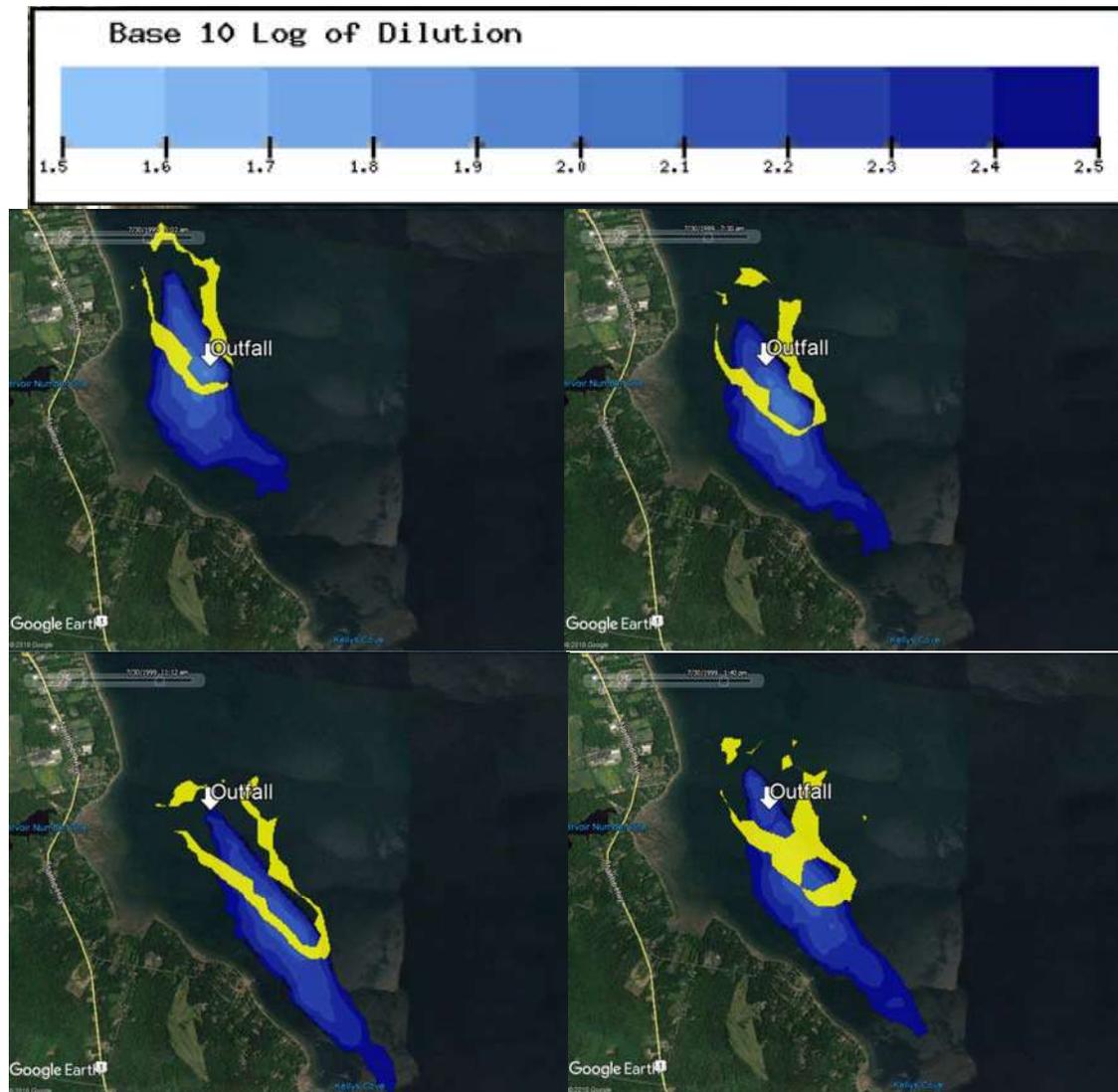


Figure 1. Snapshots of dilution throughout a typical tidal cycle. high slack (upper left), mid-ebb (upper right), low slack (lower left), mid-flood (lower right). Yellow areas show where median age of diluted effluent is between 1.5-days-old and 2.5-days-old.

In order to evaluate dilution that is associated with the 2-day-old diluted effluent, the dilution within each of the control volumes described above was calculated for each hourly output from the particle tracking simulation and then areal distribution of the dilution within the 2-day-old region was evaluated by calculating the cumulative areas at various quantiles as indicated in Figure 2. For example, the red line on Figure 2 shows a time series of the dilution that is less than the dilution in 95% of the 2-day-old area region. In other words, less than 5% of the area of the region containing diluted effluent that is between 1.5-days-old and 2.5-days-old has a dilution of about 100 (10^2) or less. Likewise, 70% of the 2-day-old area has dilution greater than about

160 ($10^{2.2}$), 50% of the 2-day-old area has dilution greater than about 300 ($10^{2.5}$), and more than 10% of the 2-day-old area has dilution greater than about 3000 ($10^{3.5}$).

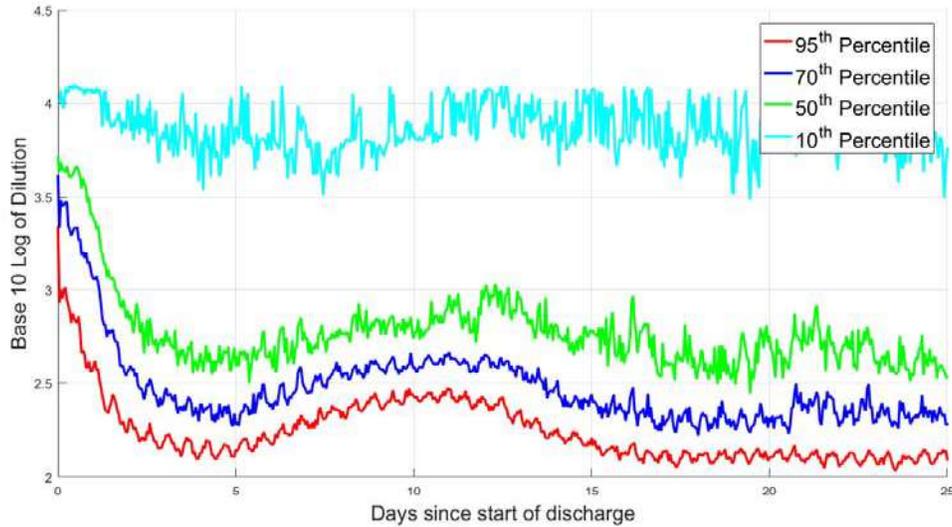


Figure 2. Time series of areal dilution distribution within region containing diluted effluent with median age between 1.5-days-old and 2.5-days-old.