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Independent Technical Review of FVCOM Modeling for Wastewater Dilution in Buzzards Bay and the North and South Rivers: Considerations for Regulatory Implementation

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Preface

This report presents the findings and recommendations of an independent technical review of hydrodynamic modeling using the Finite Volume Community Ocean Model (FVCOM) to simulate wastewater treatment plant (WWTP) effluent dilution in Buzzards Bay and the North and South Rivers, Massachusetts. The review was commissioned by WHOI Sea Grant, an independent, science-based program based at Woods Hole Oceanographic Institution, and supported by funding from NOAA Award NA24OARX417C0156. Its intent is not to critique the quality of the modeling work conducted by University of Massachusetts-Dartmouth researchers and the Massachusetts Division of Marine Fisheries (MA DMF), nor to question the regulatory decisions made by state agencies. Rather, it is meant to provide constructive scientific guidance on how to further strengthen confidence in the model results as they are considered for regulatory applications.

WHOI Sea Grant recognizes the substantial effort undertaken by the U. Mass research team and MA DMF to apply a high-resolution, data-intensive modeling approach under limited time and resource constraints. Given the importance of shellfish classification decisions to both public health and coastal economies, ensuring that the modeling tools used in this process are robust, transparent, and well-supported by data is essential. It is our hope that the Commonwealth of Massachusetts will provide additional resources to MA DMF to support the implementation of key recommendations made by the review team, including expanded model validation, improved uncertainty quantification, and engagement with interested parties. This review represents a step toward engaging modelers, regulators, and interested parties in a dialog that supports informed, science-based decision making.

Executive Summary

Coastal shellfish harvesting in Massachusetts is regulated to ensure public health, with water quality classifications guided by the National Shellfish Sanitation Program (NSSP). A key factor in these classifications is the dilution of wastewater treatment plant (WWTP) effluent, which can impact nearby shellfish beds. In response to FDA requests to clarify how dilution zones around WWTPs are calculated, the Massachusetts Division of Marine Fisheries (MA DMF) partnered with U. Mass-Dartmouth researcher Dr. Changsheng Chen's lab to use the Finite Volume Community Ocean Model (FVCOM) to estimate dilution zones around WWTP outfalls. The modeling evaluations have been completed for WWTPs in Scituate (discharging to the North and South Rivers), Ipswich (discharging to Greenwood Creek, which flows into the Ipswich River), Fairhaven (discharging to New Bedford Harbor), and New Bedford (discharging to the

open waters of Buzzards Bay). These model results have informed recent reclassifications of shellfish growing areas, resulting in large-scale downgrading of shellfish harvest classification and prompting the desire for an independent scientific review to evaluate the model's application and reliability in regulatory decision making.

To address this need, WHOI Sea Grant coordinated an independent technical review of two FVCOM modeling reports that were available as of December 2024, focused on the Fairhaven and New Bedford WWTPs and the Scituate WWTP, as well as associated validation materials provided by Dr. Chen's team. Three experts in ocean modeling and coastal processes were asked to evaluate the model's approach, performance, and suitability for informing shellfish water quality classifications and management of wastewater and combined sewer overflow (CSO) discharges. The experts were selected from outside Massachusetts and had no conflicts of interest with Dr. Chen or his research team. After the independent reviews were completed, MA DMF and Dr. Chen and his team were provided the opportunity to submit written responses. Their comments were aligned with the findings and recommendations of the review, and no changes to the report were necessary. The reviewers agreed the existing modeling framework as well as the high-resolution models are appropriate for use in assessments of wastewater treatment plant effluent dilution. They also included several recommendations and requests for additional information. Their findings can be summarized as follows:

- Enhance model validation in the areas of interest
- Improve clarity and documentation of modeling methods
- Better address spatial and temporal uncertainty
- Consider decay and non-passive behavior of contaminants

Based on the reviewer feedback, WHOI Sea Grant recommends several actions to strengthen confidence in the application of the FVCOM model for this regulatory purpose. These include expanding validation of hydrodynamics using local observational data, testing the passive tracer model through dye studies or comparisons with past field efforts, improving documentation of modeling methods, assessing uncertainty through multi-year simulations, and evaluating the potential influence of contaminant decreases via natural processes. WHOI Sea Grant also recommends establishing an advisory board of scientists, managers, and shellfish industry representatives to provide ongoing guidance and promote transparency in the use of model results.

Background

To ensure that molluscan bivalve shellfish like oysters, clams and mussels harvested from nearshore waters are safe for human consumption, the US Food and Drug Administration (FDA) works cooperatively with state regulatory agencies and shellfish industry members through the National Shellfish Sanitation Program (NSSP). The guiding document is called the NSSP Guide for the Control of Molluscan Shellfish, which is usually updated every two years and documents the conditions which need to be met to maintain safe harvest and commerce of shellfish.

In Massachusetts (MA), the responsible state authority is the MA Division of Marine Fisheries (MA DMF) in partnership with the MA Department of Public Health and the MA Environmental Police. These agencies, with oversight from the FDA, must examine potential pollution sources in combination with sampling for microbial standards to evaluate a region's shellfish growing area classification. Based on these ongoing evaluations, coastal waters can be designated in one of five classifications: Approved for harvest, Conditionally Approved (conditions may be based on rainfall, wastewater treatment plant (WWTP) operation, etc.), Restricted, Conditionally Restricted, or Prohibited to the harvest of shellfish. For an area to have allowable shellfish harvest without significant restrictions, it must be classified as Approved or Conditionally Approved and in the open status.

One factor evaluated in this process is the proximity of growing areas to point sources of pollution. The FDA's recommended dilution levels that should be maintained around WWTP discharges (Section IV, Chapter II, .19 Classification of Shellfish Growing Waters Adjacent to Waste Water Treatment Plants) are:

- 1:1000 dilution zone is recommended to be a Prohibited area
- beyond the 1:1000 dilution zone is recommended to be Conditionally Approved, with conditions for being in the open or closed status depending on WWTP operation conditions.
- 1:100,000 dilution is recommended before an area could be considered Approved

Note that the FDA's guidance allows some flexibility for the use of data to justify the level of dilution chosen for classification, pending FDA approval.

Problem description

The FDA has recently reviewed the MA shellfish growing area classifications and has asked the state to better justify the delineation of classification areas around WWTP discharges. In response, the state of MA enlisted the help of a team of hydrodynamic modelers based out of the University of Massachusetts - Dartmouth, led by Dr. Changsheng Chen, to identify dilution zones around WWTP discharge locations. Dr. Chen's team utilized the Finite Volume Community Ocean Model (FVCOM) to simulate WWTP discharges at four outfall locations at this time, but anticipates more WWTPs to be evaluated in the near future. At the time this review was initiated (December 2024), modeling results were available for the two facilities discharging into the New Bedford area (New Bedford and Fairhaven WWTPs) and the Scituate area (Scituate WWTP), which were the focus of this report.

Results from the FVCOM discharge modeling informed DMF of passive tracer volumetric dilution contours that has led to a reclassification and downgrading of thousands of acres of shellfish harvest area (Figure 1). For example, FVCOM model results suggest expansion of the Prohibited area around the WWTP that serves the City of New Bedford, MA. This WWTP discharges into the open waters of Buzzards Bay and a prohibited area surrounding the WWTP discharge is thus required. As a result, a number of shellfish farms and wild harvested areas fall within or close to the recommended 1:1000 dilution for a Prohibited zone. This has led MA DMF to reclassify the waters of several shellfish farms as Conditionally Approved (that were previously in Approved waters), but they have avoided classifying the farms as Prohibited (and closing the farms) at this time. In Scituate, modeling of the WWTP discharge there closed hundreds of acres of recreational shellfish area and further limited potential for shellfish aquaculture in the town.

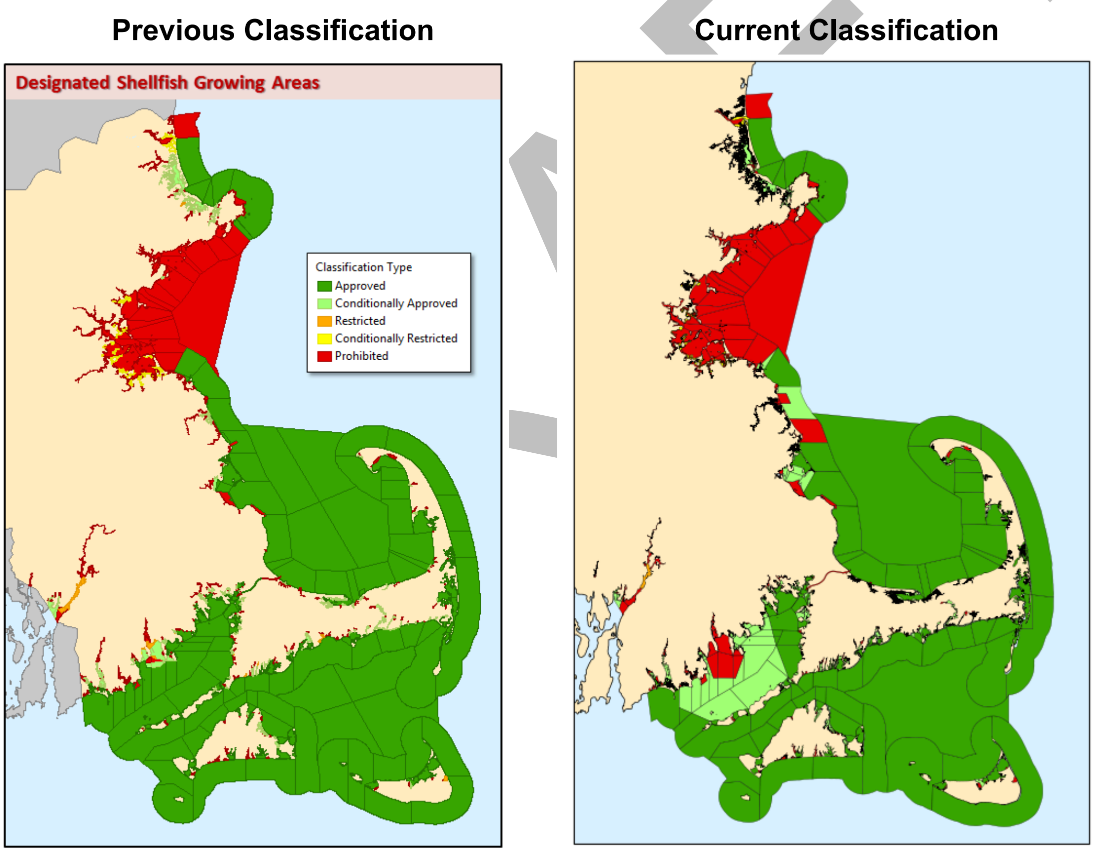


Figure 1. Left: Classification of designated shellfish growing areas prior to reclassification efforts. Figure from MassGIS (https://www.mass.gov/files/images/massgis/datalayers/dsga.png, Accessed on April 28, 2025). Right: Classification of shellfish growing areas as of February 10, 2025. Reclassification of shellfish growing areas near the New Bedford, Fairhaven, and Scituate, MA WWTPs was informed by FVCOM-modeled dilution contours. Areas previously classified as Approved were downgraded to Conditionally Approved due to proximity to the modeled WWTP outfalls, and the Prohibited Zone has been expanded. Colors indicate

classification type Approved (dark green), Conditionally Approved (light green), Restricted (orange), Conditionally Restricted (yellow), and Prohibited (red).

A second challenge that significantly impacts the six shellfish farms and numerous shellfish harvesters in the region is that the City of New Bedford has legacy combined sewer overflows (CSOs) that can discharge raw wastewater with rainfall into the waters of New Bedford Harbor and the open waters of Buzzards Bay. Depending on the volume of discharge, varying volumes of receiving water are required to dilute the untreated sewage discharges to the NSSP standard fecal coliform level that allows for shellfish harvest for direct human consumption (14 colony forming units/100ml). When CSOs overflow, areas can be closed depending on conditions such as the volume of the overflow, where the overflow occurred, as well as bay and weather conditions. These CSO-related closures have resulted in the shellfish farms being closed about 60% of the time in 2024.

The FVCOM modeling results show that discharges from the New Bedford and Fairhaven WWTPs can flow into the shellfish growing areas where the farms are located and, therefore, those areas cannot be excluded as potential receiving waters for CSO discharge. While FVCOM modeling results **do not determine CSO closures**, MA DMF does use the model grid and bathymetry to estimate the volume of water within the model domain during high and low water conditions. Dr. Chen provided DMF with a static dataset of water volume that DMF utilizes to determine how much area needs to close in order to achieve the appropriate level of dilution following CSO discharge events. The volume of receiving water needed for dilution is calculated by using the volume of the CSO discharge reported by the City of New Bedford (pursuant to DEP regulation) and using a fecal coliform level for discharge water that is informed by DMF sampling and testing of past CSO discharges (400,000 CFU/100ml). It is possible that future use of model simulations under real-time environmental conditions could better inform DMF of the fate of CSO discharges in Buzzards Bay and allow for more precise closure delineations following CSO discharge events.

As such, there is significant interest among the shellfish harvest and manager community to ensure that the modeling undergoes an independent, peer-reviewed process to evaluate both the dilution model results for average conditions that inform shellfish growing area classification as well as their potential use for decision making following discrete CSO discharge events in the context of ensuring public safety. As an independent, science-based entity, WHOI Sea Grant has been asked to facilitate this review.

Methods of Review

WHOI Sea Grant sought independent, technical evaluations of two reports summarizing the WWTP modeling results in Buzzards Bay and in the North and South Rivers as well as additional validation materials for the parent FVCOM model, the Northeast Coastal Ocean Forecasting System (NECOFS) provided by Dr. Chen and his team. Three technical experts in high resolution coastal ocean modeling who were unconflicted with Dr. Chen and his team were given six weeks to evaluate the materials provided. Reviewers were asked the following:

1) Provide a written summary and evaluation of the model in the context of the dilution of WWTP discharge.
2) Is the described approach for the modeling appropriate to identify dilution zones? If not, are there alternative approaches that could be used?
3) Is the model well validated based on the materials provided? Please describe in detail your perspective on the model's performance and validation.
4) If, in your opinion, the model is not well validated, please make recommendations as to what you think would be needed to further validate the model? E.g. additional observations, modeling scenarios, more details to the written documentation, etc.
5) The model has been used to assess the dilution zones associated with a continuous discharge of wastewater.
    - Based on your assessment of the modeling results and validation, does the model have the appropriate spatiotemporal resolution to evaluate the dilution of event-scale discharge from other point sources, i.e. CSO discharges?
6) Please comment on your perspective of the usage of this model for decision making for two purposes:
    - To establish shellfish classification areas
    - To predict the short-term impact of rainfall events and CSO discharges

Reviewers of materials provided by Dr. Chen's team will remain anonymous. Blinded review materials were provided to Dr. Chen and his team and the Massachusetts Division of Marine Fisheries to respond to. WHOI Sea Grant has compiled these three reviews and the responses to reviews into the following summary and recommendations.

Reviewer Summary

Reviewers touched on many different aspects of the modeling work. *All three reviewers agreed that the existing modeling framework as well as the high-resolution Mass Coastal FVCOM and North and South Rivers FVCOM (NSR-FVCOM) are appropriate to be used for assessments of wastewater treatment plant effluent dilution*. This modeling team has extensive experience operating global, regional, and coastal ocean models, and among other things, has implemented passive tracer tracking and biogeochemical modeling assessments in numerous use cases using various iterations of the FVCOM modeling framework. Reviewers agreed that the unstructured grid and very high spatial (up to 4m horizontal and 0.5m vertical) and temporal (up to 0.3s) resolution allows for accurate depictions of complex land-ocean boundaries, which are critical to assess the likely path of wastewater in the modeling domain. Reviewers noted that the parent model, Northeast Coastal Ocean Forecasting System (NECOFS), is a highly respected and widely used ocean modeling tool. NECOFS has been extensively validated for numerous applications such as water levels, stratification, currents, storms, and flooding, building confidence in boundary conditions for many parameters, including but not limited to tides, currents, water temperature and salinity, and the atmospheric forcing has been validated for winds, sea pressure, air temperature, and humidity. Reviewers also agreed that the passive tracer simulations were well designed and can achieve the goals outlined — to document the possible spread of wastewater discharged from the assessed WWTPs.

Four main themes emerged from the review of the modeling work. These themes include: 1) validation of the results, 2) clarity in methodology, 3) uncertainty in simulation results, and 4) consideration of non-passive behavior of wastewater contaminants. The four themes are described in more detail below.

1 - Validation

All three reviewers felt that, although the parent model, NECOFS, was well validated, this particular use-case would benefit from additional work. Validation of the NSR-FVCOM model was not described in the materials provided. Validation of the Mass-Coastal FVCOM model for this use was focused on assessments of semidiurnal and diurnal tidal amplitudes and phases at 18 locations around the modeling domain. The modeling team found good agreement with most tide gauges with the exception of two, which they attributed to poorly resolved bathymetry in some locations. Reviewers identified that, given the usage of the model to inform regulatory decision making, an additional assessment of the models' performance would be important. Reviewers suggested that comparing model results to observations of hydrographic data and current speeds in the regions surrounding the WWTPs would improve confidence in overall model performance and capabilities. This type of assessment would evaluate how well the model simulates water flow, stratification, and mixing with the target regions. One reviewer identified that further validation of the NSR-FVCOM model may not be possible with the simulations as originally designed, as the model was forced with climatologies rather than specific years. Another reviewer suggested that the passive tracer application should be directly validated by implementing a dye tracer study and associated field campaign to fully document spreading and dilution of wastewater from modeled WWTPs.

Modeling results of the New Bedford and Fairhaven WWTPs suggest the spreading of material at the surface was more extensive than at depth. All three reviewers raised concerns about the behavior of the initial discharge and mixing of the wastewater into the Mass Coastal FVCOM model domain, and raised concerns about how that led to surface spreading of material surrounding the WWTPs. All reviewers noted that there was not sufficient evidence given that, with a well-mixed water column in Buzzards Bay, concentrations should be different at the surface than at depth. The modeling team hypothesized that the energetic environment generated from the mixing of laminar flow from the wastewater pipe with the turbulent flow of Buzzards Bay drives material to the surface. All three reviewers felt that it would be important to validate these results with data to fully document the processes driving the dilution and mixing of wastewater around Buzzards Bay.

2 - Clarity in methodology

All three reviewers identified elements of the provided reporting materials that would benefit from additional clarification of the methods used in the analysis. Reviewers requested more information and description of the tracer tracking model used in the simulations. All reviewers noted that there were discrepancies between the 1:1000 dilution contour that was shown and the 0.1% concentrations reported in the dilution maps. Reviewers felt that a more detailed description of how the 1:1000 dilution ratio was quantified was warranted. Reviewers also would have liked to have seen more description of how the modeling team implemented the WWTP discharge into the modeling domain. One reviewer suggested that the team might consider a description or methodology such as reported by Kessouri et al. 2021 (https://doi.org/10.1029/2020MS002296). Reviewers felt that the description and implementation of the model forcings, such as spatial and temporal resolution of the atmospheric model and riverine discharge and WWTP effluent associated characteristics, would also benefit from expansion. Reviewers asked for more details on the model grid structure, and whether fine scale engineered structures, such as breakwaters or jetties, were included in the modeling grid. Reviewers also identified opportunities for the modeling team to clarify some of the graphics shown, add additional tables that summarized the model experiments run and add additional citations to points made.

3 - Uncertainty in simulation results

Two of the three reviewers highlighted that the presented modeling results do not incorporate any information on spatio-temporal uncertainty. The results presented for Buzzards Bay included only one year, 2021, of model runs, and the dilution contours show averages over long periods of time. A discussion of why the year 2021 was selected for modeling of the New Bedford and Fairhaven WWTPs was not included in the reporting materials. One reviewer noted that considerable variation in winds, currents, stratification, and mixing might be expected from year to year that may affect the size and location of the dilution zones. This reviewer felt that it was important to either model additional years to fully document the spatio-temporal uncertainty, or at a minimum, put the modeled year into a broader context to fully understand how representative 2021 would be of a typical year. They also wondered why a monthly or seasonal product was the appropriate timescale to evaluate dilution contours, and would have liked to see this decision justified in the text. We note that the modeling in the North and South Rivers region was completed using seasonal climatologies of forcings, which may be more representative of average conditions, but one reviewer noted that this may hinder validation of modeling results. Reviewers felt that documentation of spatio-temporal uncertainty could in part be presented through maps of the standard deviation in modeled dilution contours for each season, and that other metrics such as salinity contours might also be useful for assessing model performance.

Reviewers also raised concerns that model accuracy and other process-based uncertainty, such as that associated with the initial mixing of WWTP effluent into the model domain (described above), were not incorporated into the dilution products. Reviewers felt that providing a confidence interval in the dilution contours would be important to bound the uncertainty in results, particularly because results are being used to inform regulatory decisions.

4 - Consideration of non-passive behavior of wastewater contaminants

Two reviewers identified that contaminants in wastewater discharge may not fully behave passively over time, but may decrease with time due to natural processes such as exposure to UV radiation. Reviewers asked if tracer degradation rates might influence the extent of the dilution zones identified. One reviewer suggested that a sensitivity analysis could be completed, implementing results of Kragh et al. 2022 and/or Delre et al. 2023 which show degradation rates of colored dissolved organic matter (CDOM) and microplastic particles when exposed to UV light. Reviewers felt as though a comparison of results with and without tracer degradation rates might also help to inform uncertainty in modeled results (see section 3, above).

Recommendations

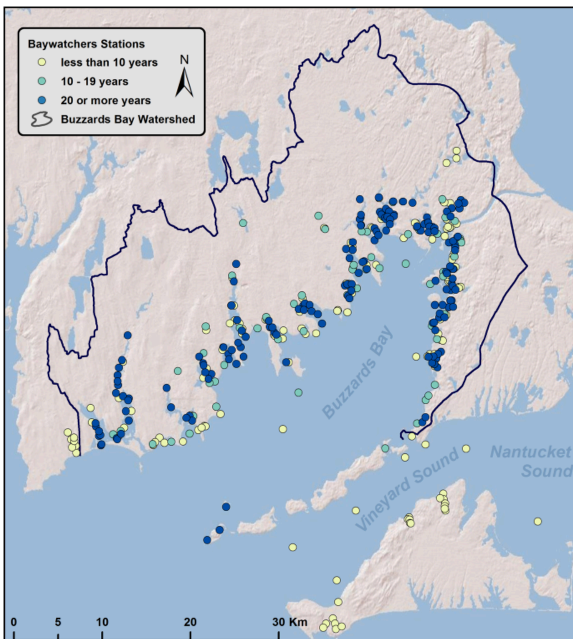
Based on the outcomes of this peer review, WHOI Sea Grant notes that the modeling approach is highly sophisticated and likely to achieve the outcomes of documenting the dilution, dispersion, and mixing of wastewater effluent into receiving waters. However, reviewers identified key points that are critical to consider before implementing these results into regulatory decision making. As such WHOI Sea Grant proposes the following recommendations to the Commonwealth of Massachusetts:

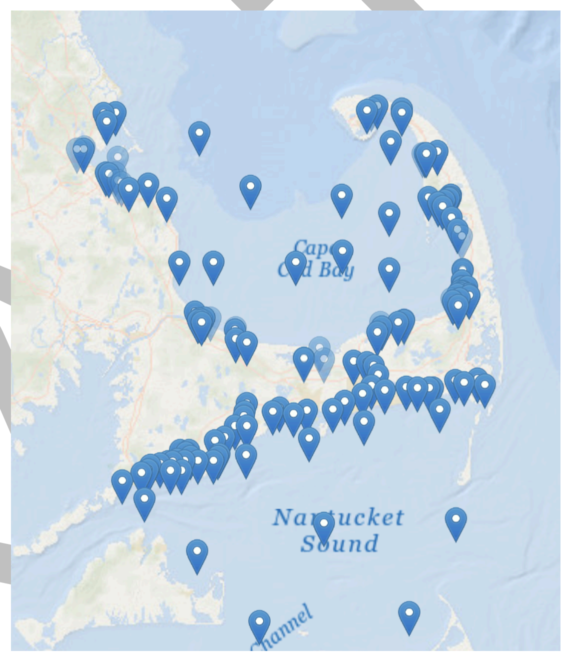
1) Expand the validation of the hydrodynamics of the Mass-Coastal FVCOM to include detailed information in and around the study domain.

We recommend expansion of the comparison of historical modeled conditions from the Mass-Coastal FVCOM to more observational data as a way to build confidence in this use of the FVCOM modeling framework for regulatory decision making. In addition to the existing comparison of FVCOM model output to regional tide gauges, we recommend expanding the analysis to assess comparisons to, at minimum, historical temperature and salinity. The Massachusetts coastal zone is remarkably well studied historically through a number of existing long-term monitoring programs that have collected hydrographic data in both coastal and nearshore open waters. For example, the Buzzards Bay Coalition, a nonprofit organization, has maintained a water quality monitoring program at more than 200 locations throughout Buzzards Bay, including in and around New Bedford Harbor. Their data, spanning 1992 - 2018, have been made publicly available via Jakuba et al. (2021) (Figure 2), with data collected as recently as summer 2023 available on their program website (www.savebuzzardsbay.org). The Center for Coastal Studies, another nonprofit organization in the region, has also collected extensive hydrographic data in the study region, which may be useful for historical validation (https://www.capecodbay-monitor.org/). WHOI Sea Grant also maintains a network of sensors in the Cape Cod, Buzzards Bay, and Duxbury Bay regions (Figure 2) that have collected high frequency (~15 minutes) water quality data, including relevant parameters temperature and salinity, extending back to 2004. Both archived and real-time data are freely available (https://seagrant.whoi.edu/regional-topics/water-quality/water-quality-monitoring-program/).

Relevant embayments have also been extensively studied through the Massachusetts Estuaries Project, with assessments completed through labs at U. Mass-Dartmouth that may also provide data for comparison. Other nonprofit or community organizations have also monitored water quality conditions in a number of relevant embayments, e.g. the North and South Rivers Watershed Association Water Quality Monitoring Program, which may be willing to share its data.

In addition to historical temperature and salinity data, observations of current speed and direction can also inform the accuracy of the model's horizontal and vertical water velocity predictions. A monitoring station maintained by the NOAA National Ocean Service regularly measures ocean currents for the purposes of navigation and safety at the Cape Cod Canal (station CA0101, https://tidesandcurrents.noaa.gov/cdata/StationInfo?id=ca0101). Other regional datasets exist that may be useful for comparison to ocean currents, such as High Frequency Radar (HF Radar, e.g. https://cordc.ucsd.edu/projects/hfrnet/), which provides information on surface currents. Although data do not extend into the regions very close to the WWTP outfalls, they may still have some relevance in comparing the model output across the broader domain.





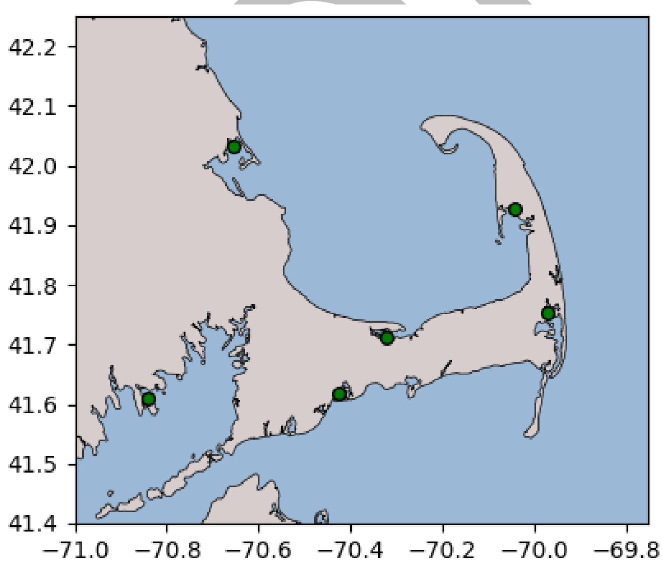


Figure 2. Upper Left: Map of water quality monitoring stations sampled by the Buzzards Bay Coalition, colored by number of years sampled. Figure reproduced from Jakuba et al. 2021. Upper Right: Water quality monitoring stations from the Center for Coastal Studies. Lower Left: Water quality monitoring stations from WHOI Sea Grant.

2) Test and validate the passive tracer modeling via a dye study, such as using the fluorescent dye tracer Rhodamine WT.

We recommend a detailed evaluation of the mixing and dispersion of wastewater in the immediate vicinity of the outfall pipes, as well as a thorough assessment of the passive tracer model in comparison to field observations. This could be completed via a number of possible approaches, with the most extensive being a field campaign that collects detailed, high resolution observations of tracers associated with wastewater discharge, such as temperature and salinity, and flow fields immediately surrounding the discharge locations. Fluorescent dye, such as Rhodamine WT, is commonly used to assess the dilution and dispersion of a passive tracer, and has been used in many applications to determine the transport and mixing of wastewater from point sources. Complementing field measurements of flow fields and hydrographic data with an injection of a fluorescent dye from WWTP infrastructure allows for tracking via sensors that are sensitive to the passive tracer down to very low concentrations.

In the absence of resources for an additional field campaign, FVCOM modeling for the Fairhaven facility discharging into New Bedford harbor could be compared to a previous dye tracer study that was completed in 2001 by Applied Science Associates, Inc (https://buzzardsbay.org/download/asa-flushing-report-jan03.pdf). This study was designed to assess the flushing of wastewater within New Bedford Harbor, and extensive field data was collected along with several Rhodamine WT releases from the Fairhaven WWTP which were monitored for numerous days post discharge. This report included both field campaigns and short- and long-term modeling to document the likely spread and contribution of wastewater to waters of New Bedford Harbor.

3) Expand on the assessment of uncertainty in results by modeling WWTP discharge in additional years.

Several reviewers noted that the existing materials used to inform regulatory decisions did not account for or document spatio-temporal uncertainty in modeled results, nor were the presented results bound by a confidence interval. We recommend that this gap be addressed through several mechanisms, each of which may require additional investment of resources. At minimum, we suggest that, using the existing passive tracer output presented in the reporting materials, the seasonal variability in dilution contours should be assessed via a quantification of the spatial variance over the timeframes analyzed. Second, if model runs already exist, hindcasts of multiple years of Mass-Coastal FVCOM should be evaluated to determine whether 2021, the year modeled for WWTP discharge tracking, is representative of typical conditions in the region. This approach would not implement additional tracer tracking work, but would focus on a deeper understanding as to whether the oceanographic conditions, and thus the tracer dilution and dispersion, modeled in the year 2021 are consistent and may be applicable to other years. Finally, the passive tracer modeling work could be expanded to include multiple years of study, and the interannual variability in dilution contours could be assessed.

4) Expand on the description and documentation of the modeling methodology used.

We recommend that the modeling team more fully document the methods and missing information described in the “Review Summary - Clarity in Methodology” section detailed above.

5) Complete an evaluation of sensitivity of dilution zones to tracer degradation rates

As described in the “Review Summary - Consideration of non-passive behavior of wastewater contaminants” section, contaminants in wastewater may not behave as a passive tracer, but may degrade over time due to exposure to natural environmental conditions. We recognize that there are many potential contaminants in wastewater effluent, and implementation of individual tracer degradation rates may not be feasible. The assumption of no tracer degradation also represents the most conservative approach with respect to public health and safety. That being said, as suggested by peer reviewers, we recommend an assessment of the sensitivity of the dilution contours with and without passive tracer degradation rates be undertaken. This analysis would explore how the dilution contours may vary with differing degradation rates, and provide some insight into how sensitive the tracer model is to this process.

6) Create an advisory board to provide input and feedback on modeling results and implementation of results by the Massachusetts Division of Marine Fisheries.

Finally, we recommend that MA DMF consider the development of an advisory board with members that include representatives of key communities that participate in and are affected by decisions on how to implement results of assessments of point sources of dilution. Members might include scientists – both with expertise in modeling as well as expertise in public health, pathogens, and shellfish biology, representatives of shellfish aquaculture and wild-harvest industries, and state and federal managers and policymakers. Such a board would ensure transparency in decision making and trust in how model or field study results are interpreted and applied via associated policy changes.

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