2300 Days at Sea:
Monitoring the Impacts of the Massachusetts Bay Outfall

Transcript of Presentations, Panel and Breakout Sessions

This document is an edited transcription of the presentations, panel discussion, and breakout sessions from the 2300 Days at Sea: Monitoring the Impacts of the Massachusetts Bay Outfall
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Transcribed by Andrea Patton and colleagues
Edited by Judith Pederson, Ken Keay, Betsy Reilley, and Mark Smith and reviewed by Robert Kenney, Matt Liebman, and Cathy Vakalopoulos

Judith Pederson, Interim Chair, Outfall Monitoring Science Advisory Panel, MIT Sea Grant College Program (retired)

Introduction

Today it is hard to imagine that Boston Harbor was once deemed the dirtiest harbor in the US, but in the 1980s over 450 million gallons of sewage that included untreated sewage, was discharged daily along with 100 tons of sludge/day that was released on the outgoing tides. After the Metropolitan District Commission was sued and with Superior Court Judge Paul Garrity threatening to bar new sewage hook-ups, the Massachusetts Water Resources Authority (MWRA) was established in 1985. The plan was to eliminate sludge discharges, build a new facility on Deer Island and after much discussion with agencies, construct an outfall located about nine miles off shore. From an ecologist's perspective, it was a field experiment on a large, very large scale and should include a monitoring program to demonstrate that Boston Harbor would become cleaner and that discharging effluent to Massachusetts Bay would not cause harm. An Outfall Monitoring Task Force (OMTF) was composed of scientists, agency representatives and public interest groups and held several public meetings. The Task Force advised MWRA and their consultants as they developed a monitoring plan. The plan was adopted in late 1991 and implemented in 1992 along with monitoring the Contingency Plan (CP). The CP was established to address a recommendation from the biological opinion from the Endangered Species Act, section 7 consultation from the National Marine Fisheries Service (NMFS). When the draft National Pollutant Discharge Elimination System (NPDES) permit was issued in 1997, an Outfall Monitoring Science Advisory Panel (OMSAP) was established to advise the Environmental Protection Agency (EPA) and Massachusetts Department of Environmental Protection (MassDEP) on scientific issues related to the monitoring plan, review of results, and as appropriate, make recommendations for modifications. Subsequently there were two updates of the monitoring plan, one in 2004 and another one in 2010.

One of the goals of today's workshop is to revisit the initial questions in the monitoring plan.

- Are we asking the right questions (for the ambient monitoring)?

- Are the questions being answered by the monitoring?
- Have some already been answered?
- What are the trending concerns?
- Is it appropriate to monitor any of them?

There have been many changes in the last 25 years, what else should we consider?

Just a brief word about what we are not discussing today that has also been an important part of the MWRA's monitoring activities. These include effluent monitoring, monitoring of beaches, monitoring of Boston Harbor, Combined Sewer Overflow (CSO) upgrades, and the long-term modeling that initially helped visualize the outfall and its dilution for the public. Modeling water quality efforts over the past several years confirm the findings from the monitoring program that there are no adverse effects from the outfall. In addition, the model is used to examine what would happen under future scenarios, e.g. increasing nitrogen loading for example. Taken together, this is a very impressive approach to ensuring that the harbor and the bay remain unaffected by the outfall. In the Harbor cleanup we needed to make sure that Mass Bay wouldn't be harmed. The clean-up effort of Boston Harbor and the monitoring plan to demonstrate no impact on Mass Bay is a research project on a grand scale that would never get funded by grants.

Today we will examine the current monitoring activities, ask what remains to be done, what questions have been answered, and what remains as issues to continue to be monitored. As we look forward to the future monitoring activities, we will also discuss emerging contaminants as well as climate change and the outfall.

This workshop is an opportunity for you to provide your input. We want your feedback on whether the monitoring plan questions address the issues of concern – namely protecting public health, aesthetics, and protecting the ecosystem and on what you think should be monitored in the future.

There are a number of opportunities for you to give us your feedback. Around the room are a number of easels with "sticky notes" and we hope you will use them throughout the day to add thoughts that you do not get to discuss or ask during the day. The second opportunity after the morning presentations is to participate in breakout group sessions on three topics: Questions Asked and Answered, Trends in Emerging Contaminants, and Climate Change and the Outfall. In addition, there is time for questions and answers, open discussions and an opportunity to send emails to us. We welcome comments on topics not covered in this workshop.

Bruce Berman, Chair, Public Interest Advisory Committee, Save the Harbor/Save the Bay

When I first started at Save the Harbor/Save the Bay we made a promise to the public–that the clean-up of Boston Harbor would not come at the expense of Mass Bay or Cape Cod. It seems obvious to us now, but it wasn't obvious before we relocated the outfall pipe. The public was concerned. After decades of having our waste wash up on shore, people were concerned. In their wisdom the regulators–EPA, MassDEP, and others who have been extraordinary partners – created a Public Interest Advisory Committee (PIAC) so the public can share their concerns with OMSAP. Today I think we will learn that MWRA, Save the Harbor, and all of us in the room

kept that commitment that the successful Harbor cleanup has not had dramatic negative impacts on the Bay.

As you all are aware the water is getting deeper, warmer, and stormier. We are lucky here to have political leaders and stakeholders who know the issues we face as the Bay has gotten about 0.48ºF warmer every ten years.

I want to thank every person in this room but in particular, the leadership and the men and women of the MWRA, the Sludge Judge Garrity, and Judge Mazzone who oversaw this project to make sure it came in on time and under budget. Judge Mazzone's legacy is lasting. I'm not going to call out individuals in this room, but I cannot help but say that Judy Pederson and the leaders of OMSAP, Betsy Reilley and Fred Laskey, and Patty Foley have done their best along with all of you to understand the impacts of the outfall on the marine environment.

We turn to the data and the scientists who know how to interpret it to increase our understanding. As we move forward I think we can help MWRA and regulators design a monitoring plan that does not ask questions that have been asked and answered but continues to ask questions that shed light and understanding on emerging issues.

Ken Keay, Senior Program Manager for Environmental Monitoring, Environmental Quality Department, MWRA

Overview of MWRA's Ambient Monitoring Plan and Contingency Plan

In the early days of the project there were a number of concerns about the effect of the MWRA's Mass Bay Outfall, but there was agreement about – building a large primary and secondary treatment facility on Deer Island. MWRA was a new and untested authority and didn't have credibility when telling people that the treated effluent would not have the kinds of impact on the Bay that the untreated sewage in the Harbor had. Regulators, as they approved the outfall tunnel, required that a comprehensive baseline monitoring take place to study background conditions as the project was built. They established the OMTF to design the monitoring program that would help establish the baseline. Agency scientists, regional academics, and members of the public and non-governmental organizations (NGOs) made up the membership of OMTF.

MWRA worked with OMTF in the early 1990s to turn four public concerns identified during treatment plant design into a monitoring program. The OMTF identified 40 monitoring questions and designed studies to address them.

The group used National Research Council (NRC) guidance, *Managing Troubled Waters*, to design the program and stressed the need to have measurable results. The Monitoring Plan was finalized in late 1991 and outfall monitoring began in February 1992. In the early days the plan was frequently reviewed and revised per the NRC guidelines. What was planned as a three-year baseline became nine years as the construction of the tunnel took longer than anticipated. Prior to the outfall coming online, concerns about managing the data and how monitoring results would be used to identify problems were raised. Of great importance were questions of how problems would be identified and if one was found, what would be done.

One example was the need to address the NMFS Endangered Species Act consultation with EPA on the outfall siting that came back with a finding of no jeopardy but made conservation recommendations that included addressing concerns about identifying and responding to problems indicated by monitoring results. MWRA entered into a Memorandum of Agreement with regulators and developed the CP. The CP is a partner to the Ambient Monitoring Plan. It identifies 76 parameters with trigger thresholds; as caution and warning levels. Essentially caution level thresholds are findings we didn't expect, unusual but might not immediately be an outfall problem. For these we notify regulators, the science panel, and the public. Others (warning levels) indicate potential harm to environment – we think of these as red lights that suggest there might be an outfall impact and may require action if an impact is found.

During mid 1990s MWRA worked with the OMTF to refine and finalize the monitoring plan for the years immediately after discharge. Some questions changed before discharge started so we refined, and the initial 74 questions were condensed. In 1997 EPA attached the Contingency and Ambient Monitoring Plans to our National Pollutant Discharge Elimination System (NPDES) permit that also included a mechanism to modify each plan and established the OMSAP to take over from the OMTF, as well as the PIAC and Interagency Advisory Committee (IAAC). It is fortunate that a mechanism for modifying the Monitoring Plan was included because the NPDES permit expired in 2005. It has been administratively continued but anything in the permit itself cannot be changed, whereas the Monitoring and Contingency plans had mechanisms included that allowed for modifications. Making changes to either plan is time consuming, taking a year to a year and half from having the first conversation through public input to getting the final changes approved.

In the permit, the CP includes language for reporting steps and goals under which we must analyze and report on thresholds. If we go past 150 days we have to notify regulators and explain why. Threshold exceedances have to be reported to regulators, the OMSAP and the public within 5 days. Additionally, the permit requires a report on required monitoring by November 15th of following year with all results. This report also fills a reporting requirement for monitoring in the Stellwagen Bank Marine Sanctuary.

We've had two major monitoring plan revision efforts working with OMSAP, its subcommittees, and regulators to identify changes with ambient monitoring. In the last revisions in 2009, e.g., we recommended reducing the water column sampling down from 34 stations to 13 based on scientific results and review. Emphasis in revisions has been on tracking long-term changes in the system, if there are any, continuing to address remaining monitoring plan questions, identifying questions that have been answered and do not need to continue to be sampled, and continuing to test CP thresholds. Previous monitoring plan revision discussions included detailed evaluations of how the proposed change might impact CP threshold testing, for example chlorophyll.

As an example of how additional monitoring plan changes might impact our ability to test thresholds, there has been discussion at OMSAP meetings about changing from a set schedule of water column surveys to event based sampling, e.g., monitoring after a big storm comes through. Since we currently have CP thresholds based on data from the set schedule, an event response

schedule would not generate comparable data. We need to make sure data are comparable after any kind of change, or some thresholds might have to be modified or dropped.

In addition to ambient (Mass Bay and Cape Cod Bay) monitoring, MWRA is required to conduct effluent monitoring, which is the backbone of the monitoring, and is for compliance with NPDES permit. For contaminants we monitor those that were of concern in 1990 like metals, polychlorinated biphenyls (PCB), and other organic compounds. There is an effluent nutrient special study as well.

A quick overview of the current monitoring program includes water column, infaunal, bacterial, and contaminant levels and disease in fish and shellfish. In addition, there have been several 'special studies' that were used to clarify whether there is or is not a problem. Additionally we have a Memorandum of Understanding with the State Division of Marine Fisheries under which we conduct monthly sampling for bacterial indicators in the near field. The water column monitoring is the most expansive part of the ambient monitoring and is designed to answer several questions about possible discharge impacts on phytoplankton and zooplankton, dissolved oxygen as an integrator of overall health, nutrient monitoring, and monthly bacterial nearshore sampling and special studies. Annually, water column monitoring consists of nine ship-based surveys and we sample 14 stations at a number of depths. At 13 stations we sample phytoplankton and zooplankton; we have whale observers on board and conduct debris observations especially near discharge. Most stations are sampled by Battelle and we have a cooperative agreement with the Center for Coastal Studies for collecting samples in Cape Cod Bay at the remaining 3 stations. We coordinate so that whenever possible sampling happens on same day.

We have a number of other water column studies that included gathering information from regional buoys. We support The Northeast Regional Association of Coastal and Ocean Observing Systems (NERACOOS) Buoy A (near Cape Ann) and pay for chlorophyll sensors, calibration and reporting. We also use satellite products to extend and interpolate data between sampling events.

We have carried out a special study in the last few years with MIT Sea Grant on ocean acidification and added pH sensors to Buoy Ain 2016. When weather permits we collect samples at a subset of monitoring stations for the analysis of alkalinity and dissolved inorganic carbon.

Our sediment monitoring has annual surveys at 14 stations for infauna, grain size, total organic carbon, and effluent tracer bacteria. Every third year sediment contaminants are sampled, including in 2017. Sediment profile images are collected annually to look at penetration of oxygen into sediment. Every third year a hard bottom remotely operated vehicle (ROV) survey is conducted providing information on species living on the bottom, including around the outfall.

The focus of fish and shellfish monitoring is to look for diseases and analyze for contaminants. Every year we collect flounder and look at contaminant associated liver lesions. Every three years we sample flounder, lobster, and mussels to analyze for tissue contaminants. One member of PIAC asked that I mention the coupled water quality/hydrodynamic computer model developed in the 1990s to predict relocation impact. The model projected very few impacts, and

annual runs are required in NPDES permit. Model runs have been conducted for 2000-2016, including runs in which we change conditions to see what would happen if there were enhanced nutrients or if they were set to zero. Model results indicate that even doubling the effluent nutrients would have little impact on Bay.

A few completed special studies included sediment metabolism and nutrient release, which documented no change in sediments near the Mass Bay Outfall in the first ten years of outfall discharge, a flow-tracking study that validated that physical and computer models of effluent dilution were accurate, and a study of primary productivity that found no changes at stations near the outfall. Until 2010 we collected debris tows across the outfall and at reference stations looking for large debris and sewage-related floatables. Ten years of sampling showed little effluent-related debris and no changes or differences between reference stations and those near the outfall except for small particulates that looked like fat particles.

Targeted field studies during high-flow events in in 2011- 2012 that confirmed projections about floatables. A 17-year US Geological Survey (USGS) joint program with MWRA forms the basis of what we understand about sediment.

All the data document that the environment in Mass Bay has been protected.

Questions:

Unidentified Speaker: Can you talk about what has happened in Boston Harbor since relocation? A: These results were discussed at last February's OMSAP meeting and are available on our web site.

Betsy Reilley, Director, Environmental Quality Department, MWRA

25+ Years of Monitoring What Have We Learned: Questions Asked and Answered

First, some background on MWRA. We serve over 2.5 million people in 61 communities. My group, the Environmental Quality Department, oversees, manages, and implements MWRA's NPDES permit for discharge in Mass Bay.

History:
In the 1980s there was a fierce battle about pollution of the harbor, rivers and beaches and who was responsible. Culmination of what became a court-mandated result was that MWRA was formed in 1985. MWRA inherited a deteriorating and failing infrastructure and had to do something about it. The Deer Island wastewater treatment facility is the crown jewel of that work. We have come a long way from the 1980s and we are proud of our accomplishments.

This year the Deer Island Wastewater Treatment Plant earned the Platinum 11 Award from National Association of Clean Water Agencies – 11 continuous years of 100% compliance with our NPDES permit effluent limits. An important part of the NPDES permit is MWRA's pretreatment program – monitoring and limiting contaminants from our industrial users in our

wastewater systems. Pretreatment program members were awarded EPA's 2016 Regional Industrial Pretreatment Program Excellence Award.

The Charles River was made famous by the song "Dirty Water" in 1965 largely due to non-point sources and failing CSOs. MWRA is working on a long-term control plan for CSOs, and has completed 183 of 184 milestones. The last of 35 major CSO projects was finished December 2015. The final milestone is to report in December 2020. Happily, EPA's most recent report card was A- for water quality of the Charles and Mystic rivers.

There was an article in the Boston Globe about how clean the beaches have become as clean as or cleaner than iconic urban bathing beaches like South Beach in Miami and Waikiki in Hawaii.

Monitoring:

MWRA had an environmental and public service responsibility to document recovery of Boston Harbor but also to demonstrate that we didn't move the problem from harbor to bay. MWRA recognizes the value of long-term data sets. Times have changed from the 1980s and 1990s when this program was initially developed to now. Monitoring has been valuable to document that some of changes we see in Mass Bay are regional and not related to the outfall.

To develop a monitoring program, we adopted three recommendations from the NRC:

1. What are the scientific questions?
2. What monitoring is needed to answer these questions?
3. Monitoring should then be flexible to learn from these programs, and adjust as new questions develop.

What have we learned? Monitoring has been ongoing since 1992, the first nine years were baseline and since 2000 have been monitoring post relocation of the outfall. After 25+ years of monitoring it is time to identify what is good and also what could be better. The development of the program identified four primary areas of focus and 33 questions: human health, seafood safety, aesthetics, and ecosystem health.

We are not trying to be flip with the "asked and answered" theme, but a lot of these monitoring questions are considered to be answered by OMSAP with agreement from EPA. For example, for outfall dilution and plume tracking, the predictions have been verified. Ongoing effluent monitoring confirms contaminants measured are not an issue. For floatables and phytoplankton, the outfall is not having adverse impacts. Sediment metabolism/nutrient flux studies similarly answered the questions they were designed to address. There have been a lot of studies and results over this period of time. Reports are available on our website. Or call us! There are literally hundreds of reports so please check it out.

A complete review of all the monitoring and questions was conducted in 2010 and is documented for your review. One thing I would point out is because of the requirement to compare results to CP thresholds; we are prevented making additional changes to the monitoring program. This means we are not in sync with the NRC recommendation to be flexible to new concerns.

Now I will briefly run through some of the examples of monitoring that has been performed and that we believe has served its purpose.

One question is in regards to whether the incidence of disease or abnormalities in fish or shellfish has changed? Tumors on flounders were considered a hallmark of pollution in Boston. Since 2004, no tumors have been detected on flounder in Boston Harbor. There has not been a decline in health of winter flounder at the outfall area. In fact levels of centrotubular hydropic vacuolation (CHV) which are liver tumor precursors are lower than they were in the 1990s in Mass Bay.

Another question is have nutrient concentrations changed in water near the outfall, or has dissolved oxygen changed near the near outfall or in Stellwagen Bank? We know that ammonia is present in wastewater and effluent. Since the outfall has been relocated into Mass Bay there has been a dramatic decrease in ammonia in Boston Harbor. And there is an increase in ammonia in the vicinity of outfall. Not surprising but we see that those levels are confined within a zone 10-20 km around the outfall and this is very consistent with model predictions. Also consistent with predictions—we have seen little or no impact in the rest of Mass Bay and Cape Cod Bay.

Another question, has phytoplankton biomass changed in the vicinity of the outfall or in Cape Cod Bay? Has abundance of noxious phytoplankton changed in vicinity of outfall? We have seen blooms of algae, including red tide *Alexandrium.* Major blooms occurred in 2005 and 2006 and studies conducted found occurrence seemed to be from Gulf of Maine and then carried on winds and currents to Mass Bay and Boston Harbor, but the blooms do not appear to be directly related to the outfall. Blooms of the nuisance algae *Pseudo-nitzschia* have been observed numerous times since 2000. However, these blooms have been generally lower post-outfall operation than during the baseline period. In no case have algae blooms been found directly related to the outfall.

Have concentrations of contaminants in sediments changed and have sediments become more anoxic? We can see the signal of effluent discharge using a bacterial marker and see that within about two km of outfall, but we have not seen an increase in sediment contaminants- in the nearfield area. Twenty-two of 26 contaminants we monitor had average concentrations in 2017 that were lower than any baseline year. Interestingly for the oxic layer in the sediment we have actually seen improvement, which is the opposite of what we would expect if the effluent discharge were having an adverse effect on the environment.

Have soft-bottom or hard-bottom benthic communities changed? Nearfield benthic infauna have increased in diversity and we have seen fluctuations in abundance that were not observed during baseline, but overall these changes are considered as not outfall-related. Many see them as being positive in nature. The hard bottom community is relatively stable. Observed changes are often associated with disturbance to hard bottom areas such as by shipping.

Have levels of contaminants in tissue of fish or shellfish increased? We test tissues of flounders, lobsters, and mussels every third year. Contaminants in flounder and lobster tissue are detected

but not increased in samples near outfall. In mussels, slight increases detected near the outfall but in all cases below U.S. Food and Drug Administration action limits.

The monitoring has provided us with a lot of information. Again, if you want more details you can visit MWRA's website that has a lot of this information or talk to us.

MWRA believes we are in a different place now than when monitoring began. Initially there were lots of questions about what would happen after relocation. We used a scientific approach to collect a lot of information that gives us a level of comfort. Many of these concerns did not materialize and we all have benefitted from monitoring.

Effluent monitoring is an important part of the NPDES permit. We are required to monitor the effluent for toxic contaminants, pathogens, solids, floatables, a plant performance requirement, and a CP threshold for nitrogen. All of these are monitored in effluent on a very regular basis, multiple times a day.

What we have learned is that a well-run and well-maintained treatment plant, an award winning pretreatment program and a high quality effluent that meets NPDES permit limits is protective of the environment in Mass Bay.

This morning we will do break outs to talk about where we go in the future. We encourage your feedback, knowledge, and insights into this program. To stimulate any ideas you have I want to go through a few considerations and questions. We want to hear about your ideas. We know MWRA's outfall is the biggest contributor to Mass Bay and its sensitive environment. We understand our responsibility and we value the long-term dataset but we also feel that some questions have been answered. So we want to know: what are the remaining questions related to the discharge? What is the monitoring that can answer those questions? And what is the process for accommodating changes as we move forward? It goes right back to the NRC document and recommendations on how to develop a monitoring program.

I would like you to consider the value of long-term versus short-term studies. We have enjoyed participating in and supporting studies with MIT Sea Grant and others. Each has a start and an end and I think they have brought a lot of value to our program. These kinds of studies give greater flexibility to our ability to identify critical issues. The monitoring benefits scientists, the state and local communities, and supports local research in the area. It makes sense to have a program that is responsive to priorities that we discover in the course of our monitoring. MWRA needs to balance the long-term data set with the monitoring responsibility for what meets today's and future questions. What are the questions that we are not answering right now? Techniques or methods changed in the last 20 years, I know that we are not talking about new technologies in today's meeting but that is something we should be thinking about.

There are a lot of opportunities out there and we'd love to hear about your ideas. With that, I am open to any questions you may have.

Questions:

Unidentified Speaker: Question about acidification – with the temperature and other changes going on, very important. This is a bit of a switch from your original focus but are you going to get into perhaps tracking those types of local changes that are going on as part of this type of monitoring?

Betsy Reilley: In our dataset we are already seeing some trends of acidification, working with MIT Sea Grant. Yes we need to think about how this relates to the outfall. For example do the contaminants or nutrients in the discharge behave differently under those changing conditions? I think that's certainly something we can look at.

Unidentified Speaker: Question about how you benefited from a very long baseline? what would be different if you had not?

Betsy Reilley: Good point. For example, Ken pointed out that the chlorophyll-a data were highly variable during the longer baseline period. We were very fortunate to be able to capture additional variability in the baseline because it is a dynamic and changing environment. We probably would have seen more threshold exceedances if the baseline period had been shorter – but would those be helpful? Would they have been helpful in understanding impacts of the outfall? I think we are finding as we have performed these studies where we had threshold exceedances, that can we go back, review the data, and determine whether it is an outfall effect or changing conditions, perhaps regionally. We have seen that with benthic fauna, where there have been changes in the area near the outfall but at other locations as well. It is important to have monitoring that can address changing conditions and put the outfall in the proper context.

Bruce Berman: I know we spoke last week and you said that in the last 30 years we have seen about 0.48° F of warming per decade. I know we have a model where we can manipulate inputs and follow potential changes. I know this is not the place to discuss technical changes, but is it possible to look ahead using this model, perhaps to see what happens if the trend continues?

Ken Keay: MIT Sea Grant funded a climate change symposium a couple years back and one of the presentations was looking at Gulf of Maine modeling using climate warming projections from the IPCC to predict how that would change circulation. That had not been done with water quality as part of the model, but it did look at how it would affect circulation and how sea-level rise would be expected to change our predictions. Scientists are looking at that.

Bruce Berman: On a practical level we see changes – not necessarily in the stuff that you have on contingency thresholds, but some of which the public are concerned about. For example, just in the last few years there have been diatomaceous algae blooms that generate huge amounts of frothy brown stuff that washed up on beaches, which smells really sweet and is not sewage. Scup and black sea bass are present in numbers never seen 30, 40 years ago and were not included in species we identified at the time. It is terrific to hear about the current plan and just real important for us to start thinking about what the impacts of a changing climate are going to be. Not all of it is bad, if you want to catch scup and black sea bass.
Betsy Reilley: Good point, there are changing environmental conditions out there. Are we really getting at those questions with our monitoring program?

Mark Smith, Director MassDEP Office of Research and Standards, Massachusetts Department of Environmental Protection

Emerging Contaminants: Pharmaceuticals, Plastics, and Endocrine Disrupters

What I'd like to do is spend a few minutes talking about emerging contaminants that might be a concern for MWRA outfall monitoring or from a broader environmental perspective.

The MassDEP has a program for identifying and addressing emerging contaminants (ECs), which I will briefly summarize as we consider this issue. Then I will focus on one contaminant class, per- and polyfluoroalkyl substances (PFAS), which is a major focus for our office and for several other states, and discuss how they might get into the outfall.

So what are ECs and what makes them emerging? There are a number of typical characteristics, one being that ECs typically do not have formal standards in effect. Thus, it is important to note that there are no regulatory standards that directly relate to whether there is any required monitoring in various programs, including MWRA and outfall. A second characteristic of ECs is that typically there is an important attribute of the chemical for which there are emerging data, either newly discovered information about toxicity or perhaps its occurrence in the environment. These may not be new compounds but ones for which we have new information that indicates we may need to learn or do more. An important consideration for my agency is – are there requirements that may be needed down the road? For most compounds we need more data to make informed decisions.

The potential scope of ECs is large. The Chemical Abstract Services (CAS) registry provides specific identifier numbers for chemical compounds and groups of chemicals. The number is huge, as in millions of compounds, and thousands of new compounds are added every day.

EPA is regulating and focusing on about 650 chemicals on EPA's toxics screening list. Here in Massachusetts we cover about 1200 CAS listed chemicals in our state hazardous waste site cleanup program. What do we focus on regarding ECs? Pre-2007, MassDEP approached ECs on an *ad hoc* basis. For example, we knew a lot about mercury, but it was listed as an EC in the late 1990s. Scientifically, it was known to be "bad", but emerging data indicated that there were some very serious regional and global impacts of mercury that had not been adequately considered. The agency put a lot of focus on this, along with other states and provinces, and developed a regional action plan to address mercury pollution. That was back in the late 1990s and we still have an ongoing efforts to address mercury pollution with a cross programmatic approach.

Another emerging compound of concern was perchlorate, which was showing up in some water supplies such as Bourne on Cape Cod. We established a working group at MassDEP to address this chemical, including drinking water program staff, as well as waste site clean-up staff, because there is a connection between these two programs for this particular contaminant. In 2006, through that group, we established the first standard in the nation for perchlorate in drinking water.

The process back then for identifying and addressing contaminants of concern was somewhat random with respect to what chemicals floated to the surface for consideration. In 2007, at the end of the perchlorate effort, it became apparent that MassDEP needed a more organized approach, across programs, to centralize our focus on ECs and foster information exchange across different groups thereby reducing the tendency to take a "silo" approach. This took advantage of expertise across MassDEP programs to identify new compounds of concern, share information, and then raise the profile of those chemicals to be prioritized. My office, the Office Research and Standards, was given the lead for this ongoing effort and has the task of organizing the process for MassDEP to identify emerging contaminants earlier, raise those of concern to a higher priority, and provide a cross agency approach to addressing them.

Priority 10 ECs

- Perchlorate[1]
- 1, 4 Dioxane (UCMR-3)[1]
- Tetrachloroethylene (PCE)[1]
- Trichloroethylene (TCE)[1]
- RDX[1]
- Tungsten[1]
- Pharmaceuticals and personal care products (PPCP)[2]
- Cyanotoxins[2]
- Nanoparticles[2]
- Polybrominated diphenyl ethers (PBDEs)[3]

[1]MCP or MCL Standard(s) derived/revised since inclusion on EC List[2]Outreach, education, BMPs, guidance
[3]To be addressed

Our definition for ECs is very broad, and covers chemicals, biological agents, and potential radiological agents that could present harm to human health or environmental health, focusing on ones without national standards. There were some ECs that had national standards that had changed, but they didn't make the first cut because we had programs that already were addressing them. Evolving information on risk and occurrence of ECs in the environment and monitoring realm, such as changing detection limits or data on significant new sources that we have identified, are also part of our assessments.

Through this process, we identified a preliminary list of 80 potential emerging contaminants that made our initial list. Primary considerations included that we had some existing data, that the chemicals were on lists available from EPA and other agencies and, that we had subject matter experts with relevant expertise on our interagency group. We then focused on ones where we had some jurisdictional authority to do something about as the priority ECs. Of course there are thousands of chemicals that we do not have the ability regulate. We ultimately whittled the initial list of 80 chemicals down to 30, and eventually down to the ten top priorities. We have had some ongoing additions, including PFAS, a chemical called chlorate, which is a disinfection byproduct that shows up in drinking water, and a category of by-product PCBs that have not been a previous focus.

Our prioritization steps were focused on risk to children; frequent occurrence; high potential for exposure, for example through drinking water or at hazardous waste sites; and, high visibility i.e., meaning in the public eye. Another but lower priority of what we have looked at was ecological risk, especially to species of concern. Certain chemical characteristics that really heightened concern included persistence in the environment or biota; bio-accumulative potential; and, substantial toxicity at relatively low exposures.

The "top 10 list" is presented in the table below. There are six compounds that we have done something about from a regulatory perspective, for example via adopted guidance values or standards for drinking water or in the waste site clean-up program. Footnote number 2 means we have ongoing efforts with respect to developing and implementing outreach, education or guidance, sometimes through interagency collaboration with the Mass Department of Public Health. The tenth one has yet to be formally addressed. A new compound group that has burst on the scene in terms of our attention is the per- and poly-fluorinated-alkyl substances, the PFAS compounds. This issue has become a focus for some of us at MassDEP right now. Other possible candidate ECs that I will also talk about briefly that may be of relevance today are byproduct PCBs and microplastics, including microplastic beads with potential impacts on aquatic systems. I will discuss these from the perspective of what one might want to monitor for, keeping in mind that these are substances with no standards so there are no requirements to monitor the outfall right now. Mechanisms to expand monitoring for these ECs may help in identifying and answering research questions about frequency of occurrence, potential for exposure, trends in concentrations, and possible risks. There is a real need here for a lot more information on ECs to help decide if we as a society need to be regulating or doing something more about them.

Priority 10 ECs

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- Trichloroethylene (TCE)[1]
- RDX[1]
- Tungsten[1]
- Pharmaceuticals and personal care products (PPCP)[2]
- Cyanotoxins[2]
- Nanoparticles[2]
- Polybrominated diphenyl ethers (PBDEs)[3]

[1]Standard(s) derived/revised since inclusion on EC List
[2]Outreach, education, BMPs, guidance
[3]To be addressed

We will talk more about PFAS, which I think is an issue, from a waste water perspective, that probably warrants attention, along with pharmaceuticals and personal care products (PPCP). Another recently mentioned and certainly another large category of chemicals in wastewaters are microplastics and we have also had number of discussions internally about what nanotechnology waste products might be getting into wastewater and its impact.

The PFAS chemicals are fluorinated compounds, meaning they have the strongest chemical bonds in nature and they are hard to break and are therefore incredibly stable when released into the environment. They are also long lasting in biota and the human body. Typically they are water soluble and there are on the order of 3000 or more that have a CAS number designation. A few hundred PFAS that have been created in labs have been and/or are still used commercially. There are major regulatory concerns because many of them are toxic, depending on which of the 3000 compounds one is talking about. The longer chain compounds tend to exhibit considerable low dose toxicity in a number of systems, such as having developmental effects, effects on the immune system, including convincing evidence in human epidemiological studies, and the potential for endocrine disruption, as well as other possible effects. They cross the placenta and are expressed in breast milk so there is direct risk to the developing fetus, infants, and children. They have long half-lives, especially the longer-chain ones, with three to six year half lives in the

body. Shorter chain PFAS turn over more quickly but they also have fairly considerable half-lives and are persistent in the environment as well. Some PFAS also tend to bioaccumulate. They are water soluble and widespread because they are used in a variety of different products. For example, these compounds can be found on shoes, carry-out food boxes (because they resist grease), firefighting foams, which are a particular source at military bases (because they are used to fight fuel and oil fires, like those caused by aircraft crashes), consumer products like ski wax, waterproof down used in sleeping bags, some hair sprays and many manufacturing applications. If you wash a sleeping bag or other product with PFAS you're probably liberating some of these compounds into the wastewater.

Sources of exposure to PFAS are numerous: some water supplies across the country are impacted by these compounds, which can be a significant exposure source. If PFAS is in the water, some can be taken up by fish and pose another significant potential source of exposure. Other sources include contaminated soil at hazardous waste sites where there can be a potential for direct exposure. There also have been instances of PFAS in compost and irrigation water at farms that have led to contamination of food, including dairy products. We probably have direct exposure from our home products, and house dust, because PFAS are in carpeting and on furniture. This creates exposure pathways for children crawling on floors. There are also occupational exposures that may occur either during its manufacturing and application or to fire fighters using PFAS.

So how are we addressing PFAS nationally? The Toxic Substances Control Act (TSCA) is responsible for identifying and regulating contaminants of concern in products and manufacturing, but has not adequately addressed PFAS. Clearly, this is an example of deficiencies in national policies for approaching and addressing some of these contaminants. Some would say it is evidence of the utter failure of TSCA in the past. TSCA was amended in 2016, and the jury is still out on whether it will improve the process or not. Under the TSCA program, EPA has the authority to gather more information about industrial and consumer compounds. In the last ten years under this program, 478 PFAS were reported to EPA, including different PFAS, and 294 new uses were identified since 2006 for various types of PFAS. So, PFAS are definitely in use and in wastewater and all of us are exposed to PFAS.

The Safe Drinking Water Act also identifies compounds of concern. So far, of the 3000+ PFAS compounds, EPA has issued health advisories for drinking water for two of them, perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), and is on the verge of having guidance issued on two more. So 2996 or so to go… it is a daunting situation. No national standards have been adopted so far for drinking water, just the two guidelines. Some states have, however, adopted guidance and regulatory values that they have derived themselves.

The main point here is that different states have come up with drinking water guidance values, mainly for PFOA and PFOS, and for a few of the other long chain ones that we are most concerned about. The states of Massachusetts, Connecticut, and Vermont, are now looking at five compounds and treating them as having similar toxic potencies, handling them together. We came out with our state drinking water guidance for PFAS in early June and in late June the federal Agency for Toxic Substances and Disease Registry came out with draft numbers that would lead to even lower guidance values than what EPA came up with. There are disputes and disagreements about these standards.

PFAS are under consideration by EPA for listing as hazardous compounds under the federal Superfund program and groundwater guidance values for PFOA and PFOS may be available sometime this fall. These compounds are already considered hazardous substances under many state programs including Massachusetts and MassDEP is in the process now of also drafting standards for the waste site clean-up program for five or six of these compounds, which should come out in the near future for public review and comment.

Unfortunately, PFAS are present in wastewater and probably also in sludge. In terms of current outfall monitoring, it would be useful to have data on occurrence, frequency and concentrations, as well as potentially looking at concentrations in biota, sediment, and influent. Effluent monitoring offers opportunities for the industrial discharge realm to look at how they might lower input sources as opposed to consumer uses.

PPCPs are also a potential concern. Information is evolving on these and in the next few years states, and possibly also federal-level programs, will be issuing information. Pharmaceuticals in particular consist of a huge universe of compounds, and could exhibit endocrine-disrupter effects in people and biota. Ecological impacts are also of concern. Our EC group is focused on getting more information on these compounds through detection and current monitoring. We also have a public awareness outreach effort to facilitate collection programs for drugs that are not needed or are past expiration dates to discourage folks from flushing them down the drain.

With respect to the plastics realm, the key word is persistent. Ever-increasing amounts of plastics are entering the environment globally. There are concerns about microplastics and nanobeads showing up in personal care products and other consumer products that are likely to contribute to them entering the environment. Plastics in marine and freshwater environments may enter from direct discharge but also through weathering of plastics that are breaking down into micro-particulates. Several questions about whether these are having any effects have been raised. Plastics have potential for direct impacts on biota that swallow them, and also have the potential to serve as carriers for other substances that might be present. There are questions of evolving methodologies for how to begin to monitor these. But certainly these are increasing in the environment and a cause for concern.

In conclusion, ECs pose a big problem. We need a lot more attention and data on many of the categories within the EC grouping, especially on PFAS. I do not think that focus is likely to go away, more likely it will increase. A number of different research groups in Massachusetts and the Northeast are researching potential health impacts of PFAS and other ECs, supporting our scientific understanding and application to evolving regulations. Many ECs end up in wastewater; but currently no compliance monitoring exists because we do not have any standards. However, from a research perspective, we are getting a better sense of some of these chemicals nationally and globally. Outfall monitoring deserves to be considered and would contribute to our understanding of possible EC risks.

Questions:

Vi Patek, Safer Waters: Question: I have a question about increases in flights at Logan and the exhaust getting in the water, which is seen as ash at my house? What type of chemicals is in the ash?

A: Usually the ash would be diesel type exhaust, but specific compounds were not discussed. However, the point of ash is well taken in identifying that there are impacts from the entire transportation infrastructure, not least the firefighting foams at the airport.

Carlton Hunt: What is the status of the studies on these compounds; do we have a handle on the toxicity like we do on others?

Mark Smith: We have a pretty good handle on a few of the groups, PFOS and PFOA in particular, not as much on some of the others.

Unidentified speaker: Is this a priority research area?

Mark Smith: Absolutely and it is certainly an area that the national toxicology program and others are focused on. Some programs are set to release information shortly. For other compounds, we have much less data although numerous studies are underway.

Phil Colarusso, EPA: Do we know much about the effect of standard wastewater treatment on removing these compounds.

Mark Smith: The compounds do not break down, so they are going somewhere. Some end up in sludge or the effluent. If they are in wastewater, they are going to end up in one of those two places.

Rich Delaney, Center for Coastal Studies: North Atlantic right whales fertility rates are way down, to zero last year. Are any studies looking at PCBs and fertility in marine animals?

Mark Smith: They clearly have developmental connections, for example PCBs and others, so there is reason to be concerned, but there is not a lot of scientific data.

Bruce Berman: Today we are talking about ambient not effluent monitoring and I know the MWRA conducts a lot of it. Has there been a look at wastewater effluent for these ten compounds?

Mark Smith: I do not think so in terms of a comprehensive look across all ten of them. Honestly I have been more concerned about drinking water or hazardous waste-site exposure as opposed to effluent.

Bruce Berman: It would be interesting to know about occurrence, and that sort of stuff.
What I'd like to do is spend a few minutes talking about emerging contaminants that might be a concern for MWRA outfall monitoring or from a broader environmental perspective.

Juliet Simpson, OMSAP Member, Coastal Ecologist MIT Sea Grant College Program

Climate Change Impacts on Massachusetts Bay and the Outfall

For this discussion I will start by taking a longer view. There is something like 800,000 years of temperature record through arctic ice cores and there is a lot of variability in the data. So the first question is, why do we care? This is what earth does, right? I think it is a concern because our civilization is not prepared for it.

About 12,000 years ago the last glacier receded and we have been in an unusually long stable climate period. Agriculture arose and civilization arose out of the Stone Age hunter-gatherers that we were for more than 100,000 years. Suddenly in the last 10,000 years we got agriculture, homes, cities, and more.

The world changes very quickly these days.

How does warming affect the ocean? We are already seeing impact. When I started lecturing ten years ago it was "how ***will***" now it is "how ***is*** the ocean changing." We have warmer ocean temperatures; we have more extreme precipitation. In the northeastern US intense precipitation events have increased by something like 75% over the last 50 years. We are not getting more precipitation overall on an annual basis, but it is falling more frequently in intense events that cause more flooding, more run-off, more movement of water, and less opportunity to get into soil and get filtered, processed, and cleaned a little bit before it gets to the ocean.

Not fully appreciated is that more intense rainfall actually means more droughts – more rainfall in spring, more intense snow events in winter, and more droughts in summer time. This is the pattern for the Northeast; other areas are slightly different based on the 50-year climate record. More increased storm intensity goes with more extreme precipitation. More nor'easters are bigger, with more energy, more precipitation, and stirring up the water more than in the past. Sea level rise is not as germane to our conversation, although it is also an issue. In addition, acidification results from increased CO_2 in the atmosphere. A lot of that gets absorbed in ocean and the ocean gets carbonated in the same way soda gets carbonated. A carbonated ocean is more acidic. It may not be bubbly, but the same thing that rots your teeth when you drink Pepsi rots a scallop's shell.

A lot of the heat the world is absorbing is ending up in the ocean. A recent study showed that even more heat is going into ocean than we thought. From 1960 to 2017, the ocean has absorbed heat and has been getting warmer, but the warming ocean is not uniform. From 1980 to 2017 sea surface temperatures show that the Gulf of Maine is warming faster than almost any other place on Earth. Not only have the trends shown the ocean getting warmer, but in the last decade or so it is getting warmer faster – the rate is increasing.

How does this affect the biology? The biota can be described broadly as bacteria and others that do most of the biogeochemical cycling, phytoplankton in the water column, zooplankton in the water column, nekton – all the swimming organisms from minnows to humpback whales, and benthos – the animals (crabs, clams, worms, corals, etc.) and plants (macroalgae, sea grasses) that live in or on the sediments, which are important to functioning of the system.

Warmer waters hold less oxygen, so less oxygen is available for a lot of differing biogeochemical processes, and bacteria that use oxygen in their metabolism cannot run as efficiently without oxygen available. In contrast increased temperature increases their metabolism. Depending on species, some are more impacted by decreased oxygen, some more impacted by increased temperature. We do not know exactly what is going to happen – which ones slow down and which ones speed up. Changes in the rates of processing things like nitrogen, carbon, and others are occurring. Our own research involves working with EPA and the Mass Bay Estuary Program on carbon storage in eelgrass meadows, which store a lot of carbon and keep it out of atmosphere. If you have warming temperatures, it may be that creatures in sediment will chew through that carbon faster, releasing more CO_2 into atmosphere. Perhaps in eelgrass meadows and other storage places there will be a faster release of carbon into the atmosphere.

For phytoplankton, their rates of growth and reproduction are dependent on temperature, light availability, changes in nutrient availability. Decreased light is interesting, and there is evidence that less light is reaching middle and bottom depths in the Gulf of Maine. This may be because more intense storms are mobilizing more sediment, and more crud is coming off the land going into ocean, all of which gets into the water column and reflects light. So a lot of eelgrass on the bottom is not getting as much light. Phytoplankton in the middle of the water column is not getting as much as light as those at the top. Much of what we observe has been documented in satellite imagery and by people going out and doing it the old-fashioned way. A reduction in productivity might also lead to community re-organization and different species becoming more prominent.

Not every species is negatively impacted. Some respond well to increased temperatures. Some won't get enough light. We may see changes in frequency in harmful algal blooms. We can add in zooplankton and nekton and benthos, where we already see a lot of change. Some of changes are range shifts as animals that do not like warmer waters move farther north or offshore. We could see food web alterations as a consequence. One of the shifts that has been documented is phytoplankton or zooplankton species that are starting to grow earlier in season because of the warmer temperatures in spring. Fish that are dependent on these species directly or indirectly are not able to take advantage of the earlier bloom in spring because their reproduction schedule has not shifted to an earlier time. These fish populations appear to be declining. This is seen in terrestrial systems as well, but underwater it is not as well-documented. We might see changes in intensity, frequency, and an increase in diseases as pathogens move around, that has been documented in tropical systems. It is well known that ocean acidification affects many species that grow in shells, because it can be difficult to get enough carbonate to build shells. Non-shelled species are also affected, e.g., fish and invertebrates that do not build shells. There is evidence that animal behavior changes. For example a recent study demonstrated that squid cannot form their statoliths as easily, which can affect their equilibrium and their response to predators. Fish also respond differently and there appears to be a neurological effect where they appear to be more susceptible to predation.

There can be range shifts in commercially important species like cod. There is evidence that juvenile cod might not be able to tolerate much of Gulf of Maine in the future, which would be a

serious impact on human economy and food supply. Not everyone is negatively impacted. Some changes are positive. The lobster industry in the Gulf of Maine has boomed, although in New York and Connecticut it crashed utterly. There are some winners and losers if you want to call it that.

Among the questions we need to be thinking about today – first the big one. How will climate-change effects interact with things already going on at outfall? Doubtless there are some already. We need to be able to break it down a little bit and think about how we can organize thoughts and our current state of knowledge. How will things happening at outfall interact with these warming temperatures, decrease in oxygen, changes in ocean circulation, or changes in biological communities, among many others.

How can we distinguish changes due directly to climate change versus something that is due directly to something happening at outfall, to what is actually coming out of diffusers? Is it possible to do so?

What newer technology can we use to answer these newer questions, like AUVs or ROVs? What other emerging technology can be used to understand emerging changes?

Questions:

Jo Ann Muramoto (Association to Preserve Cape Cod): You mentioned major climate change impacts affecting biota already. What about changes in ocean circulation or currents that could disperse or distribute water, nutrients, contaminants, etc. in different places?

Juliet Simpson: Important question. Some forecast modeling has been done but has not yet included lot of biology. It is a big open question that needs to be discussed.

Unidentified speaker: Methyl hydrates could be a problem there. We see that now in Siberia and the Arctic.

Juliet Simpson: Methane hydrates scare me. I have read that methane seeps are increasing dramatically off coast of the Carolinas and southern US. Does anyone know if are there big hydrate deposits here? This is also a possibility.

Gene Gallagher (UMass Boston): One thing to consider is that the temperature in the Gulf of Maine has been increasing dramatically since 1980s, but we also should consider the Atlantic Multidecadal Oscillation (AMO), which has about an 80 year cycle. We are at the peak of an AMO, in the warmest phase. The AMO cycle goes back at least a millennium. We are about to enter a 40-year decline so the last time we were in a cold phase was 1975. We are about to enter it, if we are not already in it, and will have 40 years of declining temperatures. Relative to global warming, AMO is the anomaly after you take out effects of global warming. So the big unanswered question is: over the next 40-year period are we going to see a decline in temperature in Mass Bay and the Gulf of Maine or is it going to increase at lower rate than it otherwise would have due to AMO. It is the number one predictor in temperature in bottom water in Mass Bay over a century time scale, documented in sea scallops going back 100 years.

All temperatures you showed were in the warming phase. If we have not already shifted we are going to shortly enter a declining or cold AMO phase.

Juliet Simpson: There is a lot of uncertainty in that. We know what has happened in past, but we do not know what it will do in the future. The AMO could shift the way that all other ocean currents have shifted.

Gene Gallagher: It is not a current

Juliet Simpson: But currents form an important part of it. I have read that there is some uncertainty in AMO and the Pacific equivalent.

Gene Gallagher: The cycle is not absolutely 80 years, and the current warming phase has been a bit unusually long by about 5 years.

Juliet Simpson: I did not mean uncertainty in past, but in the future behavior.

Gene Gallagher: A couple of different formulas are used to calculate it. You have to subtract out long-term change due to global warming to get the anomaly. It may have already gone into decline depending on which one you use.

Juliet Simpson: My personal take-home message is that there are so many sources of uncertainty. If we are thinking about how to deal with the questions of the Deer Island outfall and the impacts of the City of Boston on Mass Bay, we have to have some way to monitor and think about these things that allow for uncertainty in ocean circulation, community change, temperature changes, and possibly unforeseen changes that may come to pass.

Fred Laskey (Executive Director, MWRA): The Boston Harbor clean-up is one of the greatest environmental clean-ups in the history of this country. We need to look at where we are now and where do we need to go. There are issues now that we did not envision, e.g. right whales are not reproducing. The Ambient Monitoring Plan needs to move forward, stay relevant, but also consider the ratepayers.

Mike Connor, General Manager, East Bay Dischargers Authority (retired)
Previous Director, Environmental Quality Department, MWRA (1988-1998)

It is Time to Adopt Alternative Bay/Outfall/Regional Monitoring Strategies

MWRA has been monitoring the Harbor and Bay for 25 years, and it is time to determine whether it should be changed to meet contemporary management goals. In considering this question, I will present the San Francisco Bay (SF Bay) monitoring program in California – which has been underway about the same number of years with a similar budget – and relate our experience to MWRA's.

I was the Director of the Environmental Quality Department when MWRA started monitoring,. I was proud that we laid out everything that we were doing and how we defined the original

monitoring program set-up to convince people that the evaluations from the monitoring program would show that the assumptions we made and water quality model outputs about how the outfall would affect the Bay and Boston Harbor were either validated or shown to be incorrect. We demonstrated that MWRA's outfall wasn't having effects on the system (mostly related to impacts on phytoplankton, zooplankton and right whales dependent on that food chain that people were worried about), and that our water quality modeling to predict the impact of the outfall was consistent with the long-term data. Pieces of the monitoring program were crucial initial steps. To allay public concerns, we argued that the monitoring program we developed would be sufficient to track water quality trends so that MWRA could adjust its capital plans. Because we were just considering MWRA issues, we developed a much less sophisticated monitoring program than the Regional Monitoring Program (RMP) that was developed for SF Bay. We did not attempt to standardize tools to allow us to evaluate the cumulative impact of all the discharges to Mass Bay, develop stakeholder consensus among stakeholders as to what the factual basis is for other modifications, nor to determine future potential policy improvements we could be making. After 25 years, Massachusetts should take advantage of those opportunities.

For California, regional monitoring is a major part of how the state manages water quality regulatory priority setting. There are three very big programs – San Francisco Bay Regional Monitoring gets about $4 million from the discharge community. Massachusetts is always concerned about state budget funding, but alternative funding strategies are available. SF Bay's monitoring program is run by a nonprofit, San Francisco Estuary Institute (SFEI) where we can attract other money from grants and other regulatory requirements to increase the analysis and sampling. This strategy is similar to the approach in the early 1990s in Mass Bay, when much of the monitoring was accomplished by the USGS, or by academia and contract labs funded by MIT Sea Grant and some in-house research funded by the different agencies. SF Bay's RMP uses the governance process to get buy-in from stakeholders and donors, involve the regulatory community, and engage the environmental community. A governmental oversight process that involves all the stakeholders is necessary to get group buy-in to the consequences of the monitoring findings. Southern California is a little different. Led by the Southern California Coastal Water Research Project (SCCWRP) with an overall annual budget of $8 million, they budget $800,000 for just regional monitoring every 5 years, and the local publicly owned treatment works (POTWs) get buy-in by their regulators. Regulators are part of the SCCWRP's oversight committee with the input of the local dischargers. SCCWRP does not include an environmental NGO in their formal governance voting, but they do attend most of the meetings.

In addition to these two coastal monitoring programs, the Interagency Ecological Program (IEP) is responsible for monitoring the San Francisco Bay Delta and its tributary rivers to ensure freshwater exports do not harm local fisheries. Its budget (~$25 million annually) comes from federal and state agencies but the monitoring is mostly conducted by six federal agencies, three state agencies, and contracts to local academic labs. The governance simply includes the federal and state agencies, again with no environmental NGO participation; an approach which I think is mistaken.

There are different ways to do the governance which are options for the next stage here in Mass Bay.

Nobody wants to pay money for monitoring unless you make decisions based on it that are dependent on the findings. We had no trouble getting money to start MWRA's monitoring because it was necessary to convince EPA, MassDEP and NMFS that we could put the outfall there without harming the region's ecology. There was a very strong linkage to decisions we were making, later formalized by a CP to allow the National Oceanic and Atmospheric Association (NOAA) to sign off on the permit. To spend a little money (~$3 million annually) on monitoring to allow a decision for a $7 billion capital project was easy.

In the SF Bay area, monitoring has been used to set Total Maximum Daily Load (TMDL) assumptions, support the legislation of product phase-outs (e.g., polybrominated diphenyl ether (PBDEs) flame retardants), TMDL prioritization for high-risk contaminants like PCBs and mercury, and fish consumption warnings. These are real policy outcomes you can show people that these are decisions we are making differently based on monitoring finding. SCCWRP's Southern California monitoring has accomplished similar outcomes.

The IEP is the highest funded group, because their agencies are making multi-billion-dollar decisions about how much water can be exported from the Delta to supply drinking water to most of the state's residents.

SF Bay is a shallow bay draining the largest watershed in California and one that is very urbanized. Seven million people live in the seven counties west of the Delta, and they are served by 37 POTWs. Nearly every POTW has a different treatment set-up as engineers were all finding new ways to do treatment. They all provide similar levels of treatment but they are not standardized. Many of the design differences are due to California's history of agriculture and food processing, so POTW designs vary depending on the amount of waste and high Biological Oxygen Demand (BOD) coming from food processing.

The population is about 3.5 times higher than MWRA area but flows are about 1.3 times higher. We do some water recycling, but the region is also dryer. Plant performance is a bit better than MWRA – recent data show our metal loadings are a lot lower and nitrogen a little lower than MWRA's. I show these regional comparisons because I do not think we do that nearly enough, and it is an important benefit of regional monitoring. We always compare plants to water quality standards, but sewage treatment plants are sewage treatment plants and populations are populations. It provides important public agency motivation to see how your local POTW compares to others in the region or around the country. Nothing moves a Board like showing them how they compare to others. Mike Deland, then EPA Region I Administrator, was famously quoted that Boston should be forced to upgrade their treatment to secondary because Managua, Nicaragua had done it. "If Managua can do it, why not Boston?"

Relative POTW performance is also important in SF Bay because the many different dilution plumes from the different outfalls overlap. For instance, the San Jose POTW does not get a lot of initial dilution, maybe a factor of 3-5 as you move up the bay. You see a factor of 100 dilution for San Francisco and Oakland as you move north in the Bay. But if you start to consider the cumulative impact on the bay, each of the agencies has an overlap of their flows. If we did similar graphics for Mass Bay I think we'd see the different outfall plumes from South Essex Sewage District (Salem Sound), Scituate, and Hull affecting each other.

In 1992, the Executive Director of the SF Bay Water Board saw long-term standards coming up with very sparse Bay-wide monitoring data. Rather than have his agency do the monitoring without any budget for it, he decided to require POTW agencies do it. After the recent recession, California's Governor Brown partly addressed his budget problems for funding the State Water Board, his equivalent to MassDEP, by requiring all dischargers to pay annual permit fees. For instance, my facility pays about $400,000 a year as a permit fee and that money goes to the State Water Board.

The SF Bay Water Board set up the RMP, a monitoring collaborative that helps answer questions and address future water quality planning priorities. The SF Bay Board simplified all other monitoring requirements and removed some that were outdated and not generating useful information. The outdated focus on Priority Pollutants means that over 90% of agency data are non-detects and provide no useful information for decision makers. The RMP governance structure provided simplification of required NPDES monitoring. By engaging in joint fact-finding, agencies get joint acceptance of what issues are of concern and what actions are required. The proof of concept worked out so well in the first five years that the budget was tripled, from less than $1 million to about $3 million. Joint priority setting for water quality leveraged a lot of other funding. This was an effective way to make the process work. Between a third and a half of the budget is allocated to special studies, about a third into status and trend monitoring, and then the remainder to database maintenance and Data Quality Control work. The budget spending goes in-house to SFEI, and contracts with academia and the USGS. The money comes from all the dischargers to the bay – POTWs, dredgers, stormwater, and industry. Funding was initially based on metal loading because that was the major issue in the 1980s. Allocation within the different discharger groups is accomplished by their internal consensus. The governance structure allows everyone to weigh in – dischargers, environmental groups, SF Water Board, EPA – and working groups on specific issues are used to better refine the management goals for specific monitoring special projects.

Three elements are necessary for good monitoring programs: stable funding, sound science, and the ability to adapt. It is important to have regular meetings open to all interested parties about once a year to tell everyone what you're finding and what it means. The RMP annual meetings generally have 120-150 attendees.

Regional monitoring is only successful if it addresses issues that regulatory agencies want to focus on or the public has some concern about. You need to show that you're making decisions based on this. For example, there was a big debate about copper standards 20 years ago, so studies were conducted on that to help set an appropriate standard. Mercury is huge issue in SF Bay so we are trying to bring levels in bay fish down based on risk assessments. Mercury loadings have gone down by factor of 10 but mercury really has not changed in fish. The mercury driver seems to be methylation and the challenge is how we try to manage that. Similarly, we are using data to show trends around SF Bay setting mercury goals and where they are able to be met so far.

In addressing ECs, particularly PBDEs, early data showed high levels in fish and shellfish in the Bay, which led to an emphasis in the regulatory community and state legislature. They were

phased out and banned in California. Banning can be very effective in reducing the levels in the environment.

Spending money on ECs, nutrients, stormwater, and wrapping up some other issues that are regulatory problems like PCBs through special studies can attract extra money for these concerns. When agencies fail their permit, they have to pay a fine. The California State Water Board worked out that money generated from fines can go into more monitoring to address specific water quality issues. Since the Water Board did not feel it had enough data to crack down on nutrients, it went to the POTW agencies and asked for $1.2 million for a watershed study to increase their understanding on the nutrient issue rather than setting standards and issuing fines. To address Contaminants of Emerging Concern (CECs), the SF Bay Water Board groups them into different categories so the state can decide where to put their energy – PCBs, PBDEs, pesticides, etc. PFOS has become an important issue in Bay, particularly in the South Bay near San Jose due to the RMP studies. RMP has used "non-targeted" analytic analysis doing scans of biota to see what is there, to help refine which chemicals are rated as high priorities. Non-targeted monitoring shows which chemicals are found in the Bay's biota, waters, and sediment and prioritizes the focus of the regulatory agencies. RMP's study of mussels, harbor seals, harbor sediments, and wastewater effluent has indicated that tire-tread wear and brake-pad copper may have important bay-wide impacts. Degradates from tires have been shown to be important in inhibiting salmon spawning in Puget Sound by NOAA.

A number of these supplemental environmental projects were funded by NPDES fines. The program in place allows RMP to attract other funds. RMP is doing a lot of recent work on microplastics and microbeads. Microplastics are such an undefined category that by having a monitoring program in place, RMP was able to attract an $800K grant from a foundation to study the issue. A lot of the debate is defining what microplastics are and where they originate. RMP is also looking in wastewater to see what gets through treatment and how much removal we see at POTWs. We expected that microplastics were personal care microbeads, but we are finding most microplastics are fibers, from polyester clothes. Some fabric makers are now interested in funding these studies so they can figure out where their product ends up.

Most recently, a big issue for the SF Bay is nutrients. Compared to Mass Bay the annual loadings of nitrogen per area are pretty high, but SF Bay has very low chlorophyll concentrations. In SF Bay, remnants of mining discharged several billion tons of sediments to the Bay that are still filtering through the water column. We started to see an increase in chlorophyll in 2000 so RMP looked at the issue in more depth. Suspended solids concentrations were decreasing such that sediments seemed to be washing out of SF Bay more than in the past, so we are getting better light penetration. In addition, the North Pacific Oscillation changes the kinds of species in the fish community we have, including more fish that are eating our grazers, so our grazer populations are coming down, and that may be associated with increased chlorophyll concentrations.

To remove nitrogen, we face a huge impact from potential capital costs, estimated at $8-10 billion for the Bay Area for treating dry weather or wet weather flows to 6 ppm total nitrogen. For individual plants, the cost would range from $0-$300 million. The SF Water Board decided that setting regulations now would be premature without fully understanding the issues. In

addition, the technology for measuring the impact of nitrogen is changing quickly, so it would be cost-effective to fund the RMP to improve the quality of monitoring and modeling. On the regulatory side, it is important to more clearly define the water quality standards for oxygen, chlorophyll, and Harmful Algal Blooms (HABs) by concentration, area impacted, and temporal extent of impact. The RMP is using sensors to develop a high quality instantaneous dataset from autonomous or towed vehicles to examine how long dissolved oxygen excursions last and combine those data with fish data to see the correlation between oxygen and fish density. Fishery health data is the clear environmental benefit that concerns the public that the water quality standard is meant to protect.

HABs are another issue. A couple years ago, California's $60 million crab fishery was eliminated because of HABs. Blooms are driven by offshore winds. We were worried that if the HABs blow into SF Bay they will cause problems because of the high level of nutrients. That occurrence could lead to HAB species that are likely to cause problems for the future. RMP found that one species we have typically thought of as a freshwater upstream species, *Microcystis*, is found in the highly saline South Bay.

MWRA started with a goal to address stakeholder concerns, with its "let's prove our assumptions are right and have a CP in place in case we are wrong" model. I agree with Betsy that we have sufficiently addressed that goal. From now on, I believe we should evolve from priority pollutants, benthos, and tumors to eutrophication, HABs response, a suite of ECs, and ecosystem health. I think our ecological concerns need to evolve beyond the Endangered Species Act and just right whales, to considering new monitoring technologies that more effectively characterize overall ecosystem health. I think this workshop needs to think about what we need for the next 20 years that will help us make better decisions about how we want the Bay to be in the next 20 years.

The MWRA business plan does lay out a way. People ask whether MWRA and EPA will allow it, but the MWRA is responsive to public concerns. It's in their business plan anticipating there may be some decisions made by stakeholders and the outside community about things that need to change. There need to be trade-offs between how much we should spend on monitoring versus how extensively MWRA should be working on becoming completely energy-neutral. MWRA could develop more technology to produce more energy than they use. Should they worry about specific CECs, about washing machines for fibers, or about something else? They need to use the data in order to make priority decisions so that we know where we are going.

What is new now is that MassDEP is pursuing NPDES permit delegation[1] (i.e., accept responsibility for issuing NPDES permits as opposed to the current practice of joint preparation with EPA). Why Massachusetts never became delegated to issue NPDES permits is beyond the rest of the nation. It saved a little money but lost impetus to try to set policy. We need to use a new NPDES regulatory structure to develop regional monitoring to figure out what our issues are, get stakeholder consensus of priorities, and develop new monitoring techniques. We could do it under existing MassDEP authority and could expand and tell people that MWRA's monitoring structure is working efficiently and we need to bring more POTWs into a regional

[1] Massachusetts is currently one of only four states for which EPA issues National Pollutant Elimination System Discharge permits, and is pursuing delegated authority to issue its own permits.

permit, and then require that. I'm arguing there is some value of independent NGO leadership to get buy-in of the results so you can undertake joint fact-finding on which everyone agrees.

A map of all discharges into Mass Bay shows that the MWRA outfall is the biggest single contributor to the Bay with 2 million people, but another 2-3 million people live around Bay. The total contribution from all polluters affects the water quality of Mass Bay and contributes through storm runoff and other pathways. A lot of other obvious donors could to tie in to a regional plan. I would love to see Massachusetts move beyond permit compliance and investigating permit assumptions that are broader based and identify the monitoring that makes sense for the Bay.

Questions:

Steve Rhode: In looking at a more local field of environmental wastewater monitoring, put yourself in your shoes 25-30 years ago, what have we learned about environmental monitoring in general?

Mike Connor: It is turned out that we way overestimated pollutant loading and they've come down more dramatically than we thought. Our emphasis on priority pollutants seems out of date. Back in the 1990s we were thinking about primary effluent that had a lot of solids, so we had concerns about solids killing benthos. Much concern was focused around issues that we can pretty much dismiss today. I think for the future there are new contaminants coming in. Priority pollutants have basically become irrelevant in last 15 years because they all have declined significantly because of pre-treatment regulations and a big change in the industrial mix in the Boston area. Mom and Pop electroplaters are no longer a big part of the industrial mix. We need to focus on new contaminants of concern.

Unknown Speaker: Have the conditions in SF Bay improved in past 15 years?
Mike Connor: Levels of contaminants have come down quite a bit. We are not seeing changes in mercury levels in fish, PCBs and some other long-lived contaminants. Concentrations are decreasing but at very slow rates, and there is such a large reservoir in the sediments that it will take 50 more years before we see risk levels at one in a million excess cancer incidences. Another tough issue is biological introductions from ship ballast water. All these new non-native species present in the ballast water being discharged have resulted in SF Bay developing its own ecology with some hardy international species.

Bruce Berman: One of the issues I think we are wrestling with is regional and probably global changes, and also oscillations that happen over 5, 10, 40 years. How do you manage time scale?

Mike Connor: A crucial thing in all bays is integration of all monitoring that happens by all agencies. Unfortunately the resource agencies are in one silo and pollution agencies in another, etc. It is important to get all agencies' data synthesized in one place. A crucial part of any regional monitoring program is the synthesis of data and its conversion to information of use to policy makers. In addition, we want to collaborate among these regional syntheses to look for national and international trends. We need to intelligently prioritize our use of resources to get

the information we need to make better decisions. I think the beneficiaries here are really the ratepayer citizens so let's offer them a clear vision as to the most efficient path forward.

We also need buy-in from NGO community. They need to be part of the consensus for how to proceed. In some ways our best advocates are the Bay area NGOs because they understand the issues, and they have figured out that the answers will require consumers to develop lifestyles that are more sustainable.

Unknown speaker: What benefits have that had for the monitoring program compared to here where we feel the benefits are in the room? Just want to compare and contrast.

Mike Connor: Stakeholder participation in the MWRA process was historically strong because of the consent decree. MWRA, Conservation Law Foundation, MassDEP, and EPA mostly went before the judge with a group consensus on how to proceed on the outfall plan. Bruce and Save the Harbor/Save the Bay were closely involved in the CSO project, and other NGO groups have had a big impact on the drinking water strategy. The MWRA Board and its Executive Director (then Douglas McDonald) generally were clearly trying to balance the environmental concerns with the input from Joe Favolaro and the ratepayers. I have often said that the formation of MWRA's governance structure is the best one I have seen of the hundreds of other regional water agencies around the country. I do not think it would have changed a whole lot here, but the area that definitely could be improved is integrating the MWRA monitoring with all the other dischargers to the Bay from POTWs, stormwater, septic systems, dredging, etc.

Bruce Berman: When you build consensus over 20 years of 1.9 million people to support a $5 billion public investment, we can forget what hard work it took, and how fractious it was. But I think there is a deep consensus among the public here that it was worth it. One of the ways we know it is worth it is we have the data about the health of Mass Bay and also the $6 billion worth of real estate we are on top of right now that shows it was worth it.

Breakout Session Summaries

25 Years of Questions Asked and Answered Breakout Report
Robert Kenney, OMSAP Member

If we recall those last few slides that Mike Connor put up – that covers the whole picture of what we discussed.

This group talked about the monitoring plan as it exists and as it maybe should exist. It goes back to those same four basic public concerns: is seafood safe to eat, is it safe to swim, are aesthetics being maintained, and is the ecosystem being protected? Are those questions still relevant? Of course those questions would all be relevant if there was no monitoring program at all; the public is always going to be concerned. The real question is, are they relevant to MWRA's responsibility for monitoring the outfall? Can we argue that all four of those questions have been answered already? Yes, all of those aspects of the Mass Bay system are being protected. Now we have nine years of pre-discharge monitoring and 18 years of post-discharge and no real evidence

of any degradation in nearfield or farfield. So the next question is – when is it time to stop? Do we need to continue that monitoring? There are opposing views on this. What would a future ambient monitoring plan look like? We do have lots of detailed questions and ones that came up are hinted at the other groups' issues as well (climate change, ECs, microplastics). We need to look at where the line is between responsibility of MWRA for monitoring the outfall (that also means responsibility of ratepayers to foot the bill), and an entire range of really interesting and important scientific research questions. Where do we draw the line? How much of the research is MWRA's responsibility and how much belongs to some regional monitoring plan like Mike Connor talked about? On the one side we can argue that because we have answered the general concern and some specific questions that we are a doing good job and that you could just cut back to monitoring the effluent, because if the levels do not change in effluent it won't impact the environment. The flip side is that we have terrific long-term datasets and there is value to maintaining those. Again where is responsibility for maintaining the long-term data and how much belongs to MWRA? To Betsy's point, any future ambient monitoring plan needs to be more flexible and responsible than what is in there now. It is so rigid and has all these contingency, caution, warning threshold levels, that it is really difficult to make any changes. It could be better to have a monitoring plan that is more flexible and allows you to do basic monitoring, and if a question comes up, you can conduct special studies and make changes more quickly. Adaptability is important.

Betsy added: We did discuss a little bit about the flexibility of ways of doing it. Example might include, forming a consortium, supporting special studies, or sunsetting some studies. There are a number of ideas about that.

Contaminants Breakout Report

Juanita Urban-Rich, OMSAP Member

The discussion ranged over a variety of topics from the nature of contaminants of concern to specific contaminants, their sources, and potential impacts. The nature of contaminants of emerging concern served as the basis for the early discussion with the recognition that we did not know a lot about them. When we do, we know little about their impact on the ecosystem and biota. Related questions include: if there are no standards how do you monitor? What do we look at, what do we need to look at? But also is there potential reason to monitor? Given previous discussion, there was agreement that it should be possible to have the MWRA monitoring plan be more flexible and adaptive to respond to new pollutants that are more of an issue than historical ones.

Questions were going back to some of early issues with outfall: Do ECs affect right whale fertility or other species that are economically important? What are the sources of these ECs? What role does MWRA play in trying to determine sources? How much is coming from the outfall versus stormwater or rivers, or aerial deposition?

If we want to make changes to the monitoring plan and make it responsive, short-term survey studies could assist with determining relevance and ability to monitor contaminants present. Mark Smith talked about thousands of contaminants created each year and the need to narrow

down and select which ones are relevant. Can MWRA use other studies, e.g., from San Francisco or California or others, for narrowing down some of the ECs to focus on further study? With respect to wastewater, the ECs of most concern were those that survive treatment, not necessarily the ones that come into the treatment plant, but the ones that are released to the environment. There is a need to look at other monitoring plants for guidance as well as local culture and industry. For example, in Massachusetts, are ECs more likely to be related to healthcare and pharmaceuticals? These might not be as relevant in other locations.

If we conduct a survey, we would need to look at how much is in the effluent and how much is present in the ambient environment. If the amount of input is tiny compared to what is in Mass Bay, then maybe we do not need long-term measurements. We asked are these dissolved chemicals or particulates, or pieces of broken-down plastic? What is the distribution of dissolved or particulate forms because that could affect behavior, and what it might affect later? Potentially, we should look at concentrations in biota near the outfall, by selecting one or two species and find out if they are absorbing the EC to see if it is in the food chain, or does it have the potential to bioaccumulate? Does it move up the food web and become a human health factor? Then we can get to questions of whether wastewater is a source for it and does monitoring need to change to account for it.

A few other small issues were discussed. Sometimes contaminants are no longer produced by industry and are not still in environment or not being added to the environment any more. But we should be aware of the behavior of these chemicals after that, e.g., because these things recombine.

Climate Change Breakout Report

Lindsey Williams, MIT Sea Grant College Program

A lot of ideas were very similar to the "25 years" group. First, we need to agree on the time scale of what we are talking about and whether we need to think about sea-level rise. We decided that since Deer Island is elevated to about the same level as the Charles River Dam, and at that level lots of other critical infrastructure and operations would be no longer functional, our group decided to assume that Boston is here and Deer Island is functioning. We used a 0-20 year time scale for questions of how climate change will impact the outfall because there will be more changes in 20 years and the monitoring plan will need to revisited many times even within 20 years.

One theme that came up multiple times was the necessity of putting MWRA monitoring in a regional context. Some in the group said we should expand it. Others said that other people do or should do monitoring now, so maybe just making sure we coordinate and share results better could achieve the regional goal? It is critical to make sure data are not in a vacuum and MWRA does not have to redo everything.

Another question raised was, how can we design a program so that it can attribute changes to the presence of the outfall or alternatively to climate change? The conversation kept coming back to the regional context for the data collection and analysis. We should look at all of Mass Bay, or

the whole Gulf of Maine or whole region and compare the MWRA data to other data for the region, as opposed to MWRA data being compared to static baseline data for chlorophyll, for species composition etc. There was consensus that comparisons with baseline data are not as helpful as with regional data. That is, what is the whole region doing, i.e., is there something different from what is happening around the outfall then from what is happening around the entire region.

The use of modeling to better target sites for monitoring and to better interpret data was another issue discussed in detail. The approach should include finding new models or identifying ones that exist to better understand data.

Another issue that was discussed, but where we did not come up with any silver-bullet answer, was that the current plan was really designed for understanding and identifying impacts of the outfall and was not designed to identify climate change impacts. Probably the plan will need to be substantially altered. Using some of the 25 years of data will be very useful for the future, while some we will likely need to adjust.

One big idea that came up a couple of times was that MWRA can coordinate smaller studies to look for something that we could be doing instead of implementing a whole new monitoring plan. The idea is to work with NGOs and academics to conduct small studies, collect information, and use it to guide further changes. There are a lot of avenues MWRA can pursue, not alone but in cooperation with other entities. MWRA can try to make sure they are implementing the best available and most useful monitoring techniques. There was a brief discussion of using new technology, such as environmental DNA, to track what is out there. Because taking zooplankton and phytoplankton samples and identifying communities is so laborious and so time consuming and expensive, we look for new approaches to gather these data. Maybe some of the same answers can come from environmental DNA which is becoming more viable and may serve to automate some of what is currently very time consuming. Also using autonomous vehicles for sampling could make things more efficient.

One other consideration is that the baseline has probably already shifted so we cannot just look at 25 years of data and say "here's the baseline." Even comparing the time before the outfall was in place versus the time after the outfall was in place is probably confounded by climate change. The baseline is constantly shifting, which is important to recognize when looking to the future."

Panel Discussion

Betsy Reilley, Director, Environmental Quality Department, MWRA

MWRA was created in 1985 with the mission to address deteriorating infrastructure and clean up Boston Harbor. We are in charge of design and construction of wastewater facilities and implementing the NPDES permit, including an extensive environmental-monitoring program. We do this to document and show improvements in Boston Harbor as well as ensure that we are not causing any harm to the Mass Bay environment, and to best represent our ratepayers who cover all of this. Thank you for all your comments. We want to make sure that we are not just

turning the crank but what we are really doing is representing the needs of the public and the environment.

Robert Kenney, OMSAP Member, University of Rhode Island Research Faculty (retired)

I joined the Outfall Monitoring Task Force because I'm a right whale ecologist and one of the biggest questions at the beginning was about the potential impact going to be on right whales. We have pretty much answered that. There are new questions about whether endocrine disruptors or other factors impact marine mammals. Right whales are facing big trouble right now, but we can say with some confidence that it is not because of the outfall.

Melville Coté, Director, Surface Water Branch, EPA

Mel Coté attended on behalf of Ken Moraff who could not attend, and read Ken's statement.

"I am really sorry I cannot be with you today! I have to be in Washington today on a litigation matter, but I want to speak to you in absentia. The outfall monitoring program is one of the most significant steps EPA has taken to protect the coastal environment, and I'm proud to have played a small part in setting it up. I'd like to make two points about the program.

First, it was highly unusual – maybe even unprecedented, at the time—for EPA to require a NPDES permittee to take on responsibility for ambient monitoring. But given the scale of the MWRA discharge, we felt it was vitally important to closely monitor the impacts of the new outfall. We knew that the MWRA was already investing billions of dollars to clean up Boston Harbor, and we didn't want to impose unnecessary additional burdens. So we tried to be careful to require only what would really add value. At the same time, we wanted to be sure that enough data would be collected to reassure the public that the ecosystem was protected. We thought a lot about the best way to write monitoring requirements into the MWRA permit, and we came up with creative ways to make those requirements flexible, so that the plan could change over time as data came in. Building this type of monitoring plan into a NPDES permit was controversial at the time, but over the years we have all come to appreciate the value of the data.

The second point is that it was really important to us, from the very start, to engage the public and the scientific community. We didn't want to just pick a set of monitoring requirements and stick them in the permit. We wanted the plan to be guided by the best scientific advice, and we wanted the public to have a real voice –because ultimately, the purpose of the monitoring plan is to inform the public, who paid for the Boston Harbor cleanup, and who want to be sure that our coastal waters are protected. We designed the process to include clear mechanisms for scientific and public input. We are forever in debt to the people who gave their time and expertise to provide that input, and to guide the monitoring plan over the years –including people in this room.

Finally, I want to thank the EPA staff who have worked tirelessly to keep this process running effectively. I especially want to thank our current leader, Matt Liebman! We remain committed to this work and look forward to continuing to advance our knowledge in coming years. Thanks to all of you who have played a part." Ken Moraff

Kim Groff, Director of Watershed Planning, MassDEP

I am ecstatic to be here today and hear about all the good work that's going on. Some background about what is going on at MassDEP. I manage the watershed planning program, and permitting is now under this program. The reason for the consolidation is that we want to improve the integration of our monitoring program and our permitting. The group that I manage is called Watershed Planning Program and we manage surface water quality standards in the state, oversee the surface water-monitoring, evaluate what that data are telling us, and report the findings in our required 305B and 303D water quality reports. We look at waters that are impacted and write plans to restore water quality, either through the maximum daily load program or through the permits program. This covers a broad scale. It is exciting time for me personally at MassDEP because water quality has been made a priority and investments have been made in monitoring programs.

We recently completed a 10-year monitoring strategy – this is posted online. Two major takeaways: we want to get back to renewing and expanding partnerships, particularly for water quality data collection. We also want to focus on watersheds for planning efforts and are interested in Mike Connor's model from California, although there are a few pinch points with that approach. Once you start to try to pull data from a lot of different sources there are questions about how to share efficiently and how you interpret to better inform management decisions beyond Boston Harbor – and statewide. Recent trends include external data collectors of water quality info have grown dramatically in last 10 years. There is also an expanding number of regulated wastewater treatment plants like MWRA that are conducting ambient monitoring programs. This is wonderful. We can get more done if we all work together. We are trying to expand capacity to support all systems to collate, review, and analyze data.

Bruce Berman, Save the Harbor/Save the Bay, Chair of PIAC

I am the Director of Strategy and Communications for largest regional NGO focused on clean water. It is exciting to think that DEP and EPA will write a new NPDES permit, something I had not thought of before today. If we had done that when we started, I would guess that MWRA's $1.5 million/year investment would not have been done in the permit. It is likely that it would have been done as mitigation to chapter 91 license required by state law. MWRA has spent $5 billion on an investment that, although one of many, is the largest source of nutrients permitted to the Gulf of Maine. With that comes responsibility not only for monitoring in the narrowest sense of impacts on the environment, but for increasing our understanding of the Harbor and Bay. We get at it in a different way, I think brilliantly. Among things that the permit requires is that OMSAP has a PIAC, which is charged with bringing forward the concerns that the public has. Whether it is the "yikes" factor of flounder lesions and tumors or if it is other concerns that I think the scientists at OMSAP feel have been asked and answered. Clearly there are new questions. Figuring out how to address them between now and the time that our state or federal partners or both decide to renew the permit and perhaps change the way we think about those investments, regardless, between then and now is important.

Judith Pederson, Interim Chair OMSAP and Retired Research Affiliate, MIT Sea Grant

One thing that has often been undervalued is the ability to do small research projects –for which you need funding. In the past it has been mostly universities, and some nonprofits, that you partner with. A question to MWRA, MADEP, and EPA is: have you considered the value of special studies and thought about mechanisms for supporting some of the research that I think will emerge from recommendations in discussion today?

Betsy Reilley: We try to stay in close touch with our stakeholders and as we identify issues we have list of priority projects that gets reviewed every year. Assuming we get the same level of funding, we may be able to find a way to work some of these priorities into our program planning. I expect that we will maintain that.

Lealdon Langley (MassDEP): This conversation is helping frame what we are hearing are the important questions and what are the background findings to date to help us start that conversation. We hope to be working with EPA in whatever arrangement to look at the next generation of the NPDES permit as it goes forward and take into account all the science that everyone here has spent time and effort to develop. It will take shape over the next year or two.

Melville Coté: The regional office does not fund a lot of research as you know. We typically have planning and regulatory functions. Our Office of Research and Development is an area with some research opportunities. The water program gets an annual chance to weigh in on research priorities on water. Do we have small research pots that become available? Julie mentioned her work with us on eelgrass. We can do it in bits and pieces, and a lot of it is in partnerships. We are always looking for more – whether it is specific questions that some of you have mentioned or larger regional cooperation as has also been discussed, an integrated central monitoring concept is something that we are working to get off the ground. We are very interested in partnering with all of you. We might not always have the resources but we certainly want to work with others to fund and supply them properly.

Betsy Reilley: We have had collaborations with Center for Coastal Studies, MIT Sea Grant, UMass, Department of Conservation and Recreation, and Save the Harbor among others. We support them with a variety of programs, not just outfall-related, whether it is for beaches, rivers, or lab support. This allows us to get engaged with all kinds of programs and research people who are focused on special studies, which is fun. It is interesting to see what people are studying and what techniques they are using. Often these activities are using some new type of technology, for example, microbial source tracking with UMass Boston and using satellite imagery with MIT Sea Grant. It would be great to find a way to work the system so that that can be part of program.

Bruce Berman: I want to say a word in favor of collaborations, but also to remind you that we live in an unusual state. We are about to have a ferry from North Station to the Seaport that is not funded by the Massachusetts Bay Transit Authority or Massachusetts Port Authority but by the Convention Center Authority. The data-gathering and analysis in Lynn are not done by Lynn Water and Sewer. Lynn is not even an MWRA community. But the research is funded in large measure by MWRA. So I do want to say that I'm in favor of collaborations that can accomplish extraordinary things. But these collaborations aren't always with people you'd think are

responsible for it. One way to think about this is how to leverage dollars and spend wisely the dollars that the MWRA has been investing in understanding the marine environment and particularly the potential impacts of the bay outfall. The public does not always grasp technical issues but know what they are concerned about. We have been able to answer their questions and I'd like to see us continue.

Suppose we had a sense that we ought to do a study to figure out which of the "top ten" ECs are in our effluent and in what concentrations, in order to determine whether or not we need to design an ambient monitoring system to take a look at the near-field impacts? OMSAP should be able to say that is a great idea, let's put out a request for proposals, or MassBays should put out a request for proposals, and answer that question and move forward. I think we should be able to do that. We are counting on the new permit to do it, and between now and then we can do some experimenting. I would urge the regulators to be flexible. Stakeholders might be worried that OMSAP and MWRA have earned our trust but they have. They've earned our trust. It does not mean they get a blank check but it is important, and I urge you all to find flexibility moving forward.

Judith Pederson: Lynn has a sewage treatment plant, and they are not paying toward the monitoring, correct?

Bruce Berman: Not to Mass Bay outfall monitoring. You are absolutely right. If you rewrote their NPDES permit and said we are working with our sister agencies also in the Executive Office of Energy and Environmental Affairs, to say that there will be a chapter 91 license. If you're going to put an energy pipeline in, there is a chapter 91 license. With that license comes mitigation, which can be directed. It does not have to be to water transportation, it could be towards monitoring. But to do it we'd need to have more people from government involved in this, not just academia and NGOs.

Melville Coté: I have heard a few times about issuing a new permit, and it is been on our list for some time. I do not work in that branch but we will be bringing that message back, but at the same time – if it is not broke do not fix it. We have a big backlog and we typically focus on permits that we can get the biggest environmental impact from. That will change if the program is delegated, as an agency we are very much for delegation. What is slowed that down has been opposition from the advocacy community and distrust of MassDEP's ability to administer a program like we have, so I am told. I think they are selling themselves short in terms of their ability to hold the permitting agency accountable. Also MassDEP is selling themselves short because I think they are committed to using the best available science, and staffing up, and getting the resources to administer an effective program.

Frank Singleton (Weymouth Conservation Commission): I was recently put on the Weymouth Conservation Commission and I see we have a regulatory lag in terms of climate change. We are operating on 40 year old climate data. Every culvert we are approving is undersized. The updated atlas of precipitation frequency forecasts (NOAA Atlas 14, Precipitation Frequency Estimates: https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume10.pdf) has been sitting on the commissioner's desk for a year and a half. I am sure there are reasons that I am not aware of. But we need to start adapting our regulations to reflect reality, even in Boston where

you can kayak down Seaport Boulevard in January, but the Whiskey Priest site gets a pencil skyscraper. No one is changing the regulations to reflect the reality. Month after month we see documents coming in that reflect 1950 precipitation data. The Federal Emergency Management Agency (FEMA) is designating flood zones on the coast, and we have people putting pipelines there based on federal flood maps which are historical by federal law and cannot reflect the future. Is the state going to finally adapt its regulatory structure to reflect what has been done? I understand there is a statewide effort to help municipalities update planning. It is frustrating to sit on the commission and have to approve things you know are wrong.

Bruce Berman: You are right. I will join you for a drink at the Whiskey Priest which will flood, but it will also come back more quickly than the legacy buildings and Seaport Blvd. There is one thing I did notice over the last 40 years which is there are very few banks that lend the dollars unless they will be protected.

Lealdon Langley: Some of the things you mention are things I am specifically responsible for. As far as NOAA Atlas 14, we agree on changes to precipitation intensity and frequency and we are trying to package those changes to the stormwater handbook as well as Municipal Sewer (MS4) General Permitting Requirements report. Changes that need to occur at same time to make state requirements for stormwater mesh with EPA permit requirements are under litigation by the way. We are fixing some other things about the stormwater handbook. We are hoping to create a technical advisory committee to deal with those things in unison. We are working with EPA and Massachusetts Department of Transportation literally on a weekly basis for MS4 requirements for the transportation sector. To address other climate change related topics, since 2015, I co-chaired the land subject to coastal storm flowage, aka coastal flood plain committee to develop regulatory performance standards for the coastal flood plain. Although there is a brief hiatus on fixing other things like FEMA maps, we reconvened as of June of this year. We are meeting, I believe in December, and hoping to have a regulator package available in early 2019.

Mike Connor: With respect to ambient monitoring, it seems that MWRA has the ability to require everyone to collaborate. The California water board required everyone to do that or contribute to regional monitoring program which will cost you half as much. I presume you have the ability to do that? Besides MWRA, are there major changes or additions now?

Kim Groff: Right now it is kind of coming together organically. There will be some opportunities for the ones that are successful and become delegated to make future changes. Until that happens, we are working with system we have. There has been a gap in data and for example, I will mention actions of some stakeholders the Upper Blackstone Water Pollution Abatement District, which has a huge plant at the headwaters of the Blackstone River. They could see the MADEP was not getting out to monitor more frequently than once every five years, so they conducted their own ambient monitoring program downstream of plant. We developed a collaborative effort with them. Their goal is to collect samples just as MassDEP collects them and we review them. As another example, we partnered with USGS and Springfield Water and Sewer Commission to fund flow gauges at the New Hampshire and Vermont borders, and we have a gauge at the Connecticut border so we can measure loads entering and exiting the state. I have proposal on my desk to add more loading stations. What that's doing is investing in key data needs that bring partners together. That foundational piece of the loading is critical to do in

any kind of planning. That's just a couple of examples. We did talk to Phil a couple months ago about regional probes and looking at best practices in other states to inform the direction that we go in. So many data sources are out there and the trick is getting everyone together to optimize data collection.

Judy Pederson: What are the next steps? What is the schedule? What are the barriers?

Bruce Berman: One from Save the Harbor/Save the Bay—there are three questions on the board. This is not the last time you will be asked them. We will be sending you a thank-you note for participation along with a vehicle to give us your thoughtful answers to those questions.

Judith Pederson: We are going to put a report together from this meeting and circulate it to everyone. Realistically, that probably will not happen until after the holidays. Our second effort is to integrate all comments and make a priority list. Some of that will happen within the report and some at our next OMSAP meeting, which is likely to occur in next few months, as well as a PIAC meeting at the same time The MIT Sea Grant Director is interested in following up on technological questions about these issues that we were not able to address at this meeting so we will be planning a workshop on technology and big data analysis. Those are the specific tangible things. We have a lot to think about. I strongly feel that this might be the time to get wastewater treatment facility programs together, maybe regionally. MWRA was always seen as the 800-pound gorilla, but the idea of really collaborating at this point is an idea whose time has come. We might need to bring in more people with a better sense of the finance than OMSAP to think about how you put this whole collaborative effort together. But I think you need to have a process. It is not enough to say we are going to do ambient monitoring only to find that the state is broke in 5 years and won't follow through. What sources will be there year after year that you can depend on? That's the time scale we need to think about. The first monitoring program took a year and half to put together and adopt the monitoring plan. It was a long conversation, not done in a few days. The restrictions that Betsy expressed about her ability to change the monitoring program are similar to issues that OMSAP is having. We like to get scientists together in formal meetings, which do not happen anymore. It is hard to have a meeting outside of OMSAP because of the restrictions that the federal agency has placed on us. We would love to see those loosened, to allow us to have informal discussions on specific topics outside the OMSAP meetings.

Melville Coté: I am happy to talk with Matt about that. I have always been led to believe that there is some flexibility in the program. We have seen program updates and revisions, eight years ago and before that. The workshop today with questions posed and the feedback you're getting is a good kick-off for a review and potential revision. Mainly it is been involved in reducing the numbers of samples and depth of data collection but there may be other opportunities as well.

Judith Pederson: It is not so much that there is a secret about it, but when you get five people on an issue where they are experts, they can chat and come back to the larger group to explain what they found. But not everyone is always interested in all those topics or the minutia and details discussed. The issue of adaptability was in discussions of monitoring early on. MWRA has been adaptable, but the idea of taking this one step further is the goal. One thing I have always

advocated for and I have no idea where to get the funding, is a 3-4 day meeting to talk about the large (28 years and counting) dataset. What does it tell us about the outfall and Mass Bay, what we have learned, and how that can be used and looked at from a scientific perspective?

Rich Delaney (Center for Coastal Studies): I second this discussion of regional collaboration. We are having the same conversations on Cape Cod. There are a number of entities, with the Cape Cod Commission leading the way. There are lots of databases that are in silos. We are seeing some benefits to integration and collaboration. One last thing that we have not talked about here is not only data but building mechanisms for interpreting data and making them available for everyday people. We have lots of people who do their own collection, and bring the data in to scientists, and say how does this affect my life? I encourage us to think seriously about how we can make data available and accessible to the public.

Melville Coté: There are other regional examples. I worked on the Long Island Sound Study, which is happening as this workshop was going on up here. It was called Unified Waters Study and administered by Save the Sound, part of the Connecticut Fund for the Environment. A large part is getting all citizen monitoring groups around the sound and tributaries to adopt the same Quality Assurance Project Plans and make things more consistent and comparable, which leads right into data management and integration as well.

Bruce Berman: One thing I don't want to lose sight of as we talk about Lynn's wastewater treatment plant (WWTP) or others. MWRA is a collaborative effort with 43 cities and towns with several million people who use Boston Harbor as their discharge. With respect to those who know finance better than me, the MWRA budget and rate structure reflects that and in many ways it may be that it's an appropriate vehicle. While some think of it unfair burden on MWRA, I see it as the most effective cost sharing mechanism that I've ever seen to get 43 cities and towns to help pay for cost of clean-up. As you look for effective models, we have one.

Judith Pederson: Also we are constantly looking for members for OMSAP. Some requirements are listed in the permit. If interested send a resume and reason why you'd like to be part of OMSAP to Matt Liebman and he'll process the request.

Bruce Berman: We are looking for scientists at Save the Harbor too, to join our board, who are enthusiastic and care about their community.

Gene Gallagher: I would like to put a plea in for the benthic community work. We keep saying "asked and answered." I do not want people to leave thinking that we have been sampling for years and we have not seen an effect. We have seen an effect. This dataset is almost unmatched in the country for being able to look at top-level taxonomy and we have seen an effect. With MWRA help, and a doctoral student who based three chapters of her dissertation on MWRA data, you can partition the data in a pretty detailed way. You can see the effects, but they are not harmful effects. Compositions changed near the outfall, and species diversity has increased in the area, so we have been able to see tremendous effect. There is a wealth of effects related to MWRA's outfall, but interpreting the data – species diversity has gone up tremendously in Mass Bay during this period. I do not want people to say "asked and answered, it is not telling us anything, we have not seen any effects." That's wrong; there are tremendous effects that have

been documented in the benthic community structure analysis. It is a tremendous resource. It is a superb dataset. It is not that the 27 years of data have not shown any effects, so let's cut the darn thing.

Judith Pederson: We cannot take this dataset for granted; it is incredible. And yes, it is great to see species diversity. We kept seeing it exceeding thresholds.

Melville Coté: Stop warning us about high diversity!

Betsy Reilley: We are happy about it!

Judith Pederson: To the points made earlier, it took two years to get rid of that the threshold for the benthos.

Betsy Reilley: But the monitoring continues.

Mike Connor: That is a real value that has not been sold very well. This is probably the best long-term data set for these issues. Because it is so focused on MWRA we have not marketed the benefits but it might be interesting. There might be other foundation sources; again it gets to the integration issue, if we can relate it to other issues, climate change, long-term monitoring strategies, how to make the pieces fit.

Outfall Monitoring Conference Breakout Session
Discussion Leader: Betsy Reilley, MWRA
Facilitator: Robert Kenney, retired University of Rhode Island

Topic 1: 25+ Years of MWRA Monitoring

Session 1

- Facilitator Betsy Reilley (MWRA): This session is going to talk about the past 25 years of monitoring. I will give a quick recap of my presentation, and then open the floor for questions and comments. Sticky notes can be used to identify and summarize the conversation and Robert Kenney (URI GSO) will be the moderator.

  Our 25 years of monitoring have been answering the original monitoring questions. When we started, there was concern about moving the pollution out to Mass Bay with contaminants and eutrophication – all of which we have not seen. When looking the Mass Bay area, even though we can see a signature from the outfall outside a confined zone, we have seen no deterioration of that environment. What monitoring is still relevant and what really is not helping us understand things at the moment? Do not forget to consider effluent as well. What are the new things we should be looking at and certain questions that current monitoring is not getting at? How do we balance keeping our monitoring outfall related and maintaining the value of a long-term dataset that we do not want to lose?
- Ken Keay (MWRA): There is a briefing of some of the monitoring information and questions in appendices given out today with more detailed information. A lot of

information and reference documents can be found on the website and we can answer questions briefly as well.

- Lou Taverna (City of Newton Department of Public Works): If we are at a steady state as we have been where do we stop? It is a wide open question and food for thought but in 25 years? 100 years? Where do we stop or how do we cut back on current monitoring to allow for new things?
- Betsy Reilley: The NPDES permit has cycles. There is a process that can make changes to the monitoring plan and we have been doing it for 18 years. This process does not work well and we are stuck mainly due to contingency thresholds. How do we get unstuck to be more flexible?
- Joe Favaloro (Executive Director MWRA Advisory Board): When the outfall pipe was originally debated Cape Cod and Mass Bay had the question: "Are we going to be impacted?" Our responsibility was to prove that wasn't going to occur, so moving forward – what are we trying to prove now? Monitor for what purpose?
- Betsy Reilley: And that brings up the question: "Have we proven it?"
- Lealdon Langley (MassDEP): We have proven it for now and mostly answered the current monitoring questions, but are there other effects that we have not considered? Should there be changes in questions?
- Betsy Reilley: Do we need more specific questions, and what monitoring would we do to answer those questions and get to the big issues going on?
- Carl Pawlowski (Fore River Watershed): I work with the MWRA Residuals Department and with NPDES and helped negotiate the permit we are under. We talked about ambient monitoring and were told it would be a 5-year review of data, then answers and modifications to problems. After 25 years, it is pretty clear there are a lot of things we do not need to be doing. How is that viewed by the EPA and what mechanism is in place? We could possibly set up a Review Panel meeting every 1-3 years. At some point we need to think about what money can be used better elsewhere.
- Judith Pederson (MIT Sea Grant College Program): To some extent we think about those things through OMSAP. They come back and say this has been resolved or we should be continuing that monitoring. To drop a monitoring activity requires a good reason behind their actions. The question remains in terms of changes we are seeing in the environment and how do we deal with that and the monitoring program at the same time? For example different species are affected by these changes in different ways and figuring those out ahead of time is a challenge, which modeling will help with. OMSAP does and has made changes, just not as many as Betsy would like.
- Jo Ann Muramoto (Association to Preserve Cape Cod): I would like to point out that we at Cape Cod still get a lot of questions about outfall impact on Cape Cod and my answer is short and simple: No, not for parameters that everything was designed to treat we aren't seeing it. And Boston Harbor has improved in water quality and the ability to point to ongoing monitoring long-term is valuable. What has been done shows few and little effects. We are concerned about emerging contaminants and nutrient build up and see need for ongoing monitoring of these. I suggest many basic parameters that set the stage for more targeted focused questions. For example, the long-term effect of discharge of nitrogen and phosphorus and how it impacts algal blooms, animals, and fish. In an ideal world we would want the current program to continue and serve as a baseline for more

focused questions. We know it is a changing ocean and it will change unpredictably, who is to say we can predict it?

- Betsy Reilley: How do we streamline the program? Would it be separate, different data? Different frequency and sites?
- Lou Taverna (City of Newton DPW): The focus was that surveys would be out in the field every week, 13 stations in and out of water every day and testing thresholds. The level of effort now is a third of the first year of outfall monitoring. There are additional efficiencies that help us build on those data sets - reporting on certain questions isn't as important as it was 25 years ago. We need something that continues to build the long-term dataset but is tailored to relevant emerging questions.
- Scott Libby (Battelle): During the last round of revisions, statisticians examined what stations should continue to be sampled - e.g., the buoy off Cape Ann. Mechanisms could be put in place to try to get some of these data at a limited number of sites that can deal with questions in a different manner. Not all stations are fully equipped depending on distance to outfall. How does the CP change as sampling is changed?
- Betsy Reilley: The CP can be changed through OMSAP and there is a process. Short-term studies have a lot of value and this gets to sun-setting what we thought would be completed after 5 years but still continue on. As opposed to now it is easy to just keep going with the program, but we see value in short-term studies that have a set beginning and end.
- Robert Kenney: The current contingency plans were brought over from conservation recommendations in the Biological Opinion from a Section 7 consultation under the Endangered Species Act. Would they change if there were a reopened Section 7 consultation—if NMFS became aware that the monitoring plan revision process was going on when it was already underway and said this could be a federal action. NMFS was consulted and expressed interest in emerging contaminants but are comfortable that they will let it go forward and would need to buy in. Humpbacks are off the list of endangered species list.
- Dave Tomey (retired): NMFS could reopen Section 7 but it shouldn't sidetrack developing revisions to the monitoring plan. It could be evaluated more fully if you could start reducing sampling frequency, then I'm sure more spatial areas would respond.
- Betsy Reilley: We kind of got so far and then they raised the alarm.
- Lou Taverna: What is the geographic range of outfall monitoring?
- Betsy Reilley: The farthest northeast is 20 miles south of Gloucester with 3 stations in Cape Cod Bay, 2 in the heart of the Bay. Not in Nova Scotia, just the arc running from Cape Ann to Cape Cod.
- Michael Celona (Mass Department of Public Health): What role can continued monitoring play?
- Ken Keay: Monitoring played a vital role in the early days. There are plenty of documents online documenting what has happened and what was written into the permit, for example, running the model as it has been configured. For example modeling nitrogen levels does have some use but that particular model has done what it can do for us. A different modeling approach could address slightly different questions that can be used to answer other questions.
- Mark Patterson (OMSAP, Northeastern University) I teach a class in environmental fluid mechanics and students read the outfall report and have done pilot work previously on a

peer-reviewed paper about how the diffuser worked in 2001. Our analysis is that potentially more can be learned about how the diffuser is working, especially with more rainy days and high flows with climate change and newer techniques with data that showed the diffuser working fine. The early work did not have enough opportunity there, I know it was sunsetted a long time ago, but with new AUV technology it could be revisited. We also saw that it really is a freshwater river under the sea. In thinking about the salinity anomaly, it is not in the literature you read. We were out there and the depth-sounder alarm was going off because of a false bottom caused by the lens of freshwater at the surface. And lots of animals were seen out there. That said, I have done work in Iceland where freshwater vents act as killing fields for zooplankton that then rain down to the bottom. That's why there are diverse populations of suspension feeders. You can see tons of fish in the water column and interesting fish aggregation by looking at zooplankton-fish interaction in the freshwater-on-saline environment. It may be worth revisiting the near field and far field of the diffusers on more than just an average day in 2001.

- Ken Keay: The dilution study that was conducted in April and June-July of 2001 dealt with multiple conditions and not just one day. The epifauna, such as sea anemones and mussels, seen on riser heads have been examined as part of the hard-bottom study that have been there since before the discharge started.
- Mark Patterson: These are part of the natural biota but I am interested in the study because of differences in temperature. Also the area acted as a rich area for fish so it could be viewed as a benefit.
- Betsy Reilley: Last thoughts?
- Unidentified Speaker: With history, we were first asked and said no to advanced primary treatment which included the outfall. The Metropolitan District Commission (MDC) said let us do advanced primary and build a big long outfall for dilution. My question is about what was said to that—why did we keep the outfall idea?
- Ken Keay: That's not way things happened. MDC applied for a secondary treatment waiver, was rejected and reapplied and then in 1984/85 the waiver was denied which put us into secondary treatment planning. After that secondary treatment was always the plan. Don Harleman (formerly Civil Engineer, MIT) said we do not need secondary but that Chemical Enhanced Primary Treatment (CEPT) would get similar results. The project was already in progress.
  Dave Tomey: My recollection is that CEPT wouldn't get proper BOD removal even with a certain level of primary treatment. It wouldn't work, so EPA rejected. I wrote the rebuttal for the primary treatment by CEPT option and it has not gone away. EPA decided secondary treatment was law of the land and changed the outfall siting process as part of the plan. They looked at sites and found the one best able to reach initial dilution and depending on tidal cycle would meet initial dilution for PCBs.

25+ Years Session 2

- Betsy Reilley Facilitator: A brief summary of 25 years of monitoring focuses on what had been learned. We discussed initial monitoring questions and a lot of those for which we have developed a large data set and have been answered. Flounder, for example, is a great story. Occurrence of lesions and tumors improved and in Mass Bay we have not

seen an uptake in CHV at all, which gives us the feeling that we are not likely to see change. Eutrophication, chlorophyll, dissolved oxygen – we are not seeing declines in signatures at the outfall or beyond in deterioration of the environment. What long-term datasets still have value or what is monitoring not capturing that is concern now? What should we be looking for; what are thoughts or ideas for future monitoring and feedback>

- Bill Kiley (Boston Water and Sewer Commission): What is earliest monitoring and video before the outfall?
- Ken Keay: The study started in 1994 and went online annually. When looking at the videos; anemones and others were all there before outfall diversion. We saw animals moving in over the outfall area during the baseline and have not seen dieback on outfall risers and rocks in vicinity from footage of all 55 outfall risers taken before outfall start-up and later.
- Bill Kiley: Are there any species that thrive in an increase in level of nutrients?
- Ken Keay: Nothing that we see. Some species are getting more abundant but also because bare surface is more available for colonization – but no change because of the outfall.
- Unidentified Speaker: Any species that would enhance the uptake and cleaning of the outfall?
- Ken Keay: We know more from soft-bottom sampling than hard, because video is less intensive. In soft bottom we are not seeing new species in the previous 10 years. Relative abundances change a lot but we are not seeing species moving in abundance to those areas.
- Eric Adams (Civil and Environmental Department, MIT): I was wondering about the concern about baseline staying constant? Are existing data sufficient to see whether or not data has changed beyond 2000?
- Ken Keay: Results of the nine years of baseline are clear. Otherwise, yes—nine years did not capture all the variability in the system.
- Betsy Reilley: Baselines are not very different pre- and post-outfall, but statistically there may be some difference.
- Ken Keay: I look at phyto- and zooplankton and do not see any sign of outfall impact so in the 27 year nearfield record we do not see plankton affected by outfall.
- Melville Coté: Has MWRA given thought to parameters for emerging contaminants being added to program?
- Betsy Reilley: We have done some sampling on the PPCP end and are working on a larger study, as well as at looking for certain PCBs in the effluent and having a hard time seeing them.
- Cathy Vakalopoulos (MassDEP): Can you document any changes in temperature since 1992?
- Ken Keay: A paper was presented at the recent Regional Association for Research on the Gulf of Maine meeting looking at temperature and oxygen changes from a 25-year dataset. The temperature trend is consistent with a half degree Centigrade increase per decade, with similar results throughout the water column. There were also slight changes in dissolved oxygen, which is consistent with the water temperature change, namely a slight decrease in 20-year average.
- Carlton Hunt (Battelle): There is extensive control of effluent condition. I suggest dropping contaminant and organism monitoring because of the strong control in effluent and the contaminant levels not changing. The effluent is clean so it will not change.

- Ken Keay: We have measured lower sediment. As a geochemist, it is good to know that in 2017, 22 of the 26 contaminant groups we measured had near-field concentrations that were lower than were seen during baseline monitoring. I would look at organic carbon in sediments and if that goes up, the potential for higher concentrations of contaminants goes up and would lead to the next step. Thus, you could reduce monitoring of conventional contaminants in sediments and save lots of money on this part of the program by accessing the effluent concentrations already in place.
- Ginny Edgcomb (OMSAP, WHOI): Was there an uptick in denitrification in sediments in the nearfield?
- Ken Keay: We did not see one from a study of three stations in the nearfield. There were lots of changes in the Harbor as sediments processed archived organic nitrogen built up but not any changes in nearfield rates or nutrient fluxes or concentrations during first ten years. When starting to talk about monitoring program changes in 2009 we argued - if this were going to change it would have changed already, so did not need to continue that monitoring.
- Ginny Edgcomb: Are you characterizing microplastics in effluent and any microscopic species that could show how they are moving though food chain?
- Betsy Reilley: We did not monitor for microplastics at all, it was biosolids and data for those parameters, but no hormones or microplastics. It could be something we add.
- Ken Keay: We did some work looking at what is the upper limit to what is considered as microplastics. For ten years the Deer Island Plant operated a flow-based effluent sampler screening at the 2 millimeter level, at the upper end of the microplastic size range, and there was 4-5 parts per billion in the effluent. I would consider dropping the flounder and hydrocarbon sampling as a section that could be dropped out since there were good results of no lesions in a decade
- Betsy Reilley: I agree.
- Eugene Gallagher: There are unanswered questions, including the AMO which may enter its cold phase soon. Samples that were collected in support of the MDC's application for a waiver from secondary treatment requirements from 1979 through 1983 showed very low diversity when compared to recent monitoring results. For example, there were three species that made up 90% of individuals in the samples. If the climate is heading back to the AMO cold phase, are we going to go back to that? Is that the natural cycle of variability on this time scale of 40 years? So I urge MWRA to keep nearfield and farfield sampling that are as important as year to year variability. One could cut back on other sampling, but spores[2] are a good correlate of concentrations in the Bay. In the 1990s three benthic species really reacted to the spores and came in at high abundances and those have disappeared now so one could reanalyze spores. For the monitoring plan my fear is that sampling stops because of answered questions, and then the benthos shows a dramatic decline because of cooling. Why was it so unusual in the past? EPA recognized that diversity was really low and they rejected Boston's 301waiver concluding that Mass Bay may also be put in the same horrible state by putting the effluent into the Bay. The only way to answer that is monitoring the nearfield and farfield over the next 20 years.
- Bruce Berman: I agree and MWRA has shed some stations and it may be that we just do them less frequently, not monitor every month but not every 50 years either. The OMSAP

[2] Spores of the bacterium *Clostridium perfringens* are used in the monitoring as a tracer of effluent solids.

needs to advise on what is the frequency that seems appropriate given the event, of scale of focus, or location, etc.

- Betsy Reilley: For the record, we do not want to stop monitoring or asking questions. We are invested in the program and doing it.
- Carlton Hunt: Is MWRA solely responsible for finding climate change in Mass Bay?
- Bruce Berman: With the expired permit – hopefully when it is written, it will be fixed and mitigated and flexible. There's been a lot of stuff that is frustrating to everybody because of the long time to react to changes that we all agree on.
- Carlton Hunt: We have seen that so much is regionally driven and if we have a program looking at changes due to climate there must be group of people funded well by organizations. MWRA should be a part.
- Pam DiBona (Mass Bays Estuary Program): Betsy mentioned looking for lesions in flounder. In looking at new "yikes" we should pay attention to and incorporate climate change as an important element. A resource that we have now is the Gulf of Maine Integrated Sentinel monitoring program – 50 academics sat in a room and identified what to monitor to see changes in the ecosystem. Scientists decided on what sentinel species to look at as identified in the report. It took two years to figure out and this study includes Mass Bay.
- Carlton Hunt: Monitoring has answered high level questions well. In the face of climate change how has MWRA related its monitoring and results to climate change and what feeds the system? For example could "clean" carbon be something that helps diversity in the Bay in the face of climate change? This could be a different way to think about it.
- Cristina Kennedy (Massachusetts Coastal Zone Management): What will change over time and how does it influence population growth with say extra nutrients?
- Betsy Reilley: There is the 9.5-mile outfall tunnel and 55 diffuser heads, so there is a lot of dilution (70/1 factor) in what is entering the environment. We monitor nutrients in the effluent and see minor changes. Minor increases in ammonia are consistent with Boston's population and less than what was predicted and during planning phases. The expected removal during treatment was ten percent but Deer Island removes more ammonia so we see 30 percent reduction in nitrogen. In the CP the adopted thresholds were based on the expected nitrogen loading in 2020 and the nitrogen is substantially less than we expected when developing thresholds.
- Eric Adams: If the water temperature increases a half degree per decade, is that having a noticeable effect on stratification? Or is the profile not changing because they are coming up together?
- Judith Pederson: Studies were successful early on working in collaboration with universities to look at specific issues. We should consider whether that still works and what areas to pursue following that process?
- Betsy Reilley: There are different ways, particularly through short term studies with organizations. For example, MIT Sea Grant has supported for research studies, UMass Boston was involved in projects and with other supporters. Taken together it is a great collaborative effort.
- Ken Keay: MWRA works in cooperation with NERACOOS and partially funds their buoy south of Gloucester as well as maintaining chlorophyll sensors that address chlorophyll biomass changes, two of those are important projects. We collaborate with

the Center for Coastal Studies and contribute costs for them to collect samples in Cape Cod Bay.

- Bill Kiley: Are there any analyses of contaminant uptake by mussels in the area of the diffuser and do they pass safety measures?
- Ken Keay: Yes and yes. We see uptake of contaminants but not to levels of any concern and to concentrations you would expect. We also carry out comparative studies. We see higher concentrations in the Inner Harbor and at Deer Island Light than in the near field. We also compare to background concentrations from where we first got mussels which was considered the clean area. They are deployed for 60 days and then recovered. Mussel study results from 2018 are still in the lab.
- Todd Callaghan (Massachusetts Coastal Zone Management): Are there long-term changes in plankton in Mass and Cape Cod Bays?
- Ken Keay: We have looked at long-term trend analysis and co-variation of zooplankton and phytoplankton. Abundance trends have now reversed in last 10 years, with no change in species assemblies that stand out. We see some strong blooms and little variations but no pronounced community changes.
- Carlton Hunt: Conducting model runs for the model's sake is not a wise use of money. Is there a way to use the model to get at long-term issues and what ifs and use it and parameters to explore in a 'what if' fashion and extract useful information from the model?
- Ken Keay: Previous model results aren't as accessible to address issues like the ones you raised; we do not have 20 years of files of the model runs.
- Carlton Hunt: There should be files and this could be good money spent to answer questions that have been raised.
- Eugene Gallagher: A recent paper examined the dynamics of a process closely coupled to phases of the North Atlantic Oscillation – blobs of cold water across Mass Bay, decreasing productivity. MWRA could test if this dynamic occurs with its models – putting particles in the model to mimic plankton, address in-boundary-layer subtle effects (not an easy pattern to pull out), examine coupled and interactive effects of wind speed. Surface water temperature is largely wind-driven, depending on southerly vs northerly winds. The NERACOOS model at UMass Dartmouth has 3-4 day lag periods and can predict wind speed. It is not easy to say that you can kick in those models and it will only give you 3-4 day lag.
- Unidentified Speaker: MWRA's monitoring plan was designed to address four questions. Are people in general still interested in those issues, or should we chuck them?
- Ken Keay: That is an open ended question. Some have been answered and many are related to whether it is safe to eat fish and shellfish. We do need to think about that.
- Carlton Hunt: One could look at the earlier questions and recast them with what we know for the next 30 years.
- Christine Werme (consultant): We should start integrating all of the things that affect Mass Bay, not just have MWRA conduct outfall monitoring.
- Ken Keay: When it was designed people thought the discharge would be a major impact on Mass Bay and now we know that is not true. Other things are happening and affecting Mass Bay. Ideally we should work on incorporating everything that may be affecting the bay. I would like to see more integration instead of MWRA being responsible for looking at bay-wide issues.

Outfall Monitoring Conference Breakout Session
Discussion Leader: Juliet Simpson, MIT Sea Grant
Facilitator: Lindsey Williams, MIT Sea Grant

Topic 2: Climate Change

Session 1

- Juliet Simpson: So for anyone who has missed it before, my name is Juliet Simpson and I am with the MIT Sea Grant College Program. We are also making an audio recording, just in case we need to go back and review anything. I thought we could do this by looking at the three questions I posed before as a way of framing the discussion on climate change. These questions are:

    - How will climate change effects interact with outfall processes?
    - How can we distinguish changes/impacts resulting from climate change vs. the outfall?
    - What new(er) technologies can be used to answer these questions (AUV/ROVs, satellite sensing, others)?

    But before we even get to the first question, is there anything that anyone wants to raise for us to discuss? Is there any major issue when talking about climate change that I missed and should be brought up?

- Speaker 1: Just a question, how long is the life expectancy of Deer Island and the outfall? We do not know if its 50 years or 60 years or whatever. We know it is going to have to be pulled back; it was only designed with 3 feet for the flood margins. So as sea level rises, you're going to have to end up doing something with Deer Island.
- Speaker 2: When they built the plant they decided to include a safety height; they did elevate it by 3 feet.
- Speaker 1: It will be an interesting problem.
- Speaker 3: After the Charles River Dam is breached we are no longer talking about Deer Island, we are talking about the entire Boston area.
- Speaker 1: I do not think Boston will disappear; the coastal part will be filled in with water and the city will be pushed in. As a reminder, where Rowes Wharf is today, flat lands or marshes surrounded the peninsula called Boston. The sea is taking back what was already there.
- Juliet Simpson: Basically, the sea is reclaiming the reclaimed land.
- Speaker 4: Do we lose Logan first or Deer Island first?
- Juliet Simpson: I think a lot of Logan is lower than Deer Island. There will be major impacts on the city before both are flooded. The rate of sea level rise and subsequent flooding at Deer Island is not going to be the first major impact. So let's go forward on the assumption that for the purposes of this discussion about separating climate change effects from the effects of the outfall – we are here, and Boston functions as a city, Deer Island will function and keep the plant operational. Let's go to my second question and

postpone the first. How can we think about monitoring in a way that incorporates the uncertainty of climate change and figure out how to give attribution to climate changes versus outfall? If we see some new disease coming in, or we see a change in frequency or intensity, we need to distinguish if this is a problem coming from the MWRA outfall that can be addressed or if it is something that's happening as a result of climate change or other ecosystem changes. What is a way that we can start to thinking about that?

- Speaker 5: Does that mean we need another base station or monitoring station that would be a comparison to the outfall.
- Juliet Simpson: Like a reference location?
- Speaker 6: Or another question – should there be an additional reference station. Are the existing ones adequate?
- Speaker 5: And if there are, then where would one be?
- Speaker 7: I would alter the question slightly because I have worked with the program for years. From a nutrient issue we can model the nutrient fields very well in the discharge so maintaining the effluent monitoring is critical. We could reduce the number of stations out there to look at the spatial scales. What I'm worried about is the interaction between nutrients coming in and phytoplankton and zooplankton in the face of climate change. So that level of ecosystem change is probably more important to me than some unknown disease that MWRA effluent may or may not be responsible for. I'm looking at the monitoring program as something that could be reduced in the extent of the program and rely more on satellite imagery for chlorophyll, as an example. Maybe there are technical advances that could address some other parameters. Another question I would pose is if in the face of climate change, is the outfall a positive? In other words does it keep the organisms out in the ecosystem more functional? If you didn't have that pipe there, what would it be? And we could model that.
- Juliet Simpson: One of the things you said was a focus on more remote sensing.
- Speaker 7: I think the use of appropriate remote sensing, underwater or otherwise is an option to pursue, but that's not going to give you the biology and it is not going to get you all the ecosystem processes. That's why need to sustain some species-diversity measurements at the benthic, phytoplankton, and zooplankton levels and make those community-structure assessments.
- Juliet: But that is already part of the monitoring program, is not it?
- Speaker 7: Yes, but they sample so many stations. You could do a reduction in the number of samples and still get insight into diversity. For example years ago there was a study using equipment where they towed the system through the Bay and they looked at the zooplankton species structure and the spatial scale of change for about 40 miles. You can use that kind of data to set the parameters of where you put fewer stations. So you save some money and you could make it more responsive if you're looking at the outfall itself. If it is changing then you go out and respond. Or if a storm comes through, storms are tough; you've got to have a pre and a post monitoring on a storm. But longer term, that kind of monitoring is absolutely as critical as the effluent.
- Juliet: There is lots of pre-monitoring because there is this multi-decade database.
- Speaker 7: It is an event not an immediate pre-monitoring; it is the spatial time scale.
- Juliet: So one suggestion is to use a modeling approach to better target the monitoring sites.
- Unidentified speaker: And MWRA has done that to a degree.

- Speaker 8: Is not the important thing where is the biggest uncertainty?
- Speaker 7: Biggest uncertainty relative to what?
- Speaker 8: Whatever measurement you're making.
- Speaker 7: Zooplankton and phytoplankton counts are done manually by a person in the lab, not automated assessments made by sensors. But that is where you get some of the biggest variability and uncertainty. If you lose the laboratory-level assessment you lose all of the uncertainty you have regarding species diversity.
- Juliet Simpson: You can breakdown phytoplankton into something like size classes, right? And just automate it with a flow cytometer or similar piece of equipment? …
- Speaker 9: No we do not have that history. For phytoplankton, the key questions involved species level data where you actually have to look at the samples and identify to species. You're not going to do it with a flow cytometer.
- Speaker 10: Very early on we tried to look at that, but the technology wasn't there. But that could change.
- [undecipherable response]
- Speaker 11: But there are people who are working on that.
- Speaker 7: I do not think so.
- Speaker 12: It seems like we are expanding our work with NERACOOS and some of the regional monitoring programs. Is there some entity that is integrating those with the outfall monitoring program so we can take advantage of that data? Is there some entity that is integrating NERACOOS and some of the regional monitoring programs with the MWRA monitoring going forward?
- Speaker 13: Yes that is our hope. There is interest to monitor on an ecosystem scale, from Long Island Sound to Nova Scotia. So it seems really relevant and this is something we are trying to spin up. So yes, NERACOOS is happy to help coordinate that effort, it is just thinking about ecosystem change: there are things that are happening in Massachusetts with the outfall in the state, but there is also what is happening in neighboring states that is important to consider in coordinating state efforts.
- Unidentified speaker: It is called the Integrated Sentinel Monitoring Network that many of you probably were contributing to.
- Speaker 13: There's a little bit of funding from the Northeast Regional Ocean Council, and the US Integrated Ocean Observing System. So that's the kick off and we're hoping to build this effort over the next few years. If anyone wants to take part in the advisory council, to build this system, there's an open call right now.
- Speaker 14: Does that bring up the need for more buoys? What's the one buoy that MWRA is using?
- Speaker 13: Buoy A, yes. There are not that many buoys in Mass Bay. I keep hearing that we need more coastal buoys as well.
- Unidentified speaker: I don't think anybody would argue that we need more buoys.
- Speaker 1: Is there monitoring of the dredging of Boston Harbor?
- Bruce Berman: Yes there is actually a high level of monitoring of the contaminated sediments that are on the top that go into the Confined Aquatic Disposal (CAD) cells in already contaminated parts of the Harbor. There's almost a fight to get their hands on rocks and blue clay by folks who are thinking of everything from coastal defense etc., but because of the timing of this, it may end up at the disposal site.

- Speaker 7: I work closely with the Corps of Engineers at the disposal sites and they typically have a monitoring program both during and after. We cannot put contaminated sediments in the CAD cells. Plus in my experience the plume from the disposal event is short, it gets to the bottom quickly, so the spatial scale of that is probably twice the size, if that, of the disposal site so that interaction down on the Cape Cod Bay from the disposal site and the outfall is pretty much nil.
- Juliet Simpson: I thought that all the contaminated disposal sites were all in Chelsea Creek?
- Bruce Berman: The CAD cells are all in the Inner Harbor – you're exactly right and they are capped as well. That does not mean that when they move the sediment none stays in the water column. I'm pretty critical of dredging. We have seen a lot of incidents, specifically in Miami. But we take it very seriously here; it is a very, very collaborative process. If we all work together, we can get it done.
- Speaker 15: Are we still following the question that you posed?
- Juliet Simpson: Right, my starting question was how do we design monitoring systems or adjust or work with the data to try and figure out what is climate, what is the outfall, and is that even possible?
- Gene Gallagher (UMass Boston): The dominant pattern in the benthos since the monitoring began is increasing species diversity. During the entire pre-outfall monitoring period of 1992 up through 2000, species diversity was increasing dramatically. It is correlated with the AMO. After 2000, species diversity has continued to increase so the general pattern is that with the increase in temperature in the Gulf of Maine there has been a concomitant increase in species diversity in the benthos. Depending on the cycling of the AMO, we could very well be heading to a declining period. The pattern with the MWRA outfall has been warmer temperatures, more species diversity. We do not know whether the temperatures in the Gulf of Maine are going to decline; historically they have as AMO has gone into the cold phase. We could be looking at 40 years of decreased temperature and species diversity could decline dramatically in the entire Massachusetts Bay area. It is gone up about 20% since 1993, and it is kind of leveled off in the post-outfall period. You can detect the outfall patterns if you continue to have stations in the near field and far field. By dramatically cutting down the near-field and far-field stations you've greatly weakened the ability to separate outfall effects from climate-change effects. As a matter of fact in cutting the number of replicates as were done in the 1990s you can dramatically decrease your ability to separate the effects. Species diversity has gone up in the near field and the far field, but it is gone up at a slightly faster rate in the far field. That difference wouldn't have been detected if they had cut back to two grabs. Now they've cut back not the number of grabs but the number of stations from 38 stations to 13 stations. One of the things to project is, whether the AMO is going to go into its decline so the patterns we have observed since 1993 are going to change. There's a very good chance that the species diversity will not increase at the same rate that it has been, but then there is a really good chance that it is going to go into decline. Thus, it is important that we separate the AMO effects from the outfall effects. And to not be frightened at a species diversity decline. The current caution levels are based on a baseline from the 1992-2000. What happens when we are back to the 1992 levels, when the last time we were in a cold level was 1975. We have never seen the diversity at the 1975 levels. It is not only going to happen in soft-bottom benthos, but also in soft-shell

clams. The last time the soft-shell clam fisheries were at peak level was when the AMO was at its coldest phase in 1975. One thing I have seen presented at meetings is that green crabs do not do well when the temperatures are pretty cold. Right now they are thriving, but going into a declining period they won't be able to survive the winter for instance, and it might be a boom period of soft-shell clams. Lobsters may be hit with another effect. For cod, it might be a thriving period. The point is, you have to continue the monitoring plan. You cannot cut it any more than it is now being cut. I'd like to see them get back to taking triplicate samples in the benthos to get the replicates back because those were critical to separating the effects.

- Juliet Simpson: So we need monitoring, particularly maintaining the nearfield and farfield sampling, so that there's some form of reference comparison.
- Wendy Leo (MWRA): As time goes on it seems that it will be less interesting to ask how is it different from the baseline period to focusing more on how is the nearfield outfall different from the farfield stations because the natural changes are going to kind of swamp the effects of the outfall. Or things are going to happen naturally that were not seen during the baseline period even though it was longer than we expected. The baseline period still was of a limited duration. Things are going to occur that are novel, but not may not be related the outfall. The reference stations become even more important. It may make more sense to work with larger interagency or interstate groups, to get the context for what is happening regionally.
- Eric Adams: I'm not sure how you can do any of this without a modeling framework. It seems to me one of the main goals of data collection should be to calibrate models that can then be used in "what if" situations without climate change for example. With climate change going on at the same time as the outfall, we have variability that is random plus cyclical. I think you've got to put the data into the context of a model so that you can add and subtract factors.
- Speaker 18: The practical implication, it sounds like from what folks are saying is that right now the CP thresholds are based on the baseline conditions. They arecalculated based on the baseline results, but it sounds like what you're saying is we may need to calculate our threshold based on a reference that might be changing with climate change. So not looking at the nearfield baseline but looking at some sort of farfield climate change impact and a kind of shifting baseline site.
- Speaker 5: Looking back at why we have a CP, the thresholds developed in case something terrible happened and we have to move the outfall back to Boston Harbor. I think that question has been answered again and again. I do not know if it makes sense to set up new CP thresholds where we have to respond within 5 days, especially when we are talking about climate change.
- Gene Gallagher: So let's think, if we get to really low benthic diversity as it was in Boston Harbor – the kind of conditions that we didn't want to go back to, but what if it is low in reference stations that are not impacted by the outfall somewhere in Cape Cod Bay. Because of the AMO decline, so lower diversity is "natural" and not impacted by the outfall. That's the scenario I was trying to envision. So we have to rethink that.
- Speaker 5: I just do not think we should trade one contingency platform that's outdated for another.

- Unidentified speaker: When you say "outdated," are we saying benthic diversity, for example, is that something we do not need to worry about then with the outfall, with climate change as the context? People are still concerned about that.
- Juliet Simpson: I mean it sounds like one thing to think about for future permits—is making sure that any monitoring requirements refer not to a static baseline, but to reference conditions that are current in time and maybe set it within larger Gulf of Maine monitoring or regional work at NERACOOS that is happening.
- Speaker 7: Given the knowledge that we have, if you have to retain the CP, you might want to look at resetting the baseline to post-discharge some period. With only the pre-outfall monitoring data we knew nothing; if we only had the post-discharge monitoring data, we would know nothing about earlier conditions, because we couldn't forecast. Now we have 18 years of post-discharge data. Give the environment a couple years to adjust, so maybe 16 years of data, that this is the system. You might want to look at those data as a more telling process for a contingency process.
- Juliet Simpson: The tricky thing about that is you still cannot attribute changes to climate versus outfall effects. Whereas with the reference approach, especially if you have regional data that may indicate change not influenced by the outfall.
- Speaker 7: If we do not have the reference pre-discharge data, then how are you going to do that?
- Juliet Simpson: It sounds like there are some reference pre-discharge data.
- Speaker 7: We have reference stations throughout this Bay since 1992. And you can use those data, yes.
- Unidentified Speaker: That is the way that it works now, the way the effects of the outfall are sorted out from the effect of general changes. For example, we say that for example there have been *Phaeocystis* blooms since the outfall came online but those blooms have been regional, as in throughout the northeast.
- Juliet Simpson: I think the tricky thing about incorporating climate change into monitoring or decision making is that a hard baseline is not the most useful thing for monitoring but a reference condition as a "baseline" for comparison will be more useful, because everything is changing so rapidly.
- Unidentified speaker: Picking up on that we did have many more years now of observations so when it comes to finding what we call the baseline, we now can incorporate variability, long-term variability that is kind of what we would do in the next phase of monitoring.
- Speaker 7: The benthic community is a very non-homogeneous community out there (in the Bay). So we have to look at this. For various components of this plan, do we have definite references for this plan; do we have appropriate reference sites? Cape Cod Bay is muddy, it may not be an appropriate reference site for benthic community for outfall effects, but it may be for climate change.
- Speaker 1: We have added pH, but the whole acidification problem is different from the ocean circulation by heat so I do not know what type of monitoring that new pH monitoring recently added. How would that tie into the global changes compared to local changes, if any? How would that have an impact on fish and benthic populations?
- Juliet Simpson: Yes, pH monitoring location is right at Deer Island. But does not your place have an acidification buoy out somewhere?

- Speaker 13: There's one out near the [unintelligible. (Editorial note possibly Buoy A)]; there's a CO_2 buoy out there. We are trying to pull citizen-science groups that have been monitoring water quality parameters along the coastline, trying to pull those together in the context of acidification to get a better signal. They have great long-term datasets; some measure pH but a lot are determining relationships with salinity and other parameters so they can correlate with changing acidity.
- Speaker 20: It is important to ask how this relates to the outfall. I think any questions we ask of MWRA's outfall monitoring should have some reasonable correlation to the existing outfall as opposed to just really interesting questions. Perhaps some of the proposed questions need another funding source.
- Juliet Simpson: I think it is great to say that we cannot reduce the number of samples, we cannot reduce the frequency of sampling, and we should add more data-collection systems, but at some point the ratepayer has to pay for all of that unless we find an outside funding source. This effort is important to get a laser focus on the best way to use MWRA resources to collect information that will be the most useful. It would be super interesting to find out that all these changes are happening, but is there something that MWRA can do about it, if it is a negative change that we do not want. That is what the monitoring has to answer. Am I framing that correctly?
- Unidentified: Yes, the outfall would be the most stable part of the batch.
- Speaker 19: We have learned a lot about what the outfall effects are and what they are not based on the 33 questions, 10 of which are answered formally and approved of as answered by the OMSAP. There are others that we think are maybe answered as well. For the conversation that we are having, it should come in the context of what the outfall is and is not doing, which we already know. So one of the key unknowns is – we know the outfall has caused modest increases in ammonia local to the outfall location. The question would be how is that possibly going to be important with climate change and what is happening in our warmer ocean? This seems much more relevant to where the focus needs to be.
- Speaker 20: I think it is perfectly appropriate to use MWRA data to get at bigger questions, but it needs to be related to the purpose.
- Speaker 21: We have had about two decades of the outfall operating and with climate change. Can we use the data to figure out what the effects of climate change are? Can the data we collected via the monitoring in the last decade help us understand the data in the next two decades?
- Juliet Simpson: The question I would add to that is how has climate change impacted the system in the last 20 years? There are 20 years of data, but climate change did not start today.
- Unidentified: You may not be able to see that signal. If you cannot see it in the last two decades, you may not see it in the next two.
- Juliet Simpson: Has anyone taken MWRA data and looked at the nearfield and farfield.
- Unidentified: I have started looking at the near and farfield data and we do see long-term trends that are consistent with what other researchers are finding. So it is present in the dataset although the dataset wasn't designed to detect long-term trends.
- Speaker 7: The system was set up for nearfield and farfield comparisons, but was reduced because we didn't see significant differences. We were able to reduce the program to get information along the flow lines of the currents of the system.

Climate Change Session 2

- Juliet Simpson: The central question I think we need to talk about is that the current monitoring plan was designed to view if the outfall would have effects on the community, but now we are throwing climate change in the mix. It is important to differentiate which effects are caused by the outfall vs climate change. Is there anything that anyone wants to jump in with?
- Speaker 1 [Deborah Rutrecki? with Normandeau Associates]: One of the things that I would ask when thinking about climate change is what is the timescale we are looking at? Depending on the timescale the monitoring could have different applications. For example in 20 years as lobsters move northward, we might need to replace them with another species to look at. Whereas in 5 years we might need to keep monitoring water temperature, etc.
- Juliet Simpson: The question is what time scales are we thinking of. I would say the 0-20 year time scale. For the purpose of this discussion we will think on the 0-20 year time scale. One of the issues that the previous group came up with is that comparison of current data to baseline, pre-outfall data, may not be the most useful way to think about climate change, that we should be looking at the near field versus far field, the reference sites versus sites closer to the outfall, to get more effective data. Anyone have any thoughts on that?
- Speaker 2: It is interesting that we have reduced the amount of sampling areas over time. For example the water column farfield monitoring has been severely been reduced overall. But when you start thinking about it, perhaps we want to increase our farfield sites to more than what we have now. Back then, when we were developing the outfall, we thought about how the dynamics and water came in and changed things. How the outfall would act in a stratified situation. I think we should take another look at the farfield and look at the design differently. We know that whenever we see changes happening in the northern Gulf of Maine, we will have to look and see what the variability is. And see if we can capture some of the changes.
- Juliet Simpson: Some of the good news that just came out in the last group is that NERACOOS and some regional groups are collaborating to implement an Integrated Sentinel Monitoring Plan. There's now an integrated monitoring network, that's doing some monitoring not just in the Gulf of Maine but also down into Long Island Sound. This means there will be more data being collected, although I think right now, it is just water quality. All those people are talking to each other and sharing insights; they know each other, so it is great.
- Speaker 3: Can you summarize "integrated sentinel" and what is included in all this?
- Juliet Simpson: I do not know exactly what they are going to be monitoring, there was a long process that EPA started 5 or 6 years ago. The idea was to take something like the Long Island Sound study and implement a more regional scale program.
- Unidentified speaker: Was it a suite of species or something like that?
- Juliet Simpson: They were looking at everything, physical, chemical and biological. They brought together a number of people and separated them into three groups: the estuary, the pelagic and the benthic. The discussions focused on whether we should be monitoring organic matter or flounder lesions or phytoplankton species composition. They came up

with a very large plan to monitor the agreed upon sentinels in each category. I cannot speak to which subset is being implemented, but I think they started with water quality.

- Speaker 4: The Integrated Sentinel Program is sort of a network of networks. It is not initiating a new program; it is coordinating what is being done. If organization X is doing Y and organization Z is doing A they will continue to do that, it is just how can we get the biggest bang for the buck out of what is being done.
- Juliet Simpson: They did get some funding to start new programs.
- Speaker 4: News to me. It was never meant to be a new project.
- Juliet Simpson: News to me too, as of 20 minutes ago, but I think NERACOOS is implementing some of the new monitoring – specifically water chemistry. I think there is not a lot of biology.
- Speaker 5: Back to question about baseline versus post diversion versus nearfield: at least in water column work we look at both of them currently. We continue to talk about baseline versus post diversion numbers and comparing directly, but you always look at one station that Ken showed, farfield station 22, which is near NERACOOS Buoy A as kind of reference to what is coming in, i.e., the influence of the Gulf of Maine. But do data from buoys in Cape Ann look like data obtained in the near field? So those reference sites are already being incorporated, as far as we look at it. And looking farther upstream has become relevant, especially after 2005 red tide bloom that forced us to say "there are many things happening." Well there are many people who were looking at what was happening in the Gulf of Maine, but the linkages became more formalized after 2005 with our working with folks in Woods Hole, and their work with *Alexandrium* and what is happening in the Gulf of Maine and potentially impacting Mass Bay. Obviously with the change in climate that we are seeing, that is going to be more important in understanding not just the ecosystem in Mass Bay but whatever is happening at the outfall. You talked about these impacts from climate change, there's impact from the outfall, how do we tell the difference but more importantly and I think implied in your statement is what are the interactions of those too. With increased temperature and higher sea levels, is the outfall going to behave differently or is the ecosystem going to react differently to what is coming out of the outfall?
- Juliet Simpson: That's also one of the complications with using the last 20 years as baseline data since the outfall has been in place for nearly 20 years and changes have happened, but the baseline has already shifted from the pre-operational monitoring.
- Speaker 5: We cannot get at those answers on some of these things. For instance, chlorophyll data from the last 8-10 years indicate that we are having higher levels of chlorophyll from November through February and in February the silica levels are much lower than they were back in the 1990s suggesting that diatoms have been active all winter long. We are seeing zooplankton increase their numbers earlier in the spring potentially because of food being available but also the warmer temperatures. In the last 5-10 years we are not seeing as many big blooms all the time, especially diatom blooms. So were seeing change and it is becoming more of a thing where we are using climate change as a crutch but it would be nice to get to a point where we are not just saying "yes it is climate change" but we have true mechanisms to try and say this is why this is happening.

- Juliet Simpson: Which leads to another question I had about using technology that is not being relied on heavily, what can we learn? How can that help elucidate climate change impact and outfall impact?
- Speaker 1: In general if we have more information on the regional scale we will be able to see if the trends are more regionally applied or isolated to the diffuser sites.
- Juliet Simpson: So if you want to design a study to tell what are the impacts of the outfall vs the impact of climate change, what we be your ideal study?
- Speaker 1: I think that MWRA produces good data.
- Juliet Simpson: They produce good data, but does that data highlight the differences?
- Speaker 2: What percentage of the plankton data are from the MWRA? The agencies aren't doing a lot are they?
- Speaker 2: Are there long term data sets out there from other groups?
- Speakers 5: There's a lot of academic research.
- Juliet Simpson: There are a few long term studies, but most are local. Can you elaborate more on the new technology?
- Speaker 2: Cabo.data (Oracle hierarchical data management) has a new technology.
- Speaker 6: The phytoplankton? So, I actually have a problem with the plankton. It is really difficult to use to phytoplankton. A new technology I'd like to see implemented would to start doing environmental DNA at these sites.
- Speaker 1: Is the technology ready for something like this? Have they gotten all the kinks out for eDNA, or is it out another 10 years?
- Speaker 6: Yes it works really well and the research community is coming up with best practices, I think it is now arrived. The cost of processing samples is now low enough, that is comparable.
- Speaker 7: Just a comment about new technology. We should really be using the technology to answer the questions not just using it to get more data. What are the questions we are trying to answer and then choose our technology from that list of questions? Also when using a new technology, we have to have a period of overlap when you are doing both kinds of sampling.
- Speaker 1: There is a reference sample for certain species, but depending on technology usage may be limited.
- Speaker 2: So, yes we do need to focus on the question and we need to determine what we are trying to do.
- Speaker 8: We have looked extensively for growth in chlorophyll, but we cannot find it.
- Speaker 5: And in regards to red tide blooms, we have we have tried to set up monitoring when it comes in. We have not seen this happen yet.
- Speaker 2: Do you see it in 15 signals like we used to see in the Harbor?
- Bruce Berman: As we look at models going forward, it seems like a model that says, "this merits further study now" is helpful. It is almost the posterchild for this kind of stuff; this is the direction I'd like to see the monitoring program go in. We have not asked people how we should do that or how much money we should spend on it, but that seems like a very powerful model. These have been helpful beyond just answering the question as to what is the importance of the outfall.
- Juliet Simpson: But this takes us back to the importance of empirical data, costs, and that MWRA needs to know what is happening with the outfall.

- Bruce Berman: I do not think you should worry about the cost, but I think that it does not mean that is not important that we shouldn't keep track of stuff that may not be caused by the outfall but could affect the Bay.
- Juliet Simpson: Maybe the MWRA could partner with other groups to do so. Are there any restrictions on that?
- Speaker 7: I do not think there are any major restrictions.
- Speaker 2: Is there any general feeling that harmful algal blooms are increasing?
- Speaker 9: It will change if a new species appear.
- Bruce Berman: In the Harbor we are seeing new species and from the reports that I get, they are very different. And they are starting at different times of the year and extending to different durations. The word harmful is in the eye of the harmed.
- Speaker 1: I think that that is one of the important things about having the long-term monitoring program that MWRA has, because if you do not have something that gives you a long-term view, then you cannot see the change.
- Bruce Berman: That's the kind of thing that I find will be practically helpful.
- Juliet Simpson: But again the question comes back to whether this is something that MWRA can change or if it is coming from climate change, and how do we change the monitoring questions?
- Bruce Berman: Even if it is not something that the MWRA can change, calling out cautions has value. It is important for the MWRA to say "no, we are not responsible". At the end of the day it seems that to me that assuming some responsibility is essential. We also insisted that the pipe be able to be turned off. And there are folks in this room who at the time thought it was possible that removing huge amounts of human waste from the water would be a problem. I represent PIAC, and I think that one of things about the monitoring is to address the public's concerns and that that is the important thing.
- Speaker 2: As you were doing your talk what did you think were your major concerns about climate change and the outfall?
- Juliet Simpson: Well, given that I threw the slides together in a half hour, my personal concern is more with stormwater than with wastewater.
- Speaker 2: Why stormwater?
- Juliet Simpson: All of the stuff that is part of stormwater (such as oil, tire tread wear, metal from brakes, sediments, nutrients, wastes, etc.) and that gets into the ocean comes from humans and human activities. It is very difficult for people who live 20 miles from the ocean to realize that the things they throw in the road or come from their lawns get into the ocean. Whereas the MWRA and its treatment plants are understood, but even those are underestimated with respect as to how these are affected by stormwater.
- Speaker 5: My concern is to focus on MWRA and the outfall. We could do monitoring with more frequency, with more buoys, etc. One of the reasons we are here is for the public. Climate change is going to produce more concerns, and we cannot just keep sayings "it is not us". I think the monitoring program still has value for that.
- Speaker 2: Is ocean acidification a problem?
- Speaker 5: It is a huge issue, but I'm not sure it is particularly tied to the outfall. I do not think it is directly tied to the MWRA.
- Speaker 2: Are we seeing things in the Gulf of Maine?

- Speaker 10: We started monitoring two years ago with the help of the MWRA, but the stations run out from the harbor to the farfield. There are no results yet but we are working to develop a model to do so. It is a work in progress.
- Juliet Simpson: Since we do not have upwelling, etc., diurnal things are our primary concerns. Its nutrient driven, not related to ocean acidification.

Outfall Monitoring Conference Breakout Session
Discussion Leader: Mark Smith, MassDEP
Facilitator: Juanita Urban-Rich, UMass Boston
Topic 3: Emerging Contaminants

Session 1

- Juanita Urban-Rich: In this session we are trying to understand the sources and prioritize what could be some of the biggest issues related to emerging contaminants?
- Bruce Berman: Could not the effluent give us a window onto that? It does not answer the question as to all the other inputs but one thing I just thought about is to redirect some of the attention that we give to the effluent analysis we do so, there is synergy with ambient monitoring.
- Juanita Urban-Rich: Effluent would be input.
- Cathy Vakalopoulos: In response to Mike Connor, theoretically we get all this money to do monitoring. You're talking PFAS and PFOS but then Juanita Urban-Rich is talking about short chains that do not break down and do re-form. So what would you even do if you cannot monitor all 4000 compounds? What would you narrow down to?
- Mark Smith: I would use EPA databases and get a better handle on what compounds are being used, over the last 5 years. There is some potential to do that with the information that's available. So it is a whole additional prioritization effort that would need to take place to identify a subset of chemicals.
- Anna Robuck (Stellwagen Bank National Marine Sanctuary): There are indicator compounds that can indicate streams of ECs.
- Mike Connor: Mark Smith's got an overall framework at MassDEP for some ECs. I'm in the SF Bay Area now; we are doing it a lot differently because we are focusing on effluent. Mark Smith's got drinking water and wastewater site focus because MassDEP has strong control in those areas. Effluent is different. The California Water Board (equivalent of MassDEP) is doing a lot on effluent because we see this as the key to the regional issues. The drinking water issue is not as strong a concern because people aren't drinking water from the Pacific. We have a framework that fits with State Water Board that says: what is our priority and how do we fit these data into our priorities? We have strong state programs on how to think about these things, but we are a little weak on wastewater, drinking water, etc.
  Mark Smith: We are looking at what we will do. In California wastewater may be different quantitatively but qualitatively, what is being done to manage effluent is likely to be the same so what you are doing could be informative?
- Maury Hall: Ten years ago, we saw the same thing about dechlorination. It added metals in the waste stream and changed the effluent dramatically. In addition some chemicals were broken-up and some chemicals combined with others. Did anyone look at the effects of chlorination or de-chlorination on making these things worse or better? I'm

sure methodologies are marginal since such minute changes are hard to measure, but at the same time the effluent changed a lot.

- Mark Smith: I think answer is yes, but I do not know much about wastewater perspective, from the drinking water perspective, although there has been a lot of work.
- [Question could not be heard]
- Mark Smith: It would depend what they were looking at because chlorinating compounds are not likely to be big drivers of changes. But for other compounds, like hair products, certainly there are changes.
- Richard Delaney: In terms of monitoring programs for the Center for Coastal Studies, we do large comprehensive monitoring and added a small segment for hormone disrupters. We have found them in Cape Cod Bay regularly, a small percentage, but the problem we suspect is happening is definitely there. I do not remember the four compounds, sorry. We also are wondering if somehow hormone disrupters are affecting right whale fertility. This is a topic we want to investigate as well.
- Identified Speaker: What is the primary source?
- Richard Delaney: We do not know.
- Mike Connor: The other place we want to tap into is Cape Cod groundwater discharges and other WWTPs. We need to include everyone in the monitoring
- Richard Delaney: Yes, there are lots of discharge pipes around Massachusetts, and Cape Cod has thousands of septic systems that treat some stuff but not everything and much of the nutrients and other compounds get into groundwater and north into Cape Cod Bay.
- Pam DiBona: Mass Bays funded some work by the Silent Spring Institute and Center for Coastal Studies looked at antidepressants. For septic systems, we need to figure out how that works.
- Bill Kiley: PCB levels were exceeding EPA limits on the MWRA outfall points. Is that coming solely through the outfall or is that tied in with everything else we really cannot find?
- Mark Smith: Probably PCBs are tied into a lot of different sources. Multiple sources of PCBs and other classes of compounds that still are present in the environment; even though they are banned they exist and continue to be released. Importantly, we are not seeing new inputs of PCBs that need monitoring; the source is historic.
- Bill Kiley: Would a source of PCBs come from burning like coal, but if you burn rubbish for electricity where PCBs were used?
- Mark Smith: If rubbish were burned, there would be controls on it; so yes.
- Bill Kiley: In rivers, such as the Neponset, there are pockets of sediment we do not want to stir up.
- Mark Smith: Yes those sorts of areas that have limited change in sediments but with a connection might be mobilizing historical contamination into the Bay.
- Mike Connor: PCB data came from Steve Rhode (MWRA). We have seen a change in character of PCBs that show up that looks a lot like long-lived chemicals, which could just be persistent in the environment.
- [question about a specific test for chemicals]
- Todd Callaghan: What would it take to get MassDEP to get up and running where we are monitoring the key elements?

- Mark Smith: It depends on where we are monitoring and the quality of drinking water. The whole state was part of the UCMR-3, which is a national monitoring program for larger public drinking water systems. We have additional monitoring at hazardous waste sites and MassDEP and a few drinking water treatment plants have some funding [https://www.epa.gov/sites/production/files/2016-05/documents/ucmr3-factsheet-list1.pdf]
- Todd Callaghan: I am trying to get a sense if we come to consensus, what is the cost and how long?
- Mike Connor: In the SF Bay area we spend about $300,000-$500,000.
- Todd Callaghan: Is there technology that can address this?
- Mark Smith: For some of these things it is hard to predict – are we shifting priorities? For some of it we just do not have the resources.
- Mike Connor: Some of these things do not degrade?
- Todd Callaghan: Is public perception enough to get a ban? We know how dangerous some of these chemicals are.
- Mark Smith: If you do not have the data then you cannot make the argument for banning a compound.
- Mike Connor: SFEI is embarrassed about this issue. We are trying to figure out what we do about these things. It hard to reduce a market with no argument. We monitor microplastics in San Francisco. Once you have base program in place you can contact other funders. How does the public view this dilemma? The public is suspicious and MWRA is suspicious. A good example is mercury in WWTPs is a good example.
- Bill Kiley: Are there other ways to measure microplastics? Breakdown has such a long timeline. Is there any gauge to find out where the most microplastic comes from?
- Steve Rhode: There are people who have looked at it and see the amount that comes from polyester clothing etc. The breakdown is fragmentation.
- Anna Robuck: There was a study from two years ago that took a bunch of clothes and washed them. They researchers measured the amount of fibers that came off each piece of clothing. In all, a couple kilograms (~ 4.4 pounds) per day from a population of 50,000 people.
- Juanita Urban-Rich: How many contaminants stick onto microplastics? As an oceanographer I care about the impact to right whales when other contaminants are brought in at low concentrations.
- Bill Kiley: Are there correlations between microplastics that inflect diseases on fish? At what level can microplastics be tolerated by fish or people?
- Ginny Edgcomb: Microplastics can accumulate in phytoplankton and move up the food chain.
- Mark Smith: Intracellular concentrations have been found.
- Juanita Urban-Rich: We do not know yet, we need more time and research to find the answer.
- Mike Connor: What is the level of evidence in emerging contaminants in Massachusetts?
- Juanita Urban-Rich: We do not have the linkage yet. There are studies but not enough to make conclusion.
- Mark Smith: Some of the research efforts are looking at levels of compounds in blood.

- Anna Robuck: We have measured PFAS in birds (Great Shearwaters) that forage in Mass Bay and found higher concentrations than we would have expected, higher than found in California birds. Our next step is to look at fish.

Session 2

- Mark Smith: We had a lot of discussion in the last group here about what things we might want to be looking at via outfall monitoring, PFAS, microplastics, and some of the pharmaceuticals. We didn't get into talking about a process for getting to some of the next steps. We wanted to go down this path with MWRA and think about how one would prioritize the chemicals we might be concerned about to a reasonable subset that might be PIAC's concern to follow up on. I would like to throw that out for this group, to give some thoughts and have some discussion about it in terms of how then you might develop some plans to move this forward. If that seems to be a good thing to do.
- Andreae Downs (MWRA Wastewater Advisory Committee): The contaminants and emerging concerns that MWRA Wastewater Advisory Committee is concerned about are those compounds that survive the wastewater treatment process. We figure that some of the PCBs are removed in the wastewater treatment process, and some (not just personal care products) other chemicals that are a concern in the environment but just do not make it through. From an outfall perspective and also in terms of the residuals we are concerned about those that remain, such as microplastics. Some of the PFAS and some of the other contaminants are not making it all the way through. That is what we are concerned with.
- Mark Smith: The concern from the MWRA, with their advisory group here is the chemicals that make it through the treatment. So if it is not making it through the treatment then from the standpoint of the outfall, we do not really care about it that much. The ones that make it through should be a priority and that would include microplastics because they're clearly not getting broken down although they might be getting captured to some degree. The perfluorinated compounds are also not being effectively treated. And I imagine that some of these emerging PPCPs are probably not being treated either. So those would all elevate to compounds that are likely to be moving their way through the system.
- Andreae Downs: The things we are concerned about are the things that survive. The other one that survives that we have not talked about because it is not a chemical is bacteria that are antibiotic resistant – they appear to survive the wastewater treatment process.
- Mark Smith: Yes, we have not even thought about that.
- Lealdon Langley (MassDEP): Mark, I am interested in the expense of EC monitoring and how to gain efficiencies in that. Some of these chemicals are expensive to monitor for because they are so specific. So are there specific classes of contaminants, are there broader classes that can be monitored for what might be done at a higher level? And if they are detected should we refine the monitoring? What would be the cost and efficiency over time?
- Mark Smith: For the perfluorinated compounds, there is a lot of effort underway now to develop techniques to look at the broader classes. They are still in the developmental phase. From a cost-effectiveness standpoint, if we have money to support development,

ultimately it might prove to be cheaper. The upfront initial cost will probably be pretty substantial. And that is for the perfluorinated compounds. For the PPCP, it is such a big universe; I do not think there is one simple test that you can use that would provide insight on a big broad class of things.

- Steve Rhode: If we look specifically for endocrine disruptors, we can do that as a class . By using the actual mechanism you can test for the effect as opposed to the disruptors themselves. Not necessarily start off with all the different chemicals that may be causing these effects.
- Lealdon Langley: Are there ones that we know affect biota as opposed to humans? The contact with humans is less of an issue here. Are there ones that could be more specific to biota?
- Steve Rhode: Probably. That's a little outside my area of expertise.
- Lealdon Langley: Could we think about that a little bit? In your earlier talk you were saying some of the endocrine disruptors not only affect humans but some of them affect the biota as well. And the purpose of this conversation is that we are more concerned about those in the ambient environment than about those you know. It is less likely that we are having human contact (drinking water, primary recreation, hazardous waste sites) since it is not those vectors that we are concerned about. We are concerned more about the biota, the effects on the biota, and the effects that we are having on those communities, as well as the potential for those biota to be part of our food chain. Are there endocrine disruptors that are more specific to biota than human consumption?
- Mark Smith: Well again, as you mentioned there are some lab tests that you can do that look at endocrine disruption from an effects standpoint. Those can be done on biota in model systems; that's more or less the way it is been done.
- Steve Rhode: I am not familiar with these tests, the endocrine systems work the same way across organisms. Is it even possible to target some specific mechanism or effect that is happening rather than test for the endocrine disruptors themselves?
- Mark Smith: I would not exclude the possibility of human exposure pathways from the food chain.
- Barbara Warren (Salem Sound Coast Watch): Where are we thinking about getting these tested? It is really before it leaves the plant right, because you are not going to be testing the outfall? What is getting through and how much? Are you doing that now or is this something new?
- Mark Smith: This is something new.
- Steve Rhode: They are doing it on the list of chemicals for the monitoring plan, we are not doing it right now for PFAS or things like that.
- Anna Robuck: If we want to change some of the monitoring and include some of these new contaminants, we need some information before we start monitoring. We also want to measure how much is making it out into the environment. So I think you want both.
- Barbara Warren: You're ready to shift into the pipe because that is where you can measure this. Some compounds would get to the end of the pipe.
- Wendy Leo: Is it affecting the environment, which is a different question.
- Barbara Warren: Do we even know how much gets through?
- Mark Smith: The caveat being that for the bioaccumulative compounds that you might be concerned about, you might want to know what is already there.

- Barbara Warren: So you have to know your ambient level to know whether what you're adding is a source.
- Wendy Leo: You need to know whether it is a measureable.
- Robert Buchsbaum: Wouldn't one of the questions also be how much is MWRA's outfall contributing compared to other sources? Microplastics might be in stormwater runoff; the outfall may be contributing, but maybe only a small percentage.
- Anna Robuck: There are a number of studies looking at different ECs and plastics in Mass Bay. Today we are particularly talking about what the outfall is contributing. Finding out what is in the effluent and what is in the surrounding area seems like a logical next step in MWRA's handling of the process.
- Juanita Urban-Rich: If you are thinking microplastics, these are particles are not a dissolved chemical like some of the other things. You would also have to look at its behavior in the water. Is it being maintained under the thermocline (a temperature gradient that forms in the bodies of water, e. g., Mass Bay in the summer, and acts as a barrier to chemicals)? Is there a density, such that they are rising up through the barrier? Where and on what in the water column would they be having an impact? The behavior once they come from the diffuser would be important too.
- Wendy Leo: This is a national, global problem, in terms of the regulatory environment. It might make sense to focus on things that are of interest because we think there is something special about Mass Bay, whether it is particular biota or whatever, that is particularly sensitive to something. Or things that we think are more likely to be in wastewater effluent. We should make more of a contribution to the national effort to focus on things that are more particular to our effluent, our treatment process, and our Bay. I do not know what those are.
- Mark Smith: Me either! There might be some unique attributes. This approach would certainly warrant further thought.
- Wendy Leo: MWRA cannot answer the question for everything.
- Mark Smith: MWRA can contribute to the answer. We need to get information for some of these compounds nationally and globally. As Mike Connor noted, in California, they have a significant effort underway with discharges in SF Bay, where they are looking at a lot of these issues already. I think we should pursue trying to see what other states are doing, rather than reinvent the wheel. I think you can contribute to some of the bigger answers to the bigger (national-level) questions. It is not just what is happening in Massachusetts.
- Unidentified Speaker: The Center for Coastal Studies did some research on what comes out of septic systems, and started to show that there are particular contaminants that they saw across multiple areas.
- Robert Buchsbaum: Have there been studies of copepods (zooplankton crustaceans and food source for right and baleen whales) picking up microplastics. Is that something that's well established? Can that be studied here in Mass Bay?
- Juanita Urban-Rich: Yes, people are doing that work right now, looking at different plankton. There are people doing work in Woods Hole and myself at UMass Boston looking at some of the mollusks in the area. There is definitely some ongoing work but they are specific studies and not monitoring.
- Mark Smith: In freshwater systems, they are getting picked up in the sediments, particularly by insect larvae.

- Barbara Warren: We do not know the standards and effects; the nature of emerging contaminants is that we do not know their effects and impacts.
- Mark Smith: In order to build a case for meeting standards, we need to fill in these blanks, we need information and data. One of the first things – is it there? Is it there at a level you may be concerned about? From the standpoint of the outfall: for some of these issues we do not have the answer.
- Lealdon Langley: What are the dangers that microplastics present?
- Mark Smith: Depending on the size, it could be disrupting membranes in cells, they can absorb other things, concentrate other things in the water column like toxins.
- Juanita Urban-Rich: It depends on the size, let's take zooplankton for example. Microplastics are of the size that they eat. They can have physical impacts, e.g., block guts, such that the zooplankton does not have enough energy for growth and development, reproduction. It can rip their guts. There can be chemicals leaching out of the plastics, and that's another impact at the organism level. At the cellular level, there are chemicals that can be carriers for others or make up phosphate compounds. For microbeads, fragments, and fibers, we have less than a good understanding.
- Lealdon Langley: Wouldn't the beads degrade over time? Through exposure and abrasion, will the structure change over time?
- Juanita Urban-Rich: Do you mean a change in shape and size?
- Lealdon Langley: Shape, size, become fibrous. I was thinking about that in the context of your earlier comment about trying to understand how they are distributed in the water column and that might change as their physical appearance changes?
- Juanita Urban-Rich: Definitely, we know now that microplastics get covered in a biofilm, communities of bacteria grow on them and sometimes they are pathogenic. That changes their behavior in the water column because of density and weight. What happens to them in a treatment plant – I do not know in terms of biofilms and things growing on them.
- Barbara Warren: Bacteria and viruses can stay on the biofilm.
- Juanita Urban-Rich: I do not know what survives the treatment process.
- Mark Smith: Biofilms are often resistant to chlorination near the outfall, whether or not that applies on a microscale I do not know.
- Andreae Downes: The treatment is a pretty harsh environment, many things do not survive. The compounds are subjected to a lot of environmental factors in the treatment process.
- Jo Ann Muramoto: What can you say about the treatment of microbes that are resistant to chlorination? Have their concentrations remained constant through the wastewater treatment plant? Do they survive? What is their fate?
- Andreae Downes: The only study that I'm aware of was done with *E. coli* or fecal coliform indicator bacteria. They looked at antibiotic resistance before treatment, in effluent. They found that all of the bacteria that were not resistant at the beginning of the process were gone but what were left was the resistant bacteria. It would be another study to perform it on different bacteria.
- Jo Ann Muramoto: What species are resistant to treatment and are they very common in the environment? What happens to them in treatment and has it been looked at?
- Steve Rhode: I do not know specifically on the wastewater side, in terms of a monitoring program. *Clostridium* spores are an indicator of the effluent solids that accumulate in the

sediments. The rate at which they accumulate around the outfall shows that they are not widespread.

- Jo Ann Muramoto: My question was not so much about antibiotic resistant bacteria. Are they monitoring these?
- Dave Wu (MWRA): They are not being monitored. The secondary process is a very active process. We do not track those things in the secondary treatment.
- Steve Rhode: The secondary treatment does discourage that process.
- Barbara Warren: Maybe someone can answer my question. Of the 26 contaminants in the sediments, 22 are lower; there are four that are not. There are four that go into the sediment? What are those four?
- Unidentified speaker: The four that did not decrease remained the same, they did not get higher.
- Lealdon Langley: Do you know what the lowering is attributed to?
- Wendy Leo: The sediments in western Mass Bay were receiving contamination from Boston Harbor when we were discharging sludge and primary effluent, it accumulated in the sediment. By eliminating the effluent and with secondary treatment, the source is lower. It is closer but concentrations are much lower and it is accumulating cleaner sediment. It is being diluted at very different levels.
- Mark Smith: There have been some pretty strong storm events in the period. In terms of the historic source of contaminants for Boston Harbor and the reduction of contaminants there, is most likely the answer.
- Wendy Leo: The outfall is not a new discharge it was relocated.
- Andrea Patton: What I'm hearing is a lot of baseline questions about emerging contaminants. We need to know if they exist before we know about what the effects are. We do not know what we do not know. If you had a magic wand, what would you create for a monitoring program?
- Wendy Leo: There are studies but there's no monitoring. We need to figure out what we do not know. It would be important not to have something that says we are going to monitor a few things forever. Then we go to EPA and ask permission to change. It would make sense to be more flexible because we do not know.
- Juanita Urban-Rich: I think we need a survey: are microplastics released in the effluent? Are there endocrine disrupters potentially impacting the biota in that way? Is there PFAS in the effluent that will be discharged?
- Andreae Downes: What are the background levels? Is the effluent different from the background levels or is it the same? If were just looking at the outfall, we may be raising red flags that do not need to be raised.
- Barbara Warren: What is coming in to the plant?
- Steve Rhode: For many of these things, is wastewater source anywhere an issue? It is not clear to answer the question specifically. There are some studies that are starting to happen. That's the nature of ECs. Usually someone else comes along and we can ask where these things are, where are they coming from, and what can we do to reduce them? What is there and where is it coming from?
- Barbara Warren: I agree but nutrients come from everywhere.
- Steve Rhode: The problem with excessive nutrients in Mass Bay is well known. The permitting process is part of the process of setting limits for all these things. What is the

limit you would set for one of these things? Is it at a level that needs more attention? Where is it coming from?

- Robert Buchsbaum: What is MWRA's contribution compared to other sources? Not that we should control the MWRA but we need to control where most of this is coming from.
- Andreae Downes: So we would not just monitor MWRA, but theoretically every septic system and all the groundwater and everything and figure out how much exists?
- Mark Smith: I do not think you have to monitor everywhere, to get a handle on what the contribution might be from a particular source, in comparison to the overall impact. I think you can start getting some information to help to inform future decisions in relation to that. I do not think it would be that overwhelming of a task to do.
- Juanita Urban-Rich: If you find out the ambient levels, you can find out what comes out. If it comes out equal or more it is probably a source. Does MWRA need to be concerned with these contaminants? Not saying you can't do them all but you need to prioritize.
- Mark Smith: It would not be long-term monitoring it would be more short-term—a targeted study prioritizing what you want to be looking for. I do not think we can decide that here, I think it would be foolish to try. We can get a few experts together to look at the information that's out there. Look at what California is doing already, and then narrow down what we would want to study.
- Barbara Warren: It is not a regulating body that is going to tie you down and provide the information that has yet to come. Who pays for that?

List of Abbreviations:

AMO	Atlantic Multidecadal Oscillation
AUV	Autonomous underwater vehicle
BOD	Biological Oxygen Demand
CHV	Centrotubular hydropic vacuolation
CAS	Chemical abstract services
CEPT	Chemical enhanced primary treatment
CSO	Combined sewer overflow
CAD	Confined aquatic disposal
CEC	Contaminants of emerging concerns
CP	Contingency Plan
EC	Emerging contaminants
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
HAB	Harmful algal bloom
IAAC	Inter-Agency Advisory Committee
IEP	Interagency Ecological Program
MassDEP	Massachusetts Department of Environmental Protection
MIT	Massachusetts Institute of Technology
MWRA	Massachusetts Water Resources Authority
MDC	Metropolitan District Commission
MS4	Small Municipal Separate Storm Sewer System NPDES General Permit
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System (surface water discharge permitting)
NRC	National Research Council
NGO	Non-governmental Organization
NERACOOS	Northeastern Regional Association of Coastal and Ocean Observing Systems
OMSAP	Outfall Monitoring Science Advisory Panel
OMTF	Outfall Monitoring Task Force (OMSAP's precursor)
PFOS	Perfluorooctane sulfonic acid

PFOA	Perfluorooctanoic acid
PFAS	Per- and polyfluoroalkyl substances
PBDE	Polybrominated diphenyl ethers
PCB	Polychlorinated biphenyl
PIAC	Public Interest Advisory Committee
PPCP	Pharmaceutical and personal care products
POTW	Publicly owned treatment works
RMP	Regional monitoring program
ROV	Remotely operated vehicle
RMP	Regional monitoring program
SF Bay	San Francisco Bay
SFEI	San Francisco Estuary Institute
SCCWRP	Southern California Coastal Water Research Project
TMDL	Total maximum daily load
TSCA	Toxic Substance Control Act
USGS	U.S. Geological Survey
UMass	University of Massachusetts
WWTP	Wastewater Treatment Plant