Narragansett Bay Commission
2021 Data Report

Prepared by the Staff of the
Environmental Monitoring and
Technical Analysis & Compliance Sections

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Narragansett Bay Commission

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Introduction

The Narragansett Bay Commission

The NBC owns and operates the state's two largest wastewater treatment facilities (WWTFs) and provides quality wastewater collection and treatment services to about 390,000 persons and 7,700 commercial and industrial customers located in Providence, North Providence, Johnston, Pawtucket, Central Falls, Cumberland, Lincoln, the northern portion of East Providence, and small sections of Cranston and Smithfield.

The Narragansett Bay Commission (NBC) was created in 1980 by the Rhode Island General Assembly to reduce the amount of pollutants Providence's Field's Point WWTF was discharging into Narragansett Bay and its tributaries. At that time, nearly 65 million gallons of untreated sewage flowed into Rhode Island's waterways every day, resulting in temporary and permanent closures of shellfishing beds in upper Narragansett Bay, violations of federal laws, and most importantly, a serious threat to public health and the region's environmental and economic well-being.

The NBC acquired the facility from the City of Providence in 1982 and with statewide voter approval of an $87.7 million bond referendum, transformed this dilapidated facility, the third oldest WWTF in the nation, into a state-of-the-art award-winning facility. As the largest secondary WWTF in Rhode Island and the second largest in New England, the Field's Point WWTF provides preliminary and primary treatment for up to 200 million gallons per day (MGD) of wastewater, and advanced secondary treatment with nitrification and denitrification for up to 77 MGD. In 2020, the average daily flow to the facility was 40.4 MGD.

In 1992, the Rhode Island General Assembly expanded the NBC's mission by placing it in charge of the Bucklin Point WWTF in East Providence. In 1999, supervisory management of this plant was privatized to Professional Services Group (PSG) and was managed by Suez Environment/United Water. On July 1, 2015, NBC resumed full management and operations of the facility. Over the last twenty years, the Bucklin Point plant has undergone major upgrades to include new screening and grit facilities, wet weather facilities capable of providing primary treatment and disinfection, a new fine bubble-diffusion aeration system, nutrient removal facilities, and ultraviolet (UV) disinfection of wastewater, reducing the use of chemicals to disinfect and dechlorinate wastewater prior to discharge. The Bucklin Point facility is designed to provide preliminary and primary treatment for up to 116 MGD and advanced secondary treatment with nitrification and denitrification for up to 46 MGD. In 2020, the average daily flow to the facility was 18.4 MGD.

Environmental Monitoring Program Overview

The Environmental Monitoring and Data Analysis (EMDA) section evolved from the Pretreatment section, where prior to 1992, two Engineering technicians, assisted by Pretreatment staff, implemented the industrial and manhole monitoring activities. With the acquisition of the Bucklin Point WWTF in 1992, there were two separate and distinct Pretreatment programs, one

for each treatment facility. Shortly thereafter, the two Pretreatment programs were united and the EMDA section was created within the NBC Planning, Policy and Regulation Division, now known as the Environmental Science and Compliance (ESC) Division. Over the years, the EMDA section continued to evolve, and in 2019 a Division reorganization resulted in a name change to the Environmental Monitoring (EM) section. The EM section remains responsible not only for industrial and manhole monitoring activities, but for all aspects of environmental monitoring for the NBC, outlined further below. EM staff also conducts many special sampling initiatives to evaluate the effectiveness of new technologies and to better understand the potential impacts of the NBC operations on the receiving waters. To this end, the EM section works closely with the Technical Analysis and Compliance (TAC) section, formed during the same Division reorganization, which is responsible for developing special study procedures, reviewing existing protocols, and analyzing the monitoring data for trends.

In 2002, the NBC was awarded a grant from the United States Environmental Protection Agency (EPA) to develop a website to provide real-time data of the upper Narragansett Bay receiving waters of the NBC plant outfalls. A fixed-site continuous water quality monitoring station was constructed at an abandoned pier at Phillipsdale Landing in East Providence in the Seekonk River estuary, and a state-of-the-art monitoring buoy was acquired and deployed at Bullock Reach, just north of Conimicut Point in the Providence River estuary. In 2005, these sites became permanently funded by the NBC. These sites continue to provide invaluable data to the Rhode Island Department of Environmental Management (DEM) and the scientific community. For example, NBC's buoy data, which contains high-resolution measurements of Bay oxygen levels, played a key role in statewide efforts to document and understand the August 2003 fish

Environmental Monitoring Manager and Assistant Manager conduct a dye test at the Bucklin Point WWTF.

kills associated with hypoxic (low oxygen) events in Narragansett Bay. To maximize the utility of the NBC monitoring program to area stakeholders, the NBC frequently works with members of the DEM, several universities, and environmental groups, and is also a valuable contributing member of the Rhode Island Environmental Monitoring Collaborative, an organization formed by the Governor in 2004. The NBC coordinates monitoring activities with other agencies performing monitoring statewide. Therefore, as water quality compliance issues become more complex, the NBC EM and TAC sections' roles in environmental monitoring and compliance issues continues to expand.

The NBC EM, TAC, and Laboratory sections work together in the Water Quality Science Building (WQSB), built in 2016 and featuring state-of-the-art laboratory space to continue and expand NBC's numerous sampling and data analysis duties. The WQSB can accommodate almost all sampling, monitoring, and analysis needs of the NBC.

The EM section continued to perform the following monitoring activities throughout 2021:

- Daily sampling of NBC's two WWTFs to satisfy Rhode Island Pollutant Discharge Elimination System (RIPDES) requirements;
- Sampling of each Significant Industrial User twice annually to satisfy and exceed EPA Pretreatment Program mandates.
- Weekly monitoring of select surveillance manholes to satisfy EPA mandates;
- Weekly monitoring of select sanitary manholes to obtain data required for local limits development;
- Weekly sampling of 23 sites on urban rivers in NBC's service area for bacteria analysis;
- Sampling of 20 locations in the estuarine NBC receiving waters (i.e., the Providence and Seekonk Rivers) for bacteria analysis every two weeks;
- Sampling of 15 sites on rivers entering the upper Bay from Massachusetts and Rhode Island for nutrients once to twice per month;
- Sampling of 8 locations at the surface and bottom of the Providence and Seekonk Rivers for nutrients once to twice per month;
- Weekly mapping of the Providence and Seekonk Rivers for surface chlorophyll, dissolved oxygen (DO), temperature, and salinity;
- Sampling at Bullock Reach for qualitative and quantitative phytoplankton analysis;
- Video surveys along three permanent transects in the Providence River to track changes in benthic algae growth, species occurrences, and other indicators of environmental health several times per year;
- Special project sampling for the NBC Engineering, Operations, and other sections to assist in facilities planning, improvements to plant operations, etc.;
- Routine maintenance of the Fixed-Site Water Quality Monitoring buoy, land-based dock station, and special study stations to ensure accurate data for state partners and the public.

The NBC EM section has always done an excellent job of implementing monitoring initiatives. This annual report serves as a streamlined public dissemination of all 2021 EM monitoring data. Previous reports, back to 2007, are publicly available on the NBC website.

Acknowledgements

This report has been prepared by the staff of the EM and TAC sections, under the general direction of Thomas P. Uva, Director of Environmental Science and Compliance (ESC). This report is a summation of the collective efforts by the Environmental Monitors and Monitoring Field Supervisors that collected 29,030 samples during 2021. It represents the countless hours of processing, compiling, analyzing, and interpreting all the data by the EM Assistant Manager, LIMS Data Coordinator, and TAC Environmental Scientists, interns, as well as data entry and general assistance by clerical staff.

The NBC Laboratory staff analyzed all the samples collected by the EM section. In total, during 2021, the Laboratory generated 105,170 analyses from the samples it received. A special acknowledgement and thank you to the NBC EM, Laboratory, TAC, and other staff and interns that made this report possible:

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Field's Point and Bucklin Point WWTF Sample Collection Methodology

Introduction

It is the Narragansett Bay Commission's (NBC) mission to protect and enhance the water quality of Narragansett Bay and its tributaries through careful collection and treatment of wastewater from residences, businesses, and industries in the NBC District. The Environmental Monitoring (EM) section's primary objective is to perform routine and adequate sampling of a wide variety of parameters to ensure that both the Field's Point and Bucklin Point wastewater treatment facilities (WWTFs) are effectively meeting operational and Rhode Island Pollutant Discharge Elimination System (RIPDES) permit requirements. An extensive sampling schedule employing composite and grab samples within the two WWTFs at the raw influent, primary influent, primary effluent, mixed liquor, return activated sludge, final sludge, and final effluent are necessary to keep abreast of what is introduced to and discharged from each plant, and the removal efficiencies of all conventional and non-conventional pollutants. Synthesis of these data is a continuous and ongoing process with monthly evaluations required for RIPDES discharge monitoring reports as well as periodic evaluation of the local limits that the Pretreatment section uses to regulate industrial and commercial users and ensure that no upset, pollutant pass-through, process interference, or discharge permit limit violations occur. Clean sampling and sample-handling techniques, high quality laboratory measurements, and ease of access to data are necessary to quickly identify potential problems within the plants and to routinely reassess the removal efficiency of pollutants. All sample collection, preservation, storage, and analyses at the Field's Point and Bucklin Point WWTFs are performed with strict adherence to United States Environmental Protection Agency (EPA) protocols.

The NBC's continuing goal is to improve receiving water quality by limiting the impact of WWTF effluent on Narragansett Bay. The NBC has analyzed and tracked the toxic pollutant loading trends at its treatment facilities since the creation of the agency. EM works in conjunction with the Pretreatment, Laboratory, Operations, Engineering, and Technical Analysis and Compliance (TAC) sections of NBC to conduct sampling of wastewater from its sources, throughout its collection and treatment systems, and ultimately to its final fate as either sludge sent off-site for disposal or as effluent discharged to Narragansett Bay. In support of NBC's mission and RIDPES requirements, the EM section collected 26,938 samples and the NBC laboratory conducted 114,410 analyses during 2020. WWTF sampling data for 2020 are attached and can be found in Tables 1–44. Table numbers are referenced in each section below.

Collection of Samples at Field's Point and Bucklin Point

Samples collected to evaluate the WWTF processes are either composite samples collected over a particular time period or grab samples. Composite samples are formed by combining discrete samples taken at periodic points in time. Refrigerated ISCO autosamplers are used throughout Field's Point and Bucklin Point to collect composite samples on a regular predetermined basis. All refrigerated autosamplers are kept at 4°C. Grab samples are discrete samples collected at particular time periods but placed into separate sample bottles and analyzed individually. At

Field's Point, samples are assigned to a sample date based on the "flow-day," which is generally from 07:00 AM to 06:59 AM the following day, except as described in the following paragraph. Composite sampling therefore includes some sample water from the following calendar day. At Bucklin Point, the sampled date corresponds to the calendar day for regulatory reporting.

Environmental monitor records data at the Bucklin Point WWTF.

The differences in sampling between Field's Point and Bucklin Point mainly exist in the influent sampling at the interceptors into the facility and in the retention time used to determine when influent and effluent samples are collected. Field's Point influent samples are collected on a time-paced basis at the single interceptor that feeds the facility, after bar screening and prior to grit removal tanks. When influent samples are collected at Field's Point for metals, cyanide, or nutrient analysis, the commencement of effluent sample collection is delayed by 12 hours from the start time of influent sampling, with the goal of sampling the same parcel of water as it enters the plant for treatment and after treatment to evaluate the performance of the WWTF. This delay in sampling for the influent and effluent with allowance for hydraulic detention time is required for the metals and cyanide samples according to the RIPDES permits. For carbonaceous biochemical oxygen demand (CBOD) and total suspended solids (TSS), the influent and effluent samples are collected without any time offset, meaning the ISCO samplers that collect the wastewater for the influent sampling and effluent sampling are programmed to collect a 24-hour composite sample at the same times. Bucklin Point influent samples are collected on a time-paced basis from the two interceptors that feed the facility, the Blackstone Valley Interceptor (BVI) and the East Providence Interceptor (EPI). Composite samples are collected from both

interceptors and mixed flow-proportionally. Effluent samples are collected 17 hours after the start of the influent with the goal of sampling the same parcel of water to evaluate the performance of the plant. At both facilities, final effluent sample collections are time-paced and downstream of all treatment processes. The final effluent represents wastewater after complete treatment just prior to entering the receiving waters of the Providence River estuary or Seekonk River estuary. Collection of the final effluent sample at Field's Point takes place after chlorination and dechlorination of the wastewater, in the outfall channel downstream of the chlorine contact tank. The final effluent sample at Bucklin Point is collected downstream of the UV chamber in the UV building. The following sections provide more detailed descriptions of composite sampling at both WWTFs.

Composite Sampling at Field's Point

Composite sampling at Field's Point is conducted on a time-paced basis. All composite autosamplers sample the waste stream at 30-minute intervals and collect a volume of 100 mL. The samples are combined into 24-hour composites of the wastewater at the sampling location. EM uses refrigerated ISCO 3700, ISCO 4700, and ISCO 6712 programmable autosamplers throughout Field's Point. The samplers are located at the influent/grit building, primary influent, primary effluent, mixed liquor east and mixed liquor west, wet weather tank influent and effluent, and final effluent. Temperatures of the samplers are maintained at 4°C (acceptable range is 1-6°C) and temperature of each sampler is documented three times per day by EM staff.

Two types of suction tubing are used for composite sampling at the Field's Point WWTF. Influent and effluent peristaltic samplers collecting trace metals samples use suction tubes lined with Teflon®. Teflon® has characteristics that enable it to be cleaned to trace-metal grade. Extra care is required in handling this tubing to prevent cracking due to its brittle nature. Peristaltic samplers not collecting trace metals samples use Tygon® tubing as suction lines. This tubing is much more resilient and pliable. The Teflon® and Tygon® suction lines both measure ½-inch in outer diameter and ⅜-inch in inner diameter. Sampler suction lines are changed semi-annually, and pump tubing is changed every month. To improve cyanide data, starting August 2020, the suction line in the effluent cyanide sampler is replaced monthly. A dilute sodium hypochlorite solution is used to clean both the Teflon® and Tygon® suction line and pump tubing of the autosamplers monthly. This procedure takes place at the autosampler collection site. The Teflon® tubing is also acid-washed monthly.

The EPA released a report in 1994 assessing historically-used trace metals sampling procedures. The report found that the levels of contamination from the sampling/vessel cleaning process resulted in metals levels higher than the bodies of water being sampled. Following the report, the EPA developed a series of recommended techniques for clean sampling that EM follows specifically. These clean sampling methods are specifically used to reduce contamination in autosamplers located at the influent/grit building and final effluent that collect wastewater analyzed for trace metals and nutrients. The method requires acid cleaning of composite containers prior to use, and acid cleaning of suction and pump tubing. Blanks are collected to monitor and verify proper cleaning. A Nalgene® polyethylene carboy is used to collect composite samples for analyses of these parameters.

Composite Sampling at Bucklin Point

Composite sampling at Bucklin Point is time-paced. The autosamplers sample the waste stream at 30-minute intervals and take a volume of 100 mL. The samples are combined into 24-hour composites of the wastewater at a sampling location.

All autosamplers used at the Bucklin Point WWTF are refrigerated peristaltic pump samplers. Autosamplers used include the ISCO sampler models 3700, 4700, and 6712. These samplers are located at BVI, EPI, primary influent, primary effluent, mixed liquor, final effluent, and wet weather effluent. Influent composite samples from the BVI and EPI are combined flow-proportionally and analyzed together for all parameters. Temperatures of the refrigerated samplers are maintained at 4°C (the acceptable range is 1-6°C) and temperature of each sampler is documented three times per day by EM staff. Each composite carboy container has been marked with a permanent marker to identify the sampling location at which it is used.

Influent and effluent peristaltic samplers collecting samples for trace metals use special suction tubes lined with Teflon®. Teflon® has characteristics that enable it to be cleaned to trace-metal grade. Extra care is required in handling this tubing to prevent cracking due to its brittle nature. Peristaltic samplers not collecting trace metals samples use Tygon® tubing as suction lines. This tubing is much more resilient and pliable. The Teflon® and Tygon® suction lines both measure ½-inch in outer diameter and ⅜-inch in inner diameter. Sampler suction lines are changed semi-annually and pump tubing is changed every month. A dilute sodium hypochlorite solution is used to clean both the Teflon® and Tygon® suction line and pump tubing of the autosamplers monthly. This procedure takes place at the autosampler collection site. The Teflon® tubing is also acid washed monthly.

As mentioned above for Field's Point, Bucklin Point also uses the EPA-recommended clean sampling techniques for sample collection of wastewater for metals and nutrients analyses. The clean sampling method requires acid cleaning of composite containers prior to use and acid cleaning of suction and pump tubing. Blanks are collected to monitor and verify proper cleaning. A Nalgene® polyethylene carboy is used to collect composite samples for analyses of these parameters. Cleaning and handling of samplers, pump and suction tubing, and composite carboys are also outlined in the following sections under the specific parameters analyzed.

Sample Collection for Total Suspended Solids (TSS), Carbonaceous BOD (CBOD), and Bacteria Analyses at Field's Point and Bucklin Point

The NBC's RIPDES permits require sampling of TSS and CBOD daily using 24-hour composite samples at both the influent and effluent. As stated above, the influent and effluent samplers collect samples from the waste stream at 30-minute intervals. Carboys with collected sample water are brought to the NBC Laboratory for analysis every morning around 08:00 AM. The NBC Laboratory uses Standard Method 5210-B for CBOD analysis using a Skalar robotic BOD analyzer equipped with YSI dissolved oxygen (DO) probes. TSS analysis is conducted using Standard Method 2540-D-E. Parameters analyzed daily alongside TSS and CBOD include pH, settleable solids, and temperature. Analyses for these parameters adhere to Standard Method

4500-H+B, Standard Method 2540-F, and EPA Method 170.1, respectively. EM staff clean carboys used for TSS and CBOD sample collections in the dishwasher after each use, and carboys are replaced as necessary.

Bacteria sampling at each WWTF includes one effluent grab sample for fecal coliform analysis and two effluent grab samples for enterococci analysis per day. EM staff collect a fecal coliform and enterococci sample at 08:00 AM; operations staff also collect an enterococci sample in the time frame of 03:00-05:00 AM. The final enterococci value for that day is a geometric mean of the two grab samples as well as any duplicate samples or extra samples collected that day. Duplicate samples are collected and analyzed for fecal coliform and enterococci once per week.

The procedure for bacteria sampling at both WWTFs requires staff to wear new, clean nitrile gloves at all times during sample collection. Sterile sample bottles are placed in a sampling device (i.e., an open-ended polyvinyl chloride [PVC] cylinder with the bottle held in place by a small screw running through the cylinder body) and lowered six inches below the water surface in the center of the flow stream to collect the sample. At Field's Point, a pellet of sodium thiosulfate in the bottle neutralizes residual chlorine if present. The sodium thiosulfate tablet is not needed at Bucklin Point since disinfection is achieved via UV disinfection. Once filled, the bottle is sealed, labeled, and placed in a cooler with ice for immediate transport to the NBC Laboratory. The 03:00-05:00 AM sample is sealed, labeled, and placed in a sample refrigerator until the morning pickup by EM staff. At the Laboratory, samples are analyzed for fecal coliform using Standard Method 9221-E A-1, fecal coliform by multiple tube fermentation, and for enterococci using the IDEXX Enterolert Method 1600 with Quanti-Tray 2000 enumeration system. In December 2021, six bacteria samples from the effluent of each facility were split and analyzed for fecal coliform using the IDEXX Colilert-18 method in addition to Standard Method 9221-E A-1. Split sample results showed good agreement; results from both methods were combined into a single result for each sample prior to reporting.

Field's Point and Bucklin Point TSS and CBOD daily data and enterococci and fecal coliform daily geometric mean data for 2021 can be found in the attached Tables 1 and 2, respectively. Enterococci and fecal coliform individual sample results can be found in Table 3 (Field's Point) and Table 4 (Bucklin Point).

Sample Collection for Trace Metals and Cyanide Analyses at Field's Point and Bucklin Point

Toxic pollutant monitoring requirements include 24-hour composite sample collections for the analysis of aluminum, arsenic, cadmium, hexavalent chromium, copper, lead, nickel, zinc, and available cyanide at Field's Point and aluminum, cadmium, hexavalent chromium, copper, lead, nickel, zinc, and available cyanide at Bucklin Point. Metals and cyanide measurements are required twice weekly at both plants except for zinc at Field's Point and aluminum, cadmium, hexavalent chromium, and lead at each plant, which are required once per month. Other metals that are analyzed but are not required by the RIPDES permits include arsenic and tin at Bucklin Point, and chromium, iron, mercury, molybdenum, selenium, and silver at both plants. Total cyanide is analyzed using EPA Method 335.4, while available cyanide is analyzed via Standard Method 4500-CN-G on a Lachat Quikchem 8500 Series II Flow Injection Analyzer. Metals are

analyzed on an Inductively Coupled Plasma Mass Spectrometer (ICPMS), using EPA Method 200.8. Hexavalent chromium is analyzed on a Hach DR 3900 Spectrophotometer, using Hach Method 8023. Mercury is analyzed on a Cetac M-7600 Quicktrace Mercury Analyzer according to EPA Method 245.7. Metals and cyanide data for 2021 can be found in the attached Tables 5-8 (Field's Point) and 9-12 (Bucklin Point).

The current method for collection of cyanide at both Field's Point and Bucklin Point mandates nine grab samples to be collected over a 24-hour period, separated by a minimum of two hours. The autosamplers collect discrete samples for cyanide analysis into one-liter containers that are pre-preserved with sodium hydroxide. These samplers collect a 300-mL sample every two hours for 48 hours, once per week. At both WWTFs, nine of the twelve grab samples from each 24-hour sampling period are composited into a 2-liter high-density polyethylene (HDPE) bottle. At Bucklin Point, composite samples of nine separate grab samples for cyanide at the influent are collected from both interceptors, the BVI and EPI; samples from these interceptors are then mixed flow-proportionally. The pH is tested with indicator strips to ensure it is greater than 12 standard units (s.u.) before compositing. The composite is poured off into a 500-mL brown HDPE bottle. Composite samples are checked for sulfides and chlorine residual using lead acetate and potassium iodide indicator paper, respectively, as these chemicals can interfere with cyanide measurements.

For influent and final effluent autosamplers that collect wastewater analyzed for trace metals, a special clean sampling method is used to reduce contamination, as mentioned above. The method requires acid cleaning of composite containers prior to use, and acid cleaning of suction and pump tubing. Blanks are collected to monitor and verify proper cleaning. A 10- or 15-liter Nalgene® polyethylene carboy is used to collect composite samples. Carboy cleaning procedures and quality assurance measures are in place to ensure clean and proper sampling. Acid-washed carboys are put into place twice weekly at the influent and effluent to collect samples to be tested for trace metals, in conjunction with the samples collected for cyanide. Monthly post-cleaning blanks are collected from the acid-washed carboys to ensure the success of the cleaning procedure. These blanks are collected by adding deionized (DI) water to a cleaned carboy, swirling the DI water in the carboy, and letting it sit overnight refrigerated. The DI water is then poured off into pre-labeled, pre-cleaned containers for analysis of parameters of interest.

Field blanks are taken each time a sample is collected for mercury at both Field's Point and Bucklin Point. The procedure for collecting a field blank consists of transporting sufficient DI water into the field and collecting a sample of that DI water using sampling and preservation procedures identical to those used in collecting the mercury sample.

Sample Collection for Nutrient Analyses at Field's Point and Bucklin Point

Permit requirements for nutrients were modified by the DEM in 2005 to reduce the amount of nitrogen discharged to Narragansett Bay. The permit requirements mandated monitoring of nitrate, nitrite, and total Kjeldahl nitrogen (TKN) three times per week. Ammonia monitoring permit requirements remained at twice weekly, but NBC has sampled all nutrient parameters three times per week since August 1, 2005. Seasonal effluent discharge limits of 5.0 mg/L for total nitrogen (TN) were proposed in the 2005 RIPDES permit modification. In June 2006, a

consent agreement was signed, which imposed a seasonal interim effluent TN permit limit of 18.2 mg/L at Field's Point and 10.0 mg/L for Bucklin Point. In May 2009, the DEM modified the consent agreement for Bucklin Point to impose a seasonal interim effluent TN limit of 8.5 mg/L. The NBC worked diligently to maximize nitrogen removal at Bucklin Point and achieved significant reductions in nitrogen loading. However, the NBC determined that additional modifications were required to achieve compliance with the TN limit of 5.0 mg/L as set forth in the consent agreement. Major facility upgrades and renovations were necessary to implement biological nutrient removal (BNR) technology at each plant. Field's Point completed these upgrades in 2013, and the consent agreement effluent TN limit of 5.0 mg/L went into effect on May 1st, 2014; Bucklin Point completed upgrades and began operations under this limit on July 14th, 2014.

Nutrients are analyzed from 24-hour composite influent and effluent samples, collected three days per week. Sample collection carboys are dishwasher-cleaned, acid-washed, and DI water-rinsed before they are placed at their sampling locations. Equipment blanks are collected every other month using DI water from the acid-washed carboys and pump tubing to verify the absence of sample contamination.

All nutrient samples are analyzed by the NBC Laboratory using a Lachat Quikchem 8500 Series II Flow Injection Analyzer. The nutrients analyzed are TKN, TN, nitrite, nitrate, ammonia, and total phosphorus. Ammonia-nitrogen and organic-nitrogen comprise the TKN in a sample. TKN is analyzed using EPA Method 351.2, while TN, which includes both TKN and nitrate-nitrite, is determined via Standard Method 4500-NB. Nitrite+nitrate and nitrate are determined via EPA Method 353.2; nitrate is determined by difference from a combined nitrite+nitrate measurement and a nitrite measurement. Ammonia is analyzed using EPA Method 350.1. Total phosphorus is analyzed via EPA Method 365.4 and is the only nutrient parameter analyzed just once weekly. The NBC's Laboratory continues to update their techniques and equipment to ensure high-quality data; the nutrient autoanalyzers currently online and in use were acquired in 2017 and 2018.

Both the Bucklin Point and Field's Point facilities remained in compliance with the monthly average 5.0 mg/L TN permit limit throughout the 2021 May through October season. The seasonal effluent TN averages for Field's Point and Bucklin Point were 2.56 mg/L and 2.81 mg/L, respectively. WWTF nutrients data for 2021 can be found in Tables 13 and 14.

Sample Collection for Oil and Grease Analysis at Field's Point and Bucklin Point

The NBC RIPDES permits require effluent sampling for oil and grease once per month at each facility, via three grab samples collected over the course of a 24-hour period, with one grab sample collected per shift. The grab samples are analyzed separately and the maximum and average results are reported on the monthly Discharge Monitoring Report (DMR), though the RIPDES permit does not set a discharge limit. The NBC conducts similar sampling of the influent for oil and grease at each facility as well, though these data are not reported on the monthly DMR.

Oil and grease samples are collected using a pre-cleaned glass bottle, which is labeled with collection time and date, site, and the parameter to be analyzed. The cap is removed, taking care to avoid contamination, and the sampler is lowered just below the surface of the water at the effluent sampling location. The bottle is filled and then re-capped. Oil and grease grab samples are preserved with hydrochloric acid to a pH less than 2 s.u. by EM staff as soon as possible after collection. These samples are then brought to the NBC Laboratory for analysis of hexane-extractable materials using EPA Method 1664. Oil and grease average results for 2021 can be found in the attached Table 15.

Sample Collection for Effluent Dissolved Metals Analysis at Field's Point and Bucklin Point

The NBC has been studying effluent dissolved metals at both WWTFs since 2000. During 2021, monthly Field's Point and Bucklin Point effluent samples were collected and analyzed for dissolved metals. The NBC and DEM use these data to better understand the fate, effect, and physical partitioning of metals discharged from the WWTFs. Metals in the dissolved form are more readily absorbed by marine life than metals associated with particles, therefore, the EPA and DEM have established fresh and saltwater water quality criteria for dissolved metals

Environmental monitor collecting a sample at the Bucklin Point WWTF.

concentrations. However, WWTF effluent discharges are permitted for total metals only. Therefore, the DEM must use a "metal translator conversion factor" to set appropriate total metals limits for a WWTF, based upon the dissolved metals water quality criteria. By conducting monthly sampling for both total and dissolved metals, the NBC will be able to better assess the phase partitioning of metals in its effluent and in the receiving waters to inform the use of metal translators.

Effluent dissolved metals samples are split from the effluent total metals composite sample on one day per month, typically the first Tuesday of each month. The effluent total metals sample is a 24-hour composite sample taken after treatment of the wastewater is complete, just before the treated water is discharged to the Providence River estuary (Field's Point) or Seekonk River estuary (Bucklin Point). As part of a quality assurance plan, the NBC Laboratory analyzes laboratory equipment blank samples (DI water) along with the dissolved metals to ensure accurate results. Dissolved metals samples are filtered with a 0.45-µm pore diameter membrane filter prior to preservation and digestion and are analyzed according to EPA Method 200.8 via ICPMS. Effluent dissolved metals results for 2021 can be found in Tables 16 and 17 for Field's Point and Bucklin Point, respectively.

Collection of Final Effluent for Quarterly Bioassay Analyses

The two NBC WWTFs are required to conduct quarterly bioassay studies to determine whole effluent toxicity (WET) to test organisms. These bioassays use the response of organisms to effluent at varying dilutions to detect and measure the potential impact of substances, wastes, or environmental factors alone or in combination as they exist in the effluent. NBC met the quarterly bioassay sampling frequency requirements during 2021 for both facilities. Effluent samples are collected only in dry weather, defined as no rain for 48 hours prior to or during sampling. These samples are 195-mL composites of wastewater collected every 30 minutes over the course of 24 hours. The back-up automatic composite samplers are used for this sampling and are cleaned and maintained in the same way as those collecting samples for TSS or CBOD, with sample carboys cleaned in the dishwasher after each use and replaced yearly.

Two bioassay tests are performed as required by the NBC RIPDES permits. An acute toxicity test is conducted to examine survival of test organisms, the mysid shrimp *Americamysis bahia*, in varying concentrations of effluent. The second test is a chronic toxicity test which examines the effect of effluent on fertilization success in eggs of the sea urchin *Arbacia punctulata*. Both tests are conducted in five concentrations of effluent plus a control: 100% effluent, 50% effluent, 25% effluent, 12.5% effluent, and 6.25% effluent. Natural seawater is used for both the control treatment and dilutions of effluent.

Acute toxicity test results are summarized using the LC_{50} and the A-NOEC statistics. The LC_{50} (or lethal concentration, 50%) result is defined as the concentration of wastewater that causes mortality to 50% of the test organisms, *A. bahia*; the permit requirement of 100% or greater is defined as a sample which is composed of 100% effluent. A-NOEC or Acute-No Observable Effect Concentration is defined as the highest concentration of the effluent in which 90% or more of the test animals survive and is monitored though there is no permit requirement. The chronic test results for *A. punctulata* are summarized using the C-NOEC or Chronic-No

Observed Effect Concentration statistic. The permit limit for Bucklin Point is 50% or greater for this parameter while at Field's Point the permit requires only monitoring.

The WET tests are designed to supplement effluent monitoring to determine whether the combination of chemical species present in a WWTF's effluent is toxic to test organisms. The monitoring for individual pollutants is targeted towards ensuring that the concentrations of the individual pollutants are at levels which do not pose harm to estuarine organisms. The WET tests are an attempt to determine the synergistic impact of NBC effluent on organisms in the receiving waters. All bioassay analyses are performed by third party laboratories contracted by NBC and are conducted in accordance with protocols listed in the most recent edition of the EPA document: Cornelius I. Weber, et al., 1991, Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms. Bioassay data results for 2021 can be found in the attached Tables 18 and 19 for Field's Point and Bucklin Point, respectively.

Sample Collection for Sludge Analysis at Field's Point and Bucklin Point

Sludge from both the Field's Point and Bucklin Point WWTFs is removed and disposed of by Synagro Northeast under contract with the NBC. As part of this contract, the NBC conducts sampling and analysis of the sludge (i.e., filter cake) throughout the year. Sludge samples are collected daily for analysis by the NBC Laboratory. Grab samples are taken from each truck load and kept in whirl-pak bags labeled with the Bill of Lading number. At Field's Point, EM staff pour part of each sample into a snap-lid container for delivery to the laboratory by 08:00 AM the next day. These containers are disposed of after a single use. At the Bucklin Point WWTF, the whirl-pak bag is stored in the refrigerator until EM picks up the sample the next morning. EM staff mix the sample and pour off approximately 500 mL into a smaller container to bring to the laboratory for analysis. Sludge from each plant and scum from Field's Point are analyzed for total solids (TS) and volatile solids (VS), using Standard Method 2540-B. Sludge samples are also analyzed one to two times per month for metals and cyanide. Sludge samples for all metals are analyzed using EPA Method 200.7 via ICP-OES, except for mercury, which is analyzed by a contract laboratory using EPA Method 7471B (SW 846). Cyanide analysis is also completed by a contract laboratory, using Method SW9010C. Results from NBC WWTF sludge sampling described above for 2021 can be found in attached Tables 20-25.

In addition to the daily sample analysis by the NBC Laboratory, samples of filter cake from each WWTF are sent out to a contract laboratory quarterly for further analysis as required by Synagro Northeast. Quarterly analyses in 2021 and the laboratory methods used (in parentheses) included 11 metals, seven TCLP metals, and phosphorus (EPA 6010C); mercury (EPA 7471B); TCLP mercury (EPA 7470A); percent total solids (gravimetric); percent fixed solids and percent volatile solids (SM 2540-G); corrosivity/pH (SM 4500-H-B); paint filter/free liquids (EPA 9095B); and PCBs (EPA 8082A). Additional analyses required once annually included TCLP VOCs (EPA 8260C); TCLP Semi-VOCs (EPA 8270D-sim); TCLP pesticides (EPA 8081B); TCLP herbicides (EPA 8151A); flash point/ignitibility (EPA 1010A-Mod); reactive sulfide and reactive cyanide (SM REACTIVITY); and percent total sulfur (EPA 6010C). These annual analyses are typically conducted on the first quarterly sample of the year. Results of the quarterly and annual filter cake testing by the contract laboratory can be found in Table 26.

Sample Collection for EPA Priority Pollutants: Volatile Organic Compounds (VOCs)

Grab samples are collected monthly at the influent and effluent of each WWTF to be analyzed for 36 volatile organic compounds (VOCs), a subset of the EPA Priority Pollutants. A clean glass container is used to collect a grab sample. The sample is checked for the presence of chlorine using a potassium iodide test strip. Sodium thiosulfate is added to the samples as necessary to reduce the presence of chlorine. The sample is split into three sets of three Teflon-cap 40-mL vials. The first set of vials is left unpreserved, the second set is preserved to a pH range between 4 and 5 s.u., and the third set is preserved to a pH of <2 s.u. Hydrochloric acid is added dropwise to the preserved vials to attain the appropriate pH. All samples are kept airtight and stored at <6°C following collection. The glass vials can then be analyzed in-house or transported to a contract laboratory for analysis using EPA Methods 624.1 and 625.1 via gas chromatography and mass spectrometry. Field's Point and Bucklin Point VOC results for 2021 can be found in the attached Tables 27 and 28, respectively.

Sanitary Manhole Sampling

EPA and RIPDES permit regulations require the NBC Pretreatment Program to periodically reevaluate local discharge limitations. In order to complete this task, the NBC must monitor sanitary manholes to evaluate pollutant loadings from residential sources upstream of any industrial or commercial facilities. These background loadings are outside the realm of regulatory control by the NBC Pretreatment Program; however, NBC must understand these loadings in order to determine acceptable loading limits for industrial users to maintain effective pollutant removal at the treatment facilities. These samples reveal the composition of what is being introduced into the collection system in a more site-specific way than the influent composite samples. The NBC began sanitary sewer manhole sampling in 1993, and in 2000, EM began to collect samples using EPA-approved clean sampling techniques. As laboratory detection limits continue to decrease due to improved clean sampling techniques, these data become a more precise measure of the amount of uncontrolled toxic chemicals that enter the NBC collection system from residential, non-industrial sources.

To collect these samples, automated sampling devices are suspended in the sanitary manholes and are programmed to collect 100 mL of wastewater every fifteen minutes for 24 hours, starting in the early morning on a weekday. The aliquots collect into a 10-liter acid-washed Nalgene® bottle, and the composite sample is later poured off into specified containers for each analysis.

The initial pH of the composite sample is measured and recorded on a chain-of-custody document, and for those parameters that require preservation, the preservative used is marked and the final pH is recorded. After every use, the automated sampling device tubing and container are acid cleaned, rinsed with DI water, and a cleaning blank is produced.

In 2021, BOD, CBOD, TSS, cyanide, aluminum, cadmium, chromium, copper, lead, nickel, molybdenum, silver, zinc, mercury, arsenic, and selenium were measured in both Field's Point and Bucklin Point district sanitary manholes. These parameters were analyzed in accordance with methods for CBOD, TSS, cyanide, and metals mentioned in the Field's Point and Bucklin

Point sample collection sections above. Additionally, BOD was analyzed according to Standard Method 5210B using a Skalar robotic BOD analyzer equipped with YSI dissolved oxygen (DO) probes. Please note that sanitary manhole background monitoring for nutrients was discontinued as of November 2020.

Environmental monitors conduct sanitary manhole sampling.

In addition to informing the calculation of local limits that the NBC imposes on its industrial users, sanitary manhole data is essential for providing a point of comparison and screening of collection system data to determine problem areas within the collection system. Sanitary manhole testing results for 2021 can be found in Table 29.

Industrial and Commercial User Sampling

The EPA requires that all significant industrial users (SIUs) be sampled at least once every twelve months. The NBC has established a more stringent goal to sample each SIU twice per year and also samples a subset of other industrial and commercial users annually, utilizing the collection and preservation techniques specified in their Wastewater Discharge Permit. The NBC collected 174 sets of industrial and commercial user samples in 2021. Industrial and commercial user data for 2021 can be found in Tables 30A-C. Note that these data are not the sole basis for determining compliance of industrial and commercial users with NBC Pretreatment

requirements. Additional data, including user self-monitoring sample results, are utilized for this purpose though not included in this annual report. The NBC Pretreatment department publishes an annual report each year with all compliance data for all industrial users. This report is available via the NBC's website www.narrabay.com.

For SIU sampling, the automated sampling device tubing and container are acid cleaned, rinsed with DI water, and a cleaning blank is produced after every use. Trip blanks are collected with this type of sampling if the SIU requires metals analysis. The procedure for collecting a trip blank consists of filling a sample bottle with sufficient DI water, preserving with nitric acid and transporting it into the field.

Industrial manhole sampling is an additional means to track chemical spills or concentrated discharges, as well as to ensure that industrial users are in compliance with the limits set by the NBC. Industrial manhole sampling activities are designed to isolate a specific business within the collection system to surreptitiously determine the typical discharge from the business. Samples are taken upstream and downstream of a significant user's discharge point via manholes. The upstream sample serves to establish a background concentration with which to compare the results from the industry, as well as confirm that the source of any contaminants is from the permitted user, not additional sources. The distance between these two sampling locations is typically 150 feet, depending on the location of the nearest manhole. As with sanitary manhole sampling, autosamplers are programmed to collect samples from each manhole location every fifteen minutes for 24 hours, thereby providing a composited representation of the average discharge over that time period. Autosamplers can dispense the water collected into up to 24 sample bottles, thereby allowing for an intensive analysis of the variations within the upstream and downstream sample locations, if necessary. A Tygon® suction line with a stainless-steel strainer attached at the end is used to collect samples from the middle of the waste stream. Samples are checked for sulfides and chlorine residual using lead acetate and potassium iodide indicator paper, respectively, as these chemicals can interfere with cyanide measurements.

Cyanide sample pH is adjusted using sodium hydroxide to a pH above 12 s.u., while metals samples are acidified using trace metal grade nitric acid to a pH of less than 2 s.u. Samples are analyzed for cadmium, chromium, copper, lead, nickel, silver, zinc, and cyanide. All metals were analyzed by ICP-OES EPA Method 200.7 at the NBC Laboratory, while cyanide is analyzed using EPA Method 335.3 on a Lachat Quikchem 8500 Series II Flow Injection Analyzer.

Sampling of industrial manholes in 2021 resulted in 229 sets of data, with 2,053 individual parameter results generated for the two service districts. Industrial manhole sampling data for 2021 can be found in Table 31.

For industrial manhole sampling, the automated sampling device tubing and container are washed with non-phosphate detergent. Field blanks are also collected with manhole sampling. The procedure for collecting a field blank consists of transporting sufficient DI water into the field and collecting a sample of that DI water using sampling and preservation procedures identical to those used in collecting the manhole sample.

Sewer Line-Cleaning Sampling

The EM Department supports Interceptor Maintenance (IM) during its sewer line cleaning activities in industrial areas of concern – water is forced through a section of pipe and a pump is placed downstream to remove solids. It is expected that flushing of lines in industrial areas will resuspend contaminants that settle into low points in the pipes. Sampling of this type of activity includes an expanded list of parameters compared to routine industrial manhole sampling - metals, cyanide, TSS, oil and grease, and VOCs.

In 2021, EM collected a line-cleaning sample from one manhole. Line-cleaning sample data can be found in Table 32.

Septage Sampling

The NBC receives septage waste (waste pumped out of septic tanks) at the Lincoln Septage Receiving Station in Lincoln, RI. The Lincoln Station input point is within the Bucklin Point service district, approximately 11 miles from the Bucklin Point facility. The septage is routinely monitored by the EM section for toxic constituents to ensure that the material received does not contain toxics in concentrations that exceed NBC's Pretreatment Industrial Discharge Limitations for the Bucklin Point WWTF, to which the waste ultimately discharges. This sampling also helps NBC evaluate the percent of metals loading received from septage into the Bucklin Point WWTF. Grit removal at the septage facility removes a portion of the metals loading prior to its introduction to the sewer system and the treatment plant. Prior to septage samples being collected, IM staff sample and screen each septage truck's waste delivery. Septage samples are collected from each delivery truck after the sample port is flushed thoroughly, usually after the load has discharged for approximately one minute. The sample from each individual truck is screened for pH, odor, and other unusual characteristics. If any anomaly is observed, the sample is targeted for individual analysis; otherwise, it is composited with samples from each of the septage truck deliveries that day and sent to the NBC Laboratory for analysis.

Septage samples are collected daily Monday-Saturday. All six daily composite samples are kept refrigerated until they are picked up by EM staff on Mondays at the Lincoln Septage Station and are brought to the NBC Laboratory that same day, barring unforeseen circumstances. Three daily samples are chosen at random and analyzed by the NBC Laboratory for trace metals each week.

Revised septage sample collection techniques and equipment were introduced in June of 2004. The new equipment allowed for easier in-line sampling during septage delivery and has helped to more quickly locate potential toxic inputs to the collection system. These more representative sampling techniques may partially explain the observed increase in septage metal loadings since 2004.

During 2021, 158 septage samples were analyzed for trace metals via methodology described in the Field's Point and Bucklin Point WWTF sample collection sections above. Septage sample results for 2021 can be found in Tables 33 and 34.

Stormwater Sampling

Stormwater generated at the NBC WWTFs is regulated under the RIPDES Multi-Sector General Permit (MSGP). The MSGP was first issued in 2006 and re-issued in 2013; the 2013 MGSP expired on August 14th, 2018. A new MSGP went into effect on May 3rd, 2019. Sampling required by this permit started in January 2020.

The 2019 MSGP requires stormwater to be sampled at all stormwater monitoring locations at each NBC WWTFs. Sampling is conducted at eight locations at Field's Point and five locations at Bucklin Point. A sixth stormwater location at Bucklin Point (outfall 002-Y) has been sealed, will no longer discharge, and therefore is not sampled. Four storm events must be sampled each year, specifically, twice in every six-month period with at least one month between sampling events. The sampled storm events must not have been preceded by measurable rainfall within the prior 72 hours, and samples must be collected within the first 30 minutes (or as soon as practicable, with documentation) following the start of storm event discharge. Stormwater parameters required for analysis include fecal coliform, oil and grease, TSS, and TN (calculated as TKN plus nitrate-nitrite), analyzed as described for WWTF samples above.

In 2021, the NBC performed the required sampling of four storm events at each WWTF. TSS and oil and grease analyses are required as part of Benchmark Monitoring under the MSGP. 2020 results for these parameters remained below benchmark monitoring thresholds listed in the MSGP, therefore, the requirements for these parameters have been fulfilled for the permit period and further monitoring is not required until permit renewal. Fecal coliform and TN analysis is required as part of Impaired Waters Monitoring under the MSGP. TN concentrations measured were believed to be due solely to background sources and not from sources associated with NBC activities, therefore, this monitoring is also considered complete for the permit period. Fecal coliform monitoring continued in 2021. The results of NBC stormwater monitoring for 2021 can be found in Table 35.

NBC Receiving Waters Monitoring Activities

Introduction

The NBC not only monitors wastewater from the sources to the WWTFs (e.g., industries and manholes) and throughout the plant process, but also monitors the receiving waters, where treated effluent and combined sewer overflow (CSO) discharges enter. Receiving waters monitoring includes sampling the estuarine waters of the Seekonk and Providence Rivers as well as the urban freshwater rivers that enter upper Narragansett Bay from Rhode Island and Massachusetts. This monitoring is vital to determine the impact of NBC effluent on the river and Bay ecosystems. The data are useful in evaluating the success of the CSO Abatement Project and WWTF upgrades in improving the quality of receiving waters. The EM and TAC sections' roles in environmental monitoring and compliance issues also continue to expand as these issues become ever more complex.

In 20210, EM continued sampling for nutrients at several locations in the Providence and Seekonk River estuaries of upper Narragansett Bay and within the watershed at local river stations and at river stations on the Massachusetts/Rhode Island border. These measurements are aimed at effectively characterizing the magnitude, composition, and distribution of nutrient inputs to these rivers, and comparing these results to previous years to examine factors influencing nitrogen loading into the Bay. The characterization of nutrient loading dynamics is integral to understanding coastal nutrient pollution issues. Determination of background loadings, effluent discharge impacts, and fate of nutrients from the NBC facilities are necessary components of sound environmental policy. This monitoring initiative was undertaken to provide greater insight into nutrient cycling dynamics within the rivers, and to help quantitatively define the amount of nitrogen that the WWTFs can safely discharge without adversely impacting water quality.

In addition to nutrient sampling, the NBC conducts routine field sampling for bacteria in the local freshwater rivers and the estuarine waters of the Providence and Seekonk Rivers. Specifically, fecal coliform and enterococci are monitored as indicators of potential presence of pathogens (disease-causing organisms) in these waterbodies. Generally, if bacteria counts are elevated, there is a high potential for the presence of pathogens that could be harmful to both humans and wildlife. Raw, undiluted sewage contains high levels of both fecal coliform and enterococci bacteria because this type of bacteria is found in the feces of all warm-blooded animals, including humans. The wastewater treatment process at NBC's facilities eliminates almost all of these bacteria after the waste stream passes through primary and secondary treatment and, ultimately, disinfection via chlorination or UV light. Final effluent wastewater discharged from the Field's Point and Bucklin Point WWTFs typically has very low levels of fecal coliform and enterococci bacteria.

Both fecal coliform and enterococci data are utilized by state agencies to monitor water quality in the Bay and rivers. Measurements of enterococci bacteria, considered a more accurate metric for potential human health impacts from primary contact, were adopted to replace fecal coliform as the primary bacteriological indicator for both fresh and saline waters in 2006. Fecal coliform

criteria are only applied when enterococci data are not available. However, shellfishing standards continue to be based on fecal coliform bacteria levels. Collecting data for both groups of indicator bacteria also allows the NBC and others to evaluate whether there is a consistent relationship between enterococci and fecal coliform results in the receiving waters environment.

Bacteria monitoring is particularly important for evaluating the impacts of the NBC's combined sewer system. During large rain events, the two treatment facilities use special wet weather treatment tanks to treat and disinfect the higher volumes of combined rainwater and sewage influent. However, during intense rain events when the collection system is overwhelmed, the NBC's CSOs can send untreated stormwater and sewage that the collection system cannot contain directly into the freshwater rivers and upper Bay. The NBC river bacteria monitoring stations are strategically located upstream and downstream of CSOs to regularly evaluate their impact.

EM also conducts monitoring of particular CSO discharges during wet weather events. The NBC has embarked on an historic public works project to eliminate the negative impact that CSOs can have on water quality, with a three-phase CSO Abatement Project, of which Phase I began operation in the fall of 2008. The major achievement of Phase I was construction of a 3-mile long, 65-million-gallon storage tunnel that collects approximately 1 billion gallons of combined stormwater and sanitary sewage each year, which is then pumped to the Field's Point facility for full advanced-secondary treatment. Phase II systems, completed and online during 2015, included sewer separation projects, a screening and storage facility and constructed wetland, and additional connections to the Phase I tunnel. Phase III of the project

As part of monitoring the overall health of the Bay, the NBC monitors water quality and marine biota through several additional initiatives. The fixed-site monitoring initiative includes two water quality monitoring stations, one located at a dock at Phillipsdale Landing in the Seekonk River estuary and one on a buoy at Bullock Reach in the Providence River estuary. EM maintains these monitoring sites to continuously collect temperature, dissolved oxygen, salinity, pH, chlorophyll fluorescence, and turbidity data. In addition, vertical water quality profiles are collected approximately weekly (May - October) or every other week (November - April) at nine locations throughout the upper Bay. These profiles are collected by lowering sensors through the water column which record temperature, salinity, dissolved oxygen, density, chlorophyll fluorescence, and photosynthetically active radiation (PAR). To complement these data, water clarity is measured at each monitoring site via Secchi disk. While the research vessel is underway, an effort to conduct real-time surface water quality mapping occurs, as water is circulated through a sensor on the boat and analyzed for temperature, salinity, dissolved oxygen, pH, and chlorophyll fluorescence. Marine biota are monitored via monthly grab and plankton net samples for phytoplankton analysis and video surveys of the benthos several times per year.

Receiving waters monitoring activities are discussed in further detail in the sections that follow.

Please note, the NBC's research vessel, the R/V *Monitor*, was out of service from the end of August to early December. Therefore, limited bay bacteria and nutrient data may be available during this time period. Most data generated from the receiving waters monitoring initiatives are posted for public use on the NBC's website "Snapshot of Upper Narragansett Bay" (https://snapshot.narrabay.com/app/) or may be requested at any time.

An environmental monitor collects a bacteria sample from Narragansett Bay.

River and Bay Nutrient Monitoring

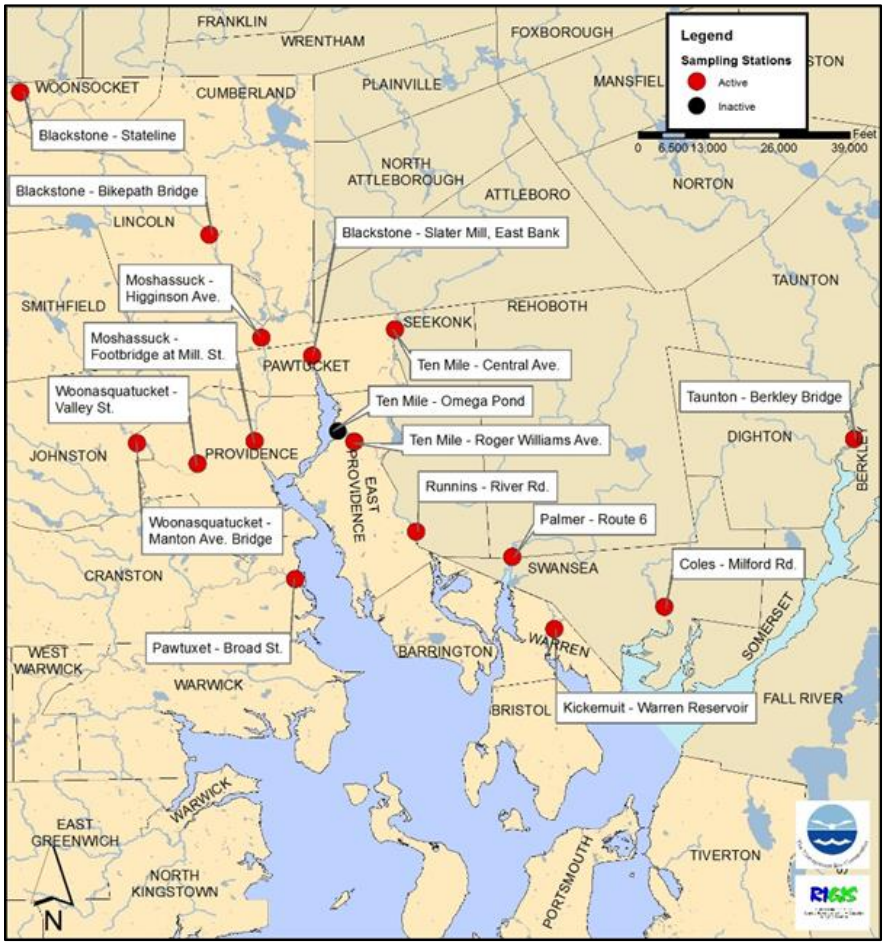
The NBC has been proactive in responding to environmental concerns regarding Narragansett Bay and the state of Rhode Island. As a part of a continuing effort to both address and understand the magnitude of the impacts that facility operations have on our receiving waters, an intensive sampling program of the urban rivers that are part of the Narragansett Bay watershed has been developed for nutrient analysis and loading determination. This sampling program was designed to encompass two components: an evaluation of the loadings from the urban rivers that empty into Narragansett Bay just upstream of tidal influence, and an evaluation of the nutrients entering Narragansett Bay via rivers from Massachusetts. Both components are important to accurately determine the nutrient inputs to Narragansett Bay and the impact of sources outside of the NBC service district. By determining the magnitude and relative importance of these nutrient loads, the NBC will be able to more accurately determine the impact of biological nutrient removal (BNR) systems at the wastewater plants as well as plan future upgrades at both facilities. These data will also contribute to developing a thorough understanding of nutrient fluxes to Narragansett Bay.

The NBC initiated nutrient monitoring of the local urban rivers in 2005 and expanded the sampling locations and increased the frequency of sampling in 2006. During these first two years of the program, sample splits were submitted to both the NBC Laboratory and the University of Rhode Island Graduate School of Oceanography Marine Ecosystems Research Laboratory (URI GSO MERL) facilities to assure data quality. An additional station was added on the Ten Mile

River in December 2011 to get a better representation of nutrient loadings from Massachusetts into this river. In November 2017, the Ten Mile River at Omega Pond site became inaccessible to NBC EM staff; a new Ten Mile River site at Roger Williams Ave. was initiated in August 2018 to take its place. During 2019, the Slater Mill, East Bank site was temporarily inaccessible due to dam repair work; alternate sites at Exchange St. and Main St. Bridge were sampled during this period. In 2021, there were fifteen sample stations monitored one to two times per month. The locations of river nutrient sampling stations can be found in Figure 1.

River nutrient samples are collected near the midpoint of the flow in the river channel, at a depth of approximately 0.5 to 1 meter below the surface, using a peristaltic pump, Tygon® tubing, and

Figure 1: NBC River Nutrient Sampling Stations



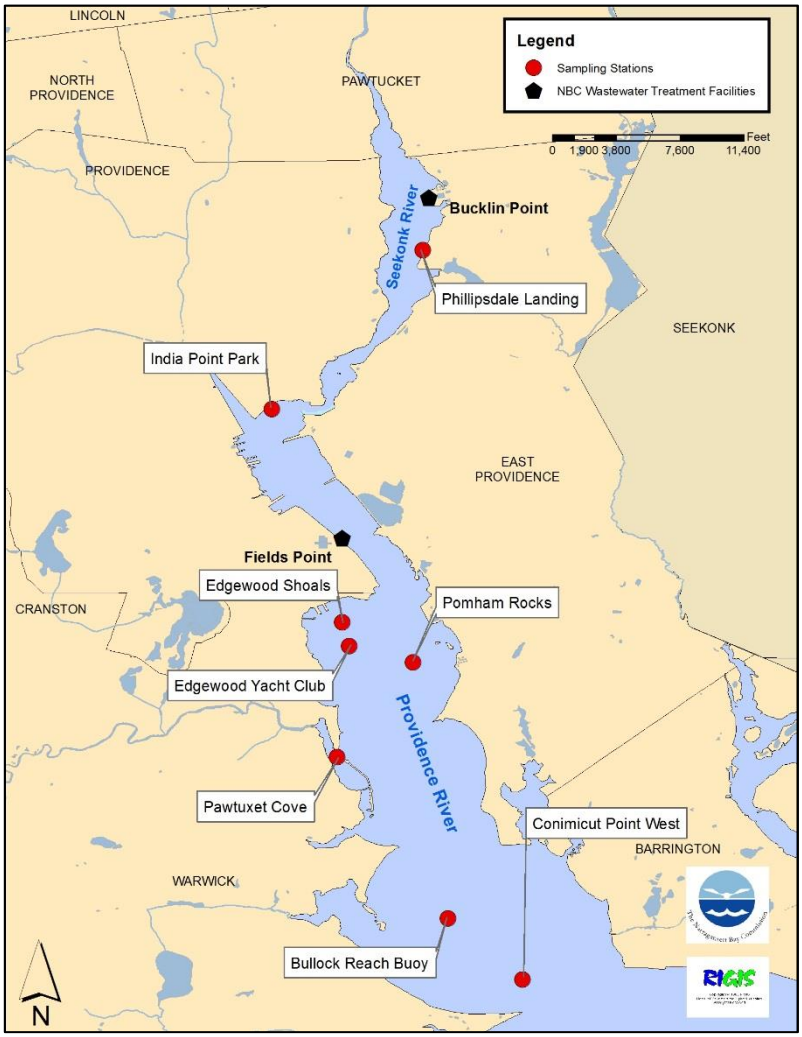
large plastic collection bottles. Samples for TSS are also collected as part of nutrients surveys. Prior to the sample day, all tubing, collection bottles, and sample containers are washed with non-phosphate detergent and acid-rinsed with 10% HCl, then rinsed with DI water. Most individual sample bottles are new and sterile at the start of this process, though ammonia bottles are washed and reused. During sampling, water is first pumped into the large (e.g., 2-liter) collection bottle, then split into individual sample bottles for each set of analyses (described below). All tubing is

rinsed with DI water between sample stations. At each station, tubing is also flushed with river water prior to sample collection. As part of EM's quality assurance efforts for this program, field blanks and duplicates are collected in order to determine the accuracy and precision of sampling methods and sample handling techniques. Field blanks are collected by each team during each nutrient sampling day to measure the ability of staff to maintain clean sampling techniques, and to rule out any potential contaminants from normal "open-air" exposure. These blanks are collected in the field using DI water in place of river water, with the same handling techniques as the actual river samples. Duplicate samples are collected by splitting the main large collection bottle of water into two sets of sample bottles for analysis. In addition to these sampling QA/QC measures, the NBC Laboratory has a rigorous analytical QA/QC program in place for all nutrient analyses.

The water in the large collection bottle is divided among smaller bottles for individual analyses while on site. Unfiltered samples are poured into bottles for TSS and TN analysis, while the remaining sample bottles (for total dissolved nitrogen, nitrate+nitrite, nitrite, orthophosphate, silicate, and ammonia) are filled after filtering the sample water through 0.45-µm filters; the results of analyses on these filtered samples therefore represent the dissolved (or soluble) concentrations only. The filter and each individual sample bottle are rinsed with sample water prior to filling, and filters are discarded after each sample or duplicate sample has been filtered. Once the sample bottles have all been filled, they are labeled with site ID, sample number, date and time of collection, and collector's initials. The samples are held in a portable cooler with ice packs for transfer to the NBC Laboratory. Sample bottles may be frozen for storage before analysis, except for ammonia and TSS samples, which remain refrigerated. If samples exceed the holding time, they are analyzed but data are flagged as non-reportable.

To measure any direct changes in nutrients in the upper Bay as a result of WWTF upgrades and the CSO Abatement Project, the NBC began sampling for nutrients in the Providence and Seekonk River estuaries during the summer of 2005. The direct water column nutrient measurements provide important insight regarding the amount of nutrients in the upper Bay from all sources, including river loading, surrounding WWTFs, atmospheric deposition, groundwater, runoff, failing septic systems, and nutrients from the middle and lower Bay area as well as from offshore. Original bay sampling stations in 2005 included five surface stations and one bottom station. These bay stations included Conimicut Point, Edgewood Yacht Club, Pomham Rocks, and India Point Park at the surface and Phillipsdale Landing at the surface and bottom (Figure 2). In July 2006, one additional bay station was added and NBC began collecting bottom samples periodically at all bay stations. The new bay station was located at the Bullock Reach Buoy, where the NBC fixed-site continuous water quality monitoring occurs. In August of 2012, a seventh site was added in Pawtuxet Cove, near the mouth of the Pawtuxet River, at the channel marker of Red Can #6. This site was added to observe the effects of the Pawtuxet River on upper Narragansett Bay. An eighth site was added in 2014, at Edgewood Shoals. As seen in Figure 2, the Conimicut Point, Bullock Reach Buoy, Pawtuxet Cove, Edgewood Shoals, Edgewood Yacht Club, and Pomham Rocks stations are located in the Providence River estuary. The Phillipsdale Landing station is located in the Seekonk River estuary at the fixed continuous water quality monitoring dock site, and the India Point Park station is located near the mouth of the Seekonk River estuary.

Figure 2: NBC Bay Nutrient Sampling Stations



Bay samples are collected, filtered, and preserved onboard the NBC research vessel, the R/V *Monitor*. All surface collections in bay waters are made at a depth of approximately 0.5 to 1 meter below the surface. Bottom collections are made approximately 0.5 to 1 meter above the sediment. Samples are collected using an acid-washed and DI water-rinsed Niskin sampler, with sample water then poured off into a large collection bottle. All tubing and bottles are acid-washed and then rinsed with DI water before the sampling day, and tubing is rinsed with DI water between sample stations. The Niskin sampler and bottles are rinsed with sample water at each site prior to sample collection. Duplicate samples and DI water field blanks are collected as described above, with duplicate samples being poured from the same Niskin sample in order to determine the accuracy and precision of sampling methods and sample handling techniques. As described for the river samples, the water in the large collection bottle is divided among smaller bottles for individual analyses while on site. A chlorophyll *a* and phaeophytin *a* sample (not collected at river sites) is filtered using a GF/F 0.7-µm, 47-mm diameter TCLP filter and is preserved with magnesium carbonate prior to storage in a dark cooler. Unfiltered samples are poured into bottles for TSS and TN analysis, while the remaining sample bottles (for total

dissolved nitrogen, nitrate+nitrite, nitrite, orthophosphate, silicate, and ammonia) are filled after filtering the sample water through 0.45-µm filters. The filter and each individual sample bottle are rinsed with sample water prior to filling, and filters are discarded after each sample or duplicate sample has been filtered. Ammonia samples collected from bay sites are preserved with a few drops of chloroform, then all samples are labeled with site ID, sample number, date and time of collection, and collector's initials. The samples are held in a portable cooler with ice packs for transfer to the NBC Laboratory. Sample bottles may be frozen for storage before analysis, except for ammonia and TSS samples, which remain refrigerated. If samples exceed the holding time, they are analyzed but data are flagged as non-reportable.

The NBC Laboratory analyzes both freshwater and saltwater sample sets for nitrite+nitrate, nitrite, total dissolved nitrogen, ammonia, orthophosphate, silicate, TN, TSS, and chlorophyll *a* and phaeophytin *a* (saltwater samples only). Total nitrogen, including both dissolved and particulate phases, has just been analyzed in these samples since 2012. Each of the NBC Laboratory's methods includes rigorous analytical QA/QC procedures to ensure data quality. For all samples, the Laboratory employs methods for brackish water analysis on a Lachat Quikchem 8500 Series II Flow Injection Analyzer. Orthophosphate is analyzed via EPA Method 365.5, ammonia is analyzed via EPA Method 349.0, nitrate-nitrite is analyzed via EPA Method 353.4, and total dissolved nitrogen is analyzed via Lachat Quikchem Method 31-107-04-3-A. The Laboratory analyzes for silicate using EPA Method 366.0. Total suspended solids are analyzed using Standard Method 2540-D. Chlorophyll *a* and phaeophytin *a* are analyzed using a Turner Designs Trilogy Laboratory Fluorometer in accordance with EPA Method 445.0. Lastly, water quality parameters, including pH, temperature, and salinity, are measured by EM at the time of sample collection using a YSI EXO1 sonde equipped with an EXO handheld (river nutrients) or a YSI EXO2 sonde that pumps water continuously (bay nutrients) during routine sampling. During the time the R/V Monitor was out of service reduced samples were collected with the help of Heather Stoffel and water quality parameters were collected using a YSI EXO1 and handheld. All data from 2021 River and Bay Nutrient sampling can be found in the attached Table 36. Additional chlorophyll *a* and phaeophytin *a* grab sample results collected in support of the fixed-site monitoring initiative are included in this table. These samples are collected, filtered, preserved, and analyzed according to the same methodology described above, and merged in this data table for simplicity.

Urban River Pathogen Monitoring

Consistent NBC monitoring for fecal coliform in the Providence area urban rivers began in 1997 and became the responsibility of EM in 1998. This monitoring was developed in conjunction with the CSO remediation stakeholder process and has served as a tool for the IM section to check for potential problems occurring at any of the 61 CSOs the NBC currently owns, operates, and maintains. Over the past decade, some CSOs have been eliminated as part of CSO abatement. Since 2007, samples have also been collected for enterococci analysis at a subset of stations. Routine sample collections for analysis of fecal coliform and enterococci are made each week, with stations on the Blackstone, Woonasquatucket, Moshassuck, Seekonk, Providence, and Pawtuxet Rivers sampled on Mondays and stations on the West, Woonasquatucket, Moshassuck, and Providence Rivers sampled on Tuesdays. In the event of a holiday or any unforeseen circumstance that would prevent sampling under the regular schedule, the sampling

routine will begin the next day sampling is possible. Samples are collected by EM staff in the morning and delivered to the laboratory at Field's Point no later than 11:30 AM that day. All stations sampled on the same river on the same day are collected within a two-hour period. NBC's IM, Construction, EM, TAC, and Engineering sections determine locations to be added or omitted as needed.

Samples are collected regularly from six sites on the Woonasquatucket River, four sites on the Blackstone River, seven sites on the Moshassuck River, three sites on the West River, and one site each on the Pawtuxet, Providence, and Seekonk Rivers. The locations of these sites are shown in Figure 3; special sampling events may include sampling at additional sites not shown. Due to site access issues, sampling was discontinued at the Seekonk River at Pitman St. location following January 20th, 2021. This location was replaced with the Seekonk River at River Dr. site in late January 2021. During 2021, a total of 1,768 river bacteria samples were collected; 1,768 analyses were conducted for fecal coliform and 728 analyses were conducted for enterococci.

In order to improve the NBC's identification of dry weather overflow (DWO) discharges and to identify other sources of bacterial contamination in the rivers, in 2002, EM began resampling weekly river collections when high bacteria counts are observed. Rivers are not resampled when collections have occurred following wet weather, because high bacteria counts are expected due to the normal functioning of CSOs. When results from collections exceed the threshold of 1,000 MPN/100 mL and there has been dry weather (i.e., less than 0.1 inches of rain in the preceding four days), EM will resample those stations a second time within the week. Resampling will also occur when results are very high (i.e., greater than 10,000 MPN/100 mL) when no rain has occurred in the preceding two days. These general resampling criteria are subject to change based on river flow, bacteria level at background stations, and staff availability. This year, following reports of three DWO events to receiving waters by Interceptor Maintenance, special DWO river and bay bacteria sampling was conducted on four dates (January 25th, March 3rd, March 4th, and August 3rd). In response to these events, 30 additional bacteria samples were collected, and 30 fecal coliform analyses and 6 enterococci analyses were conducted. Additionally, special sampling was conducted following DWO events that discharged to impervious surfaces within the Bucklin Point collection system on April 12th and April 20th; two bacteria samples were collected in total (one for each event) and analyzed for both fecal coliform and enterococci. Additional detail and results of special DWO bacteria sampling can be found in Table 37.

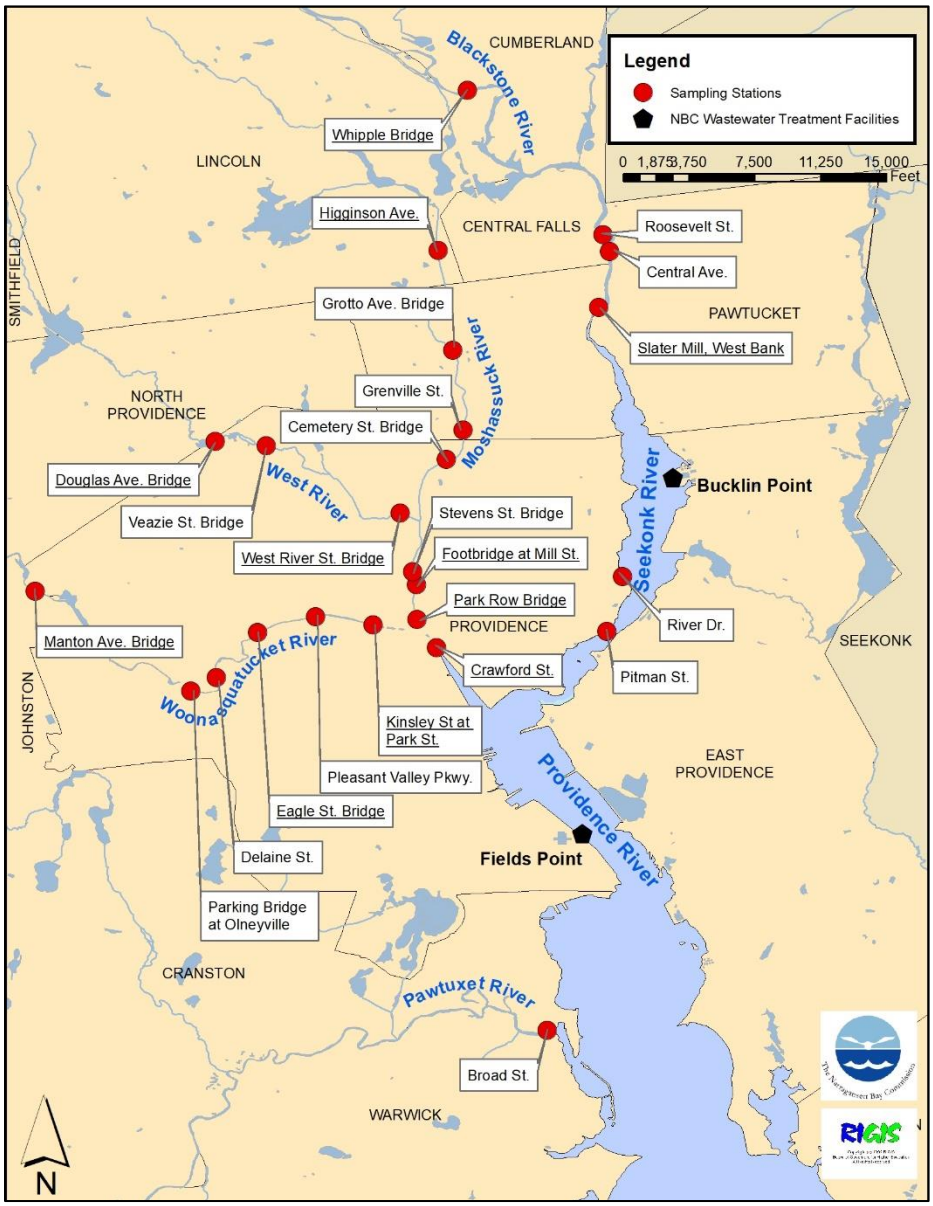
Water samples for fecal coliform and enterococci analysis are collected from the center of a bridge or from a riverbank. A sterile, 120-mL sample container is used for the sample collection. Collections from bridges are conducted by placing the sample container in an open-ended PVC cylinder with a small screw running through the cylinder body to hold the sample in place. A line is attached for lowering the sampler into the stream being sampled. There are two samplers – one for a 2-bottle configuration and another for a 4-bottle configuration. Samples collected from a riverbank are taken by dipping the sample container into the stream by gloved hand. The sample is taken from the surface as close to the center of the water flow as possible.

Once the sample has been collected, the sample container is sealed and labeled with site ID, sample number, date and time of collection, and collector's initials. The samples are held in a

portable cooler with ice packs for transfer to the NBC Laboratory. All samples are brought to the Laboratory for analysis to begin within the 8-hour holding time. If samples exceed the holding time, they are discarded and not analyzed. The analytical method used by the NBC Laboratory for fecal coliform analysis is the 24-hour Fecal Coliform Determination by Multiple Tube Fermentation, using A-1 broth or media. The Standard Methods reference number is 9221E for this EPA-approved methodology. Positive and negative controls are routinely run in the Laboratory; in addition, tubes of uninoculated, freshly prepared media are incubated and analyzed in order to confirm the sterility of the media. Enterococci analysis is performed using the IDEXX Enterolert Method 1600 with Quanti-Tray 2000 enumeration system. The NBC Laboratory is EPA and Rhode Island Department of Health certified.

As part of EM's quality assurance for this program, collection and analysis of DI water field blanks and duplicate samples occurs on all regular sampling days. These collections and analyses

Figure 3: NBC River Bacteria Sampling Stations. Underlined stations are sampled for both fecal coliform and enterococci. All other stations are sampled only for fecal coliform.



may be used to help determine analytical and sampling accuracy and precision. Field blanks are collected as described above for nutrients sampling. Duplicate samples are collected from specific sampling locations on each regular sampling day. These sampling locations are Eagle St. Bridge (W7C) in Providence on the Woonasquatucket River, Footbridge at Mill St. (M5) in Providence on the Moshassuck River, and Grenville St. (M4A) in Pawtucket on the Moshassuck River. The Eagle St. Bridge sampling is conducted from a bridge in the center of the main current flow. The Footbridge at Mill St. site sampling is conducted from the center of the main current flow from the private footbridge near Mill Street. Sampling at the Grenville St. site is

conducted from the road, using a telescoping pole device to reach the center of the main current flow. The duplicate samples are taken simultaneously with the sampling device, by securing two bottles into the device at the same time. Fecal coliform data for routine monitoring at the sampling stations located in the urban rivers can be found in the attached Table 38. Enterococci data for the urban rivers can be found in Table 39.

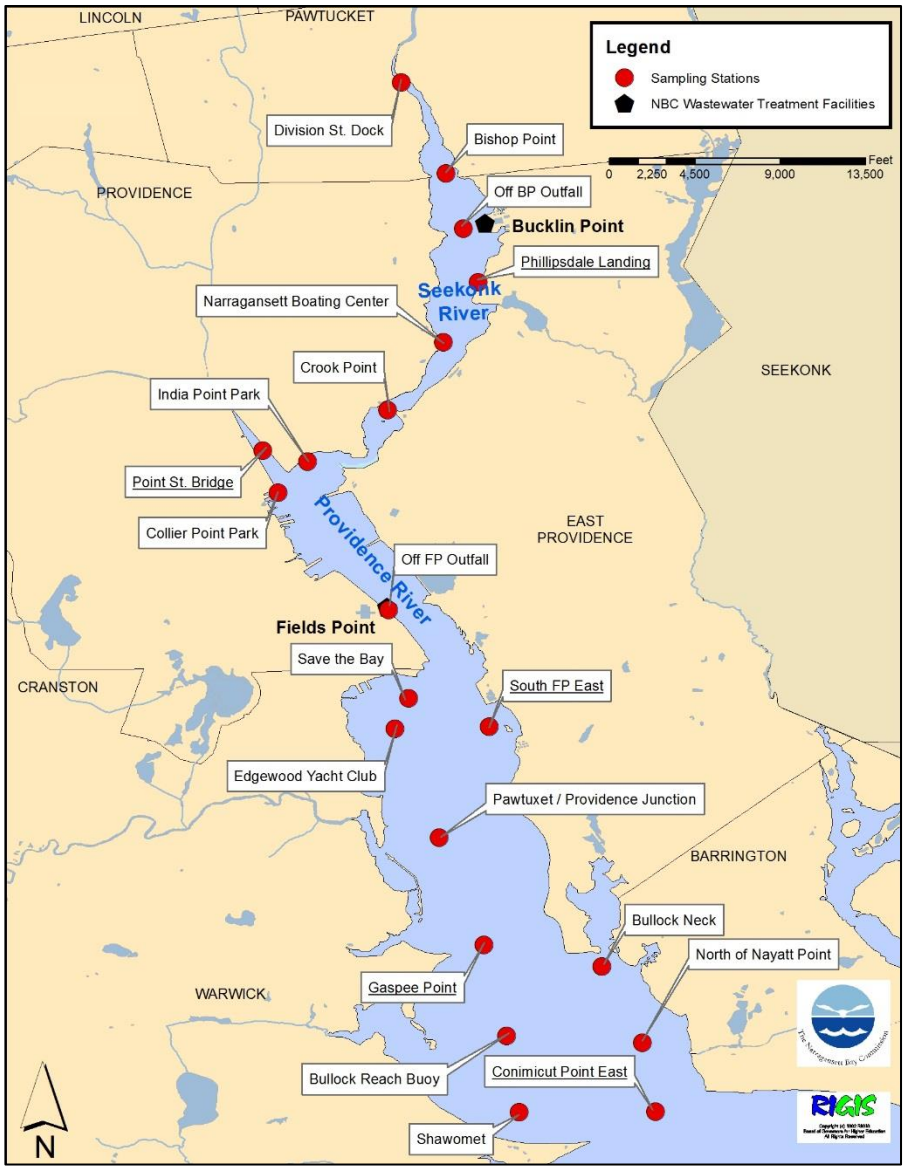
Bay Pathogen Monitoring

Fecal coliform sampling in the estuarine Providence and Seekonk Rivers began in 2003 in response to the need to understand the spatial and temporal impacts that discharges to these waterbodies have on Narragansett Bay; sampling for enterococci at a subset of bay sites began in 2006. Routine sample collections for the analysis of bacteria are conducted every other week, usually on Wednesdays or Thursdays throughout the year, dependent on weather. All station samples are collected within a three-hour period on the same day. In the event of a holiday or any other unforeseen circumstance that would prevent sampling under the regular schedule, the sampling will resume on the next possible regular workday. Samples are collected by EM staff and delivered to the NBC Laboratory no later than 12:00 PM on the day of sampling.

Bay bacteria samples are collected from the NBC research vessel the R/V *Monitor* at six sites in the Seekonk River estuary and fourteen sites in the Providence River estuary, as shown in Figure 4. Under special circumstances, including after some heavy rain storms, special sampling may take place, which includes collecting bay bacteria samples consecutively over several days in the Seekonk and/or Providence River estuary as well as in the conditional shellfishing areas just south of the Providence River estuary. Depending on the circumstances, the sample stations may include all or some of the usual stations and/or additional stations further down the bay.

Bay water samples for bacteria are collected by placing a sterile 120-mL sample container in an open-ended plastic cylinder. The sample container is held in place via a small screw running through the cylinder body. A metal handle extends from the top of the cylinder with a vinyl line attached for lowering it into the water being sampled. The sample is collected from just below the surface, then the sample container is sealed and a label with site ID, sample number, date and time of collection, and preservation method is placed on the container. The samples are held in a portable cooler with ice packs for transfer to the NBC Laboratory. All samples are brought to the Laboratory for analysis within the 8-hour holding time period. If samples exceed the holding time, they are discarded and not analyzed. Duplicate samples are taken at the Conimicut Point and Phillipsdale Landing stations. The duplicate samples for each site are collected simultaneously using a second 120-mL sample bottle. A blank sample using DI water is also collected in the field and brought to the Laboratory along with the bacteria samples for quality assurance purposes. Bay bacteria are analyzed according to methodology described in the above section on freshwater river bacteria analysis. During 2021, 368 routine bay bacteria samples were collected, and 368 fecal coliform analyses and 128 enterococci analyses were conducted. Three additional bacteria samples were collected on October 7th following a reported fish kill in Pawtuxet Cove on October 4th. Three fecal coliform analyses and three enterococci analyses were conducted from these samples.2021 bay fecal coliform and enterococci data are shown in the attached Tables 40 and 41, respectively.

Figure 4: NBC Bay Bacteria Sampling Stations. Underlined stations are sampled for both fecal coliform and enterococci. All other stations are sampled only for fecal coliform.



Combined Sewer Overflow Monitoring

In support of the NBC's mission to protect Narragansett Bay and its tributary rivers, and to fulfill the requirements of the EPA and DEM Nine Minimum Controls Program (which implements technology-based measures to reduce the impact of CSOs on receiving water quality), the EM section attempts to sample CSO wet weather overflows several times per year. The aim of such wet weather sampling is to characterize the water quality of CSO discharges and to evaluate the success of the NBC Pretreatment and Pollution Prevention programs at controlling the discharge of pollutants through CSOs. In addition to the Pretreatment and Pollution Prevention programs, the NBC CSO Abatement Project, once fully implemented, will further reduce CSO impacts by eliminating 98% of CSO discharges. Until both the CSO Abatement Project and the EPA's

Capacity, Management, Operations, and Maintenance program (an element of the Nine Minimum Controls Program) for the NBC are fully implemented, all other feasible controls of CSO discharge are expected to be utilized.

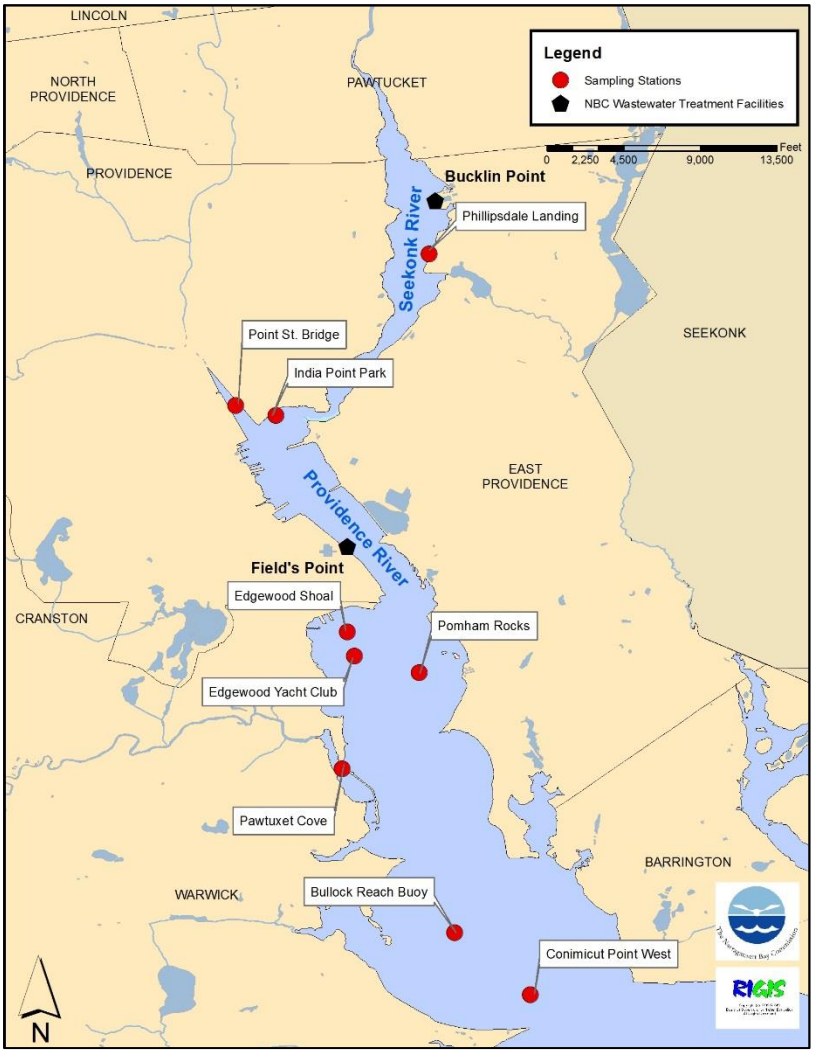
The NBC's CSO sampling plan was designed to collect three samples at each targeted outfall throughout the overflow event. The first sample is collected during the initial overflow, or first flush stage and is expected to contain wastewater with the least degree of rain water dilution and the highest concentrations of materials washed from street and land surfaces into the combined sewer system. A second sample is then taken during the stage of highest overflow rate and a third sample taken near the conclusion of the event. Successful CSO sampling requires prediction of when and where adequate discharges for sampling will occur, which is not always possible. Sampling of three CSOs was planned for 2021, including the Bucklin Point North Diversion Structure (NDS), however none of the planned sampling events were successful. Throughout the year, crews were sent out both during normal working hours and after-hours when storms were predicted, but necessary flows were not observed. Towards the end of the year, in a deviation from past sampling procedure, automatic samplers were installed at sites in an attempt to catch late-hour storms with crews on standby to deliver the samples. Again, these attempts were not successful. In 2022, the NBC plans to deploy automatic samplers routinely at secure CSO locations to improve the chances of successful CSO sampling.

Water Column Profile Monitoring

In 2006, the NBC began measuring water quality profiles at bay sites using a Seabird Electronics profiler (SBE 19 plus). In 2020, the NBC upgraded to a newer model SBE 19 plus V2. This instrument measures depth, temperature, salinity, dissolved oxygen, density, fluorescence, and photosynthetically active radiation (PAR) four times per second as it is lowered through the water column at each site, providing valuable information on how water quality varies with depth. In particular, the data are evaluated to identify areas of stratification, where the surface and bottom waters are poorly mixed. Such conditions are normal in estuaries, particularly near freshwater inputs and in the summer, when surface waters are warmed by the sun and winds tend to be low. Stratified conditions are monitored as they can contribute to hypoxia in estuarine waters by preventing dissolved oxygen mixing from the surface to the bottom waters. These profiles also provide valuable information on water clarity, through measurements of PAR, or the amount of sunlight, at depth. The PAR measurements on the profiler are coupled with data from a PAR sensor on deck, measuring ambient sunlight strength above water. Deployment of the profiler includes a "surface soak" of several minutes well below the surface to ensure the instrument temperature equilibrates to the ambient water temperature and all air has been purged from the flow path tubing. Following the surface soak, the profiler is brought up to the surface before dropping for the full downcast. The Seabird instrument is cleaned and maintained after each deployment by trained NBC monitoring staff and sent back to the manufacturer every two years for servicing.

All data downloaded off the profiler are analyzed using a set of steps recommended and provided by the manufacturer to align data based upon known sensor time response differences, filter out digital "noise," correct for thermal impacts on salinity data, and derive calculated parameters. Data are visually inspected by the NBC LIMS Data Coordinator to exclude the surface soak data before bin-averaging the downcast by 0.25 meter increments. This bin-averaging interpolates a smooth profile and produces a more manageable amount of data for public presentation on the Snapshot of Upper Narragansett Bay website, where the 2021 data and all historical data are available for download. In 2021, 150 water column profiles were collected. Stations where water column profiles are conducted are shown in Figure 5.

Figure 5: NBC Water Column Profile and Secchi Depth Monitoring Stations



Secchi Depth Monitoring

The NBC has been conducting Secchi depth water clarity monitoring at sites in the Providence and Seekonk Rivers consistently since 2009. This monitoring consists of lowering a black and white disk through the water column and noting the depth at which it is no longer visible, then lifting slowly and noting the depth at which it becomes visible. These steps are repeated three times per site and averaged. The measured depth varies depending on the turbidity of the water column, or the amount of suspended materials in the water. Suspended materials may include sediment (clay, silt, and sand), algae, and materials from anthropogenic sources including waste discharge and urban runoff. High turbidity reduces the amount of light available for photosynthesis by algae and submerged aquatic plants and can ultimately lead to decreased oxygen levels in the water. Suspended materials can also affect aquatic organisms by clogging fish gills, impacting egg and larval development, lowering growth rates, and reducing disease resistance. The NBC collects Secchi depth measurements weekly on the same days and at the same sites (Figure 5) as Bay Nutrients (Figure 2) monitoring and Bay Pathogen (Figure 4) monitoring boat trips. In 2021, the NBC collected 189 Secchi depth measurements in the Providence and Seekonk River estuaries. These data can be found in Table 42.

Benthic Video Monitoring

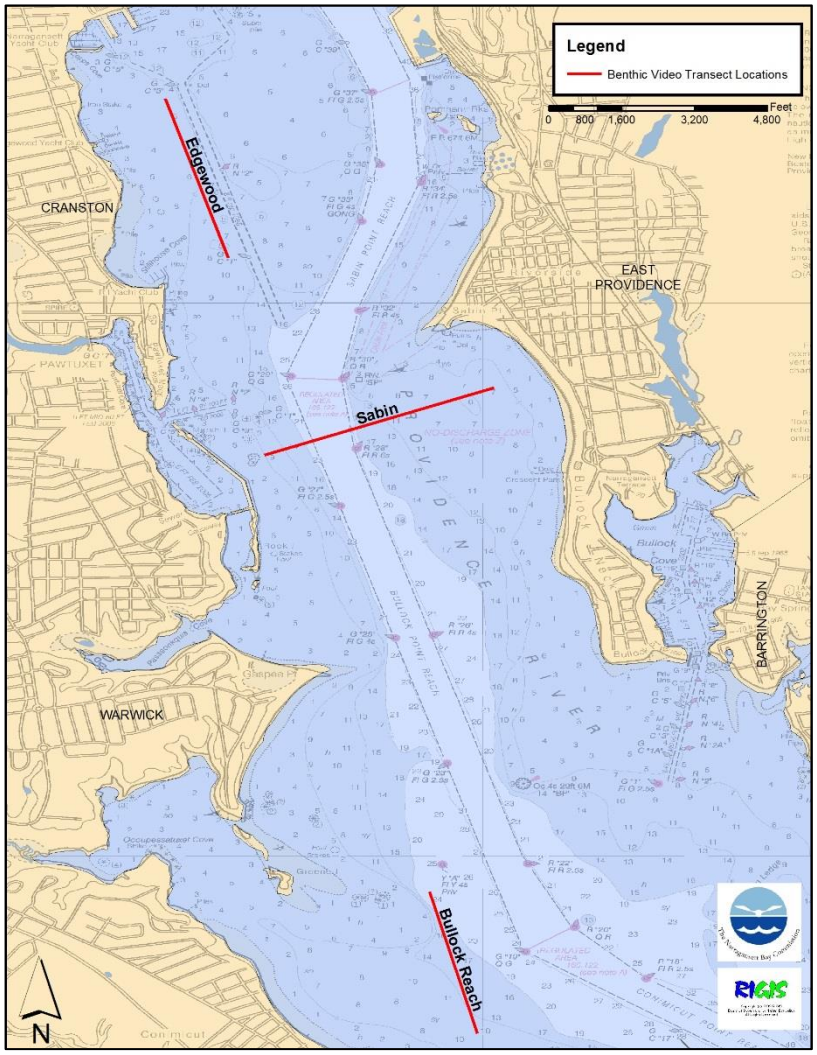
In 2011, the NBC purchased a SeaViewer Sea-Drop analog underwater video camera for the purposes of viewing and monitoring the benthic conditions in the Providence River in relation to plant upgrades and improved quality of WWTF effluent. A specialized sled mount was created to enable smooth towing of the camera and provide a consistent field of view for observations. In late 2014, the NBC designated three permanent transects to target in benthic surveys to be conducted monthly, weather permitting. The locations of these transects can be seen in Figure 6. In 2017, two underwater lasers were added to the sled to provide a measure of scale in the footage. Underwater lighting is also utilized as often as possible to help improve visibility.

In 2021, the NBC collected approximately six hours of underwater footage along these three transects, continually improving field methods and refining this monitoring initiative. An additional hour of underwater footage was collected on December 14th, 2021, to document bottom conditions and benthic organisms at three sites in consideration for an artificial reef project in the Providence River estuary. The videos reveal a diverse community of estuarine organisms living in the Providence River including fish, crustaceans (e.g., mantis shrimp, spider crabs, hermit crabs), horseshoe crabs, sea stars, tube-building worms, and mollusks (e.g., soft-shelled clams, mud snails, slipper snails). In addition, variable habitat types were documented, including mudflats, zones covered in shell hash and shell rubble, and areas of rafting macroalgae.

Video footage collected along these transects will increase the NBC's understanding of changes to the biological conditions in the upper Bay in relation to changes in effluent and related receiving waters monitoring. Summaries of each survey, with screenshots of interesting

observations, are made available to the public via the NBC's Snapshot of Upper Narragansett Bay website after analysis. Additional detail and video files are available upon request.

Figure 6: NBC Benthic Video Transect Locations



Phytoplankton Monitoring

The NBC began monitoring of the phytoplankton community at the Bullock Reach Buoy site in the Providence River estuary in 2012. Phytoplankton are microscopic plant-like organisms that form the base of the marine and estuarine food web. These organisms use nutrients in the water column and sunlight to photosynthesize, producing dissolved oxygen in the process. The NBC initiated this monitoring program to measure changes to this important community that may be related to the drastic nitrogen reductions made by the NBC and other WWTFs in the Narragansett Bay watershed. Monitoring is conducted every two weeks as weather and staffing allows and includes a whole water sample to measure the density of various phytoplankton groups as well as a concentrated sample collected using a plankton net to identify the diversity of

phytoplankton in the sample. From the whole-water sample, a single milliliter is extracted and all phytoplankton are identified and counted. From the concentrated sample, a subsample is examined under the microscope with each different group recorded. All identifications are made by the NBC's trained biologist. In 2021, the NBC collected fifteen sets of phytoplankton samples. Data from this sampling may be found on the NBC's Snapshot of Upper Narragansett Bay website, discussed below.

Narragansett Bay Fixed-Site Water Quality Monitoring

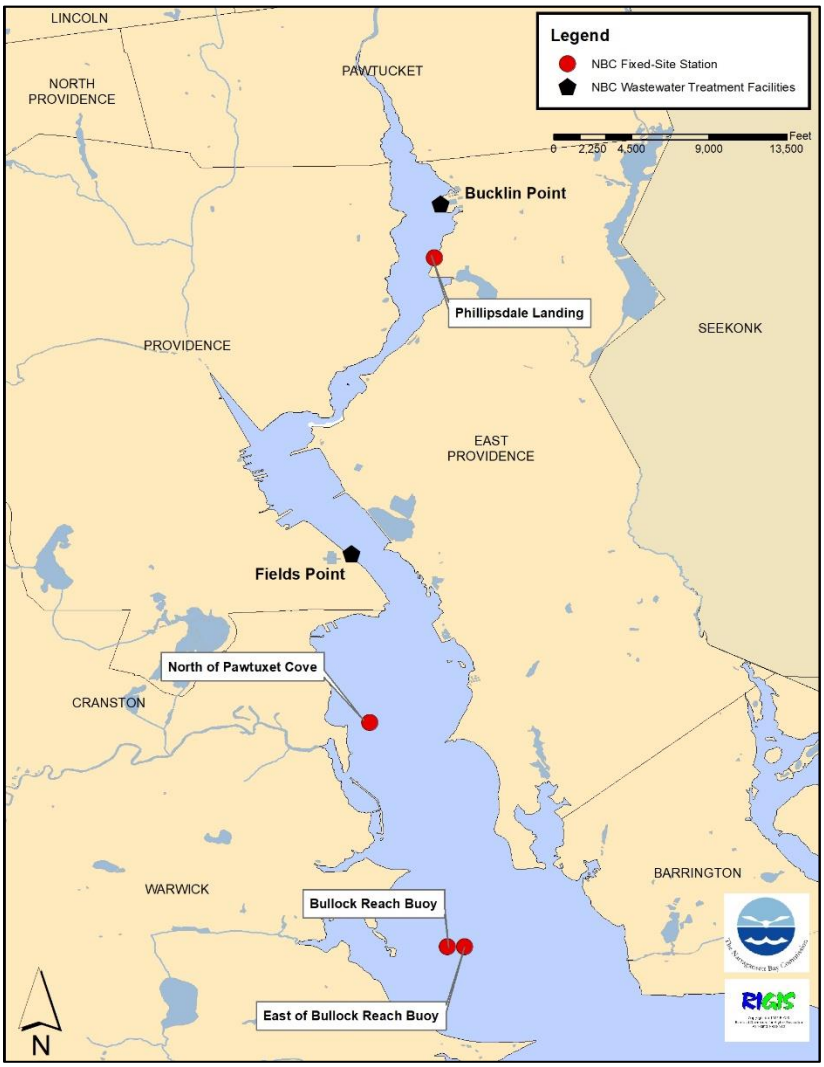
The NBC routinely maintains two estuarine fixed-site water quality monitoring stations, one in the Providence River estuary and one in the Seekonk River estuary. These stations were established in 2000 as part of a former EPA-grant-funded "Environmental Monitoring for Public Access and Community Tracking" (EMPACT) Project. The NBC has maintained full funding of these sites since federal grant funding ceased in 2002. The stations were established in proximity to the Field's Point and Bucklin Point WWTF outfalls. The Bullock Reach station is a floating buoy located between Gaspee Point and Conimicut Point in the Providence River estuary, and the Phillipsdale Landing station is affixed to a dock located in the Seekonk River estuary in East Providence. In 2021, a temporary buoy was deployed east of the Bullock Reach Buoy from May 2021 through July 2021 and then north of Pawtuxet Cove from August 2021 through November 2021. The sites were selected by Dr. Chris Kincaid of URI-GSO to support data collection for the URI and NBC collaborative Regional Ocean Modeling System (ROMS) project, which models circulation and nutrient transport to predict algal bloom dynamics and oxygen levels in the Bay. The site located east of the Bullock Reach buoy was selected to look at lateral shifting between channel and shoal water, while the site located north of Pawtuxet Cove was selected to examine how the Pawtuxet River plume travels into the Edgewood Shoal gyre. The locations of these fixed sites are shown in Figure 7. These monitoring stations directly benefit Narragansett Bay research by collecting continuous, real-time water quality monitoring data in the more urbanized portions of the upper Bay, enabling Bay researchers to consistently track changes in the estuaries from remote locations. These data also provide a baseline of water quality data across seasons and reveal yearly trends. The two routine locations are part of the Narragansett Bay Fixed-Site Monitoring Network (Fixed-Site Network) of water quality instruments deployed throughout the Bay and maintained by multiple agencies.
The NBC historically used 6600-series YSI water quality sondes to collect measurements of depth, temperature, salinity, pH, dissolved oxygen, turbidity, and fluorescence (a proxy for chlorophyll and phytoplankton activity) at each fixed site since the project began. In 2018, the sondes at Bullock Reach were upgraded from the 6600-series equipment to the newest YSI EXO technology; Phillipsdale Landing sondes were upgraded to YSI EXO technology in 2019. The 2021 temporary fixed site also utilized YSI EXO equipment.

YSI sondes (EXO and 6600-series) are typically calibrated the day before deployment for each site at the EM Laboratory in the Water Quality Sciences Building (WQSB) at Field's Point. All sondes are calibrated using YSI-recommended methods in the YSI Operations Manual as well as agreed-upon protocols from the Fixed-Site Network. All calibrations use YSI standards and are conducted by trained EM staff. Sondes are designated for each specific site, deployed, and then retrieved after approximately two weeks in the water. Upon return to the EM lab, sondes undergo post-deployment checks, which consist of placing the sonde probes in each calibration

solution, as done during calibration, to check readings in that solution of known concentration. These data can be used in assessing how closely the sonde is reading to the actual solution levels, and therefore how far it has drifted from the original calibration or if there has been a probe failure. After the post-deployment check, sondes are cleaned and stored, then re-calibrated just before the next deployment period. Calibration and post-deployment check results are recorded and kept for reference and data editing purposes.

Once at the deployment site, the first readings of the newly deployed sondes are observed for any suspect readings by comparing to the last readings of the retrieved sondes and a hand-held sonde suspended at the same depth. If any problems are observed in the data, an attempt is made to troubleshoot and replace the sonde if necessary. Summer deployments are kept to a maximum of two weeks in the water due to fouling concerns. All field work information is recorded on a field sheet to aid in troubleshooting during data editing. During sonde deployments and retrievals, grab samples are collected from all sonde depths to be analyzed for chlorophyll *a* and phaeophytin *a*. Methods for sample collection, filtration, preservation, and analysis are as described above for the nutrients monitoring initiative. These samples are collected to facilitate potential post-calibration of sonde chlorophyll readings to the concentrations measured in the grab samples, to give researchers a more accurate picture of phytoplankton dynamics in these waters.

Figure 7: NBC Fixed-Site Station Locations



Data measurements by the water quality instruments are recorded every 15 minutes and transmitted via cellular communications from Bullock Reach Buoy and via LAN-line connection from Phillipsdale Landing to a base station at Field's Point every hour. Data at the temporary sites were also collected every 15 minutes, though they were not transmitted, rather, they remained saved to the instruments until download at the EM Laboratory upon retrieval.

The EM and TAC staff are continually making improvements to equipment, infrastructure, and QA/QC protocols to ensure the reliability of data collected. As part of the Fixed-Site Network, EM and TAC currently work in partnership with DEM's Office of Water Resources, URI, the Narragansett Bay National Estuarine Research Reserve (NBNERR), the Massachusetts Department of Environmental Protection (MA DEP), the Narragansett Bay Estuary Program (NBEP), the Southeast New England Program (SNEP), and the Northeast Regional Association of Coastal Ocean Observing Systems (NERACOOS) under a Quality Assurance Project Plan (QAPP) that sets standard operating procedures for calibration and maintenance of the sondes as well as data handling to maintain consistency between organizations. The DEM maintains a website which allows easy access to data from each of the fixed sites in one central location

(http://www.dem.ri.gov/programs/emergencyresponse/bart/stations.php). The DEM Bay Awareness and Response Team (BART) website currently displays a map showing station locations, weekly summaries of data from all network sites, and historical Fixed-Site Network data in raw, edited, and corrected formats (note data from recent years are not always available if review is still underway). In addition to the DEM BART website, the NBC also shares the data from Bullock Reach Buoy and Phillipsdale Landing on its Snapshot of Upper Narragansett Bay website. Raw data are available on the Snapshot of Upper Narragansett Bay website in near real-time in an easy-to-use and easy-to-understand format, including downloadable data tables. The raw and edited data are also packaged and sent to the Fixed-Site Network Quality Control Officer annually, following an internal NBC data review. Fixed-site data are not included in this Environmental Monitoring Data Annual Report due to the extensive nature of this sampling, but they are easily accessible via the websites named above. Chlorophyll *a* and phaeophytin *a* grab sample data collected in association with the fixed-sites are included in Table 36 with chlorophyll *a* and phaeophytin *a* data collected as part of the nutrients monitoring initiative.

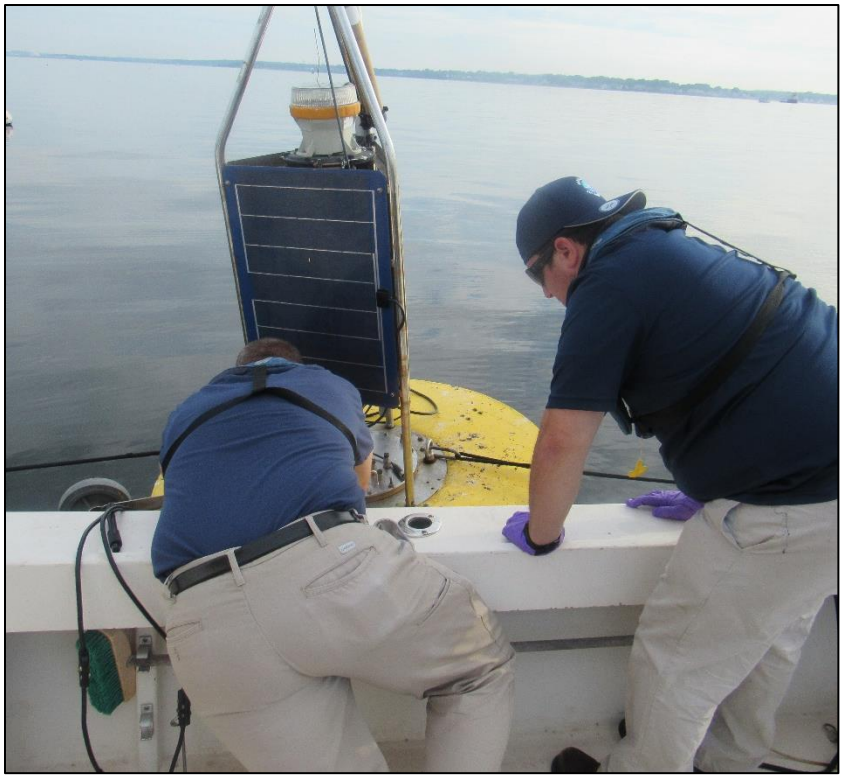
As WWTFs reduce nitrogen inputs to the Bay, monitoring water quality can help researchers better understand ecological responses to these reductions. For instance, nitrogen is often associated with eutrophication and hypoxia. Hypoxia is the condition where dissolved oxygen concentrations fall below a critical level, negatively affecting marine or aquatic organisms. As part of the Fixed-Site Network, the NBC supports the understanding of the overall health of NBC's receiving waters and contributes to monitoring the response of these waters to nitrogen reductions from WWTFs. The water quality instruments (sondes) that NBC and the other agencies use at these fixed sites continuously monitor dissolved oxygen via optical sensors. With the NBC receiving the data in real-time from its two fixed sites, NBC staff can immediately determine when hypoxia is occurring and for how long. These data are extremely helpful for the NBC, DEM, and other organizations in studying the dynamics of these events and how the organisms in the Bay respond.

Phillipsdale Landing Dock Site

The Phillipsdale Landing fixed-site is located on the east side of the estuarine Seekonk River in East Providence. The monitoring location is very close to large freshwater river sources and is also open to the tidal estuarine Providence River. This makes the Seekonk River a tidal estuary, defined as a place of fresh and saltwater mixing, in the truest sense. The freshwater rivers feeding the Seekonk River estuary include the Blackstone River at the northern terminus and the Ten Mile River, which enters the Seekonk River estuary just south of the Phillipsdale Landing station. The Phillipsdale Landing site is located in about 3.5 meters (11.5 feet) of water, just south of the Bucklin Point WWTF. YSI EXO2 sondes collect water quality data from two depths – near the surface at approximately 0.6 m and just off the bottom at approximately 2 m. With these instruments attached to a dock, staff have easy access to the instruments from shore, allowing them to get to the instruments quickly in the event of any problems. The sondes measure depth, water temperature, specific conductance (and salinity), pH, dissolved oxygen, phycoerythrin, and chlorophyll. For the 2021 season, the sondes were first deployed on March 3rd, 2021 and continued collecting data through the end of the year.

Bullock Reach Buoy Site

The Bullock Reach Buoy site utilizes a floating buoy that is anchored near the edge of the shipping channel in the southern section of the Providence River estuary. This location is in deeper, more saline waters than the Phillipsdale Landing station and is farther from freshwater sources. The nearest major freshwater source is the Pawtuxet River, located to the northwest of the buoy site. The position of the buoy is north of Conimicut Point in about 8 meters (26 feet) of water, west of the Providence River shipping channel and south of the Field's Point WWTF. There are three water quality instruments at this site, deployed at the surface (approximately 1 m depth), mid-water (approximately 4 m depth), and bottom (approximately 8 m depth). The surface YSI EXO2 sonde is deployed in a PVC tube that is integrated into the buoy. The bottom and mid-depth YSI EXO2 sondes are attached to the buoy on one line with a mushroom anchor at the bottom and a float just above each sonde to keep them in an upright position. Each of the three sondes measure depth, water temperature, specific conductance (and derived salinity), pH, dissolved oxygen, chlorophyll, phycoerythrin, turbidity, and total dissolved solids. The buoy is also outfitted with meteorological instrumentation, and collects data on wind speed and direction, temperature, and humidity. Power to the buoy is maintained by a solar-powered battery. For the 2021 season, the buoy was deployed in late-May; data collection began on June 2nd, 2021 until the sondes were removed for the season on November 18th, 2021.



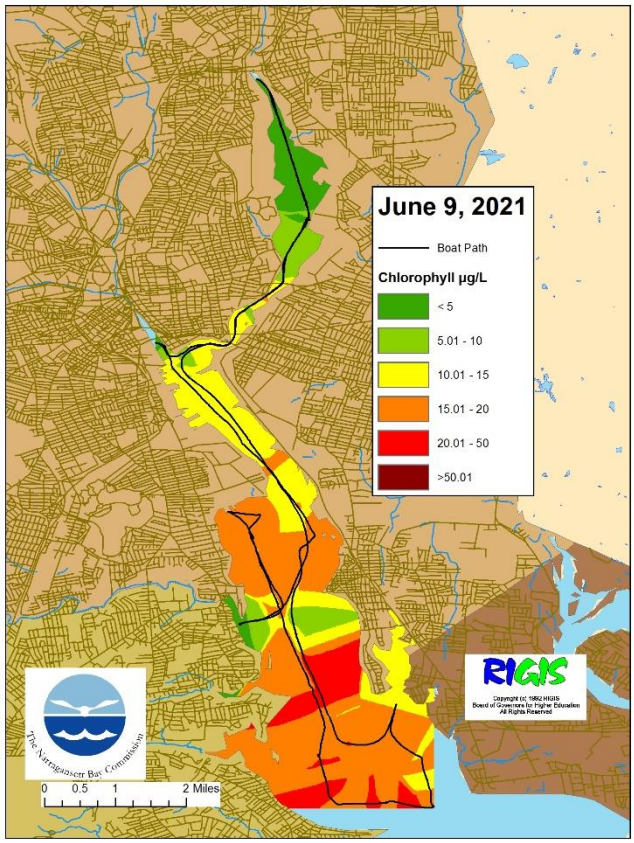
Environmental Monitoring staff service the Bullock Reach Buoy fixed-site. station.

2021 Temporary Sites

A temporary water quality monitoring initiative was active during 2021 in order to provide further site-specific data to inform the URI and NBC ROMS project. The temporary sonde was deployed East of Bullock Reach Buoy on May 4th, 2021; this temporary sonde was moved to North of Pawtuxet Cove on August 12th, 2021. The sonde was removed for the season on November 17th, 2021. This temporary monitoring initiative consisted of a single YSI EXO2 sonde that internally logged data every 15 minutes. This sonde was changed out for maintenance every two weeks, at which time the logged data were downloaded at the EM Laboratory. The surface sonde was located at an approximate depth of 0.5 m and the parameters measured included water temperature, specific conductance, salinity, depth, pH, chlorophyll fluorescence, and dissolved oxygen. Data from the temporary water quality monitoring locations are available upon request.

Bay Surface Mapping

In 2010, the NBC began a receiving waters monitoring effort to map surface water quality as the research vessel conducts bay monitoring throughout the Seekonk and Providence River estuaries. As the boat is underway, a pump draws surface water up and through a water quality YSI EXO2



An example of a chlorophyll map from surface mapping on June 9, 2021.

sonde (formerly a YSI 6-series sonde through the first half of 2022) on the deck, which collects data every four seconds. This sonde is calibrated and maintained as described above for the fixed-site monitoring sondes. The sonde collects data on temperature, conductivity, dissolved oxygen, pH, and chlorophyll. The current focus of the monitoring effort is on the chlorophyll data as a proxy for phytoplankton abundance. The data are analyzed to create maps of chlorophyll concentration along the boat track to illustrate presence and distribution of phytoplankton blooms. Chlorophyll data are processed and mapped using the ArcGIS suite, interpolating values using an inverse distance weighted methodology looking at the 12 nearest neighbors. The interpolation of data all the way to the shoreline is for visual clarity, though it is also highly artificial. In 2021, the NBC mapped surface water quality on 23 days. Surface maps of chlorophyll data are posted to the Snapshot of Upper Narragansett Bay website, while the full datasets are available upon request.

NBC Snapshot of Upper Narragansett Bay Website

As discussed in several sections above, the NBC hosts a webpage, launched in 2011, called "Snapshot of Upper Narragansett Bay" (https://snapshot.narrabay.com/app/), where almost all of the results of receiving waters monitoring are shared with the public. This site was continually updated through 2021 with data postings and a blog that is updated weekly with the most recent results of sampling events. Sampling procedures are described for each monitoring initiative and tables with up-to-date monitoring results can be downloaded. The most recent data at the fixed-site water quality monitoring stations is displayed through dials and gauges as shown in Figure 8 below. This display allows users to quickly assess current water quality conditions. An interactive interface (the Buoy Data Export Tool) allows users to choose fixed-site parameters to display in table format, which can then be downloaded. The NBC Snapshot of Upper Narragansett Bay website represents a comprehensive look at water quality in upper Narragansett Bay by providing the general public with near real-time data and a wide range of information regarding water quality in Narragansett Bay. In 2012, the NBC received a National Association of Clean Water Agencies (NACWA) National Environmental Achievement Award for Excellence in Public Information and Education for the Snapshot of Upper Narragansett Bay website. NACWA's Public Information and Education Awards are presented for outstanding programs in video, printed publications, educational programs, or e-media.

Figure 8: Fixed-Site Dashboard View on the NBC's "Snapshot of Upper Narragansett Bay" Website